Tectonic Evolution of the Ancestral Cascades Arc *Sensu Lato:* Eocene to Pliocene, U.S. to Mexico

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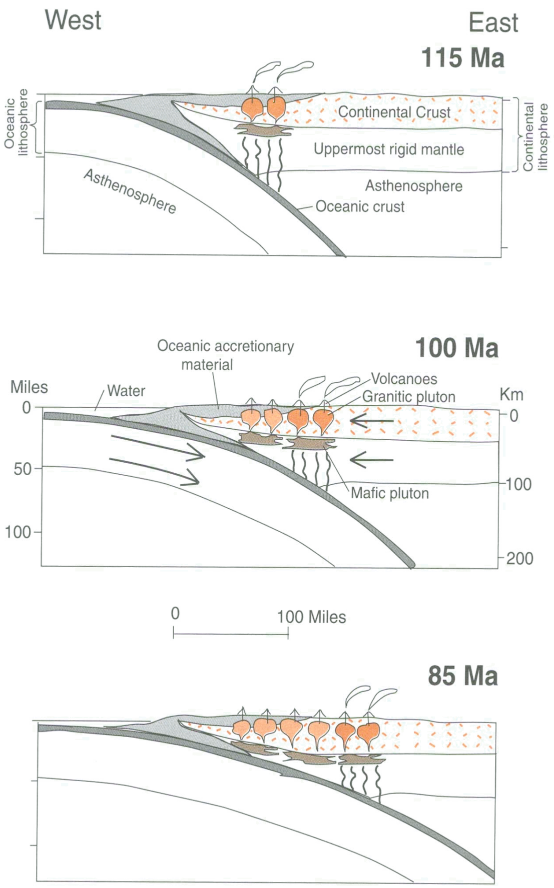
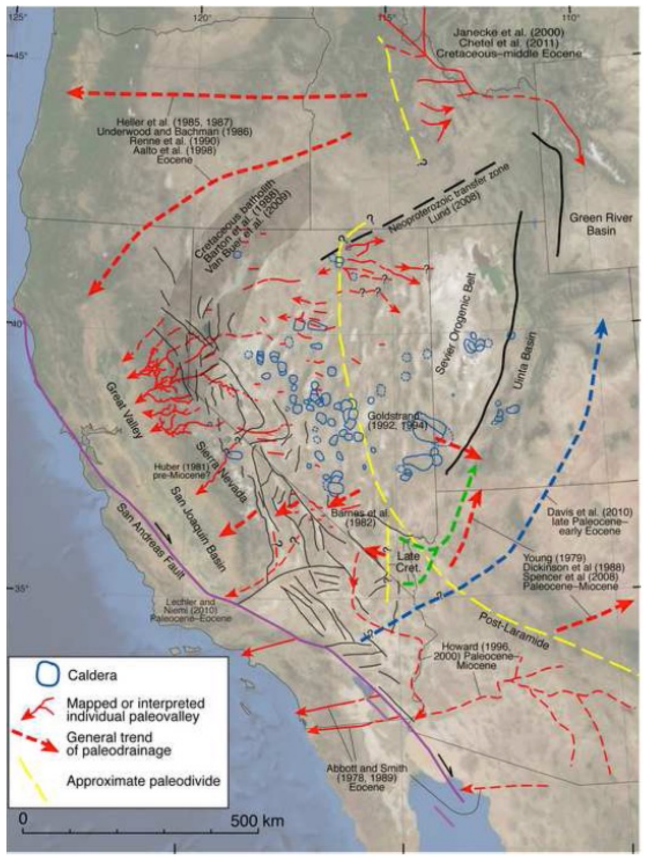
Sensu lato: We present an overview of the tectonic setting for Cenozoic arc magmatism in the Cordilleran U.S. and Mexico, including the Ancestral Cascades arc *sensu stricto*.

References cited in this overview are provided in the last slide.

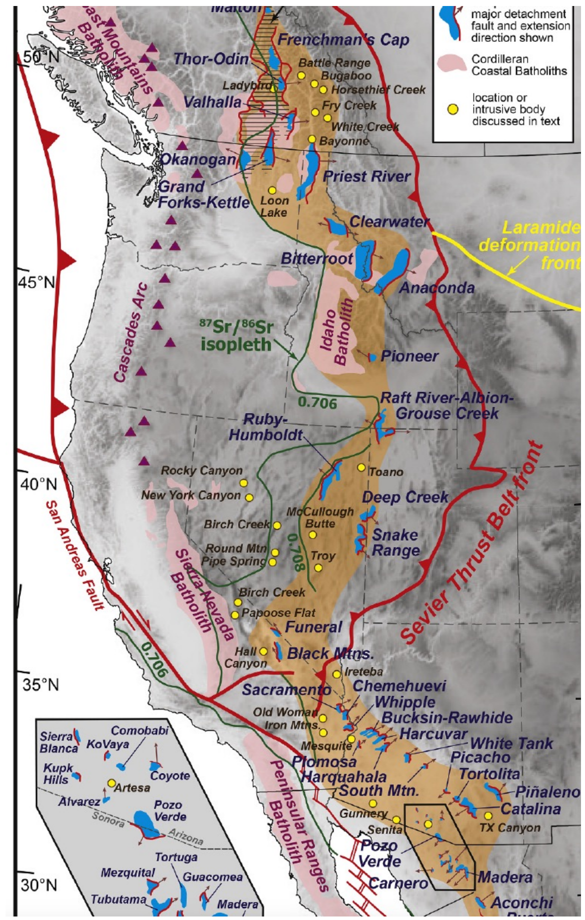
INHERITED CRUSTAL ARCHITECTURE FOR CENOZOIC ARC: Late Cretaceous-Paleocene slab flattening and crustal thickening and melting, and Paleocene-Eocene carving of paleochannels.

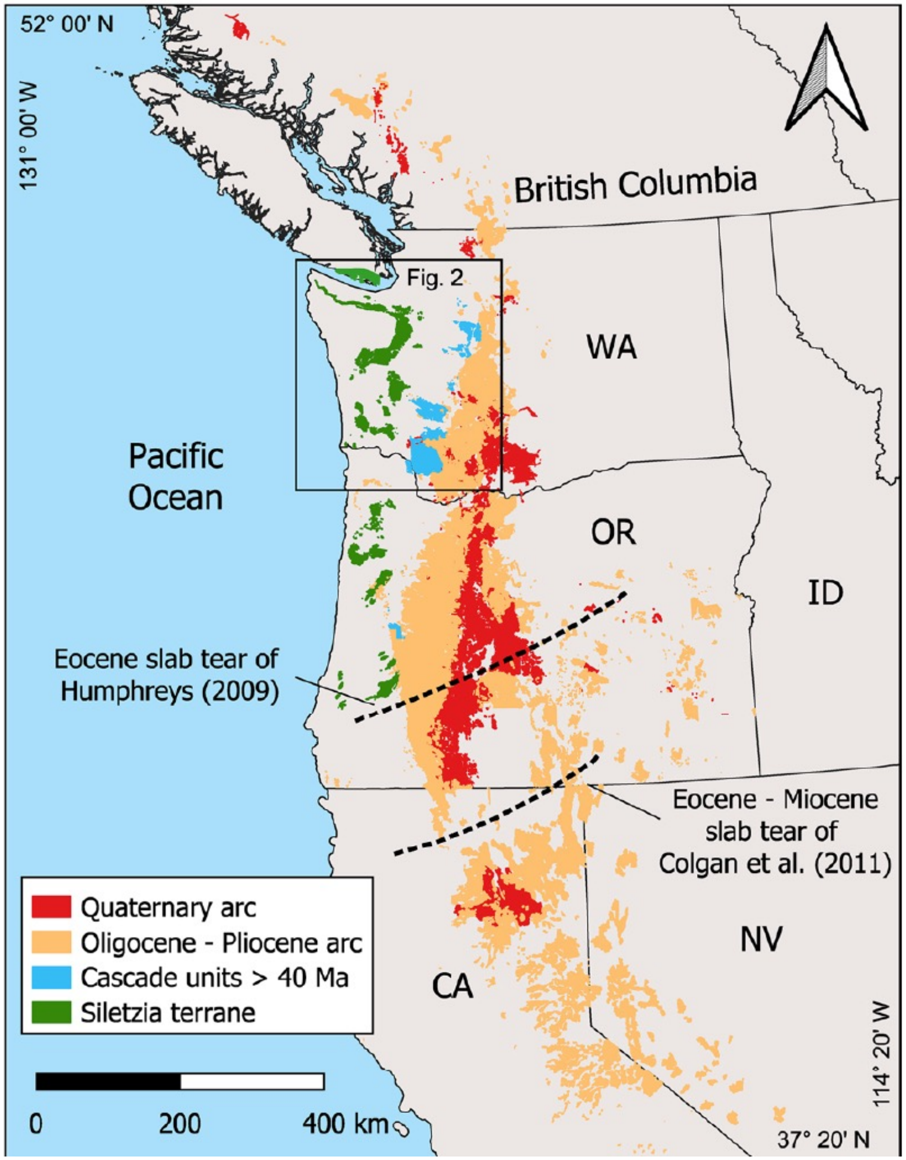


Yellow dashed lines = paleo-divides.
Red lines = paleochannels.
From Henry et al., 2012.



