Comparing Impactor History to Shallow Subduction in South America

Steven M. Skinner & Robert W. Clayton

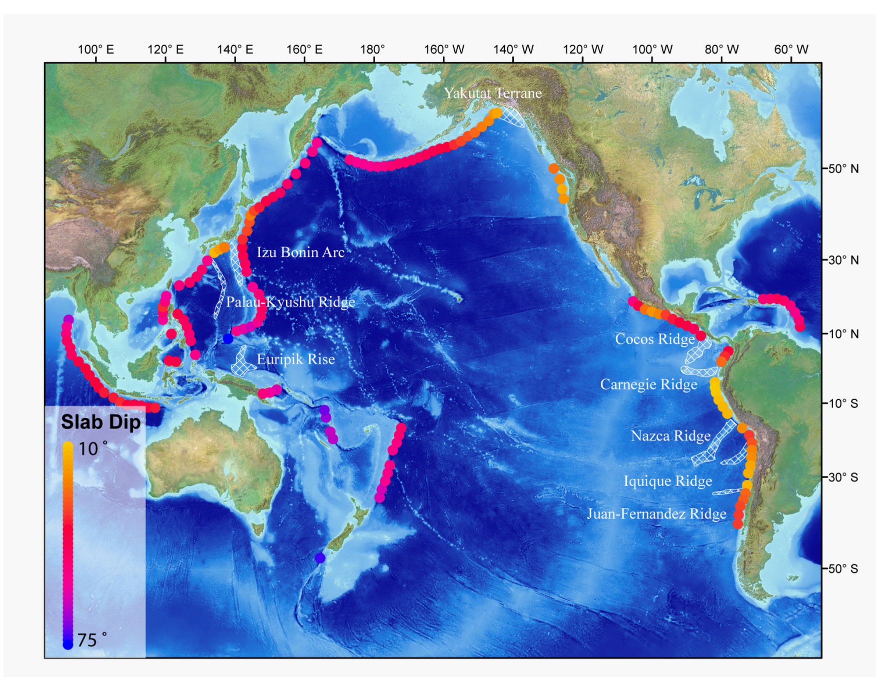
Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena CA

skinner@gps.caltech.edu

Abstract

Flat and shallow subduction are proposed to be both caused by buoyant ocean impactors (plateaus, ridges, etc.) and to be part of orogenic cycles. Neither process can explain all instances of shallow subduction (e.g. central Mexico and Cascadia). In this study we use standard plate tectonic reconstruction methods to investigate the spatial and temporal relationship between the subducting Farallon and Nazca plates beneath South America. We reconstruct conjugate features to bathymetric anomalies believed to have been formed on the spreading ridge and track their location and convergence with the South American margin. These are compared to the history of flat subduction as given by Ramos and Folguera (2009). We have found that in detail the subducting anomalies do not correlate well with zones of shallow subduction in space or time.

