The Upper Mantle Shear Velocity Structure beneath the Gulf of California

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A. Abstract

We imaged the 3-D shear velocity structure beneath the Gulf of California using surface wave data to obtain a better insight in the tectonics of the region. We find evidence for a strong high shear-velocity anomaly in the mantle beneath the southern part of the Gulf of California which we interpret as a remnant of the subducted Guadalupe slab. The anomaly provides the clue to the reconstruction of the slab detachment of a former Farallon microplate, followed by the cessation of its subduction and spreading, and the formation of a transform fault next to former trench. The current location of the anomaly indicates that the slab remnant was also cut at this transform fault, because it stuck at the location of subduction rather than being dragged through the mantle.

B. introduction

The Gulf of California rift system forms a geologically young and active plate boundary that links the San Andreas strike-slip fault system in California to the oceanic spreading system of the East Pacific Rise. Its formation is directly related to the change in plate contact along the North American coast from the Farallon-North America subduction to the Pacific-North America transform motion after the first Pacific-Farallon spreading center reached the trench. Unsubducted Farallon microplates (Guadalupe & Magdalena) have been identified along much of the western Baja California coast and may extend under the margin of North America. To understand the evolution of this plate boundary zone, a detailed image of the shear velocity structure in the upper mantle beneath the Gulf of California region is essential.

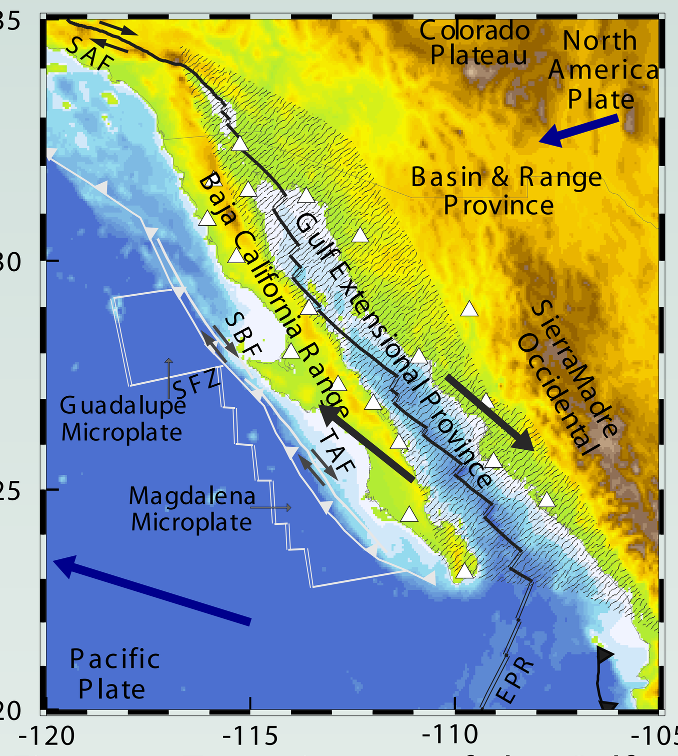

Figure 1. Tectonic map of the Gulf of California region. Present-day plate boundaries shown as dark lines. Inactive plate boundaries shown as white lines.

C. Shear velocity tomography

The shear velocity model presented here is conducted by using fundamental mode Rayleigh waves through 3 steps.

1) By using the two-station cross-correlation method described by Meier et al., (2004) and the automated multimode inversion method by Lebedev et al., (2004), we determined the fundamental Rayleigh wave phase velocity dispersion curves for 450 station pairs around the Gulf of California.

2) From there, we constructed phase velocity maps (isotropic, 2ψ and 4ψ anisotropic terms) for 32 periods ranging from 9 - 250 seconds.

3) The phase velocity curves at all grid points were inverted to shear velocity models, and a 3-D shear velocity structure to a depth of 350 km beneath the Gulf of California was obtained.

