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Shale gas and fracking related induced seismicity: Lessons from abroad and implications for Switzerland»

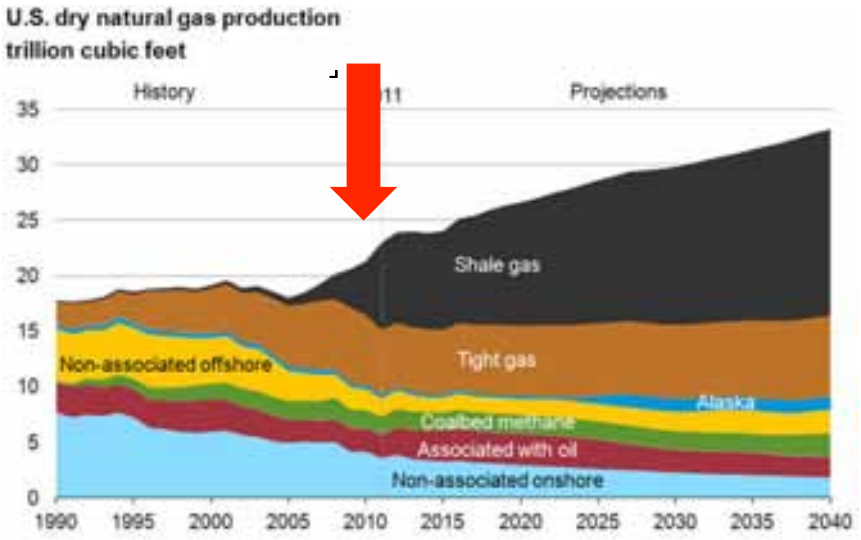
Stefan Wiemer

Zurich

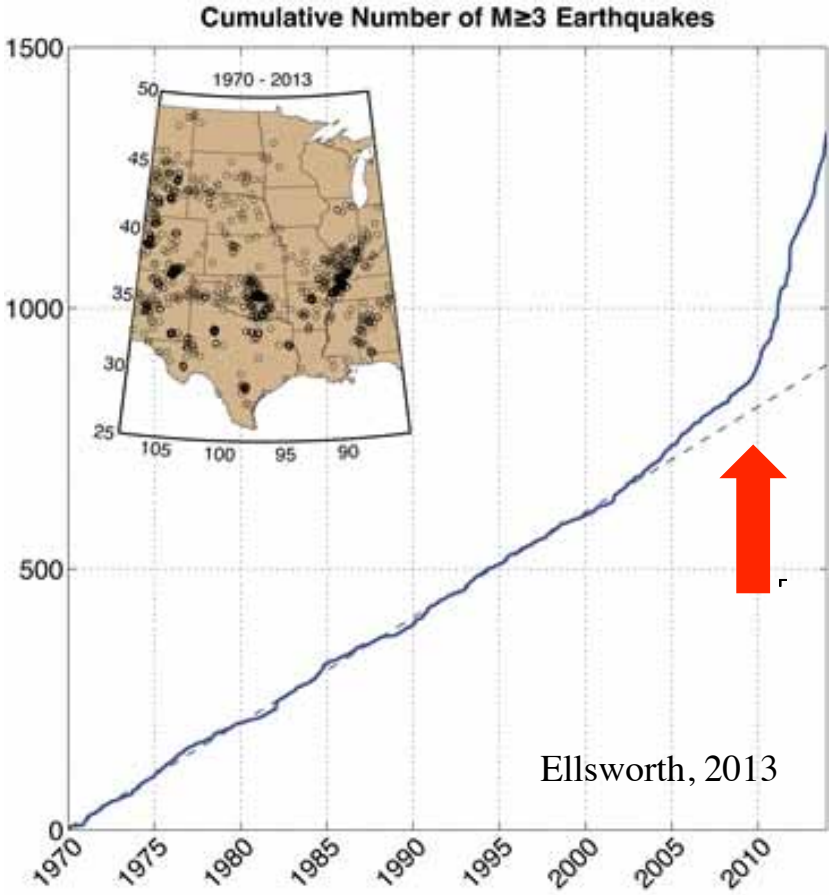
April 2, 2014

Fracking and induced earthquakes?

- The rate of earthquakes in the Eastern US has more than tripled in the past 5 years – at the same time that shale gas production took off.



Source: U.S. Energy Information Administration, *Annual Energy Outlook 2013 Early Release*



Fracking and induced earthquakes?

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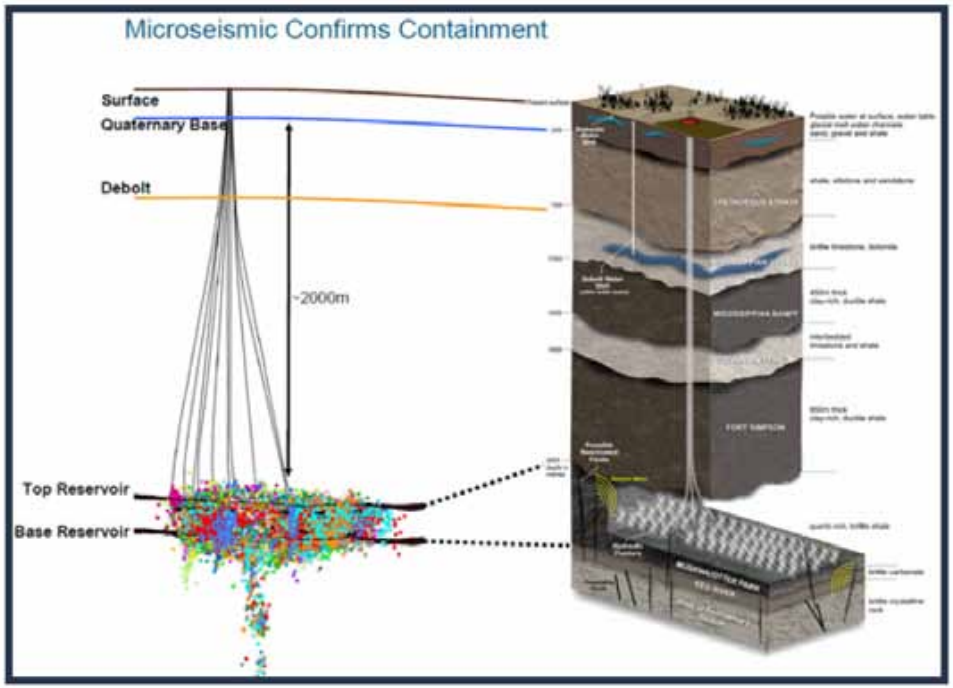

