



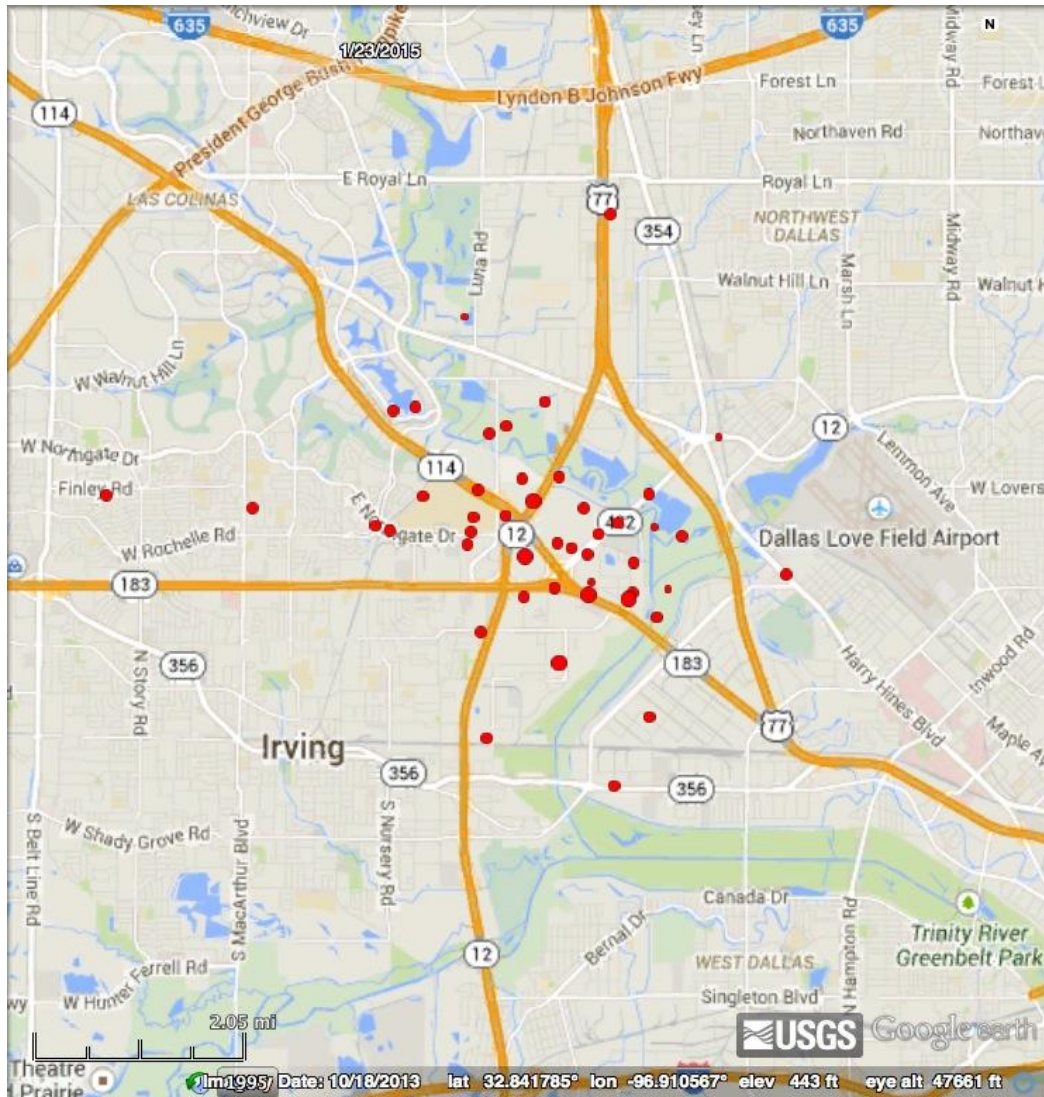
## **Preliminary Report – Irving, Texas, earthquake sequence**

6 February, 2015

In response to the recent earthquakes felt in Irving and Dallas, seismologists at Southern Methodist University (SMU) and the U.S. Geological Survey (USGS) have been collaborating to produce more accurate locations for felt and smaller events and to identify the source region of the ongoing activity. The purpose of this letter is to report on the initial earthquake relocations using the local seismic network, which provides a more accurate understanding of the true geographical extent of the epicenters. At this time, we cannot identify a causative fault nor provide any conclusions as to cause.