Tan = North American anatectic belt.
From Chapman et al., 2021.





Northern Ancestral Cascades arc initiation at 40-52 Ma
Tepper and Clark, 2024

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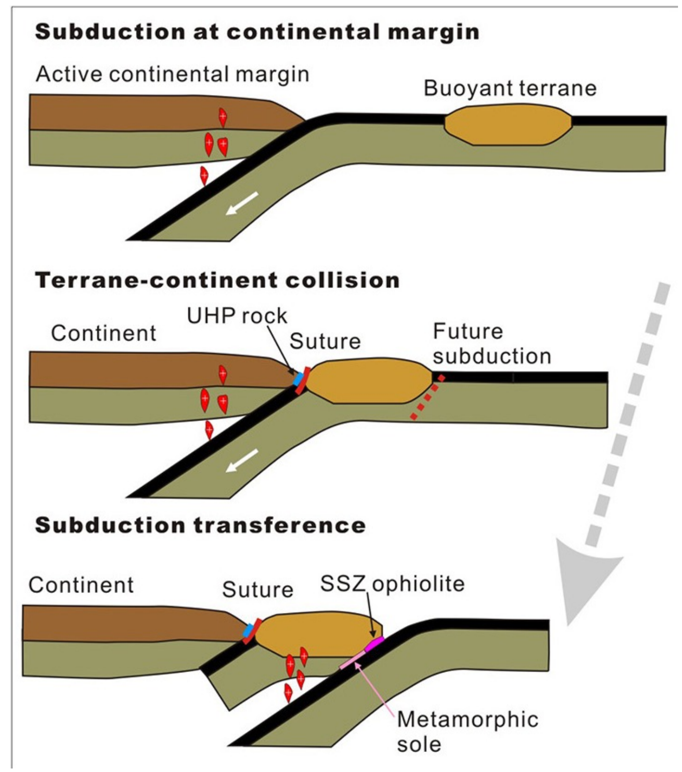
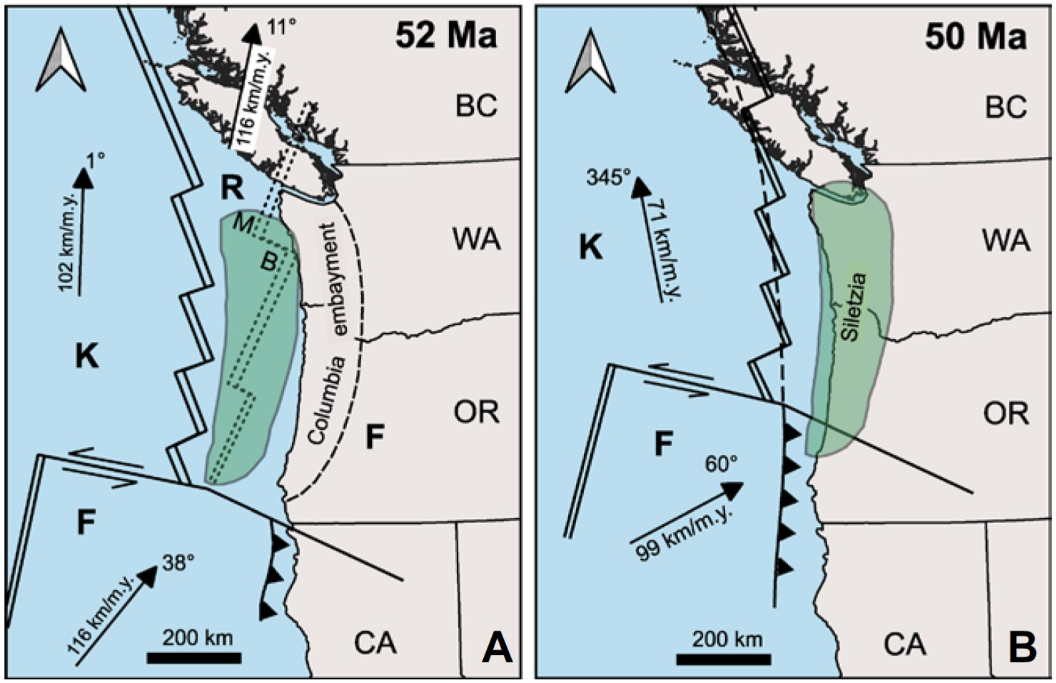
1. Siletzia oceanic plateau (green) subducted and accreted by 48.3 Ma (Eddy et al., 2017), causing slab breakoff.

2. Northern Ancestral Cascades arc magmatism begins by 46.5 Ma (blue) in western Washington.

The collision-induced subduction zone transference or "trench jump" model DOES NOT WORK because subducting slab can't get that deep that fast.

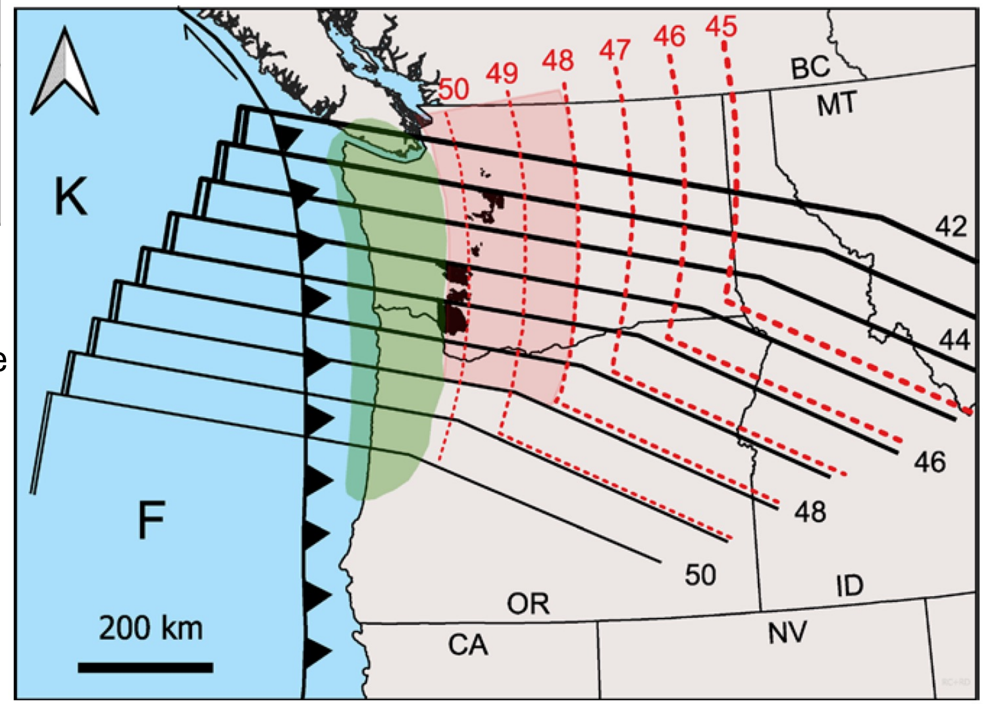


Tepper and Clark 2024, continued.



NE-directed subduction of Farallon plate (F) before and after Siletzia (green) accretes.

Leading edge of Farallon plate advances northward with time: trench grows northward (instead of trench jump).



Solid black lines: leading edge of subducting Farallon slab (F).

Red dashed lines: trailing edge of the detached segment of the Farallon slab.
Red shading: 48 Ma slab window volcanic rocks.

