Initiation of the Cascade Arc by Northward Migration of the Farallon Slab

The Culmination of Siletzia Accretion, Slab Rollback, & Slab Breakoff

Jeffrey H. Tepper (jtepper@pugetsound.edu)
Kenneth P. Clark (kclark@pugetsound.edu)
Geology Department, Univ. of Puget Sound
Tacoma, WA 98416-1048

Introduction

The modern Cascade arc was initiated between ~45-43 Mya, shortly after accretion of the oceanic Siletzia terrane at ~50 Mya. Creation of the new arc required: (1) breakoff of the subducting slab, followed by (2) initiation of a new subduction zone located outboard of the Siletzia terrane. Most previous studies assume this westward "jump" of the subduction zone was accomplished by transference (**Fig. 1**), but this is mechanism is difficult to reconcile with the young age of the Kula-Farallon plates (**Fig. 2**).

We propose an alternative model in which subduction was reestablished by northward migration of an already subducting segment of the Farallon slab. This segment, located south of Siletzia, was not involved in the breakoff and thus positioned to translate northward into the no-slab gap.

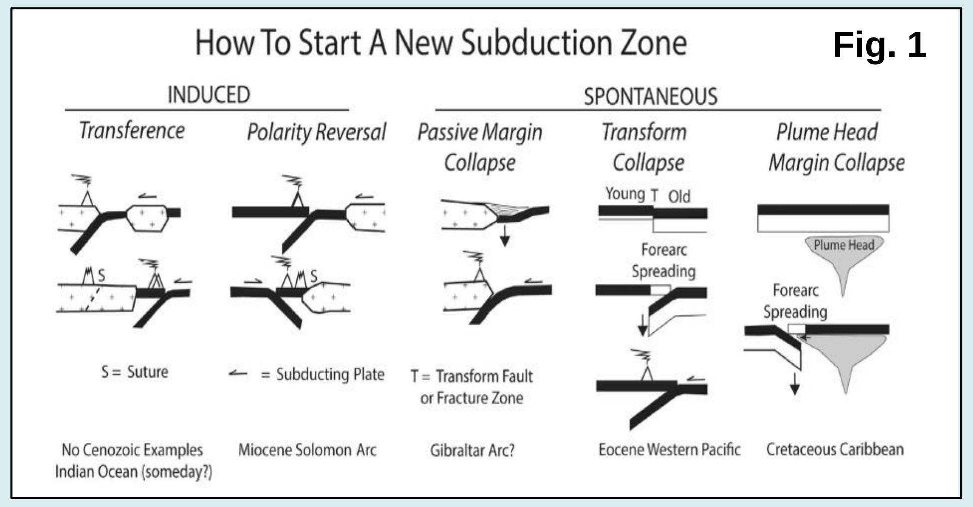


Fig. 1. Mechanisms for subduction zone initiation (from Stern & Gerya, 2018, Tectonophysics 746). All of these models are incompatible with either the Cenozoic geologic history of the Pacific Northwest (polarity reversal, passive margin collapse) or the young age of the subducting slab (transference, collapse of transform or plume head margin).

