



Schweizerischer Erdbebendienst
Service Sismologique Suisse
Servizio Sismico Svizzero
Servizi di Terremoti Svizzera

ETH

Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

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

Stefan Wiemer

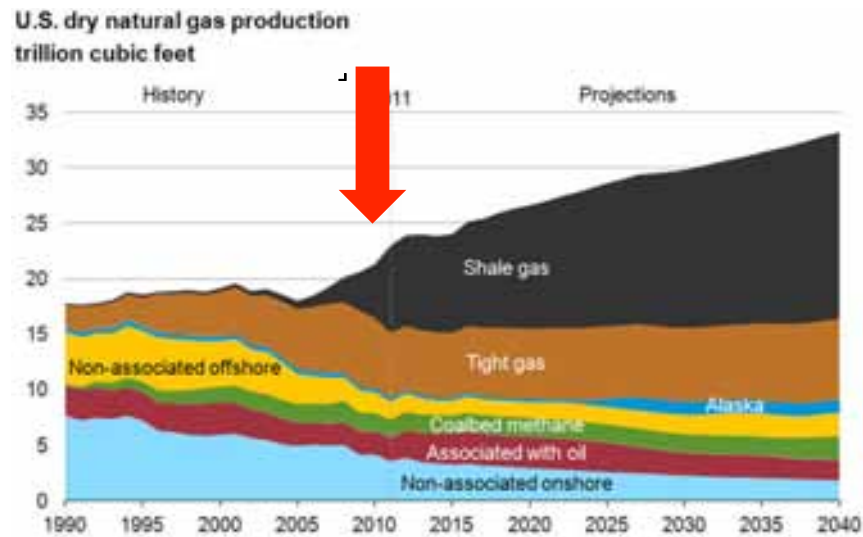
Zurich

April 2, 2014

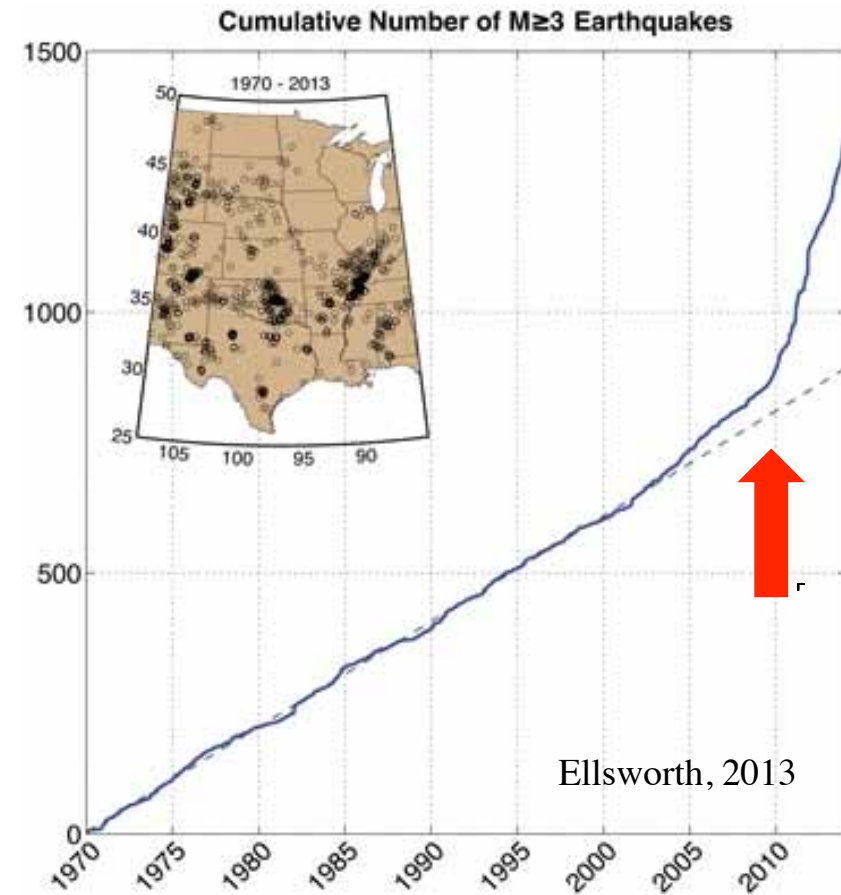


Fracking and induced earthquakes?

- 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?

- The rate of earthquakes in the Eastern US has more than tripled in the past 5 years.
- Fracking operations in the UK were stopped for several years because of the 'Blackpool earthquake' (M2.3).

- advertisements -

waterLink
INTERNATIONAL

Platform
technical solutions
Subscribe to the free

POLLUTION
Pollution > Blackpool Earthquake Triggered by Fracking?

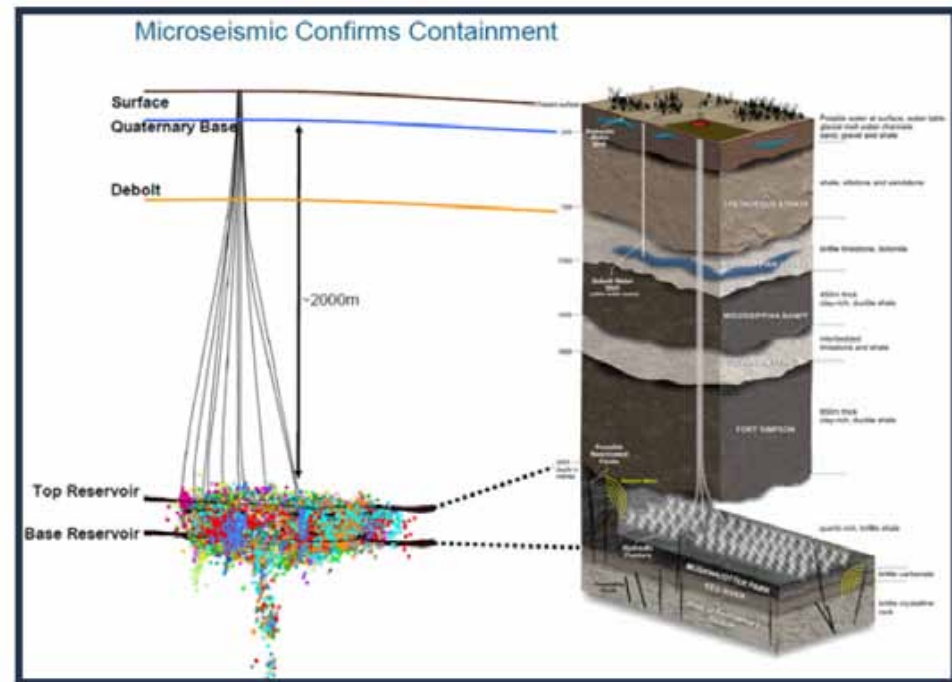
Blackpool Earthquake Triggered by Fracking? 07/06/2011

The controversial new drilling operation for natural shale gas in Lancashire has been suspended following a second earthquake in the area that may have been triggered by the process. The earthquake last Friday near Blackpool occurred at the same time that the energy company Cuadrilla Resources were carrying out experimental 'fracking' operations.



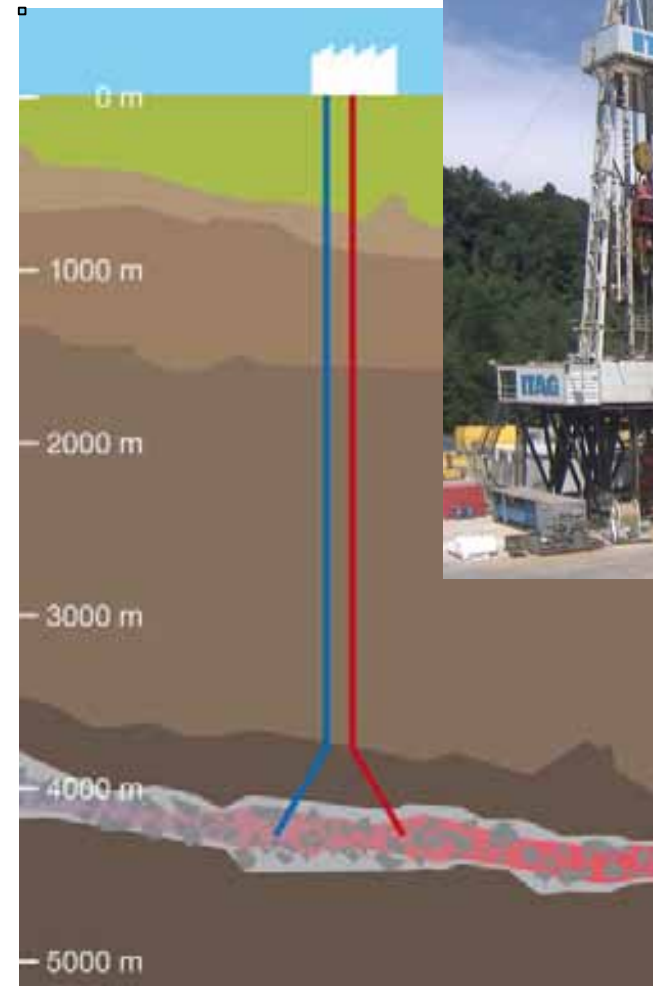
Fracking and induced earthquakes?

