Bathymetric Highs and Slab Dip

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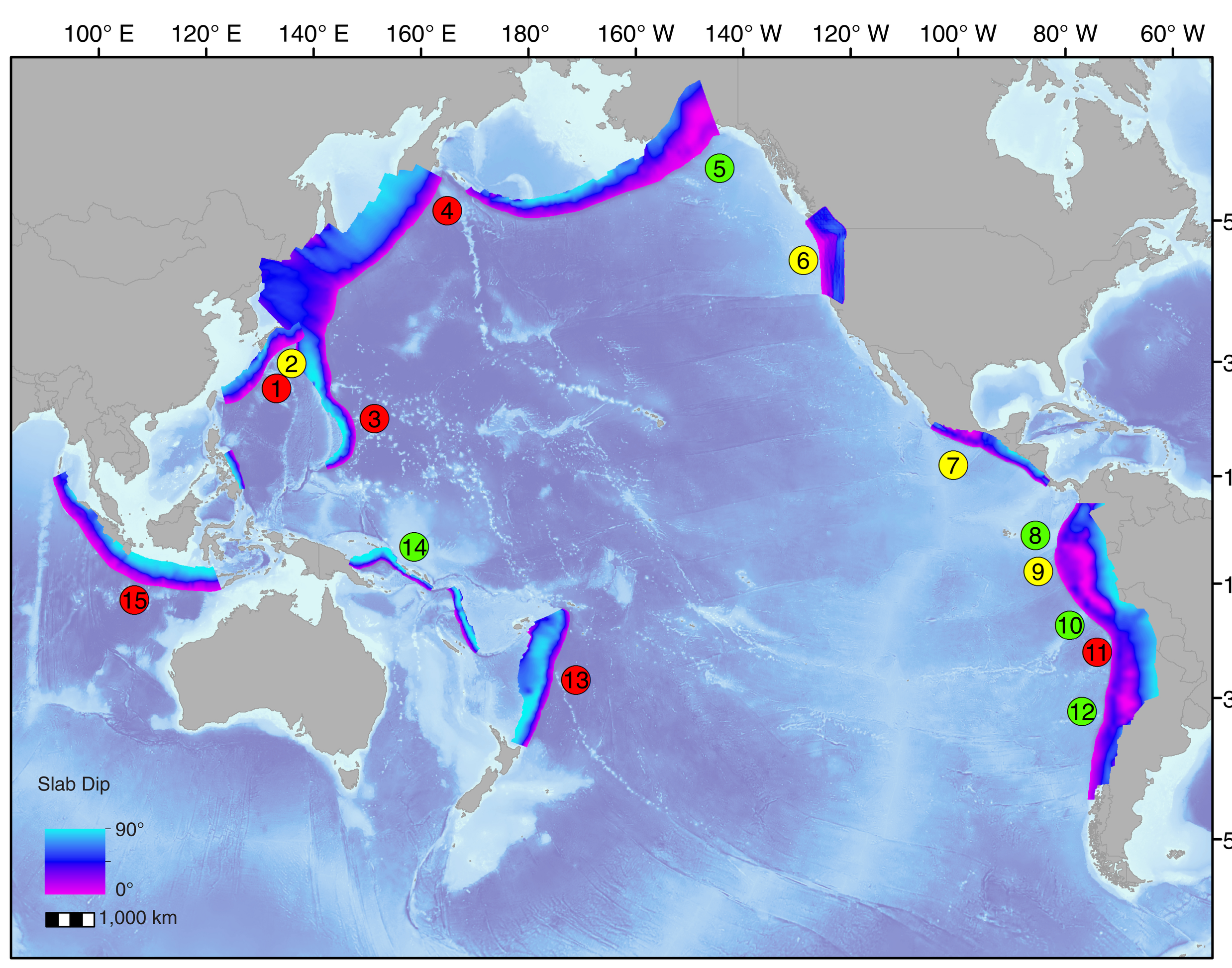
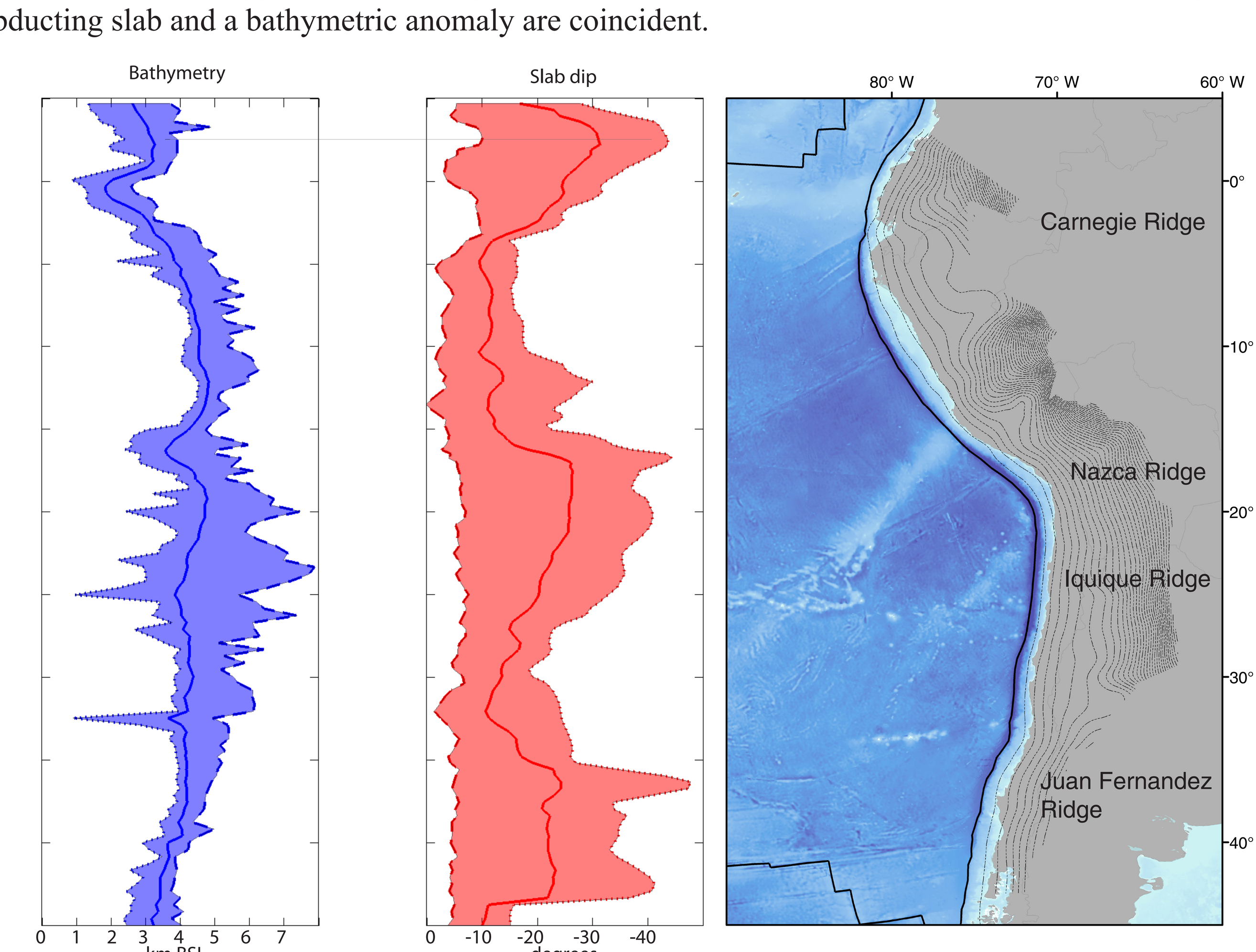
Abstract

