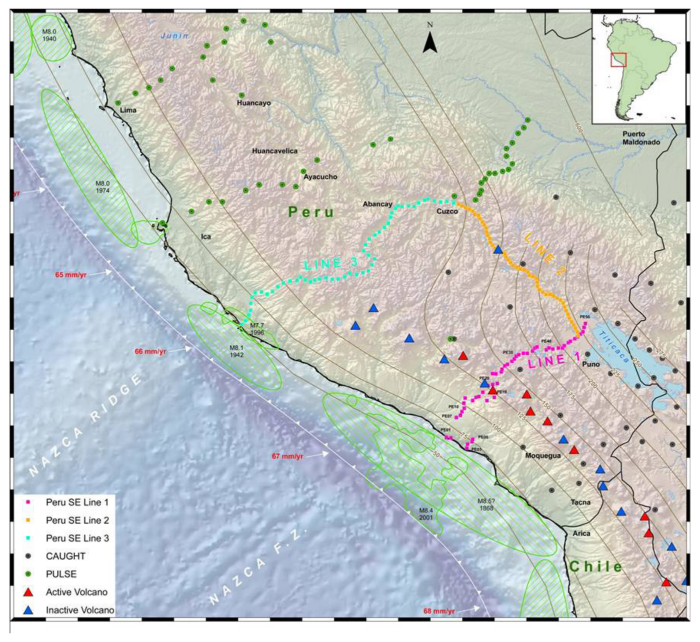
Structure of the Subduction System in Southern Peru from Seismic Array Data

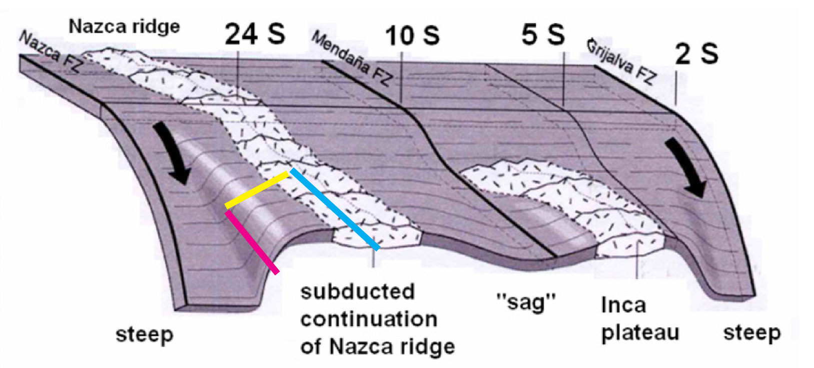
Kristin Phillips and Rob Clayton

CALTECH

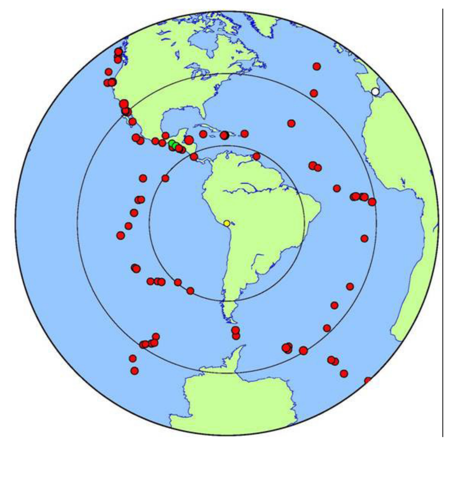
ABSTRACT

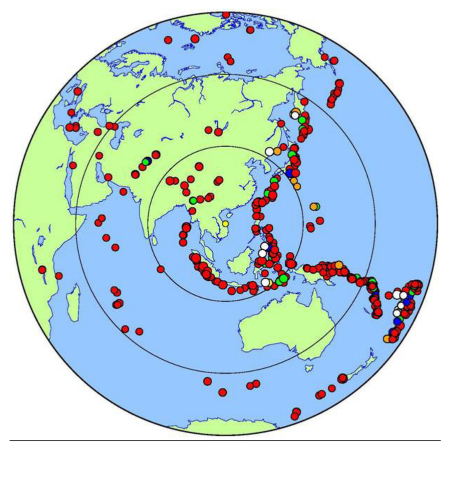
Three linear seismic arrays consisting of a total of 100 broadband sensors were deployed in southern Peru to study the transition from shallow to normal subduction (30 degree dip angle). Information obtained from this study is intended to help explain the causes of flat subduction in Peru and has implications for the timing of uplift of the Altiplano plateau. Receiver function profiles based on P, PKP, and PP wave phases image the slab to a depth of about 200km and show a crust that is 75 km thick under the Altiplano. There is a positive-impedance mid-crustal feature that may indicate underthrusting by the Brazilian shield. There is also a negative-impedance feature at 20 km depth that could be a magma body similar to that reported in Chile. We also use S-wave receiver functions to study the lithosphere/athenosphere boundary (LAB). In addition to structural information, receiver functions were stacked to obtain the Vp/Vs ratio to investigate hydration of the asthenosphere or lower continental lithosphere. Additional information about variations in S-wave velocity can be obtained from an inversion of receiver function amplitudes.

