Geo-Resources

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- Induced Seismicity
  - Injection
  - Production

Some exciting research around georesources at KIT

How tight is tight ? The COBRA project

Reservoir Management and Seismicity

INTRODUCTION

Humanity's Top Ten Problems for next 50 years

1. **ENERGY**
2. **WATER**
3. **FOOD**
4. **ENVIRONMENT**
5. POVERTY
6. TERRORISM & WAR
7. DISEASE
8. EDUCATION
9. DEMOCRACY
10. POPULATION

2003	6.3	Billion People
2050	8-10	Billion People

Richard Smalley, 2003

What do you think when you hear Georesources ?

What do you think when you hear georesource ? ....

- water
- heat
- coal
- oil
- Natural gas
- Coal Bed Methane
- Gashydrates
- Oil sands
- Shale-Gas, Tight Gas
- Mineral Resources (Rare Earth Elements)
- Industrial rocks and minerals (incl. „cement“)

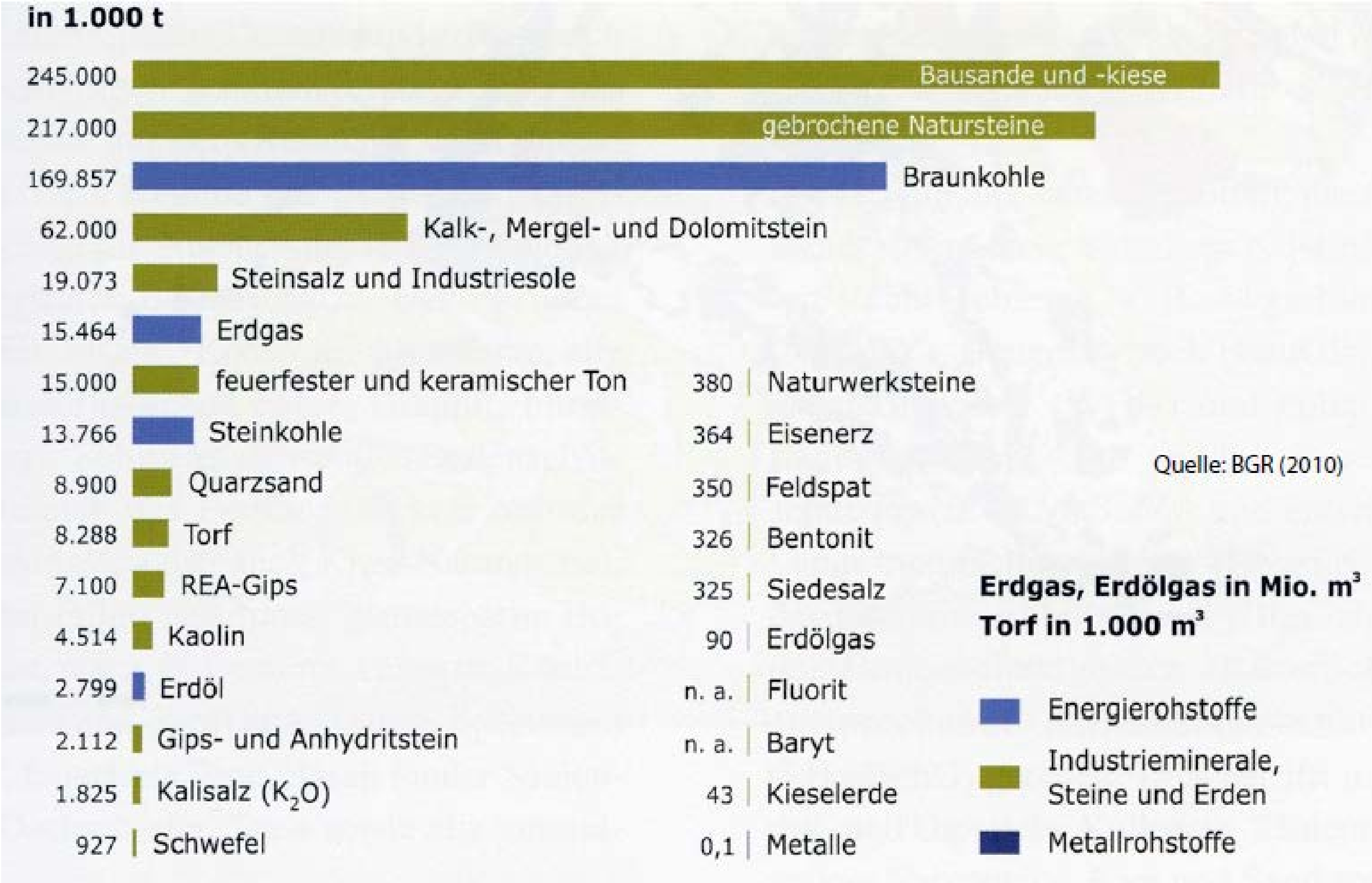
A political hypotheses for Germany?

Germany has no resources– except its brains

A Geofact

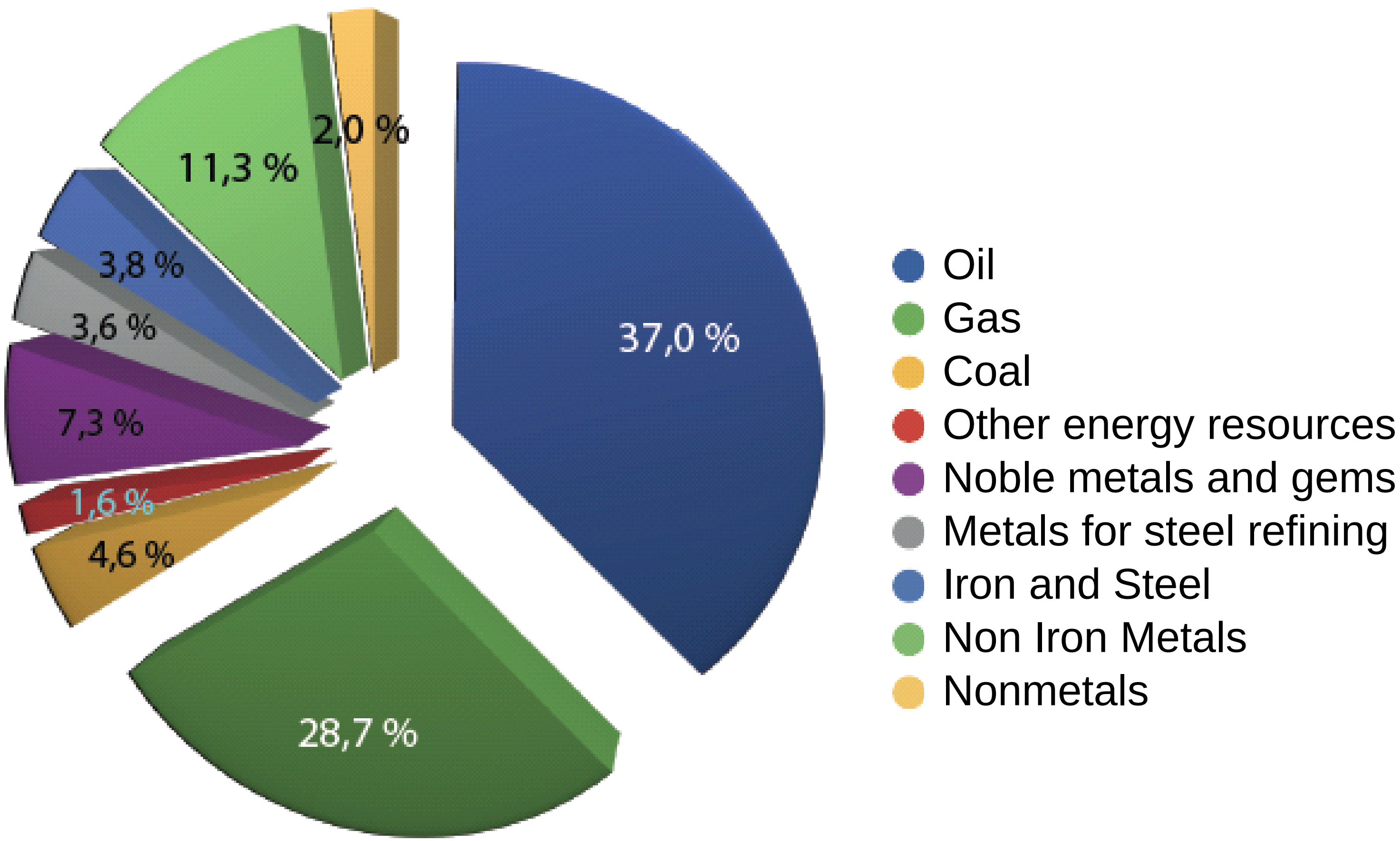
In Germany more Georesources are mined than imported (they ensure our supply and are rather inexpensive)

Production in Germany in 2009 (Total Value: ca. 17,5 Mrd. €)



Imports (83,9 Mrd. €)

- Most Imports are for Energy Resources!



BGR 2009

„RESOURCES“ VS. „RESERVES“?

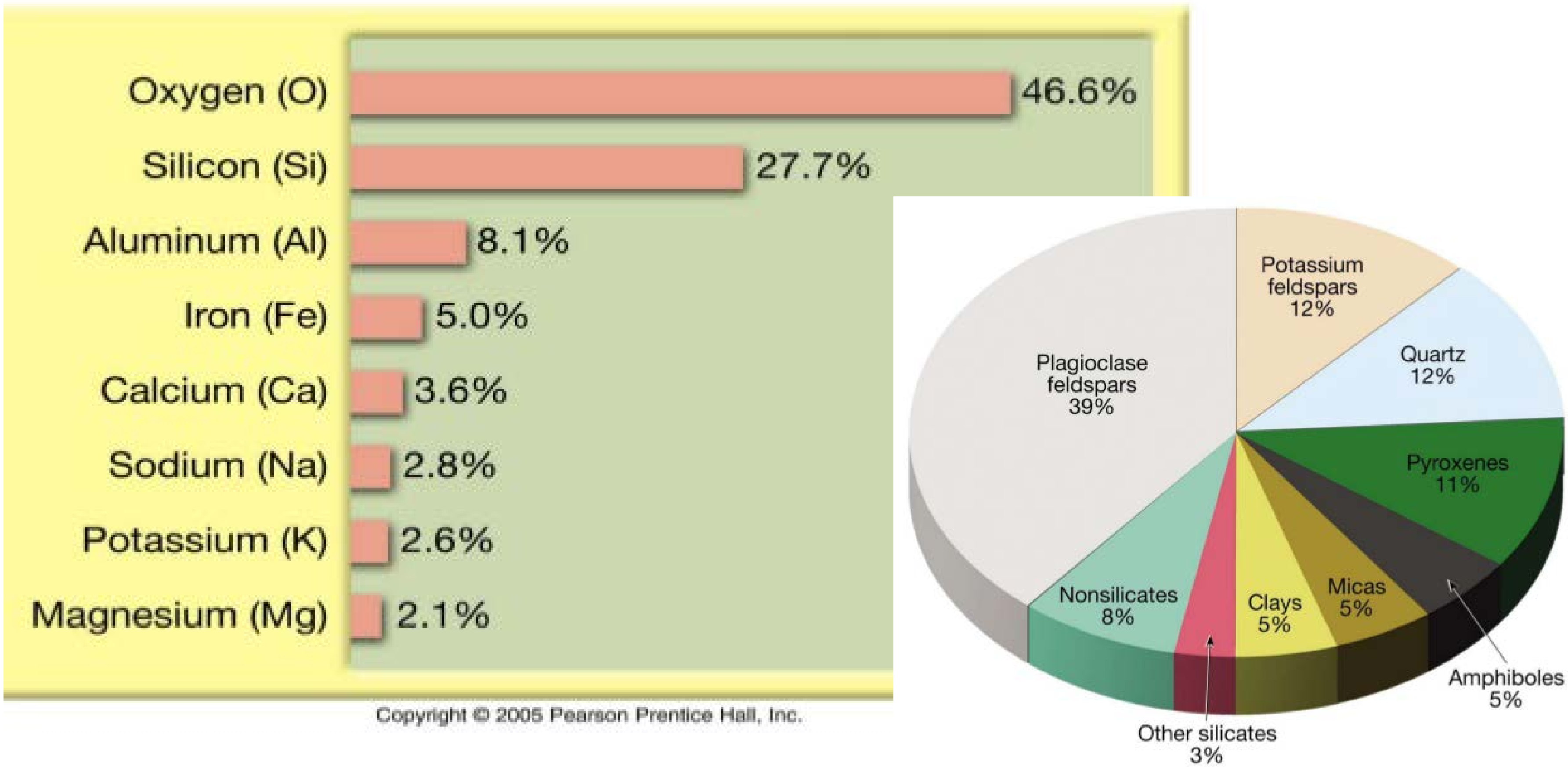
Reserves – Ressources
(Standard Definition! Some differences for Hydrocarbons)

- Reserves – economically feasible for extraction/use using today’s technologies and market prices

- Resources – known occurrence within the Earth’s crust – possible to extract/use at higher prices or while using new technologies.

Which are the most abundant Elements in the Continental Crust

Elemental abundances in continental crust



Feldspar

- Feldspar is a common raw material used in glassmaking, ceramics, and to some extent as a filler and extender in paint, plastics, and rubber.

Engineers use K-spar in highways to increase pavement reflectivity and wearing surface

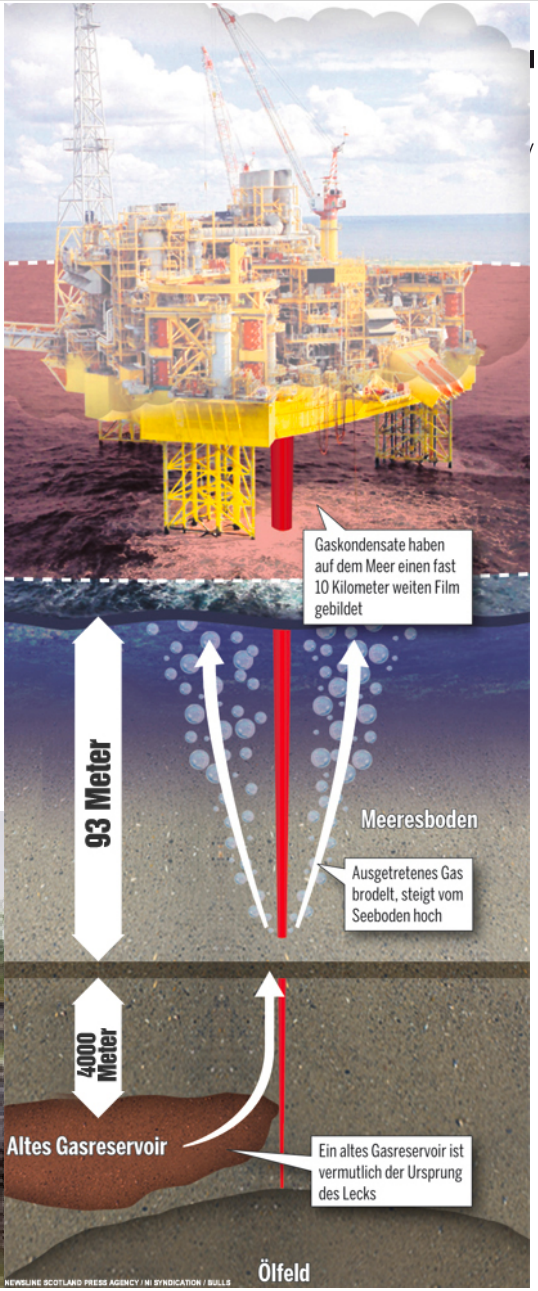
How much feldspar is produced annually? Where ?