Since 2008, the USGS National Earthquake Information Center (NEIC) in Golden, CO, began reporting felt and locatable earthquakes in the DFW area, a region with no prior earthquake activity going back to at least 1970. We identify the beginning of the ongoing earthquake sequence in Irving as April 17, 2014 based on the first felt earthquake (magnitude 2.4) reported for eastern Irving and Dallas. Since then, the rate of earthquakes has varied but increased significantly in early January 2015 including the occurrence of two magnitude 3.5 and 3.6 events on January 6. For this sequence, the NEIC reports that the largest earthquake to date has been a magnitude of 3.6, that there have been five earthquakes over magnitude 3, and that there have been 46 total reported earthquakes with the smallest reported magnitude being 1.1. The NEIC locations are scattered over a roughly circular area with a 2 mile radius, approximately centered on the TX Highway 114-183 exchange, locally referred to as the old Texas stadium site in the City of Irving (Figure 1). The rate of felt earthquakes in the sequence slowed in late January and early February, and the last reported felt earthquake reported by the NEIC was a magnitude 2.2 on January 23, 2015. SMU continues to record smaller earthquakes that are not locally felt.

SMU, assisted by the City of Irving, has deployed seismic recorders within 10 miles of the NEIC epicenters. Two days after the widely felt November 23, 2014 magnitude 3.3 earthquake, SMU reinstalled a seismograph south of the DFW International Airport that was used to record the 2008-2009 DFW earthquake sequence. On January 5, 2015, as soon as instruments became available, SMU worked with the City of Irving to install a station in north Irving. Following the widely felt earthquakes on January 6, the USGS provided two “NetQuakes” seismographs, and SMU deployed these and an additional 12 temporary seismographs designed to stay in the field for 10 days. Over the following weeks, SMU has continued to deploy longer-term, higher-quality seismographs made available through the Incorporated Research Institutions for Seismology (IRIS) to record the ongoing seismicity and has recovered the 12 temporary stations with associated data. We deeply appreciate the help in siting stations we have received from the staffs and local residents of Irving, Dallas, Farmers Branch and Coppell, and the telemetry equipment provided by Irving that allows the data from almost all stations to be relayed directly to the USGS and publicly archived. The instrument locations are shown in Figure 2.