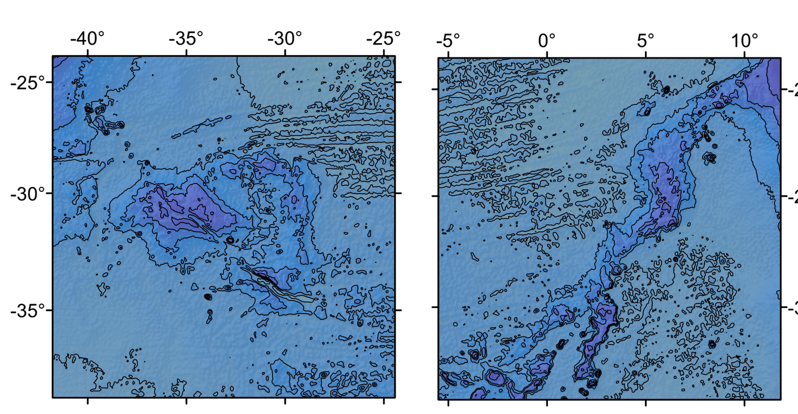
Bathymetric Highs

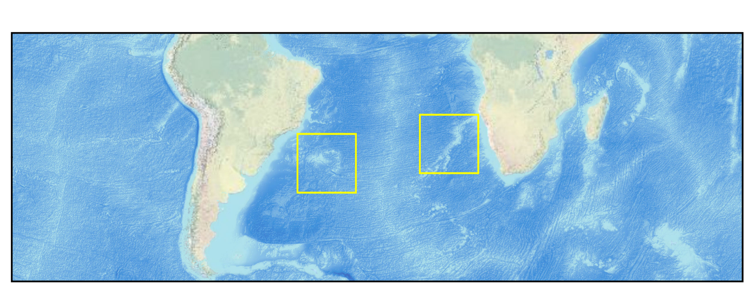


Approximated 10 percent of the present subducted slabs are considered to be flat slabs, which means that their dip angle beyond the seismogenic zone is very shallow (Gutscher et al., 2000). This phenomena has been shown to exist in the geologic record where cycles of alternating flat and normal-dip subduction are proposed (Ramos and Folguera, 2009) . The popular explanation for these zones is excess positive buoyancy related to the subduction of a bathymetric anomaly.

Conjugate Features

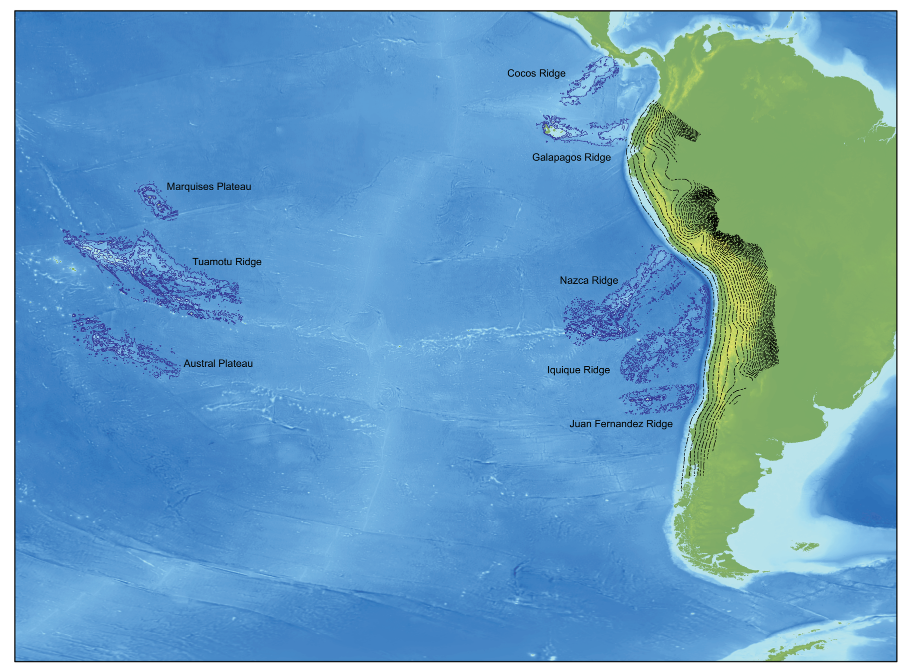
To evaluate the buoyant impactor hypothesis for historic flat slabs we must make several assumptions. The subsequent assumptions rely on the inferred symmetry of conjugate features formed on the spreading ridge. Here we show with one of the best documented set of conjugate features that exists today, the limitations of this argument. The Walvis ridge off Africa and the Rio Grande Rise off South America formed as conjugate features on the Atlantic spreading center. It is clear from these bathymetric maps that the two features are not mirror images of each other.