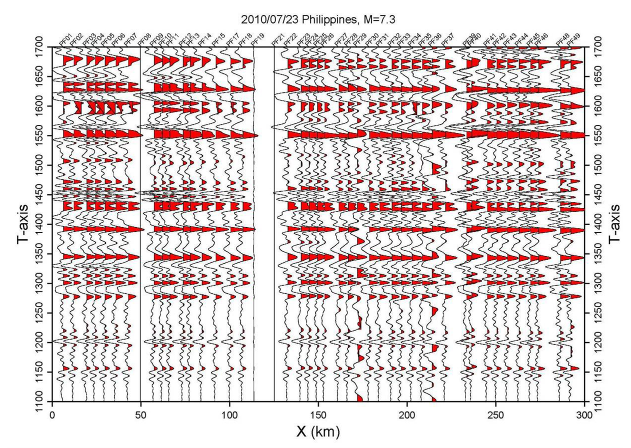




Seismic arrays: **Line 1** - Mollendo (coast) to Juliaca (inland near Lake Titicaca), was installed in 2008, and is located in the steeper subduction region
Line 2 - Juliaca to Cusco, started collecting data in Dec 2009, covers the transition from normal subduction to flat subduction regimes.
Line 3 - Cusco to Nazca (coast), recently installed in 2010, consists of half of the stations from Line 1, and runs through the flat subduction region.