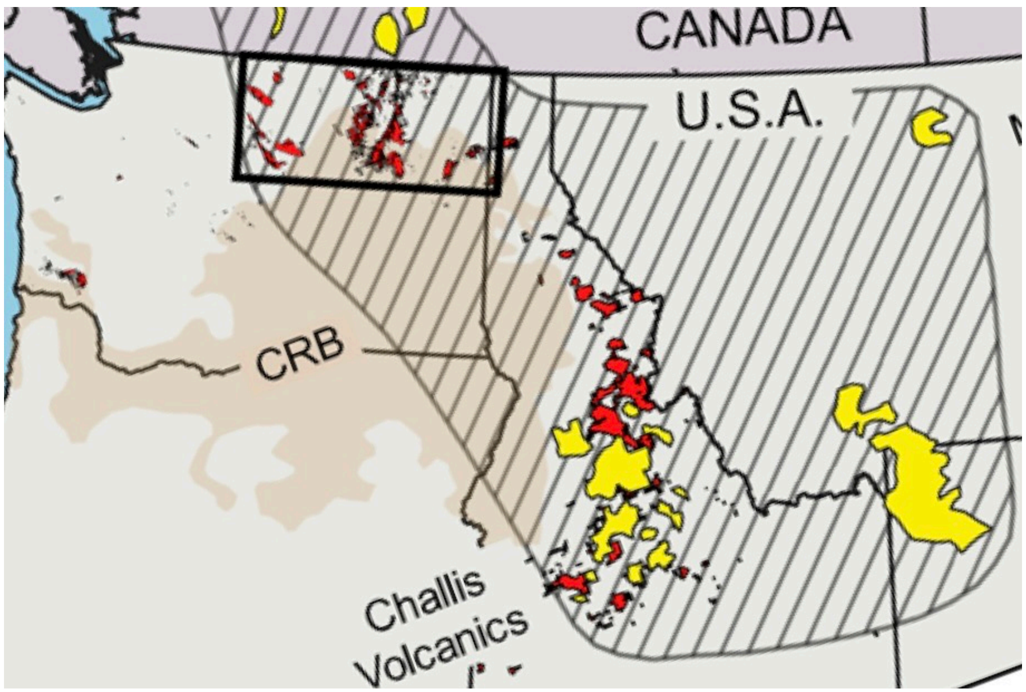
Black: 46-43 Ma Northern Ancestral Cascades arc volcanic rocks.

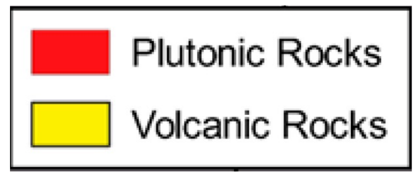
The Challis episode. Northern U.S. - Tepper et al., 2024.

52-39 Ma, followed 60-53 Ma magmatic hiatus due to flat slab subduction.

Slab breakoff and rollback of the Farallon slab following accretion of Siletzia terrane at ca. 50 Ma, with magmas younging to SW, contemporaneous with extension.

Arc geochemical signatures inherited from lower-crustal sources, but drier with deep source (i.e. not arc).





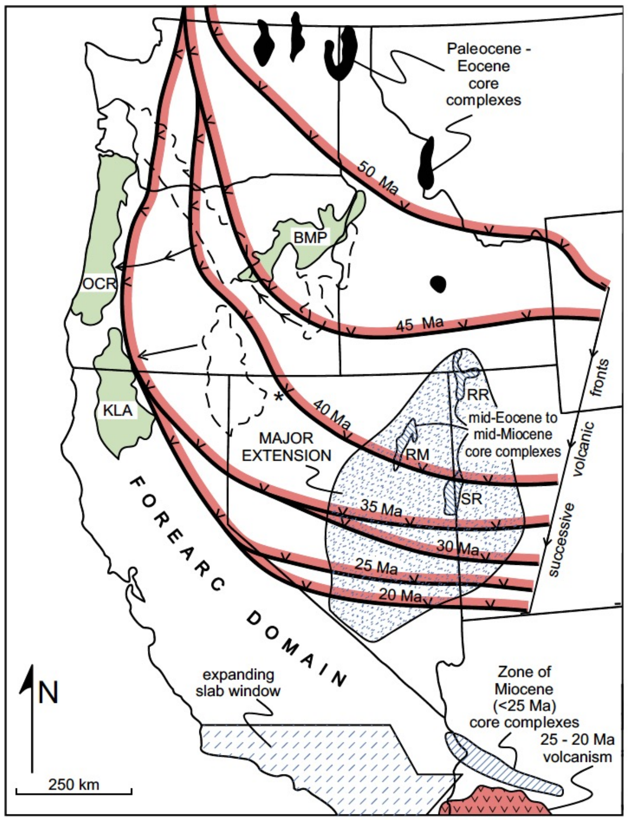
AT THE SAME TIME TO THE SOUTH OF ACCRETED SILETZIA:

BROAD ROLLBACK BEGAN ACROSS GREAT BASIN

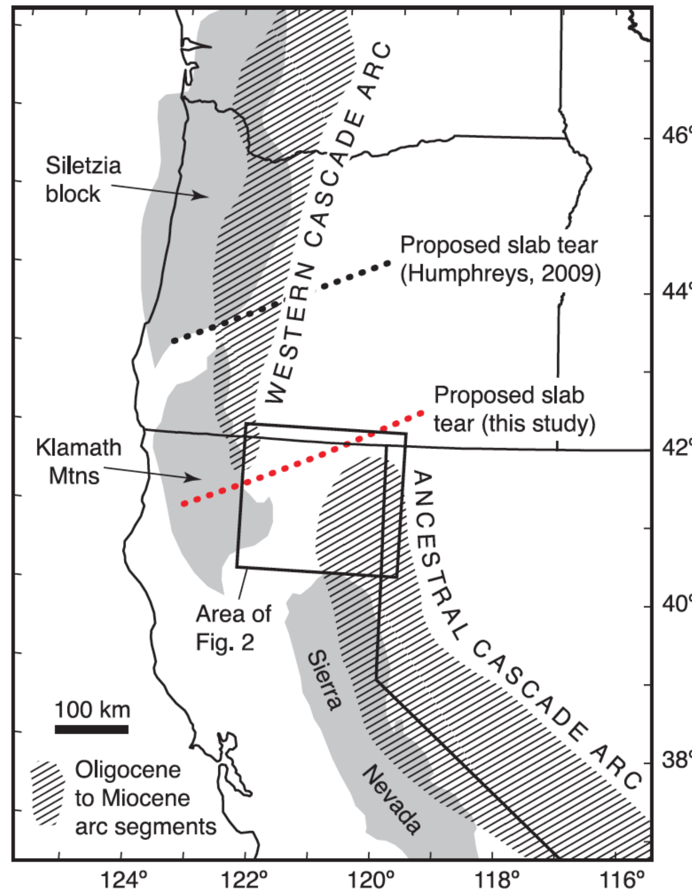
Shown on next slide.

Southern Ancestral Cascades: Eocene to Miocene slab rollback and arc front migration accompanied by extension.

First proposed by Dickinson, 2006, but that did not have the slab tear so no distinction between northern and southern Ancestral Cascades arc.

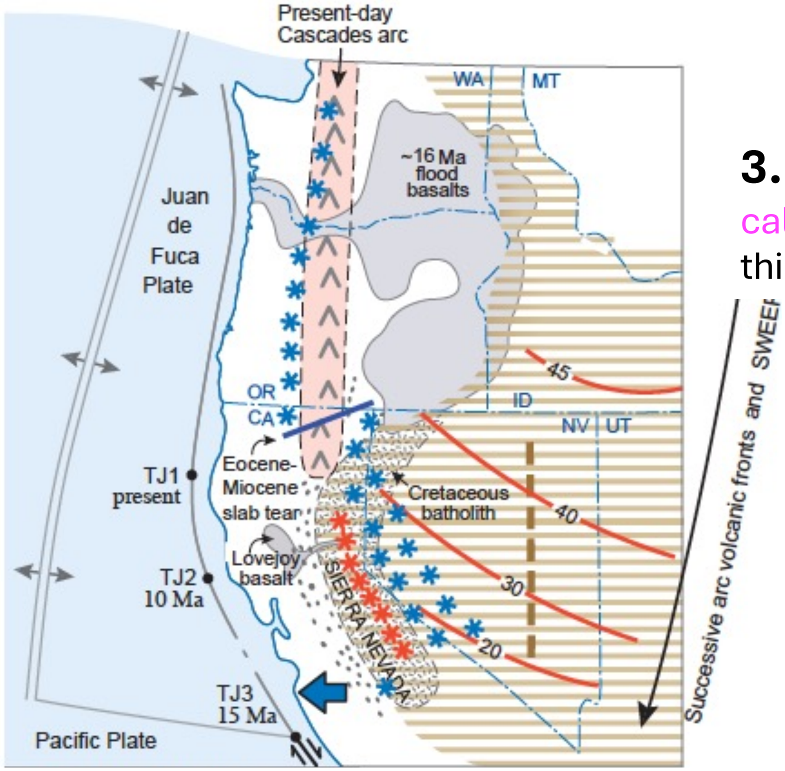


"This study", Colgan et al. 2011. Position of slab tear based on the jog between "Western Cascades" and "Ancestral Cascades" arc segments, aka NORTHERN AND SOUTHERN ANCESTRAL CASCADES ARC.