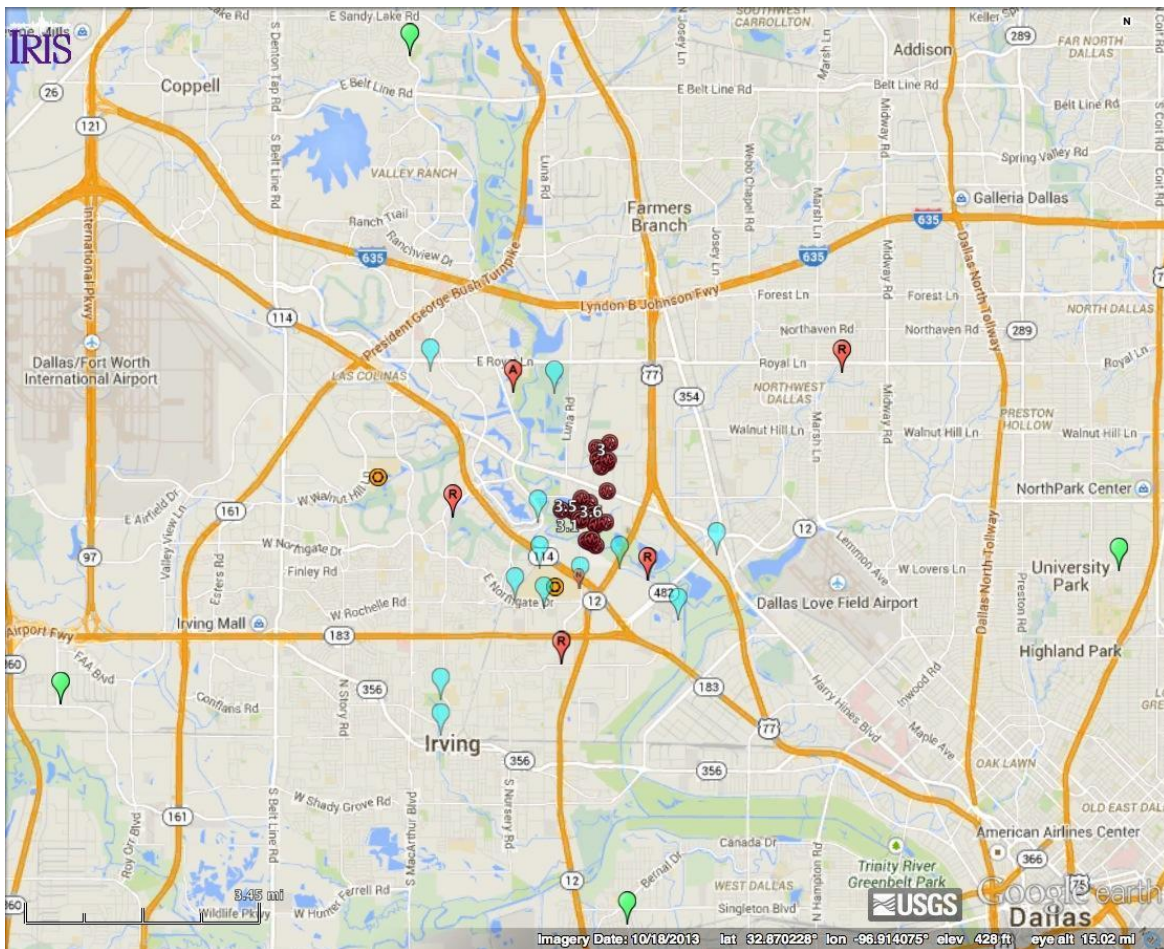


**Figure 1.** Earthquake epicenters determined by USGS-NEIC, April 17, 2014 through January 23, 2015. Circle size is scaled by magnitude, which ranges from 1.1 – 3.6. Because the NEIC must rely on a regional seismic network in this area where station spacing is over 100 miles, the reported locations near Dallas may be in error by as much as 5 miles, especially for earthquakes smaller than about magnitude 2.5. Scale at lower left is 2.05 miles.