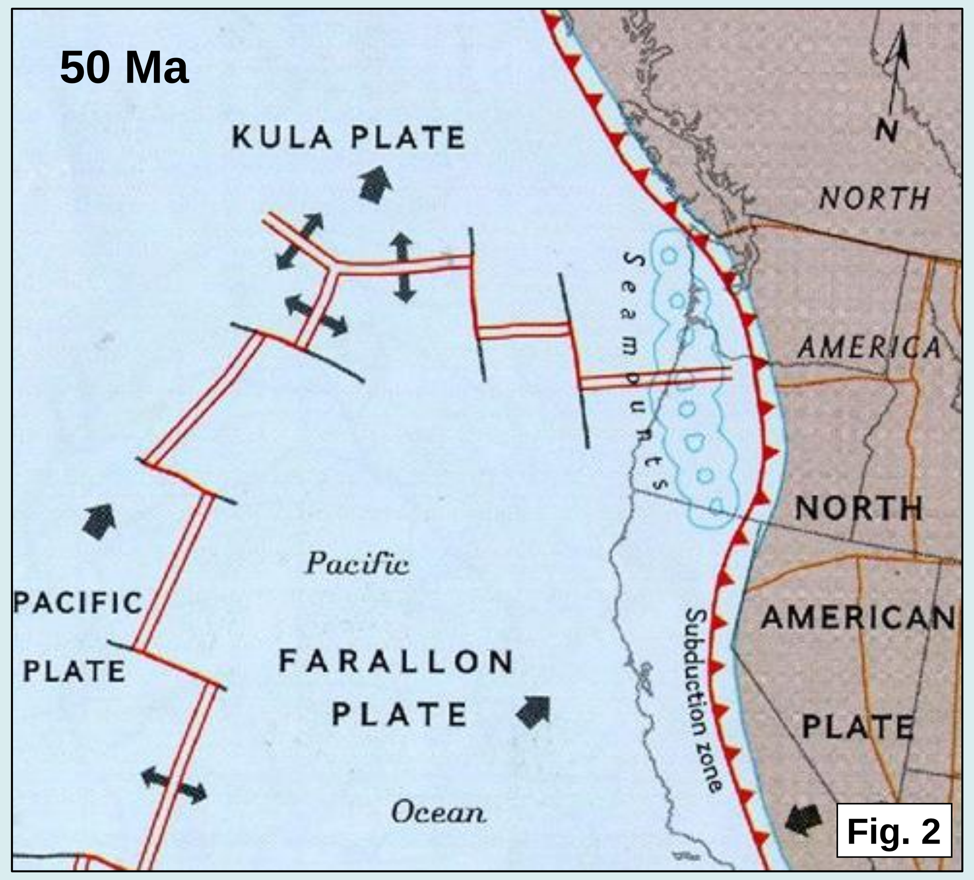
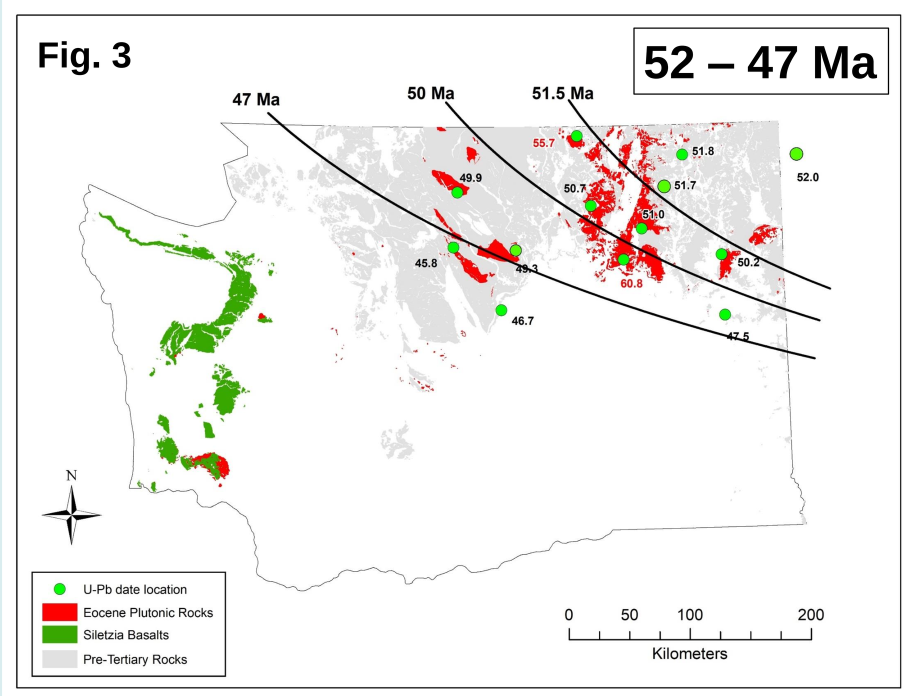
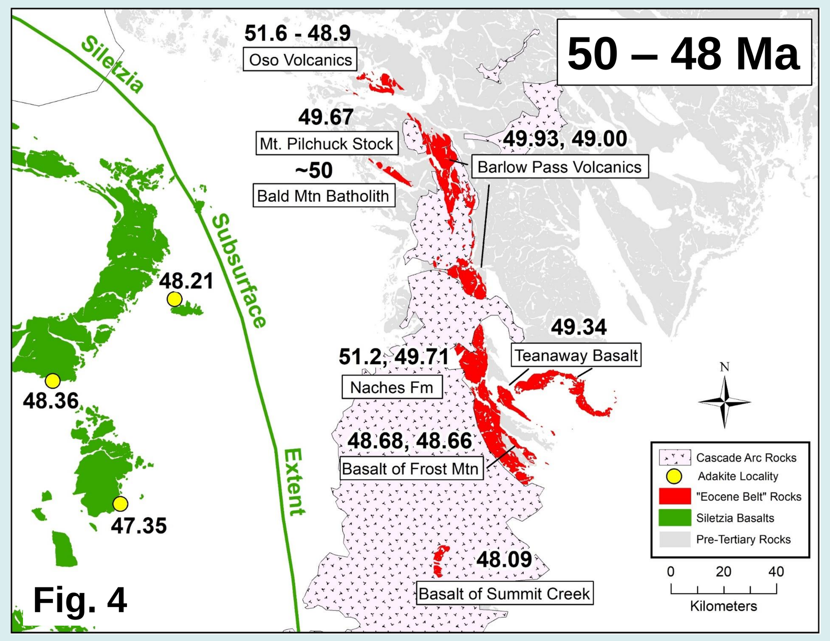