Quartz

Because of its piezoelectric properties quartz is used for oscillators, resonators, because of its ability to rotate the plane of polarization of light and its transparency in ultraviolet rays it is used in heat-ray lamps, prism, and spectrographic lenses

Challenge : Sustainable Use of Georesources

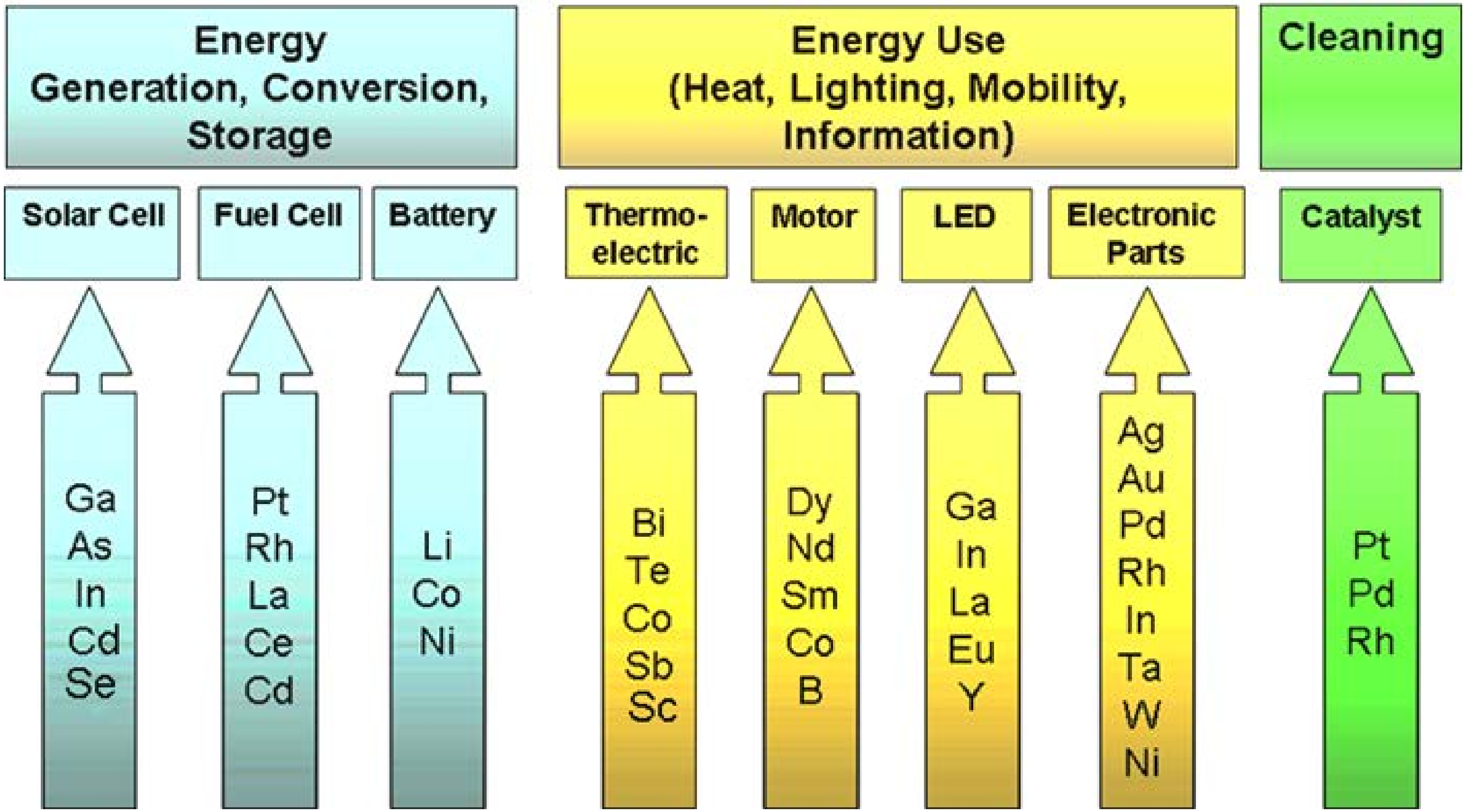
BP, Shell, Total failure



2013 04 10 Zeit, Spiegel-Online, Bild

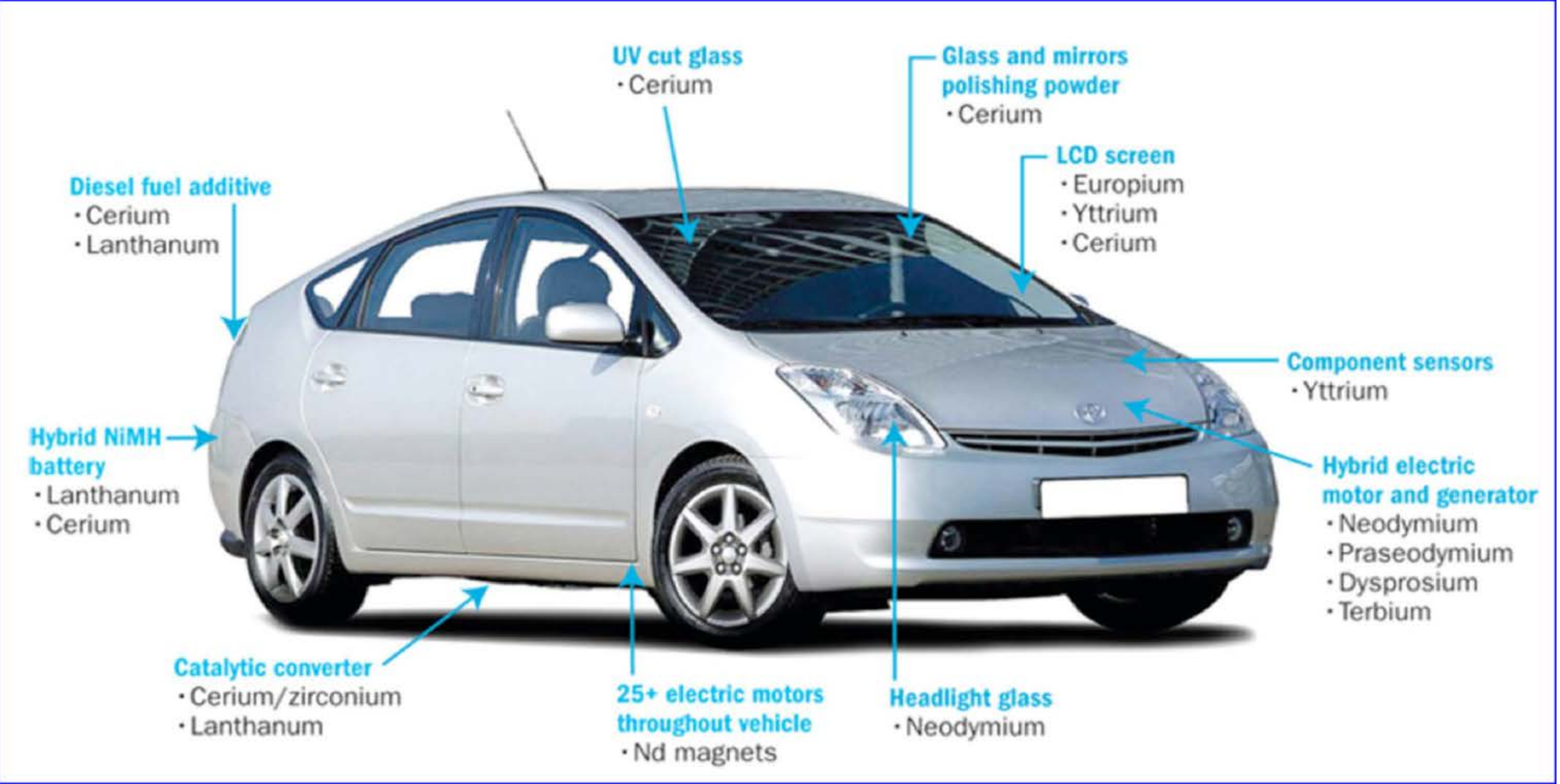
Use of Geo - Resources

Metals for Innovative Technologies



Littke 2009

REE in Hybrid-Cars



From EE Times: Rare earth supply chain: Industry's common cause by Colin Johnson

..in Wind Turbines

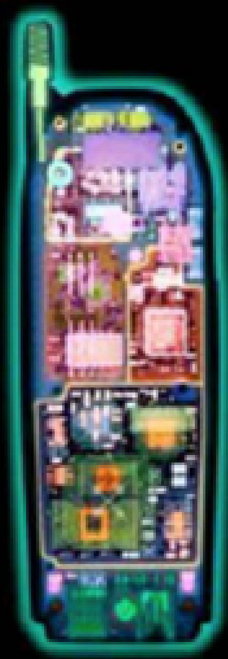
- Offshore turbines need > 1200 t steel
- According to Kooroshy et al. 2011:

Metall	Mass [kg] per MW
Chrome	902
Manganese Mn	80
Molybdene Mo	136
Niob NB	663
Dysprosium Dy	18
Neodym Nd	198 ND
Copper	3000 t (2011)

http://wordlesstech.com

25% of a Cell Phone is Metal

~1.5 Billion Cell Phones sold in 2010



60 kg Tantalum
510 kg Platinum

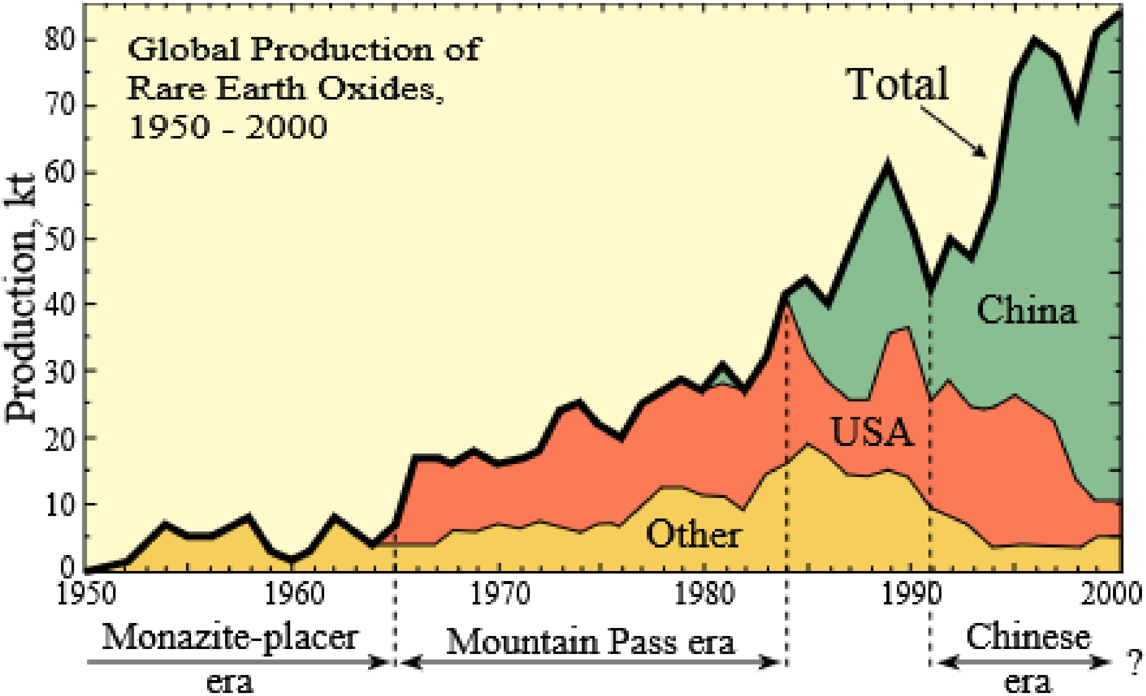
22.5 tons Palladium
51.0 tons Gold
525 tons Silver
24,000 tons Copper

Plus many others e.g. REEs

There will be only 20 years supply of tantalum if the global per capita use rises to 50% of the current U.S. per capita use; 40 years for copper

Usgs

Rare Earth Elements Producing Countries



Mining one ton of rare earth minerals produces about one ton of radioactive waste, according to the Institute for the Analysis of Global Security

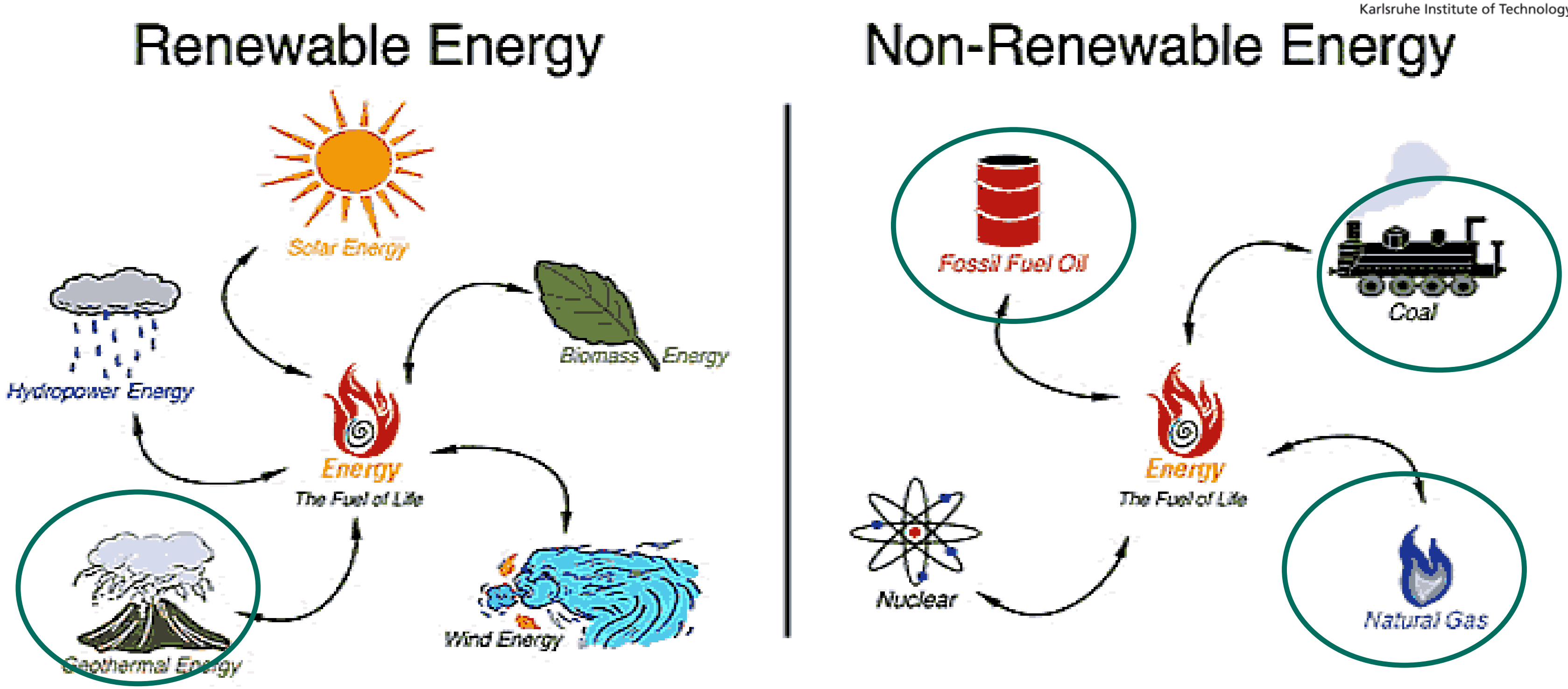
Schwere Seltene Erden (engl.: heavy rare earth elements, HREE)

Y	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Yttrium	Gado-linium	Ter-bium	Dys-prosium	Hol-mium	Erbium	Thulium	Ytter-bium	Lute-tium

Leichte Seltene Erden (engl.: light rare earth elements, LREE)

Sc	La	Ce	Pr	Nd	Pm	Sm	Eu
Scan-dium	Lanthan	Cer	Pra-seodym	Neodym	Prome-thium	Samar-ium	Euro-pium