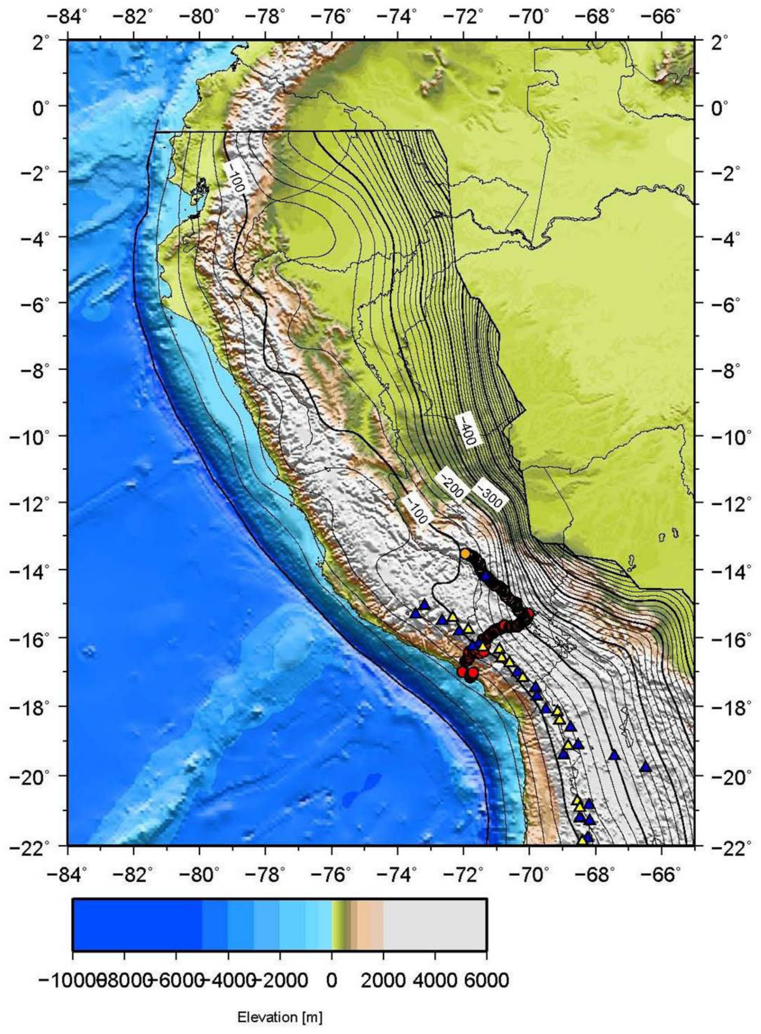




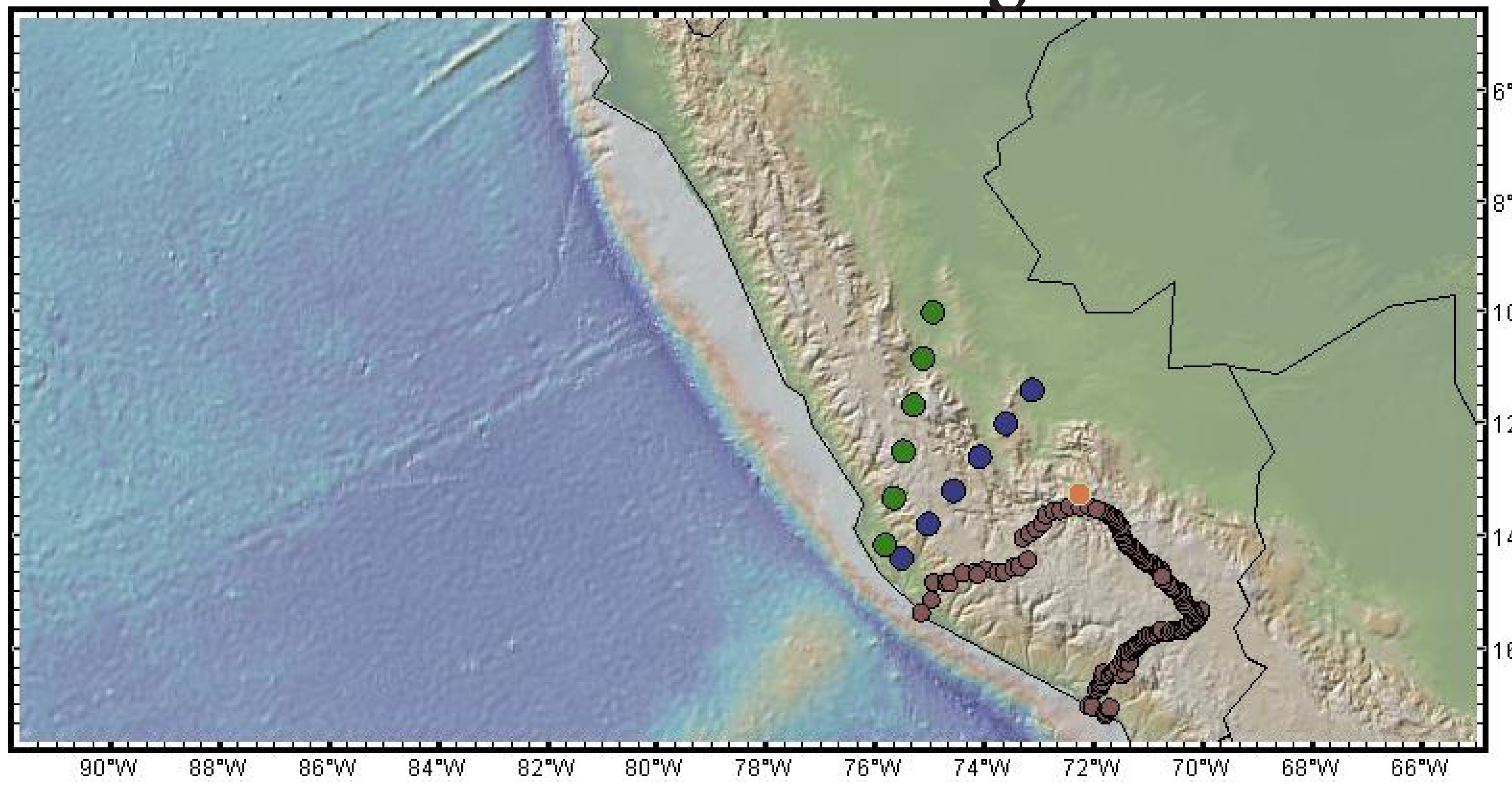
Above: Event locations for events within 90 degrees from Peru (left) and greater than 90 degrees (right). The P arrivals of teleseismic events from 30 to 90 degrees are typically used for receiver functions. Many events occur at greater distances so PP and PKP phases are also analyzed.

Right: Locations of lines 1 and 2, volcanic arc (triangles), and slab contours.

Left: Sample array data from the recent Philippines Mw 7.3 earthquake on July 23, 2010 from Line 2.