Fig. 2. Plate configuration at 50 Ma. The Siletzia "seamounts" resulted from the Yellowstone hotspot being in close proximity to the Kula-Farallon Ridge, a situation analogous to present-day Iceland. Oceanic lithosphere in the vicinity of the ridge would have been less than 10 m.y. old, which is the minimum age at which it would have been denser than asthenosphere and inherently subductable (Cloos,1993, GSAB 105). Note also that the Farallon plate is moving northward relative to North America and subducting along the entire western margin of the continent.

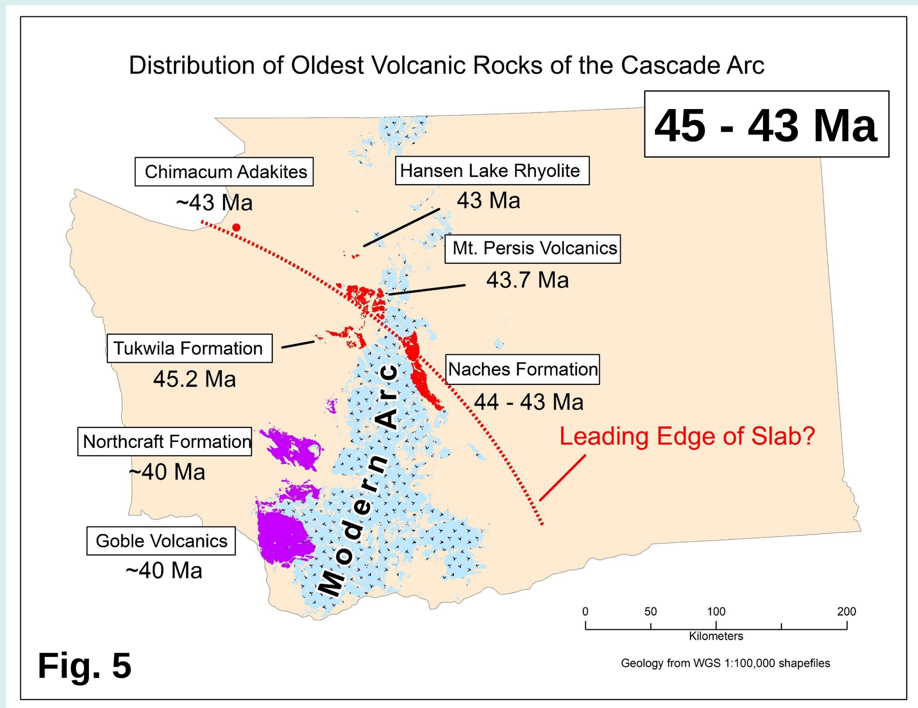
Geological & Geochronological Constraints



