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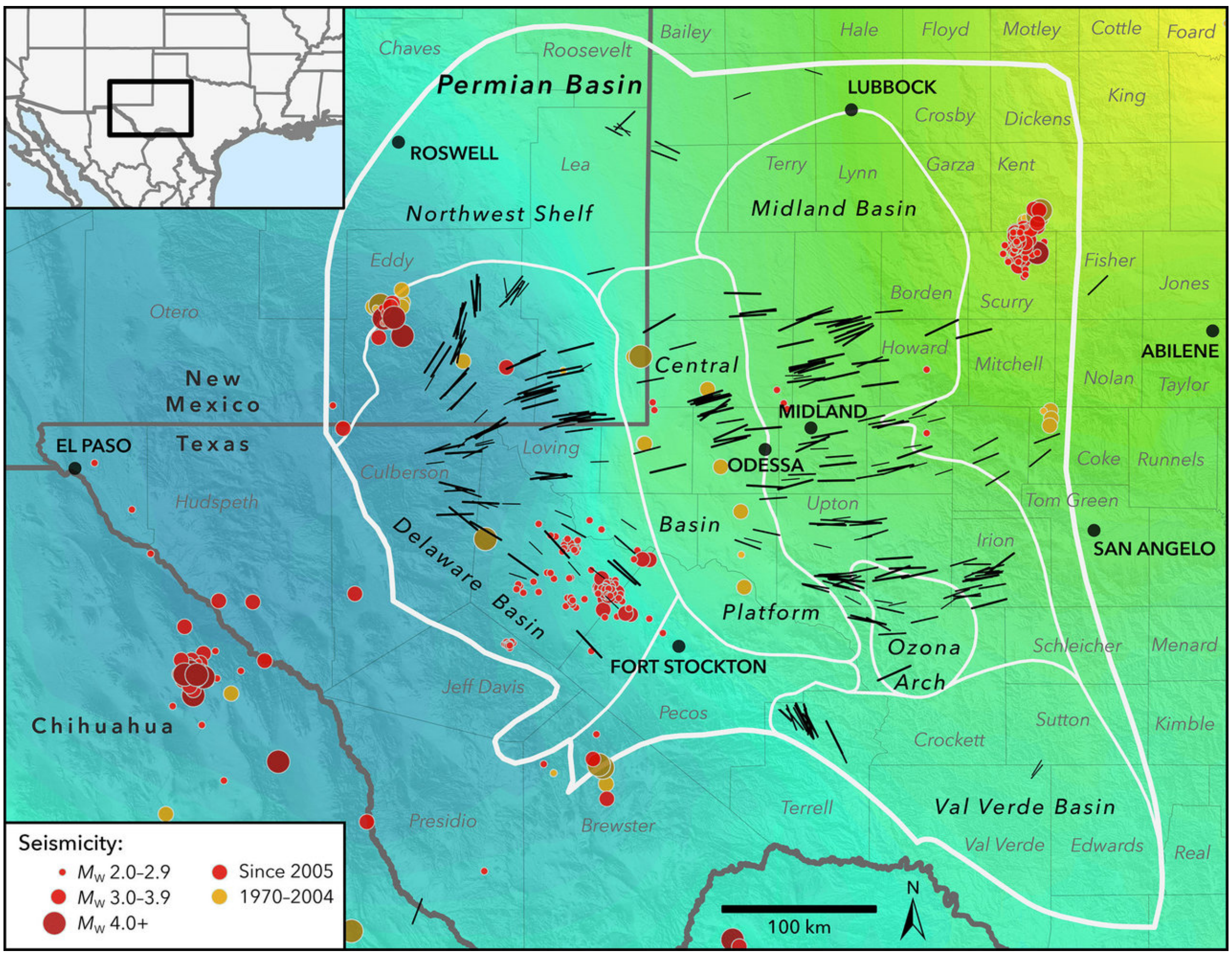
Seismic stress map profiles induced earthquake risk for West Texas, New Mexico

February 8 2018, by Barbara Buell



This new map of Earth's stress field in the Permian Basin of West Texas and southeastern New Mexico could help energy companies avoid causing earthquakes associated with oil extraction. Credit: Jens-Erik Lund Snee

Stanford geophysicists have developed a detailed map of the stresses that act in the Earth throughout the Permian Basin in West Texas and southeastern New Mexico, highlighting areas of the oil-rich region that could be at greater risk for future earthquakes induced by production operations.

