New Faculty in Geophysics

Meet Richard Allen

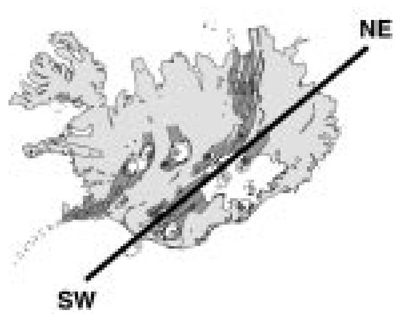
Richard Allen joined the Department of Geology and Geophysics in January 2002. Before moving to Madison, Richard received his PhD from Princeton (2000) and was a post-doctoral fellow at the California Institute of Technology from January to December 2001.

I am writing this report on the one-year anniversary of my arrival in Madison. This realization causes me significant pleasure as I cannot count the number of times fellow faculty in Madison, and elsewhere, have told me "the first year is the hardest." The first year has been great. The support provided by the department as I build a research and teaching program has been fantastic. Geology and Geophysics offers a great environment to be working in – though as alumni this is not news to you. My interactions with students, ranging from the semi-participants of introductory undergraduate courses to graduate students have, without exception, been a pleasure. Fellow faculty are also keeping me in check: several days after reaching the one-year mark I received a Chronicle article from **Lou Maher** (coincidentally I'm sure) titled: "Teaching: the first 25 years are the hardest."

As a seismologist my research interests include the dynamic processes of the Earth's crust and mantle and the physical process of earthquake rupture. It is an exciting time to be a seismologist as both the number of instruments distributed around the world is rapidly increasing, and the technologies available to bring that data back to my desk can provide information within a fraction of a second. A geology department is perhaps not a place where timescales of seconds are discussed very much; however, rapid assessment of geoscience data is necessary for hazard mitigation—I will return to this topic later.

The Earth's dynamic system can be viewed at many scales. I am interested in processes on the kilometers to thousands of kilometers scale, encompassing the magmatic systems of crustal formation, large scale mantle convective processes, and the interactions between the two. At the larger scale, that of mantle convection, we have a good picture of the downwelling component from ocean trenches, earthquake hypocenter surfaces dipping down from the trenches, and tomographic images. Tomography uses seismic arrivals recorded from earthquakes around the world to generate snap-shots of the velocity structure of the Earth's interior. Mantle downwelling is seen as cold slabs extending from the trench through the upper mantle, and into the lower mantle in some cases. In contrast with downwelling, the upwelling component of mantle convection remains to be defined. The mantle plume hypothesis has been broadly accepted for over thirty years but conclusive evidence of the existence of a buoyant column of rock spanning the mantle remains to be found. My current research is aimed at characterizing mantle upwelling in an effort to determine the dynamic processes responsible, whether they be plumes or some other upwelling process.

Iceland is one of the classic plume locations. The elevation of the sea-floor above sea-level requires low density mantle, and the large volumes of magma imply this low density is due to high temperatures. As a result of these observations, and the anomalous geochemical signature, Iceland has long been classified as a plume location. Over the last few years I have been working on a project to image the deep structure beneath Iceland to see if a low velocity conduit extends from the surface to depth. The data gathered provides an image to about 400 km depth and, sure enough, we



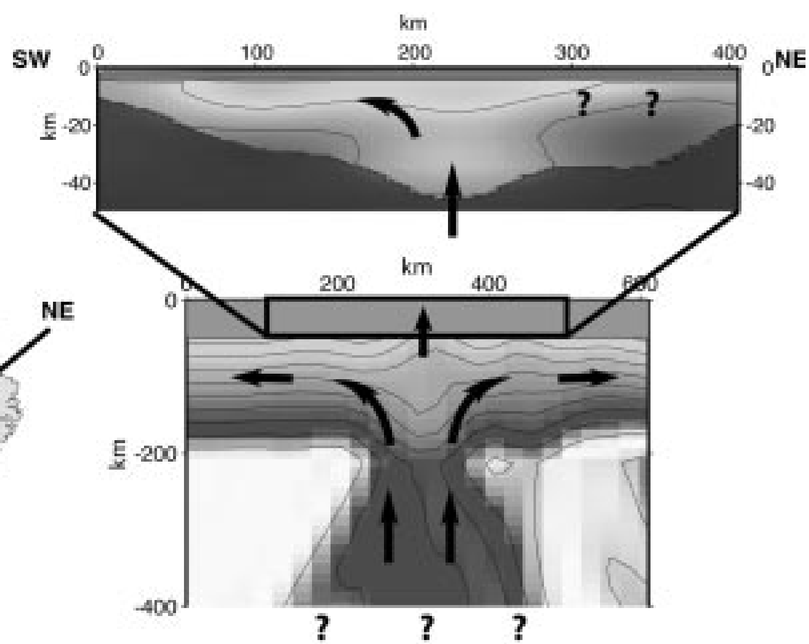


Figure 1. Tracing melt pathways beneath Iceland: *The figures show vertical cross-sections through the crust (upper) and mantle (lower) S-velocity models for Iceland. The slices run SW to NE as indicated on the inset map of Iceland. In the mantle a vertical column of low velocity material extends from 400 km up to 200 km where it spreads out horizontally beneath the lithosphere. This flow provides hot mantle material which melts beneath central Iceland. The melt fluxes across the Moho and into the crust. In the crust a low velocity pipe indicates that the melt flows vertically through the lower crust and then horizontally down the Mid-Atlantic Ridge to the SE, but not to the NE.*