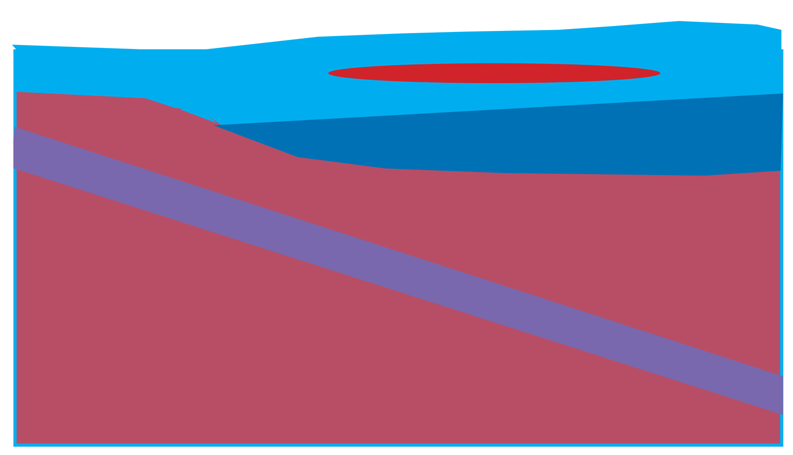


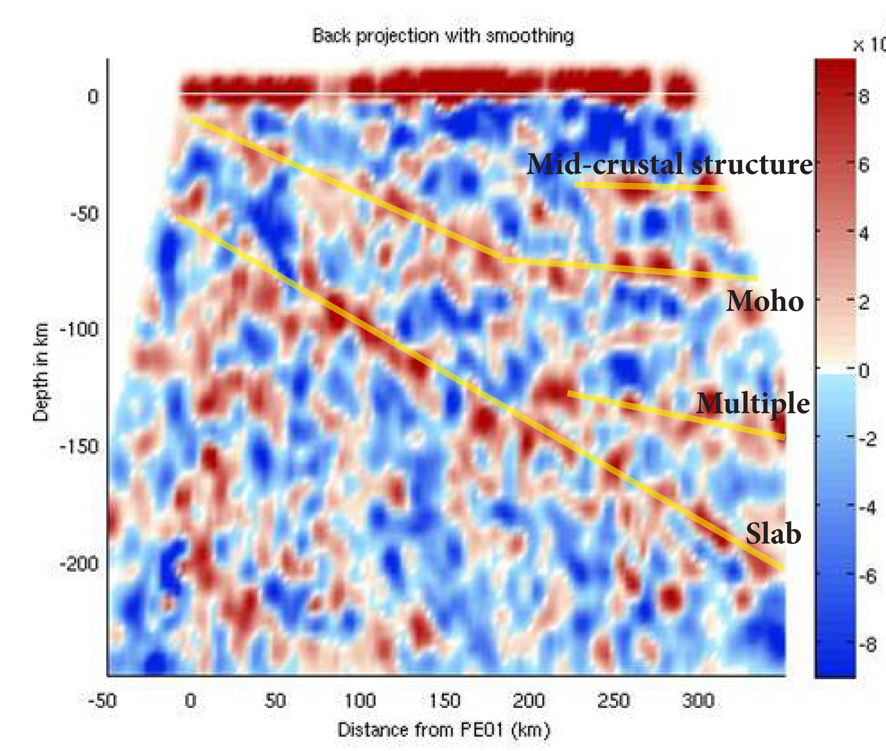
Nazca Ridge

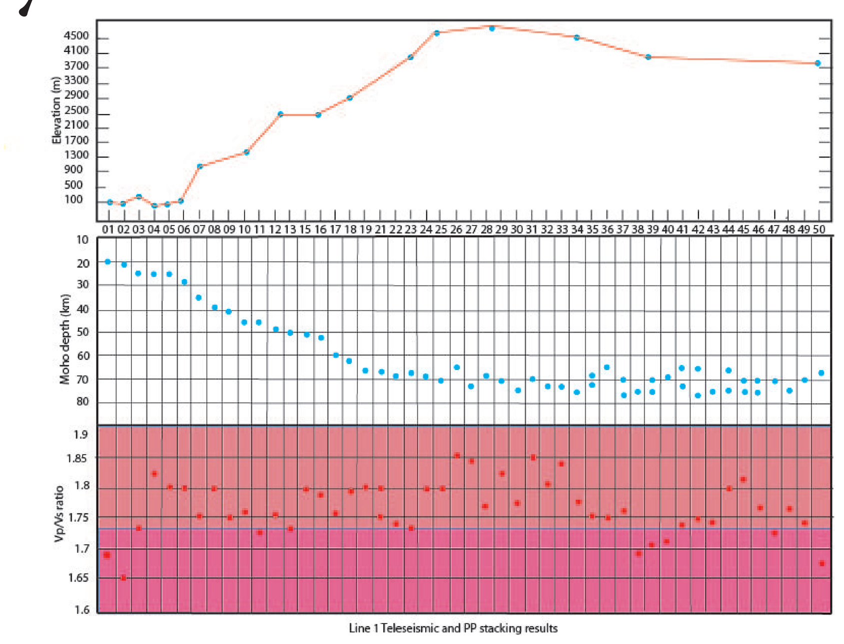


Causes of flat subduction: investigation of effects of subduction of thickened crust beneath Southern Peru
Subduction of the Nazca Ridge and "Inca Plateau" have been suggested as a possible mechanism for making the subducting Nazca plate more positively buoyant and more likely to subduct shallowly.
The location of the arrays near the Nazca Ridge may provide information on the effect of the Nazca Ridge on subduction geometry. The Nazca plate originally began subducting beneath Peru further north and has been sweeping southward at about 42cm/yr. The long region of flat subduction beneath Peru coincides with the area swept out by the subducting Nazca Ridge over time.
In the above figure, the blue circles represent the inland projection of the current location of the Nazca Ridge with circles spaced every million years. The green circles represent the corresponding locations of those same points on the ridge projected back in time given the convergence velocity and migration rate of the Nazca Ridge. The gray circles are the location of the seismic arrays.

