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Tectonic History
Hildebrand Project 3C
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The ~120-80 Ma magmatism along the Mesozoic arc is far more voluminous than would be expected for a typical arc.

Is Hildebrand's model substantially different from the under-thrusting of continental sediments envisioned by Ducea (and brought up in the DeCelles et al. overview)?

Robert S. Hildebrand states in his Geological Society of America Special Publications "Did Westward Subduction Cause Cretaceous–Tertiary Orogeny in the North American Cordillera?" and "Mesozoic Assembly of the North American Cordillera" that a ribbon continent called Rubia collided with the North American craton at ~124 Ma. This initiated the Sevier orogeny, deforming North America, and creating Cordilleran magmatism to the west. The North American margin, as he puts it, is east of the Sevier Hinterlands, and was transformed from a passive to active margin at this point. It subducted underneath the Rubian continent westward, generating tremendous amounts of magmatism in high flux events (HFE) (Figure 1). The HFE were due to the great amount of subducted upper lithospheric material, and the dewatering of continental rise prism sediments on the edge of the passive margin. This was followed by slab break-off, and a polarity reversal with Rubia later subducting under North America. Magmatism concluded around ~80 Ma, with the compressional regime slowing due to the difficulty of subducting a thick section of buoyant continental crust.

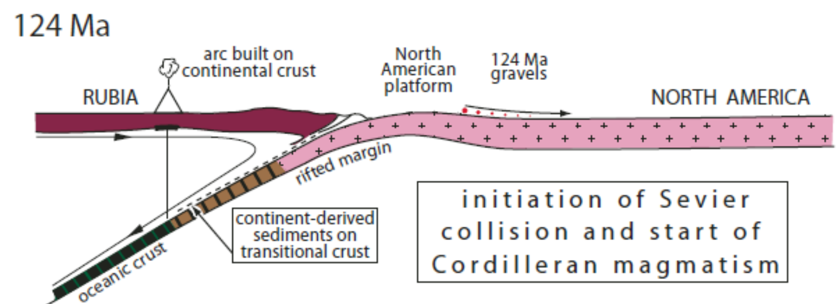

Figure 1: The initiation of Cordilleran magmatism, Hildebrand's model. From Hildebrand, 2013.

This viewpoint on the North American Cordillera is in contrast to the ideas of Mihai Ducea and Peter DeCelles, seen in their articles "The California Arc: Thick Granitic Batholiths, Eclogitic Residues, Lithospheric-Scale Thrusting, and Magmatic Flare-Ups" by Ducea, "Igniting flare-up events in Cordilleran arcs" by Ducea and Barton, and "Cyclicity in Cordilleran orogenic systems" by DeCelles et al. These authors follow the more conventional understanding of the North American Cordillera, in that the Cordilleran Batholiths such as the Sierra Nevada range,

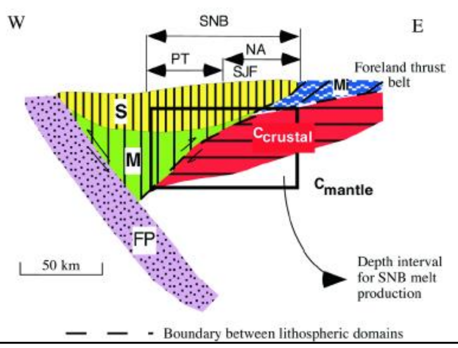

Figure 2: Subduction of the Farallon plate (FP) underneath continental crust (C), with accreted mantle (M), accreted crustal rocks (S) and miogeoclinal rocks (Mi). (SNB): Sierra Nevada batholith. (SJF): San Joaquin xenolith probe. (PT): Panthalassan source. (NA): North American source. From Ducea, 2001.

