Tectonics of the Basin and Range Province and the Colorado Plateau

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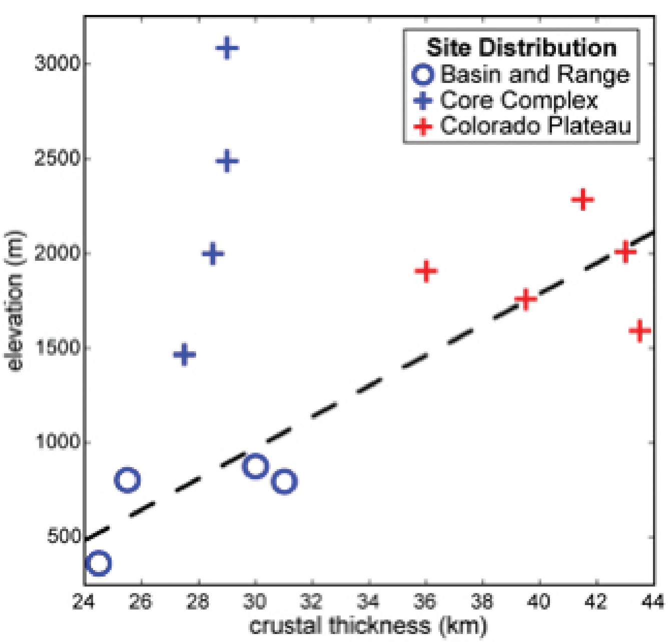
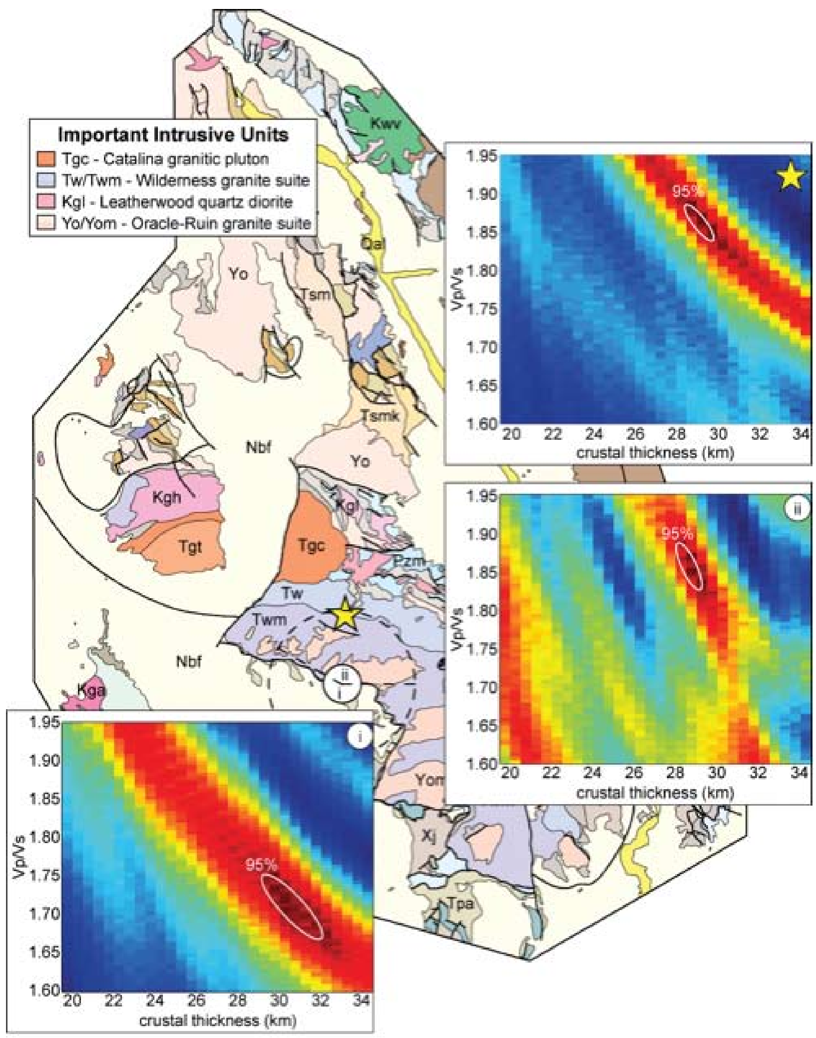
During the summer of 2003, I was a recipient of an IRIS Undergraduate Internship, allowing me the opportunity to spend ten weeks at the University of Arizona working with my now-PhD advisors George Zandt and Susan Beck. Conducting an independent study far from my familiar environment at the University of South Carolina proved to be a challenging, frustrating, but rewarding time. The internship proved to be a turning point in my academic career, an opportunity which pushed forward my understanding and appreciation of seismology and drew my interest to further exploring the research questions associated with Cordilleran tectonics. The initial internship experience, which began as a simple summer project, expanded into an AGU fall meeting abstract and then senior thesis before finally culminating in a peer reviewed article [Frassetto et al., 2006]. From a personal standpoint it has been exciting to see an initially small aspect of my undergraduate degree expand into an important cornerstone of my graduate education. My experience and the stories from other interns with whom I have interacted convince me that these internships provide an unparalleled opportunity to learn and appreciate seismology as an undergraduate. In my case, it set me on a journey that continues today.

