

Fracking and (Sometimes) Earthquakes

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History of human-caused earthquakes

Injection of fluids into subsurface: Denver Rocky Mountain Arsenal



1962-1966: U. S. Army injects 165,000,000 gallons of toxic waste into 3.6 km deep well near Denver

Injection begins
March 1962

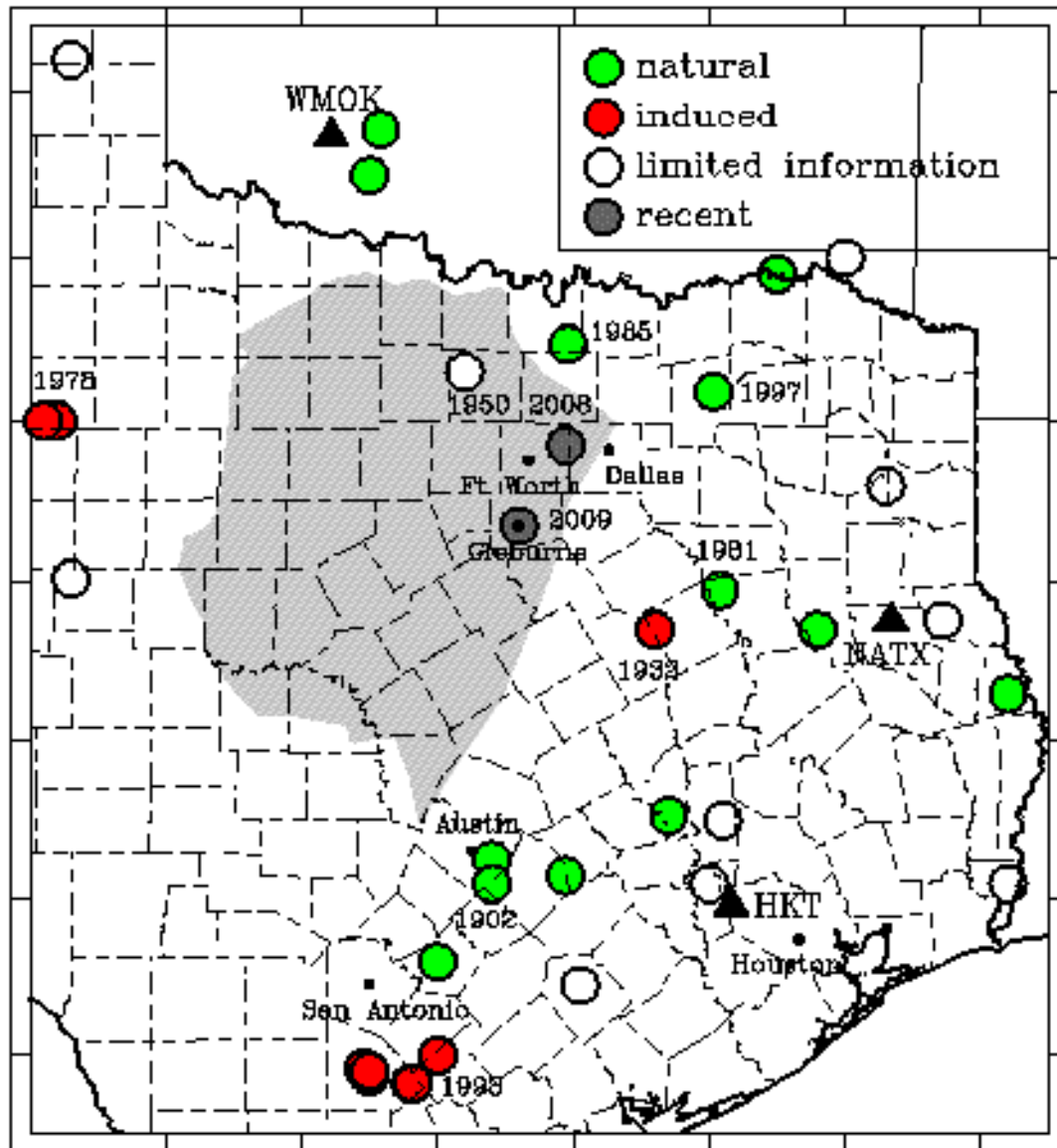
1st earthquakes
April 1962

Injection stopped 1966

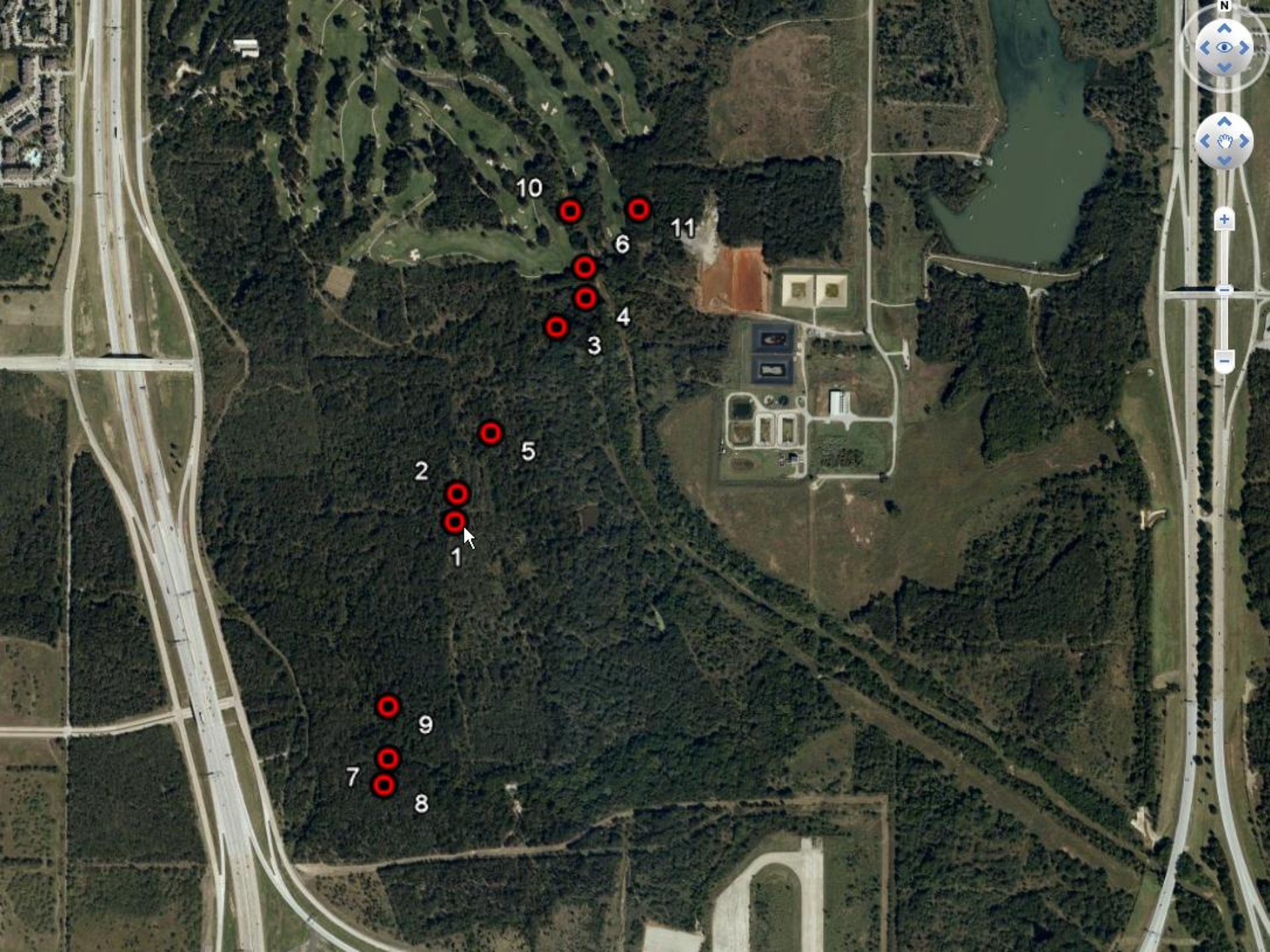
Earthquakes continue, M5.3 August 1967; M5.2 November 1967