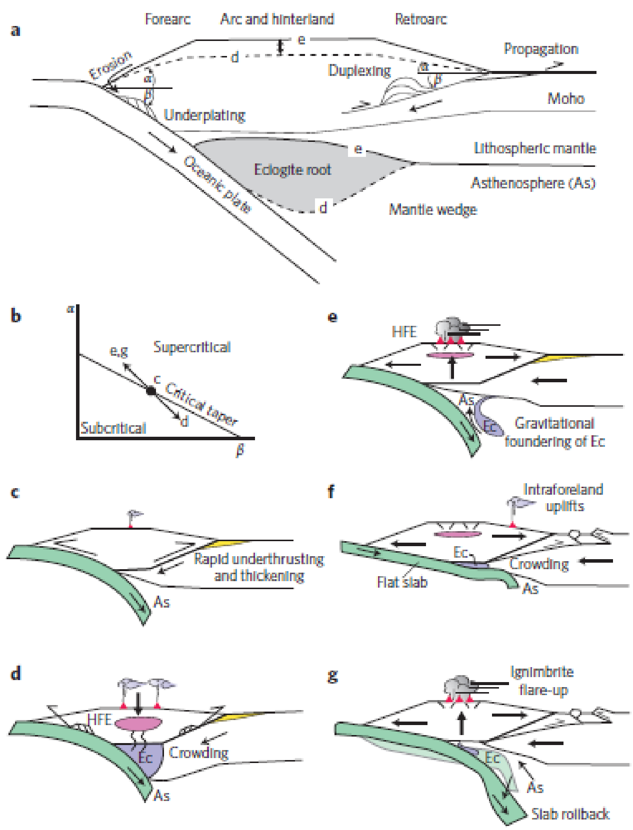

Figure 3: Cyclic cordilleran arc schematic. (a): the initial system set-up. (b): orogenic wedge at critical taper. (c): retroarc under-thrusting. (d): developing an arc HFE. (e): eclogite root foundering, flare-up. (f): crowding of slab into continent driving strain. (g): upwelling asthenosphere with a normal

were due to the eastward subduction of the oceanic Farallon plate (Figure 2). They generate their HFE during episodes that are out of phase with times of crustal shortening and thickening.

DeCelles et al., 2009 postulates that Cordilleran arcs creating a HFE must be strongly convergent, with upper crustal sedimentary rocks scraped off the under-thrusting continental plate. The HFE is triggered by an influx of melt-fertile lower crust and mantle lithosphere, and extra hydrous continental lithosphere. Going further with DeCelles et al., 2009, it is noted that each HFE correlates with an isotopic pull-down. Following a HFE is Hinterland extension, and gravitational foundering of melt residues. The foundering generates space to restart the cycle. The lulls between HFE are due to the time required for the under-thrusting to replenish sufficient melt-fertile lithosphere, after being drained. Swifter shortening of the crust increases the rate of feeding the arc. The cycle is seen in Figure 3. Ducea, 2001 argues on the basis of isotopic evidence from xenoliths and midcrustal exposures that the magmatic flare-ups between 160-150 Ma, and again from 100-85 Ma in the Sierra Nevada batholiths could not be explained just by increased convergence or magmatic activity; there must have been additional North American lower crustal and lithospheric mantle thrusted underneath the arc. Ducea, 2007 also states that the flare-up responsible for the Sierra Nevada batholiths could have been due to the shortening of the North American plate during the Sevier orogeny, providing crustal material from the foreland. The cessation of magmatism in their model would be due to the mantle lithosphere and lower crust became melt-drained an infertile at ~80 Ma (Ducea, 2001) and was unable to recharge. They have tested their cyclic model both the Northern and Southern American Cordilleras, and found that the model holds fairly true, albeit with differences in the period of events due to different convergence rates.

Both the Hildebrand model, and the DeCelles and Ducea models use the Sevier orogeny as the source of shortening of the North American plate and the source of upper continental lithosphere. In each model, the melt to generate a Cordilleran arc comes from a mixing of asthenospheric material and upper lithospheric material. Much of this material is from the North American plate in DeCelles and Ducea model, despite the eastward subduction of the Farallon plate. North American crustal material would be required by the model to get the correct $\delta^{18}O$ and negative ε_{Nd} values, along with greater than 50% of the melt derived from crustal sources, as opposed to asthenosphere.