Previously it was thought that the age of the subducting lithosphere controlled the angle of a subducted plate. Numerous studies have since shown that there is no direct correlation between the age of the subducting slab and its geometry. Currently the standard explanation for flat slabs is that the excess positive buoyancy of subducting bathymetric anomalies, in the form of an oceanic plateau or aseismic ridge, drives the subducted plate to a shallow geometry. Today we find that flat slabs lack subducting bathymetric anomalies and that subducting bathymetric anomalies do not all produce flat slabs. Hence, thickened lithosphere cannot be the main mechanism for slab flattening. The driving forces of subduction are controlled by many characteristics of the subducting and overriding plates. Here we present the along trench variation of subducting bathymetry and show that there is no correlation between it and the dip of the subducted slab. In addition to the present day extent of subducting bathymetric anomalies, we extend our observations into the past using plate reconstructions to determine the location of conjugate bathymetric anomalies.

Bathymetric Highs

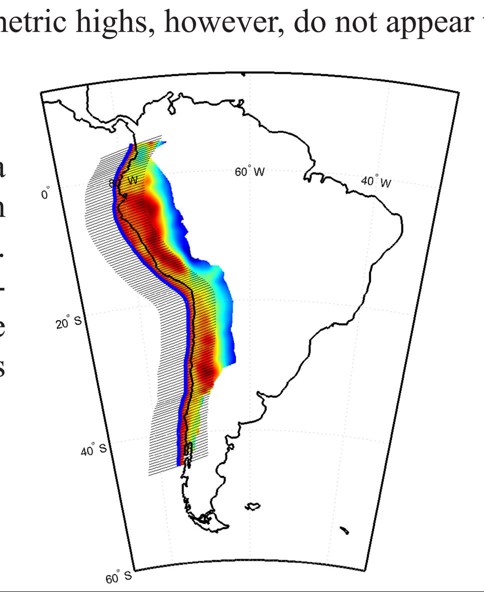


Map of circum-Pacific subduction zone slab dip. Data for subduction zone geometry are from Hayes et al. (2012) and McCrory et al. (2006). Numbered circles represent our interpretation of the validity of the buoyancy hypothesis at each location where we have data constraining changed in the geometry of the subducted slab. Circles are colored red where there is a subducting bathymetric anomaly but no associated flat slab, yellow where there is a flat slab without any apparent subducting bathymetric anomaly, and green where a change in the geometry of the subducting slab and a bathymetric anomaly are coincident.



