

Source Mechanisms of Earthquakes in Northwest Louisiana

Emily Kraus¹, Cynthia Ebinger², Samantha Hilburn³

¹Tulane University, New Orleans, LA

Introduction

Hydraulic fracturing and wastewater injection are natural gas industry operations executed at high pressures. Earthquakes induced by these processes are generally too small for human detection; however, hydraulic fracturing and wastewater injection near pre-existing faults can trigger earthquakes of larger magnitudes. Project ISLA (Investigating Seismicity in Louisiana) collaborators installed 10 seismometers in June 2019 and 4 in late 2020 to assess baseline seismicity in the Haynesville basin and Sabine uplift of northwestern Louisiana and eastern Texas. **Continuous seismic monitoring facilitated depth and location measurements of area earthquakes to determine their correlation with locations of hydraulic fracturing and injection well sites.**

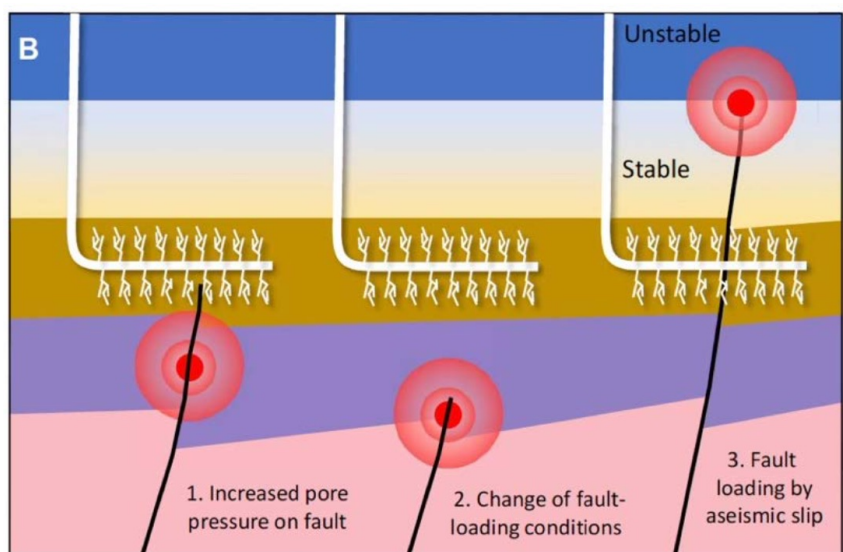


Fig. 1. Depths of hydraulic fracturing and wastewater injection are controls on induced seismicity. Operations at depths below the injection horizon can elicit prolonged effects, whereas operations at depths above the injection horizon induce transient earthquakes that cease with industry lulls (e.g., Eyre et al., 2019)