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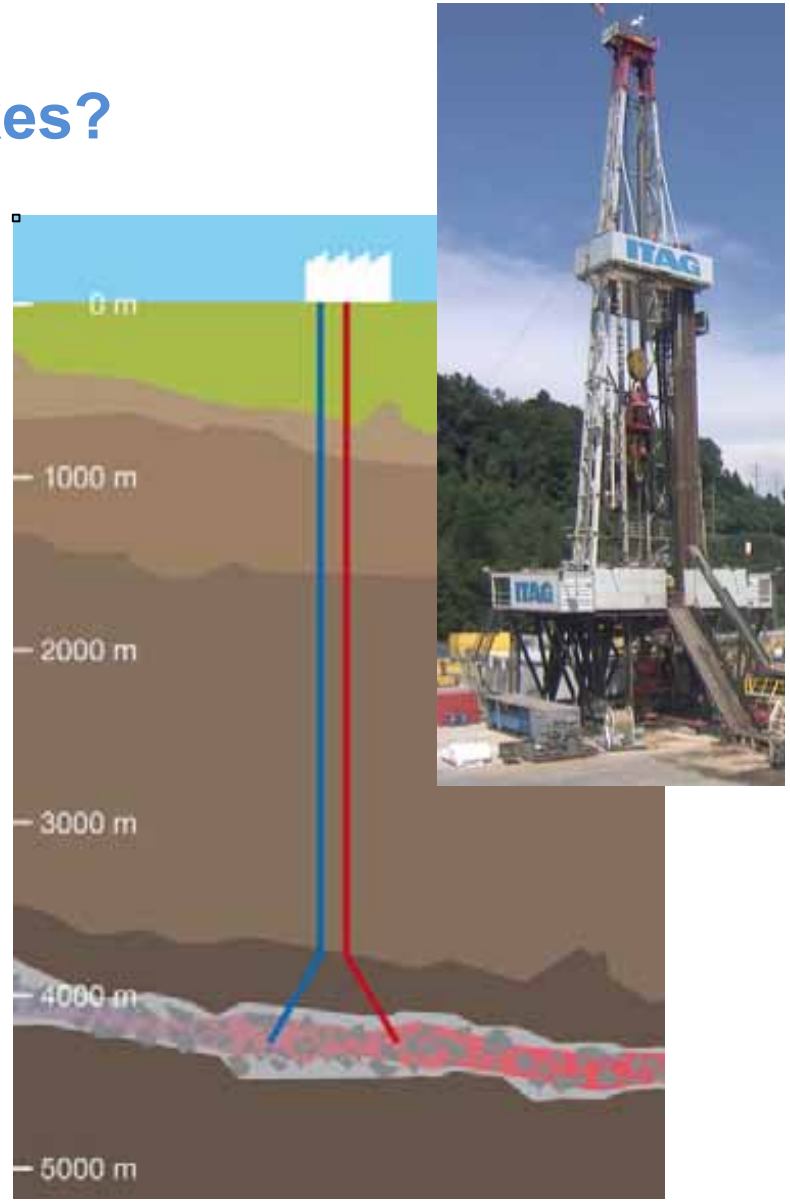
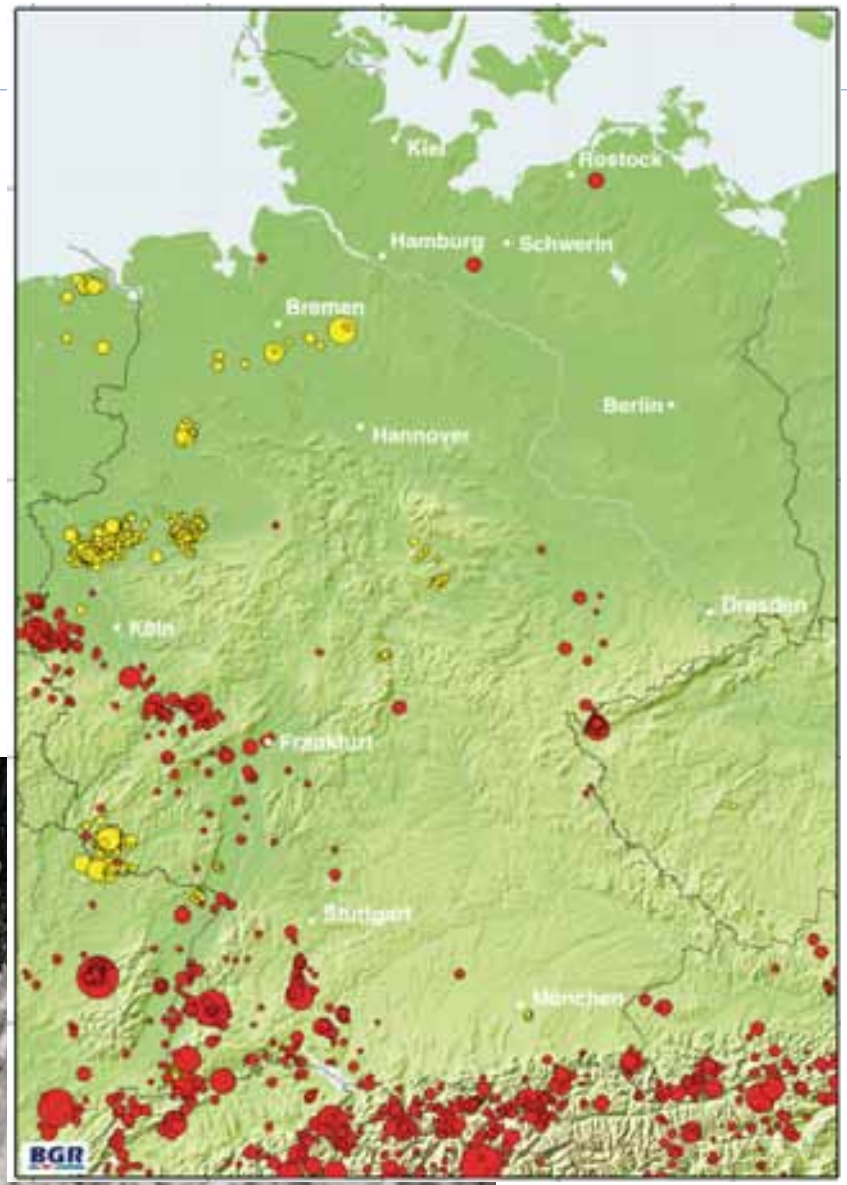
- In Switzerland, two geothermal projects have failed because of Magnitude 3.4 and 3.5 events.
- Enough reasons to be concerned!



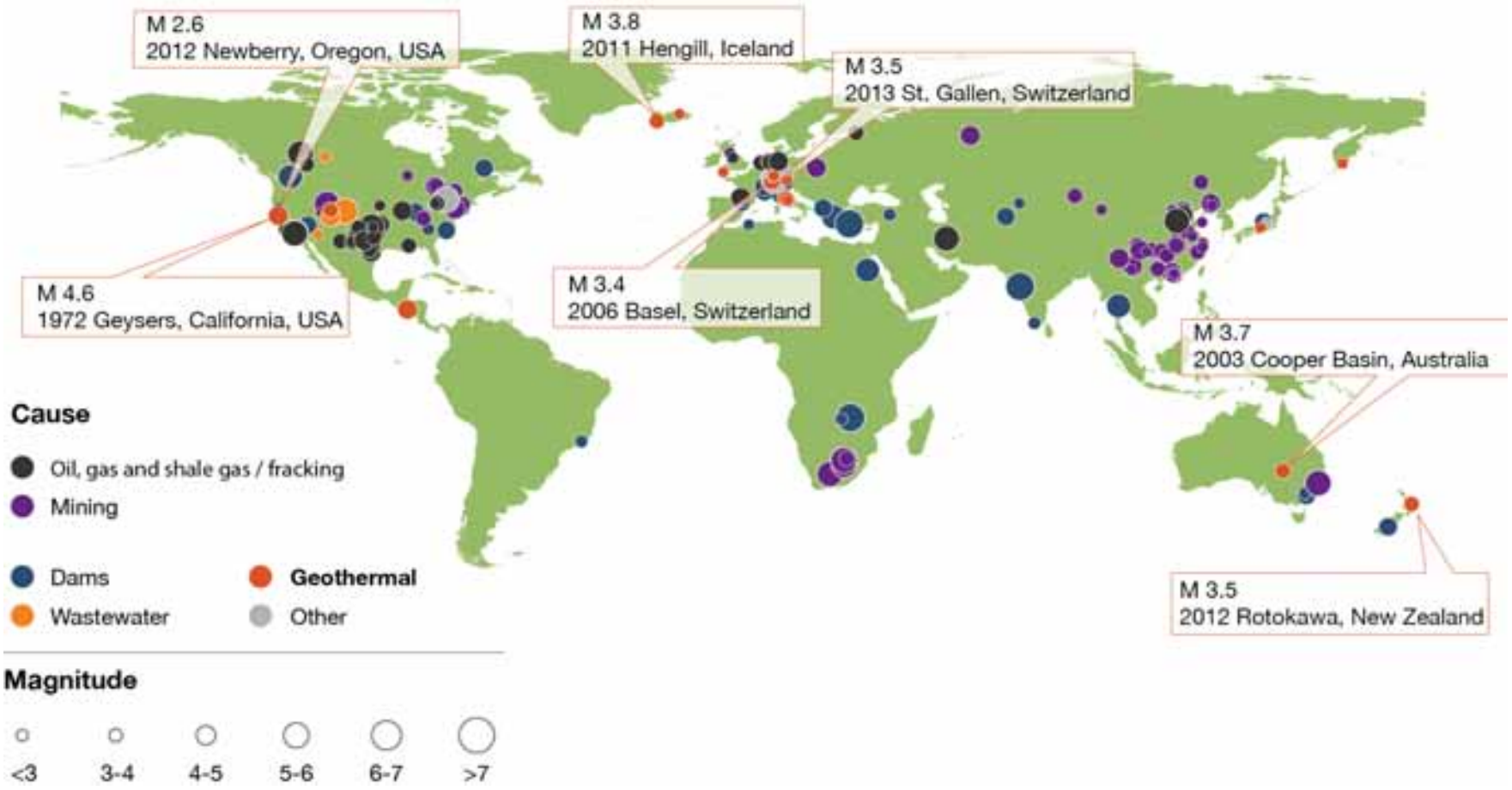
Induced seismicity – an old story

- Mining induced seismicity in Germany, the UK has been around for more than 100 years.
- Magnitudes have not exceeded M~3.5