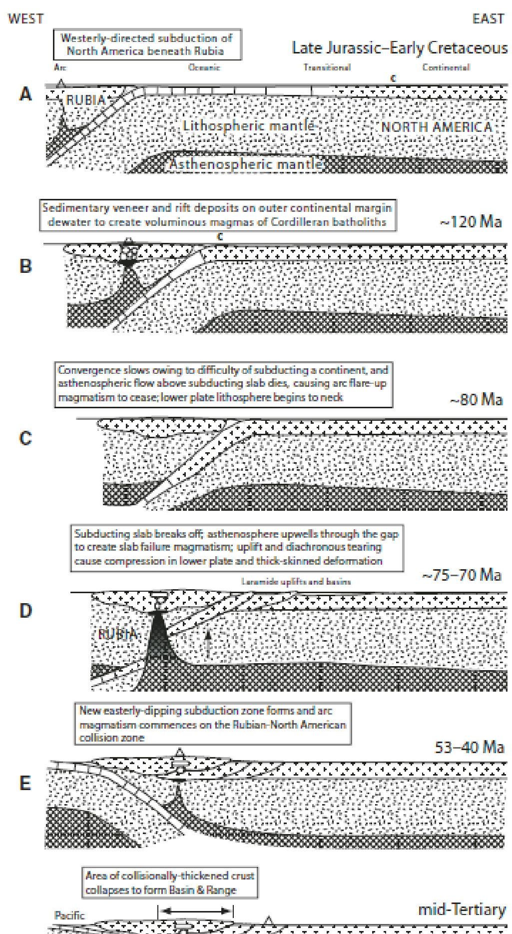

Figure 4: Hildebrand's model of subduction of North America and Rubia. From Hildebrand, 2009.

While DeCelles and Ducea are content getting the continental material from the retroarc under-thrusting of the North American plate, Hildebrand would state that crustal material comes directly from the continental plate being subducted after the initial oceanic edge of North America subducted to the west, and would only have continental crust subduction after the slab polarity reversal (Figure 4).

Additionally, Hildebrand states that his model does not require 400 km of crustal shortening to achieve HFE. The DeCelles and Ducea model does require this great amount of crustal shortening in order to feed their Cordilleran arc. This amount of crustal shortening is large, considering a lull of roughly 50 Ma between magmatic episodes in the North American Cordillera, however, it is not an unheard of postulation. The Himalayan continental collision would require the shortening of Asia by 1000-1500 km since continental subduction began at 55-50 Ma (Chemenda et al., 2000). Whether or not 400 km of shortening could have happened during the Sevier orogeny is not discussed in the DeCelles et al., 2009 article however. Hildebrand critiques this point severely, as he claims that the North American crust composition would not be able to generate the correct melt and restite to create the Sierra Nevada range, if significant crustal shortening is the source of crustal material in the DeCelles and Ducea model.

Another discrepancy between the models is that Hildebrand is less specific about periodicity of the North American Cordillera, while it is a key feature for DeCelles and Ducea. Hildebrand's model quite nearly does not allow for this type of behavior, as the North American plate would have experienced slab failure and break-off underneath Rubia eventually. That leads to a magmatic flare-up, but not as much of an HFE as suggested by DeCelles and Ducea, and he states that the slab break-off magmatism could only lead to plutonism, instead of volcanism.

The Hildebrand model for the Mesozoic North American Cordillera is only compatible with the DeCelles and Ducea models on the point that both require upper continental material from the North American plate to generate their magmas. The mechanisms behind their systems are too discrepant to reconcile otherwise. Cyclicity in the North American Cordilleran arc is not a radical idea compared to the classic model of eastward subduction of the Farallon slab over many millions of years; the model is an elaboration on it, requiring more nuances and possibly explaining more features such as HFE and lack of consistent magmatism. The model of a continent subducting for a short time to generate vast amounts of magmatism, followed by slab break-off however, is drastically radical and much more difficult to prove. Proving the direction of subduction and quantity of crustal shortening would require more techniques than DeCelles and Ducea offer, such as tomographic images in addition to spatial isotopic variations within a Cordilleran arc.

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