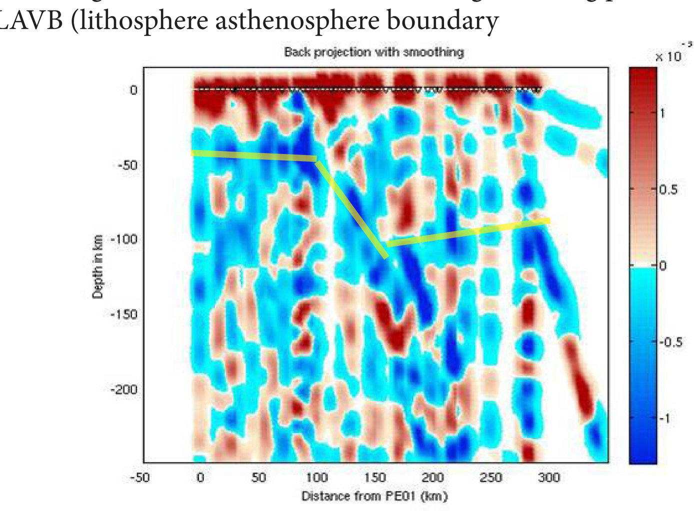
Line 1





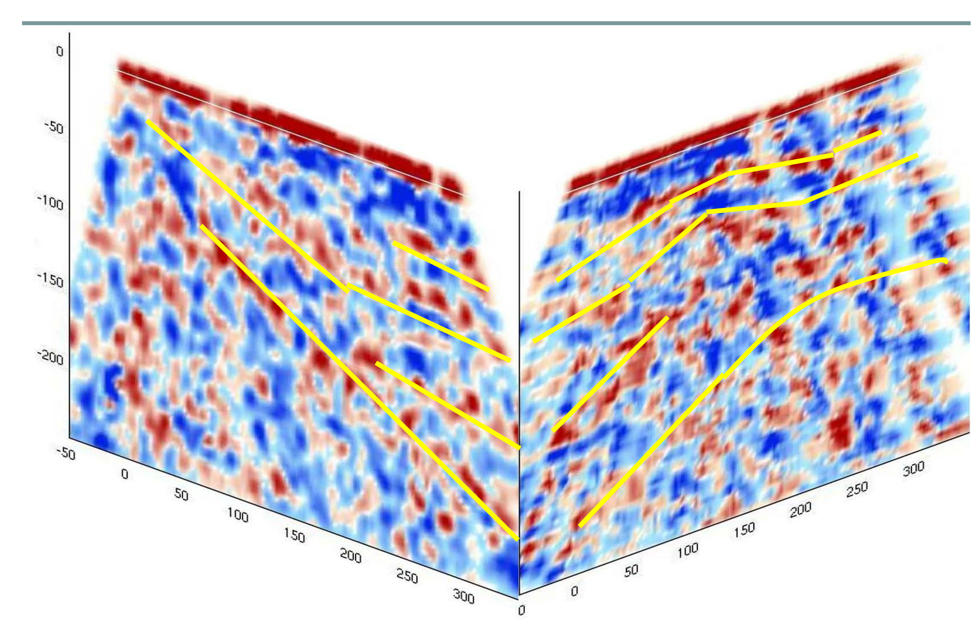


Upper left: Possible model for Line 1 depicting slab, moho, mid-crustal structure, and magma body.
Lower left: Receiver function image based on P and PP phases from the NW azimuth using backprojection of seismic waves
Upper right: Elevation, Moho, and Vp/Vs ratios from stacking of receiver functions
Lower right: S wave receiver function image showing possible LAVB (lithosphere asthenosphere boundary



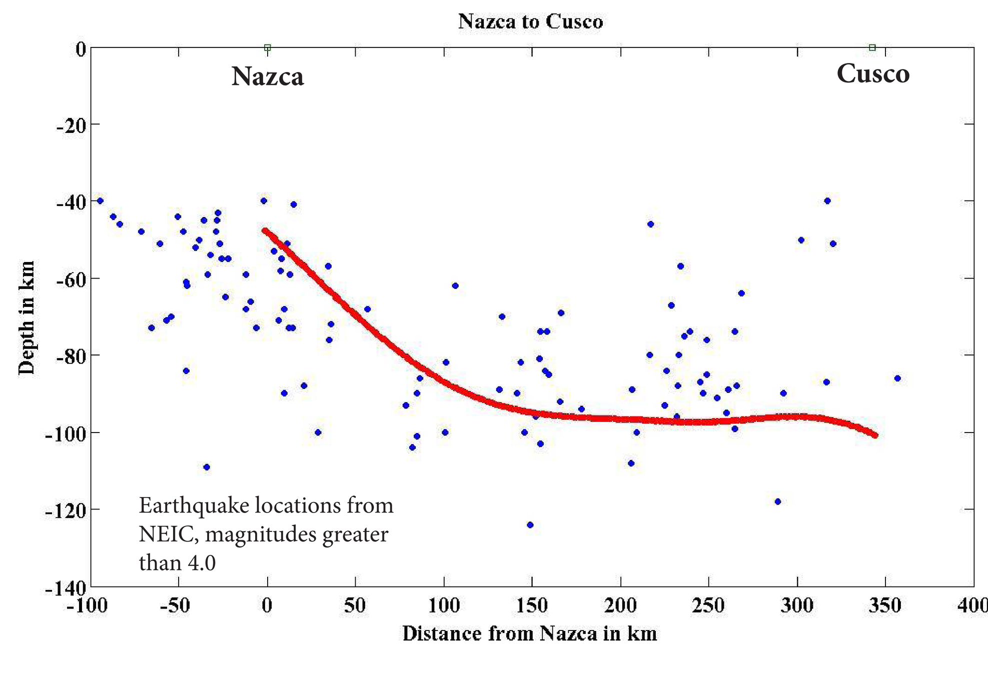
Right: Comparison of Line 1 and Line 2 images. The mid-crustal structure, moho, multiples, and slab are visible in both images.

Below: Installation of Lines 1-3. Most stations get power from solar panels. Stations on Line 1 were linked wirelessly via antennas and data was automatically uploaded to internet. Seismic data from Lines 2 and 3 is manually collected every month.