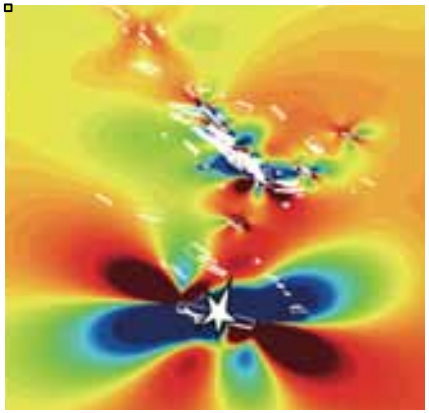
Induced Earthquakes around the World

Published data from 1930 to present



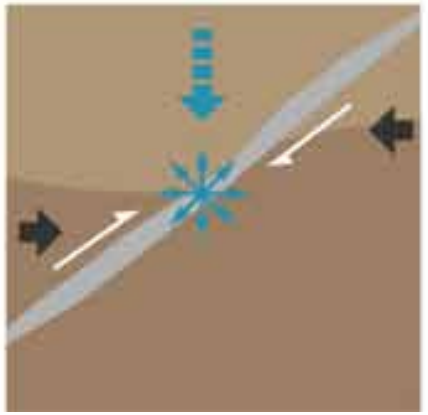
Different physical mechanism

Earthquake interaction



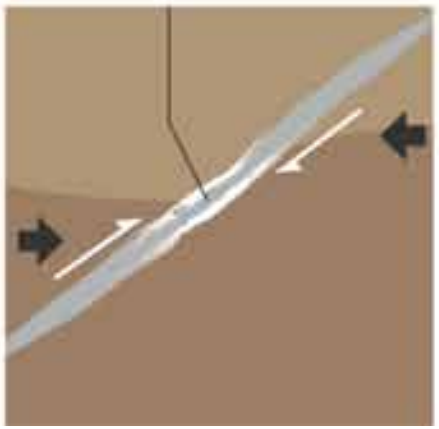
Load change

Pore pressure change

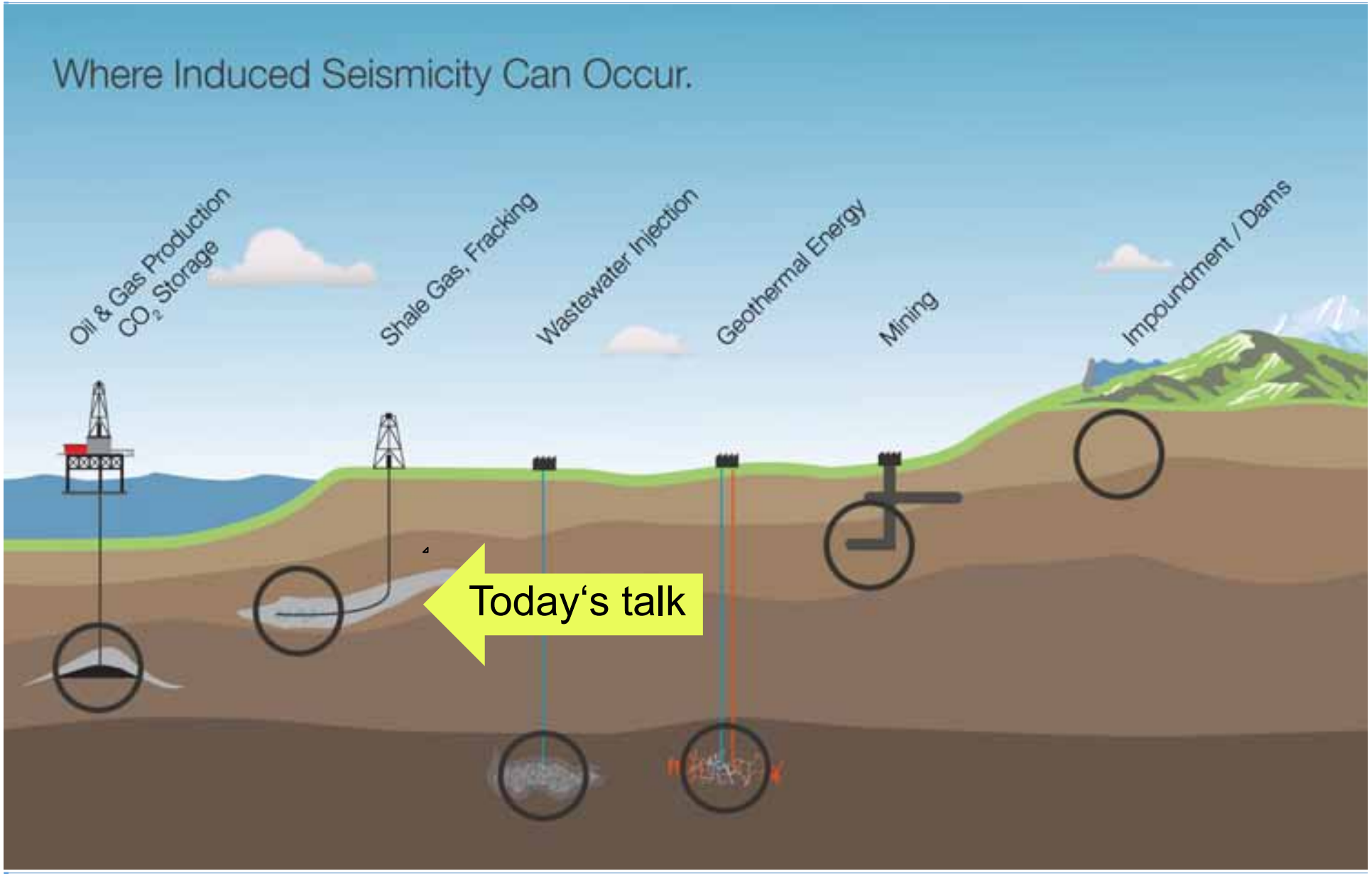


Volume change

Chemical alterations



Thermal strain


Where Induced Seismicity Can Occur.
Oil & Gas Production
CO_2 Storage
Shale Gas, Fracking
Wastewater Injection
Geothermal Energy
Mining
Impoundment / Dams
Today‘s talk

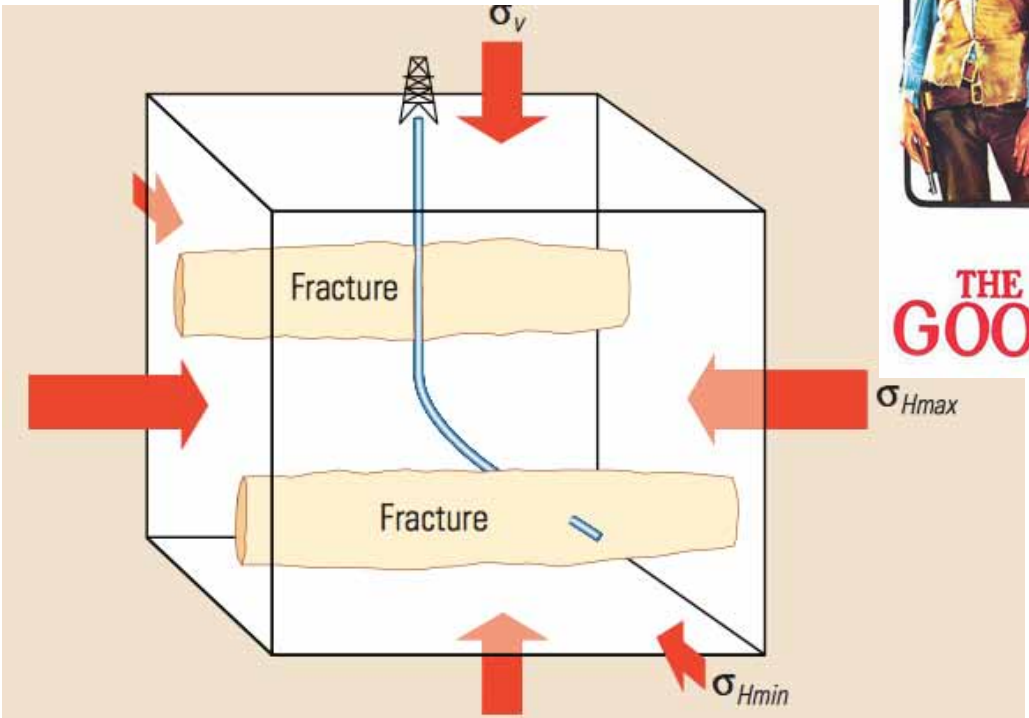
Fracking induced seismicity …

1966 Italian Spaghetti Western film directed by Sergio Leone, starring Clint Eastwood, Lee Van Cleef, and Eli Wallach

Fracking related seismicity: The good

THE GOOD

- "Fracking" occurs when the pore pressure exceeds the minimal (horizontal) stress.
- The frac itself can propagate seismically – and/or a-seismically.
- The micro-earthquakes and a-seismic slip creates the pathways for the gas/oil.
- And help to image what is going on.
- Details are surprisingly poorly understood.