- The rate of earthquakes in the Eastern US has more than tripled in the past 5 years.
- Fracking operations in the UK were stopped for several years because of the 'Blackpool earthquake' (M2.3).
- An $M_I = 3.8$ earthquake was triggered by fracking operations in Canada in the Horn River basin in 2011



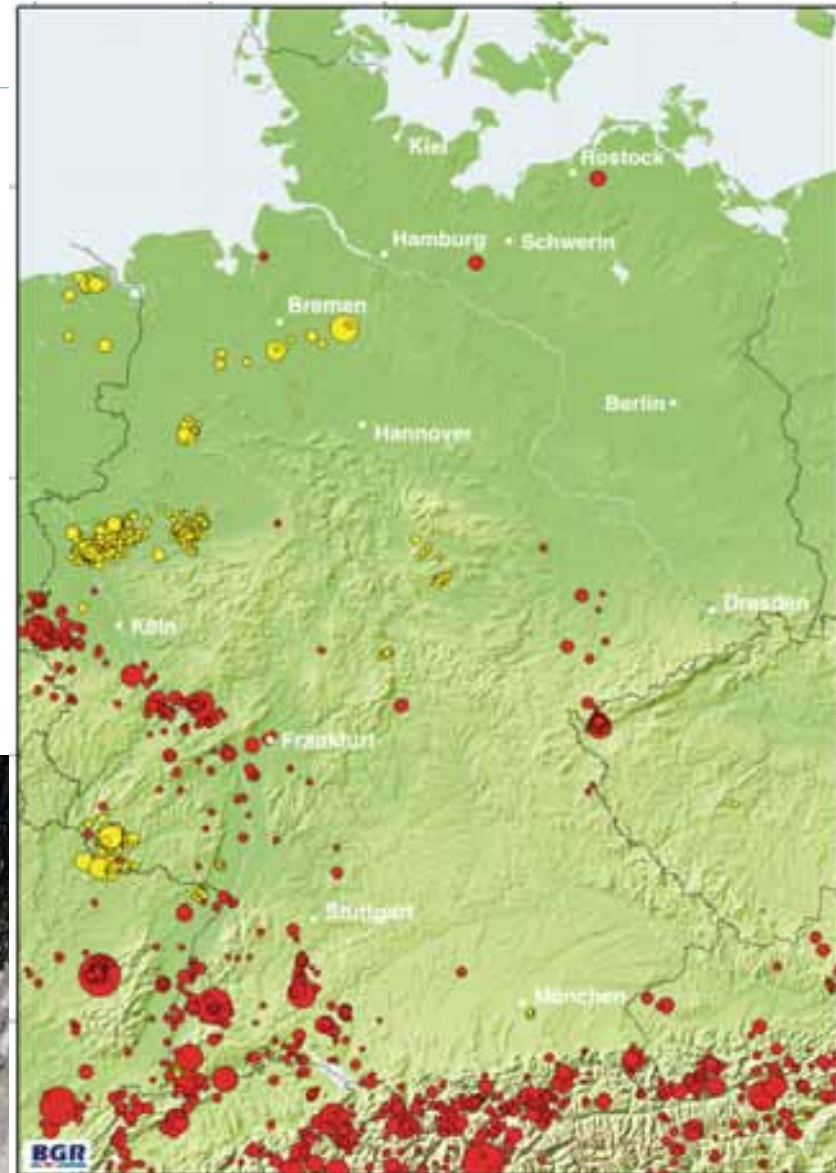
Fracking and induced earthquakes?

- The rate of earthquakes in the Eastern US has more than tripled in the past 5 years.
- Fracking operations in the UK were stopped for several years because of the 'Blackpool earthquake' (M2.3).
- An $M_I = 3.8$ earthquake was triggered by fracking operations in Canada in the Horn River basin in 2011.
- In Switzerland, two geothermal projects have failed because of Magnitude 3.4 and 3.5 events.
- Enough reasons to be concerned!