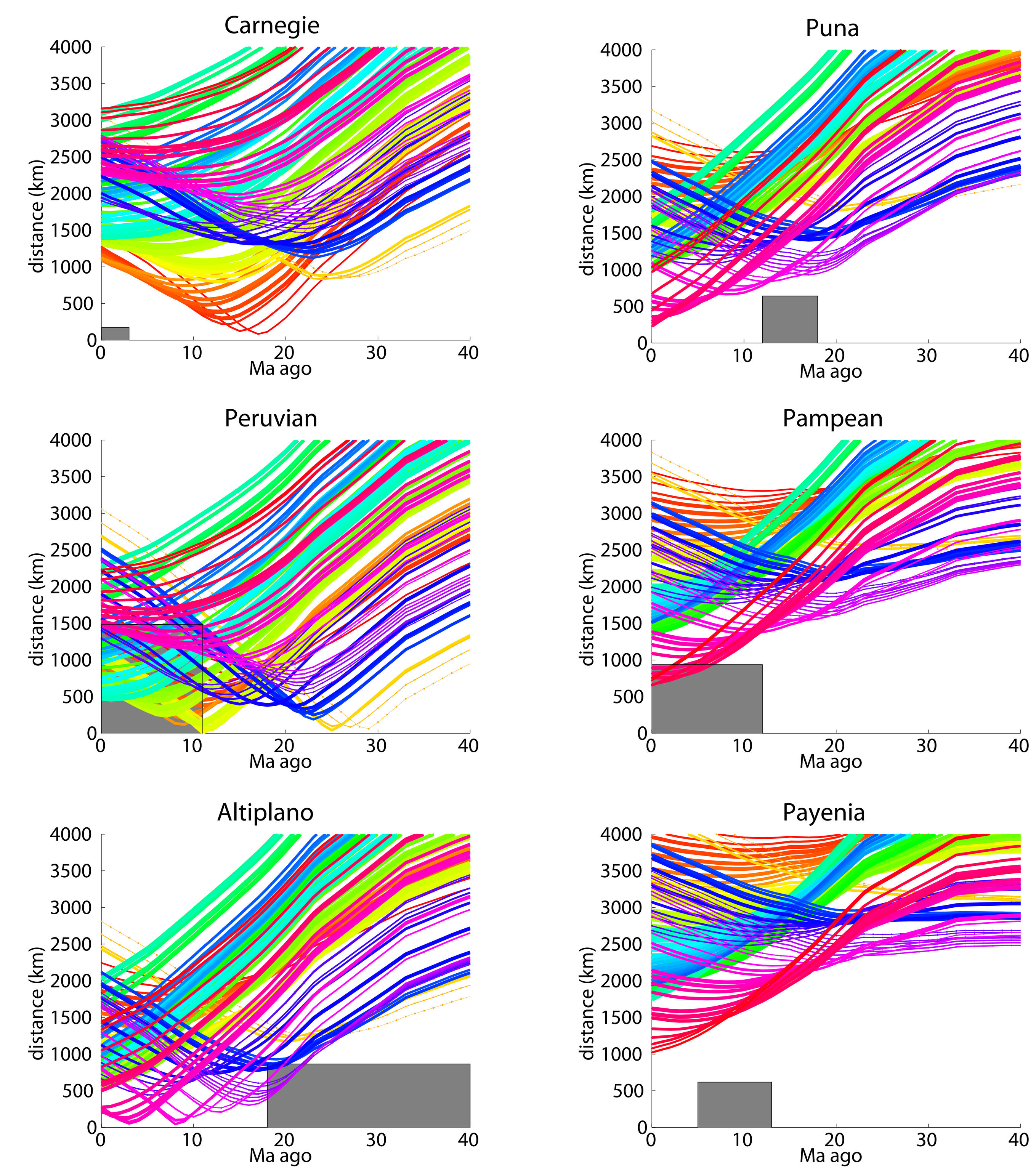
The figure above shows the along trench variation of slab dip and near trench bathymetry for the South American margin. The solid lines represent the mean of the bathymetry and slab dip at a given latitude. The shaded area of each plot is bounded by the minimum and maximum values at each latitude. Zones of shallow subduction appear in the slab dip plot as a narrowing and a shift in the distribution towards shallower dips. The Carnegie, Nazca, Iquique, and Juan Fernandez ridges are all visible as bathymetric highs, however, do not appear to be directly correlated with changes in slab geometry.

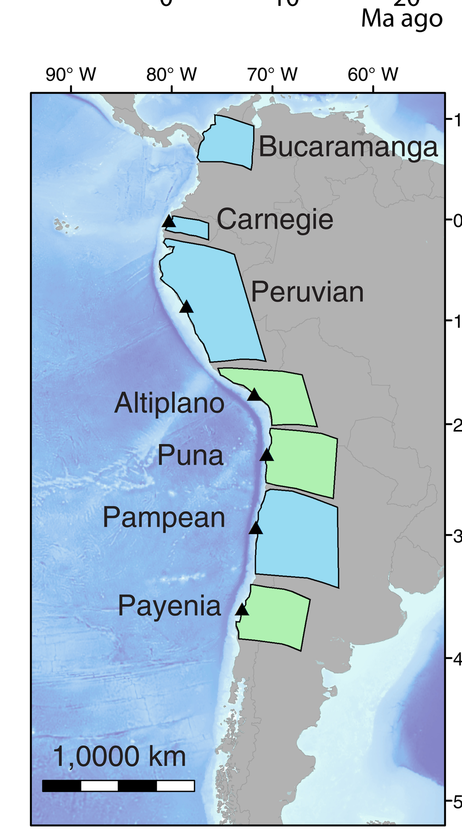
To produce the plots above we have taken evenly spaced points along a digitized South American trench. At each point we extract a cross section of the near trench bathymetry along the azimuth of plate convergence. Similarly we extract a cross section of the Slab 1.0 model from the landward size of the trench. Below is an example cross section from each side of the trench. The cross sections are sampled at 100 evenly spaced points and that data is presented above.



