Seismic Refraction Tomography Study of the Potrillo Volcanic Field in the Southern Rio Grande Rift: Opportunity for Collaboration Between Geosciences and Computer Science

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INTRODUCTION

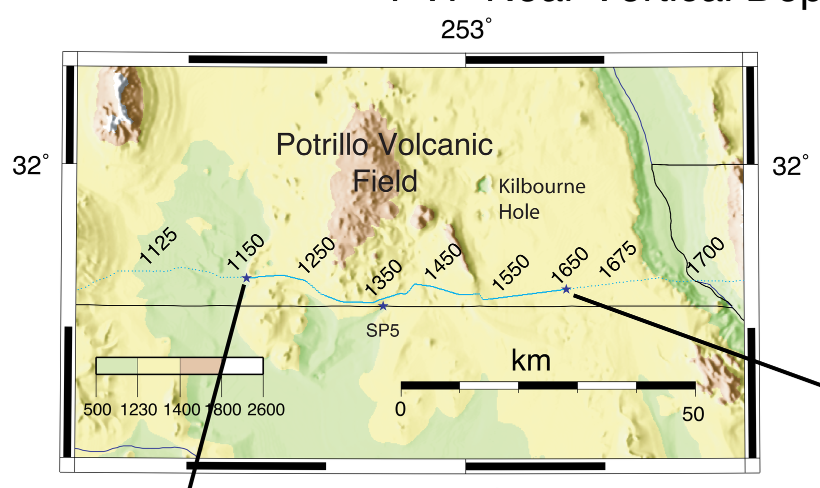
On May 16-18, 2003, the geophysics group at the University of Texas at El Paso conducted a wide-angle seismic refraction/reflection experiment across a portion of the southern Rio Grande Rift centered on the Potrillo Volcanic Field (PVF). The PVF is perhaps best known for its xenolith localities at two maar volcanoes within the field, Kilbourne Hole and Potrillo Maar. The experiment is part of a joint project to study magmatic contributions to crustal evolution in an intracontinental setting using the southern Rio Grande Rift as a natural laboratory. A pool of seismic instruments that were designed and built with funds provided by the Texas Higher Education Coordinating Board and the National Science Fopundation were deployed by a team of about 65 student volunteers. The field work and data analysis was funded primarily by a grant from the Texas Higher Education Coordinating Board to UTEP and Texas Tech University. Additional funding came from the National Science Foundation EAR (Continental Dynamics Group) and The El Paso Water Utilities.

BACKGROUND

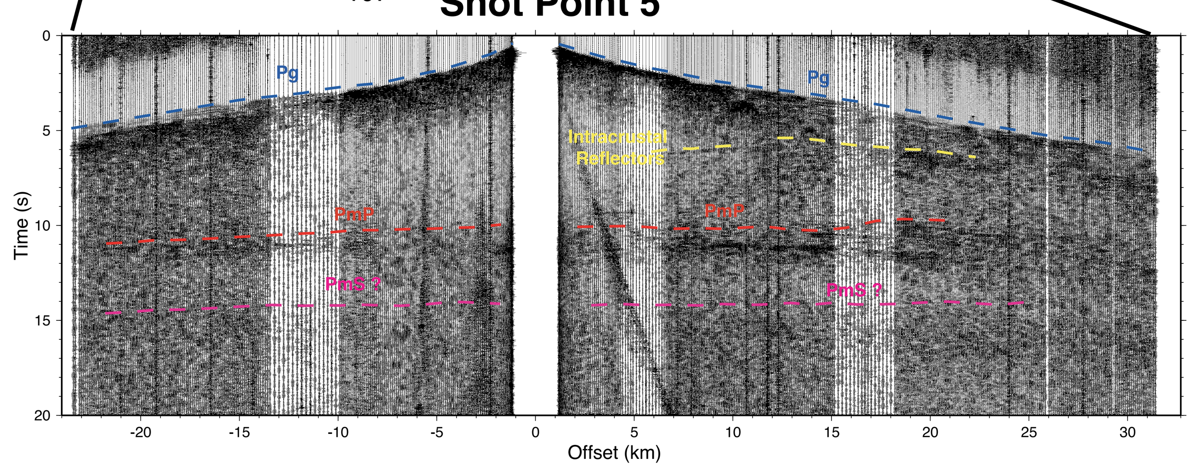
The Rio Grande Rift is a major Tertiary tectonic feature that profoundly modifies the lithospheric structure of the southern Rocky Mountains of North America. Patterns of magmatism and extensional structures of the rift both crosscut and reoccupy older structures including those associated with Precambrian continental assembly, late Paleozoic Ancestral Rockies and late Mesozoic to Early Tertiary Laramide tectonism. The region is an excellent place to study magmatic modification because it is a location where comprehensive geophysical data sets and a rich suite of basement samples can be obtained. In fact, all crustal levels are accessible, with (1) shallow basement exposed in nearby mountain ranges, (2) a remarkably diverse deep- and middle-crustal xenolith suite in two Quaternary maar volcanoes, and (3) a middle crustal xenolith suite in Eocene intrusions near El Paso. Thus, these data sets provides a fantastic opportunity to establish the relative importance of magmatic input to formation of the crust by integrating the geophysical structure of the region with detailed geobarometry, geothermometry, geochronology, and chemistry of surface and xenolith samples. The modeling of these data with current tomographic inversion algorithms is an opportunity for further interdisciplinary collaboration between our geophysics and computer science groups, because the software is difficult to use, models are hard to edit, and the inversion is inherently unstable.