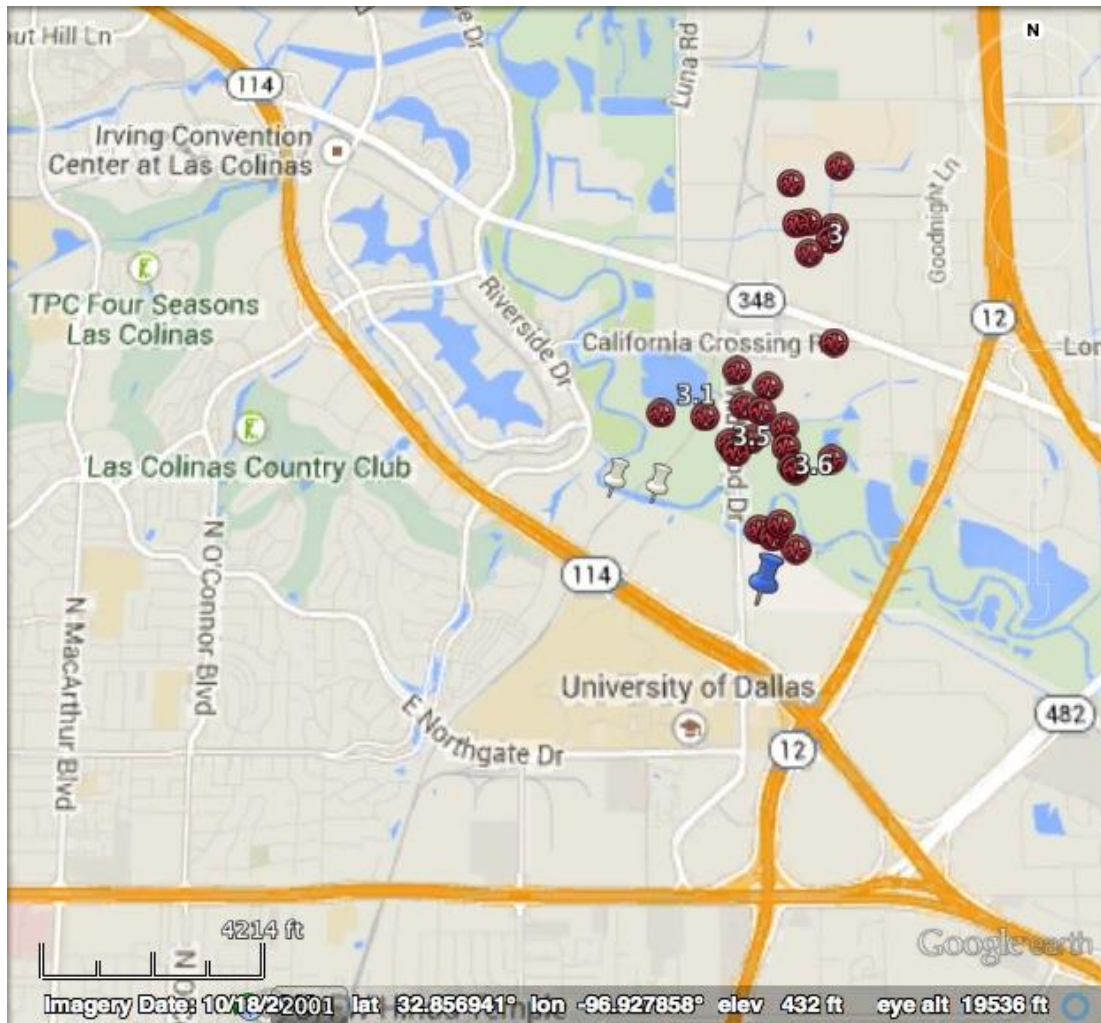
SMU scientists have now relocated 26 felt earthquakes reported by the NEIC in January 2015, using the data recorded by the SMU/USGS temporary local seismic network combined with a geologically based model for the velocity of seismic waves beneath the urban region. The improved epicenters are confined to a limited area extending north from TX Highway 114 to Walnut Hill Rd. along the Trinity River (Figure 3). Note that the new earthquake locations extend the source area through parts of Irving and west Dallas. This source area includes the epicenters of the magnitude 3.5 and 3.6 earthquakes of January 6, 2015. Figure 4 shows the same earthquakes and instrumentation in a series of time-slices so you can better see how the instrumentation and earthquake locations have changed over the month of January.

As with previous North Texas earthquake sequences (DFW, Cleburne, Azle), the local stations provide more precise locations and reduce the earlier scattered NEIC locations shown in Figure 1 to linear

feature(s) potentially consistent with a fault(s) trend. As they did in our analysis of the Azle sequence, the epicenters shift to the north relative to the NEIC initial locations. The earthquakes are shallow, between 4.5 and 7 km deep. It is not unusual to have a range of depths like this, as the earthquakes may be occurring on different parts of the fault(s). The depths are uncertain, however, because critical details of the subsurface geology and seismic velocity remain poorly known. The current locations and depths were determined with a slightly modified geologic model that was used in the study of the DFW earthquakes just to the west. We tested a various subsurface geologic assumptions to determine the range of probable earthquake depths (focal depths). Based upon this analysis, we conclude that most of the earthquakes are located in the shallow crystalline basement (granites) below the sedimentary rocks (sandstones, shales, limestones, etc.) that comprise the Fort Worth Basin. We expect that the depth uncertainty in our current locations will be reduced as we integrate additional geologic information.