^In situ stresses and hydraulic fracture propagation. The three principal compressive stresses (red arrows) are a vertical stress (σ_V) and a maximum and minimum horizontal stress (σ_{Hmax} and σ_{Hmin}). Hydraulic fractures open in the direction of the least principal stress and propagate in the plane of the greatest and intermediate stresses.

Fracking usually induces very small earthquakes

(M = -1; the size of a dinner plate)

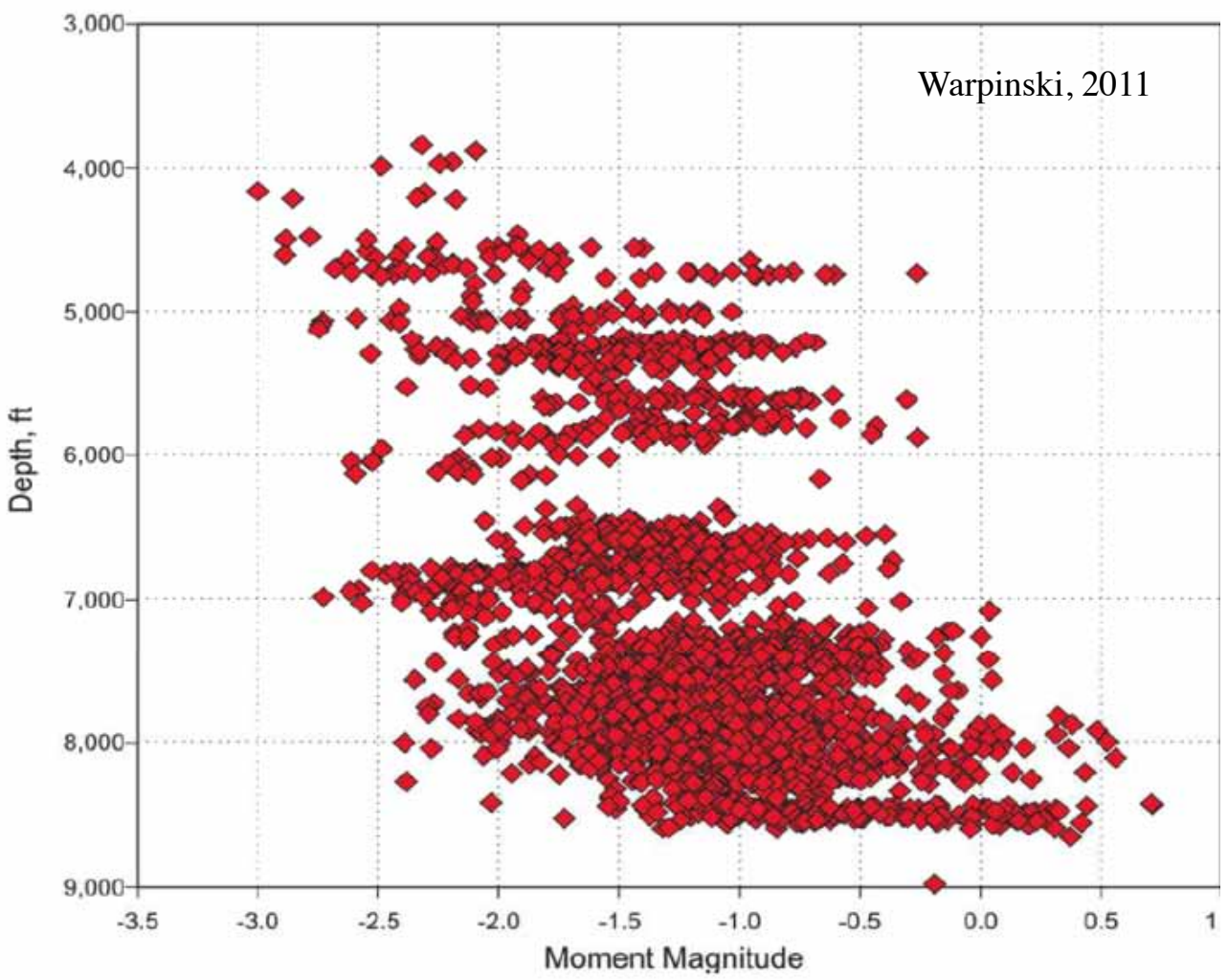
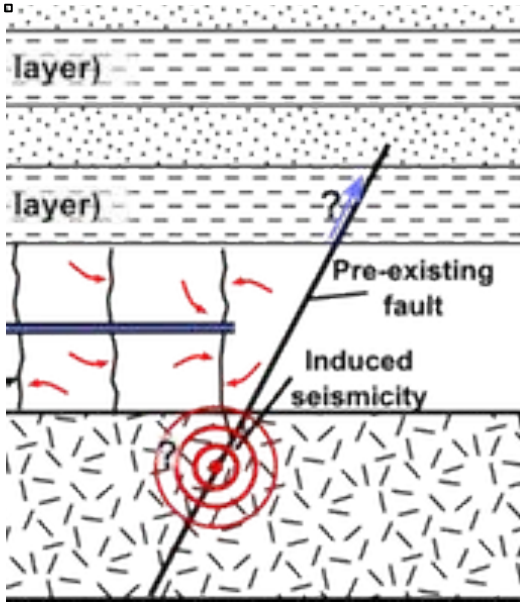


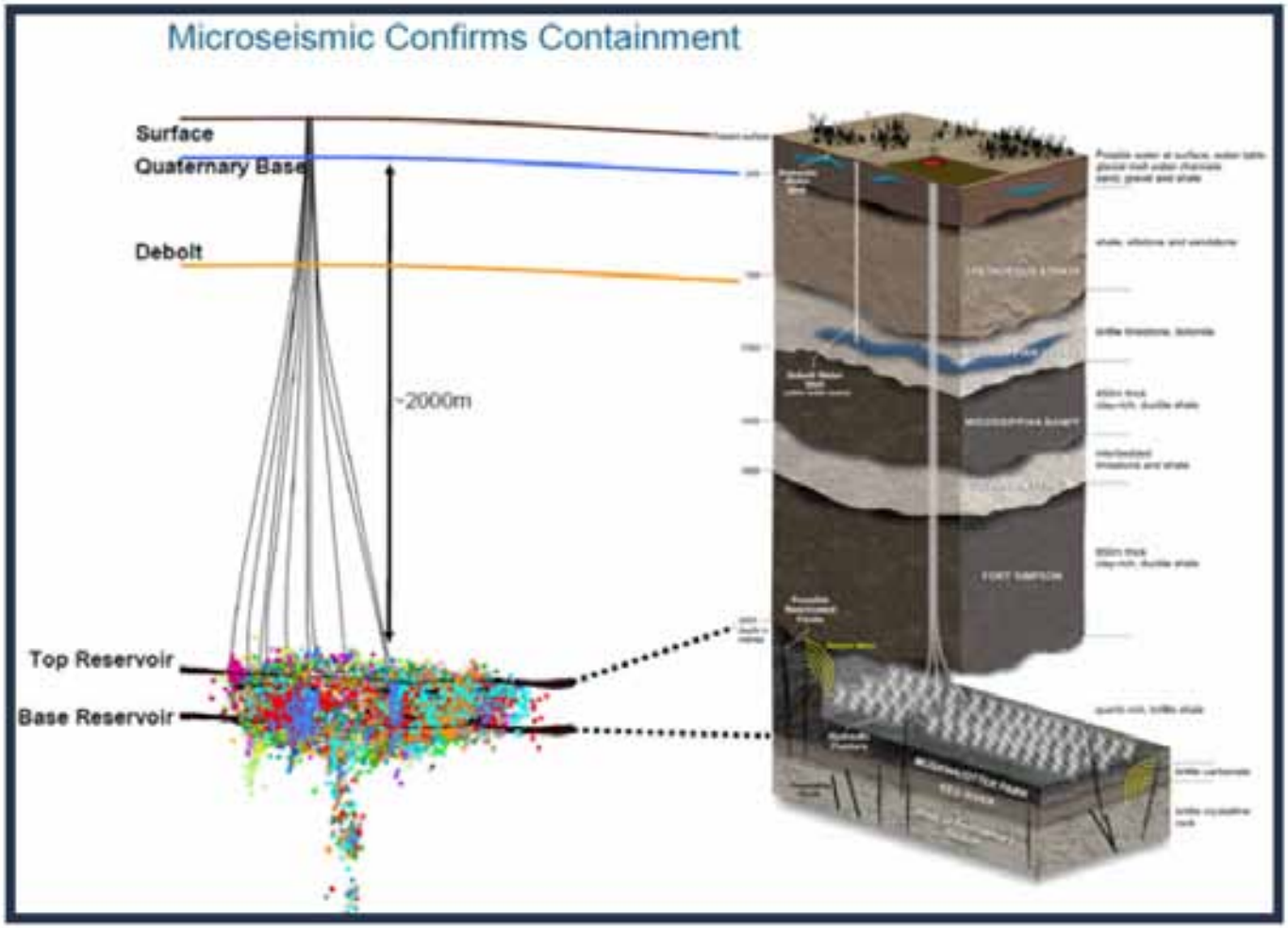
Fig. 1—Barnett shale maximum moment magnitude results for monitored stages through mid 2011.