find a low velocity—interpreted as high temperature—column of rock extending from depth up toward the surface, Figure 1. At 200 km depth the low velocity material spreads out beneath all of Iceland as the upwelling material impinges on the base of the lithosphere. Through high resolution imaging of the crustal structure we are able to map melt pathways from the core of the mantle anomaly up through the crust and into magma chambers at depths of about 5km. What is surprising about the melt pathways is that they are not vertical. Instead, the melt travels first vertically through the lower crust in central Iceland, and then horizontally within the upper crust to supply magma chambers along the Mid-Atlantic Ridge as it runs across Iceland. I am continuing my work on the Iceland dynamic system with graduate student **Mei Xue**. We are studying the anisotropic structure—how the velocity of rock beneath Iceland varies as a function of direction—to better constrain the flow patterns of the upwelling material. *To read more about the structure of Iceland visit:* http://www.geology.wisc.edu/~rallen/ICELAND/ *which includes an article written for non-seismologists titled "Plumbing in Iceland: Imaging plate formation in the Earth's Interior."*

Seismic hazard mitigation is my other research interest. I have been studying the rupture process of earthquakes in an effort to develop new methods for determining magnitude. The new method provides the first magnitude estimate with only one second of data – much more rapidly than was previously possible. With ultra-rapid magnitude determination, and a dense seismic network in an earthquake prone region, it is possible to provide a few to tens of seconds warning of significant ground motion in an earthquake. This is enough time to take cover under a desk, or exit a low-rise building. Industries can initiate shutdown of machinery, workers can move away from dangerous chemicals and machinery. This information can also be used by engineers to design a building that can respond to the ground motion warning in order to better protect the occupants. Such active response systems have already been integrated into some buildings in Japan. The final goal would be a system that leaves building occupants unaware of the earthquake that their building just experienced.

The prototype early warning system I have developed is currently being tested with the realtime seismic system in southern California. Southern California is a particularly challenging place to provide an early warning system because the earthquake source region coincides with the metropolitan areas. However, the region also benefits from a state-of-the-art seismic network (TriNet), consisting of hundreds of stations from which data is transmitted back to a central processing site at Caltech. The early warning system includes processing of seismic waveforms on-site at each station, transmission of the information to central processing, identification of earthquakes in progress, and determination of the hazard posed by the earthquake. Every second the hazard assessment is updated as new information is received from the stations, Figure 2. Once the system is operational (with an acceptable accuracy), warning messages can be issued. While the California system continues online development, graduate student **Drew Lockman** and I are pursuing algorithms necessary for earthquake early warning systems in other earthquake prone regions in both developed and developing nations. *More information and examples of how the early warning system would work in southern California is available at:* http://www.geology.wisc.edu/~rallen/ELARMS/.

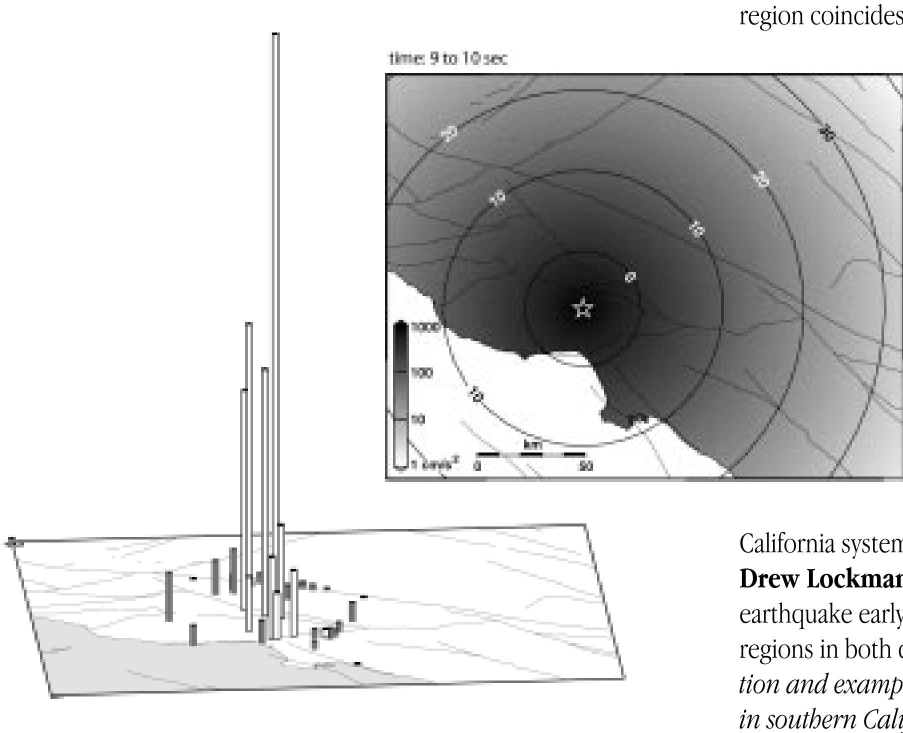


Figure 2. Realtime earthquake early warning in southern California: *Shown is what the output of the early warning system would look like 10 sec after the initiation of the Northridge earthquake which occurred in 1994. The lower perspective map shows the amplitude of ground motion (represented by height of bars) across southern California 10 sec after earthquake initiation. The ring of grey bars shows the first (low amplitude P-wave) ground motion radiating away from the epicenter, the tall white bars show high amplitude ground shaking which was destroying buildings in the San Fernando Valley at this time. The upper map shows the best estimate of hazard that was available at this time. The star indicates the epicenter, the concentric circles indicate the time till peak ground motion is expected, and the grey scale shows the peak ground motion prediction across southern California. The system continually gathers information from the network and updates the hazard estimate every second. You can view the full time sequence of ground motion and hazard maps on the web at: http://www.geology.wisc.edu/~rallen/ELARMS/.*