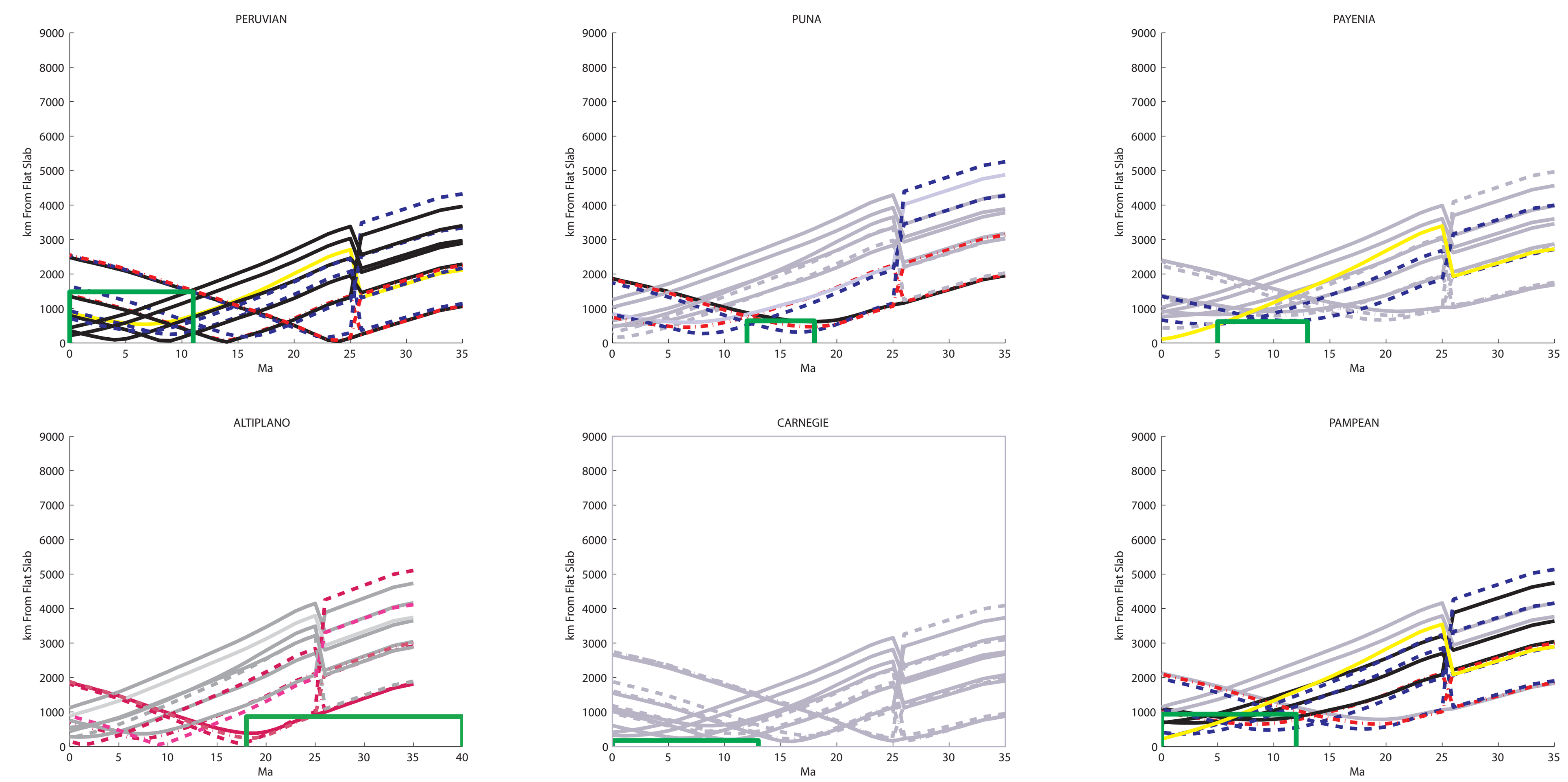


Tracking Impactors

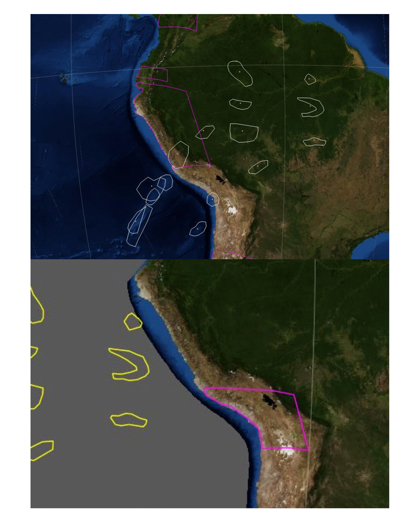
We have expanded our investigation of the buoyant impactor hypothesis by looking for a correlation between proposed zones of shallow subduction in the past and areas of thickened oceanic crust reconstructed as possible conjugate features to present structures on the Pacific plate. Following the analysis 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.