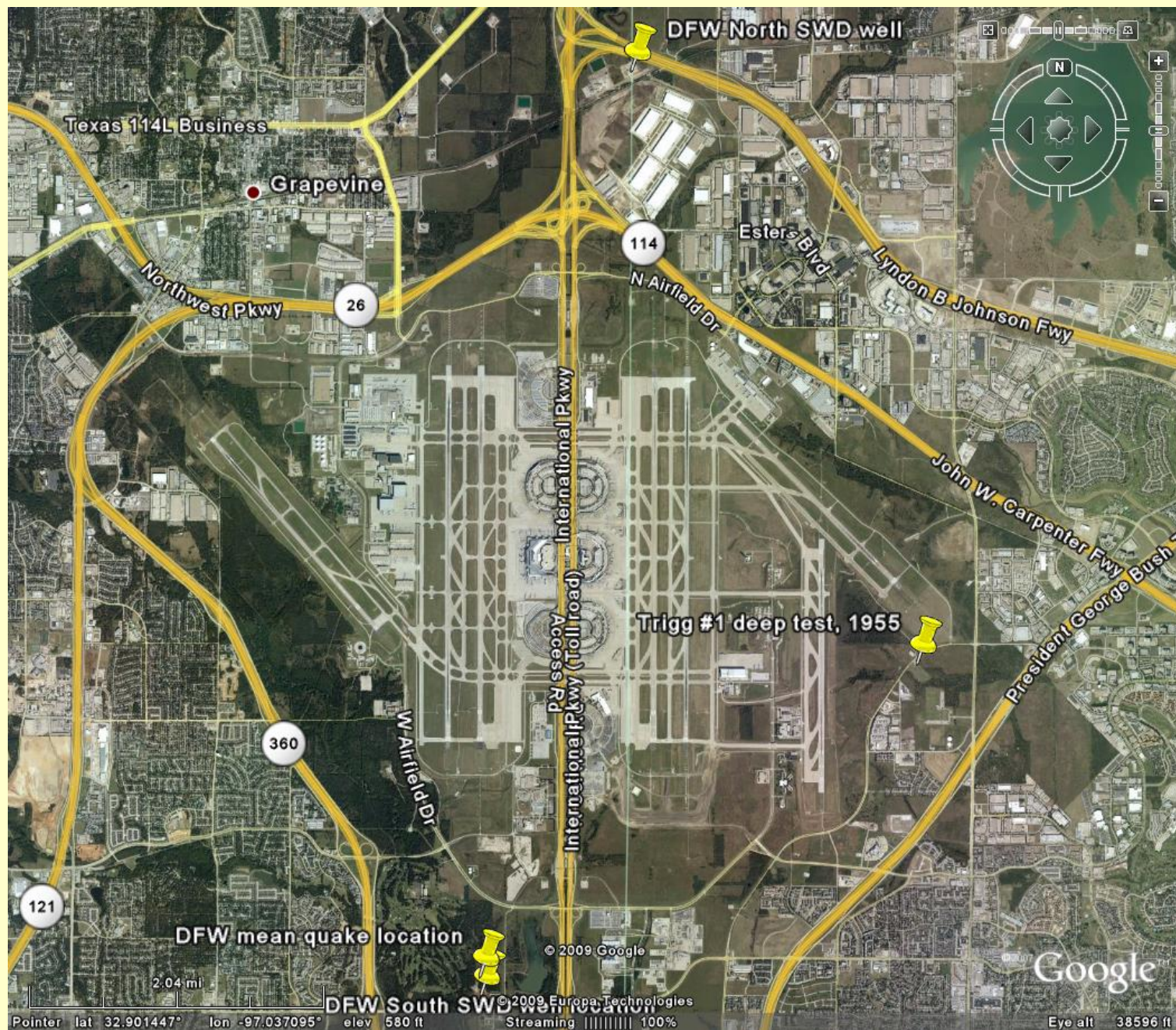
**** Largest quakes AFTER injection stopped ****