Wikipedia, 2014, Ökoinstitut 2011



ENERGY GEORESOURCES

Resource Market –not only driven by demand

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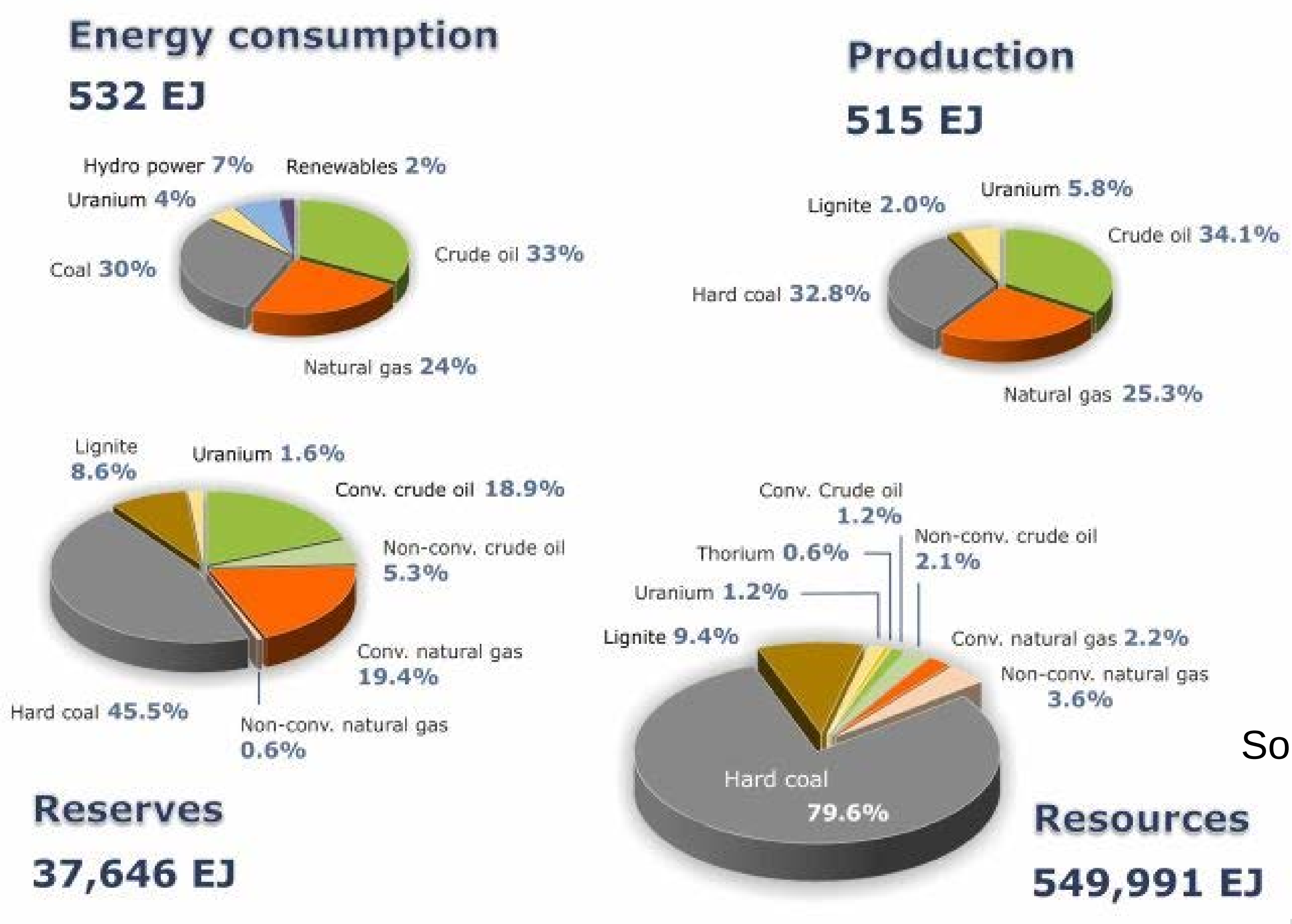
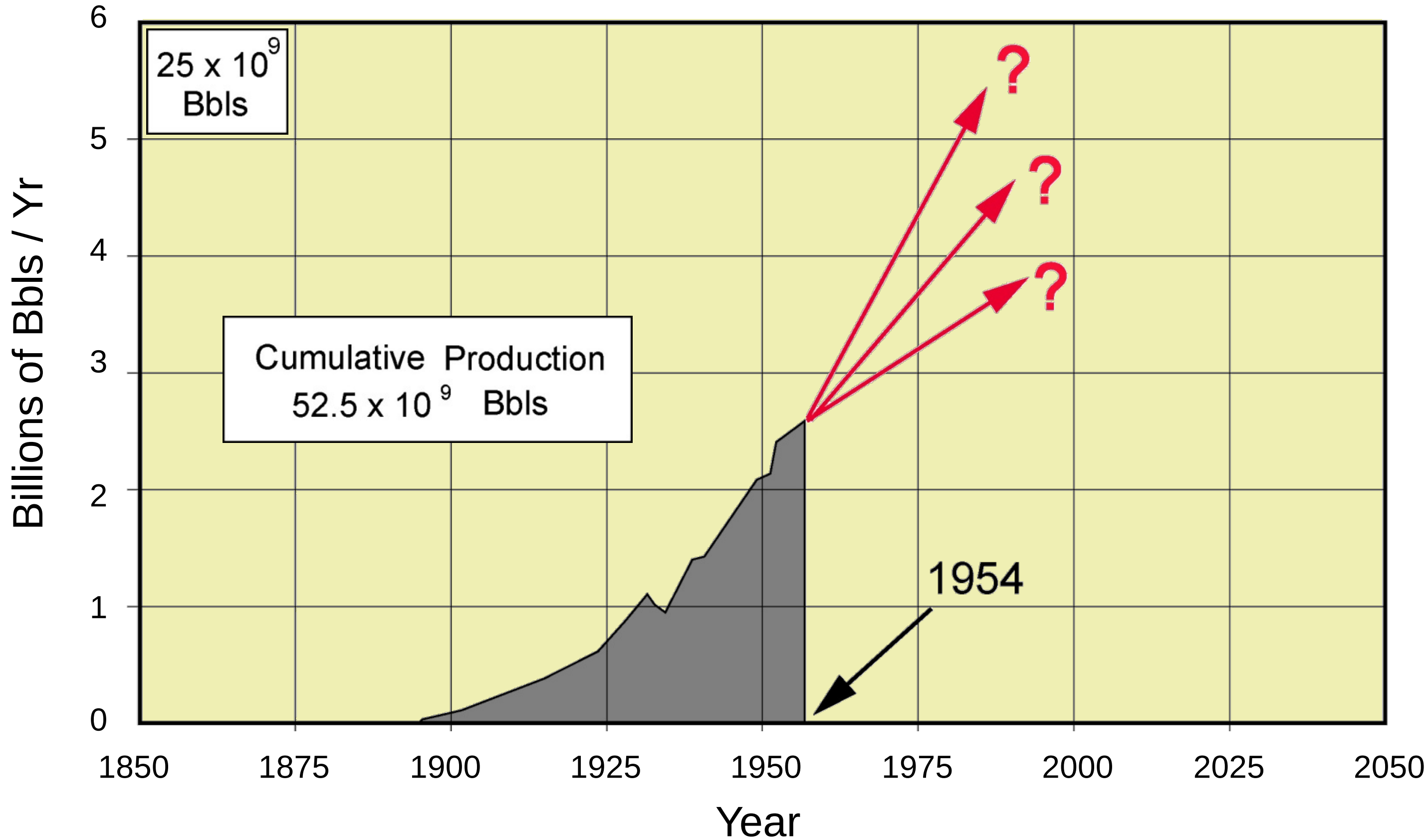
Prodekan Geowissenschaften

Global shares of all sources of energy in consumption (BP 2014) and the shares of non-renewables in production, reserves and resources, as at the end of 2013



Source: BGR

Lower 48 US Crude Oil Life Cycle

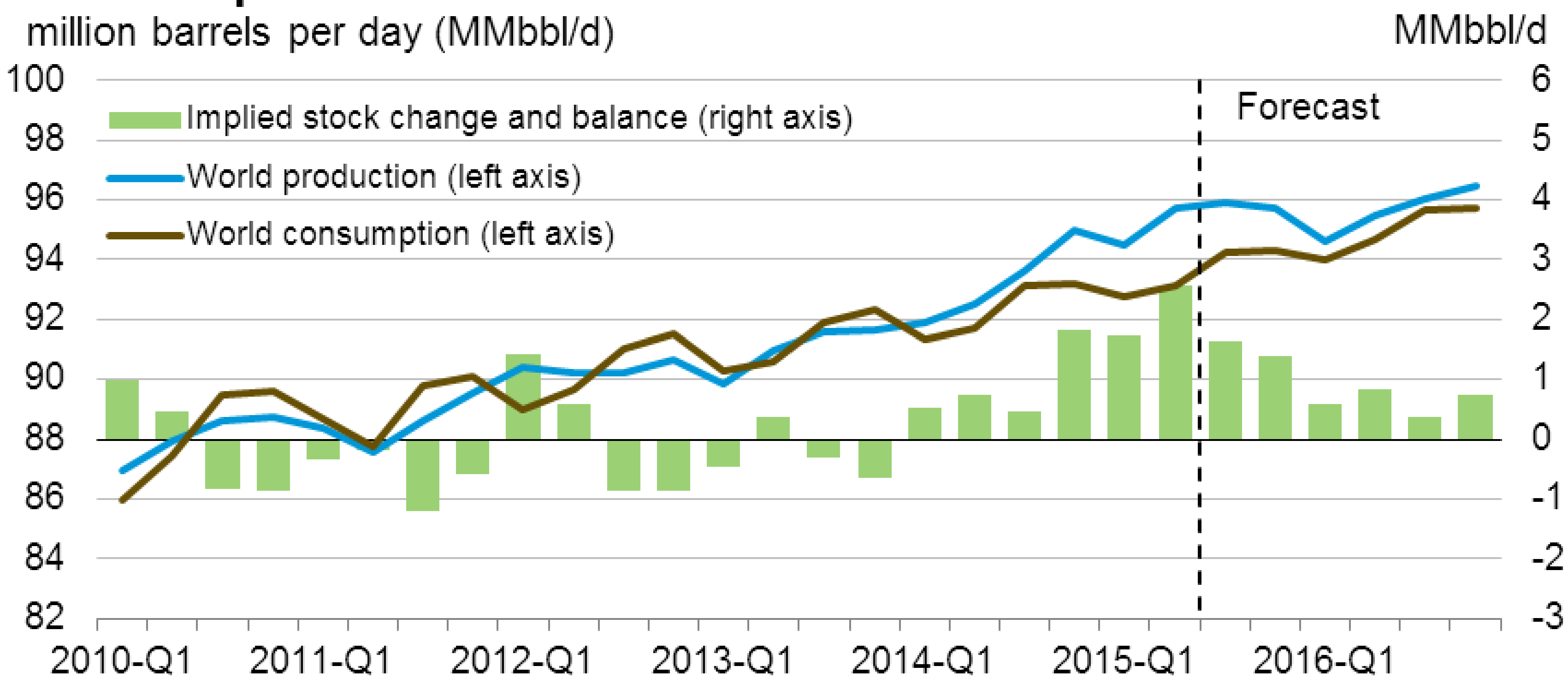


The cycle is based on assumed ultimate recovery of 150 and 200 billion bbls.

Mod: Hubbert, 1956

World Liquid Fuels Production and Consumption Balance

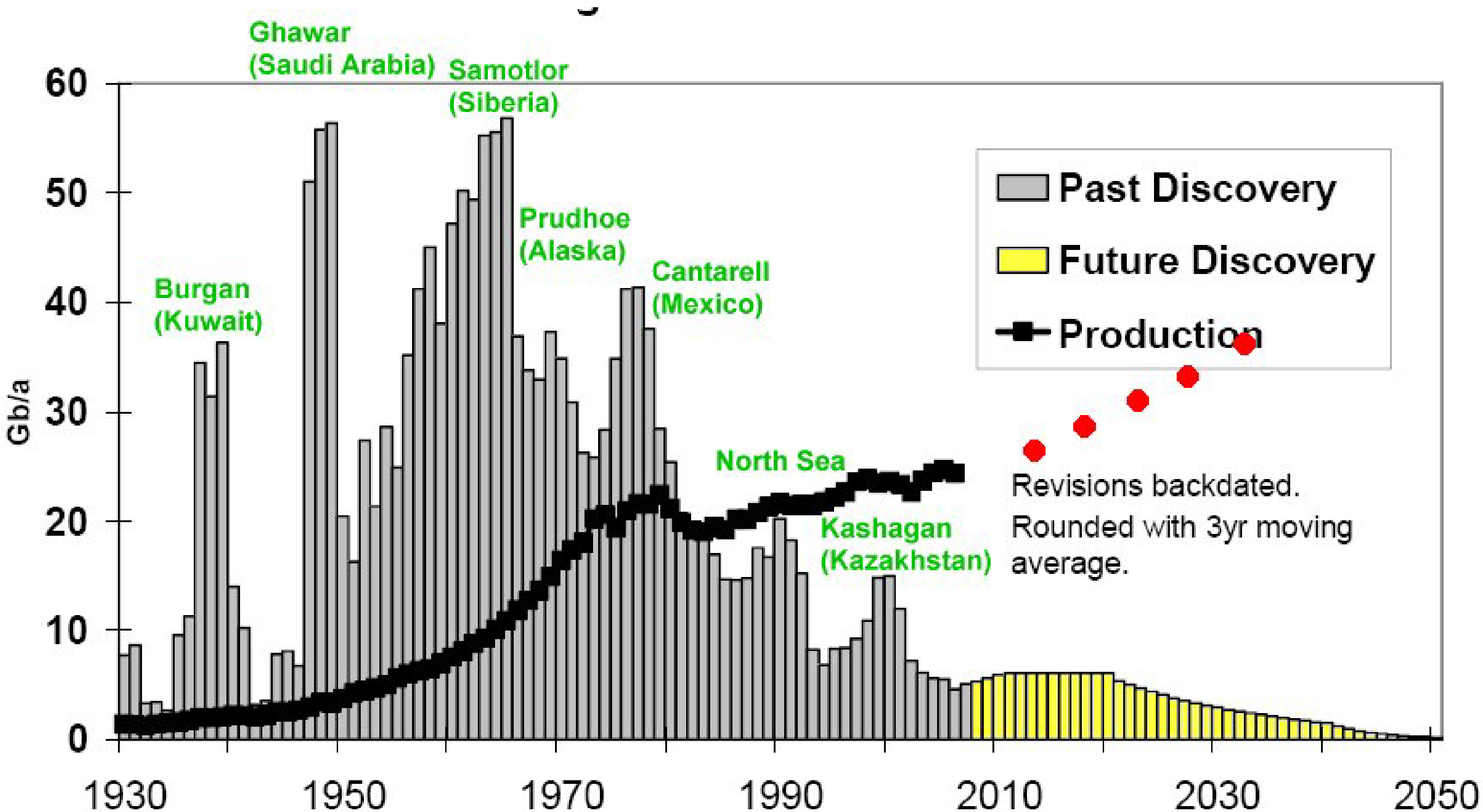
million barrels per day (MMbbl/d)



Source: Short-Term Energy Outlook, July 2015.