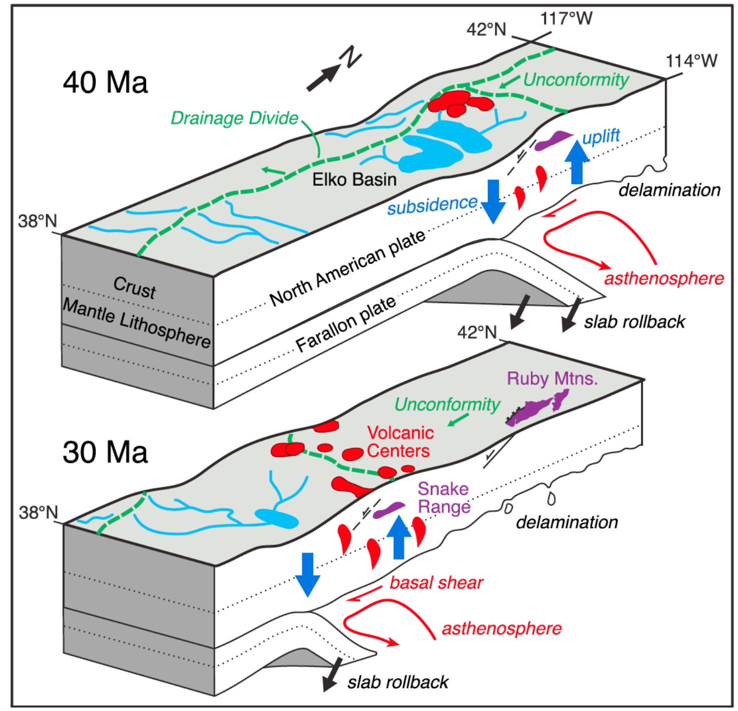


Southern Ancestral Cascades: Eocene to Miocene slab rollback and arc front migration accompanied by extension, continued.

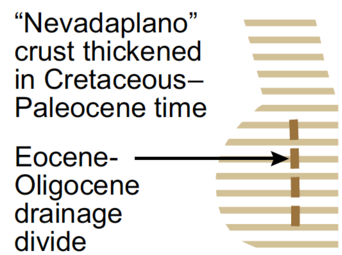
1. Overview by Busby, 2013: Rollback of arc front magmatism and extension, 45 Ma to 16 Ma



2. Began by 40 Ma (Eocene) in NE Nevada (Cassel et al., 2019)



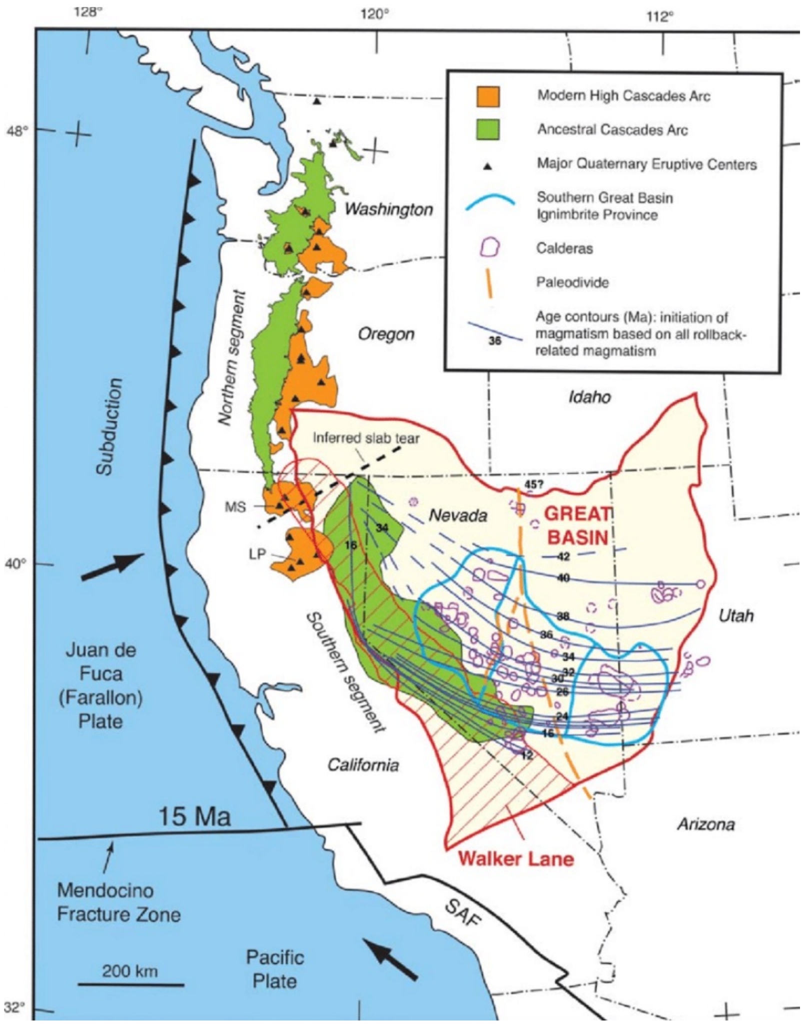
3. Oligocene rhyolite calderas formed over thickest crust.



* **4.** Miocene Ancestral Cascades arc of Colgan et al. (2011) – andesites.

* **5.** 16 Ma and younger Sierra Nevada Ancestral Cascades Arc of Busby and Putirka (2009) – andesites.

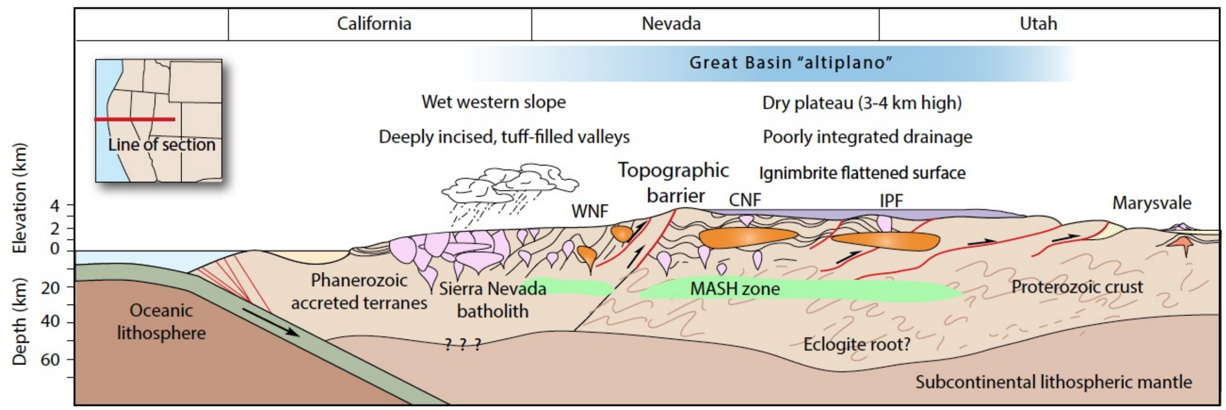
Southern Ancestral Cascades: Slab rollback and arc front migration accompanied by extension.



John et al., 2015

Oligocene giant continental calderas (purple circles) and andesite volcanoes of the Ancestral Cascades arc *sensu stricto* (green).