Dallas-Fort Worth 2008-2012

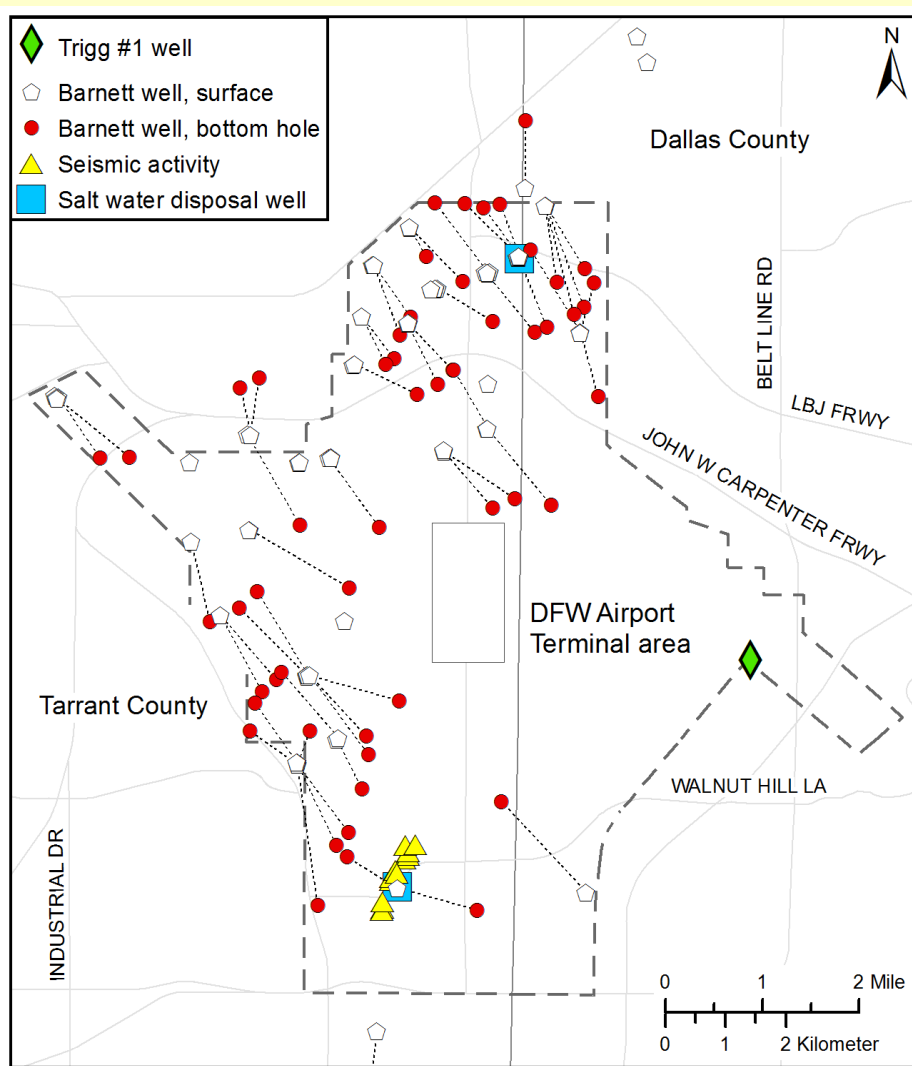


- 10 small earthquakes (largest, M3.0) occur near DFW Oct 31- Nov 1 2008
- 4 small earthquakes (largest M3.3) occur near DFW May 16 2009
- **NO** previous historical seismicity near DFW