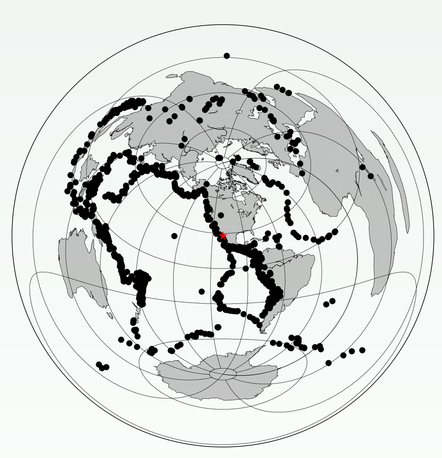

Figure 2. Event locations

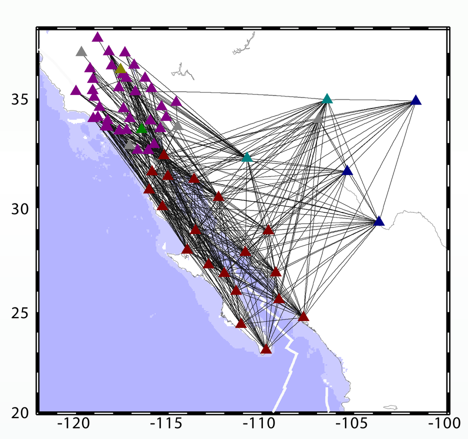

Figure 3. Ray path coverage

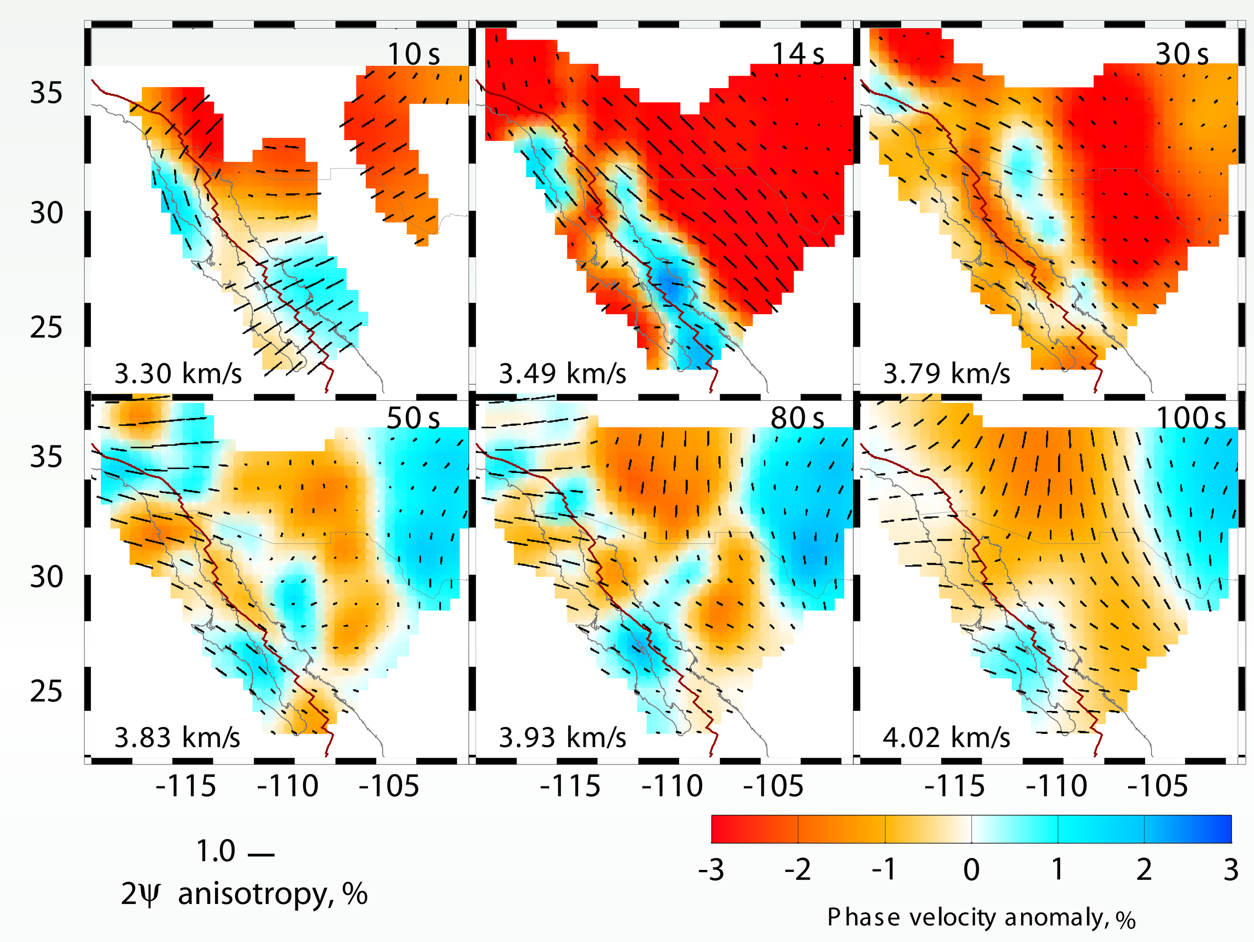

Figure 4. Anisotropic phase velocity maps at at 6 different periods.