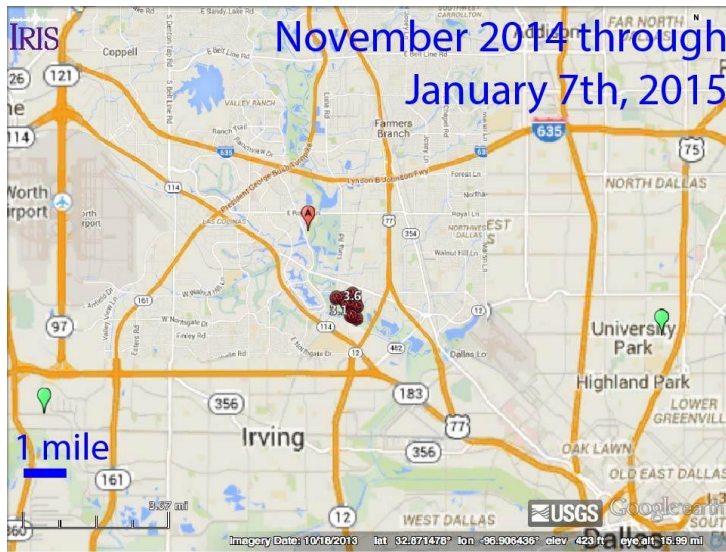


**Figure 2.** Locations of seismographic instruments as of January 30, 2015 together with revised earthquake locations (dark red). The network became fully operational for the purpose of locating earthquakes well on January 5<sup>th</sup>, but significant real-time location improvement did not occur until mid-January. Short-term stations deployed from Jan 7-17<sup>th</sup> are shown in cyan. USGS “Netquakes” stations are shown in orange circles. SMU/IRIS stations are shown in green (broadband sensors) and red (short-period sensors). Earthquake relocations are described further in Figure 3. Scale at lower left is 3.45 miles.



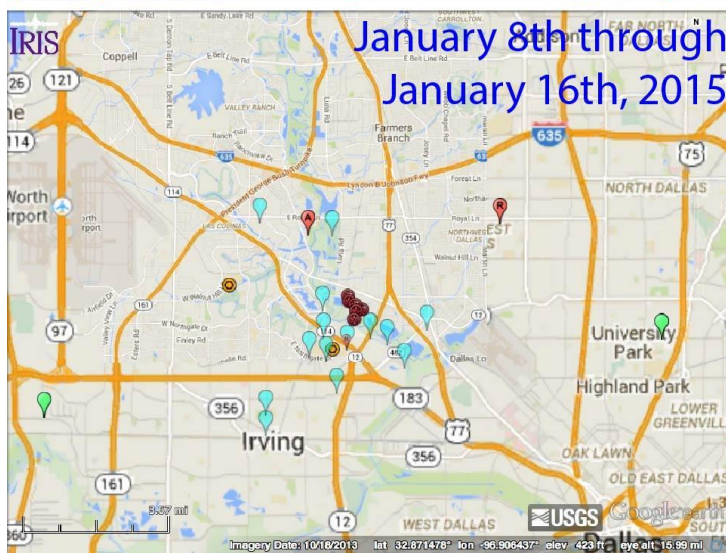
**Figure 3.** Detail showing epicenters of earthquakes (red symbols) located using the local seismographs from January 6-23, 2014. Magnitude 3+ earthquakes reported by the NEIC have been marked. The only production wells in the region [API 42-113-30147 and API 42-113-30189] (pad site: blue pushpin; well bottoms: white pushpins) was developed in 2009 and ceased production in 2012. The scale at the bottom left is ~0.80 miles.

Scientific questions about the nature of events in North Texas have heightened local and national concerns about the impact of activities related to shale gas production on geological infrastructure and subsurface structures. SMU scientists continue to explore all possible natural and anthropogenic causes for the Irving earthquakes and do not have conclusions at this time. Due to the public interest in these questions, however, we note here that there is one set of inactive shale gas production wells [API 42-113-30147 and API 42-113-30189] near the Irving earthquake epicenters (Figure 3). The wells ceased production in 2012 and are the only known production wells in the region mapped in Figure 3. A more detailed history on the wells can be found through the Texas Railroad Commission public archive. The nearest wastewater injection well is located ~8 miles to the northwest. Production and disposal activities in this region are generally confined to the sedimentary units overlying the basement rocks discussed in the preceding paragraph. As part of our studies of North Texas earthquakes in general, we continue efforts to gather more detailed information on the history of production and wastewater disposal activities throughout the region.

