fall 2010

earthscope onSite

news from USArray

From the *onSite* Editor

In this issue, David Ritzwoller, a student in Colorado, describes his award-winning eighth grade science fair project that utilized Transportable Array data to investigate the frequency of earthquake occurrence in Colorado. His interest was sparked by a couple of small magnitude earthquakes that rattled the state in August 2009. We are pleased that David was willing to share his experience and hope that you find his story inspiring and informative.

The end of summer brings the start of another school year, as well as festivals, fairs and football. As reported on page 2, the demolition of the Texas Stadium in Dallas provided an unusual source of ground motions for a group of geophysicists from Baylor University. They discuss how their recordings will be used to learn more about the deep structure beneath this region. And at the Missouri State Fair, an exhibit presented information about earthquake risk and the arrival of the Transportable Array in Missouri, and featured the EarthScope Active Earth Display, an interactive kiosk with real-time earthquake data.

Over the last few months, new stations have been installed in Nebraska, Iowa, South Dakota, North Dakota, and Minnesota, following removals in Colorado, Wyoming and Montana. The 1,000th station in our rolling array, C35A, near Max, Minnesota, was installed in mid-September! We also initiated activities on the eastern side of the Mississippi River by teaming up with 12 students from 7 universities to help us locate more than 130 future sites.

We value your continued interest in our project and greatly appreciate your contribution to expanding our knowledge of the structure and formation of continents and the physical processes that control earthquakes and volcanic eruptions. If there is a topic of special interest to you, please let us know by contacting me at onsite@usarray.org or the USArray office.

Perle Dorr
Public Outreach Manager

featured science:

Do Earthquakes in Colorado Follow the Gutenberg-Ritcher Law?

A Science Fair Project Using Transportable Array Data

On August 17 and 18, 2009, when I was starting 8th grade at Summit Middle School in Boulder, Colorado, a pair of earthquakes jolted the state. These earthquakes were small, with magnitudes only a bit above 3. In most western states, these events would not be worthy of a mention, but they were reported in the local news as being very rare. I wondered if such earthquakes were really as rare as reported. Eighth graders at Summit MS are required to participate in the state science fair competition, and addressing the question of the frequency of earthquakes in Colorado seemed like an interesting and timely project to undertake.

The US Geological Survey (USGS) maintains a database (also called a catalogue) available to the public (www.earthquake.gov) that allows a person to determine the frequency of earthquakes in Colorado rather quickly, at least for earthquakes with magnitudes between 3 and 5 (smaller earthquakes are not catalogued and larger earthquakes in Colorado really are very rare). Over the last 10 years, the USGS determined that 82 earthquakes occurred in Colorado – 75 earthquakes with magnitudes between 3 and 4 and seven earthquakes with magnitudes between 4 and 5. Therefore, an earthquake with a magnitude of 3 or greater actually is expected about every other month. While not that rare, the occurrence in Colorado of two earthquakes on consecutive days is unusual. The numbers from the USGS also revealed an interesting pattern that is seen in many earthquake zones around the world – about 10 times more earthquakes with magnitudes between 3 and 4 were observed in Colorado over the last decade than with magnitudes between 4 and 5. This observation – that the reduction in magnitude by a unit results in an increase in the number of earthquakes by a factor of about 10 – is so common that it is referred to as the Gutenberg-Richter Law.

The Gutenberg-Richter Law not only explains the numbers of earthquakes at magnitudes above 3, but it also predicts the number of smaller earthquakes that should be occurring in Colorado even if they are not felt, not reported, or not located. Given approximately 75 earthquakes with a magnitude between 3 and 5, Colorado should have ~750 earthquakes with a magnitude between 2 and 3 and ~7500 earthquakes with a magnitude between 1 and 2 over a 10-year period or, on average, about 6 earthquakes per month with a magnitude between 2 and 3 and about 60 earthquakes per month with a magnitude between 1 and 2 (see Table 1 on page 3). If the Gutenberg-Richter Law holds, small magnitude earthquakes should regularly occur in Colorado, but they are simply too small to be felt by humans, do not cause damage, and organizations like the USGS do not catalogue them.

Figure 1a. Locations of events near the Trapper Mine in Craig, Colorado. These events are judged to be human-caused because of their proximity to major mining operations.