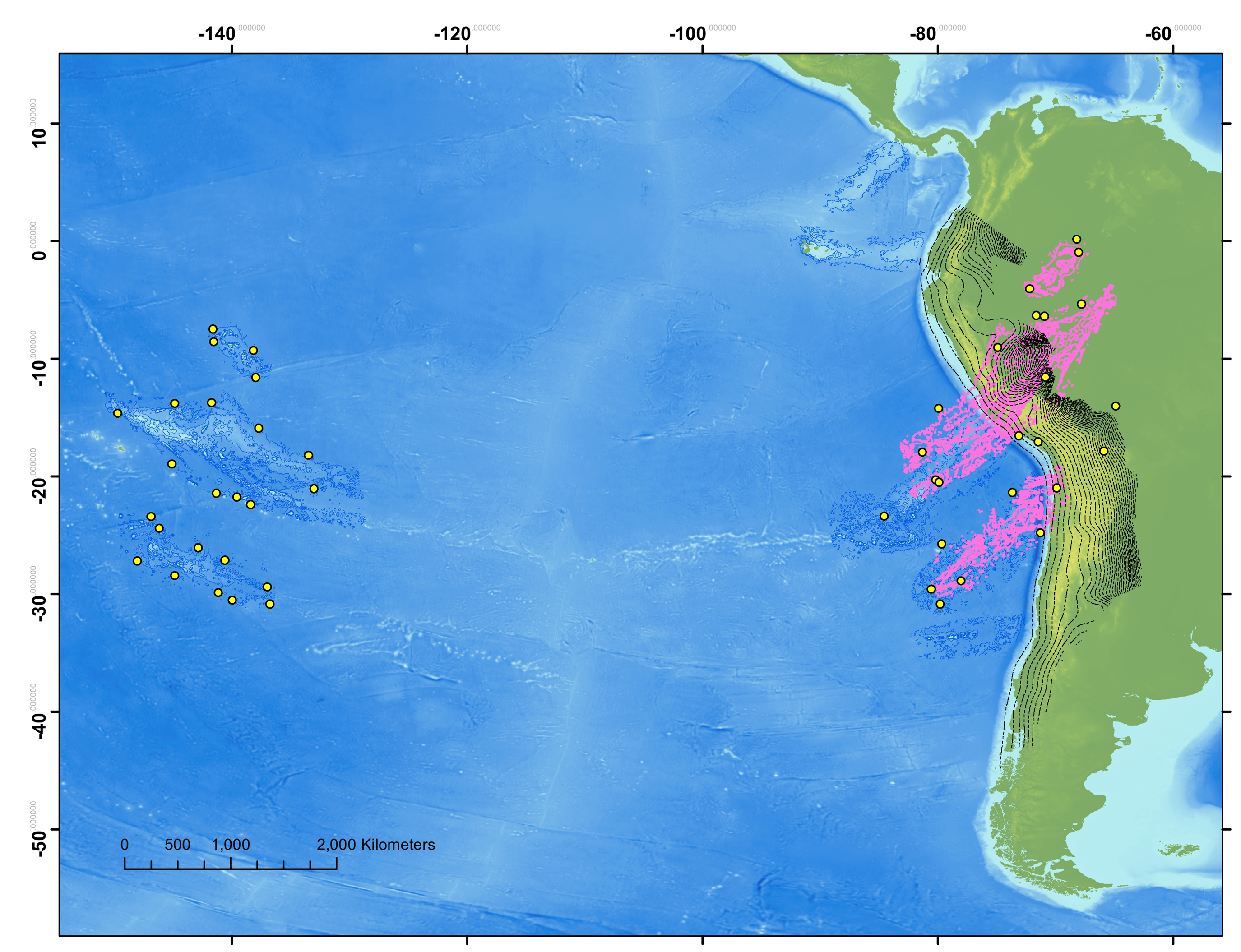


This map shows subducting anomalies offshore South America and possible conjugates on the Pacific plate. A possible conjugate to the Marquises plateau has been fully consumed by the subduction zone.