The Growing Gap – Regular Conventional Oil

Major oil discoveries are behind us…



There is a growing gap between discoveries and production.-

→ Soon there will be a gap between production and demand

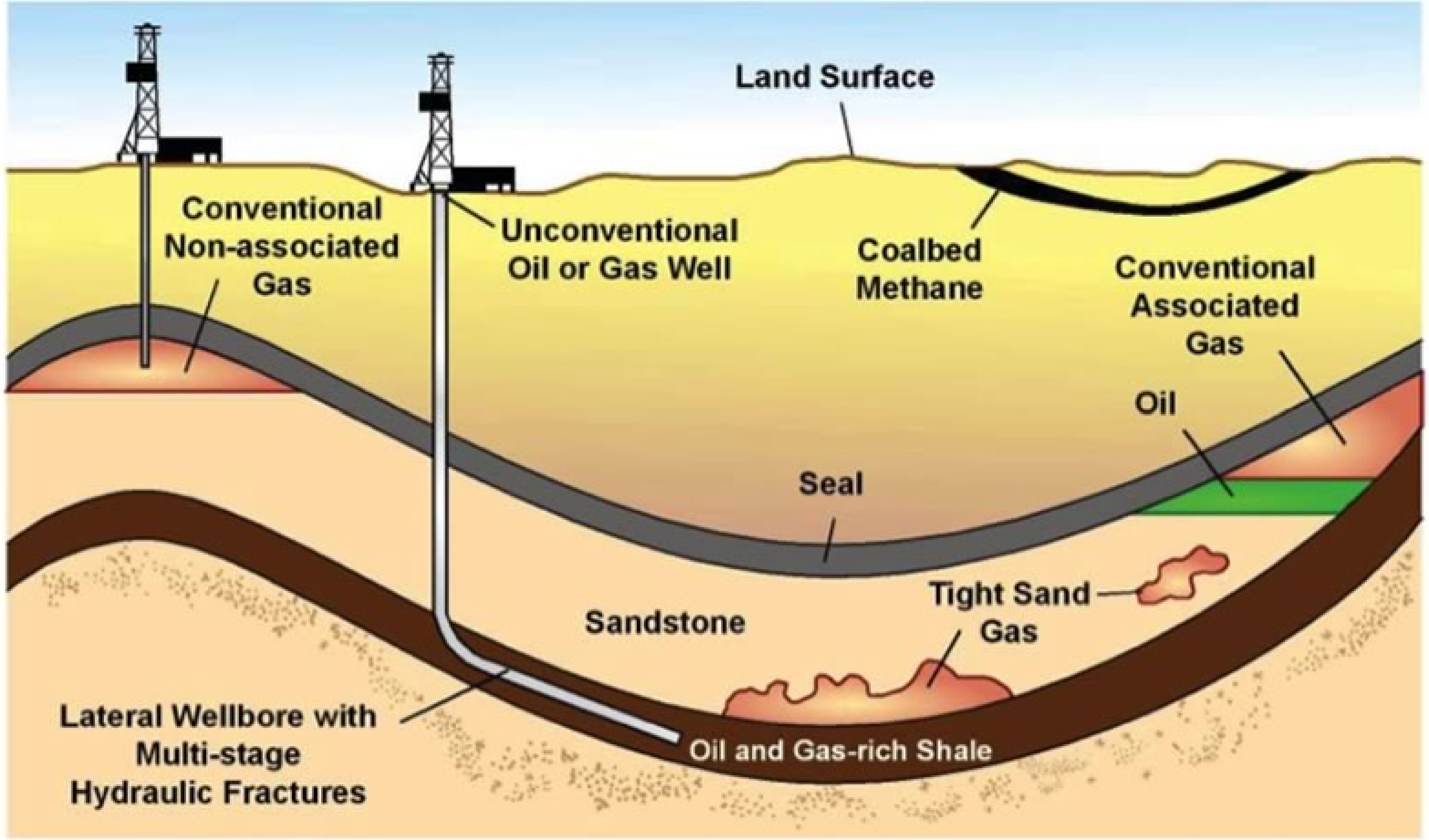
Hypothesis:
Oil Market is Supply Driven

- If I would have an oil field worth 10 Billion US$, I would find a way to sell the oil

- However, most “Energy Scenarios” are modeled as an only “demand driven market”

Conventional and Unconventional Oil and Gas

The Geology of Conventional and Unconventional Oil and Gas



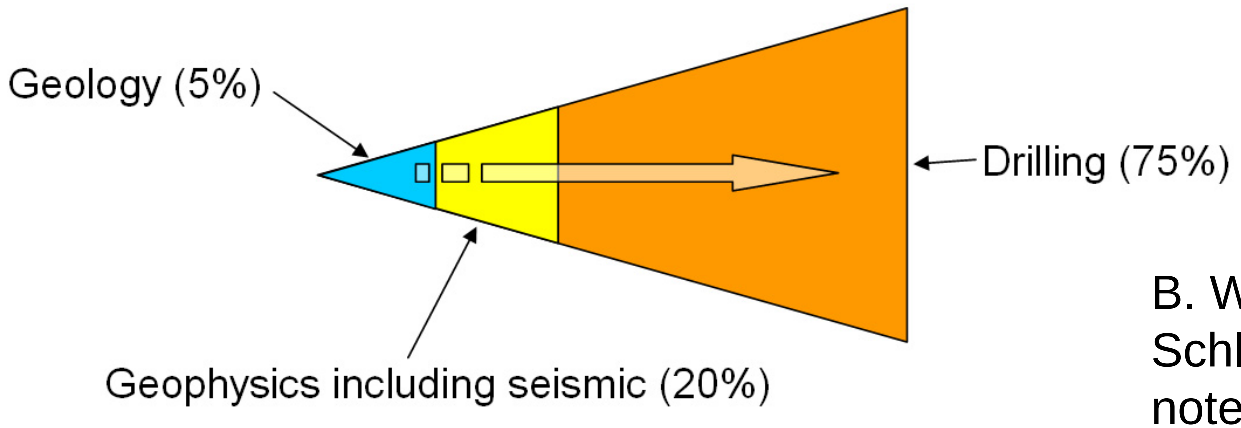
Source: EIA

EXPLORATION

Oil and Gas

What has to be considered?

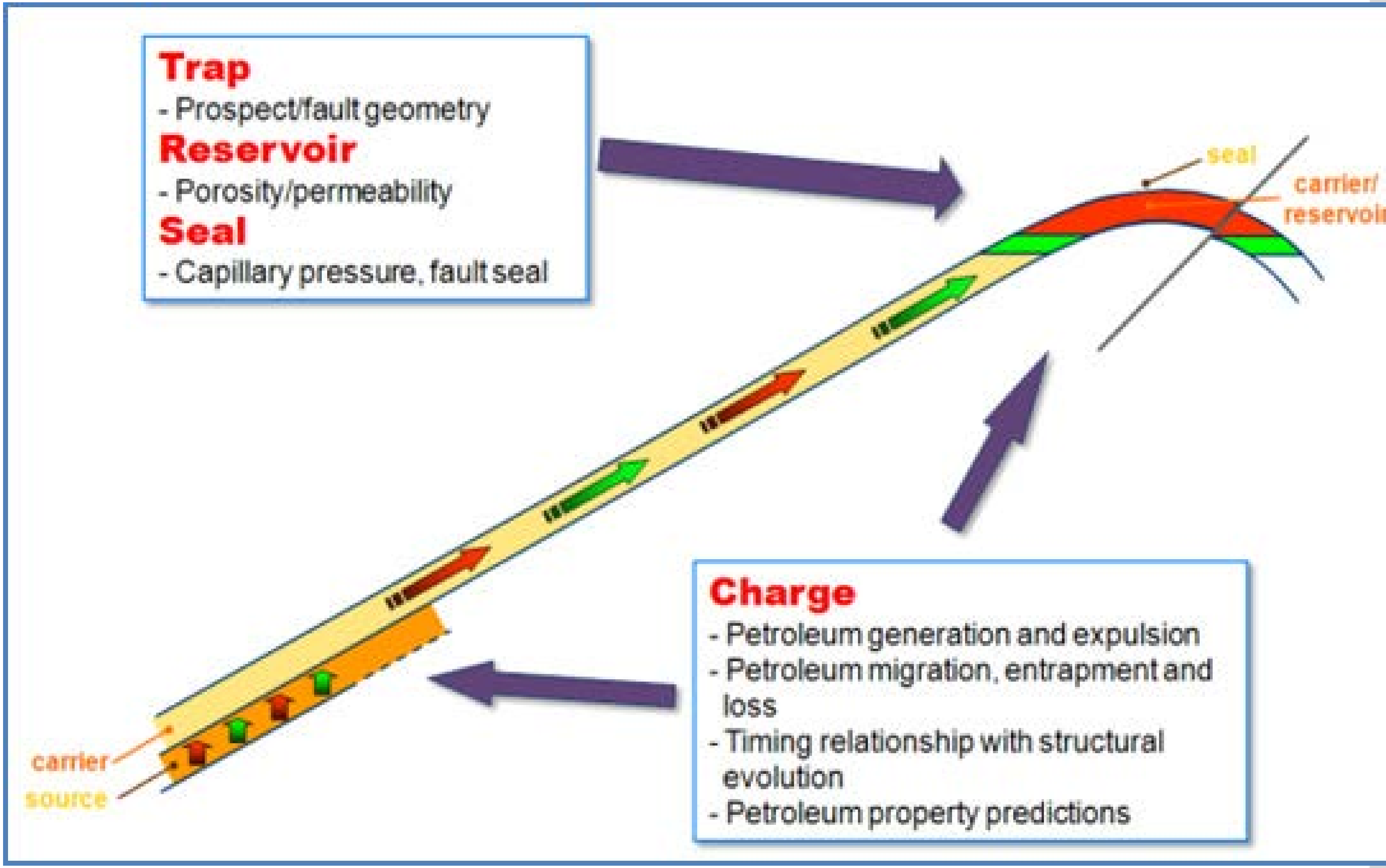
- the **Trap** (geometry, reservoir, seal)
- \- the **Hydrocarbon Charge** (the amount of hydrocarbons which can reach the trap)
- \- the **Timing** relationship between the Charge and the formation of the Trap.

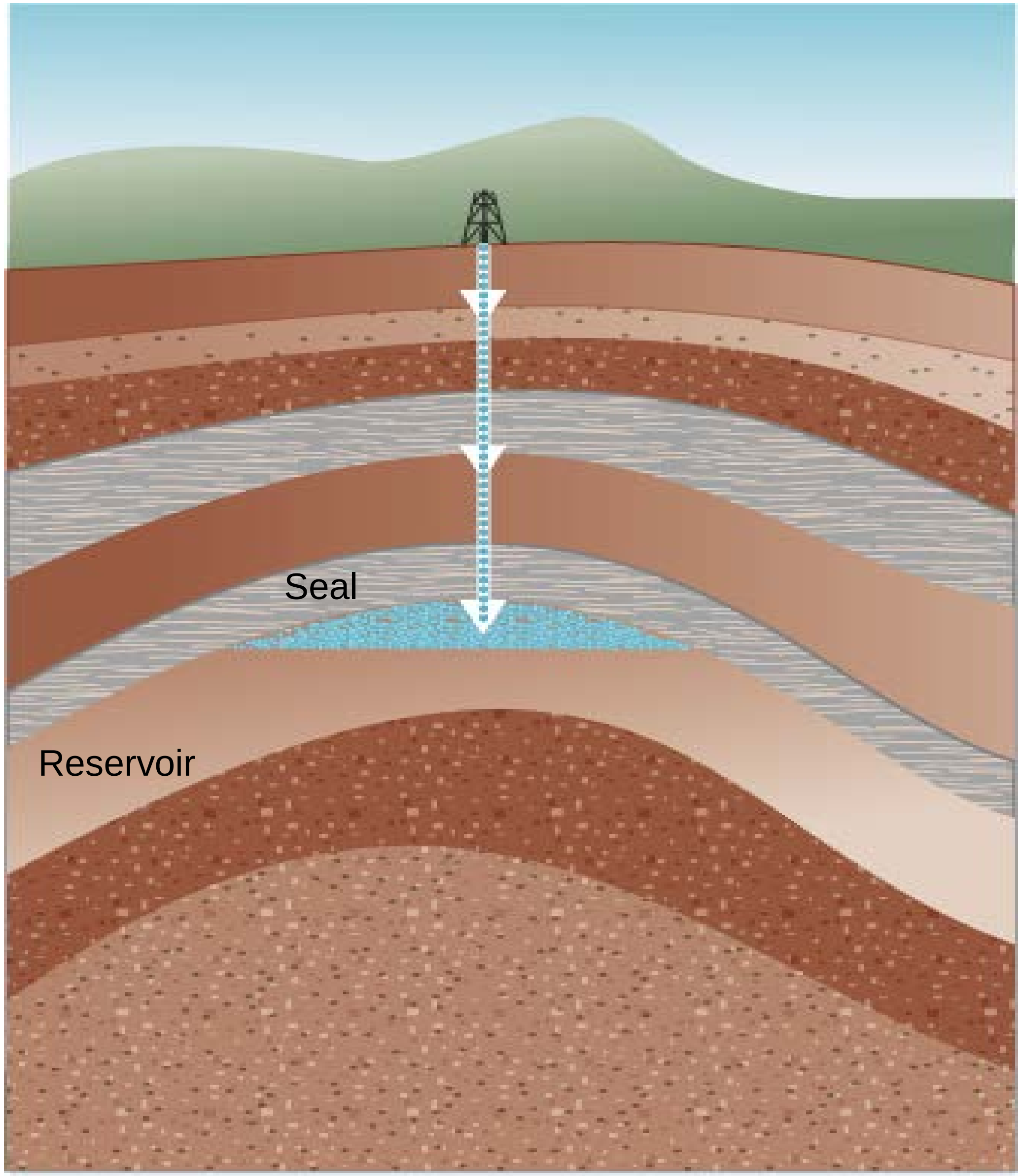


The geoscience component of petroleum exploration contributes only a small part to the total costs

B. Wygrala, Schlumberger, lecture notes, 2012

Geological Factors in Exploration



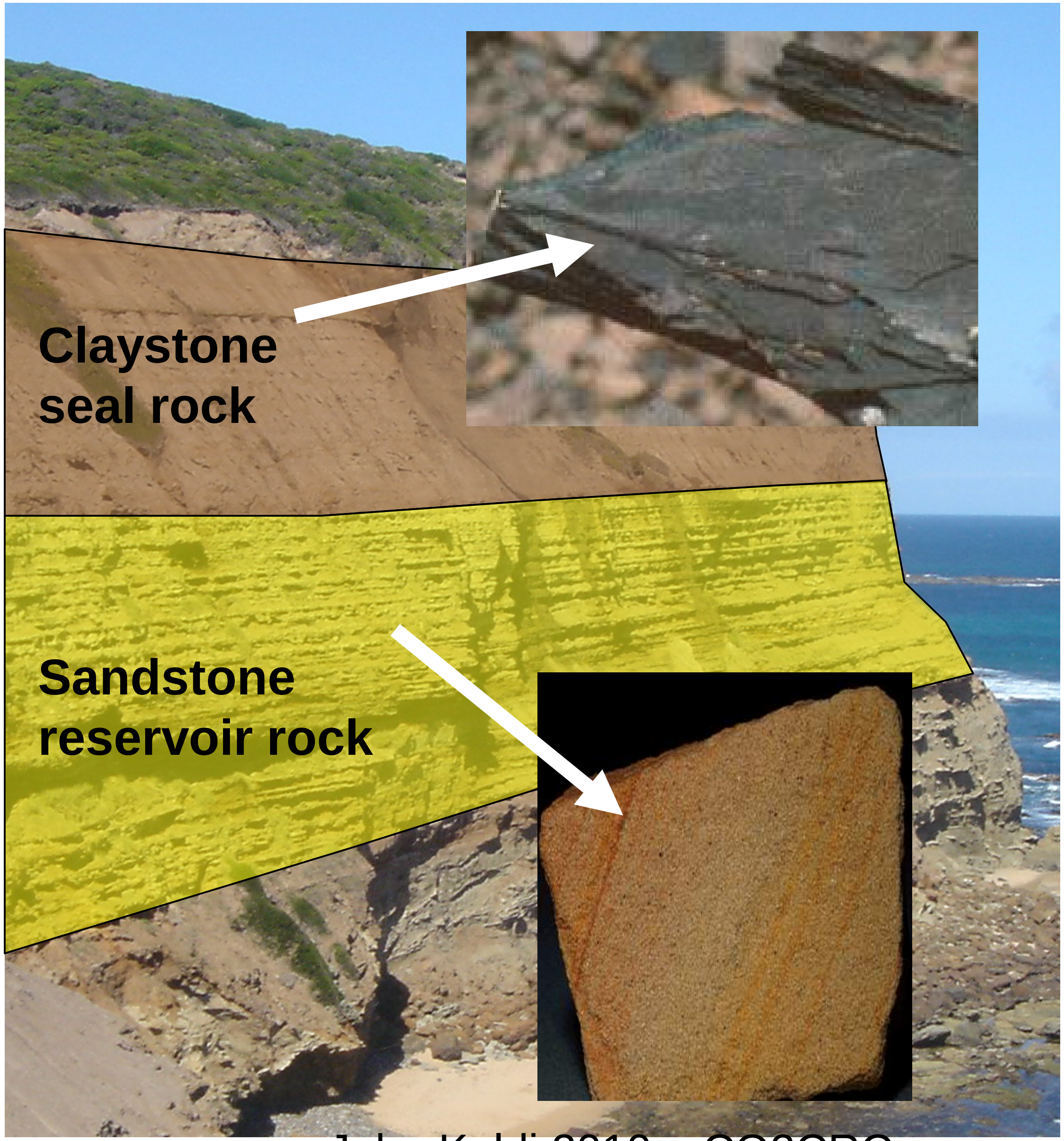


Structural Trap Reservoir

Anticline

- Buoyancy drives hydrocarbons upwards
- Top seal prevents escape
- Such features have safely held oil, gas & natural accumulations of CO_2 for millions of years and can also serve as storage sites

Geological Reservoir



John Kaldi 2010 – CO2CRC

What do we need?