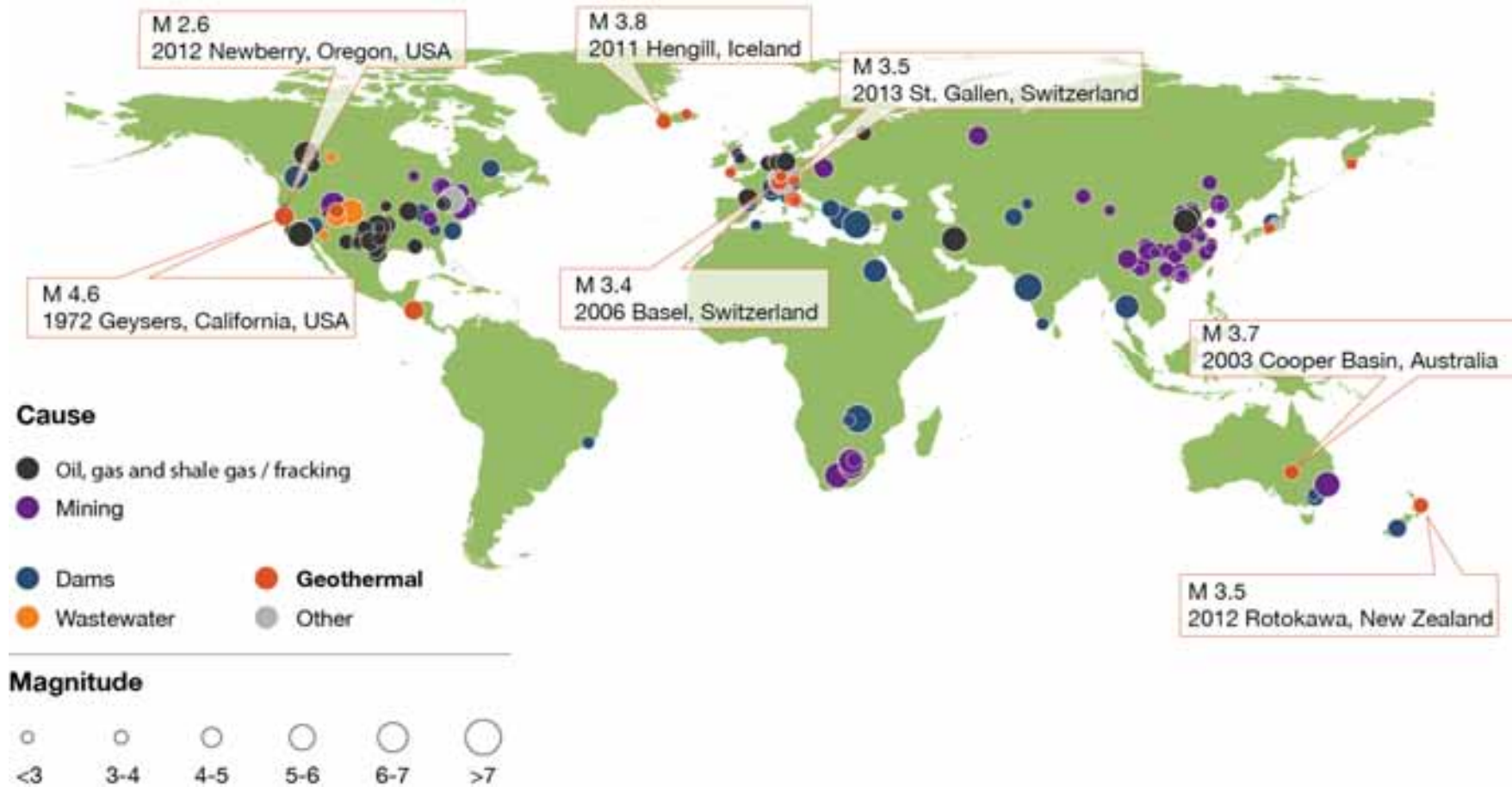
Induced seismicity – an old story

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



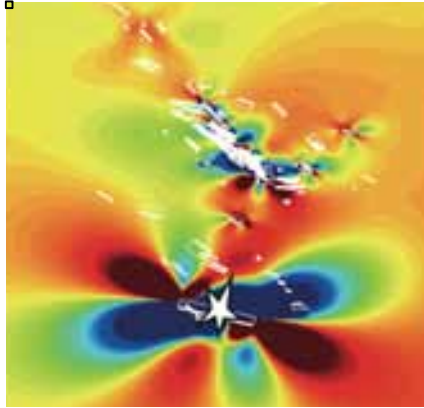
Induced Earthquakes around the World

Published data from 1930 to present

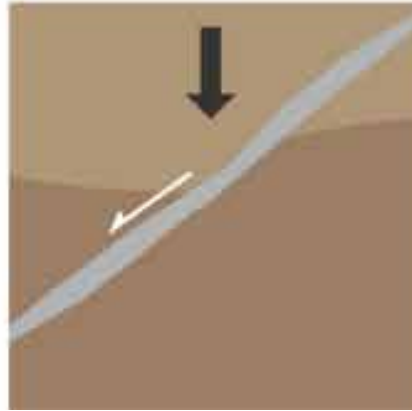


Different physical mechanisms

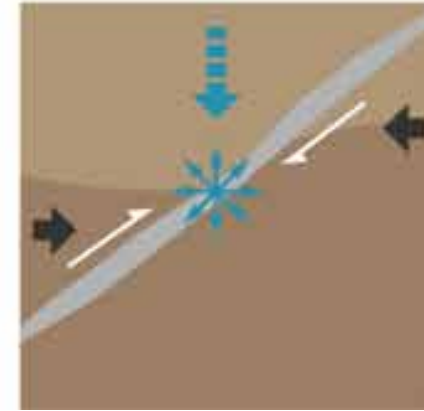
Earthquake interaction



Load change



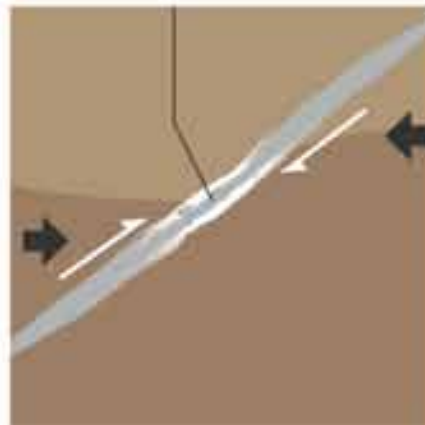
Pore pressure change



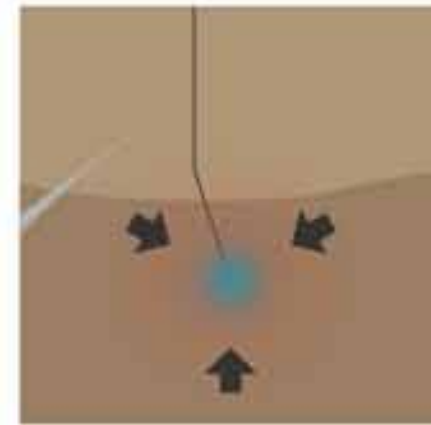
Volume change



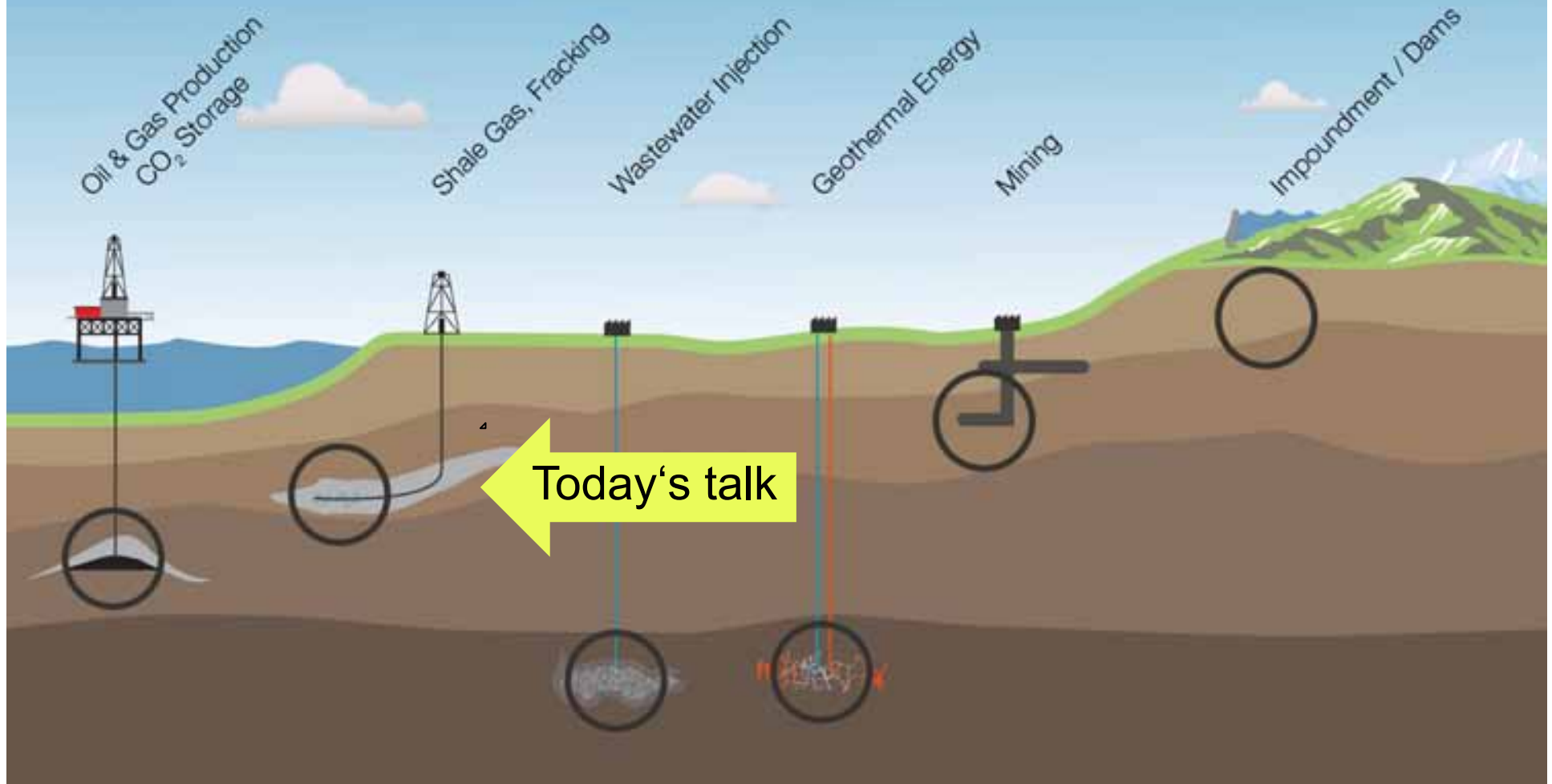
Chemical alterations



Thermal strain



Where Induced Seismicity Can Occur.



Fracking induced seismicity ...