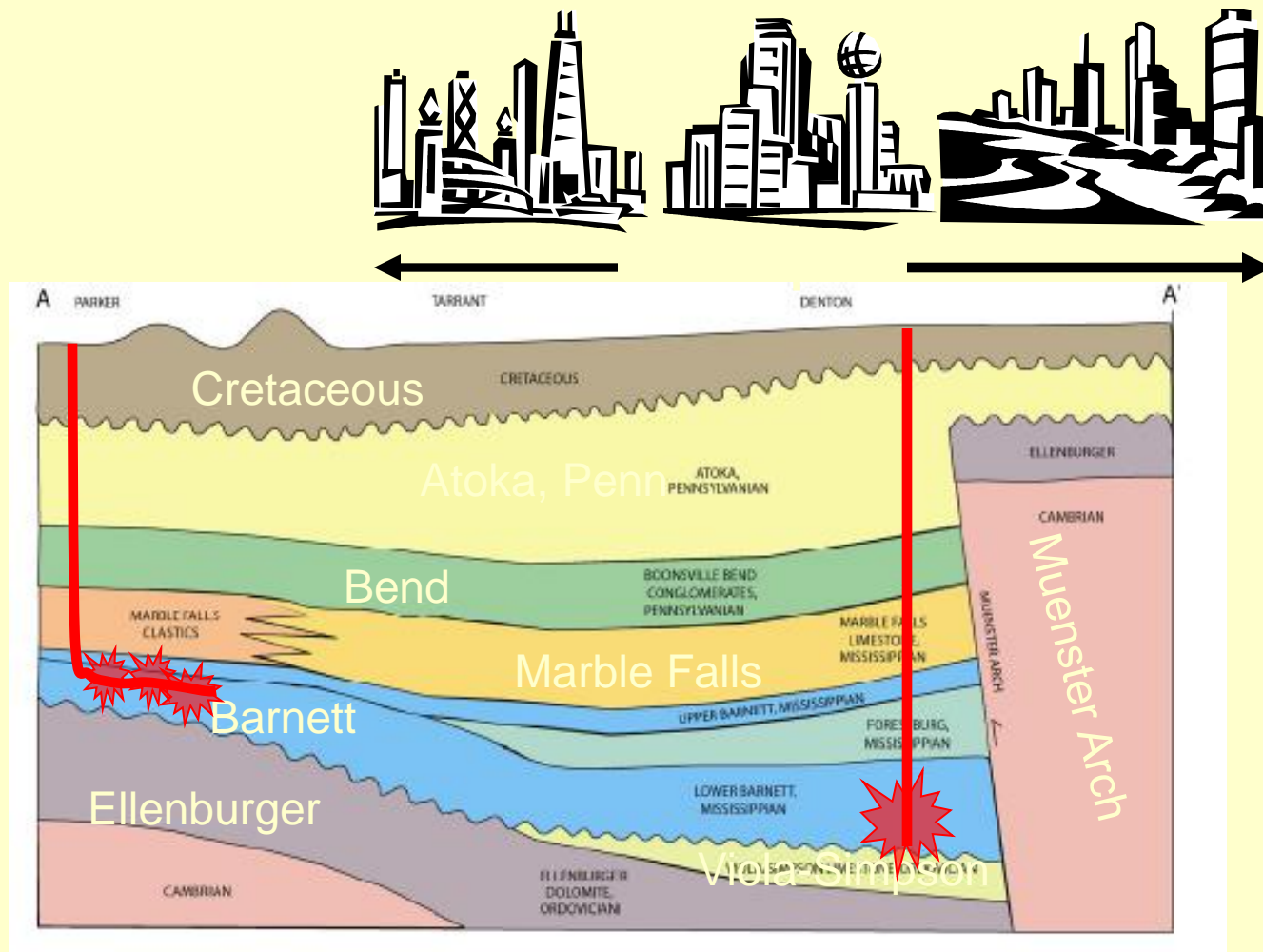




DFW earthquakes, literally on DFW airport property



- yellow triangles:
Nov-Dec 2008 quakes
depth: 4.5 ± 1.0 km.
- white-red symbols, producing wells
- procedure:
 - wells drilled
 - wells hydrofracked
 - brines (and gas) produced
 - brines pumped into permeable strata for disposal
- blue squares: disposal wells pump into depths 10,752-13,729 ft (3.3-4.2 km)
- **quakes near disposal well**
(not frack/production wells)