- Granitic rocks in NE Washington show a younger-to-the-SW age progression beginning ~52 Ma (**Fig. 3**).
- This is attributed to rollback of the Farallon slab, which ruptured to the east as Siletzia approached the margin and resisted subduction.

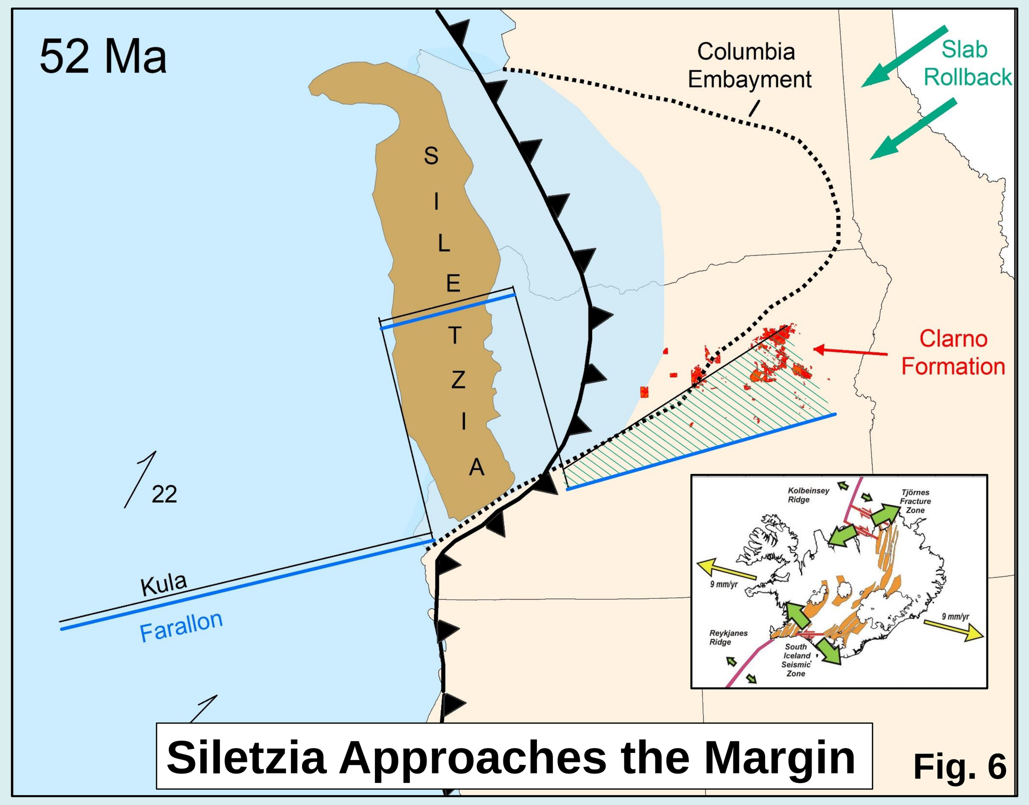


- Volcanic and plutonic rocks emplaced in western WA during this interval are petrologically diverse (adakites, OIBs, S-type granites) but generally lack arc signatures.
- These rocks define a N-S trending belt (**Fig. 4**) that parallels the edge of Siletzia in the subsurface (Trehu et al., 1994).
- This belt is interpreted as a response to breakoff of the Kula slab after the accretion of Siletzia.. Magmatism resulted from decompression of asthenospheric mantle that upwelled through the tear.

