# PROJECT UPDATES — November and December 2017

**Summary** — Project personnel at the Bureau, along with our UT-Austin, SMU, and TAMU research partners, continue to make progress on this highly successful program, as highlighted below.

Network Installation and Operations

- TexNet installed two additional seismic stations in the Permian Basin region (PB03 and PB05) and one in the Eagle Ford play area [EF04].
- *SMU* installed two additional stations in the Ft. Worth Basin in November/December 2017 (FWTW at Texas Wesleyan University and IFSC over the Irving-Dallas earthquake sequence).

Synopsis of November - December 2017 Seismicity in Texas

- TexNet cataloged 294 events in Texas including five events of $M_L \geq 2.5$. The highest magnitude event ($M_L=3$) occurred in the Delaware Basin between Pecos and Ft. Stockton.
- *SMU* network operations reported a total of 26 earthquakes in the Ft. Worth Basin. Earthquakes in northeast Johnson County dominated (19 events). Six earthquakes were associated with relatively recent sequences, near Lake Lewisville and in the city of Ft. Worth, that are now being more closely monitored. The Irving-Dallas sequence generated one earthquake that was not felt in the metropolitan area.

Synopsis of 2017 Seismicity in Texas

- From January through December 2017, TexNet recorded 1,590 earthquakes of $M_L 0.0$ to $M_L 3.1$. This includes nine events of $M_L \geq 3.0$, 168 events of $3.0 > M_L \geq 2.0$, and 1,413 events of $M_L < 2.0$.
- Earthquakes occurred in the Dallas-Ft. Worth area, Cogdell Field north of Snyder, Delaware Basin near Pecos, south of San Antonio in an arc from I-10 to I-35, and in the Texas panhandle.
- Preliminary calculations of the magnitude of completeness of the TexNet network is less than $M_L 1.3$, meaning that TexNet is recording all earthquakes greater than $M_L 1.3$ state-wide. This is very strong network performance considering the limited date range for which TexNet data are available.
- Please refer to the TexNet Earthquake Catalog for more specific earthquake information.

Partnership

- *UT Earthquake Risk Social Science* team created an industry working group for the CISR industrial sponsors and hosted an online conference November 8 to review the team's 2016-17 research results and forward plans.

Recruitment

- Lily Horne has joined the *Bureau Geological Characterization* team as Structural Interpretation Specialist.
- Rebecca Gao has joined the *Bureau Hydrogeology* team as Fluid Flow Modeler.

Research

- *Bureau Seismology* team
  - Finalized a 3D crustal velocity model for West Texas and the Panhandle regions using current and previous seismicity studies.
  - Identified four different earthquake clusters in the Delaware Basin using grid search algorithms and also performed double difference relocation analysis of earthquakes in the area.
- *Bureau Geologic Characterization* team
  - With research partner Stanford University, completed a slip potential analysis of faults in the Ft. Worth Basin which identifies 250 faults which sum to a map length of over 2,500 km. 51% of this length is critically stressed as are all of the faults in the region associated with earthquake sequences.
  - Began work with subcontractor Southwest Research Institute to develop a 3D uncertainty treatment of faults of concern in the Ft. Worth Basin as a supplemental study to the Fault Slip Potential Analysis. Initial results focusing on analysis workflow selection are being evaluated.

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- Completed a stratigraphic interpretation for the Ft. Worth Basin using 1,286 wells and a petrophysical rock properties analysis using 46 wells of deep units used for injection.
- Completed the development of a 3D/4D Petrel geocellular model of the entire basin needed for mechanistic analysis which is deterministically populated with data including earthquakes, injection wells and volumes, faults, and stratigraphy; and geostatistically populated with reservoir properties.

- *Bureau Hydrogeology* team continued development of the fluid flow model of the Ft. Worth Basin with a focus on importing the most recent and accurate stratigraphic structures. The team has progressed in determining how much Ellenburger water is produced through Barnett wells.
- *Bureau Geomechanics* team
  - Developed generic geomechanical models on fault reactivation by injection and production into different horizons, extended 2D models to 3D, incorporated the effects of varying poroelastic and hydraulic parameters; and investigated hydraulic and mechanical boundary conditions on the poroelastic solution and consequent fault reactivation.
  - Continued site-specific injection simulations for the Azle case using fully coupled poroelastic response, improved MATLAB code for solving equations to get induced seismicity rate, and conducted sensitivity study on wellbore effect and permeability on 2D and 3D fully-coupled poroelastic solutions.
- *TAMU Reservoir Engineering* team performed detailed sensitivity calculations in the Azle case based on variations in loading difference and concluded that a higher loading difference can result in larger strain changes. Coupled fluid flow and geomechanical simulation of the reservoir model shows that the change of strain in the basement fault can be caused by an unbalanced loading on different sides of the fault due to differential water injection and reservoir hydrocarbon production. This is a different mechanism for induced seismicity than would result from pressure increase within the fault itself as attributed in previous studies.
- *UT Reservoir Engineering* team continued work on rupture propagation modeling of earthquake slip events and is working to parallelize the analysis code to allow for subsurface case studies.
- *UT Seismic Hazard and Risk* team
  - Created computational models that simulate the seismic performance of anchored brick veneers attached to wood structures, which are common in residential construction. The computational models have been validated against experimental data available in the literature and will be used to produce fragility curves for use in seismic risk assessments.
  - Compiled earthquake catalogs and injection data for two study areas: Oklahoma and DFW and initiated processing and homogenizing datasets for use in the new time-dependent seismicity model.
  - Completed shear wave velocity inversion, $V_s30$ calculation, and uncertainty analyses for the 52 stations tested. These results are summarized in a conference paper for Geotechnical Earthquake Engineering and Soil Dynamics 2018. Initiated discussions to select sites for deeper (+500 m) $V_s$ profiling.

<u>Outreach</u>

- TexNet was featured in more than 26 newspaper, television, and radio stories that ran November-December.
- The 2017 Annual TexNet-CISR annual research review was conducted at the Bureau Dec 6-8 and consisted of 40 technical presentations for an audience of 75 industrial associate members and research staff.
- *Bureau and SMU Scientists* presented three talks at the SPE/SEG Induced Seismicity workshop in Dallas on topics of TexNet network performance and Ft. Worth Basin seismicity and Fault Slip Potential.
- *Bureau and SMU Scientists* presented six talks and posters at the American Geophysical Union meeting in New Orleans on the topics of TexNet network performance, TexNet-CISR research program design, Delaware Basin seismicity, and Ft. Worth Basin seismicity, Fault Slip Potential, and hydrogeologic modeling.
- *Bureau Seismology* team presented TexNet at the Annual Sponsors Meeting of the Microseismic Consortium in Calgary.
- *Bureau Seismology* team submitted a paper for the Geotechnical Earthquake Engineering and Soil Dynamics V 2018 and an abstract for the EAGE Workshop on Passive Seismic 2018 (Session: Induced Seismicity).
- The Regional Induced Seismicity Collaborative (RISC), a new program that brings together researchers from TX, OK, NM, and KS was approved by the U.S. Department of Energy, through grant funding to the Groundwater Protection Council. RISC will kick off activities in early 2018.