Background Information

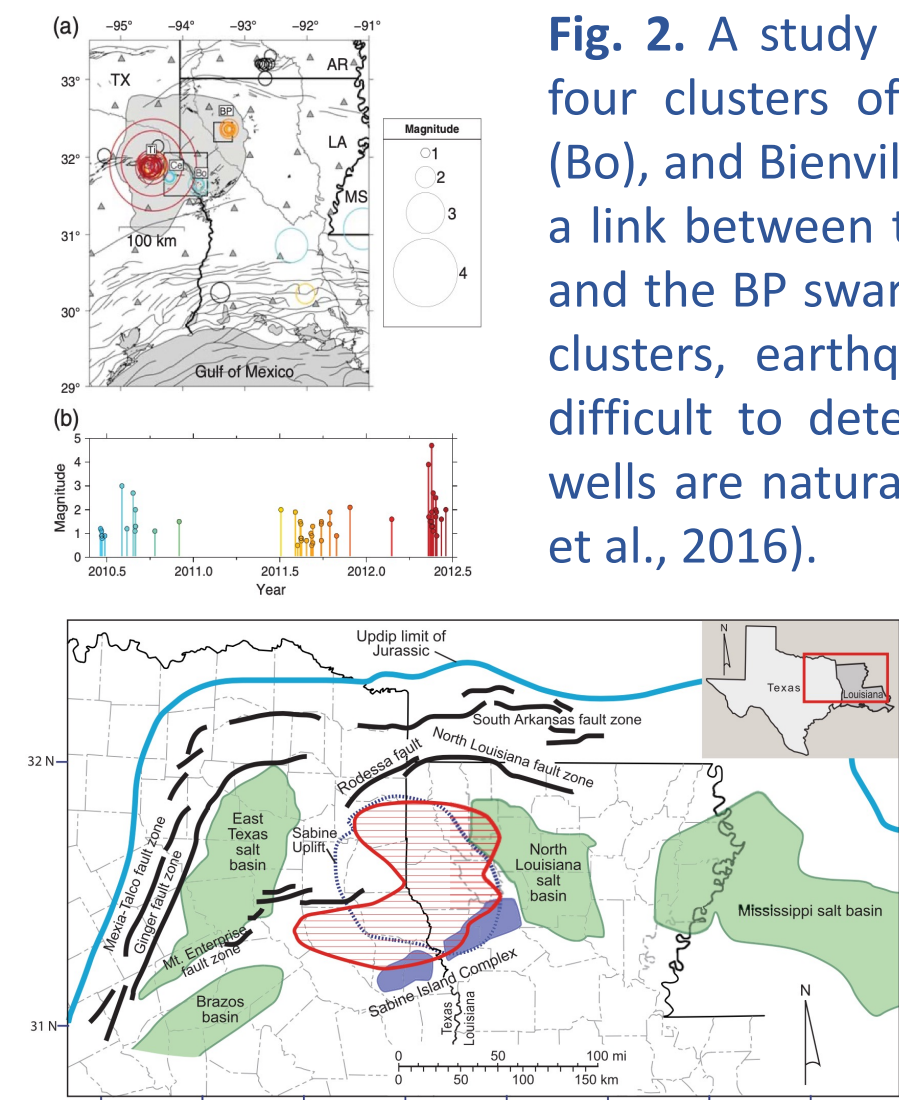


Fig. 3. The North Louisiana fault line is represented by the solid dark black line. The Haynesville Shale productive area is outlined with a solid red line (e.g., Hammes & Ewing, 2011).

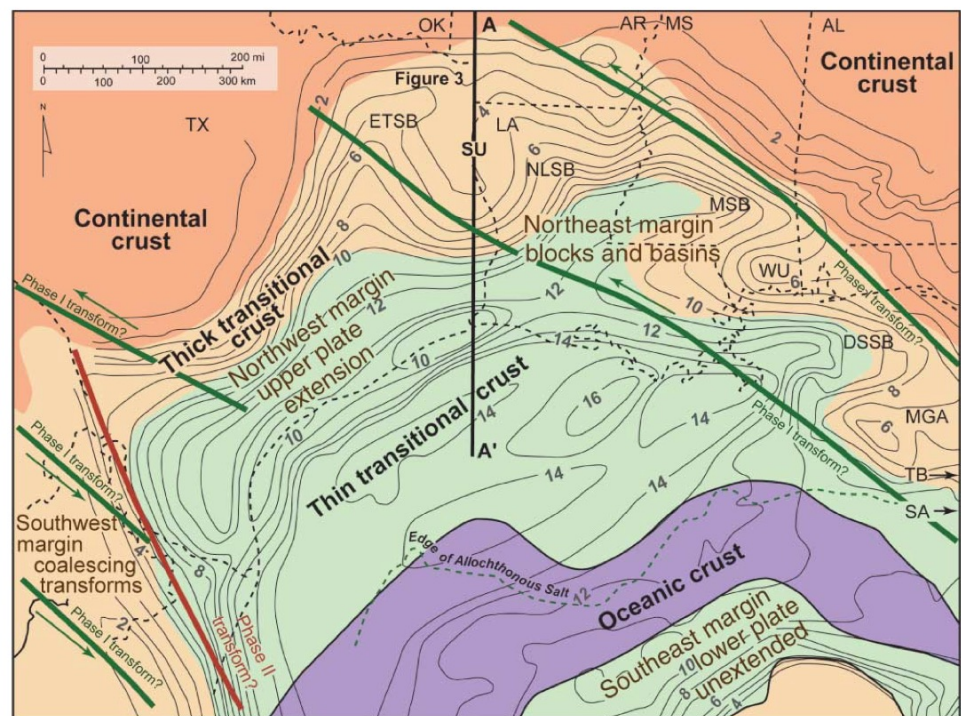


Fig. 4. Depth to basement of study area is about 6km. Earthquakes in this project are all shallow depth, above 6km (e.g., Hammes & Ewing, 2011).

Methods

This study analyzes earthquakes of magnitudes ML 2.5-3.2 from April 2021 using data extracted from the ISLA seismic array in northwestern Louisiana from 2019 to present. To decrease azimuthal gaps, additional data are extracted from permanent TEXNET and USArray stations in Arkansas and Oklahoma. Absolute locations are determined using the velocity model by Walter et al. (2016) and HYPOINVERSE-2000 by Klein et al. (2000). Focal mechanisms are determined by picking the polarity of P arrivals and plotting them on a stereonet, using take off angles and azimuths from hypoinverse results. Using first motion data, nodal planes are determined, and focal mechanism solutions are revealed.