Near-Vertical Reflection Data

PVF Near Vertical Deployment

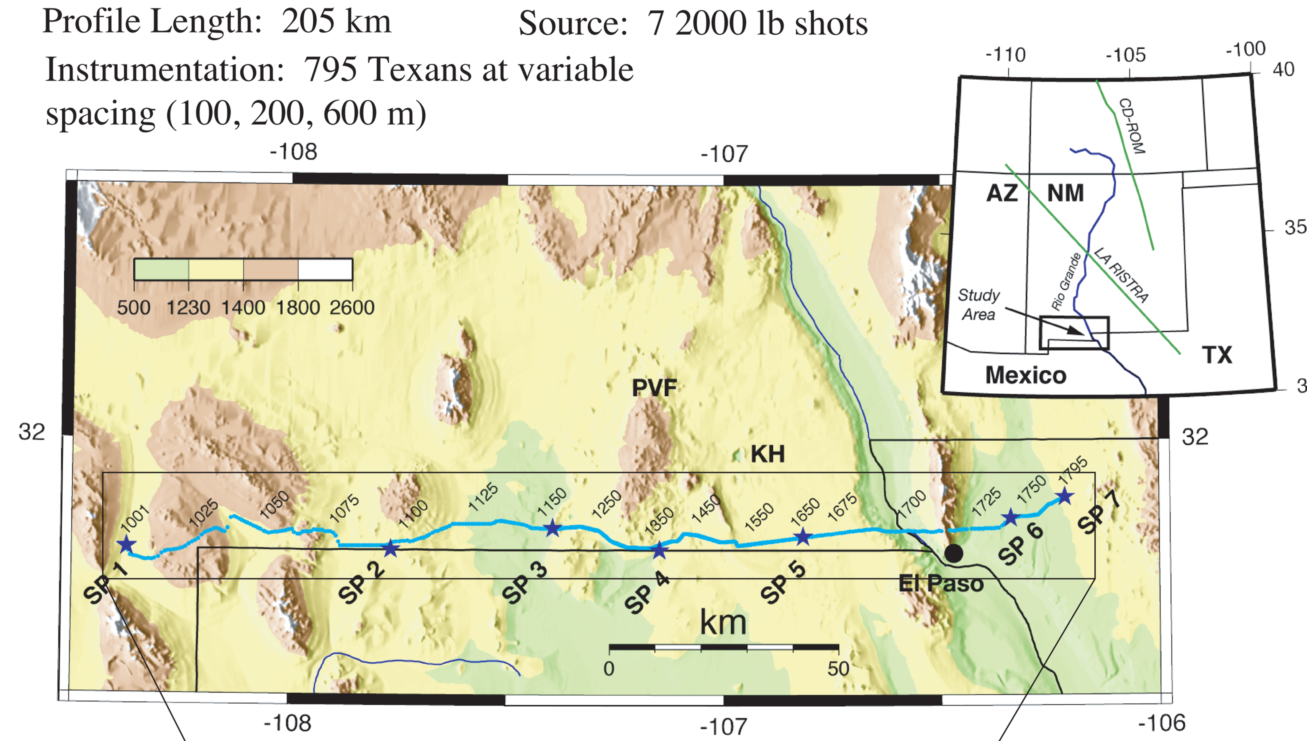


Shot Point 5

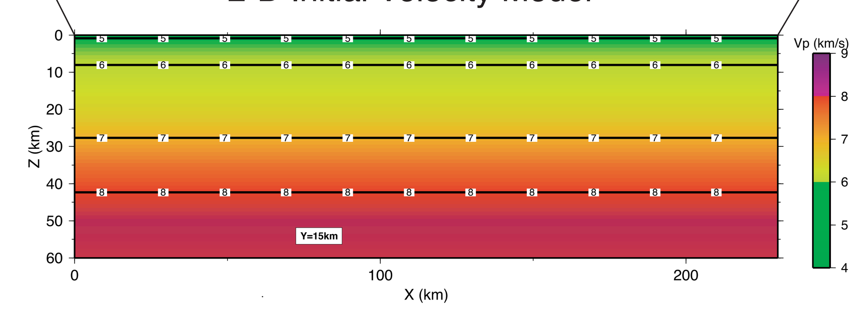


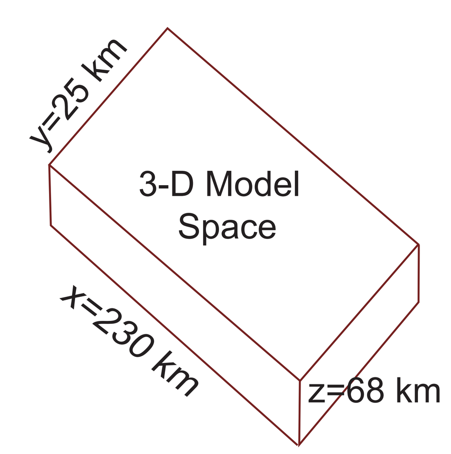
PVF Experiment Layout and Record Sections

Profile Length: 205 km
Source: 7 2000 lb shots
Instrumentation: 795 Texans at variable spacing (100, 200, 600 m)



