Imaging the Ruby Mountains Core Complex with ambient noise tomography

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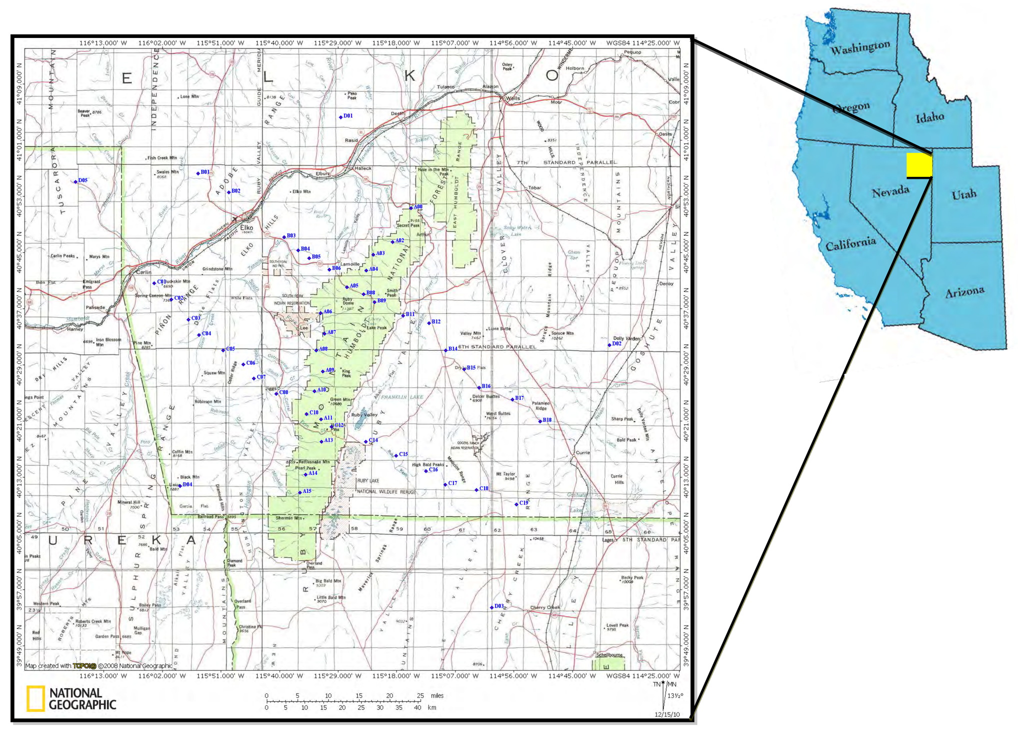
Introduction

The Ruby Mountains Core Complex (RMCC) in northeastern Nevada is a well-studied example of a metamorphic core complex, yet many questions remain about its formation and deep structure. Here we use ambient noise tomography to make a preliminary velocity model of the area around the RMCC with data collected in the first nine months of the Ruby Mountains Seismic Experiment, and data from 50 Transportable Array stations in the surrounding area. Velocity models have the potential to resolve the degree to which mafic lower crust is involved in the formation of the core complex, perhaps only directly below the Ruby Range, or perhaps as part of a more regional crustal flow.

Ruby Mountains Seismic Experiment

The objective of the Ruby Mountains Seismic Experiment is to produce a high-resolution geophysical model of the area around the RMCC using passive seismic imaging. The project consists of a 50-station broadband seismic array with dense station spacing of 5-10 km that is arranged in three crossing lines over the Ruby Range (see map). The array was deployed in June 2010, and data acquisition is expected to last about two years.



The RMCC is an example of a metamorphic core complex, consisting of:

- domed metamorphic-plutonic footwall
- unmetamorphosed hanging wall
- mylonitic sub-horizontal sheared detachment

It was selected as a target because a large amount of geological data has been gathered from previous studies, but the subsurface structure is still relatively unknown. Active source seismic studies have been conducted in the surrounding basins, but none have been done across the core complex itself.

When complete, our project will provide new constraints on the structure of the RMCC and should help differentiate between various models of core complex formation.