- **RESERVOIR ROCK – porous, e.g. sandstone**
- **SEAL ROCK – non-porous, e.g. claystone**

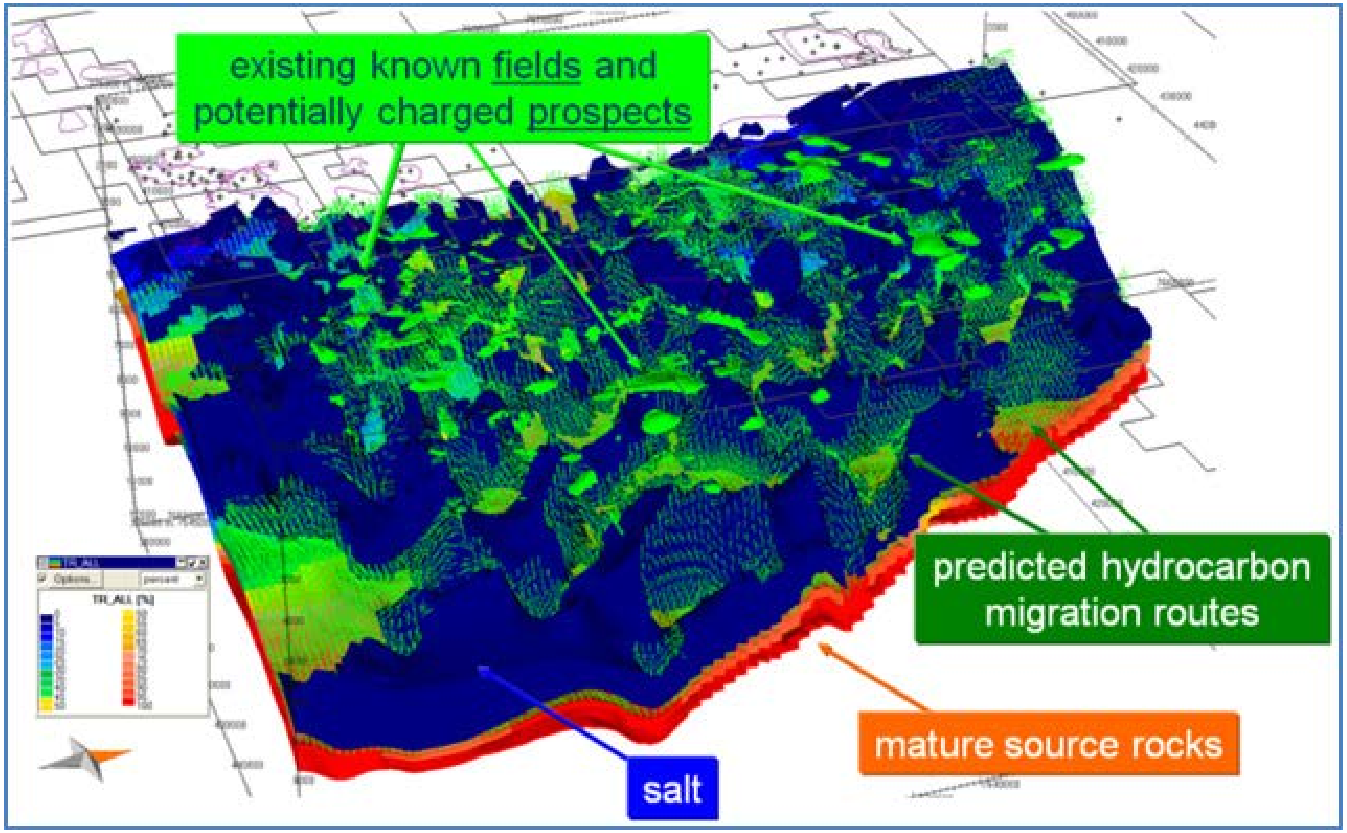
How does it work?

- **Hydrocarbons are in porous reservoir rock**
- **Hydrocarbons held in place by overlying non-porous seal rock**

Standard Exploration Procedure

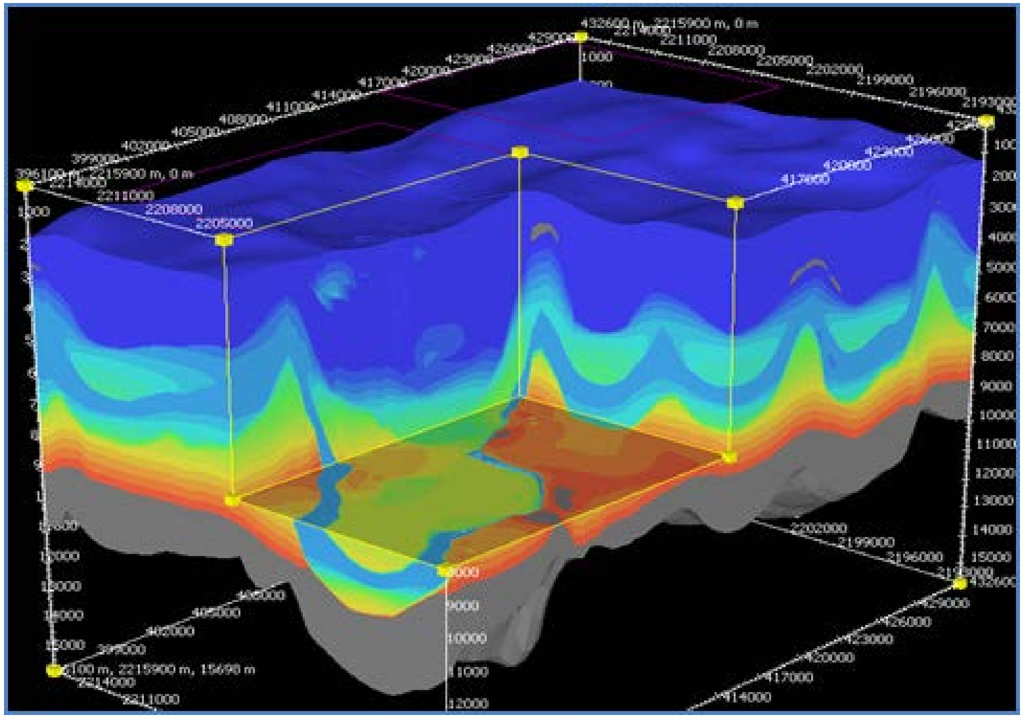
- Surface Surveys (aerial photography, satellite, imaging radar, topographical and geological mapping)
- Subsurface survey (gravitational pull, magnetic fields, seismic studies)
- Exploration Well

Petroleum System Models

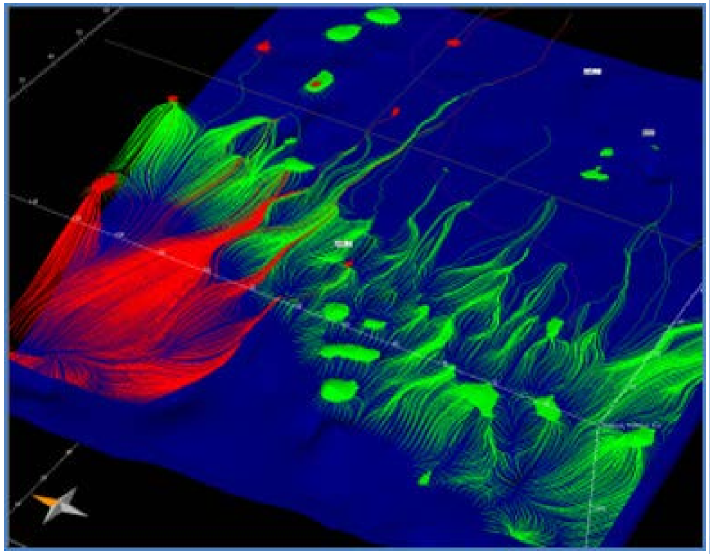


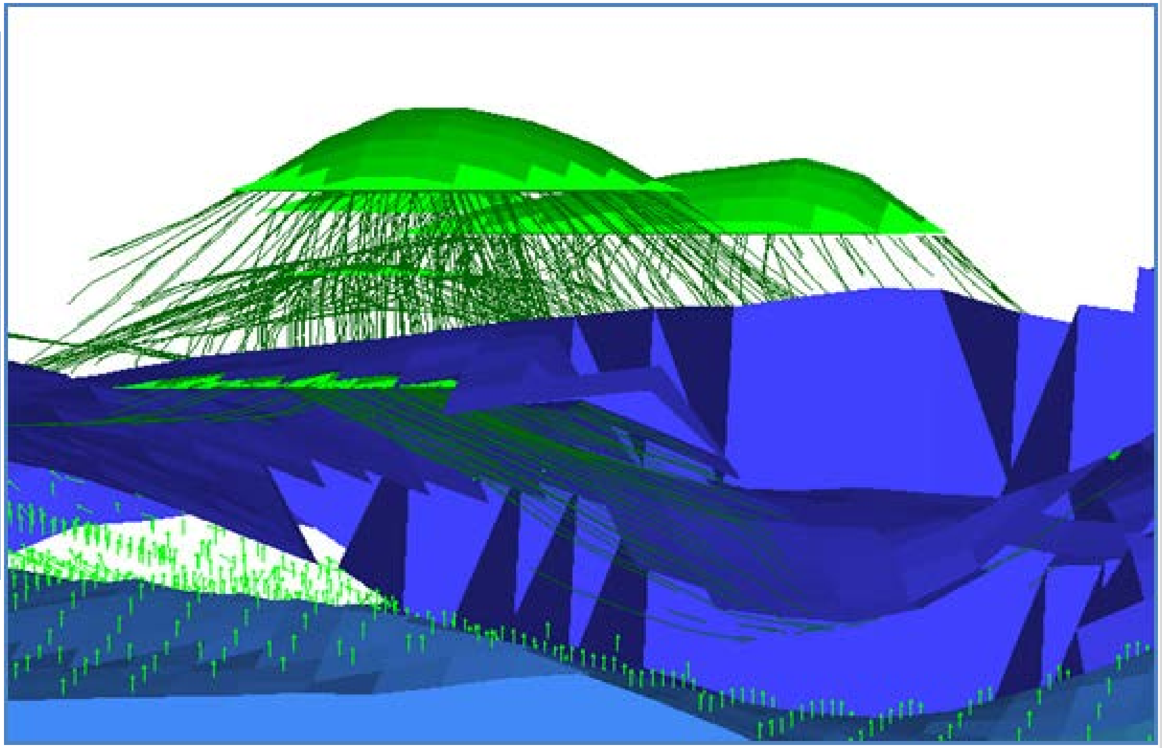
Pore Pressure Prediction

- To determine compaction behaviour
- To detect regions of over or underpressure



Flowpath Modelling

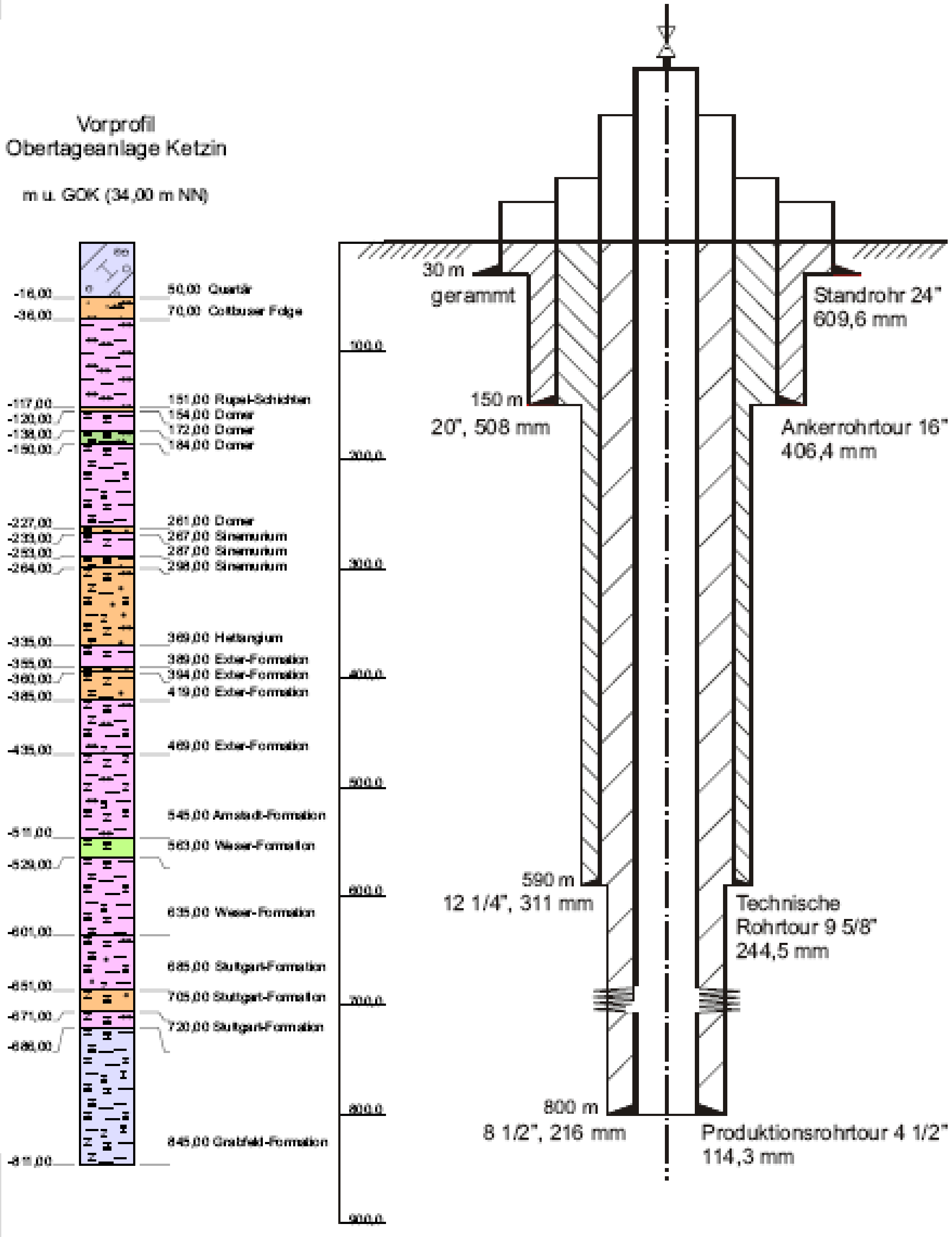




vectors indicate petroleum expulsion from source rocks modeled with Darcy flow, and the dark green Flowpath flowlines indicating petroleum migration in higher-permeability units into petroleum accumulations. The dark blue colours show salt.