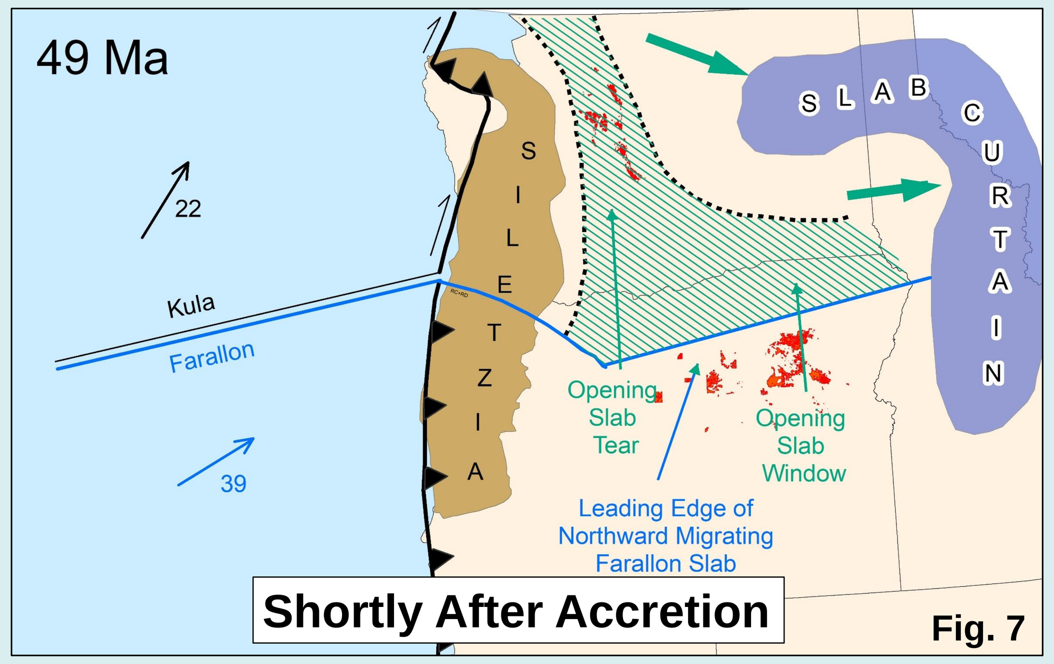


- New LA-MC-ICP-MS U-Pb dating has yielded ages of 45-43 Ma for the earliest rocks associated with the Cascade arc (**Fig. 5**).
- These rocks define a NW-trending belt that may reflect the arrival of the leading edge of the Farallon slab under Washington. This hypothesis is supported by the presence of adakites among these early arc rocks.