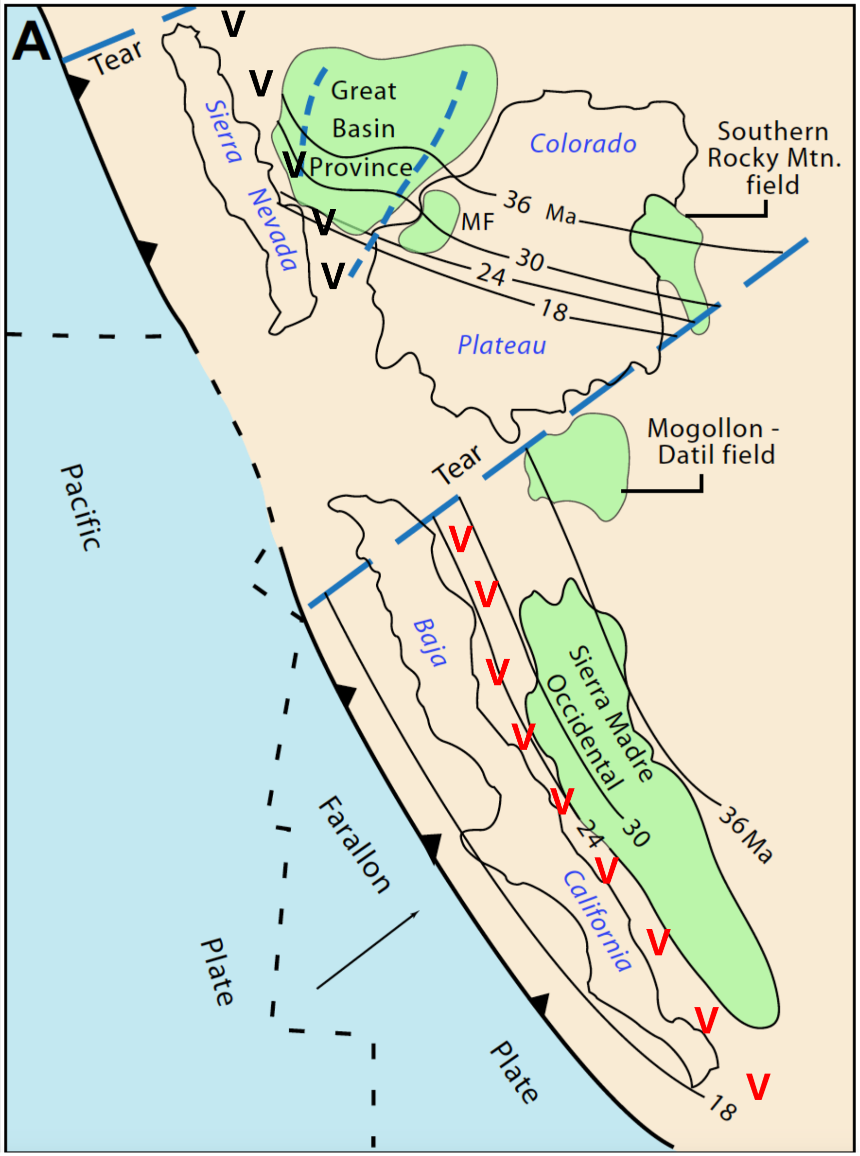
These calderas formed on the thickened crust of the Nevadaplano aka "Great Basin altiplano" (plutons in orange).



Best, Christiansen, de Silva and Lipman, 2018:

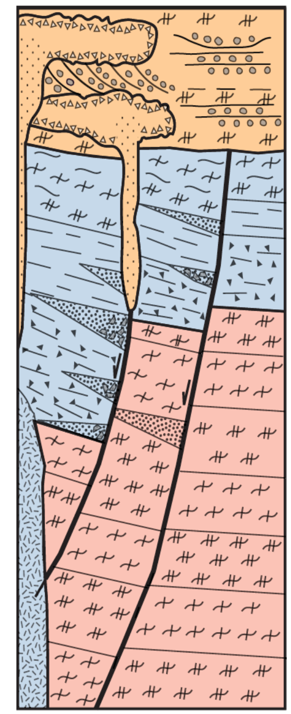
"Slab-rollback ignimbrite flareups……A distinct style of arc volcanism"

The calderas are SUBDUCTION RELATED and are part of the ANCESTRAL CASCADES ARC *sensu lato*.



1. Oligocene **arc** ignimbrite flareups due to slab rollback (36-25 Ma), Best et al. 2015. Slab tear from McQuarrie and Oskin (2010).

Includes the Sierra Madre Occidentale silicic large igneous province in Mexico, where extension accompanied ignimbrite flareup and gold mineralization.



(Murray et al., 2013; Murray and Busby, 2015; Murray et al., 2025).

Isotopes in zircon indicate 80% primary addition from mantle - MAJOR CRUST-BUILDING EPISODE (Andrews et al., 2023).

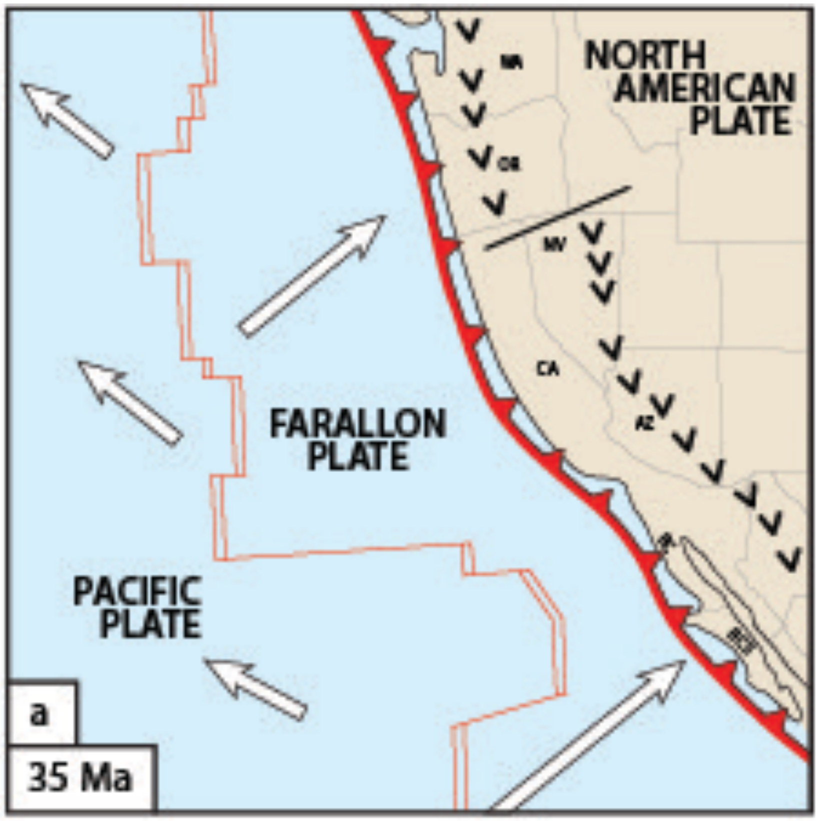
2. Arcs sweep into eastern Siera and future Gulf of California by ca. 16 Ma:

Comondú andesite arc, Mexico **V V V V V**

Ancestral Cascades arc, U.S. **V V V V V**

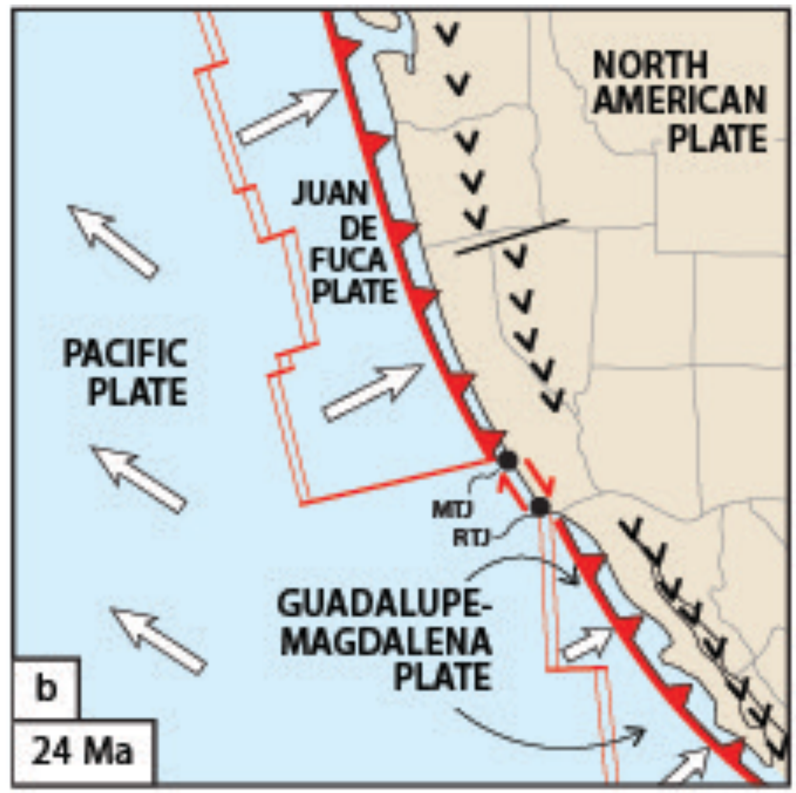
With growing transform margin in between.