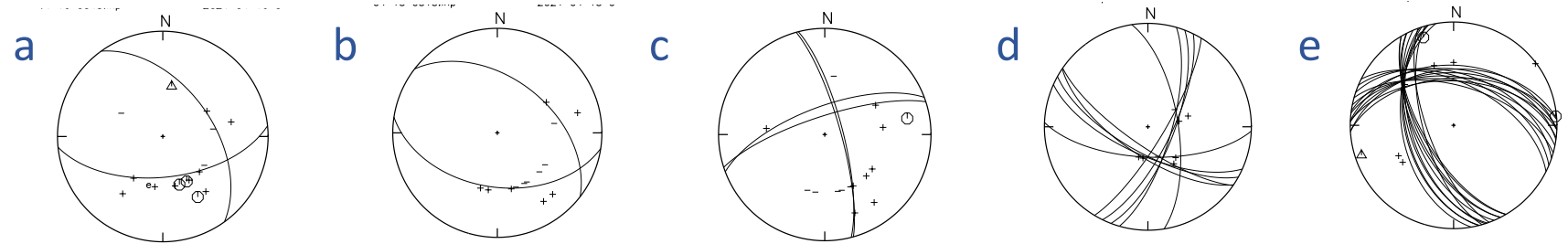
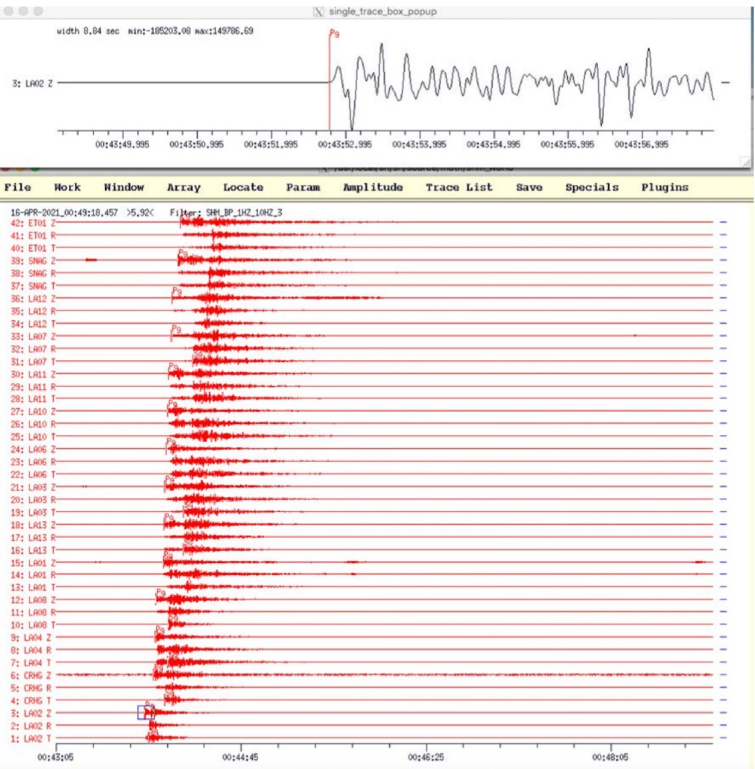


Fig. 5. Examples of ISLA focal mechanisms a) 16-04-21 00:43 b) 15-04-21 05:13 c) 01-04-21 07:26 d) 11-04-21 22:01 e) 23-03-21 01:25, two of which are oblique slip (a and b). Hexagons are up; triangles, down; +, - are emergent.