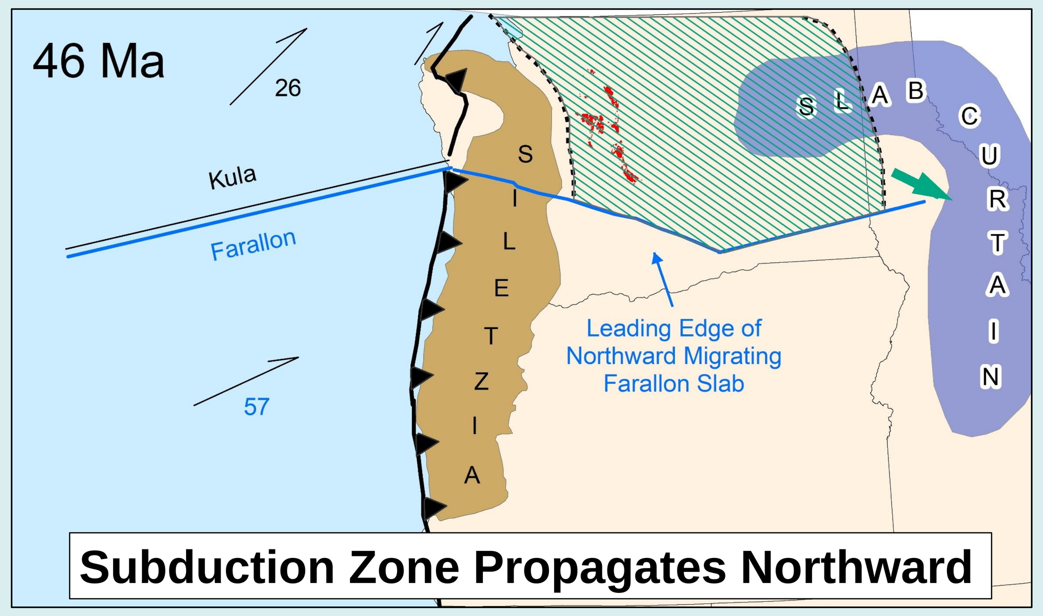
Proposed Sequence of Events



- Siletzia approaches the margin at the latitude of the Columbia Embayment (as delineated by Gao et al., 2011).
- Geometric constraints of the model require that Siletzia occupy an offset segment of the ridge, analogous to the setting of Iceland today (**inset figure**).
- The southern boundary of Siletzia corresponds to a geophysical lineament inferred (Gao et al., 2011) as a tear that detached Siletzia from the Farallon slab.
