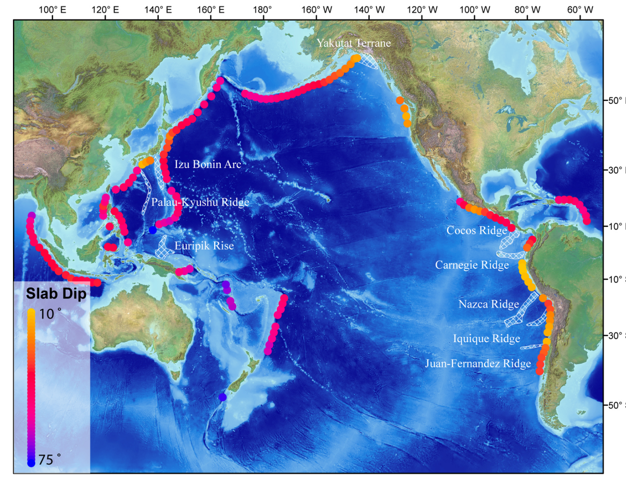

Map of the Pacific seafloor showing the dip of the shallow (less than 125km depth) portion of subducting slabs (Lallemand et al., 2005), and subducting bathymetric highs(white crosshatched pattern) that have been correlated with zones of shallow subduction.

Re-examining the Cause of Flat Subduction

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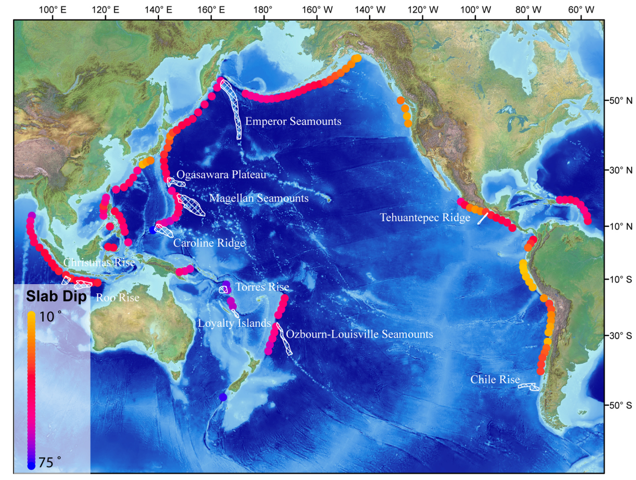


Map of the Pacific seafloor with labeled lithosphere anomalies (white crosshatched regions) that are subducting with no apparent effect on slab dip. Colored dots are slab dip from Lallemand et al. (2005).

Abstract

The subducted Cocos Plate beneath Mexico has been imaged to be horizontal for a distance of 200 km and underplates the continental crust. The fact that one of the flattest and longest lived slabs is not explained by the standard buoyancy arguments associated with the subduction of anomalously thick oceanic crust has prompted a reevaluation of impactor buoyancy as the sole mechanism to cause flat slabs. We are currently collecting data across several transects in Peru to confirm the applicability of the hydration model to this region.

There are areas with anomalous oceanic crust where an impactor on the subducting plate has not caused any apparent change in the subduction style. These counter examples lead to a model where impactor features are at best a catalyst in the system and the true "cause" is more likely due to mantle wedge fluids. The model we favor is based on the observation that zones of flat subduction appear to be correlated with truncated continental shelves. The subduction erosion process is a mechanism to deliver excess fluids to the mantle wedge which drives changes in slab geometry, through erosion of the margin which may be aided by the subduction of anomalous bathymetry.

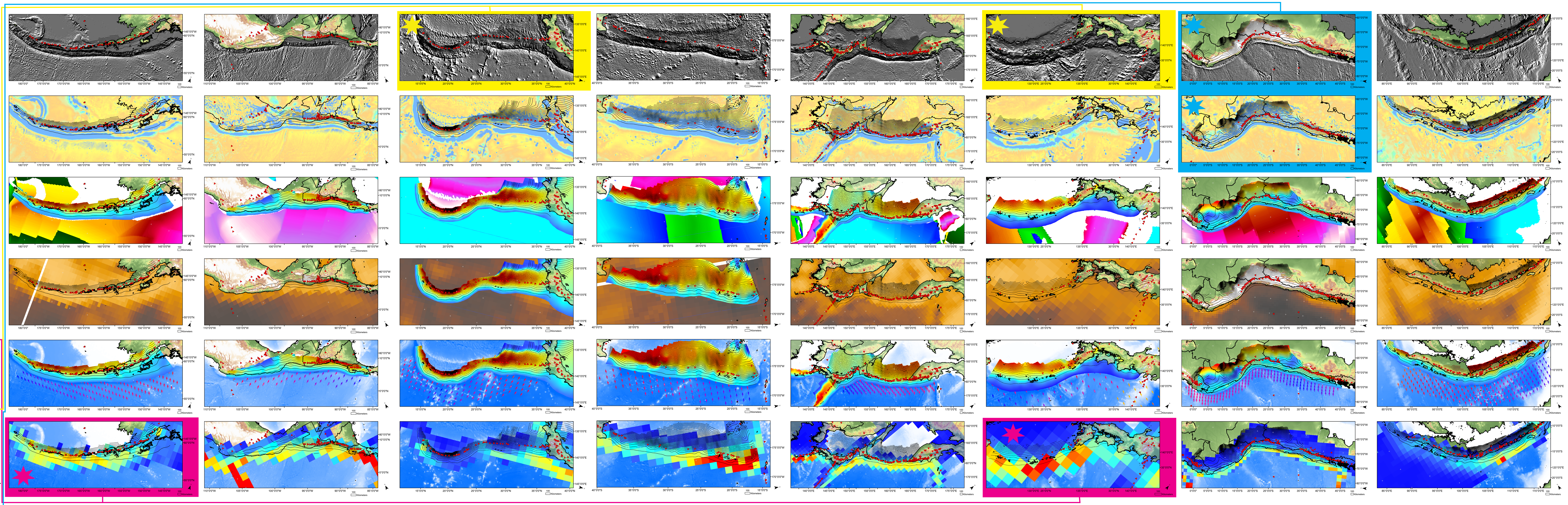
Key observations

The magenta boxes highlight the correlation of two flat slabs with changes in strain rate. The lowering of the strain rate indicates a change in plate coupling that can be explained with the hydration model of slab flattening.