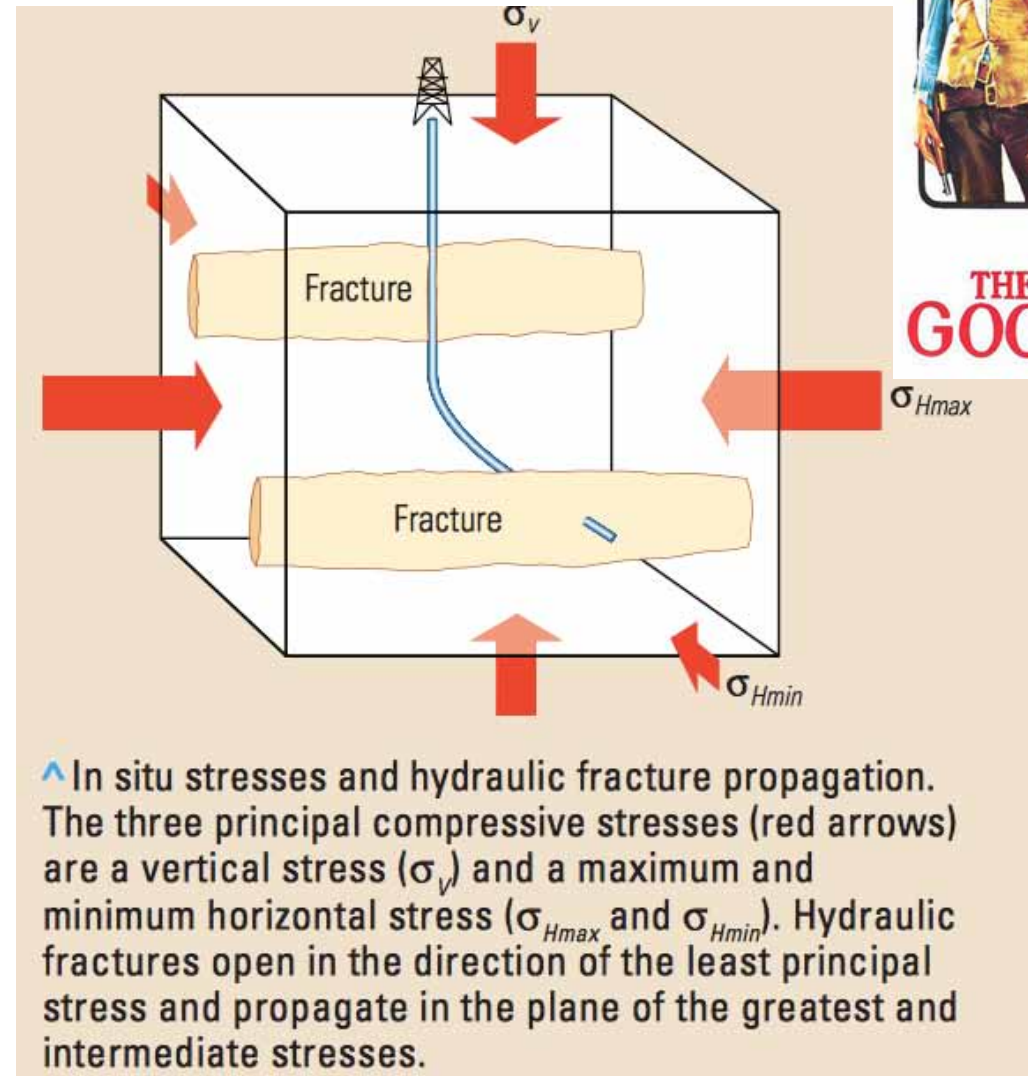
1966 Italian Spaghetti Western film directed by Sergio Leone, starring Clint Eastwood, Lee Van Cleef, and Eli Wallach



THE
GOOD

Fracking related seismicity: 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.



Fracking usually induces very small earthquakes

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

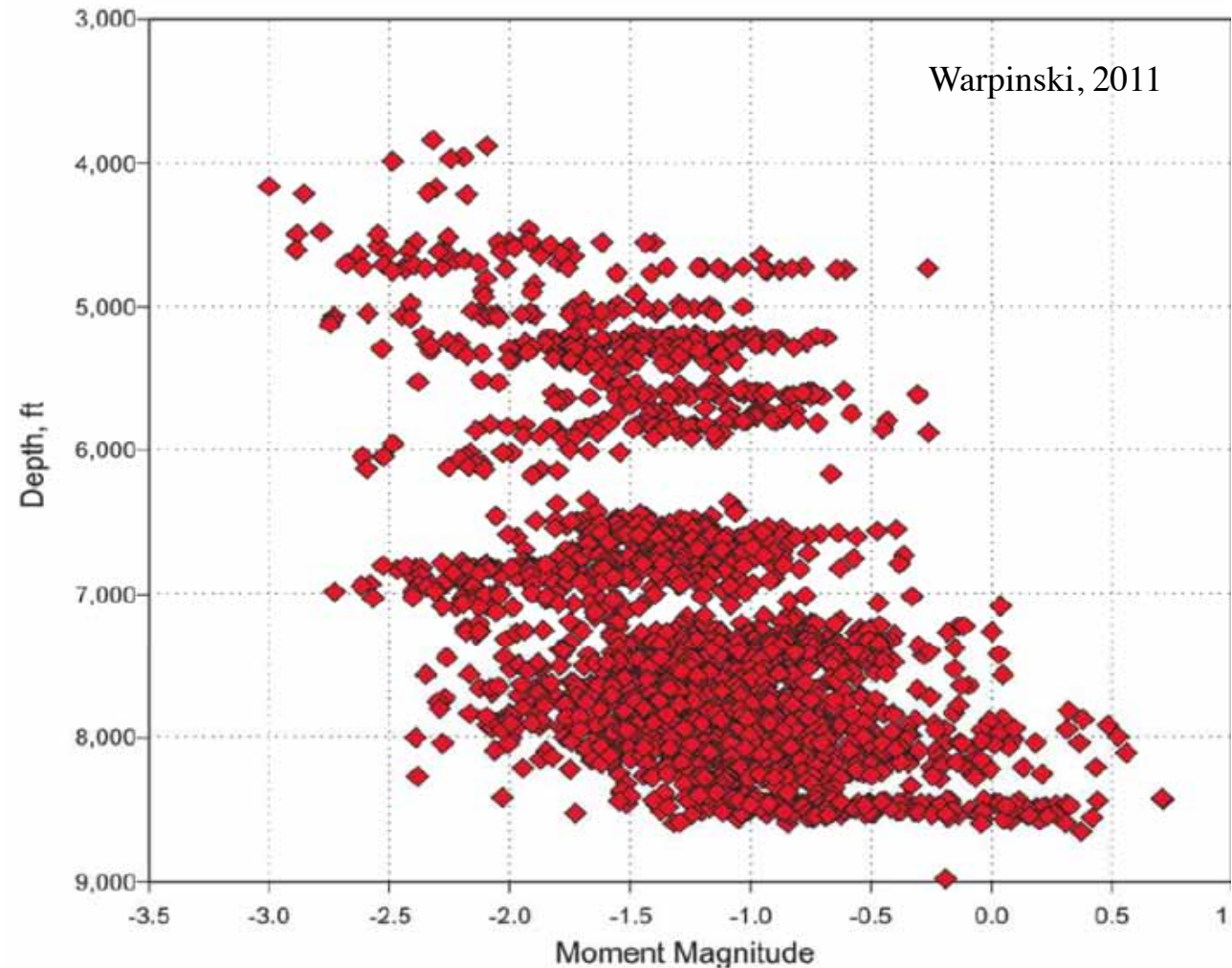
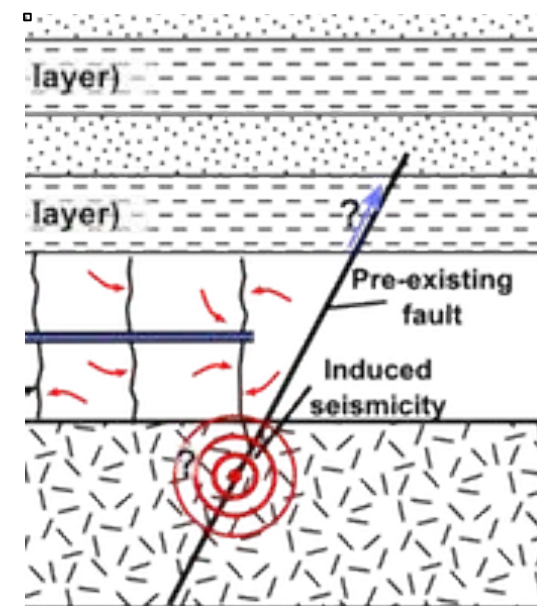


Fig. 1—Barnett shale maximum moment magnitude results for monitored stages through mid 2011.