Tracking Impactors

We have expanded our investigation of the buoyant impactor hypothesis by looking for a correlation between proposed zones of shallow subduction in the past and areas of thickened oceanic crust that have been reconstructed as possible conjugate features to present structures on the Pacific plate. Following the analysis of Gutscher et al. (1999) we propose a set of bathymetric anomalies that mirror the Marquesas, Pitcairn, Tahiti, and Macdonald seamounts/plateaus. We use the EarthByte plate model (Müller et al., 2008) to reconstruct Pacific plate features to the time and location of their formation on the Pacific-Farallon/Nazca spreading ridge. We create a feature on the conjugate plate and track its location forward in time. A lack of data from both sides of the spreading ridge and possible ridge jumps introduce more assumptions into the reconstructions (Cande and Haxby, 1991), however, we have confidence in our rotation model and methods based on the agreement of the location of our hypothetical conjugates with actual conjugate features such as the Nazca ridge.

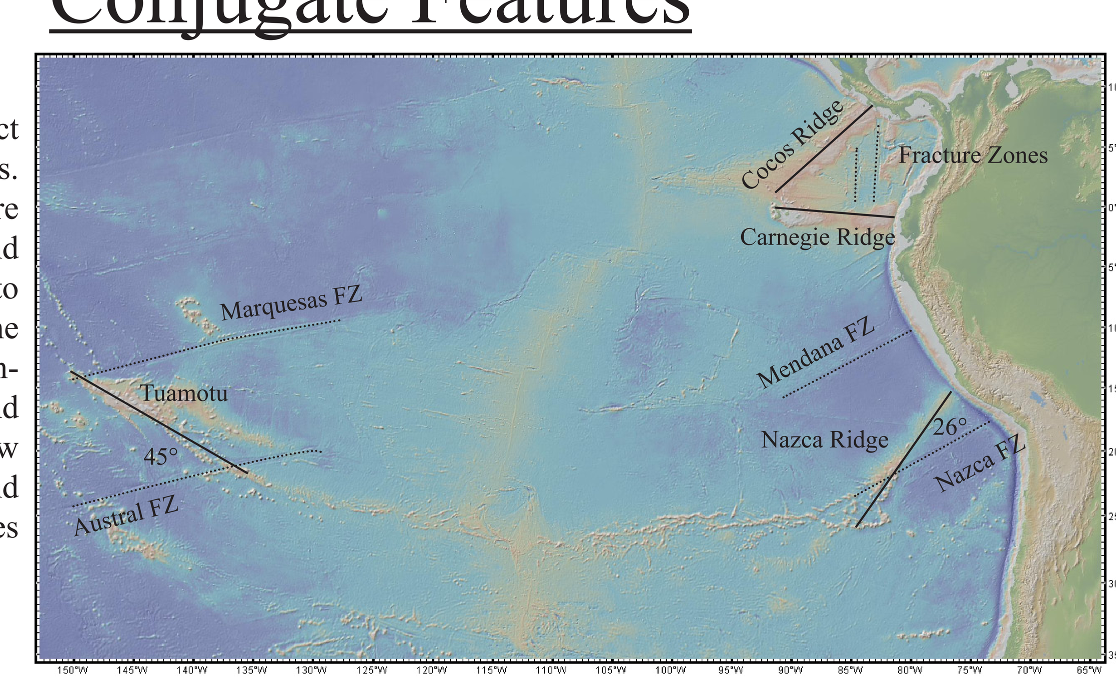




Location of Pacific - Farallon/Nazca conjugate features relative to a given flat slab. We have placed points along Pacific plate bathymetric highs, and created conjugate features using standard plate reconstruction techniques and the rotation model of Müller et al. (2008). A plot for each flat slab shows the proximity of a reconstructed point on the bathymetric anomaly to that flat slab, plotted as a function of time. The thickness of the line scales with the crustal volume in a 100 by 200 kilometer box around the Pacific plate conjugate point. The grey box represents the spatial and temporal extent of the flat slab from Ramos. We expect impactors to pass through this target zone if the buoyancy hypothesis is the cause of the flat slab. The map shows the location of the flat slabs along the South American margin (Ramos and Folguera, 2009). The black triangles are the point from which our distances are calculated.