Fracking: The Bad

- Usually the frac growth stops, because the rupture runs out of energy. This is what happens by now thousands of times a day all around the globe.
- In rare cases, however, the progressing frac finds new energy: tectonically loaded faults, in the sediments, or in the basement.
- **Hydro-fracing → Hydro-shearing**
- In this scenario, (much) larger earthquakes are possible and have been observed.
- But the volumes of injected fluids are small, depth are relatively shallow → Mmax(obs) so far = 3.8.

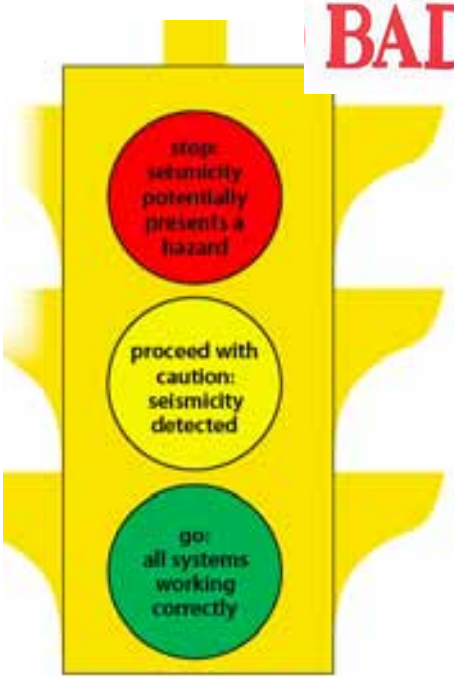


Horne River: M3.8 and many more …

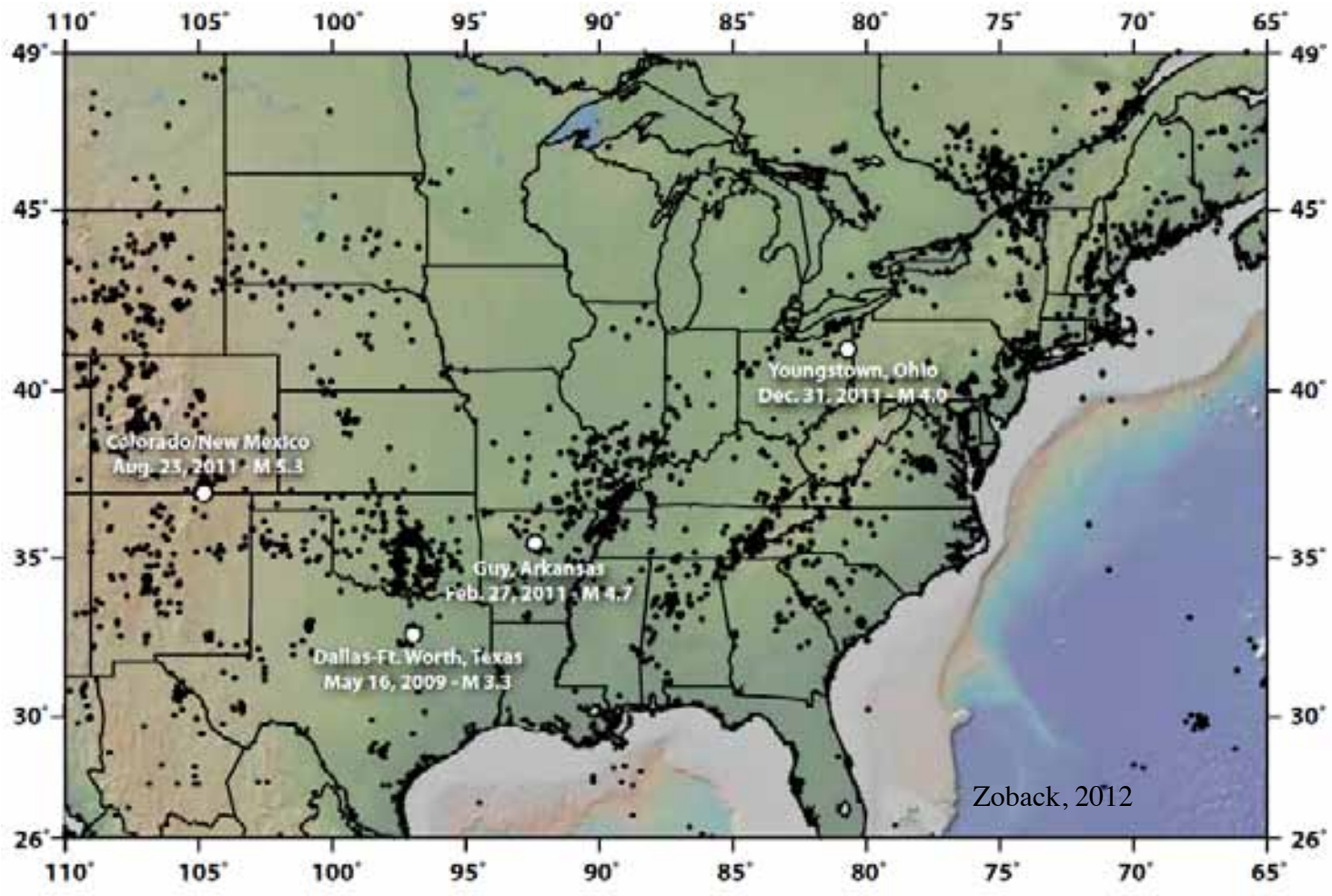


Dealing with 'the bad'