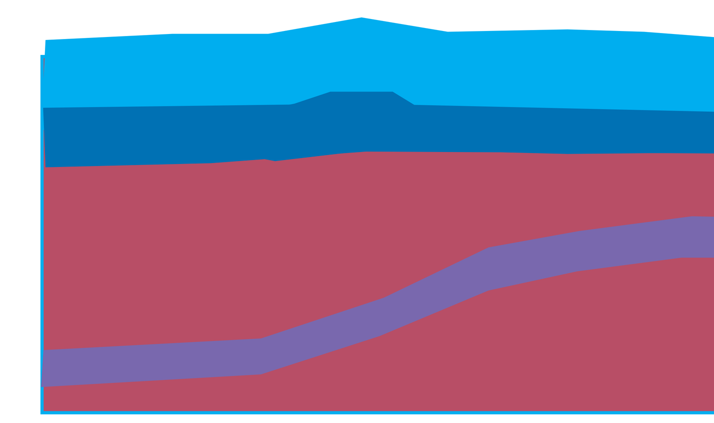
Line 3

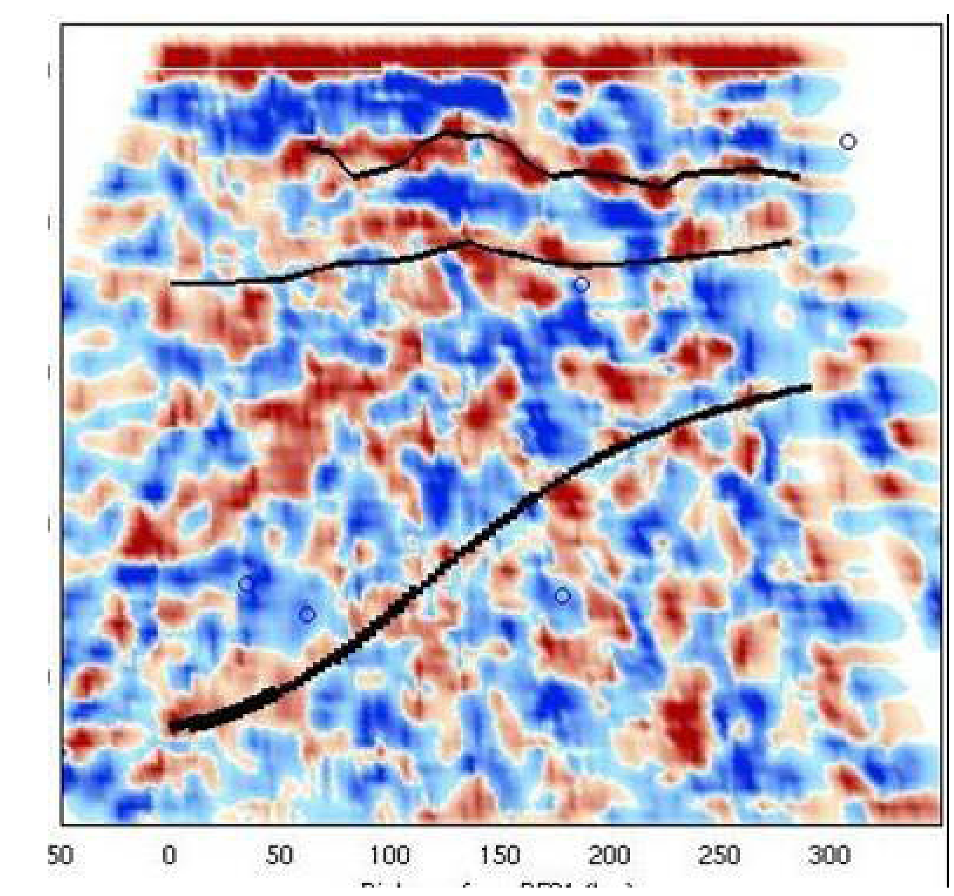
Line 3 is being installed between Nazca and Cusco using half of the stations from Line 1. Later it will be supplemented with half of the stations from Line 2. The plot below shows a cruss section of seismicity along the line and a model for the slab location based on slab contours.