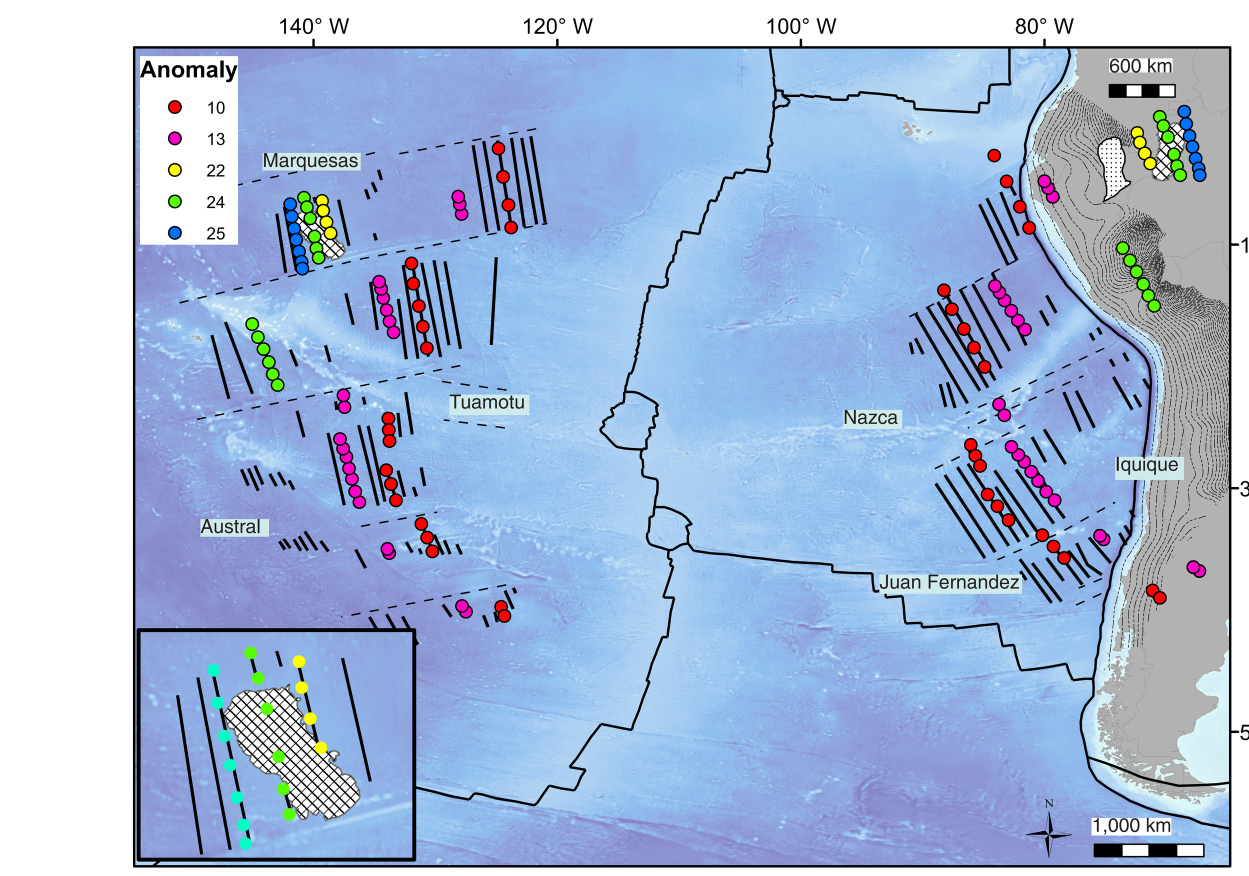
Conjugate Features

This map indicates the imperfect symmetry of conjugate features. We can see that conjugates are not perfect mirror images and that conjugates do not have to be the same size or shape. The Cocos and Carnegie Ridge conjugates and the Tuamotu and Nazca Ridge conjugates show that the angle between the trend of the feature and fracture zones is not constant.