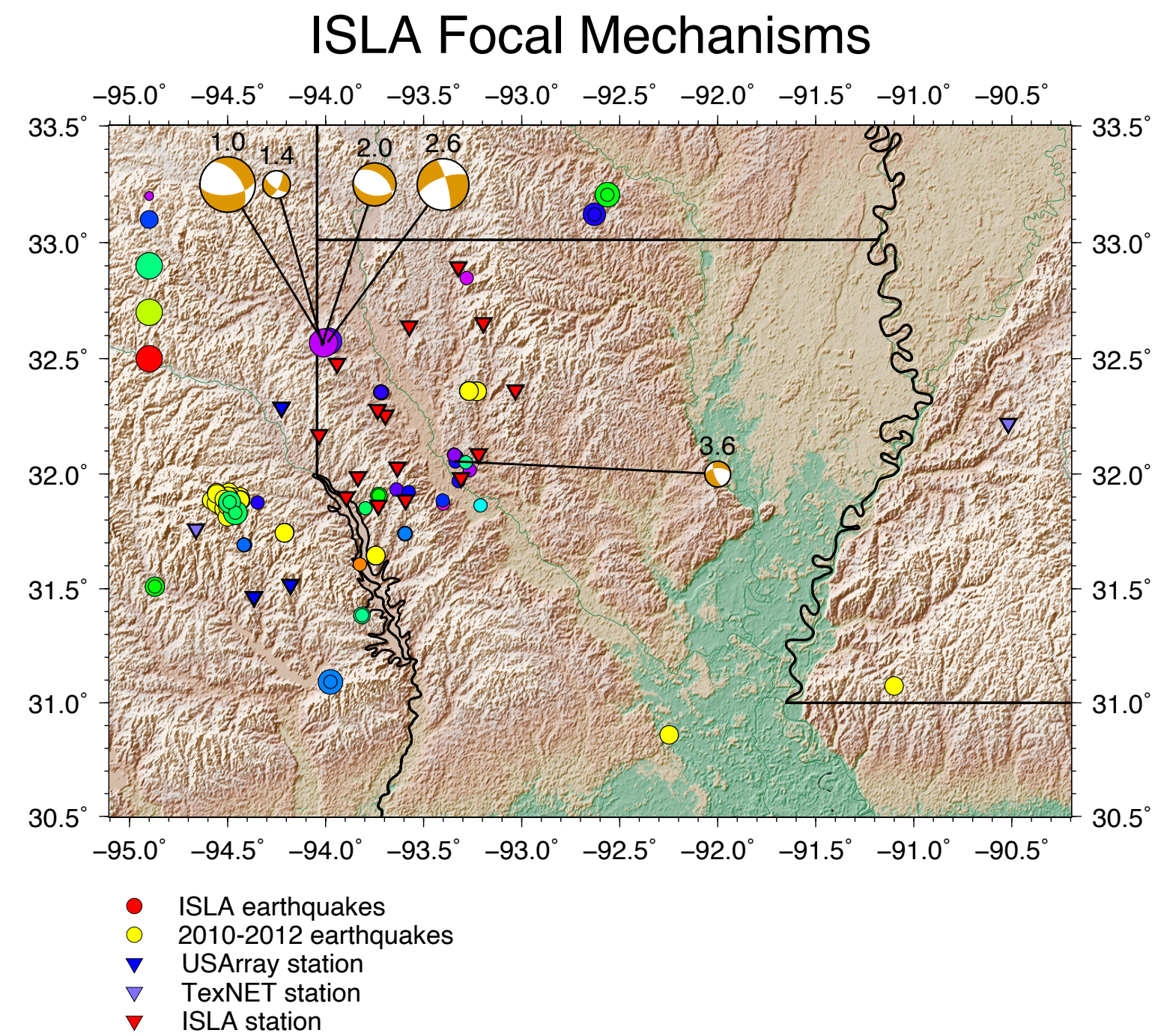
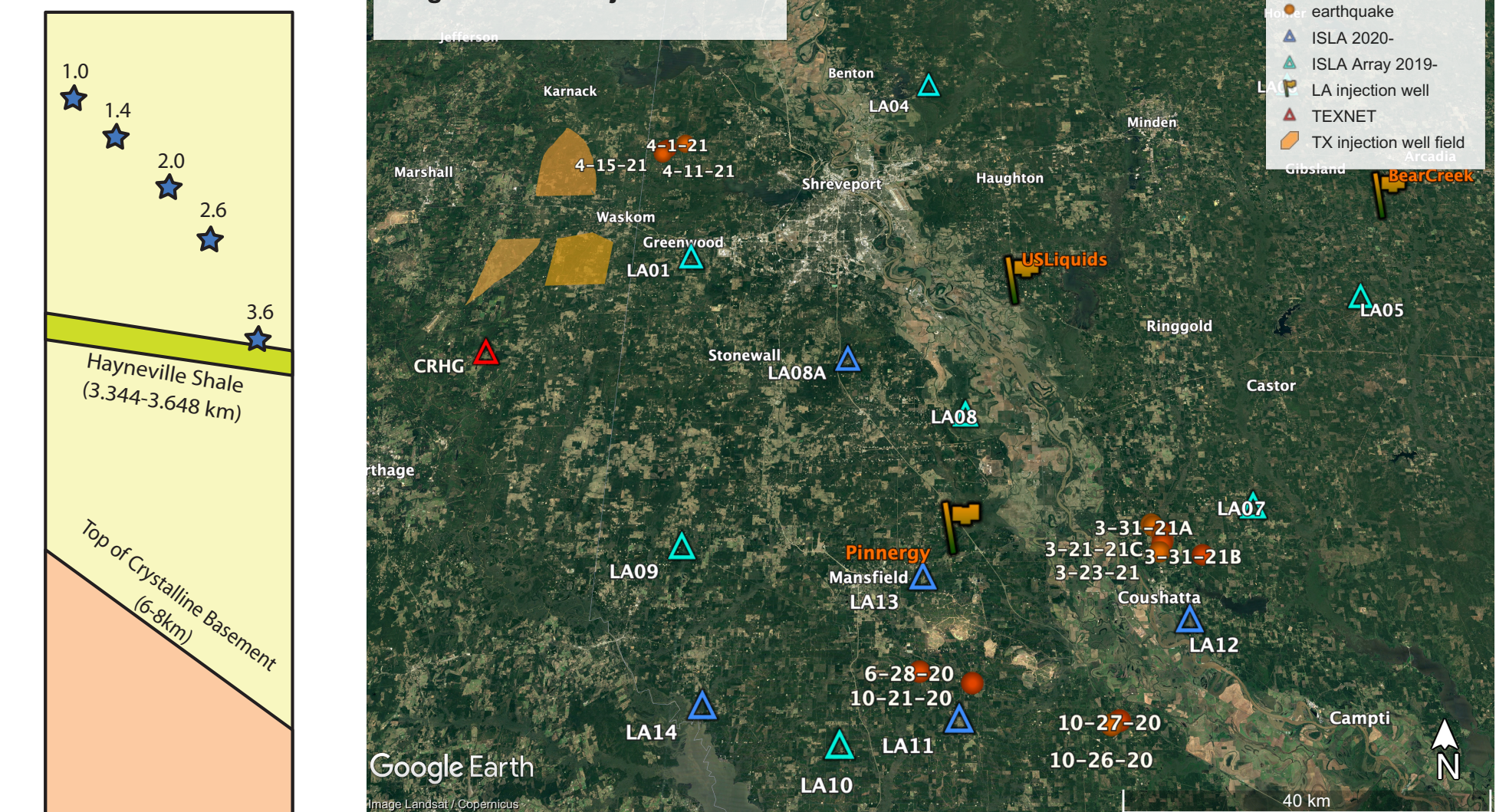