The yellow boxes indicate two locations where the subducting ridge model of slab flattening breaks down. The Izu Bonin arc is being bombarded with bathymetric highs that fail to produce any change in the slab geometry. The Ryuku flat slab is adjacent to a subducting ridge which indicates that the ridge itself is not the source of buoyancy but may initiate a change in mantle dynamics.

The blue boxes highlight the Peruvian flat slab. The Nazca Ridge is coincident with the Peruvian flat slab but its positive buoyancy is unlikely to be the direct cause of the change in dip. The Nazca Ridge is visible in the shaded relief, though it is not the most dominant feature. There is little to no gravity anomaly associated with the Nazca Ridge indicating that it is isostatically compensated which reduces the effective density of the column. Most of the Peruvian flat slab is on the leeward side of the ridge as it subducts obliquely. The persistence of the flat slab indicates another process at work besides the buoyancy of the ridge itself.

Subduction Zones



Aleutian: The Yakutat Terrane is the purported cause of the Aleutian flat slab. The terrane is not visible in shaded relief or gravity fields. There are several smaller bathymetric and gravity anomalies that are subducting to the west of the flat slab. There are no significant changes in sediment thickness or plate motion that correspond to a change in dip. The second invariant of strain rate is deflected to the north by the flat slab.

Central America: The most significant anomaly offshore of central America is the Tehuantepec ridge and it is not associated with a flat slab. The age of lithosphere off Mexico is older in the flat zone which is the inverse of the theoretical effect. There are no discernable effect of plate motion and sediment thickness variations. The change in strain rate is not clear in central America due to the large uncertainty of the model due to a lack of GPS data in the region.

Izu Bonin: The Izu Bonin arc has numerous subducting bathymetric and gravity anomalies without any associated flat slab. There is no age variation along strike and little variation in sediment thickness.

Kermadec: The Ozbourn-Louisville seamounts subducting at the Kermadec trench are clear in bathymetry and gravity yet produce no flat slab. The seamount chain is also on the youngest subducting lithosphere along this trench.

Kuril: The Emperor seamount chain subducting at the north end of the Kuril trench does not appear to create a flat slab.

Ryuku: The flat slab in Japan is spatially correlated with the subduction of the Shikoku basin and not the Palau-Kyushu ridge that bounds the south side of the basin. Japan is another example of where there appears to be a correlation between the flat slab and a lower strain rate.

South America: There are numerous aseismic ridges subducting beneath south America but they do not all produce large gravity anomalies. The flat slabs are not spatially restricted to subducting ridges which suggests that it is not the buoyancy of the ridge itself causing the change in dip. No direct link between age or sediment thickness and the variation in dip is obvious.

Sumatra: Sumatra has almost as many bathymetric and gravity highs subducting as south America but no associated shallow slab segments.

Gravity Anomaly: 943 mGal – -363 mGal
Slab Dip: 0 – 89°
Seafloor Age: 180 Ma – 0 Ma

Sediment Thickness: 20 km – 0 km
Plate Velocity: Slow – Fast
2nd Invariant of Strain Rate: 3162 x 10e-9 /yr – 0

Conclusions

It is still unclear what processes account for the global variation in slab dip. We have shown that there is not a direct link between ridge or seamount subduction and the formation of a flat slab by the fact that not every subducting ridge produces a flat slab and flat slabs persist in the wake of an impacting ridge which suggests a change in mantle dynamics to support a flat slab. We favor changing mantle wedge viscosity by hydration based on our study of the Mexican flat slab and await more data to test the fit of the model in Peru. The effect of hydration on the strain rate is a recent discovery and needs further study. Now that we have assembled this global dataset of variables we will produce a more quantitative high resolution analysis of the along strike variation of subduction parameters.

Properties

Bathymetric Anomalies

Shaded relief image derived from SRTM30 PLUS. The shaded relief image aids in the identification of bathymetric highs that are part of potential impactor chains or especially rough areas.

Free-air gravity anomaly

Gravity anomalies from Sandwell and Smith. If a bathymetric anomaly is compensated then the effective positive buoyancy is reduced. There are also anomalies that are not associated with anomalies that are not visible bathymetric highs.

Seafloor age

Global seafloor age grid of Mueller et al. Although there is no direct correlation between young oceanic lithosphere and the dip of the subducting slab, especially old lithosphere may create a slab that no process can drive flat.

Sediment thickness

NGDC Global sediment map. The subduction of fluid rich sediments can change the viscosity of the mantle wedge and influence the dip of the subducting slab.

Subducting plate motion

Rotation model of Kreemer with the plate motion vectors given in the reference frame of the overriding plate. Variations in the magnitude or direction of plate motion could have an effect on slab dip.

Strain rate

Data from the Global Strain Rate Map Project. The second invariant of strain rate is not a cause of flat slab subduction, however there is an interesting relationship in a few locations. There are zones of flat subduction that have a lower strain rate relative to the adjacent trench. This fact would suggest a lack of coupling between the flat slab and the upper plate.

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