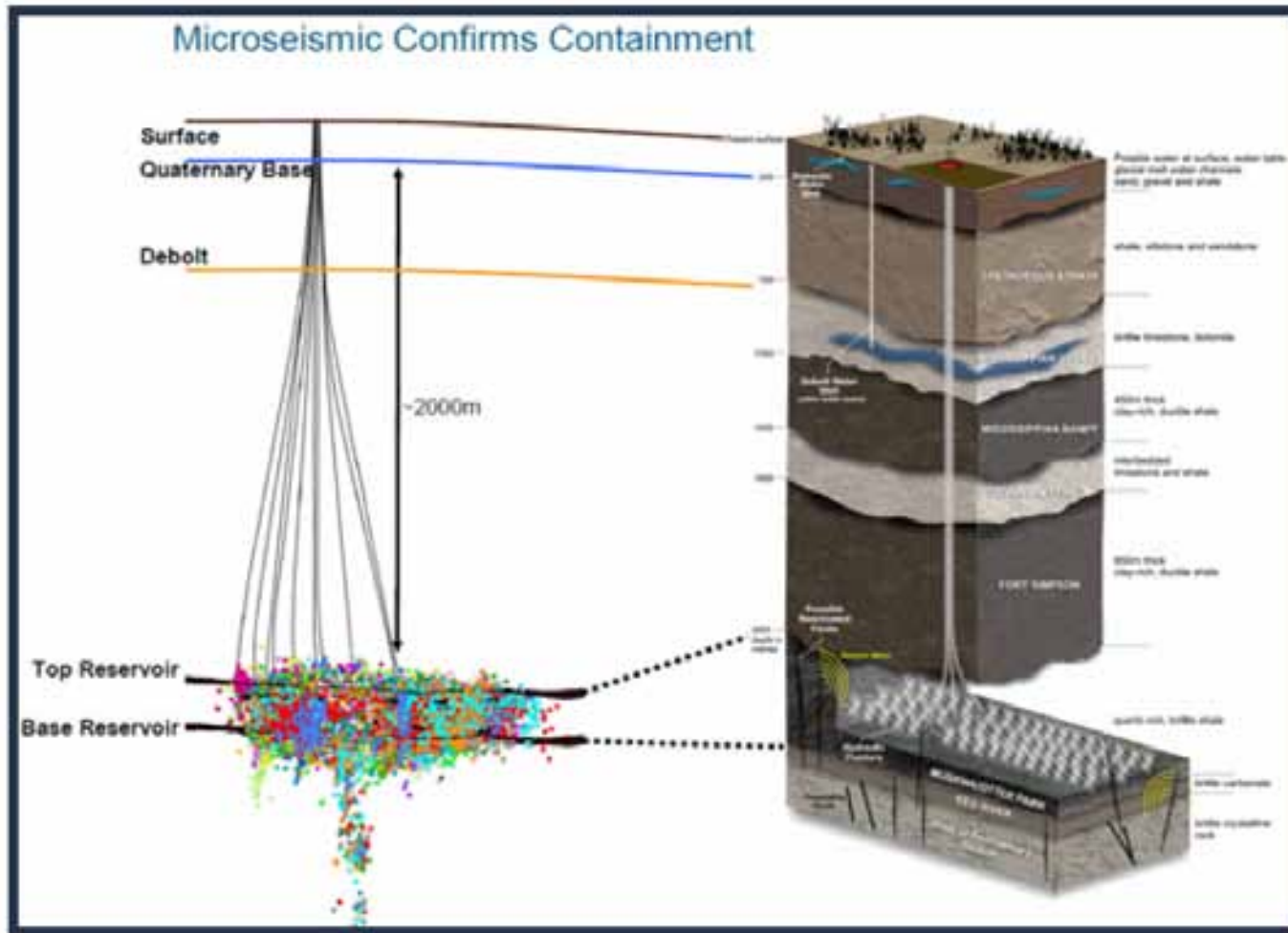
Fracking: The Bad

- 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 → $M_{\max}(\text{obs})$ so far = 3.8.





Horne River: M3.8 and many more ...



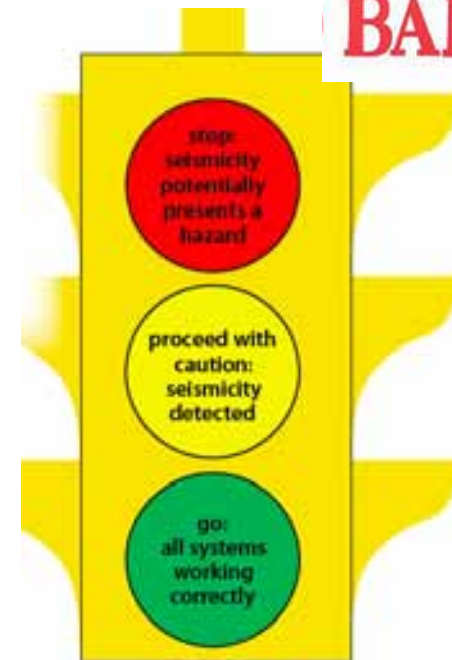
**THE
BAD**

Dealing with ‘the bad’

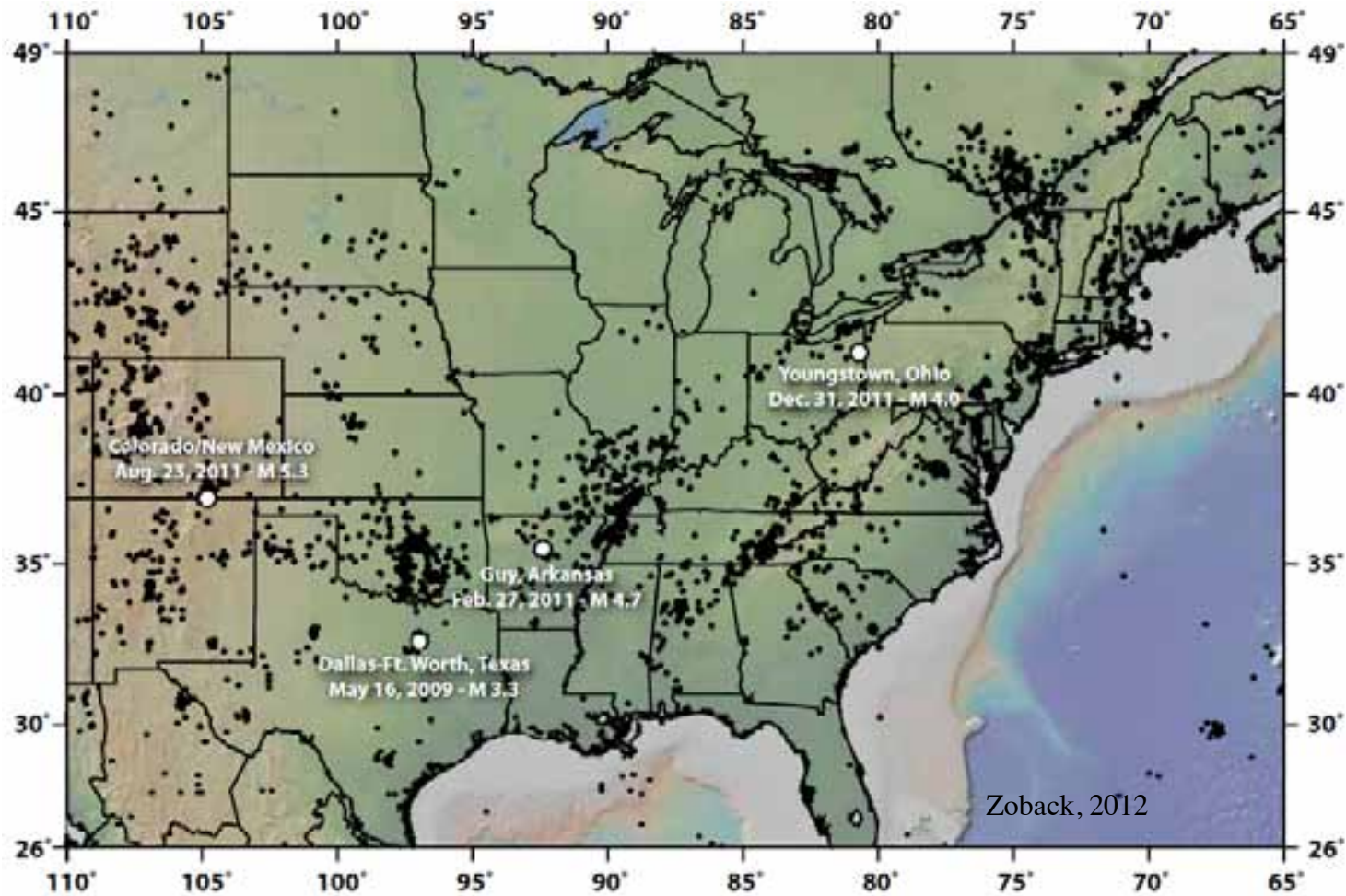
- Seismic monitoring of fracking operations is essential, so that branching out of seismicity is detected early and correlated with the operation.
- A simple, conservatively tuned ‘traffic light system’ is advisable to interrupt operation if earthquakes start to be a concern (i.e., M0.5 observed).
- 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 ...)