- Subduction of the Kula-Farallon Ridge produced a slab window (coincident with Claro / John Day Fm) that represents the northern edge of the Farallon slab.



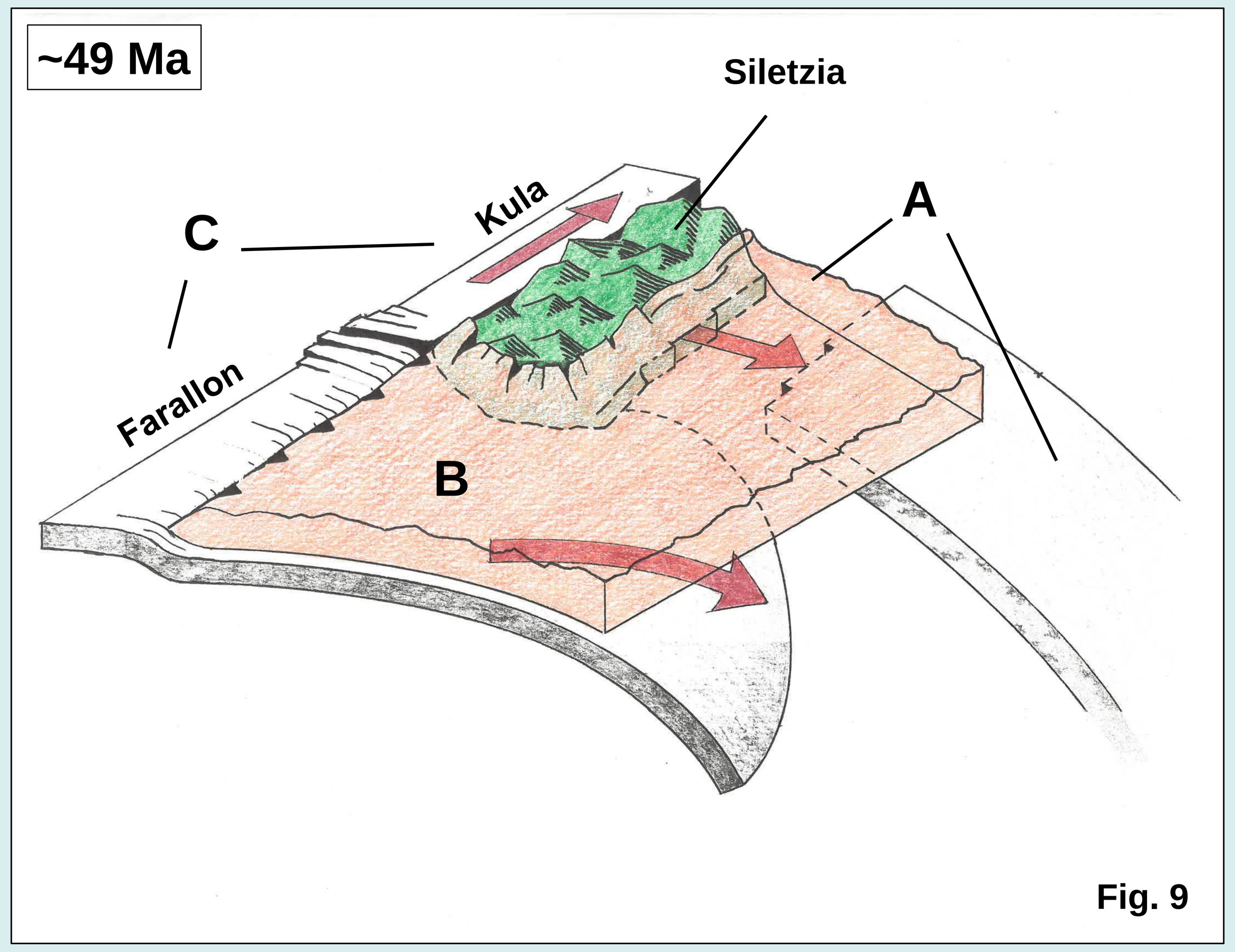
- Siletzia has rotated into the Columbia Embayment.
- Rupture of the Kula slab has produced an opening tear. Slab pull drags the detached plate eastward to become the "slab curtain" imaged seismically beneath eastern WA and ID (Schmandt & Humphreys, 2011).
- "Anomalous volcanism" (**Fig. 4**) occurs above the slab tear.
- The Farallon slab migrates northward; the former transform fault on west side of Silezia becomes the new subduction zone.