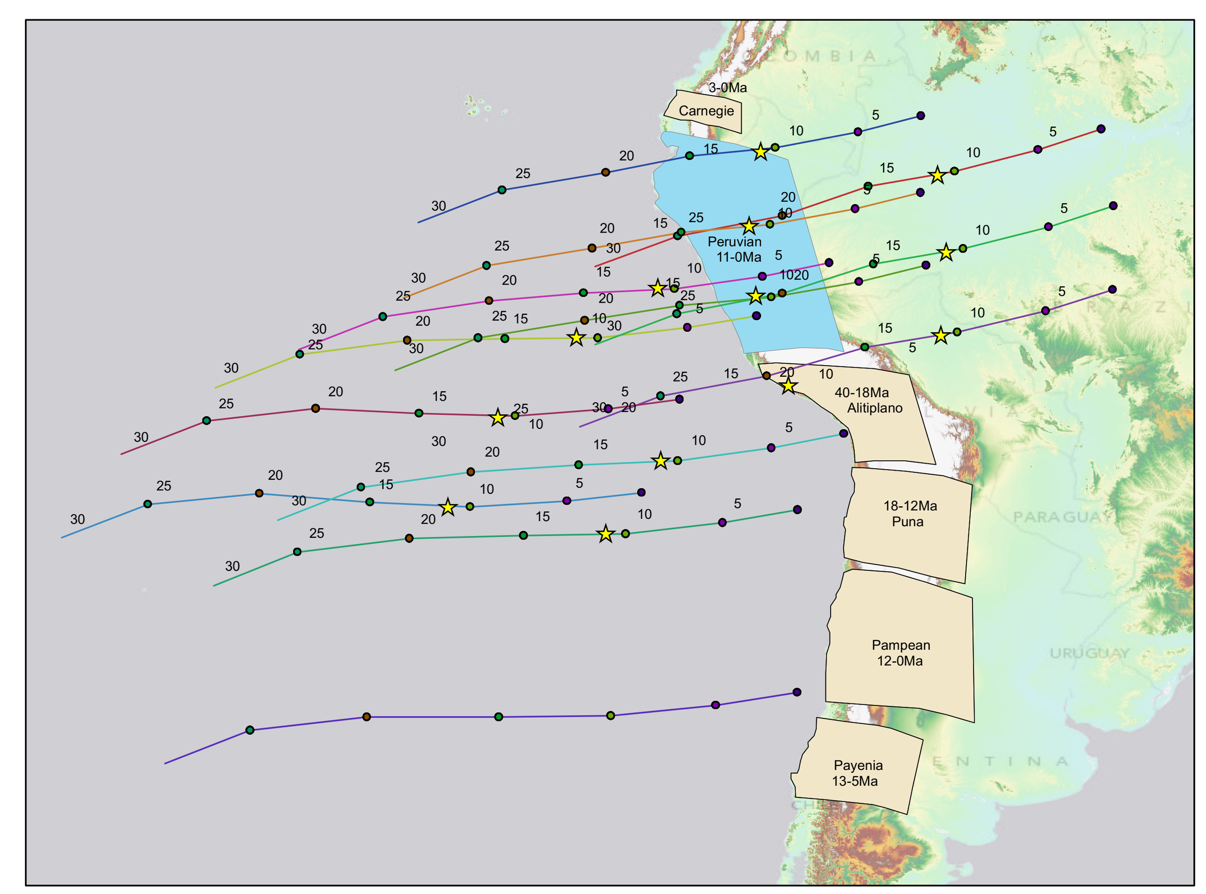


In order to visualize the spatial and temporal relations between our conjugate features and the proposed historic zones of flat subduction we track the center of the bathymetric anomalies and calculate the distance from each flat slab. The proximity of the subducting feature is plotted together with a box that represents the spatial and temporal extent of the flat slab as reported by Ramos and Folguera (2009). For one of our conjugate features to be considered as a cause for the flat slab we expect it to intersect the target region near the onset of shallow subduction.