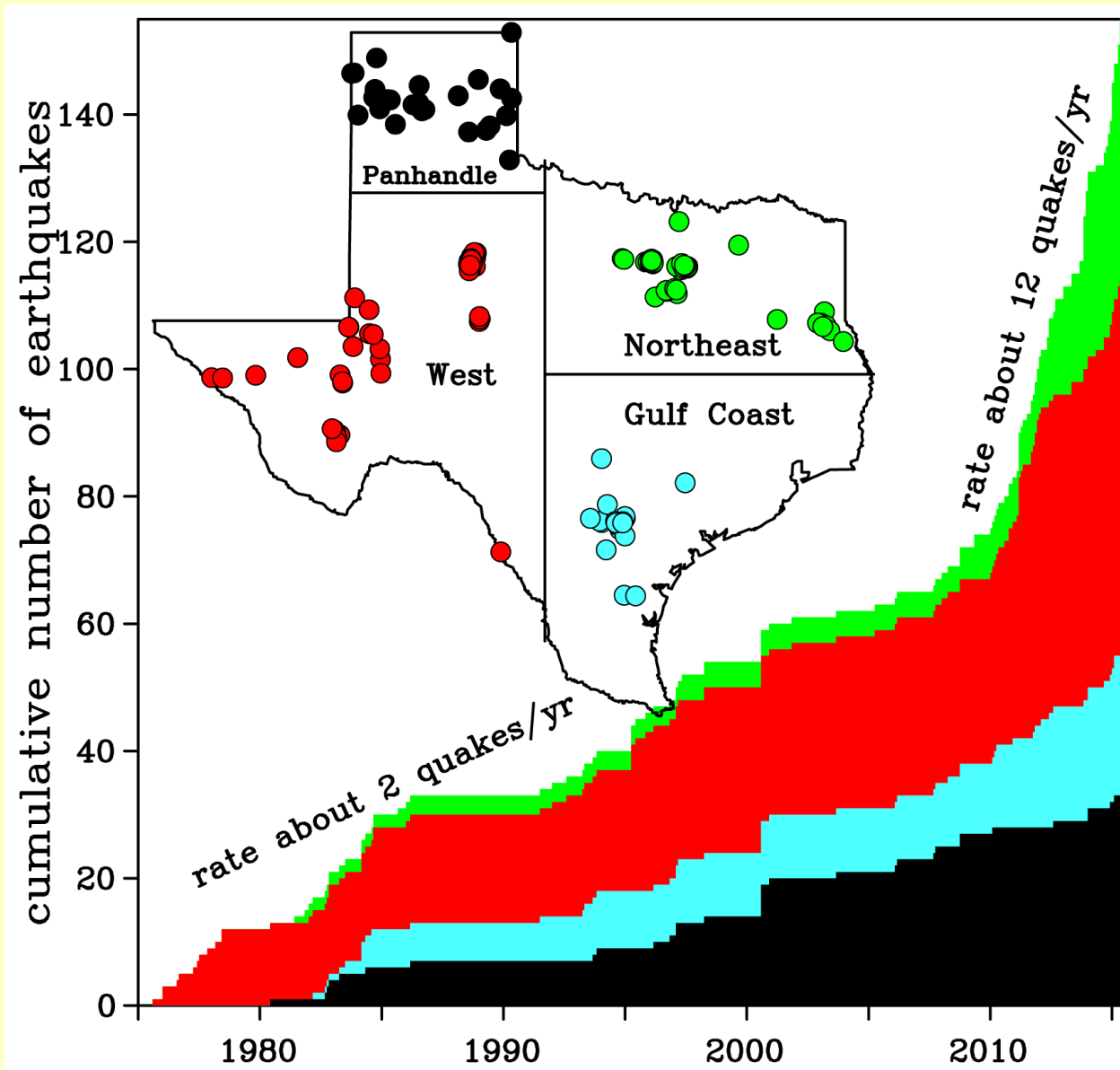


Diagrammatic figure; no scale

Hydrofracturing to increase fluid flow = “fracking”

Stratigraphy from Bowker, 2003, and poster by Republic Energy, 2005

Texas “hockey stick” plot: EQs $M>3$ vs time

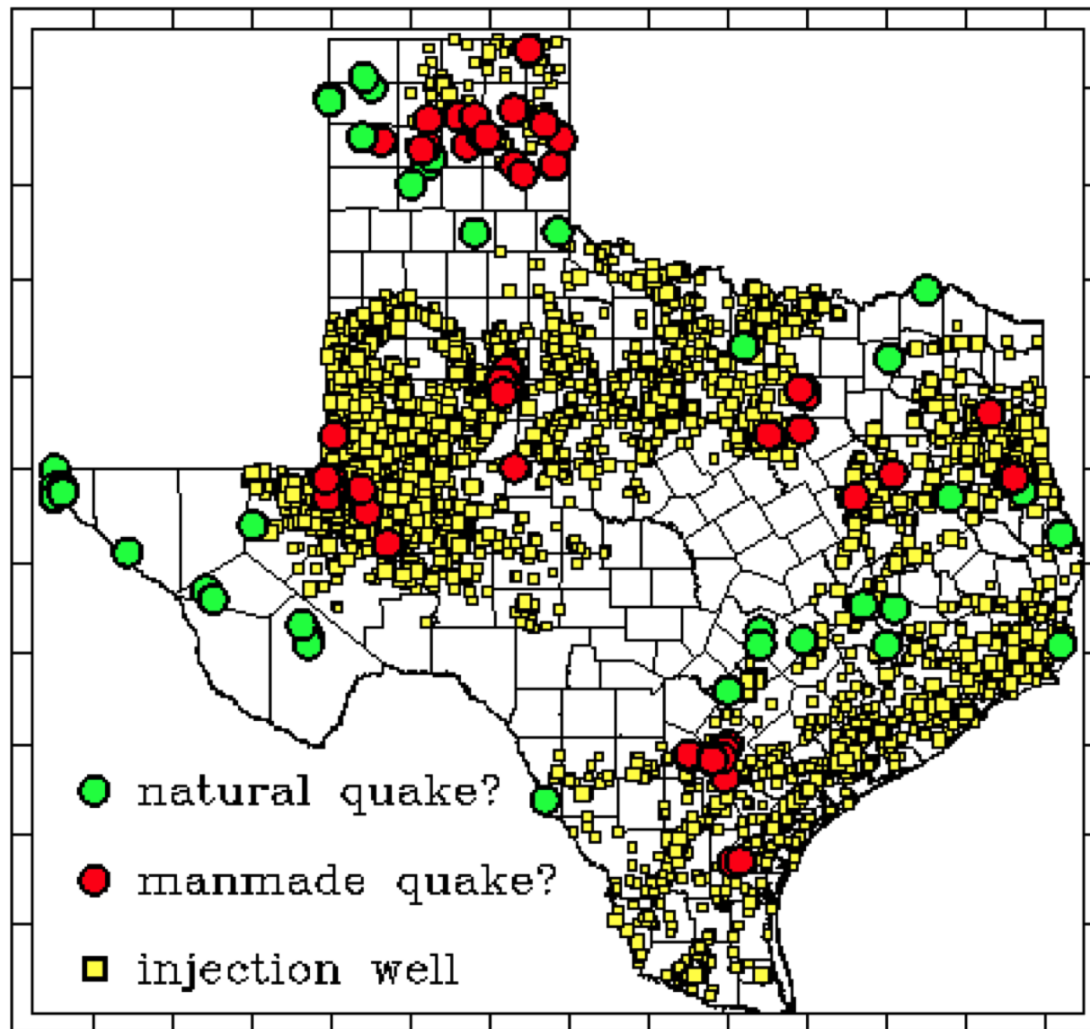


FACT:

