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Tomographic images of subducted oceans matched to the accretionary records of orogens – Case study of North America and relevance to Central Asia

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Accretionary orogens are the surface record of subduction on the 100-million-year timescale; they aggregate buoyant crustal welts that resisted subduction. The other record of subduction is found in the deep subsurface: oceanic lithosphere preserved in the mantle that records ocean basin closure between successive generations of arcs. Seismic tomography maps out these crumpled paleo-oceans down to the core-mantle boundary, where slab accumulates. One such accumulation of enormous scale is under Eastern Asia, recording the assembly of the Central Asian Orogenic Belt (CAOB).

Deep CAOB slab has hardly been explored because tomographic image resolution in the lowermost mantle is limited, but this is rapidly improving. We present new images of the CAOB slabs from our P-wave tomography that includes core-diffracted waves as a technical novelty. The previous slab blur sharpens into the type of elongated geometries expected to trace paleo-trench lines.

Since the North American Cordillera is younger than the CAOB (mostly <200 m.y. versus ∼650-250 m.y.), its slabs have descended only to mid-mantle depths (<2000 km), where tomographic resolution is much better. Hence we can make a detailed, spatiotemporal match between 3-D slab geometries and the accretion history of the Cordillera – a blueprint for continental-scale investigations in other accretionary orogens, including what may become possible for the CAOB.

Lower-mantle slabs beneath North America reveal evolving configurations of arc-trench positions back to the breakup of Pangea. These can be combined with quantitative plate reconstructions to show where and when the westward-drifting continent overrode pre-existing, intra-oceanic subduction zones, and accreted their associated arcs and basement terranes in Jurassic and Cretaceous times. Tectonic predictions from this "tomographic time machine" can be checked against the geological record.

To demonstrate, we propose a resolution to the longstanding debate of how and when western North America accreted the microcontinental Insular Superterrane (Wrangellia, Alexander, Peninsular) and its southern relative, the Guerrero Superterrane. Mantle structure supports an unconventional paleogeography whereby these Mesozoic arcs had grown in a long-lived archipelago located 2000-4000 km west of Pangean North America, its paleo-trench lines marked by massive, steep slab walls >10,000 km long. North America converged on the two microcontinents by westward subduction of two intervening basins (which we name Mezcalera and Angayucham oceans), culminating in diachronous suturing between ∼150 Ma and ∼50 Ma.

Hence geophysical subsurface evidence negates the widely accepted "Andean-style" model of Farallon-beneath-continent subduction since at least 180 Ma, and supports a Jura-Cretaceous paleogeography closer to today's Southwestern Pacific, or to the Paleozoic CAOB. Though advocated since the 1970's by a minority of geologists, this scenario had not gained wide acceptance due to a record obscured by overprinting, margin-parallel translation, and oroclinal bending. The new subsurface evidence provides specific indications where to seek the decisive Mezcalera-Angayucham suture. The suture is evident in a trail of collapsed Jura-Cretaceous basin relics that run the length of the Cordillera.

Reference: Sigloch, K., & Mihalynuk, M. G. (2013). Intra-oceanic subduction shaped the assembly of Cordilleran North America. Nature, 496(7443), 50-56. doi:10.1038/nature12019