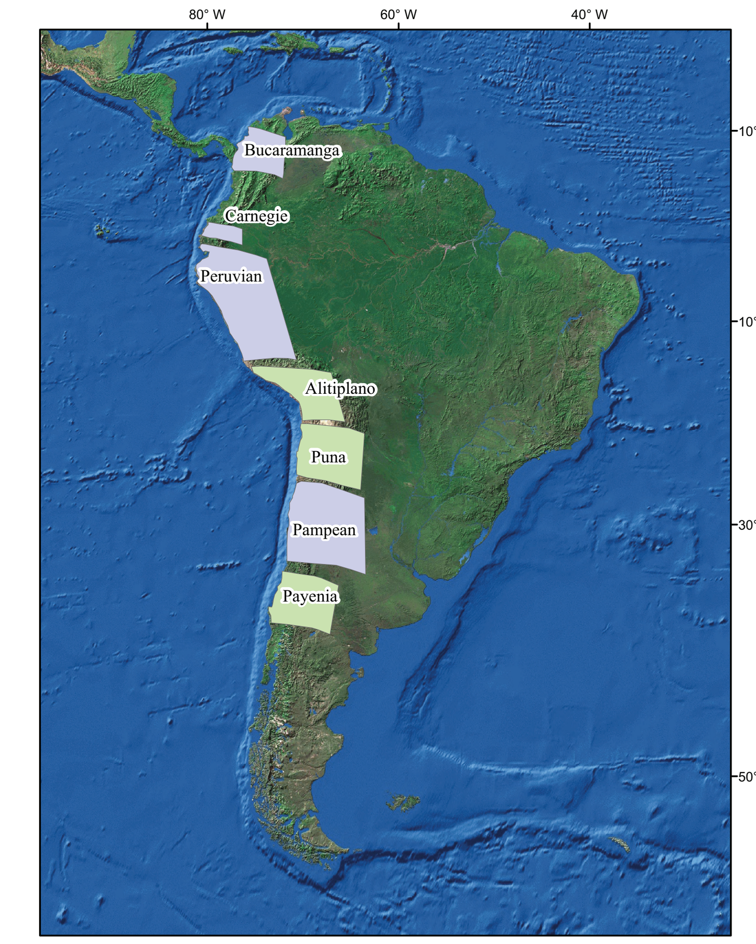




This map shows the agreement between our reconstructed features and the possible conjugates. Yellow dots on the Pacific plate are the intersection of isochrones and topographic contours of the bathymetric feature. Yellow dots on the Nazca plate are the reconstructed conjugates. Blue contours are 1 km contours of modern bathymetry, pink contours are the reconstructed mirror image of the modern Pacific contours.