Big picture view (Busby and Putirka, 2025)



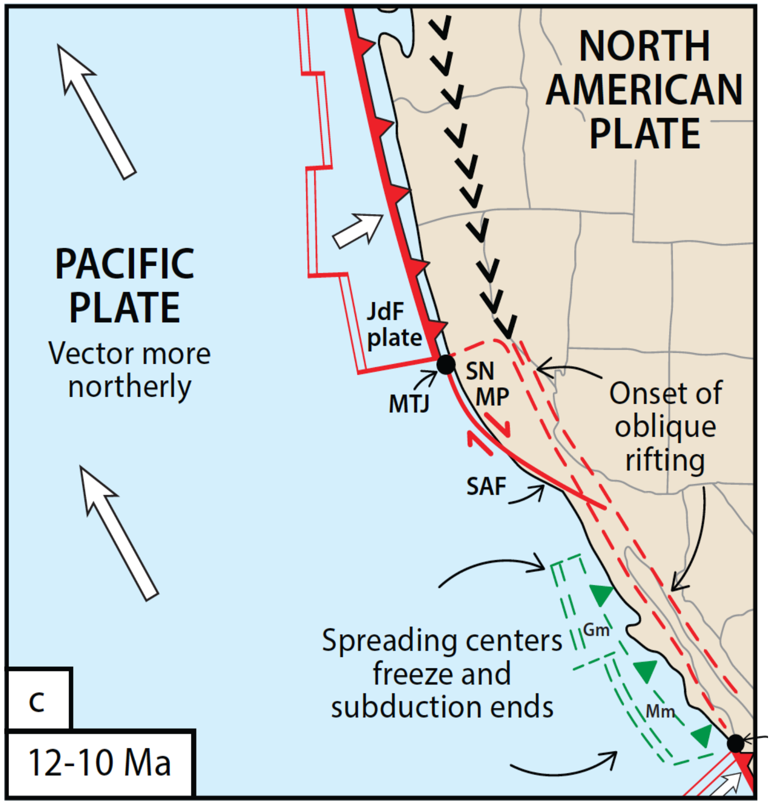
A. By 35 Ma – One continuous arc from Canada to Mexico (with a jog at the slab tear).

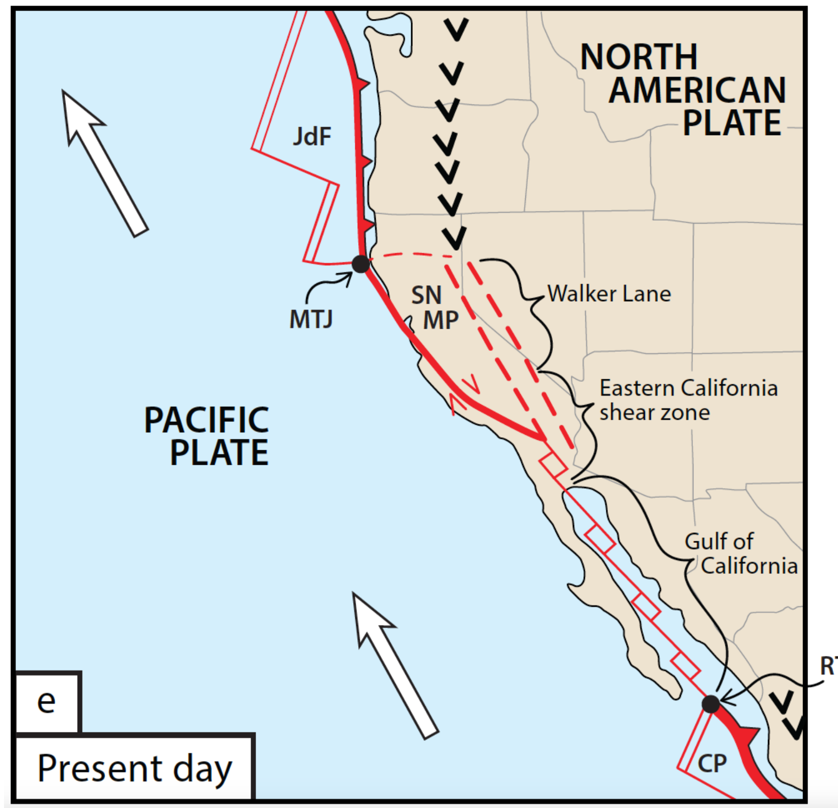
B. 24 Ma – Ridge subduction under LA divides the arc into two segments: Comondú arc in Mexico, and Ancestral Cascades arc in the U.S.



C. 12-10 Ma - Change in Pacific plate vector to a more northerly direction initiates **oblique extension WITHIN THE COMONDU AND SOUTHERN ANCESTRAL CASCADES ARCS.**

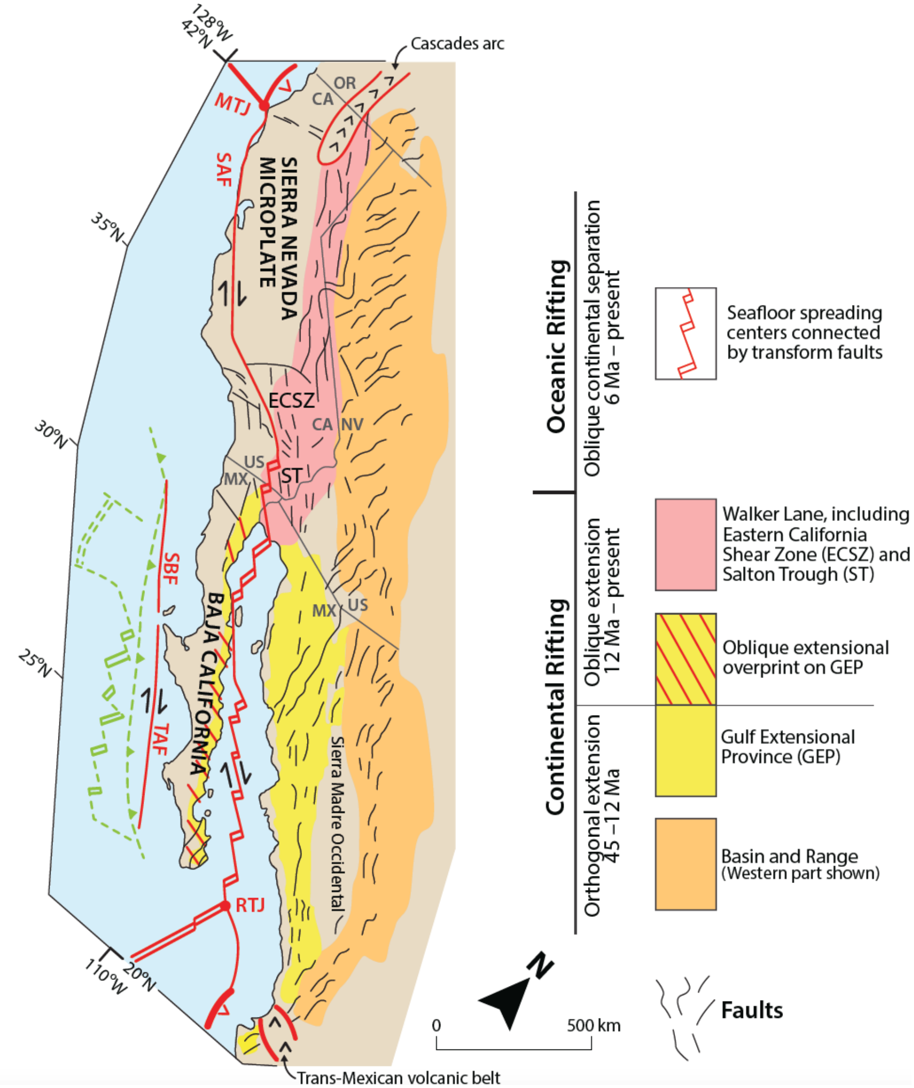
Birth of a plate boundary: the Gulf of California-Walker Lane oblique rift.