TOWARDS PRODUCTION: DRILLING

Wellbore


Vorprofil
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m u. GOK (34,00 m NN)
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-36,00
-117,00
-120,00
-138,00
-150,00
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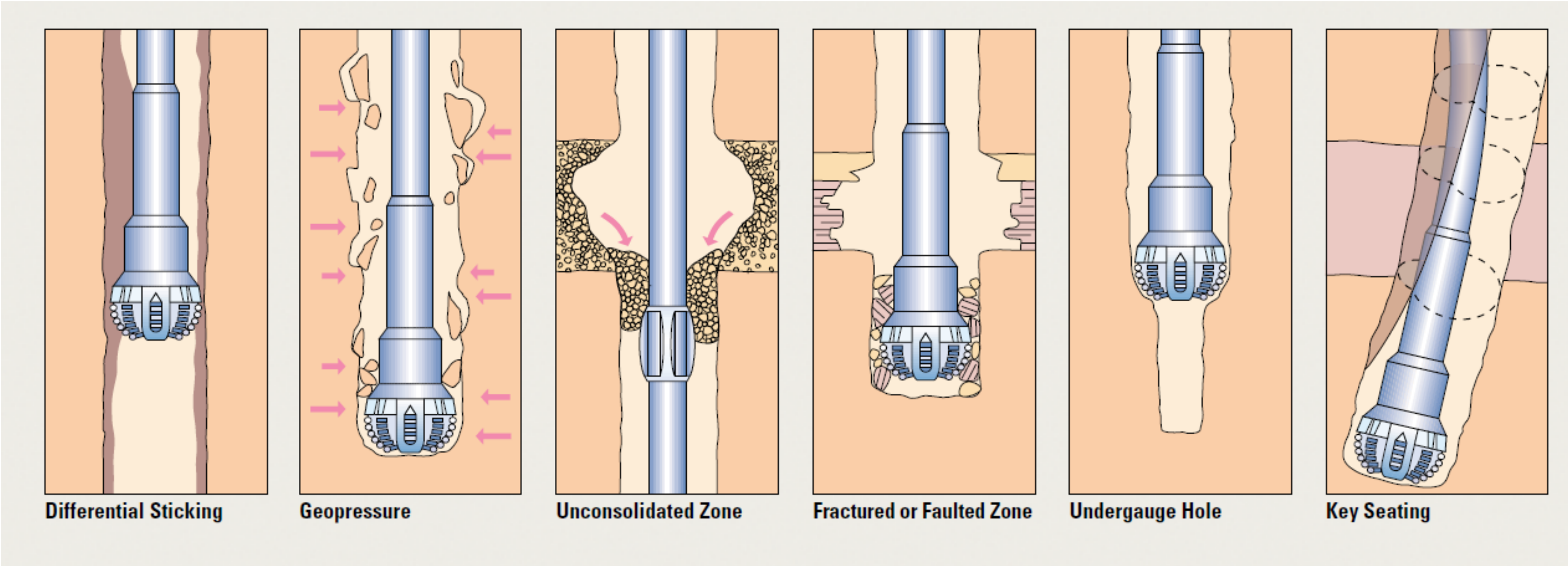
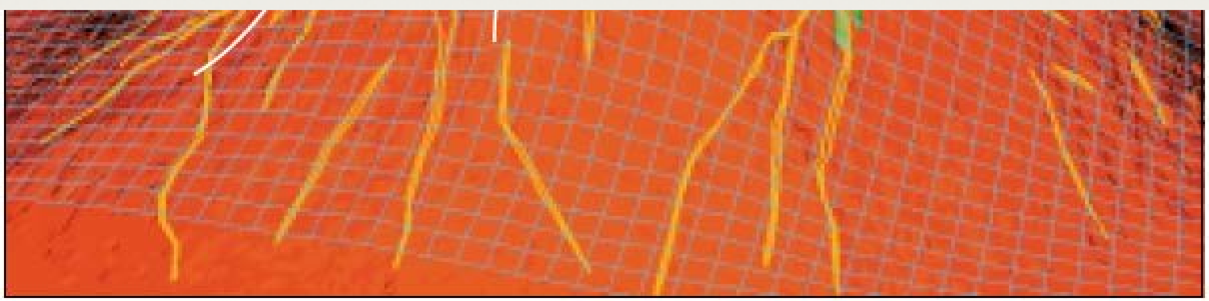
-253,00
-264,00
-335,00
-355,00
-360,00
-385,00
-435,00
-511,00
-529,00
-601,00
-651,00
-671,00
-686,00
-811,00
50,00 Quartär
70,00 Cottbuser Folge
151,00 Rupel-Schichten
154,00 Domer
172,00 Domer
184,00 Domer
261,00 Domer
267,00 Sinemurium
287,00 Sinemurium
298,00 Sinemurium
369,00 Hettangium
389,00 Exter-Formation
394,00 Exter-Formation
419,00 Exter-Formation
469,00 Exter-Formation
545,00 Arnstadt-Formation
563,00 Weser-Formation
635,00 Weser-Formation
685,00 Stuttgart-Formation
705,00 Stuttgart-Formation
720,00 Stuttgart-Formation
845,00 Grabfeld-Formation
100,0
200,0
300,0
400,0
500,0
600,0
700,0
800,0
900,0
30 m
gerammt
Standrohr 24"
609,6 mm
150 m
20", 508 mm
Ankerrohrtour 16"
406,4 mm
590 m
12 1/4", 311 mm
Technische
Rohrtour 9 5/8"
244,5 mm
800 m
8 1/2", 216 mm
Produktionsrohrtour 4 1/2"
114,3 mm

Drilling is an expensive task….

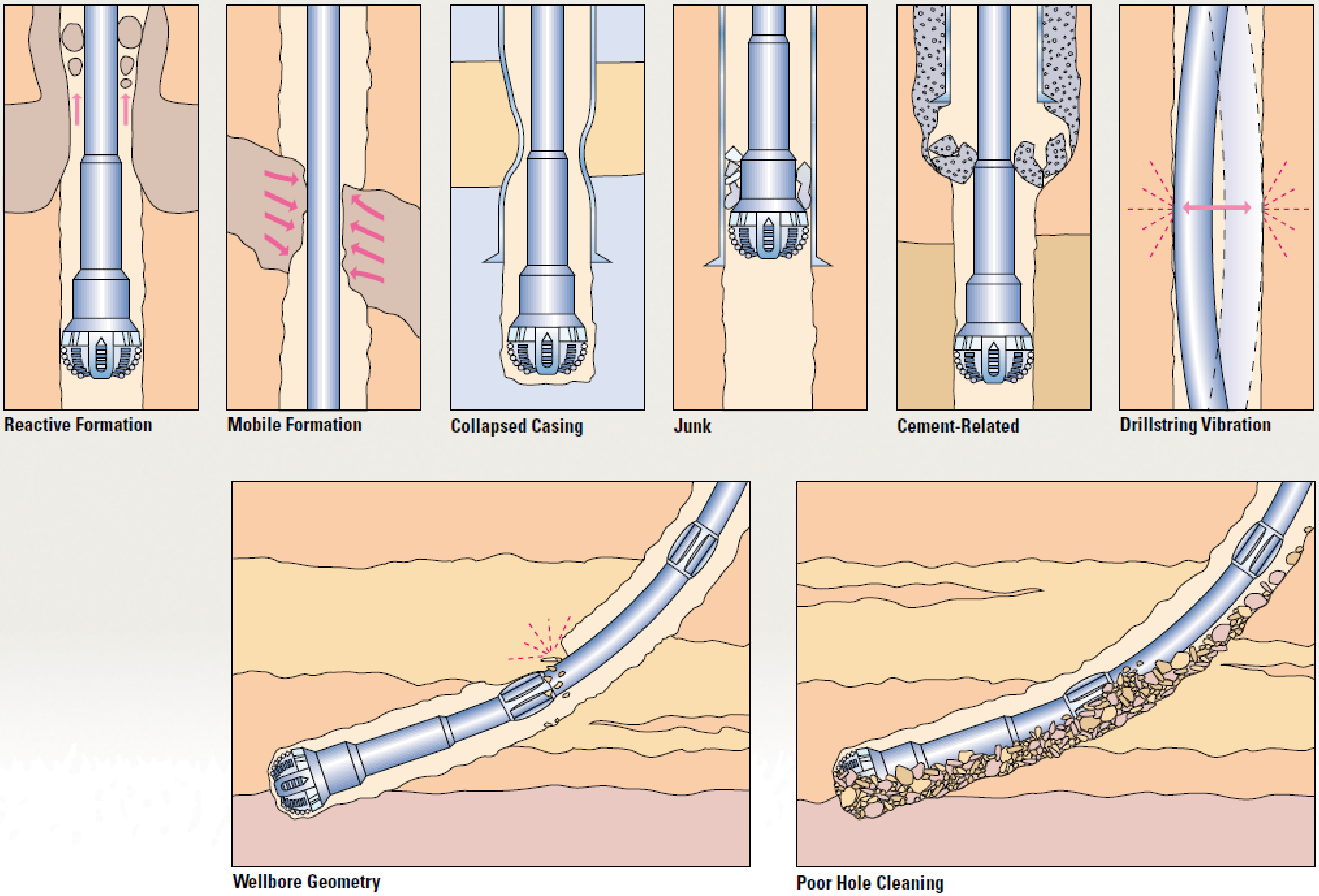
Drilling Risks:





^ Structure of the salt dome responsible for the Mungo field accumulation. White curves are well trajectories and the yellow lines on the dome are interpreted faults.

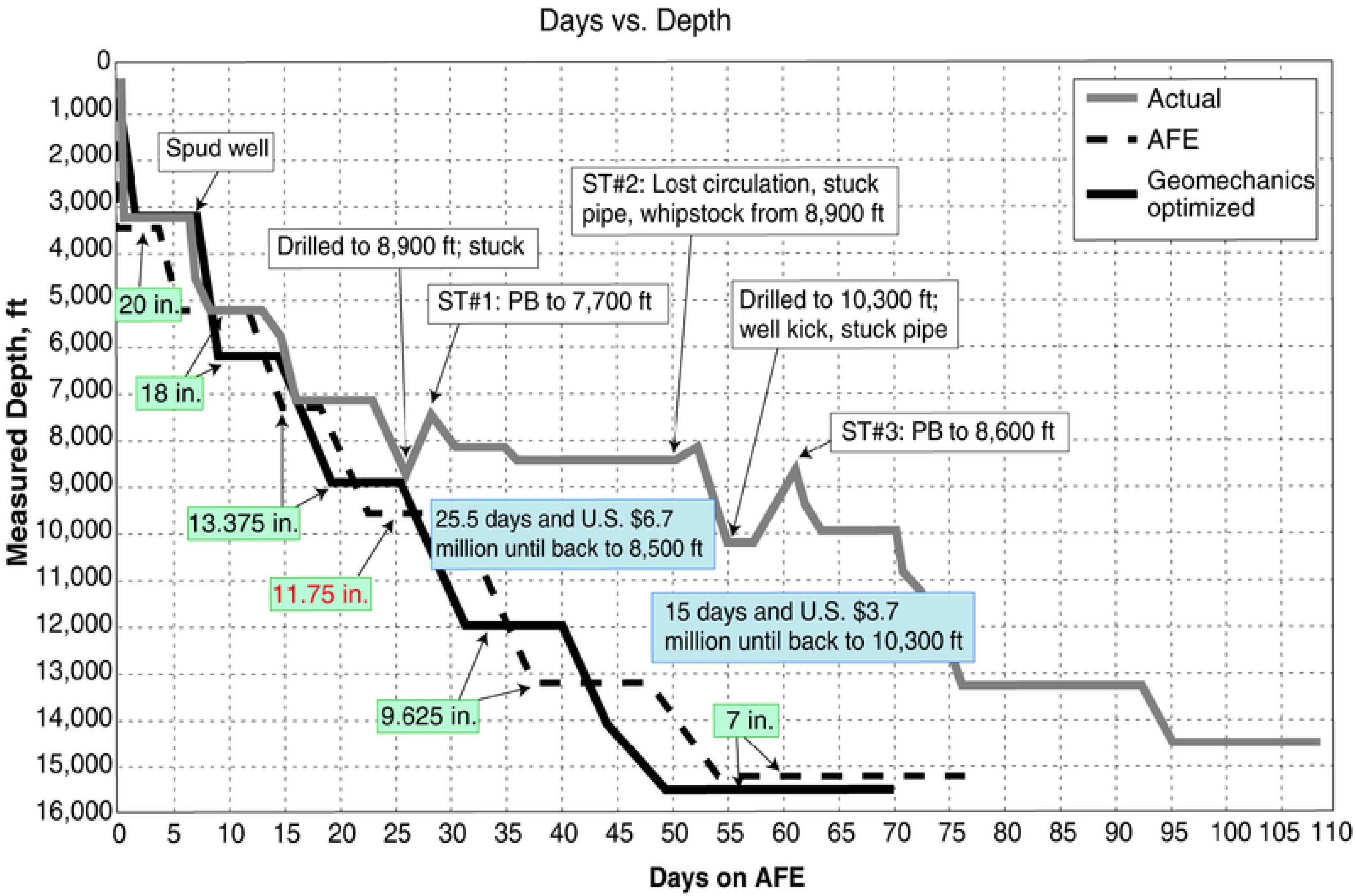
Aldred et al., 1999



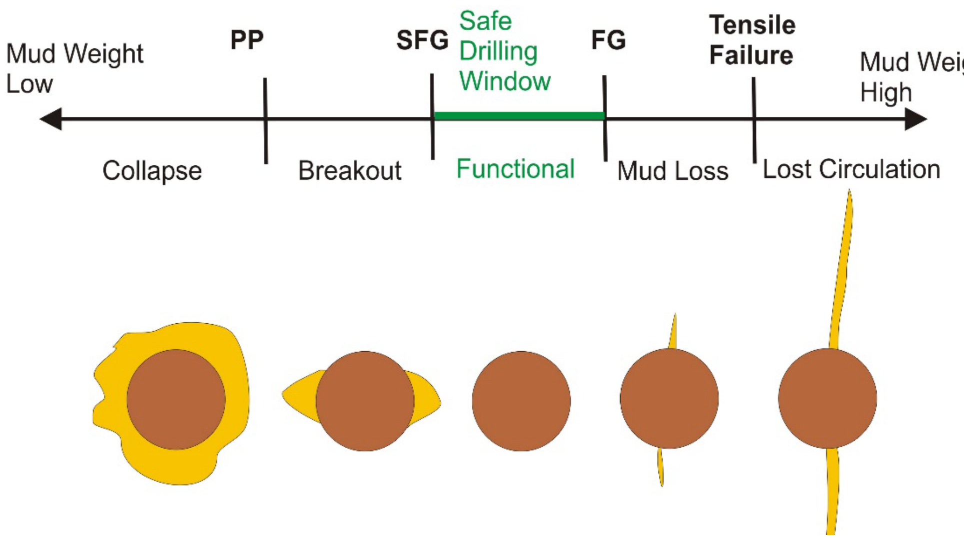
^Common drilling problems.