Acknowledgments

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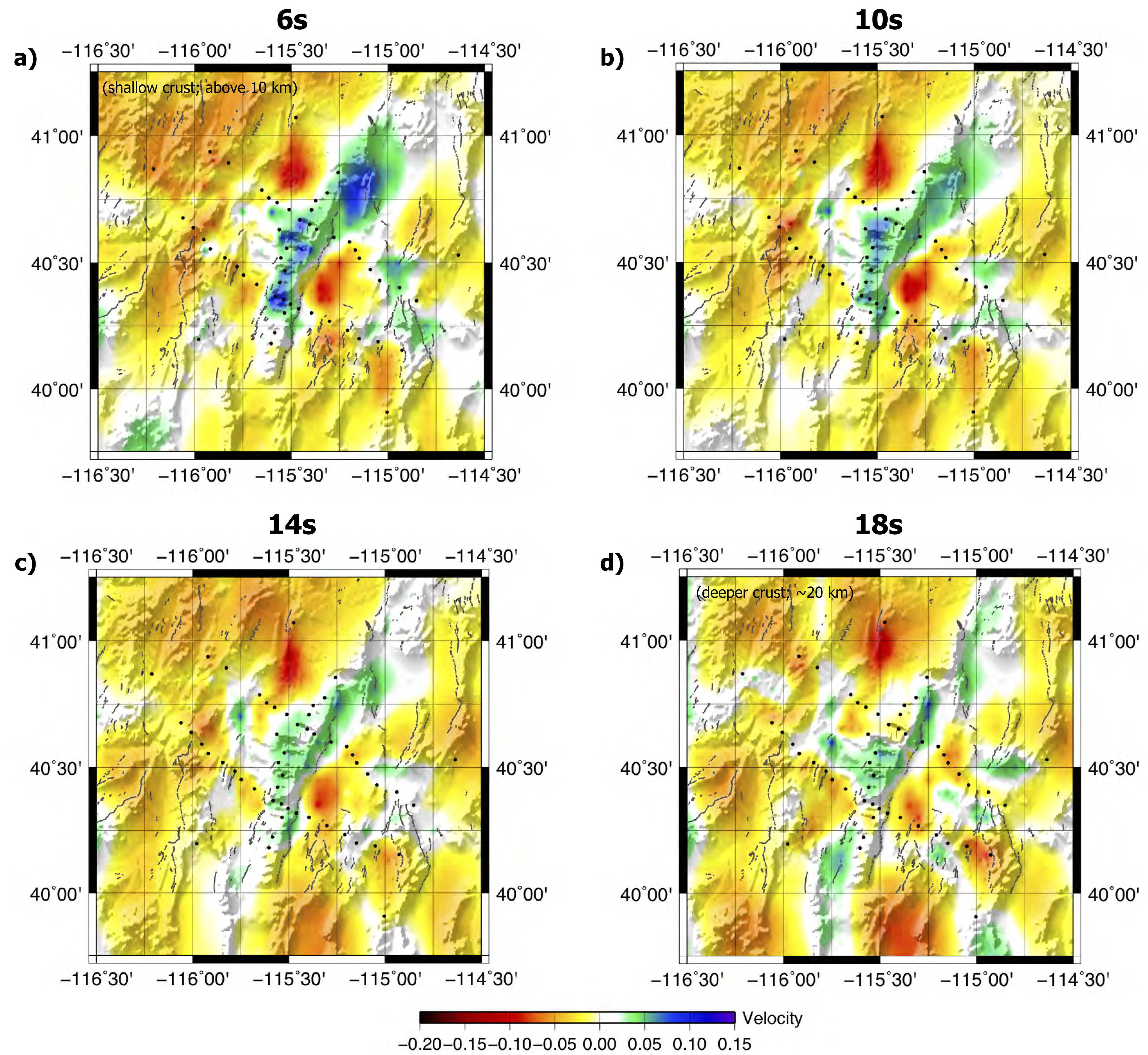
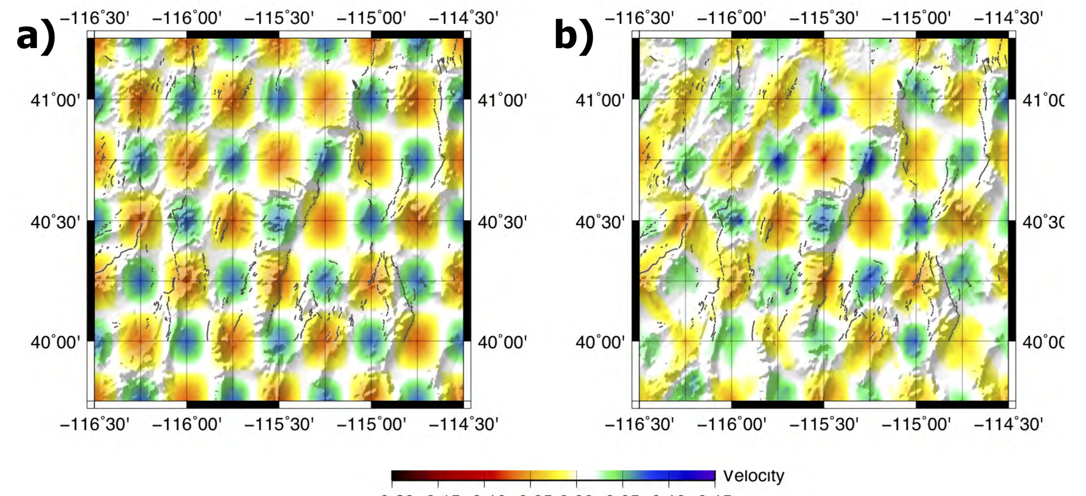
Preliminary Velocity Model