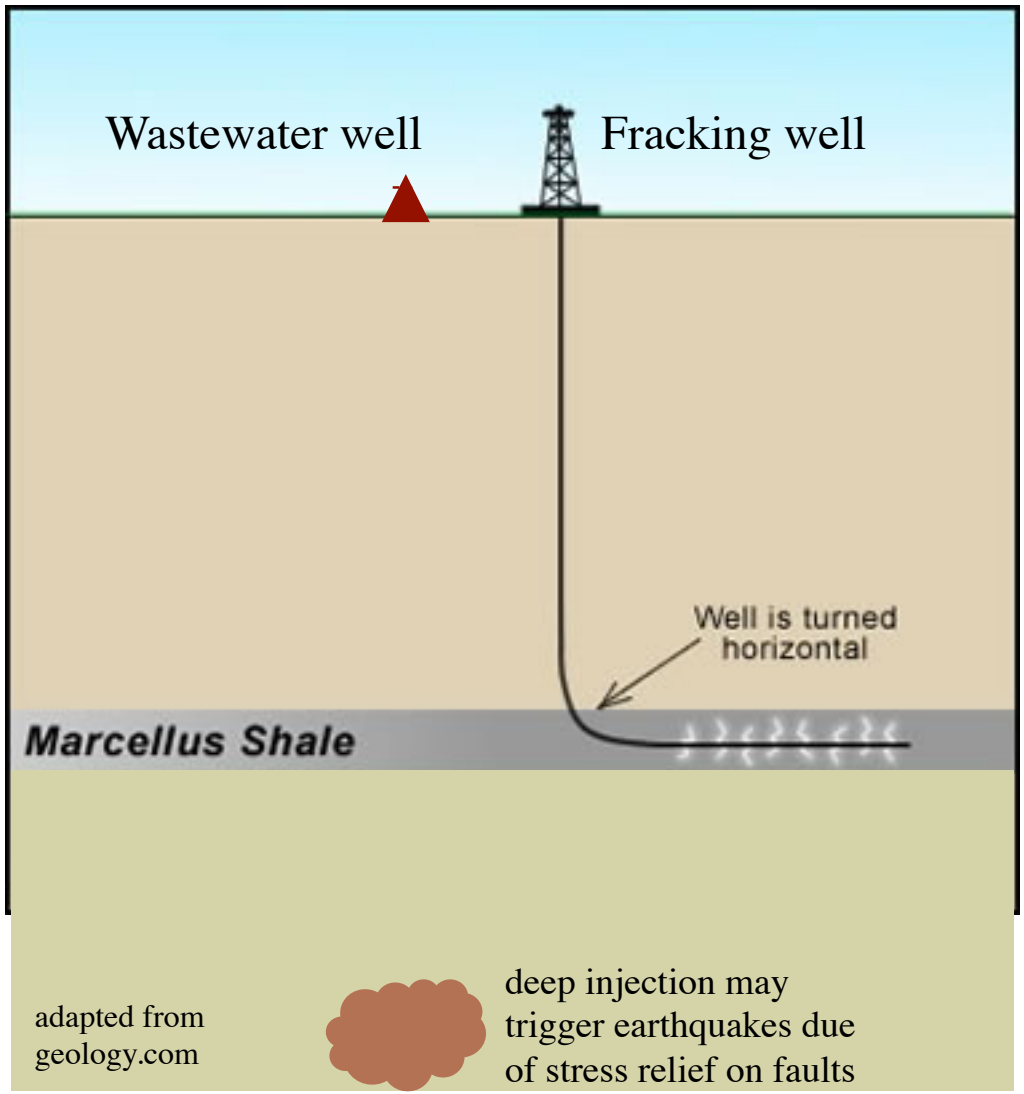
- Seismic monitoring of fracking operations is essential, so that branching out of seismicity is detected early and correlated with the operation.
- A simple, conservatively tuned 'traffic light system' is advisable to interrupt operation if earthquakes start to be a concern (i.e., M0.5 observed).
- Staying away from major fault zones may be a good idea.
- Not so different from other underground technologies (geothermal, mining, onshore oil and gas extraction, large hydro-dams, ground water extraction …)



Fracking … when things go seriously wrong…



… it seems to be the 'waste water'.



Wastewater (brine) injection depths are usually deep, in rocks naturally stressed with faults capable of generating earthquakes

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Fracking Wastewater Disposal Linked to Remotely Trigg Quakes

The finding could help scientists identify critically stressed faults.

Water impoundments like this one beside a Colorado oil rig are typical at hydraulic fracturing sites. Underground disposal of the wastewater after fracking may increase seismic risks from remote earthquakes, a new study says.

Recent Energy News

North American Natura Markets Overseas

Some 40 multibillion-dollar projects have been propose North American natural gas overseas. Prog environmental and industry opposition—an competition.

Green Fracking? 5 Tech Cleaner Shale Energy

As U.S. oil and gas product grows, new technologies a and chemical use and emissions. Can hydr green?

East Harlem Explosion of Natural Gas Leaks

A natural gas leak is suspe deadly explosion Wednesd East Harlem. Recent studies have shown t with aging cast-iron pipes are at high risk.

See More at The Great Energy Challen

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(Drilling fluid splashing past the liner, Dimock, PA, Spring 2009)

"Oklahoma is now the second most seismically active state in the continental U.S., after California."

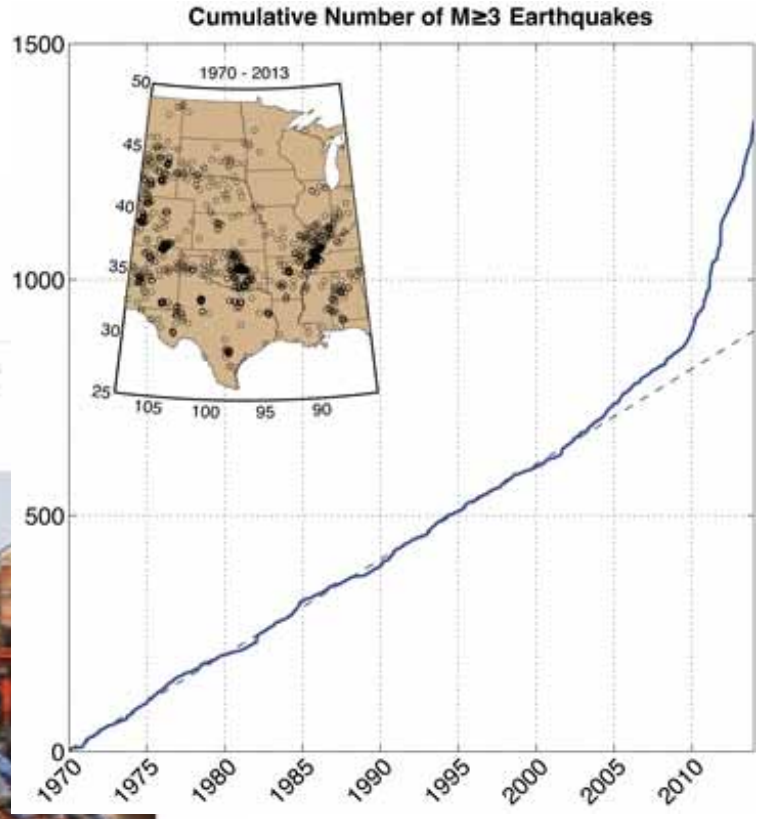
Oklahoma Shakes—Is Fracking to Blame?

Bryan Walsh @bryanrwalsh Feb. 18, 2014

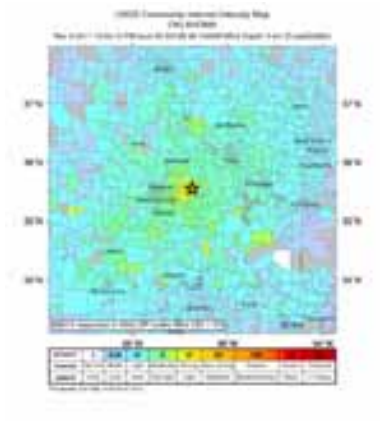
A normally calm state is hit by a wave of minor earthquakes—causing some to point the finger at fracking. But wastewater disposal wells likely play a bigger role

It's been a shaky week in Oklahoma. The Sooner State has experienced more than 150 earthquakes over the past week, far more than the Okies usually get. And while the vast majority of the quakes were fairly minor, one, on Feb. 16

Earthquakes have been linked to oil and gas disposal wells in states like Kansas.



