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A complex, two-phase subduction history of the Farallon plate revealed by finite-frequency tomography

K. Sigloch (1,2), N. McQuarrie (1), G. Nolet (1,3)
(1) Princeton University, (2) LMU Munich, (3) Universite de Nice

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We use finite-frequency tomography to jointly invert for P-velocity and attenuation structure under North America down to about 1500 km depth. The input data are traveltime and amplitude anomalies of 569 teleseismic earthquakes recorded in North America between 1990 and 2007. Amplitude and traveltime anomalies were measured in a finite-frequency sense by matched filtering of predicted and observed waveforms in six distinct frequency passbands.

Eastward subduction of oceanic tectonic plates has shaped the geologic history of Western North America over the past 150 million years. The mountain-building and volcanism that brought forth the spectacular landscapes of the West are credited to the vast ancient Farallon plate, which interacted mechanically and chemically with the overlying continent as it plunged back into the mantle. The Farallon plate has almost disappeared from the surface but it has been expected to remain more or less intact underground as a cold sheet surrounded by warmer mantle.

We show that in reality two clearly distinct subduction systems are present under North America, separated by an east-west distance of about 1000 km. The currently active one descends from the Pacific Northwest coast to at least 1500 km depth beneath the Great Plains, whereas its abandoned predecessor occupies the transition zone and lower mantle beneath the eastern half of the continent. We argue that the separation between them is linked to the end of the Laramide era 50 million years ago, a time of unusual tectonic and volcanic activity during which the flatly subducting slab is inferred to have caused the uplift of the ancestral Rocky Mountains. Our images reveal two more major breaks or tears in the submerged plate. One runs along the Farallon's equivalent of the Mendocino Fracture Zone, a long-lived line of weakness on the Pacific seafloor. The second strikes 2500 km northeast from Oregon to southern Saskatchewan in the direction of relative plate motion, paralleling the Yellowstone hotspot track.