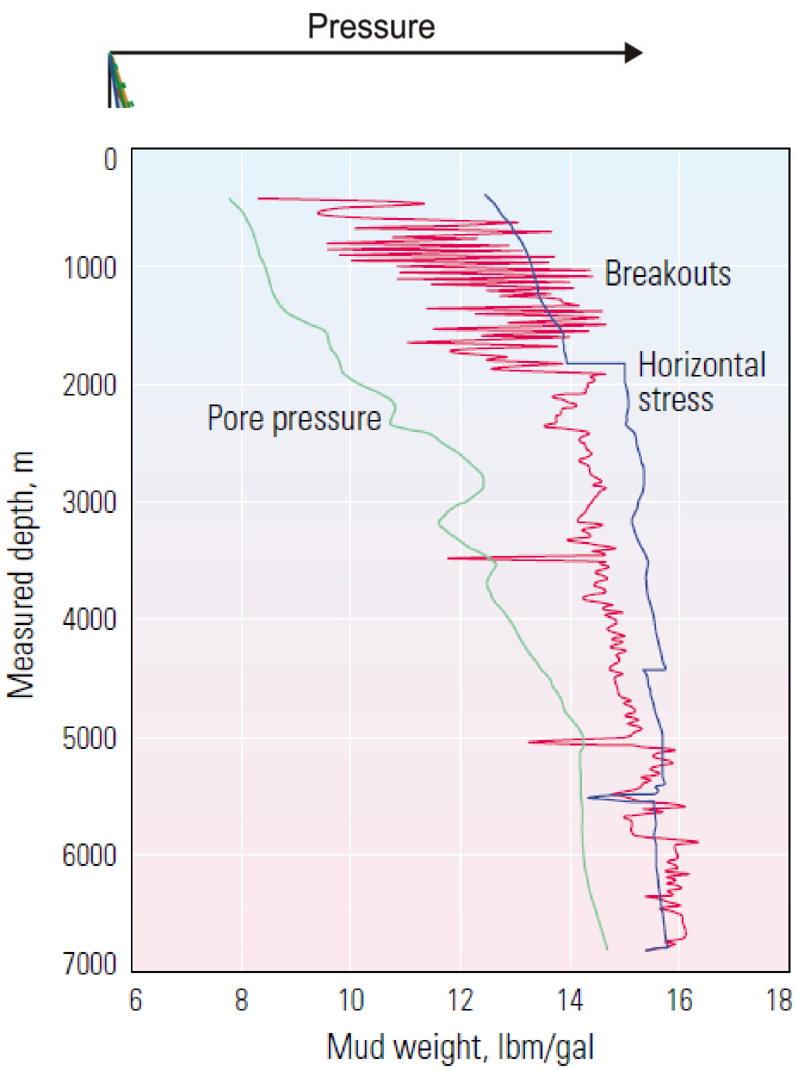
Aldred et al., 1999

Depth vs time of an offshore well



Safe Mud Weight Window





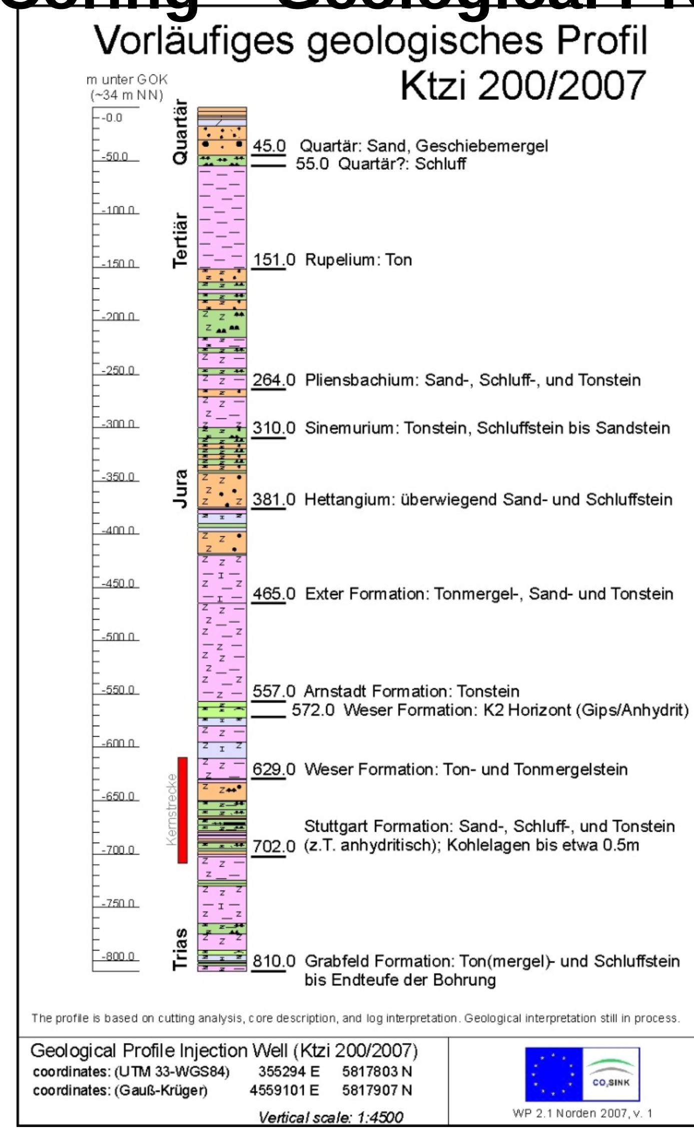
Aldred et al., 1999

Monitoring within the well - Logging

- Mud Log
- Caliber log
- Resistivity
- NMR Log
- Sonic Log
- Bond Log
- Microfrack
- Fluid composition
- …

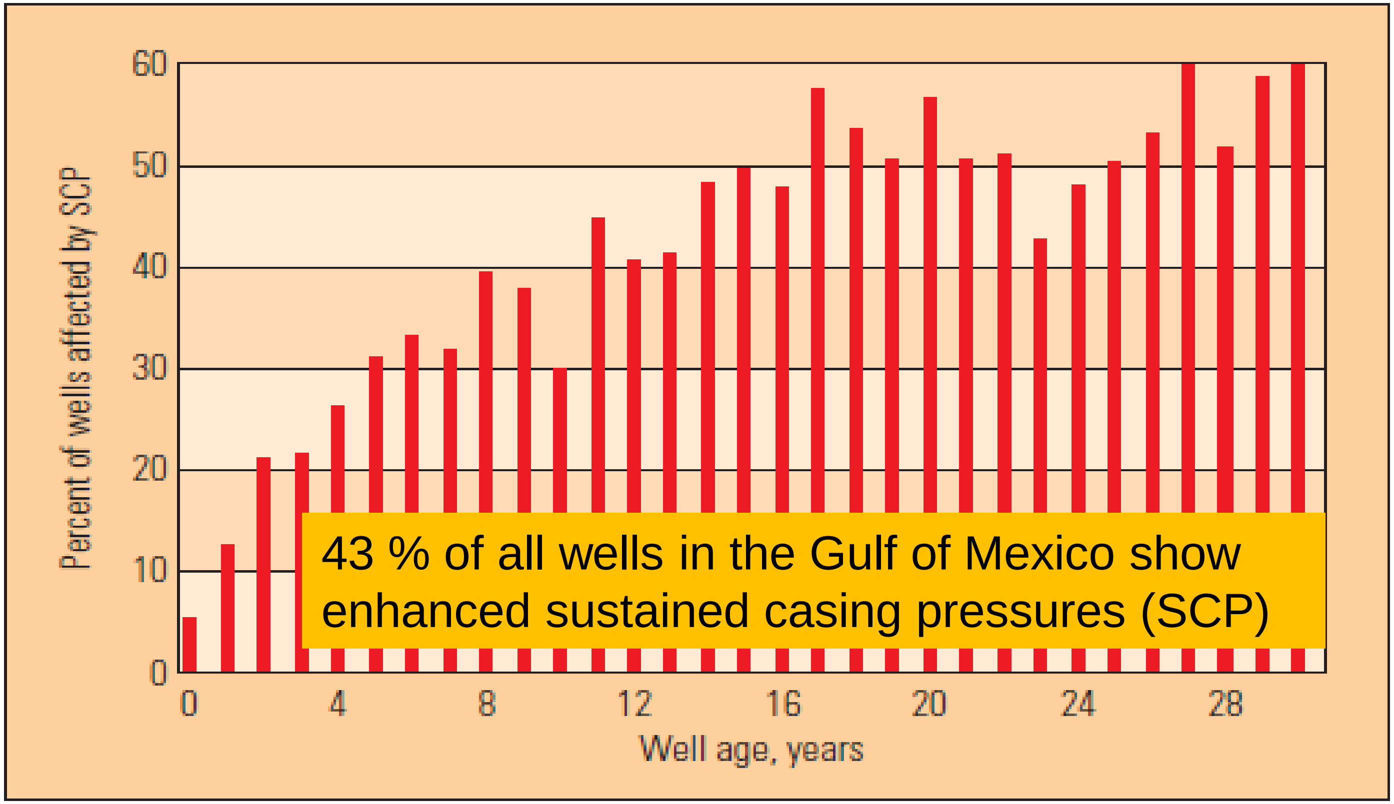
one should learn and know as much as possible about the reservoir

Coring – Geological Profile



Norden *et al.* – 2007

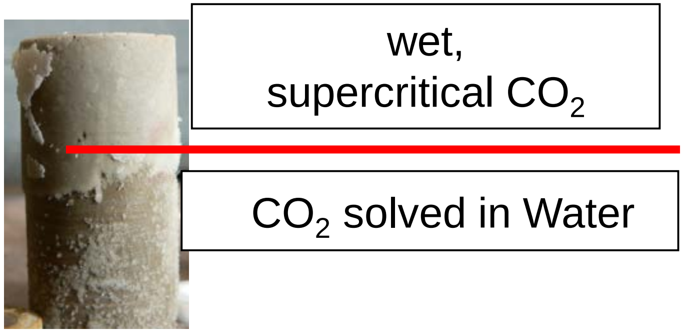
Well Integrity – the Reality



Brufatto *et al.*, 2003

COBRA Project: The basic Idea

Large Scale Experiments: Development of a 1:1 **Experimental Setup** for *in-situ* tests of well integrity and abandonment concepts

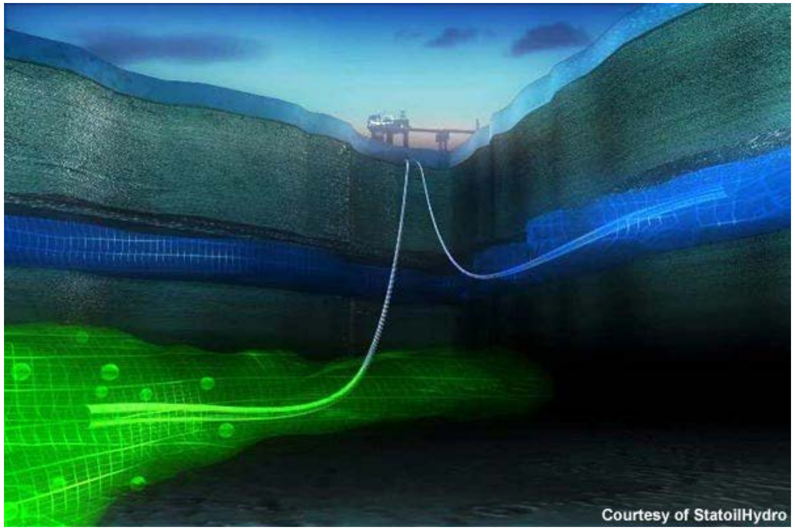


to bridge the scale from

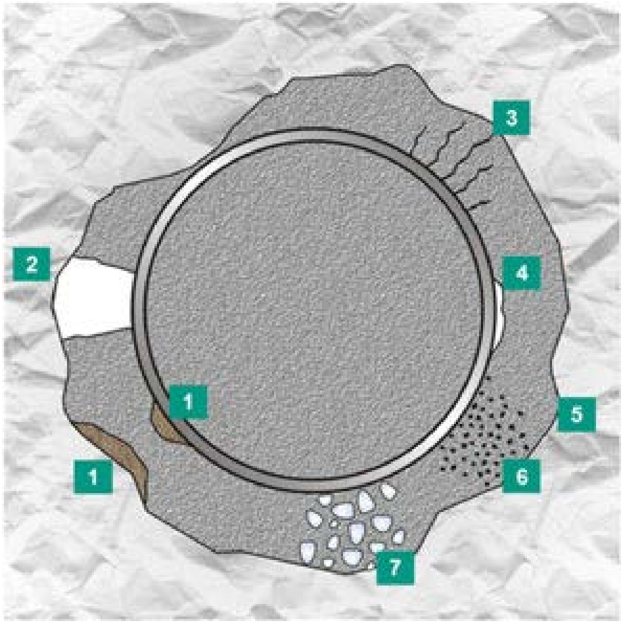
Laboratory-Experiments (cm – Scale)

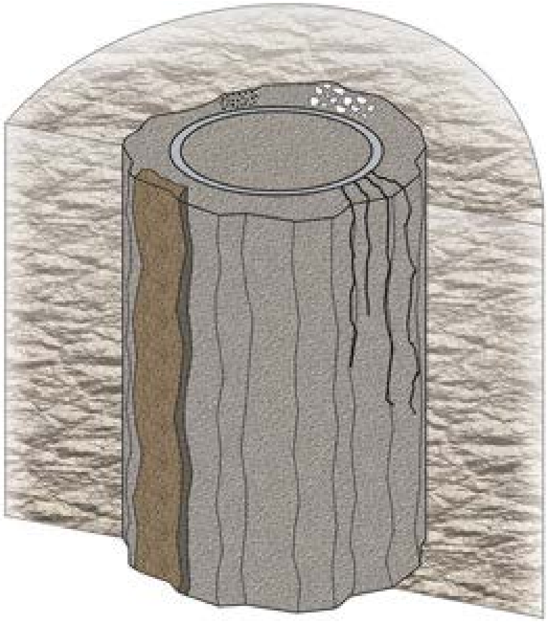
to

Field experiments (km-Scale)



Backfilled borehole - casing and cementation flaws



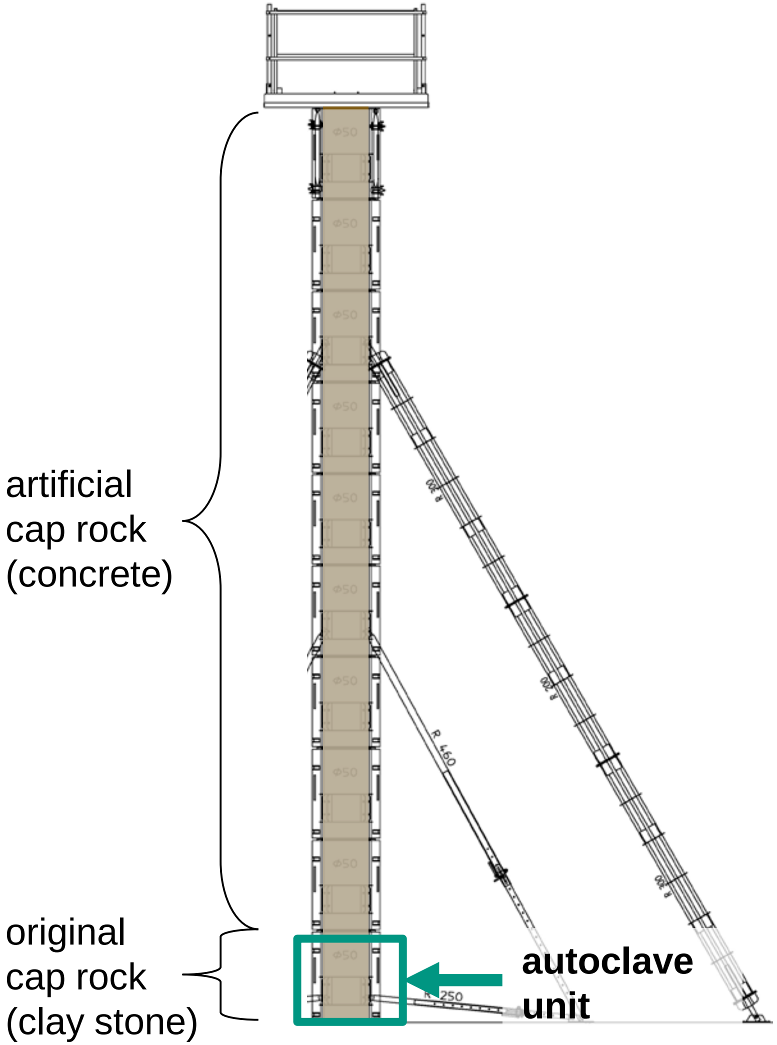


1 and 2 channels filled with and without mud,
which can form during cementation, 3 cracks, 4 gap, 5 micro-annuli, 6 higher permeable area and
7 invaded gas (Kromer et al. 2014)