November 2011 Prague, Oklahoma Earthquake
Mw 5.7; 0 fatalities; very few injuries



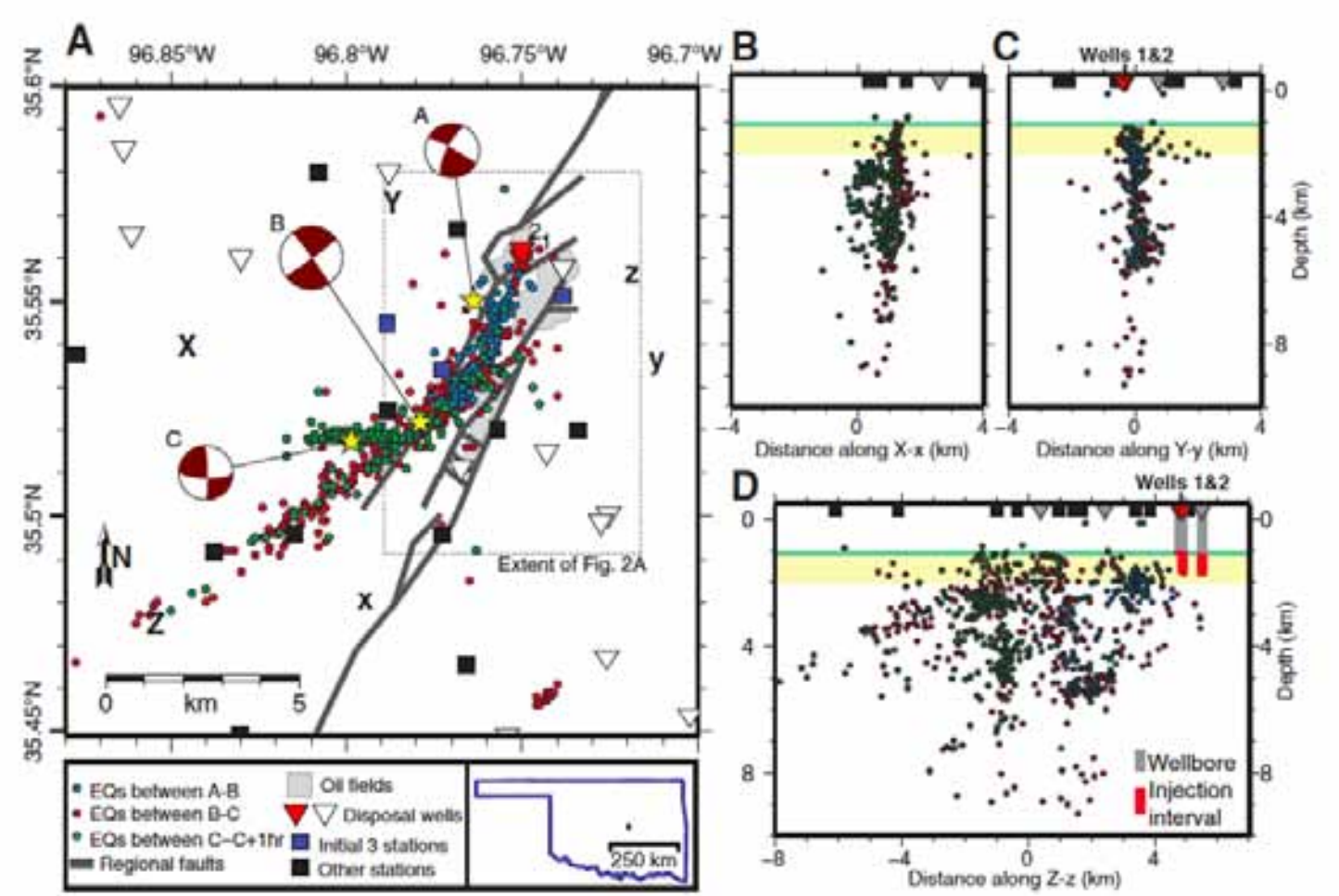
Too big for comfort …

Geology

Potentially induced earthquakes in Oklahoma, USA: Links between wastewater injection and the 2011 M_W 5.7 earthquake sequence

Katie M. Keranen, Heather M. Savage, Geoffrey A. Abers and Elizabeth S. Cochran

Geology published online 26 March 2013;
doi: 10.1130/G34045.1



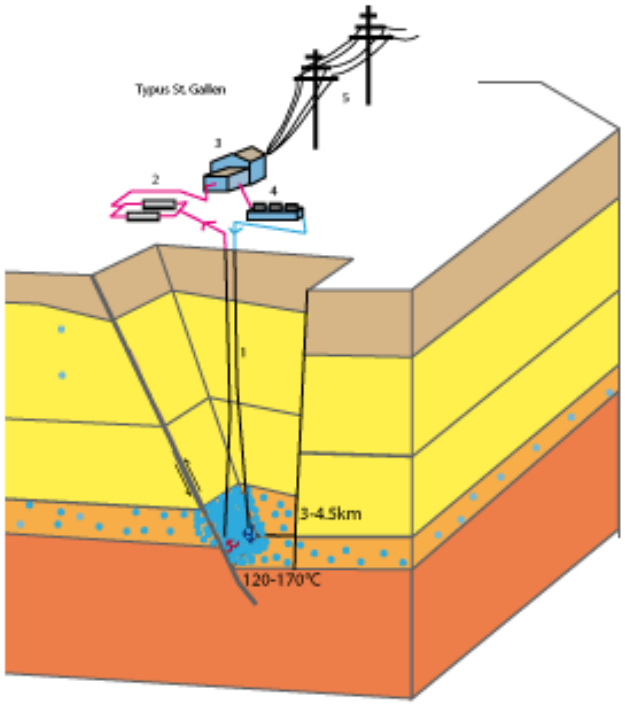
So what is happing here?

- Waste water injected into the underground that finds critically pre-stressed faults seems to be capable of inducing/triggering larger events.
- This is also rare – there are tens of thousands of water-water wells that seem to cause little or no seismicity.

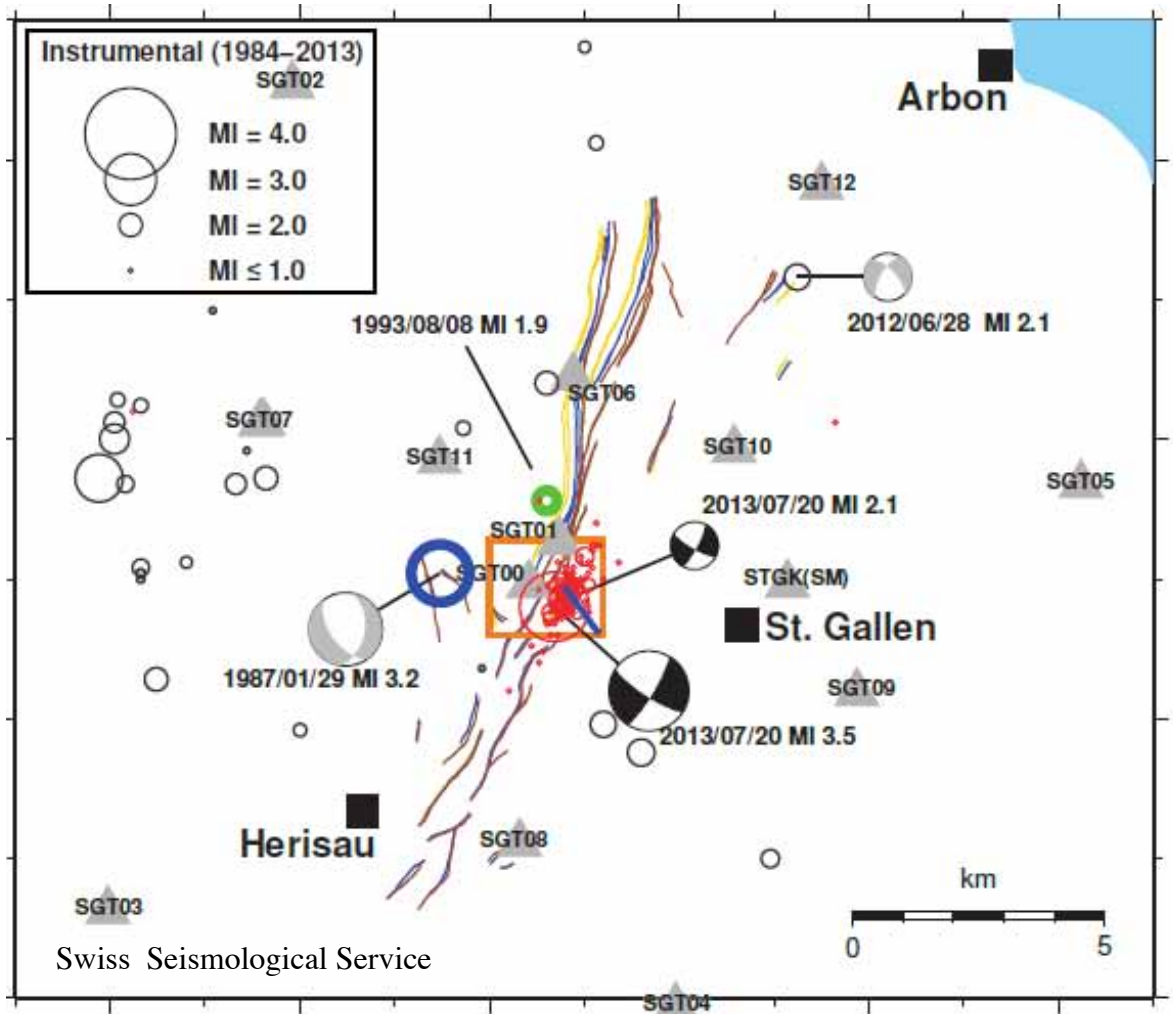
- Why? Because very large and rapidly growing volumes are involved, because the layers are deeper, close to the crystalline basement, and maybe because faults are a target also as they offer higher permeability.
- In the US, it is a game changer. And now the lawyers or on the case.
- Such earthquakes in areas of poor building practice could be disastrous.