For my 8th grade science fair project, I wanted to determine the number of earthquakes with a magnitude between 1 and 3 that actually occur in Colorado. Three coincidences made it possible to address this problem: (1) the EarthScope Transportable Array was operating 63 high quality seismometers in Colorado during

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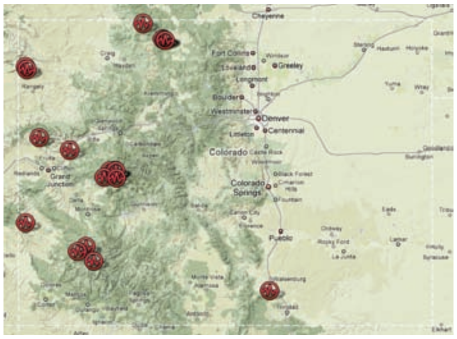


Figure 1b. The locations of the 20 events in June 2009 that I judged to be earthquakes.

USArray Operating Stations as of October 4, 2010

REAL-TIME STATION STATUS: To view a map of current EarthScope instruments, visit www.earthscope.org/current_status/.

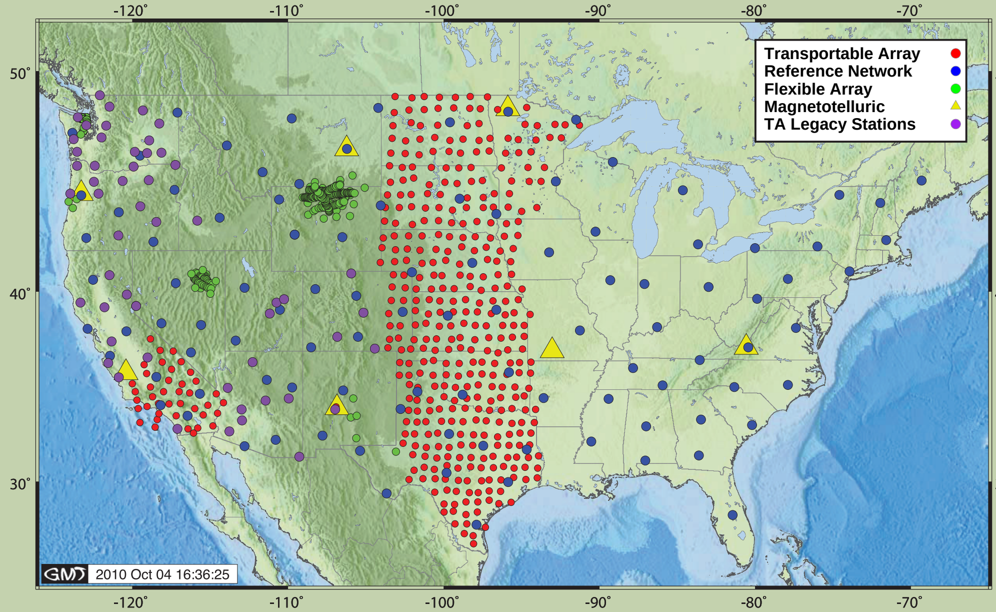
To view seismograms recorded at a USArray station, go to www.usarray.seis.sc.edu/ and enter the station code. You can also enter a zip code to view the recordings from the USArray station closest to that area.

To select a station from a map and view its seismograms, go to www.iris.edu/activeearth/content/es_TA_status.phtml. Click on a station location (red dot) and view today's or yesterday's data.

TRANSPORTABLE ARRAY COORDINATING OFFICE:

usarray@iris.edu 1-800-504-0357

Where is USArray?



featured science:

Football is Important to Texas (Seismologists)

Texas Stadium has been the site of thunderous crashes for nearly 40 years. It served as the home field for the Dallas Cowboys from 1971 through the 2008 football season and established itself as one of the winningest teams in the NFL. The Cowboys played at Texas Stadium during the lead up to all five of their Super Bowl wins before moving to the new "Cowboys Stadium" in 2009.

On April 11, 2010, Texas Stadium was the site of a final crash, as it was demolished to make way for a shopping mall. But before the demolition began, several geophysicists from Baylor University installed a seismograph next to the stadium, on the University of Dallas campus. Not wanting to lose an opportunity, we planned to record the shock waves produced by the massive falling concrete blocks to study the Earth's crust in the vicinity of the stadium!

Although the sedimentary layers of Texas' geology have been studied extensively, the deeper structure remains a mystery. At Texas' Gulf coast, EarthScope's Transportable Array encounters a type of terrain that is different from any it has traversed previously. As shown in Figure 1, a zone extending from northeast Texas to the southwest through Dallas, Waco, Austin and San Antonio is the transition between the continental crust of North America and crust that was stretched and thinned before it rifted apart to create the Gulf of Mexico. Very few seismographic stations were installed in Texas before the arrival of the Transportable Array due to its low earthquake hazard. Now that the Transportable Array stations are here, we still lack a significant number of local and regional seismic sources that would allow us to image the Earth's structure under the Dallas-Fort Worth region in more detail. The demolition of Texas Stadium was a novel source that might provide a glimpse of the lower crust and upper mantle beneath this tectonically important part of Texas.