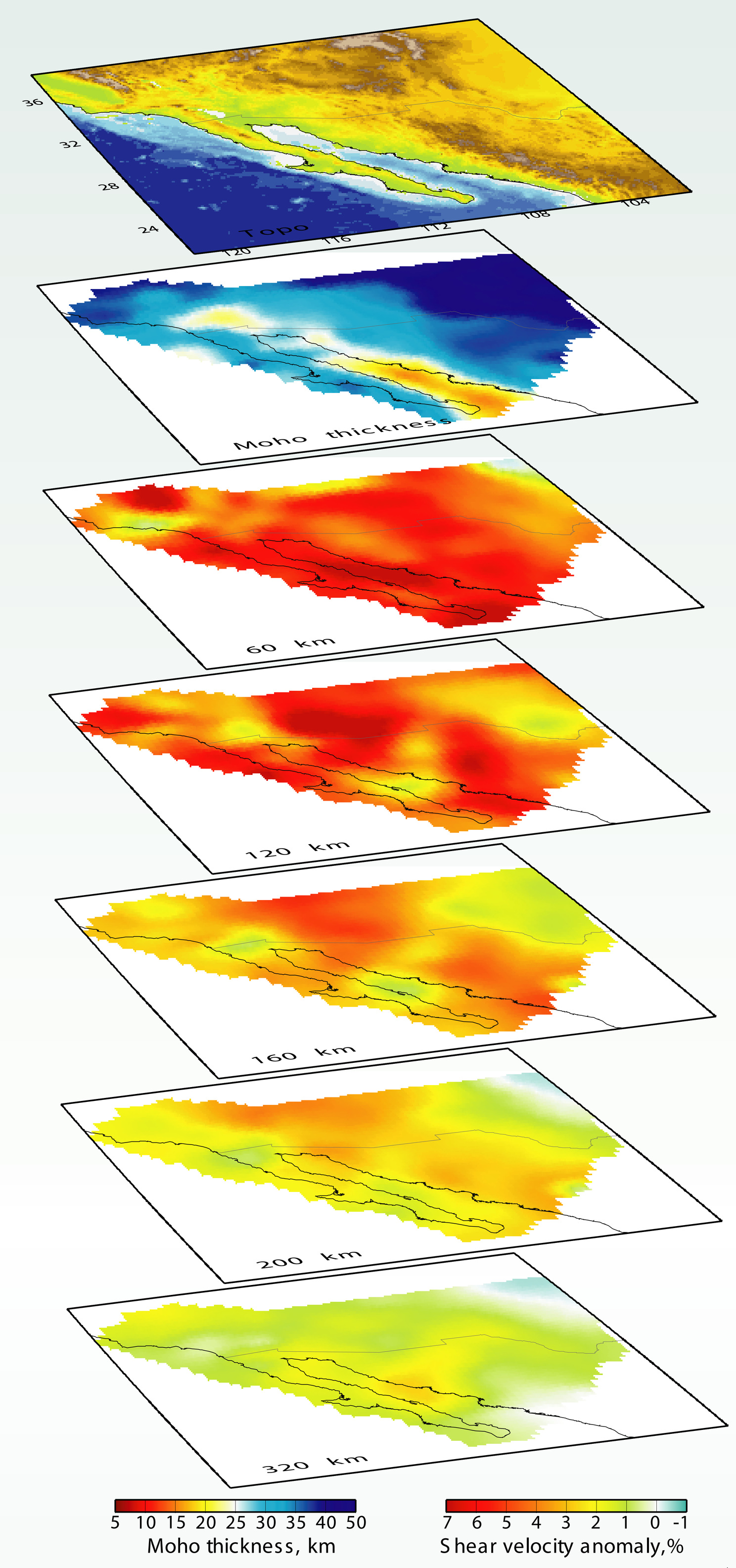

Figure 5. Shear velocity structure relative to global reference AK135.

D. Proposed tectonic scenario

The most conspicuous feature of the 3-D shear velocity structure is a relatively high velocity anomaly beneath the central part of the Gulf of California at around 150 km depth. We interpret this anomaly as a slab remnant of the Guadalupe microplate.

Our tectonic interpretation is as follows:

(1) > 12.5 Ma: The Pacific-Farallon spreading centers approached the trench in a southward direction. The plate boundary thereby changed from a Farallon-North America convergence boundary (Farallon subducting under North America) to a Pacific-North America transform boundary, leaving a 'slab window' beneath most of the western edge of North America. Gradually, this slab window thermally weakened the subducting lithosphere north of the Guadalupe microplate.