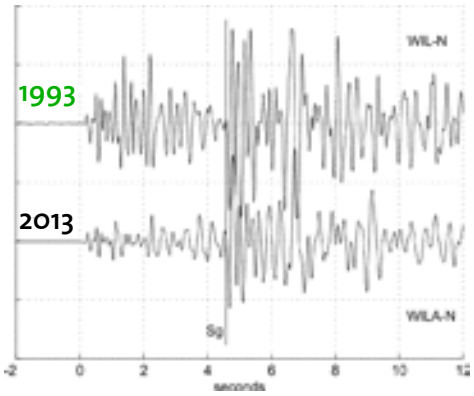
Switzerland has relevant experience….

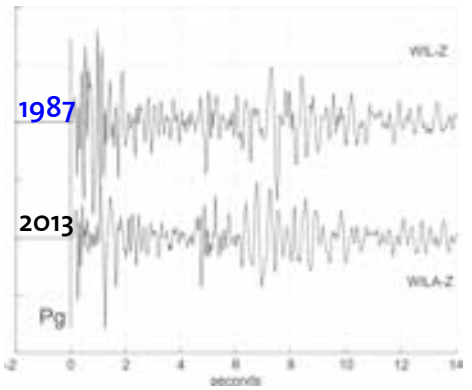
- The induced seismicity related to the re-injection part of deep hydrothermal projects share many similarities with waste water re-injection.



St. Gallen seismotectonic setting and induced earthquakes



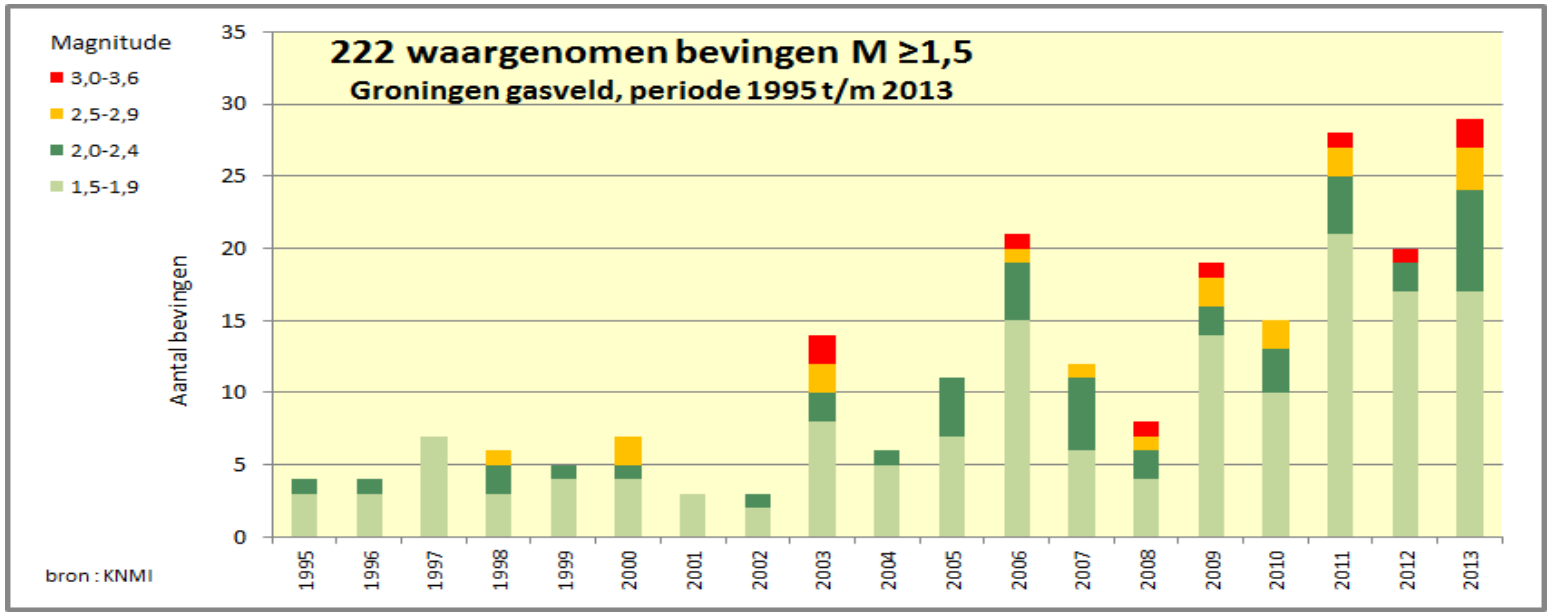




→ Diehl et al., 2013

Is 'classical' oil and gas production any better?

- Classical Oil & Gas exploitation is also facing major challenges from induced seismicity these days in some areas.
- Similar 'plays' to shale gas. No/less initial fracking, but long term depletion and subsidence can load nearby faults.



Question

Can gas/oil wells trigger earthquakes?

In May 2012 an earthquake (5.9 M) struck in Emilia Romagna region (North Italy; http://en.wikipedia.org/wiki/2012_Northern_Italy_earthquakes), an important petroleum province. Some non-scientists (or para-scientists) affirmed that the earthquake had been triggered by gas and oil wells and gas storage. It followed a wide discussion and at the moment an international scientific commission called by the Region is evaluating the possible connections between oil&gas activities (including storage and the phantom of hydraulic fracking, never used in the
oil&g
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ENERGY | 10/08/2013 @ 10:56AM | 484 views

Spain's Seismic Situation

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Spain's northeastern Mediterranean coast has never had much concern for earthquakes. Sure, there's a fault line nearby and towns further south had experienced tremors, but the stretch of coastline between Valencia and the southern border of Catalonia had never had much to worry about. They were never much of a concern, which is why these last few weeks have been so jarring

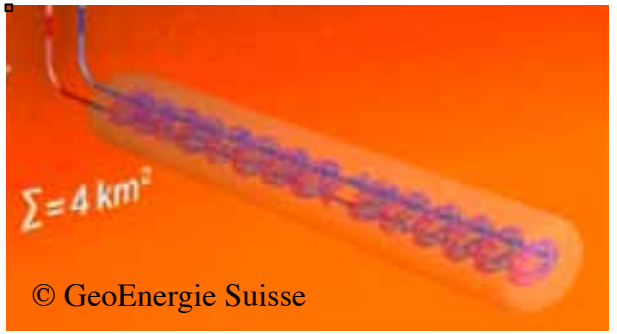
A platform, part of the Castor Project, located in the Ebro Delta off the coast of Alcanar stands at sea on October 2, 2013 following ten earthquakes with a magnitude between 1.4 and 2.9 registered today and

How to deal with 'the Ugly'

- Avoid large volume waste-water injections if possible (surface treatment).
- Stay away from active or easily re-activated faults.
- Seismic monitoring of fracking operations is essential, so that branching out of seismicity is detected early and correlated with the operation.
- A simple conservatively tuned 'traffic light system' is advisable to interrupt operation if earthquakes start to be a concern (i.e., M0.5 observed).

What about "geothermal fracking" for Enhanced Geothermal Reservoirs?

- Many similarities, some differences.
- Deeper, crystalline rock → higher hazard.
- Volumes/pressures similar to shale gas, but much smaller than waste water re-injection.
- More closed systems than hydrothermal & waste water → similar to shale gas.
- Proximity to major faults should be avoided.




FactSheet

Eine Technik im Fokus: Fracking

Potenziale, Chancen und Risiken

Summary

- Induced seismicity related to shale gas exploitation is an important issue, and one that needs to be taken serious.
- The challenges are not so different from other underground operations.
- For the safety of operations, forward planning and mitigation strategies go along way.
- But: There is no zero risk → Risk governance & regulation is needed.