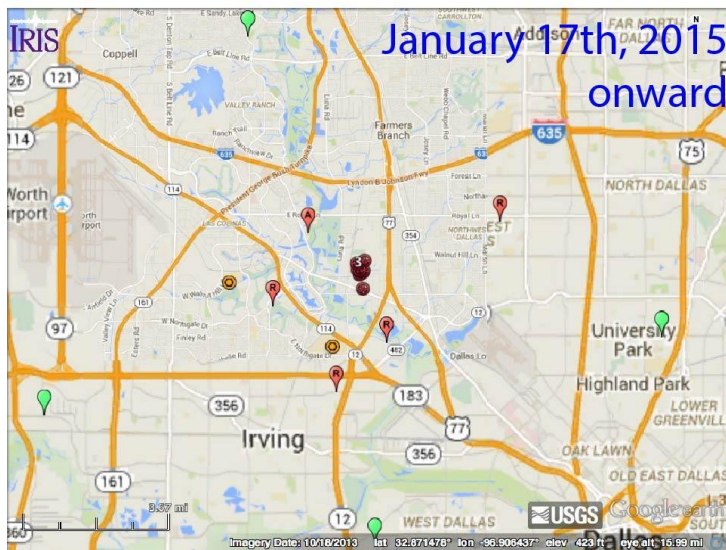


**Figure 4.** Time history of epicenters and station distribution.

**Top)** Epicenters and station distribution from late November 2014 through January 7th, 2015. During this time period, we had up to three local stations in place (red and green placemarks). Earthquakes reported by the NEIC and relocated using the local stations are shown (red earthquake symbols). These stations captured the high level of activity on Jan. 6-7th, 2015.



**Middle)** Epicenters and station distribution from January 8-16, 2015. In response to the increase in activity, short-term seismographs (blue placemarks), USGS “Netquakes” seismographs (orange circles), and one additional local station (red placemarks) were deployed during this time period. Seismicity reported by the NEIC and relocated over this time period are shown (red earthquake symbols).



**Bottom)** Epicenters and station distribution from January 17, 2015 and moving forward. Five additional local stations (red and green placemarks) have been or will be placed to provide sufficient distance and azimuthal coverage to monitor the ongoing seismic activity. There will be 11 seismographs run as part of the temporary Irving network moving forward. Seismicity reported by the NEIC and relocated since January 17th is shown (red earthquake symbols). Earthquake activity shifts about 0.5 miles north during this time interval.

The next steps of the Irving earthquake study are already underway. The USGS will continue to report 24/7 felt earthquakes in near real-time and post this information (event pages, Did You Feel It? reports, ShakeMaps) of use to the general public on their website (earthquakes.usgs.gov). Due to differences in how the NEIC and SMU handle local and distant station data, it should be expected that the USGS catalog locations may continue to fall outside of the epicenter trend shown in this report. SMU will continue to maintain the seismic network and locate both felt and smaller earthquakes in the area, including repeating our relocation analysis to improve upon the initial NEIC locations of any future felt earthquakes in the sequence. This will help refine the geometry of the fault(s) at depth and aid in hazard assessment. We will also continue to work on more advanced location methods, determine the direction of fault motion, and investigate causal factors leading to this swarm. As we refine the geologic models and re-analyze the earthquake data, it would not be surprising for the refined epicenters to be as much as a half-mile different than what we now estimate. In other words, our estimated error in location is currently at most about a half-mile. Even so, we think that it is unlikely that the overall picture will significantly change; therefore, we are providing this current information to help guide the cities moving forward.

Questions regarding data and analysis presented in this document should be directed to Heather DeShon ([hdeshon@smu.edu](mailto:hdeshon@smu.edu)), Brian Stump ([bstump@smu.edu](mailto:bstump@smu.edu)), Robert Williams ([rawilliams@usgs.gov](mailto:rawilliams@usgs.gov)) and Michael Blanpied ([mblanpied@usgs.gov](mailto:mblanpied@usgs.gov)).

Sincerely,

Heather DeShon  
Southern Methodist University



Brian Stump  
Southern Methodist University



Chris Hayward  
Southern Methodist University



Matthew Hornbach  
Southern Methodist University



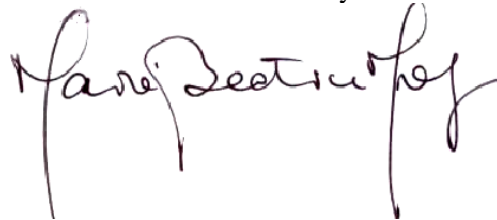
Robert Williams  
USGS Geologic Hazards Science Center  
Golden, CO



Michael Blanpied  
USGS Earthquake Hazards Program  
Reston, VA



M. Beatrice Magnani  
Southern Methodist University



cc: Rocky Vaz, Director of Emergency Management, City of Dallas  
Jason Carriere, Emergency Manager Coordinator, City of Irving  
Craig Pearson, Texas Railroad Commission Seismologist