**THE
BAD**

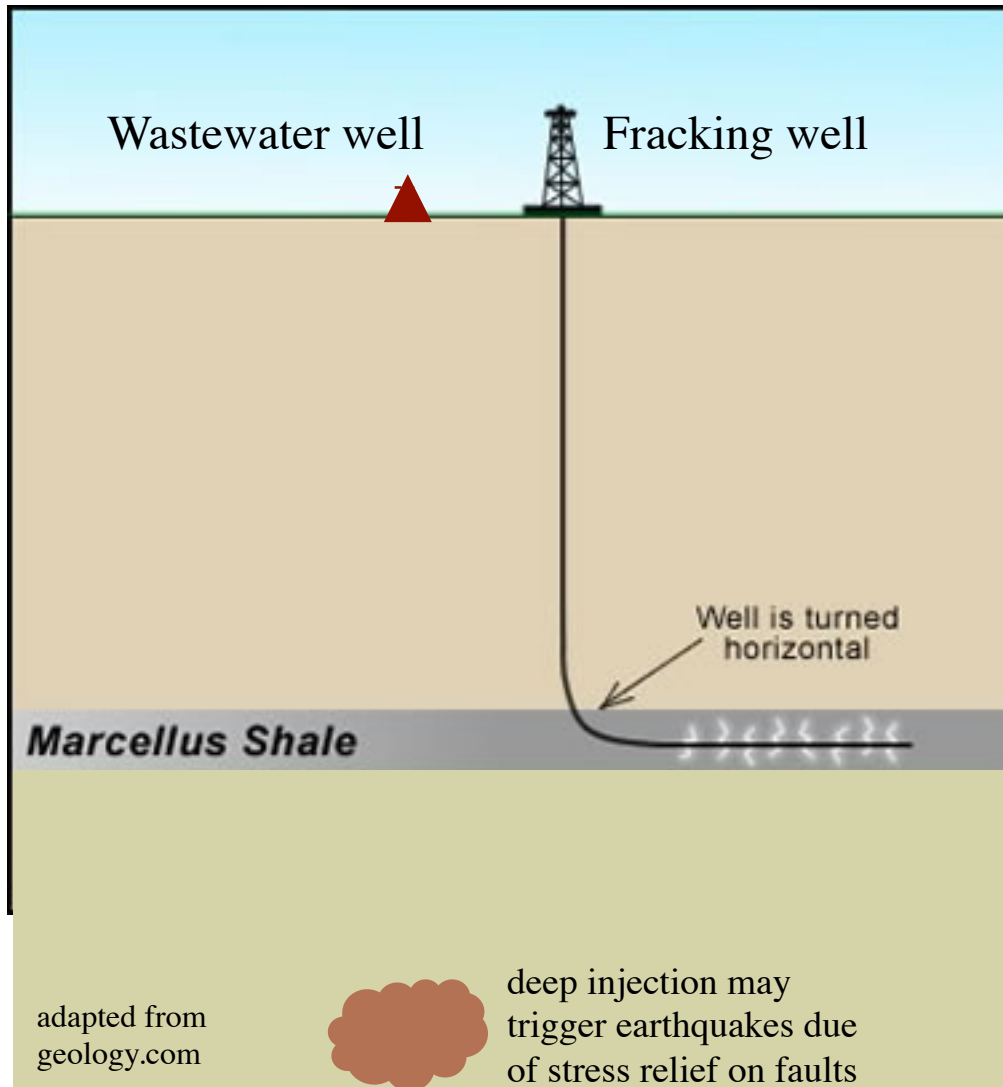


Fracking ... when things go seriously wrong...



**AND THE
UGLY**

... it seems to be the 'waste water'.



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



NATIONAL GEOGRAPHIC Daily News

Home Animals Ancient Energy Environment Travel/Cultures Space/Tech Water Weird News Photos News Video News Blogs

Fracking Wastewater Disposal Linked to Remotely Triggered Quakes

The finding could help scientists identify critically stressed faults.



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



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 Natural Gas Markets Overseas
Some 40 multibillion-dollar projects have been proposed for North American natural gas overseas. Proponents face environmental and industry opposition—an uphill competition.

Green Fracking? 5 Technologies for Cleaner Shale Energy
As U.S. oil and gas production grows, new technologies aim to reduce environmental and chemical use and emissions. Can hydraulic fracturing be green?

East Harlem Explosion of Natural Gas Leaks
A natural gas leak is suspected to have caused a deadly explosion Wednesday in East Harlem. Recent studies have shown that old gas pipes with aging cast-iron pipes are at high risk.

ADVERTISEMENT



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

Oklahoma Shakes—Is Fracking to Blame?

Bryan Walsh @bryannwalsh Feb. 18, 2014

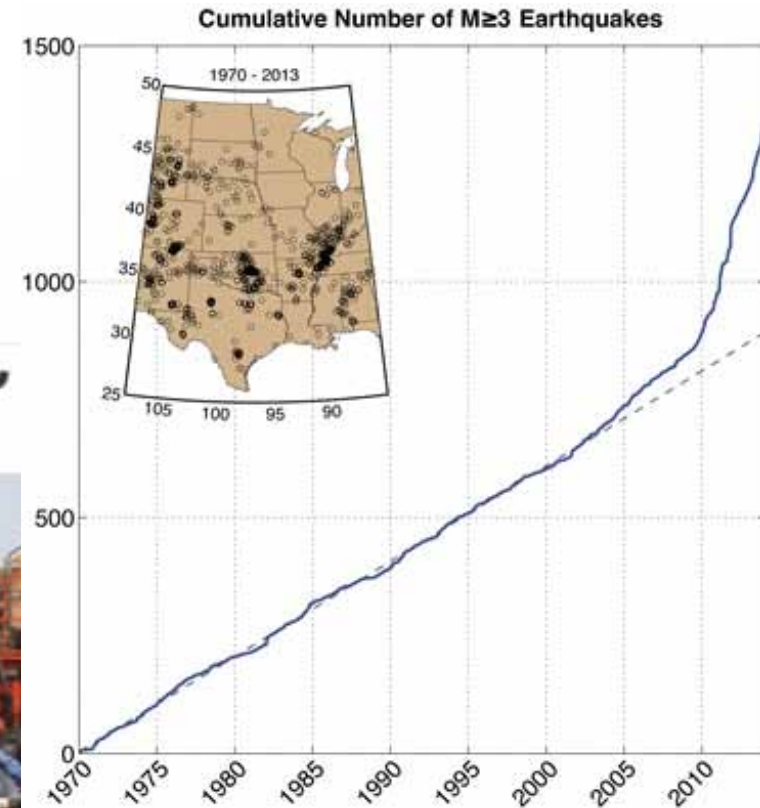
A normally calm state is hit by a wave of minor earthquakes—causing some to point the finger at fracking. But wastewater disposal wells likely play a bigger role

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

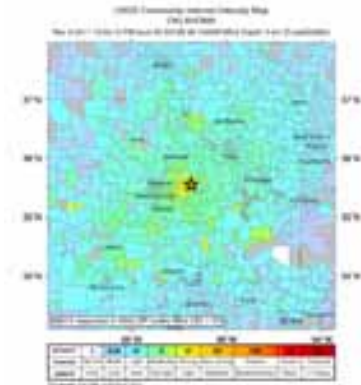


Earthquakes have been linked to oil and gas disposal wells in states like Kansas.

Stock Image: Witta Egle/MCT/Getty Images



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



Earthquake Hazards Program

Home | About Us | Contact Us

EARTHQUAKES HAZARDS LEARN PREPARE MONITORING RESEARCH

PAGER

Home

Background

Background Information

Topic Headers

Data, Products, and References

FAQ

Disclaimer

Contact Us

PAGER - M 5.6 - OKLAHOMA

Alert level does not include impacts from earthquakes related hazards such as tsunamis, landslides, fires or riprocks.

Earthquake Shaking Alert Level: YELLOW [Download Alert PDF](#) [View Map](#)

Sunday, November 06, 2011 at 02:52:19 UTC (21:52:19 local)

Location: 35.2° N, 96.7° W Depth: 5km

Event ID: US00000412

Alert Version: 0

Created: 1 day, 11 hours after earthquake

Alert Information

Yellow alert level for economic losses. Some damage is possible and the impact should be relatively localized. Estimated economic losses are less than 1% of GDP of the United States. Past events with this alert level have required a local or regional level response. Green alert level for shaking-related fatalities. There is a low likelihood of casualties.