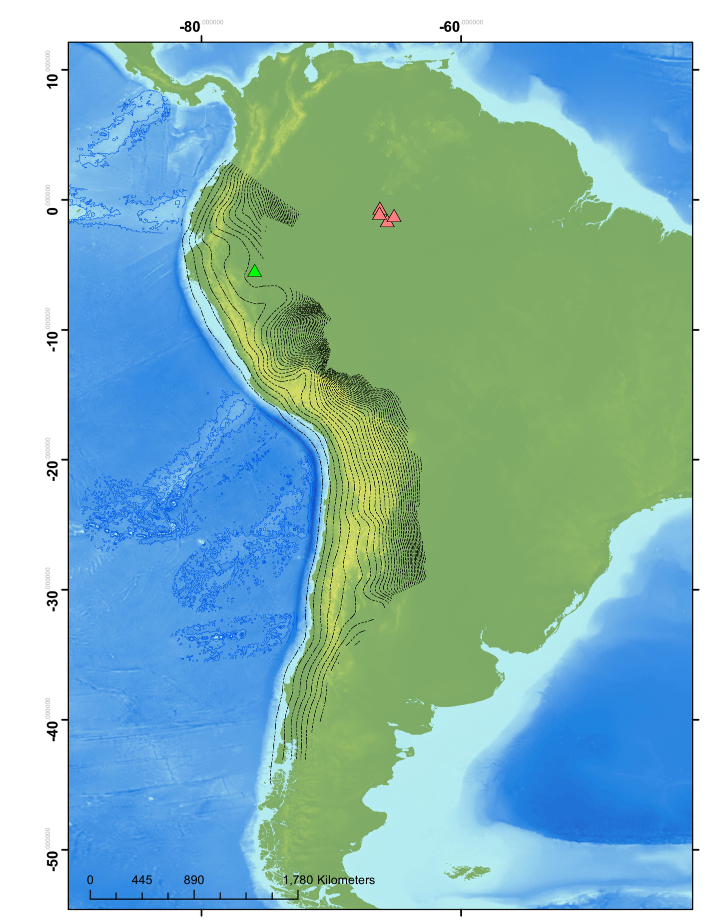
This map shows the path of conjugate features thorough time. Each conjugated point is represented by a different color line. In order to visualize the relationship between the subducting features and the geometry of the slab, the lines are marked with a star which indicates the features position in space at the time of shallowing of the Peruvian slab.



Location and timing of flat slabs in South America. After Ramos and Folguera.

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 used 4 different rotation models for Nazca-South America motion to reconstruct the location of a Marquesas conjugate and show that its current location cannot provide buoyancy for the flat slab.



Green triangle is the location of the Inca Plateau from Gutscher (1999). The 4 pink triangles represent 4 different plate reconstruction models.

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.

Cande, S. C., and Haxby, W. F., 1991, Eocene Propagating Rifts in the Southwest Pacific and Their Conjugate Features on the Nazca Plate: J. Geophys. Res., v. 96, no. B12, p. 19609-19622.
Gutscher, M. A., Maury, R., Eissen, J.-P., and Bourdon, E., 2000, Can slab melting be caused by flat subduction?: Geology, v. 28, no. 6, p. 535-538.
Gutscher, M. A., Olivet, J. L., Aslanian, D., Eissen, J. P., and Maury, R., 1999, The ''lost Inca Plateau'': cause of flat subduction beneath Peru?: Earth and Planetary Science Letters, p. 335-341.
Müller, R. D., Sdrolias, M., Gaina, C., and Roest, W. R., 2008, Age, spreading rates, and spreading asymmetry of the world's ocean crust, Geochemistry Geophysics Geosystems, Volume 9, American Geophysical Union, p. Q04006.
Pardo-Casas, F., and Molnar, P., 1987, Relative motion of the Nazca (Farallon) and South American Plates since Late Cretaceous time: Tectonics, v. 6, no. 3, p. 233-248.
Ramos, V. A., and Folguera, A., 2009, Andean flat-slab subduction through time: Geological Society, London, Special Publications, v. 327, no. 1, p. 31-54.
Rosa, J. W. C., and Molnar, P., 1988, Uncertainties in Reconstructions of the Pacific, Farallon, Vancouver, and Kula Plates and Constraints on the Rigidity of the Pacific and Farallon (and Vancouver) Plates between 72 and 35 Ma: J. Geophys. Res., v. 93, no. B4, p.