The new study, published this month in the journal *The Leading Edge*, provides a color-coded map of the 75,000-square mile region that identifies those potential oil and gas development sites that would be would be most likely to trigger an earthquake associated with fluid injection.

Previous Stanford research has shown that wastewater injected as a step in hydraulic fracturing (fracking) underlies an increase in seismic activity in parts of the central and eastern U.S., particularly in Oklahoma, starting in 2005. While none of these small-to-moderate earthquakes has yet caused significant property damage or injury, they represent an increased probability of larger earthquakes.

Now, Texas is poised to take center stage as the Permian Basin is becoming the country's most important oil- and gas-producing region. In the 1920s, energy companies began extracting the basin's bountiful petroleum deposits during a boom that lasted decades. More recently, the advance of hydraulic fracturing techniques has spurred a new development frenzy. Hundreds of thousands of wells could be drilled in the region in the next few decades.

"We want to get out ahead of the problem in Texas," said study co-author Mark Zoback, the Benjamin M. Page Professor of Geophysics in Stanford's School of Earth, Energy & Environmental Sciences (Stanford Earth), who led a number of the Stanford studies in Oklahoma. "We want to stop fluid injection from triggering even small earthquakes in Texas so that the probability of larger earthquakes is significantly reduced."

High-stress environment

To gauge the risk of future quakes, researchers must first understand the direction of the stresses in a region and their approximate magnitude. When the stress field aligns with a pre-existing fault in a certain manner, the fault can slip, potentially producing an earthquake. In regions such as the central and eastern U.S., far from tectonic plate boundaries such as the San Andreas Fault, this slippage occurs as a natural process, but very rarely. But increasing fluid pressure at depth reduces the friction along the fault, sometimes triggering an earthquake.

"Fluid injection can cause a quake on a fault that might not produce a natural earthquake for thousands of years from now," said study lead author Jens-Erik Lund Snee, a Ph.D. student in the Department of Geophysics at Stanford Earth.

In a previous study, Zoback and postdoctoral scholar Cornelius Langenbruch found that in Oklahoma, fluid injection caused about 6,000 years of natural earthquakes to occur in about five years.

Creating a next-generation stress map

Building on previous efforts to create maps of stress and seismic potential in the Permian Basin, the Stanford researchers added hundreds of new data points from West Texas and southeastern New Mexico, much of the data being provided by the oil and gas industry. Their findings paint a complicated picture of the Permian Basin, which features some relatively consistent horizontal stress areas along with others that show dramatic directional rotations. "We were surprised to see such high variability," said Lund Snee. "It raises a lot of questions about how you can have rotations like that in the middle of a continental plate, far from a plate boundary."

"This is the one of the most interesting stress fields I've ever seen," Zoback said. "While the stress field in this region is surprisingly complex, the data is excellent and having documented what it is, we can now take action on this information and try to prevent the Permian Basin from becoming Oklahoma 2.0."

A tool for safer, more efficient drilling

The Stanford researchers said the new stress map provides oil companies with detailed quantitative data to inform decisions on more effective drilling operations in the Permian Basin. "This is the most complete picture of stress orientation and relative magnitude that they've ever had," Zoback said. "They can use these data every day in deciding the best direction to drill and how to carry out optimal hydraulic fracturing operations."

Future studies will focus on improving knowledge of fault lines in the region and gaining a better understanding of fluid pressure, specifically how the amount of water injection (both now and in the past) has impacted the geological mechanisms at work in the area.

"There is the potential for a lot of earthquakes in this area," said Lund Snee. "We want to understand what's causing them and provide companies with the tools to avoid triggering them."

More information: Jens-Erik Lund Snee et al. State of stress in the Permian Basin, Texas and New Mexico: Implications for induced seismicity, *The Leading Edge* (2018). DOI: 10.1190/tle37020127.1

Provided by Stanford University