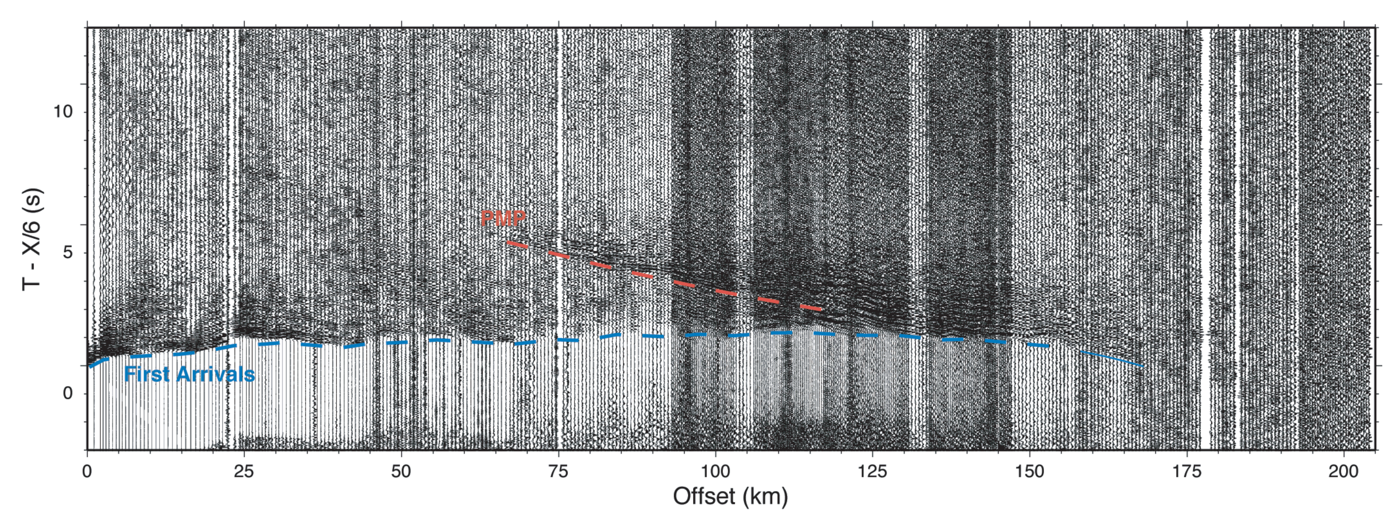
2-D Initial Velocity Model



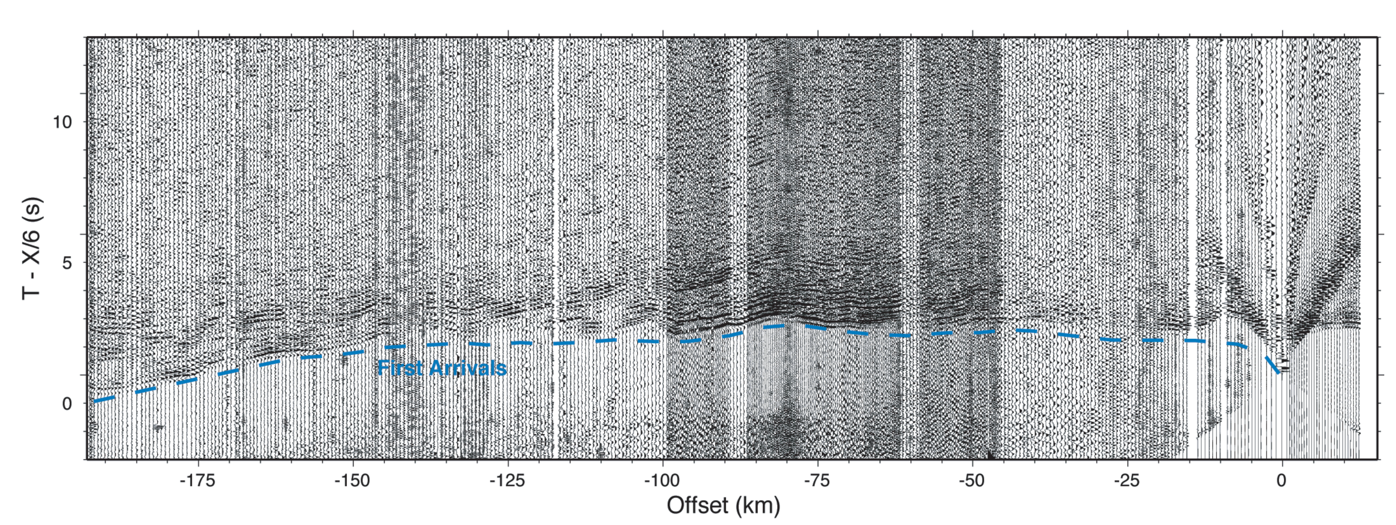


RECORD SECTIONS

Shot Point 1



Shot Point 6

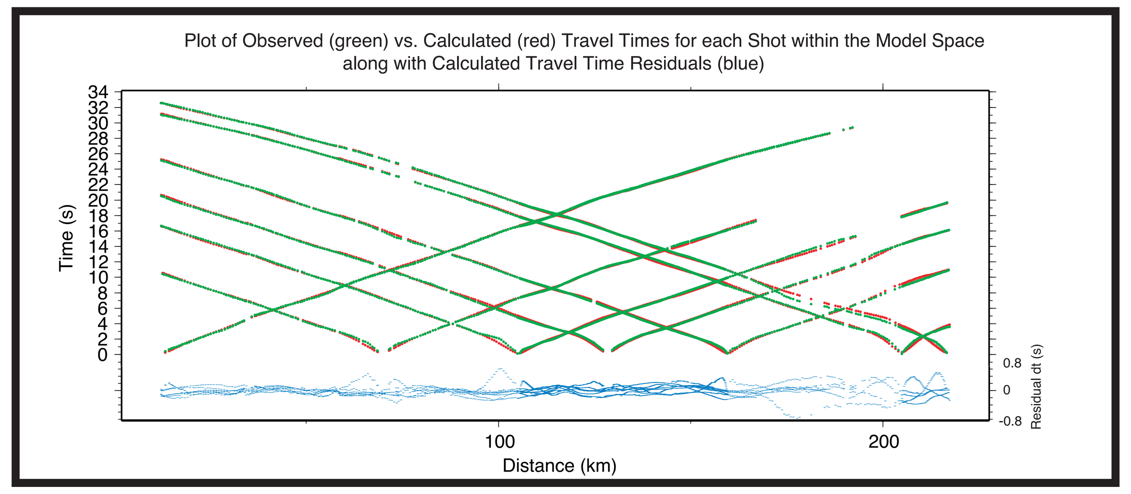


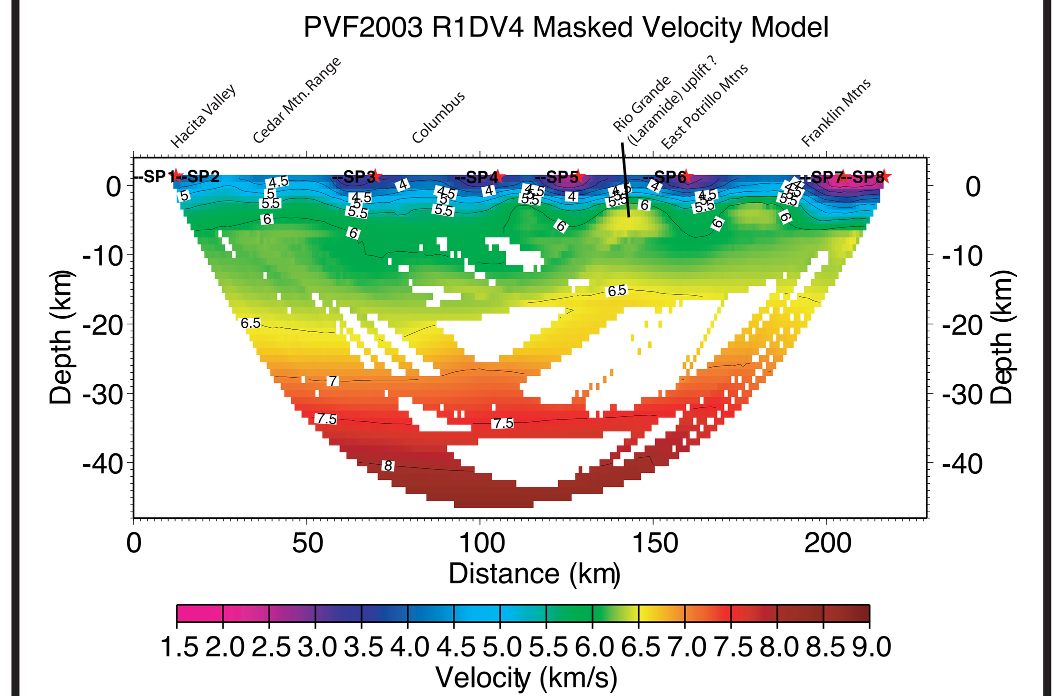
INITIAL RESULTS

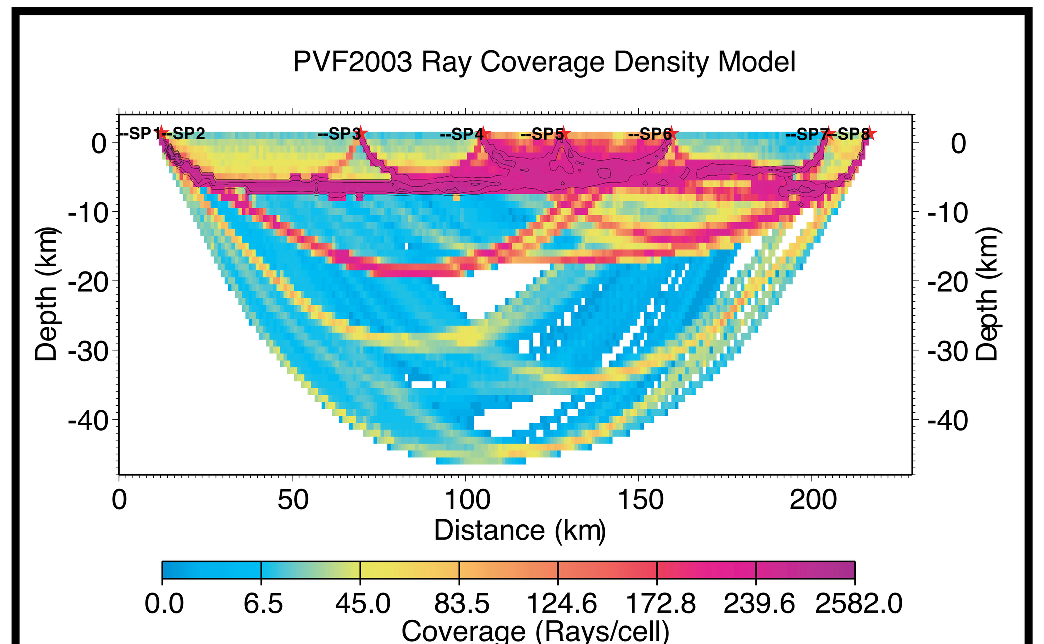
The velocity model below was derived from 5188 first arrival times input to a 3D tomography (Hole, 1982). The inversion was carried out in a 230x25x68 km model space with a grid interval of 1 km. The RMS misfit for the model is 0.13 s.

For purpose of display, the 3D result has been averaged in the y-direction to produce 2D model plots. The velocity is masked by the ray coverged shown at the bottom.

The velocity model shows the signature of Basin and Range structure with low velocity basins between higher vlocity uplifts within the upper 5 km. A high velocity zone (> 6.2 km/s) between 5 and 10 km underlies the East Potrillo mountains and may represent the basement cored Rio Grande Laramide deformation. A broad elevated region of velocities greater than 6.5 km/s is located below the Potrillo volcanic field. Moho depth across the model is at approximately 32 to 36 km.