Present day: Walker Lane rift tip continues to propagate northward into the axis of the Cascades arc

Busby and Putirka, 2025

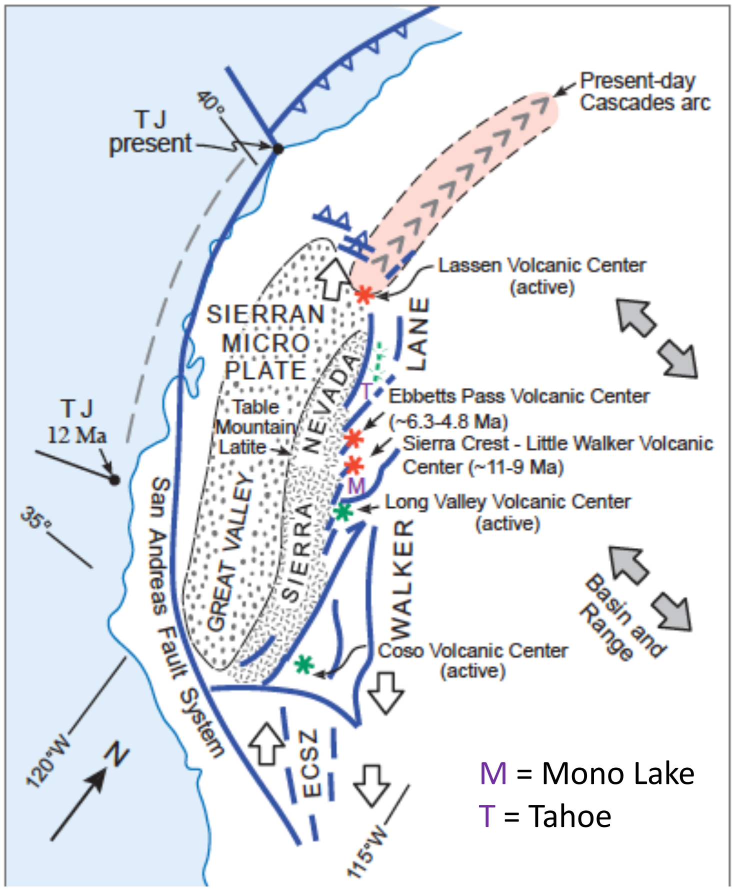


Busby and Putirka, 2025

Walker Lane-Gulf of California oblique rift formed in the axis of the Comondú and Ancestral Cascades arcs, at the western edge of the Basins and Range and Gulf Extensional Province.

Siting of large arc and rift volcanic centers on releasing transtensional stepovers.

In the U.S, the WALKER LANE oblique rift tip has propagated northward with time in concert with northward migration of the Mendocino triple junction; arc volcanism shuts off northward with time and rift volcanism follows in its wake. Rift tip is currently under Lassen.



Modern

* Lassen arc volcanic center (Muffler and others)

* Long Valley rift volcanic center (Bursik, 2008; Riley et al., 2012)

* Coso rift volcanic center (Pluhar et al., 2006)

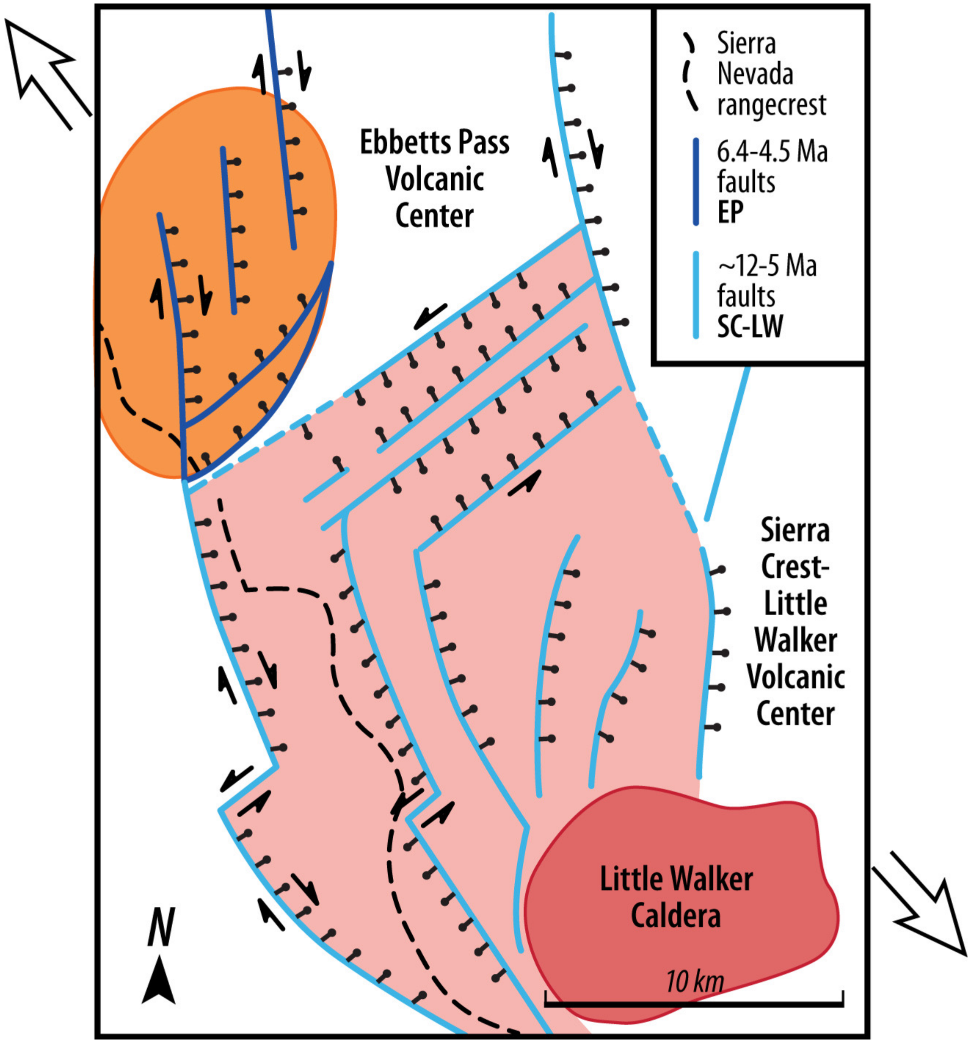
Miocene and Pliocene

* Sierra Crest- little Walker arc volcanic center, 12 - 9 Ma

* Ebbetts Pass arc volcanic center, 6 - 4 Ma

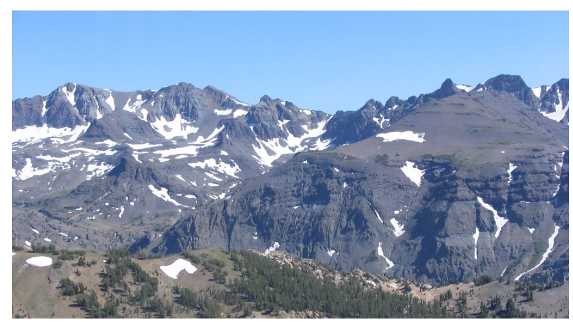
Busby et al. (2013a, 2013b, 2016, 2018)

Siting of large Ancestral Cascades arc volcanic centers on releasing transtensional stepovers, Walker Lane.

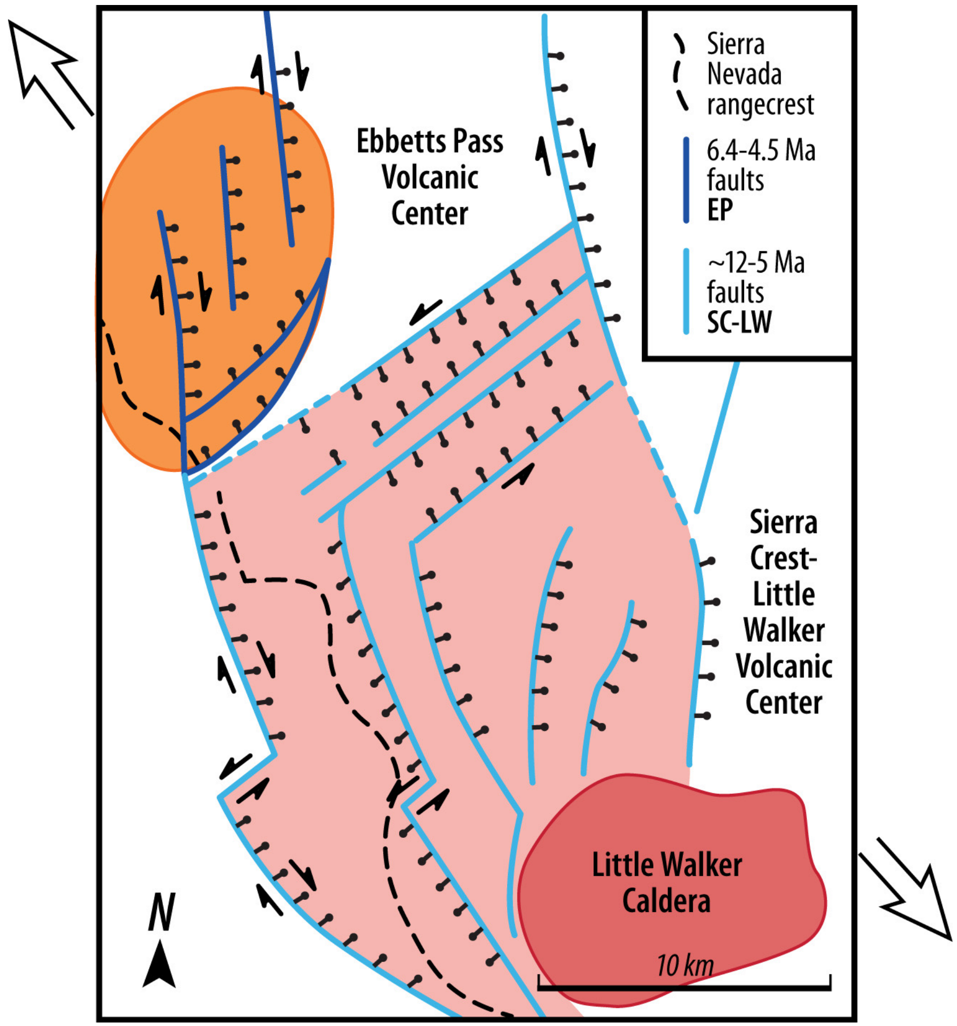


Two adjacent pull-apart basins, very well exposed along the central Sierra Nevada range crest and range front, with 5-km of structural relief.