After the demolition, the recordings were retrieved from the station installed near Texas Stadium and the surrounding Transportable Array stations (Figure 2). Using the data from the Texas Stadium station as a pattern, the recordings from the other stations will be searched for signals from the demolition. The variations in the seismic wave velocities from west to east will help us better understand the geologic history of this region. ■

By Jay Pulliam, David Boyd, Vince Cronin, Mark Speckien, Carrie Rockett, Ryan Dhillon, Dan Lancaster, Ben Phrampus, and Alan Gunnell, Department of Geology, Baylor University.

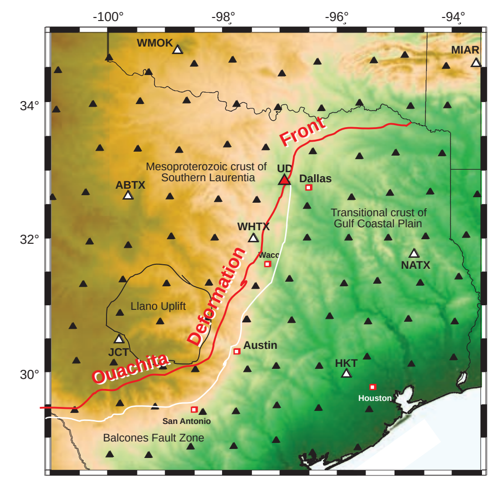


Figure 1: The location of the Texas Stadium (red triangle labeled UD) is at the western edge of the transitional crust, near the limit of the Ouachita Deformation Front (red line). Continental crust to the east is likely to be different from crust to the south and west.

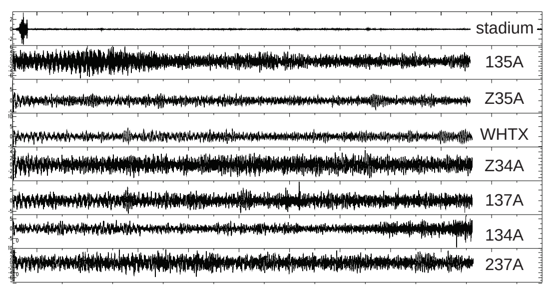
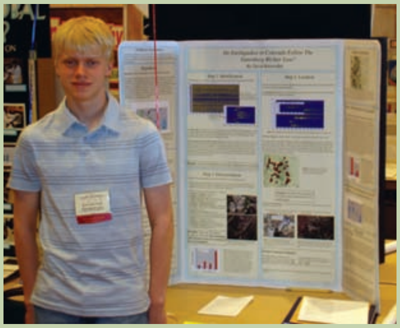


Figure 2: Seismograms from seismic station UDTX, next to Texas Stadium on the University of Dallas campus, and from Transportable Array stations in the surrounding region (ordered by increasing distance from the stadium). Signals from the demolition appear clearly on the UDTX record following the stadium's demolition, but are buried in noise on the records from the Transportable Array stations.

science fair competition: Colorado Earthquake Study Wins Award in 2010 Colorado Science and Engineering Fair



As an 8th grader at Summit Charter Middle School in Boulder, Colorado, David Ritzwoller participated in the Colorado Science and Engineering Fair (CSEF). CSEF honors excellence in science, engineering, and technology. It provides opportunities for students from all regions of the state to create and present their research in environments that nurture interests in science and technology.

As he describes in the accompanying article, David used data from the Transportable Array component of USArray to study small earthquakes in Colorado. Working for most of the school year with a research mentor, Dr. Anatoli Levshin at the University of Colorado at Boulder, David discovered that earthquakes below magnitude 2 do not follow the Gutenberg-Richter Law. For his work, he received first place in the Earth and Space Sciences Division of the Roche Colorado/Boulder Valley Regional Science Fair on February 23, 2010. This qualified him to participate in the state competition held on the campus of Colorado State University from April 8-10, 2010. CSEF winners were chosen from among 279 projects represented by 308 finalists from 104 schools and 13 regions within the state. More than 120 professional scientists, engineers and mathematicians interviewed the students and evaluated their projects.

David's project finished second in the CSEF Earth and Space Sciences Division. He also received special awards from the National Geophysical Data Center and the Colorado Scientific Society. David is now a freshman at Boulder High School. ■

[Editor's Note: David is also the son of Michael Ritzwoller, a seismologist at the University of Colorado and an active EarthScope scientist.]

featured science: Do Earthquakes in Colorado Follow the Gutenberg-Ritcher Law?