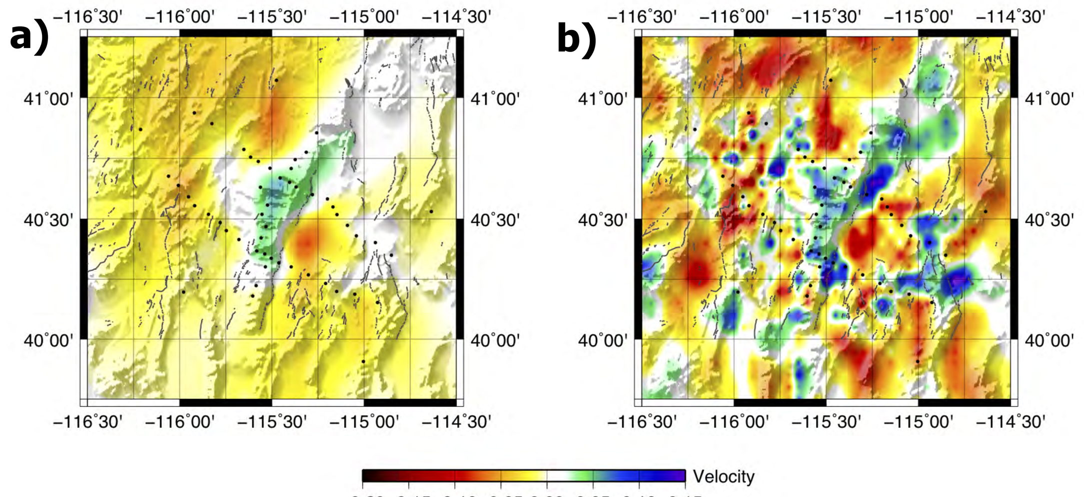
Each layer shows the velocity model for a particular period; larger periods sample deeper crust but each period covers a range of depth (see method). Color-bar represents differences from the average velocity across the map area at each period.

Checkerboard Test



a) To test the data coverage of the array, a checkerboard pattern was created with half-wavelength 0.25°. The checkerboard was sampled using the same raypaths and we used the same inversion method as with the actual data. It is shown here at a period of 10s. b) The checkerboard pattern is is recovered very well in the area inside the array, and only moderately well outside, where the only coverage is from the TA stations.

