



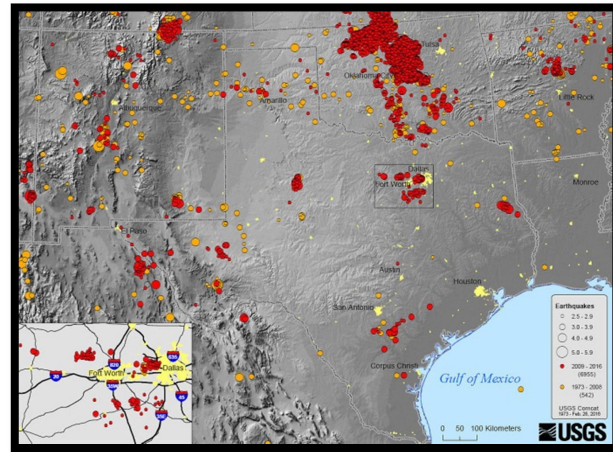
Manmade Earthquakes ...

The Earth's crust is comprised of large plates that slowly move relative to one another. This movement causes elastic strain energy to develop deep below the Earth's surface. A Tectonic Earthquake (TE) occurs when this accumulated energy is suddenly released along a fault line. Earthquake magnitude is based on a logarithmic equation of the recorded ground motion. Each increment represents a 32-fold increase in the energy released. For example, a M5 quake releases 32 times more energy than a M4 quake and 1,024 times more energy than a M3 quake. It has been estimated that a M8.6 quake releases about the same amount of energy as 10,000 WWII-era atomic bombs. M6.0 and larger quakes can cause structural damage, while M4.0 and larger quakes can cause nonstructural damage. People generally cannot perceive, or feel, quakes smaller than M2.7.

Large TEs in North America occur mostly along the Pacific Coast, from California to Alaska, as well as in Southeast Missouri. Texas and nearby states have historically not experienced significant seismic activity. This changed in 2008 when the energy industry began to embrace hydraulic fracturing, or "fracking", to enhance oil and gas production. A by-product of fracking is large quantities of wastewater and drilling chemicals. These fluids are usually disposed of through high pressure injection wells at depths of at least two miles. When these fluids lubricate a naturally occurring fault, accumulated strain energy can suddenly be released, causing an Induced Earthquake (IE).

Prior to 2008, Oklahoma experienced no IEs. IEs then increased each year until, in 2015, Oklahoma experienced 4,000 IEs. Regulators then began to limit the number, depth, and pressure of injection wells. Nevertheless, due to the volume of previously injected fluids, Oklahoma experienced three M5.0+ quakes in 2016. The largest was a M5.8 quake that occurred in Pawnee in September. It caused significant nonstructural damage and one injury.

Two months later, a M5.0 quake in Cushing damaged nearly 50 buildings.



There have been more than 200 IEs in North Texas since 2008, including nearly 100 in the Dallas suburb of Irving between April 2014 and September 2016. The largest IE in Texas was a M4.0 quake that occurred in Venus, about 34 miles southwest of Dallas, in May 2015. Researchers have subsequently determined that the Venus fault could support a future M5.0 quake. More recently, a M3.1 quake occurred in Dallas in August 2017, and a M2.6 quake occurred in nearby Irving just three weeks later. In Texas, regulators have mostly denied the scientific findings of the USGS and numerous academic researchers. To date, they have not publicly limited the practice of fluid injection.

IEs are fundamentally different from TEs. Compared to TEs, IEs occur more frequently, release less energy, and have shallower epicenters and higher vibration frequencies. Unfortunately, the seismic provisions of current building codes are based on designing for TEs, and the provisions are not directly applicable to IEs. To date, IEs have not caused structural damage. The damage caused by most IEs will likely continue to be nonstructural ... to architectural components, MEP equipment, and so forth. Nevertheless, nonstructural damage can cause significant injury and economic loss. Future building codes should therefore include appropriate provisions to address IEs.