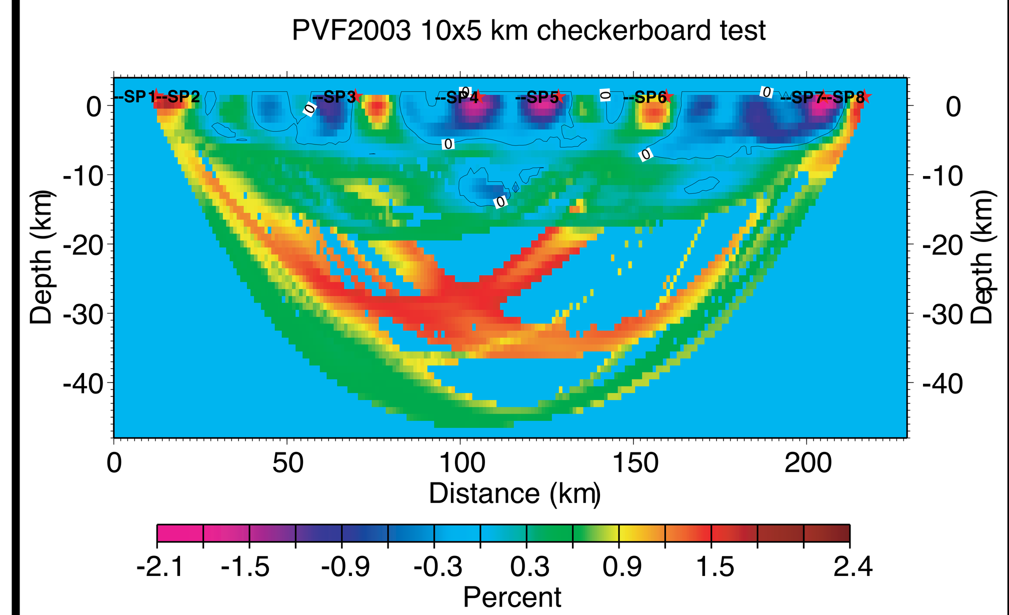


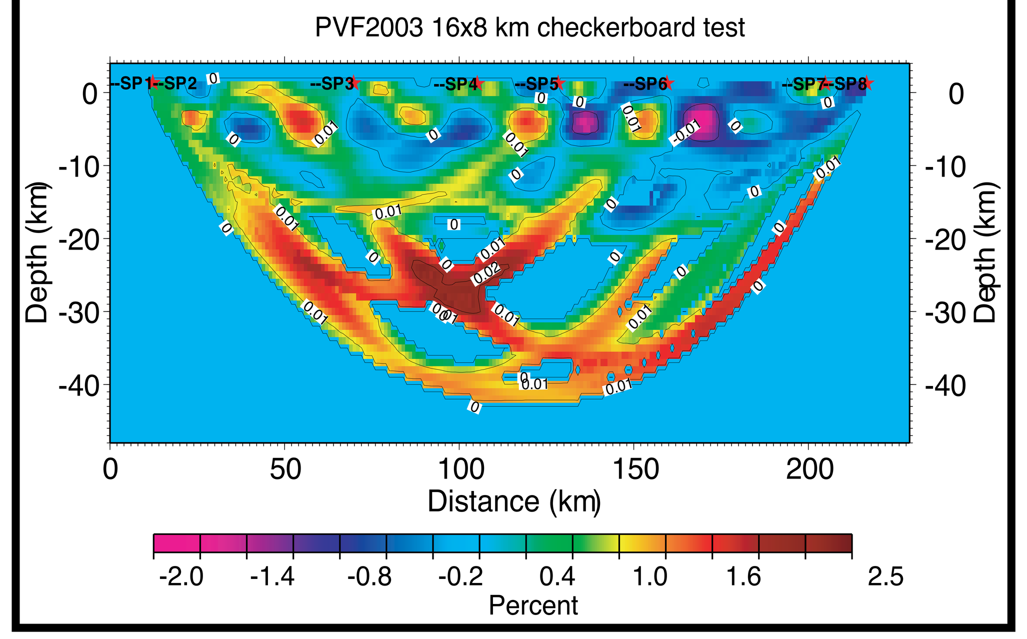


CHECKERBOARD TESTING

Checkerboard testing was carried out by adding 0.5 percent sinusoidal perturbations to our smoothed velocity models with x and z dimensions of 10x5 km and 16x8 km.

Checkers are well resolved within the upper 5 km for the 10x5 km velocity perturbations and down to 10 km for 16x8 km perturbations. Deeper than 10 km we lose both ray coverage density and resolution of features less than 16x8 km.





COLLABORATIVE WORK

Incorporate expert knowledge:

In order to improve the usability and expand the usefullness of the tomographic inversion code we are combining the knowledge and experience of our geoscience department with the resources and programming experience of the our computer science department. Our goals include development of user interface software designed for both ease of data input, creation of the initial model, and displaying results adapted to needs of the geoscience community, parallelization of the inversion algorithms to better utilize computing capabilities and possible improvement of inversion algorithms to incorporate additional available data and stabilization of the calculations.

Some of the solutions computed by the current methods are mathematically sound, but geophysically unsound. The geophysicist then realizes the source of the error and repeats the process. We plan to incorporate interval uncertainty and other types of uncertainty to use a geophysicist's knowledge and intuition in the solution process, to produce models which also agree with geophysics.

Use advanced methods:

Fast Marching Method (Sethian, 1996): Unlike typical methods, this method avoids iteration by, among other optimizations, adapting Dijkstra's shortest-path algorithm to the continuous case. It runs in O(n log n), where n is the number of points in the domain.

Level Set Method (Osher and Sethian, 1988): This method, although slower than the Fast Marching Method, is more general. It efficiently takes into account discontinuities which are important in geophysical applications