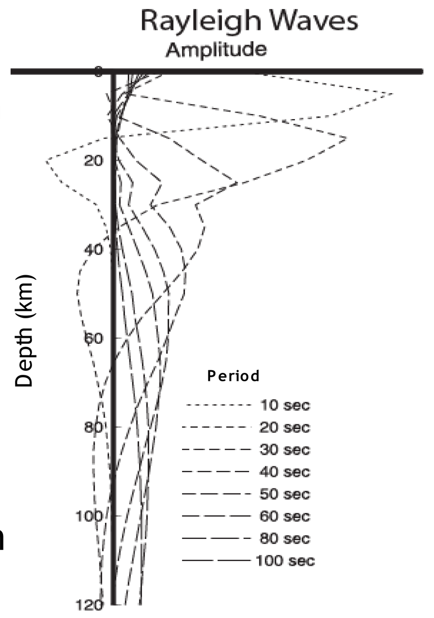
Smoothness



The amount of smoothing used in the inversion has a significant impact on the velocity model. These images show the effect on the 10s period velocity model of using a) 250% of the smoothing that was applied to the final model, and b) 25% of the final amount of smoothing.

Method: Ambient Noise Tomography

Ambient noise tomography takes advantage of the noise present in all seismic recordings to measure velocity in the earth. By cross-correlating hundreds of samples, random noise is is canceled out and the result is a noise correlation function that approximates the Green's Function between two stations. This allows us to model the traveltime of a hypothetical surface wave traveling between the two stations, and produce a velocity map from it.



Longer period waves sample to greater depths than short period waves, so different periods can be used to find the velocity at different depths. In the example on right, calculated for one specific velocity model, 10 s waves are most sensitive to wavespeeds at 5 km depth, but average all velocities down to 10km depth; a period of 20 sec is most sensitive at 15 km but averages depths from 5 to 30 km.

This means the four images shown for our velocity represent overlapping "thick slices" from the surface to the Moho, not specific depths.

Processing steps:

1) Split data into day-long sections, filter and remove instrument response: for this project we used approximately nine months of data at 50 stations.
2) Compute cross-correlation and stack data: we reduce amplitude variation, and compute the cross-correlation with multiple filter technique.
3) Measure group velocity: the group velocity at different periods is used to make the tomographic map for different layers.
4) Analyze error

Discussion

The velocity model produced here provides some initial constraints on the structure of the region, but it is not intended to produce a precise map. We can observe some general features of the area:

- Three separate Tertiary depocenters surrounding the Ruby Mountains, Lamoille Valley (NW), Huntington Valley (SW) and Ruby Valley (SE) [1]. The basement arch west of the Ruby Mts., between Lamoille Valley and Huntington Valley, is apparently well-resolved.
- Generally faster velocities in the northern part of the range, consistent with higher metamorphic grades / greater exhumation.
- Relatively higher velocities at 18 s period beneath the Ruby Range and the Cherry Creek Mtns. At this preliminary stage it is unclear whether this is an artifact of the broad depth averaging that is common to all surface-wave studies.

Future work will include receiver function analysis of our data, and joint inversion of receiver functions and ambient noise data to produce the final 3D velocity model incorporating discrete boundaries eg. below basins and at structural discontinuities. We have also performed shear-wave splitting on the data [2] to study the anisotropy, showing to a first order strong variation across the region. After all the data is collected, we will combine our observations to provide insight into the processes that control core complex formation.

References

[1] Satarugsa, P. and R. A. Johnson(2000), Cenozoic tectonic evolution of the Ruby Mountains metamorphic core complex and adjacent valleys, northeastern Nevada, Rocky Mountain Geology , 35(2):205-230
[2] Schiltz et al. (2010), Anatomy of a metamorphic core complex: preliminary results of Ruby Mountains Seismic Experiment, NE Nevada, Abstract T51C-2051 presented at 2010 Fall Meeting, AGU, San Francisco, Calif., 13-17 Dec.