[View profile AL1000](#)

Estimated Fatalities

Estimated Economic Losses

Detailed information

[Summary](#) [Recent Earthquake History](#) [Full City Exposure List](#)

Estimated Population Exposed to Earthquake Shaking

Estimated Shaking Level	I	II	III	IV	V	VI	VII	VIII	IX	X
Estimated Population Exposed	100	100	100	100	100	100	100	100	100	100
Estimated Shaking	Very Weak	Weak	Light	Weak	Strong	Very Strong	Severe	Violent	Extreme	Extreme
Estimated Structure Damage	None	None	None	Light	Light	Violent	Extensive/Heavy	Heavy	Heavy	Heavy

Estimated exposure may increase population with unaccounted mobile pop. data.

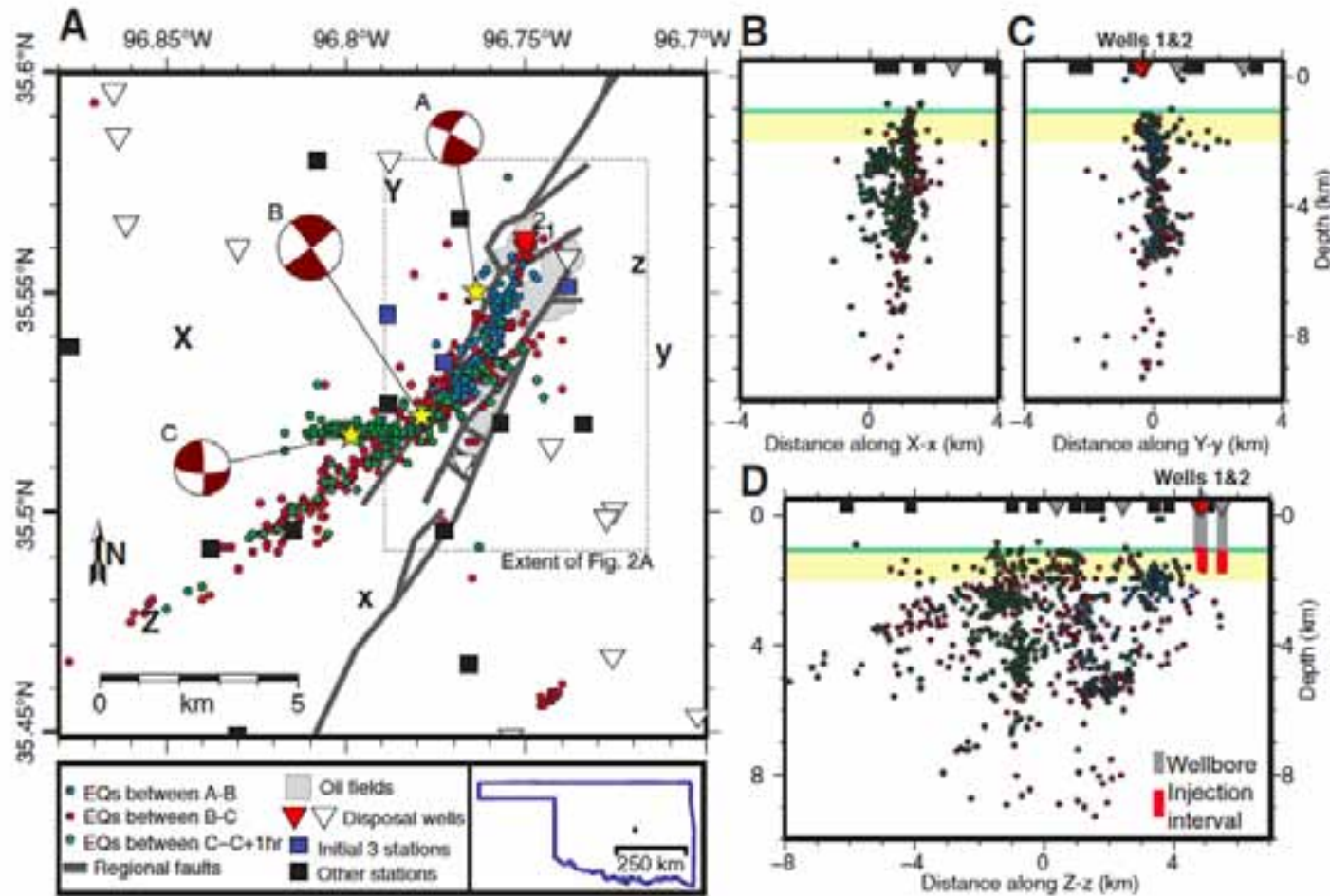
Too big for comfort ...

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



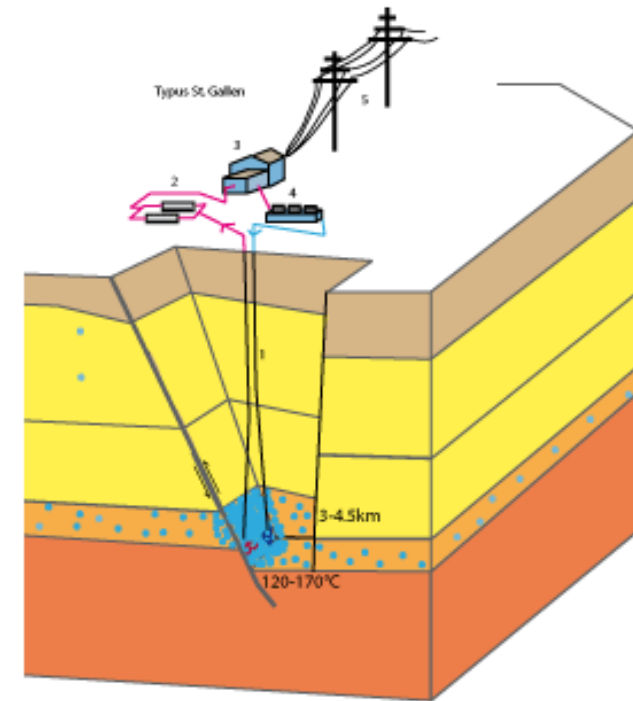
So what is happening here?

- 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.

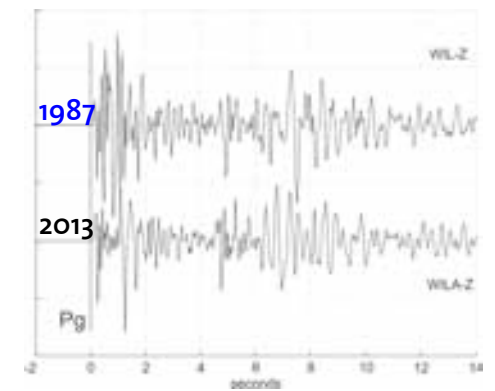
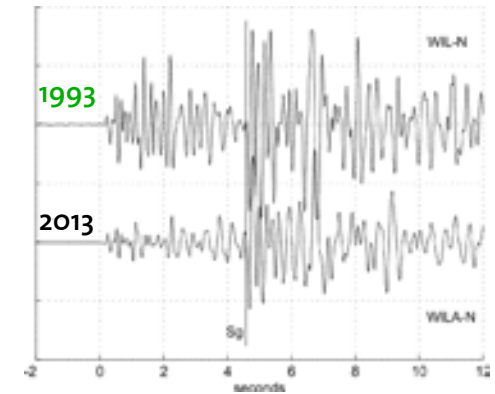
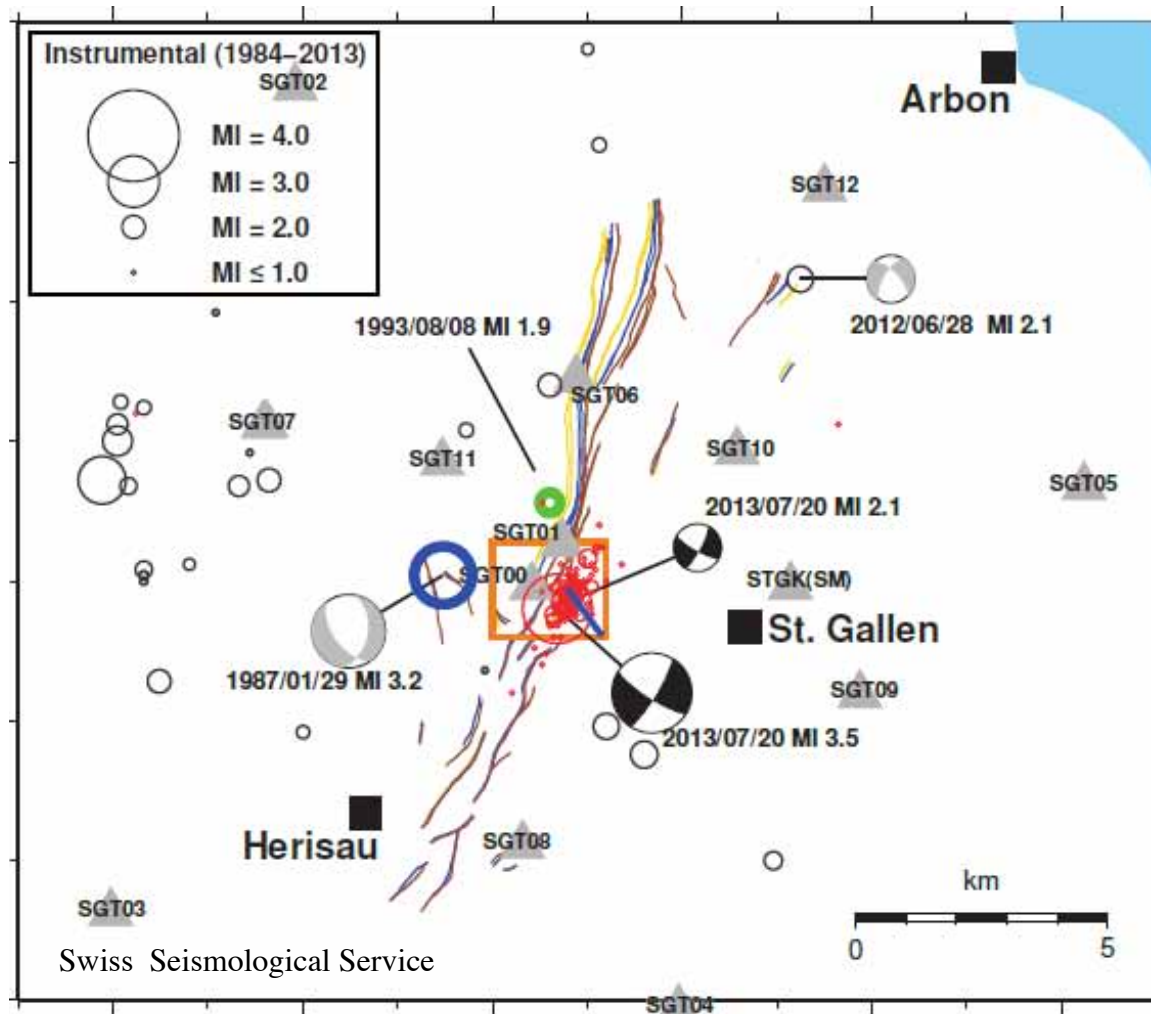