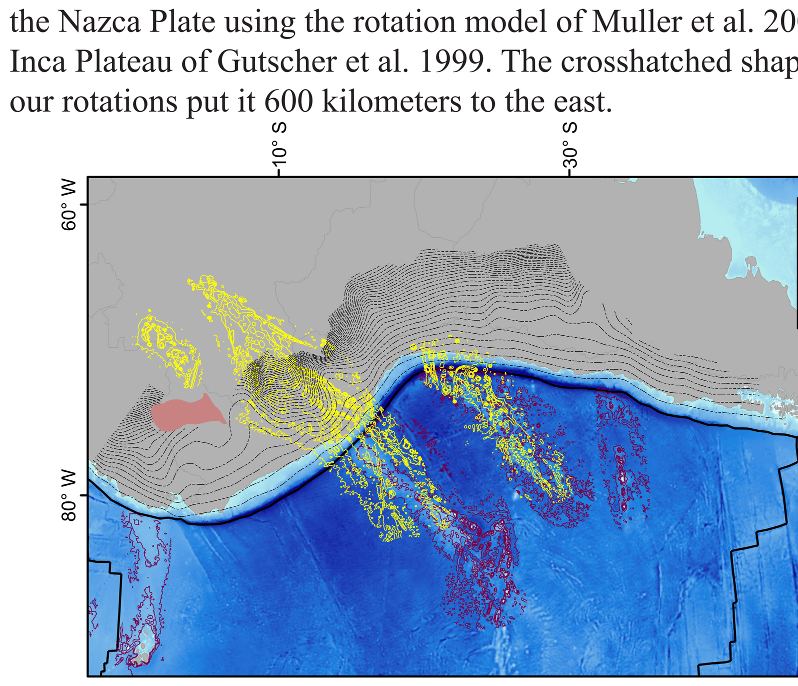


Locating the Inca Plateau

Previous authors have used an inferred location of the Marquesas conjugate, the "lost Inca plateau", to explain the modern Peruvian flat slab. We have tested five different rotation models for Nazca-Pacific motion to reconstruct the location of a Marquesas conjugate and show that it was previously mislocated and that its current location cannot provide buoyancy for the flat slab.