(continued from front page)

2009 and these data, as well as data recorded by stations in surrounding states, are available to the general public by IRIS; (2) Dr. Anatoli Levshin, a prominent seismologist at the University of Colorado, agreed to help me with this problem; and (3) easy-to-use software was available at the University of Colorado to process most of the data so that I did not have to do any detailed programming to carry out the project.

My work proceeded in four steps: (1) data acquisition and processing; (2) event location; (3) discriminating earthquakes from human-caused seismic events like mine blasts; and (4) magnitude estimation. In the first step, I downloaded from the IRIS Data Management Center seismic data recorded by about 100 stations in Colorado and in the surrounding states for the month of June 2009. Over a period of a couple months, I looked through all of the waveforms; identified potential seismic events such as earthquakes, human-caused explosions and mining events; and measured (picked) the arrival time of the first recorded seismic wave, or P-wave, for each event. Then, using the P-wave travel times, I located a total of 130 events. Of these, 94 occurred in Colorado. Next I had to discriminate between earthquakes and human-caused seismic events. This can be tricky. I decided to plot the locations of the events on satellite images using Google Earth. I found that 74 events were located near 11 large mines in Colorado, which suggested these were caused by human activity. Figure 1a (on page 1) shows the locations of human-caused events near the Trapper Coal Mine in Craig, Colorado. Only 20 locations (Figure 1b) were not near a mine and I judged these to be earthquakes.

This procedure is admittedly imperfect, but in my study, I also considered the time of day the events occurred. Half of the mining events occurred between noon and 6:00 pm Mountain Daylight Time. Mine operators typically blast in the afternoon hours so that the dust can clear and the debris can settle before the material is extracted the next day. The earthquakes are more evenly distributed during the day, but the fewest happened in the afternoon hours. Since so many mining blasts occur during this time period, particularly in the huge coal mines in Wyoming, it is difficult to identify the earthquakes.

Testing the Gutenberg-Richter Law also requires measuring the magnitude of each earthquake. This is normally done either by (1) measuring how the amplitude of the P-wave decays with distance or (2) observing the duration of the P-wave arrivals. Unfortunately, I made neither of these measurements. However, Dr. Levshin and I devised another magnitude estimation method based on the maximum distance at which an event is observed. Using this technique, there were 13 earthquakes with magnitudes between 2 and 3. This is in rough agreement with the prediction from the Gutenberg-Richter Law – six earthquakes. Unexpectedly, however, there were only seven earthquakes below magnitude 2, far fewer than the 13 earthquakes that had magnitudes between 2 and 3.

Table 1.

Number of Earthquakes in Colorado							
Over a 10-Year Period				In an Average Month		June 2009	
Actual		Predicted		Predicted		Actual	
Magnitude 4-5	Magnitude 3-4	Magnitude 2-3	Magnitude 1-2	Magnitude 2-3	Magnitude 1-2	Magnitude 2-3	Magnitude 1-2
7	75	~750	~7500	6	60	13	7

Therefore, as shown in Table 1, at magnitudes below 2, my measurements were not in agreement with the Gutenberg-Richter Law. But why? Most seismologists I have talked with believe that I was simply not able to observe smaller earthquakes even though I could see small mining events. There does not seem to be agreement as to why, but it may have to do with the fact that earthquakes are deeper than human-caused mining events and, therefore, the seismic waves may scatter into oblivion before they are observed. However, the earthquakes I examined near and below magnitude 2 were actually very clear; there were just few of them. So, I am not convinced by this argument and I believe that there really is a deficit of earthquakes below magnitude 2 in Colorado. I also believe that this may say something about the unusual nature of faults in the state. Resolving this issue will take a seismic network designed explicitly to observe small earthquakes – one which will require seismometers to be placed much closer to one another than the 70-km (~43-mile) spacing between Transportable Array stations.

Finally, I am deeply indebted to landowners in Colorado and surrounding states for hosting Transportable Array stations on their property to record seismic data; to IRIS for archiving and freely distributing these data; to the programmers of the great computer processing software I used; and particularly to my research mentor, Dr. Anatoli Levshin, without whom I could not have devised, let alone completed, this work. ■

By David Ritzwoller, Boulder (Colorado) High School.

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Transportable Array Featured at Missouri State Fair

The Missouri Department of Natural Resources' Division of Geology and Land Survey exhibit at the Missouri State Fair in Sedalia, August 12-22, 2010, prominently featured the Transportable Array. Visitors learned about the earthquake hazard in Missouri, observed where EarthScope seismographs will be located in their state, and were fascinated with the interactive kiosk, Our Active Earth, that displayed real-time earthquake data. The first Transportable Array station installed in Missouri, Q37A near Lee's Summit, became operational this spring. ■