Switzerland has relevant experience....

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

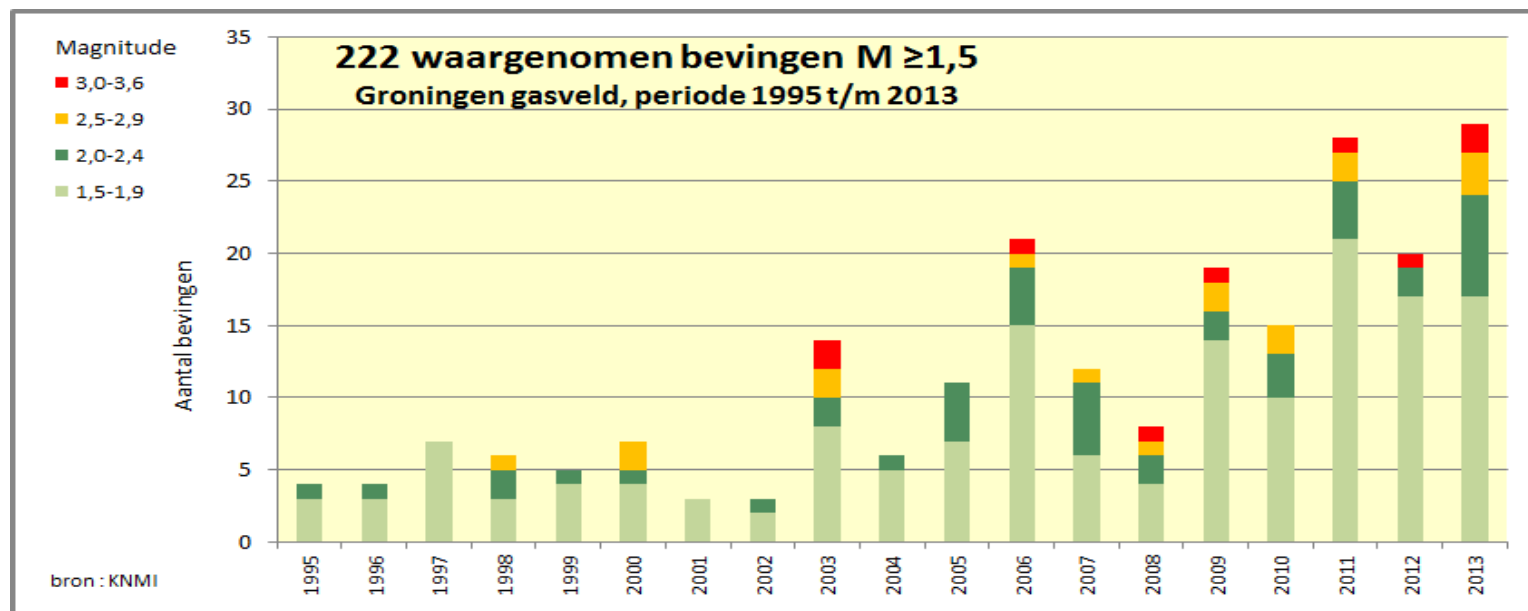


St. Gallen seismotectonic setting and induced earthquakes



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
 com
 know

ENERGY | 10/09/2013 @ 10:56AM | 484 views

Spain's Seismic Situation

+ Comment Now + Follow Comments

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 irritating.



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

○ The magnitude 6 quake struck around 22 miles north of Bologna at 4:04am yesterday morning



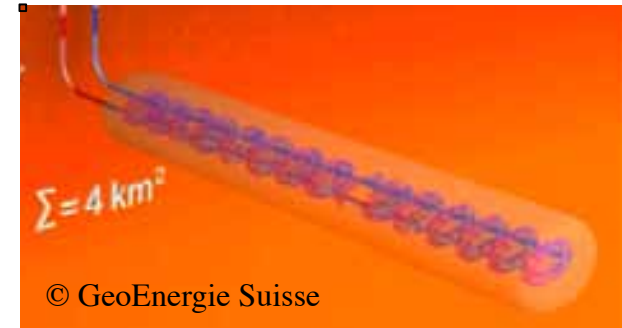
How to deal with ‘the Ugly’

- 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.



Eine Technik im Fokus: Fracking Potenziale, Chancen und Risiken

Fracking wird für die bessere Ausschöpfung von fossilen Kohlenwasserstoffen (Öl und Erdgas) bereits seit Jahrzehnten eingesetzt. Eine neuere Variante ist die gezielte Frakturierung von Gesteinsschichten mit flüssigen Medien. Die wirtschaftliche Nutzung von unkonventionellen, d.h. schwer erschließbaren, Kohlenwasserstoffen durch die Frakturierung wird als Fracking bezeichnet. Dabei werden durch Fracking zum Beispiel Gesteinsformationen erschlossen.

Die Technik des Fracking

Grundsätzlich bedeutet Fracking (auch Hydraulic Fracturing oder hydraulische Frakturierung), dass Fluide (meist Wasser) unter hohem Druck in den Untergrund gepumpt werden, um die Poren zu vergrößern, neuen Porenraum durch Riss- und Bruchbildung zu erzeugen und miteinander zu verbinden. Durch das Vergrössern der Porengröße in den Untergrund wird ein System von Wasserströmung und dadurch die Durchlässigkeit des Gesteins erhöht. Wenn der Prozess der Frakturierung abgeschlossen ist, wird das in der Tiefe erzeugte Überdruck abgebaut, indem die Frakturflüssigkeit wieder an die Oberfläche geleitet wird. Ein Teil der Flüssigkeit verbleibt in der Regel in den erzeugten Porenräumen.

Wasserkörper beeinflussen die Umverteilungen der Porenflüssigkeit und die Gesteinsbrüche.

Wasserkörper

Die Technik der hydraulischen Frakturierung wird bereits seit Ende des 1. Weltkrieges in konventionellen Öl- und Gaslagerstätten eingesetzt. Dort lässt sich durch das Vergrößern der Ausschöpfung bereits erschlossener Lagerstätten ein höherer Anteil der Reservierung in konventionellen Lagerstätten durch die Frakturierung auch abheben. Bei der Frakturierung von Tight-Gas-Vorkommen eingesetzt.

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.