(2) At ~12.5 Ma, the northern tip of the Magdalena ridge segment first encountered the trench at the Shirley Fracture Zone (the southern boundary of the Guadalupe microplate). The Guadalupe microplate became isolated between two triple junctions; at this point, we infer that the Guadalupe microplate broke off from the subducted Farallon plate deep down. Through thermal weakening, the Guadalupe slab tore southwards from its (subducted) northern fracture zone to its (subducted) southern fracture zone. Subduction stopped due to slab pull removal which in turn caused the cessation of spreading. Thus, the Guadalupe plate was effectively captured by the Pacific plate. The new Pacific-North America transcurrent motion was taken up by a new transform fault that developed next to the (former) trench. This fault cut through the subducting Guadalupe lithosphere, leaving the Guadalupe slab remnant beneath Baja California completely detached from its origin.

(3) 12 - 6 Ma: The thermally weakened slab remnant became the source of the abundant magnesian andesites in the region above it, as well as the adakitic volcanism situated predominantly along its western margin.

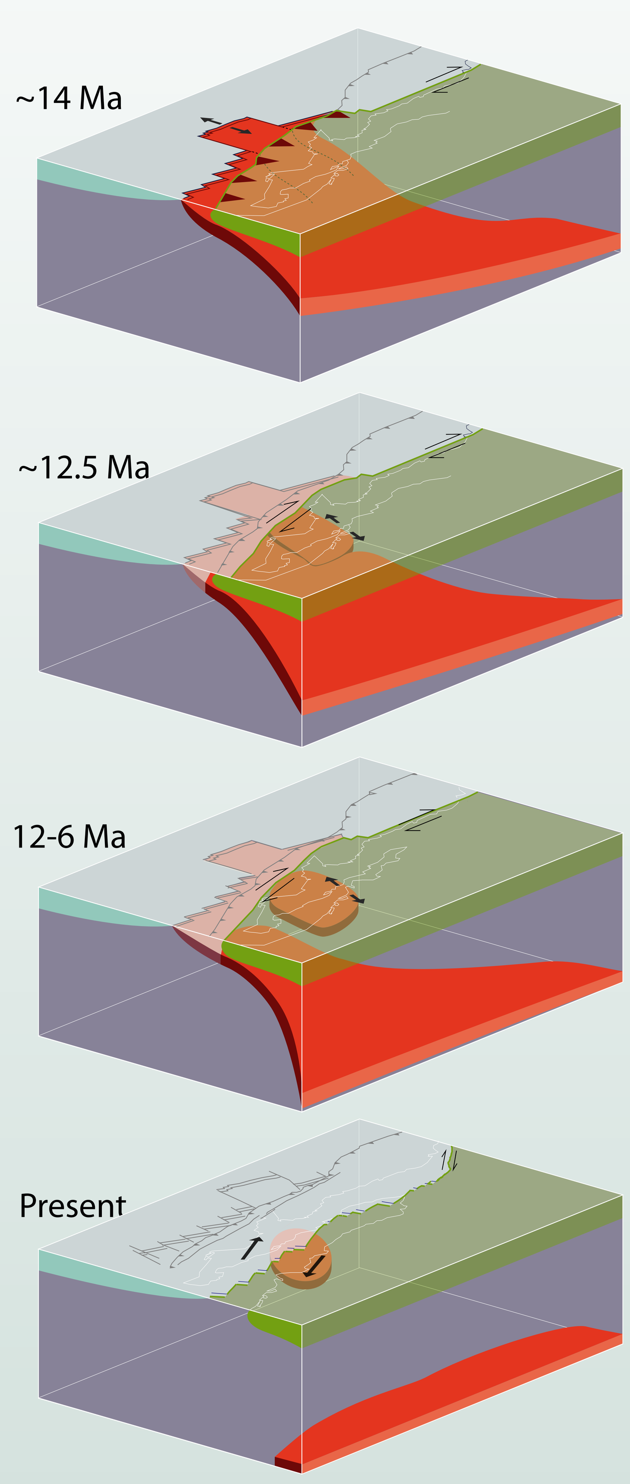

Figure 6. Schematic block diagrams showing the proposed tectonic scenario in the Gulf of California.

E. Conclusion

Following the first ridge-trench collision, the Pacific-North America plate boundary has been localizing itself in the weakest point among the interacting plates. There were already weakened features in these plates, such as the pre-existing linear features in the slab (ridges, fracture zones), faults and extended back arc basins in the overriding plate. The southward propagating slab window (induced by the first ridge-trench collision) has been continually meeting the fracture zones, together with some newly subducted ridges; this had produced secondary slab windows. One unexpected consequences of this is the leaving behind of part of the Guadalupe slab and the opening up of the Gulf of California.

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