- The Farallon slab is migrating northward at ~50 km / Ma (calculated from Babcock et al., 1992).
- Leading edge of the subducted slab (drawn assuming a 30 degree slab dip) lags behind the ridge because new crust is not forming.
- North of the Farallon slab much of present-day Washington is underlain by a no-slab region, as recognized chemically (e.g., Breitsprecher et al., 2003).

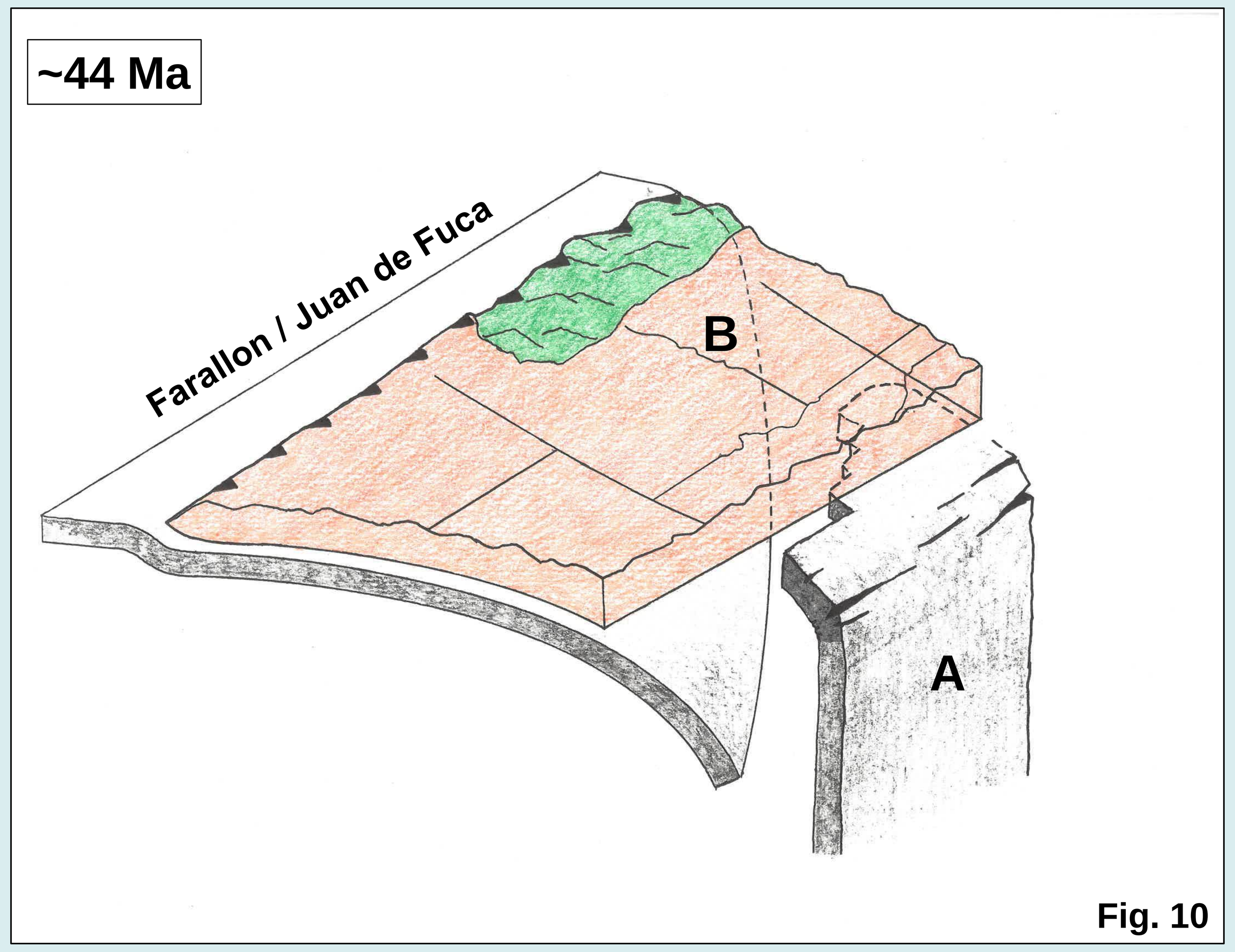
A Model for Subduction (Re-) Initiation in the Cascade Arc

We assume: (1) northward movement of the Farallon-Kula-Pacific plates relative to North America, and (2) plate motion vectors calculated from Babcock et al. (1992). The onshore geologic record is used to constrain the positions of ridge – margin intersections and slab windows..



(A) The Kula slab breaks off inboard of the accreted Siletzia terrane. Slab pull drags the detached slab eastward, opening a window beneath Oregon and Washington.
(B) South of the Kula-Farallon slab window (and south of Siletzia), the Farallon slab remains intact and continues migrates northward.
(C) As the Farallon Plate moves northward, the transform fault outboard of Siletzia is converted to a subduction zone.

- Because of its low angle of subduction, the arrival of the Farallon slab beneath Oregon and Washington does not initially result in arc magmatism.



(A) The detached segment of Kula slab now "hangs" vertically beneath Idaho.
(B) The leading edge of the Farallon slab has migrated to beneath central Washington, sinking as it moves northward and reaching a depth that allows tor re-initiation of arc magmatism (Fig. 5).

- With steepening of the slab dip, arc magmatism is subsequently re-established along the length of the arc, beginning in SW Washington (**Fig. 5**).
- Underthrusting of Olympic Core rocks beneath Crescent Formation basalts after 44.7 Ma (Eddy et al., 2017) constrains the "arrival" of the subduction zone beneath the northern Olympic Peninsula.