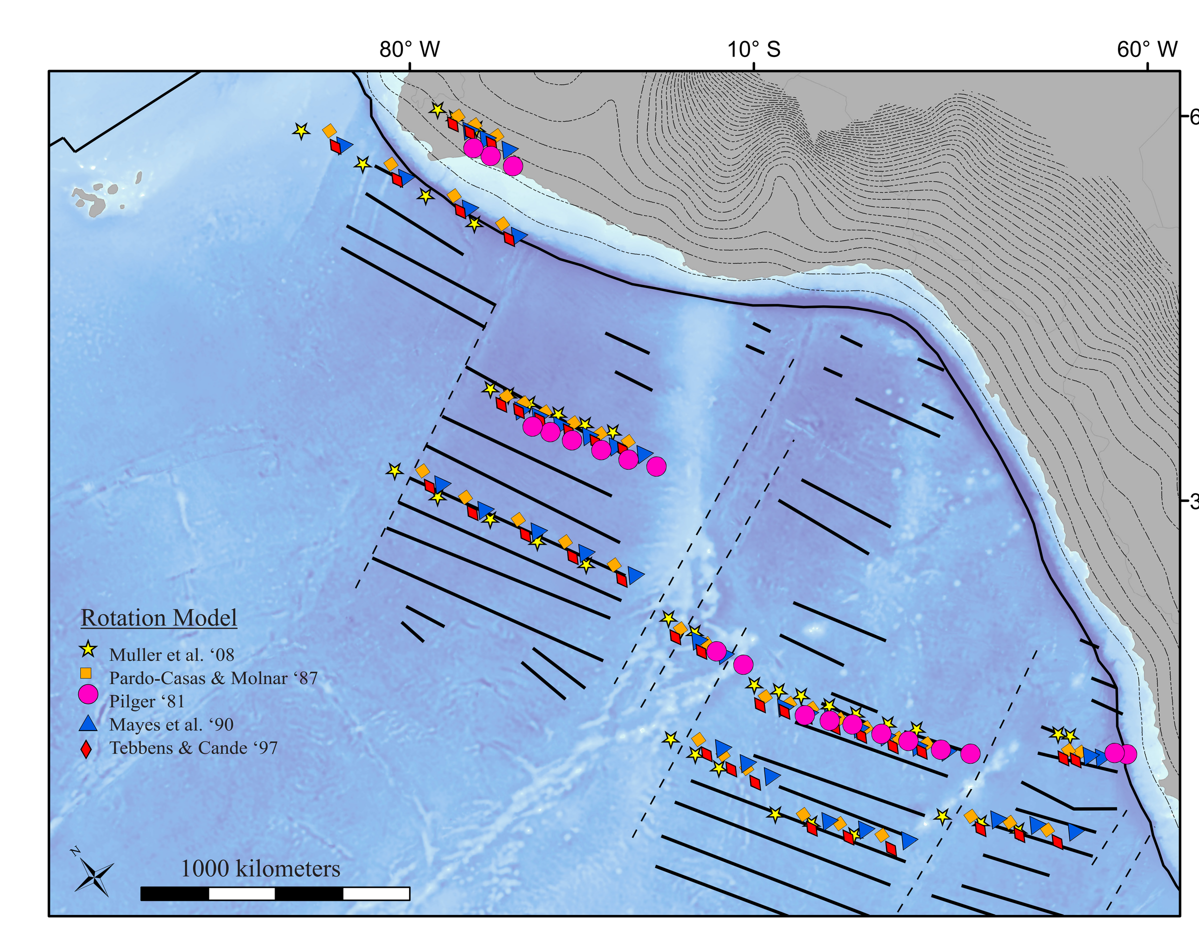


This map shows the location of chrons 10,13,22,24, and 25 on the Pacific Plate and our conjugate location on the Nazca Plate using the rotation model of Muller et al. 2009. The stippled shape is the MM2 location of the Inca Plateau of Gutscher et al. 1999. The crosshatched shape is our Marquesas and it's conjugate. Notice that our rotations put it 600 kilometers to the east.



This map shows the agreement between our reconstructed features and the possible conjugates. Purple contours are 1 km contours of modern bathymetry on the Nazca plate, yellow contours are the reconstructed mirror image of the modern Pacific contours. The pink feature is the Inca Plateau of Gutscher et al. 1999.

We have performed our reconstructions using the model of Muller et al. 2008. To assess the choice of our rotation model we have rotated a set of points on magnetic isochrons 10 and 13 and compare them with the isochron map of Cande et al. 1989. The figure below shows the agreement between the five rotation models for Pacific-Farallon motion.



Conclusions

Our plate tectonic reconstructions of the South American margin and potential conjugate crustal anomalies when paired with the history of flat slabs compiled by Ramos and Folguera (2009) shows that there is no clear link between a subducting anomaly and zones of flat subduction. We have shown previously that the correlation between current flat slabs and subducting crustal anomalies does not exist and therefore buoyant bathymetric anomalies cannot be the cause of flat slabs. With this series of reconstructions we have shown that the correlation between bathymetric anomalies and flat slabs did not exist in the past. With so much evidence against the hypothesis that flat slabs are caused by the subduction of a buoyant crustal anomaly, we believe it is time to abandon this hypothesis and investigate other possible mechanisms.

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