(Busby et al., 2018)



Siting of large Ancestral Cascades arc volcanic centers on releasing transtensional stepovers, Walker Lane, continued



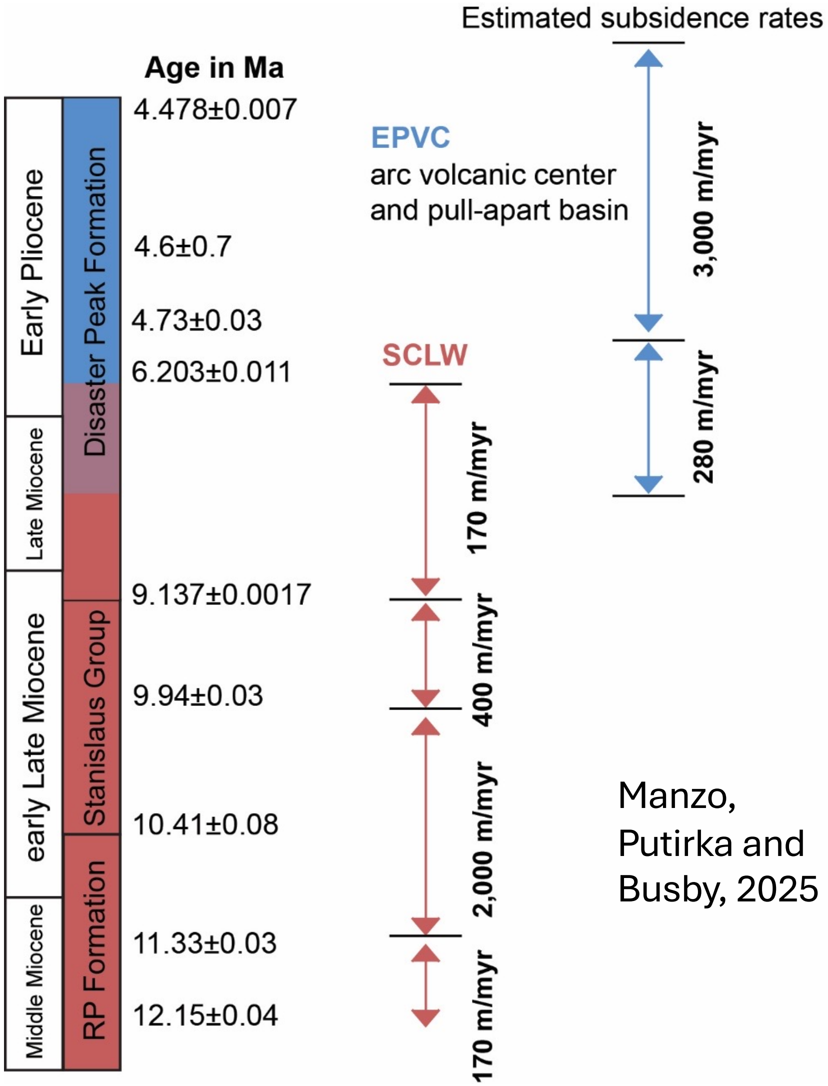
Sierra Crest-Little Walker arc volcanic center and pull-apart basin:

As large (~4,000 km^2) as the active Long Valley rift volcanic center and pull-apart basin, and similarly contains a caldera over part of the field.
(Busby et al., 2013a, 2013b)

Ebbetts Pass arc volcanic center and pull-apart basin:

Smaller, comparable in volume to the active Lassen arc volcanic center and pull-apart basin at the present day transtensional rift tip.

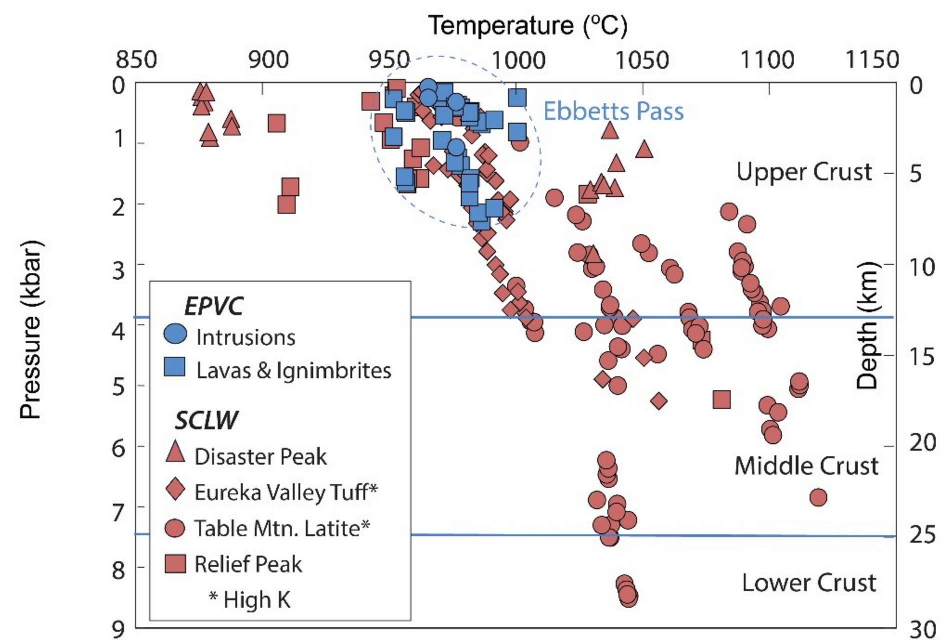
(Busby et al., 2018)



Manzo,
Putirka and
Busby, 2025

Athough Ebbetts Pass arc volcanic center (EPVC) is smaller than Sierra Crest-Little Walker arc volcanic center (SCLW), it has a higher subsidence rate and higher inferred transtensional strain rate.

So magmas rose to higher crustal levels (blue dots) and the Ebbetts Pass volcanic center is NOT TRANSCRUSTAL, in contrast with the Sierra Crest-little Walker volcanic center (orange dots).



A.

The main points, Cenozoic volcanism in the western U.S. and northern Mexico:

Cenozoic volcanism preceded by Cretaceous-Paleocene flat slab subduction and arc magmatic hiatus, crustal thickening.

Eocene: Accretion of Siletzia in Washington and Oregon (48 Ma) shuts off subduction there, but northern Ancestral Cascades arc volcanism quickly begins in the western Washington Cascades by 46 Ma, due to northward advancement of the Farallon trench.

Eocene-Oligocene: South of a slab tear roughly defined by the south margin of Siletzia, gradual rollback of the Farallon flat slab produces arc volcanism far inboard, which sweeps southwestward across the Great Basin (southern Ancestral Cascades arc *sensu lato)*. Slab rollback also occurs under western Mexico (Sierra Madre Occidentale). Giant continental calderas form.

Miocene: Continued rollback produces andesite volcanoes on thinner crust of western Nevada to eastern California (Ancestral Cascades arc *sensu stricto*) and also in the Gulf of California region of Mexico (Comondú arc). Extension continues.

Late Miocene (12 Ma): Walker Lane-Gulf of California oblique rift forms in the axis of the southern Ancestral Cascades arc and the Comondú arc, at the western edge of the Basin and Range and Gulf Extensional Provinces, respectively.

THIS WAS A REVIEW TALK. For talks loaded with new data about the arc-rift transition in Baja California, please come see me and Keith give talks at 8:30 and 8:50 tomorrow morning in the Cenozoic Tectonics and Magmatism session.

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