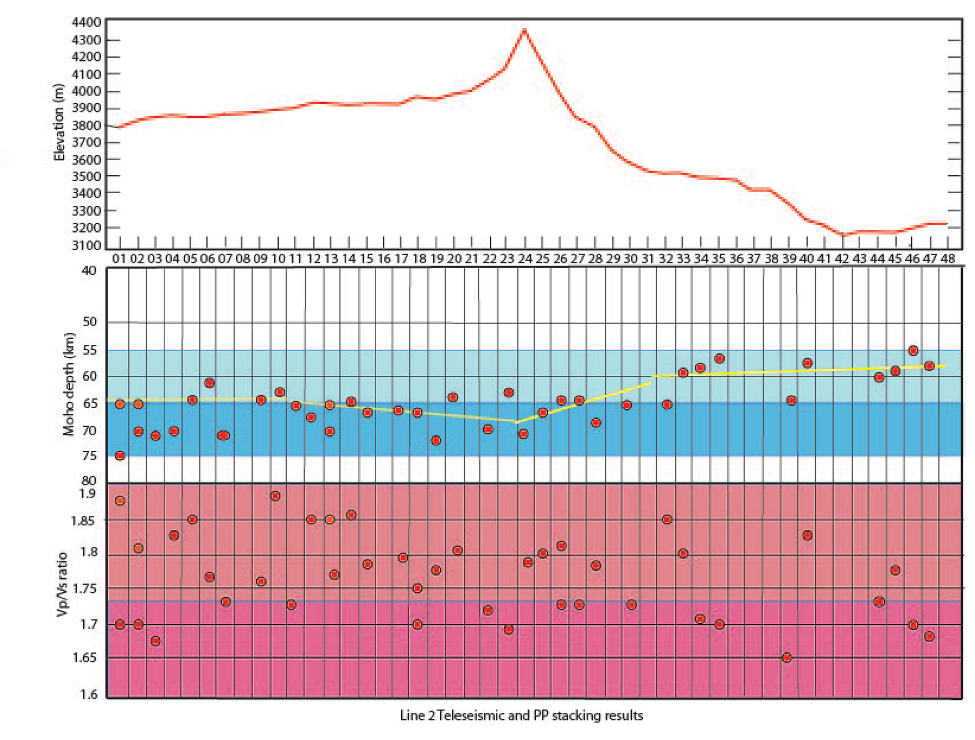


Acknowlegements: Steve Skinner (Caltech); Paul Davis (UCLA); Richard Guy (UCLA); Igor Stubailo (UCLA); Emily Foote (UCLA); Victor Aguilar (Peru); Hernando Tavera (IGP), Laurence Audin

Line 2

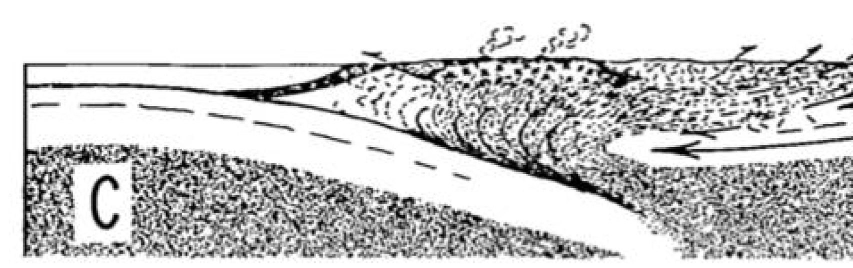






Line 2 Results:
Top: Cartoon model of structure based on receiver function images
Middle: Receiver function image of Line 2 showing mid-crustal structure, moho, and slab locations
Bottom: Crustal results from stacking of receiver functions. Top panel is elevation, middle panel is calculated moho estimates, and bottom panel is corresponding Vp/Vs ratios.

Discussion

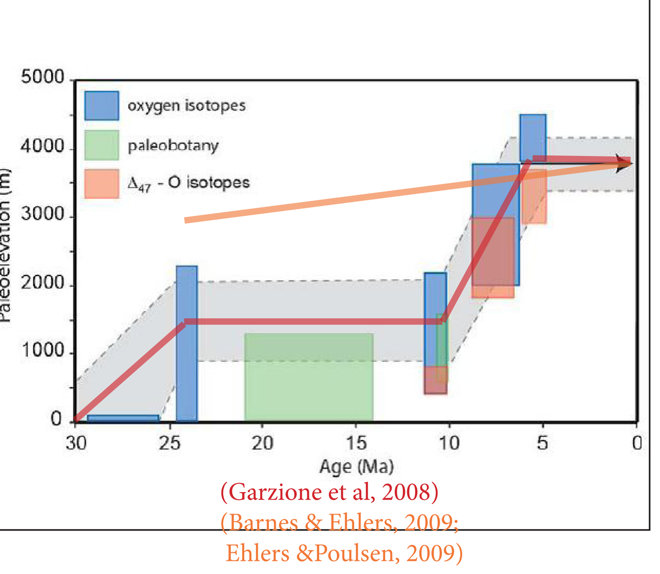


Brazilian Shield Underplating

A possible interpretation of the observation of a positive impedance mid-crustal structure beneath the altiplano in Southern Peru is that we are observing underplating from the Brazilian shield beneath Peru. This has been supported by several different authors.

Underplating by the Brazilian shield has implications for the timing up uplift for the Altiplano plateau. The observed crustal thickness beneath Peru appears to be consistent with isostatically compensated topography and could be produced by gradual crustal shortening. Observation of the Brazilian shield thrusting beneath Peru would support the idea that uplift of the altiplano occurred gradually. This contrasts with recent proposals of rapid uplift of the Andes caused by lithospheric delamination.

More detail of the structure beneath Southern Peru which can be provided by receiver functions and other methods should lend futher insight into studies of the tectonic evolution of Peru and uplift of the Andes.



(Garzione et al, 2008)
(Barnes & Ehlers, 2009;
Ehlers &Poulsen, 2009)