Fig. 6. In the figure to the left, the inverted triangles of various colors represent the location of seismometers in the ISLA array (red), the TEXNET array (light purple), and the 2010-12 US Array (dark blue). The yellow circles represent earthquakes from 2010-2012. The multicolored circles represent ISLA earthquakes of various colors and diameters depending on depth and magnitude. Depths range from 0 km (dark purple), 5 km (dark blue), 10 km (green), 15 km (lime green), and 20 km (red). Focal mechanisms are represented by the orange (compression) and white (extension) beachball diagrams, are labelled by their depth, and scaled by their magnitude.

Take Aways



- Oblique slip pattern was observed for two earthquakes (natural or due to pre-existing faults being reactivated).
- Normal and strike slip were observed for others
- Earthquakes occurred at depths above the crystalline basement and right at the surface of the Haynesville shale (**Fig. 7.** on the left).
- April 2021 earthquake cluster is near Texas injection well fields (**Fig. 8.** on the right).
- Difficult to draw definitive conclusions for the cause of these earthquakes due to a lack of information for earthquakes of these magnitudes in Louisiana and lack of daily pumping data.
- Future work can consist of continued monitoring of the area for earthquakes and injection data.

References

- Ewing, (2009). The ups and downs of the Sabine Uplift and the northern Gulf of Mexico basin; Jurassic basement blocks, Cretaceous thermal uplifts, and Cenozoic flexure. Transactions - Gulf Coast Association of Geological Societies, 59, 253–269.
- Eyre, T., Eaton, D., Garagash, D. I., Zecevic, M., Venieri, M., Weir, R., & Lawton, D. C. (2019). The role of aseismic slip in hydraulic fracturing-induced seismicity. Science Advances, 5(8), eaav7172–eaav7172.
- Klein, F.W. (2000). *User's Guide to HYPOINVERSE-2000, a Fortran program to solve for earthquake locations and magnitudes.*
- Hammes, U., Hamlin, H. S., & Ewing, T. E. (2011). Geologic analysis of the Upper Jurassic Haynesville Shale in east Texas and west Louisiana. AAPG Bulletin, 95(10), 1643–1666.
- Walter, J. L., Dotray, P. J., Frohlich, C., & Gale, J. F. W. (2016). Earthquakes in northwest Louisiana and the Texas-Louisiana border possible induced by energy resource activities within the Haynesville shale play. Seismological Research Letters, 87(2A), 285-294.