My internship project focused on examining variations in the crust and upper mantle using data from the recently deployed Consortium for an Arizona Reconnaissance Seismic



Relationship of elevation and crustal thickness as estimated from receiver functions. A least squares trend-line is fit to all stations with the exclusion of those atop metamorphic core complexes. The departure of core complexes from the trend-line shows their deviation from a traditional isostatic relationship between increasing elevation and thickening crust that is evident elsewhere throughout the COARSE survey area.



The map shows the locations of the COARSE station atop the Catalina metamorphic core complex as yellow star and of the GSN station TUC as a divided circle in the Catalina foothills. The receiver function stack labeled with a yellow star shows the crustal thickness-Vp/Vs "bull's eye" for the COARSE station. The other receiver function stacks are of arrivals at TUC from (i) the southwest and (ii) the northeast. The division of the circle in the map shows the azimuthal limits for the two TUC stacks. An ellipse representing greater than 95% of the maximum stacked amplitude is applied to represent uncertainty of the measurement. These stacks show a crust of equal to lesser thickness with substantially greater Vp/Vs beneath the high elevations of the Catalina core complex range. Such a large increase in Vp/Vs is rarely seen, and indicative of a confined but significant change in the crustal composition and density within the Catalina core complex.

Experiment (COARSE) broadband network. These broadband instruments, managed primarily by my advisors Matt Fouch at Arizona State and Hersh Gilbert (now at Purdue), were spread across central and southeastern Arizona and formed a dataset that sampled several previously unstudied regions of the Basin and Range province and the Colorado Plateau. Working with George Zandt and Hersh Gilbert, my role as an intern and now graduate student has been to characterize the structure and composition of the crust and upper mantle using P-wave to S-wave converted phases generated by discontinuities in the lithosphere beneath a broadband station. These converted phases and their multiples appear prominently in receiver functions, created by removing through deconvolution the source and instrument response from three-component broadband records for large earthquakes at teleseismic distances [e.g., Langston, 1979]. Receiver functions respond most sensitively to variations in the thickness and S-wavespeed of individual layers and, if a P-wavespeed for a layer (e.g., the crust) is estimated, receiver function traces can be stacked in the thickness-Vp/Vs domain to constrain the crustal thickness and composition (as a function of Vp/Vs) [Zhu and Kanamori, 2000].

Receiver function analyses show that the southern Basin and Range province has a relatively thin crust of ~28 km thickness, versus the ~40 km thick crust of the Colorado Plateau. These results are consistent with the tectonically extended vs. unextended nature of the two geologic provinces. A proportional relationship between elevation and crustal thickness can be viewed for most stations throughout the COARSE array. However, the absence of a crustal thickness increase beneath the high metamorphic core complexes in the Basin and Range province lead us to further explore these highly extended and uplifted sections of the middle crust which have Vp/Vs of 1.79-1.87. This value is higher than the global average for Vp/Vs of 1.73 in Cenozoic and Mesozoic orogenic belts [Zandt and Ammon, 1995]. In particular, two seismic stations near Tucson and in proximity to the Catalina metamorphic core complex show a significant local increase in Vp/Vs beneath the core complex. Forward models created to constrain crustal composition and isostatic compensation using the seismically determined Vp/Vs, crustal thickness, and the Bouguer/isostatic gravity field reveal that core complexes in this region are supported by relatively buoyant segments of crust that are rich in plagioclase and poor in quartz. Additionally, in the case of the geologically well-mapped Catalina core complex, these zones of high Vp/Vs coincide with a compositionally distinct series of intrusions that were emplaced during late Cretaceous magmatism. These findings have broader implications for the manner in which the low-angle extension that formed core complexes was distributed during Tertiary orogenic collapse in southern Arizona. For a more detailed explanation of this study, please see the original publication.

The benefits of my internship experience with IRIS reach beyond research results. The fieldwork aspect of COARSE project prepared me for working on extensive seismic deployments as a graduate student in the Coast Mountains of British Columbia, the Sierra Nevada of California, and the Olympic Mountains of Washington. Most recently, Michael Hubenthal and John Taber invited me to serve as a mentor to the most recent group of IRIS interns. This involved me giving two presentations on my internship experiences and graduate school at the Internship Orientation Workshop in Socorro, NM in May 2006. Additionally, throughout the summer I served as a remote resource for interns with issues and questions as well as an advisor based on my experiences as a researcher in seismology. IRIS not only invigorated an interest in seismology and provided a broad and interesting research topic that I continue to explore, but also allowed me to gain valuable field experience and recently afforded me the opportunity pass on my enjoyment of seismology to other interns and hopefully impact those who are in the same important stage of their lives that I found myself during the summer of 2003.

Andy Frasetto at a seismic station in the Coast Mountains of British Columbia.

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