**There are LOTS of
wastewater disposal
wells in Texas
(>50,000) and...**

few earthquakes..

**Largest
earthquakes
associated with
disposal are M4.8,
MUCH smaller
than M7-M9 as in
Japan, Haiti, San
Francisco**



For earthquake risk and real estate, the three most important factors are...



location, location, and location

**Regulation should take account of this
[think: zoning]**

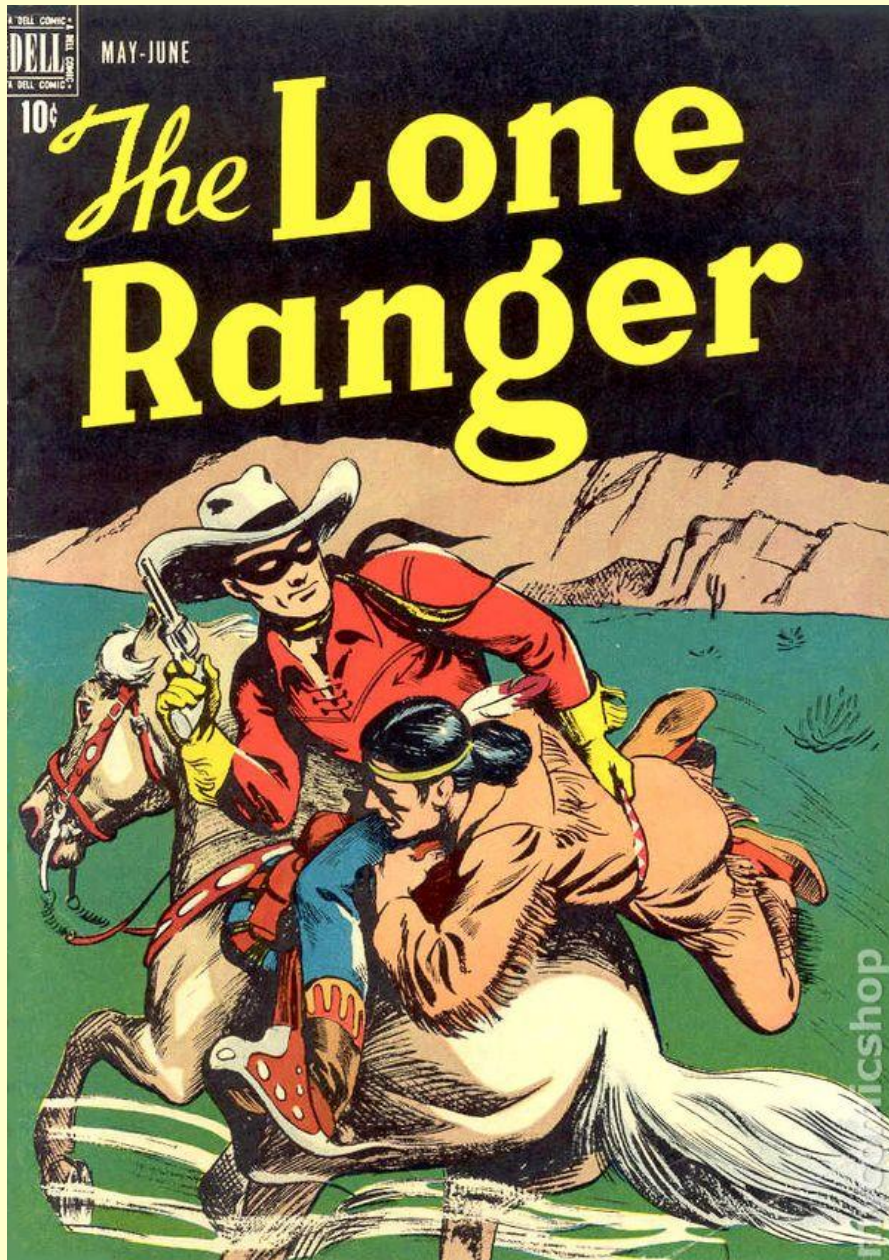
Timpson Texas May 2012 M4.8



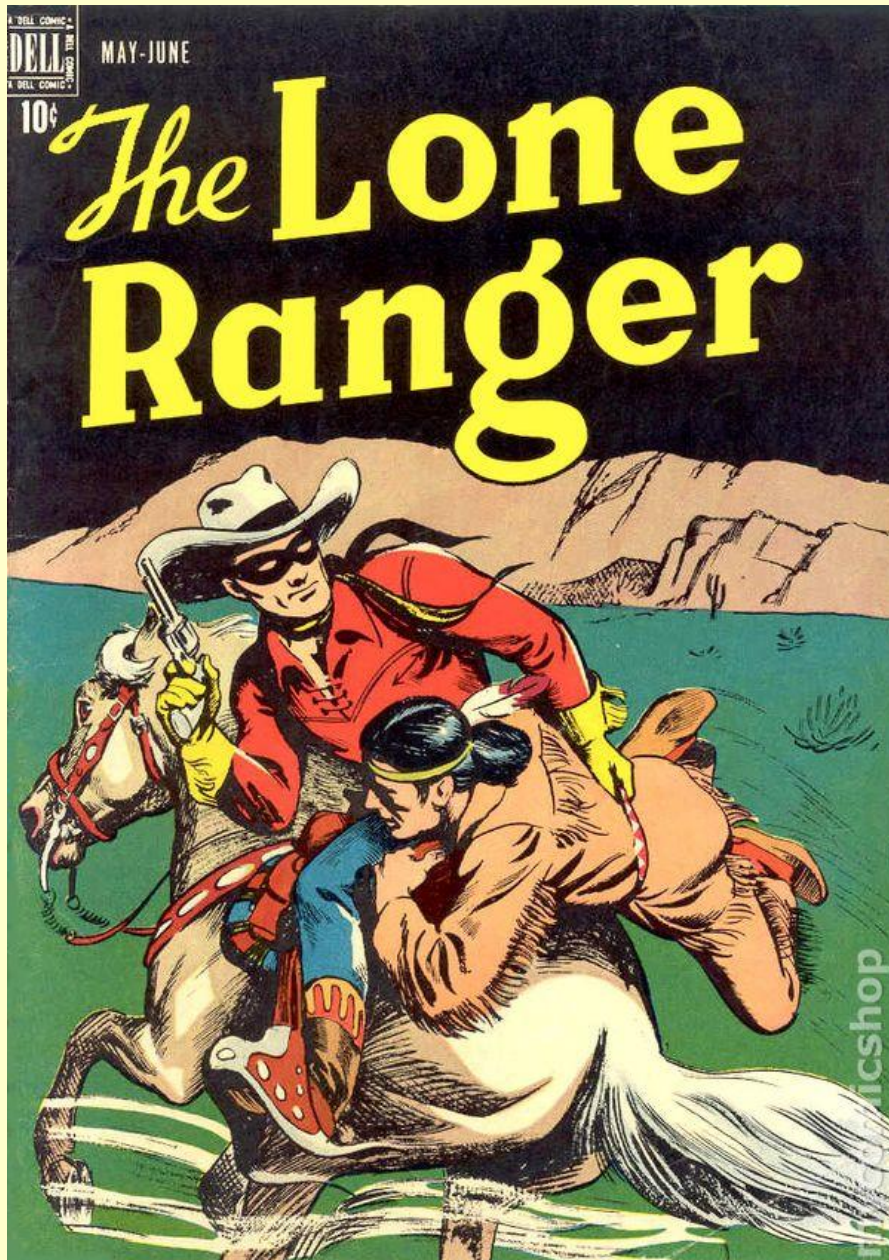
Principal cause of induced earthquakes (by location)

<i>Location</i>	<i>Wastewater injection: frack flowback</i>	<i>Wastewater injection: H2O produced with oil</i>	<i>Production of oil or gas</i>	<i>Fracking (during or just after)</i>	<i>Few or no earthquakes,</i>
Texas Barnet Eagle Ford	YES		YES	No No	
Oklahoma		YES			
Alberta	yes		yes	YES	
North Dakota					YES

- Texas – frack flowback water, oil production, both concentrated around specific wells or fields
- Oklahoma – produced water and quakes spatially distributed
- Alberta – Quakes during fracking
- North Dakota – Quakes? What quakes?



Silver bullet = A simple result about human-caused earthquakes that would make it straightforward to manage them and avoid hazard



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Silver bullet not yet found...
Silver bullet may not be found..

The End