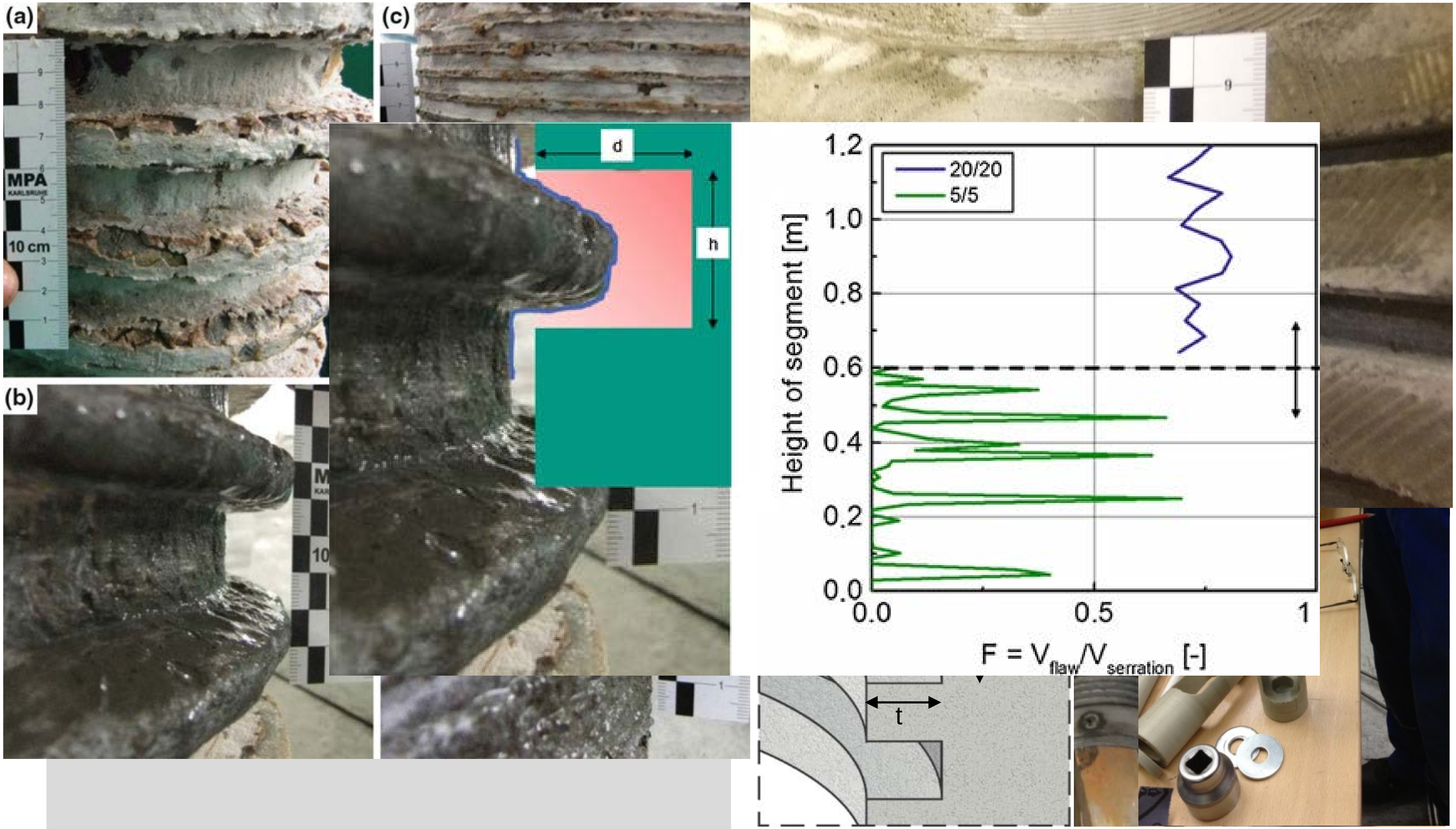
Cementation process

10 m borehole from cap-rock elements

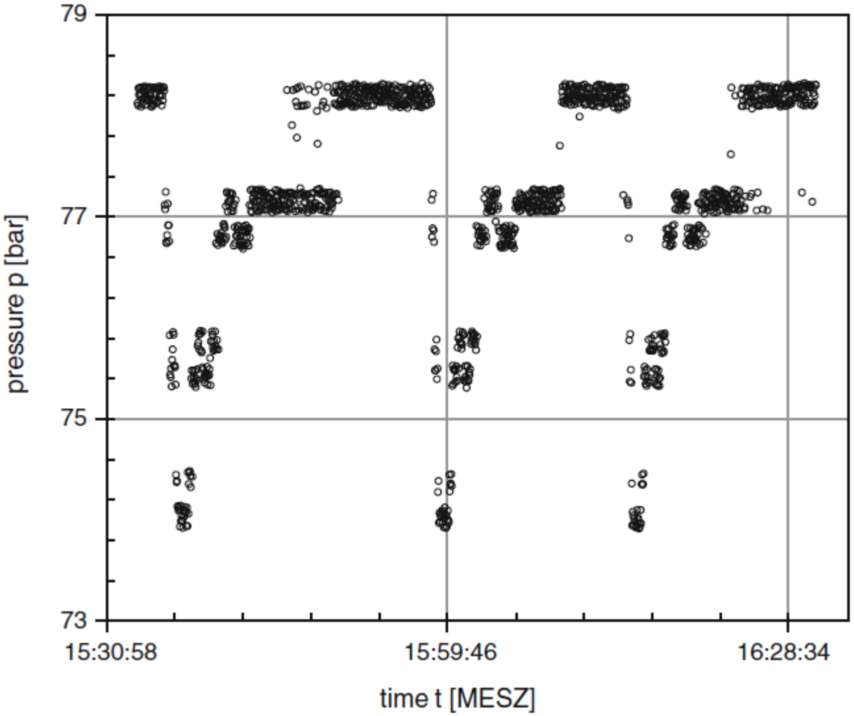
- heating of borehole to defined conditions up to 100°C
- filling of borehole with drilling mud, spacer fluid and cement-suspension
- monitoring of material properties: rheology, segregation behavior, pressure and temperature
- borehole and cementation sectionally disassembled
- quantification of cementation flaws
- lowest 1,2 m is put in the autoclave

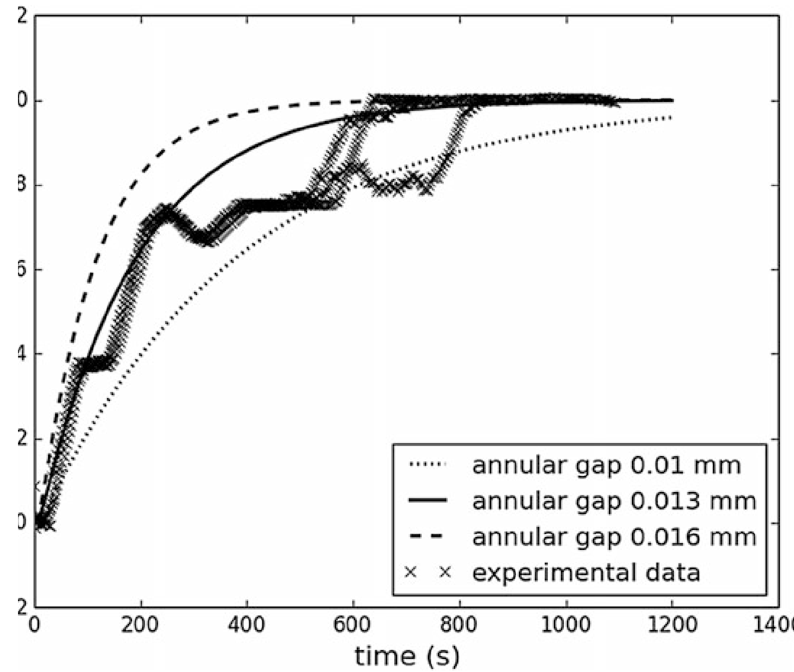


Cementation – experimental set-up



Modelled and Observed Pressure Data in the permeability experiments





Three times pressure reduction of the upper vessel by about 4 bar and reequilibration due to CO_2 migration during experiment 2.

INDUCED SEISMICITY IN RESERVOIR EXPLOITATION

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Induced Seismicity in Reservoir Exploitation

- Induced Seismicity and Stress: Mohr and More
- During Injection
  - Geothermal
  - Fracking (Hydraulic Fracturing)
  - Waste Water Injection
- During Production

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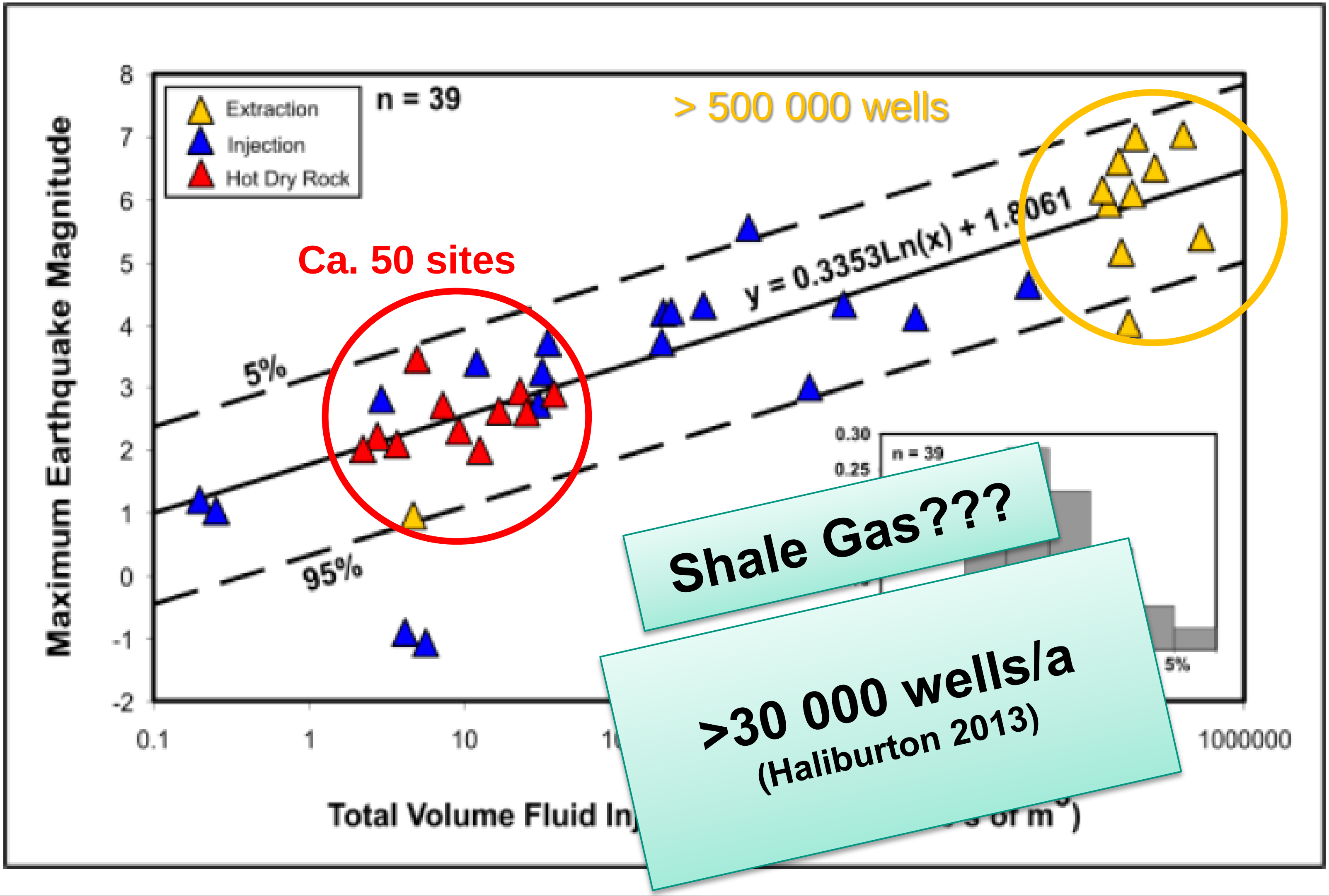
Prodekan Geowissenschaften

Maximum Magnitdes and Fluid Injection and Production

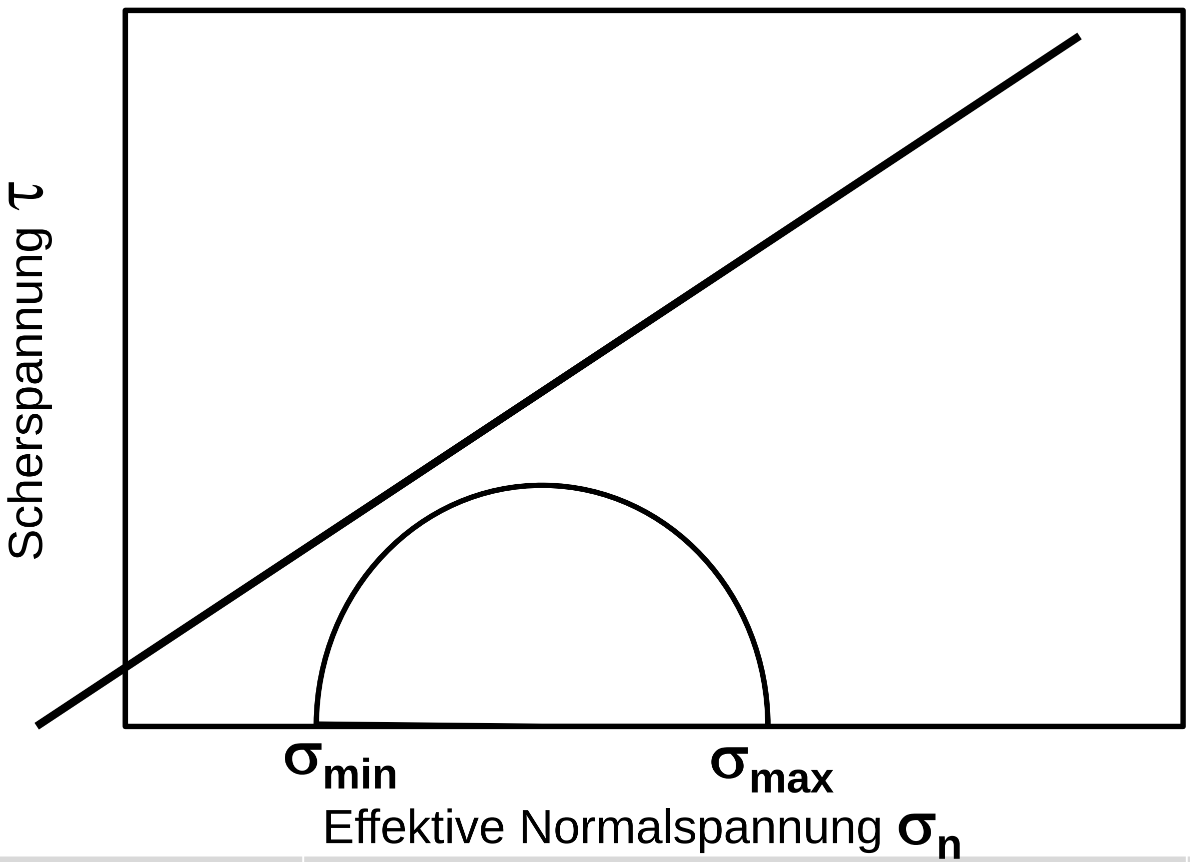


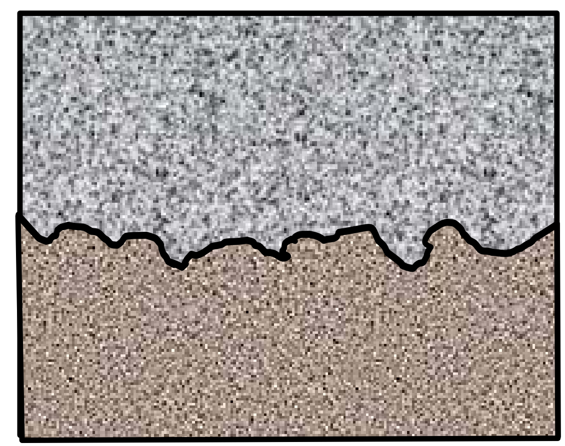
Nicol *et al.*, 2011

MOHR AND MORE
INDUCED SEISMICITY AND STRESS

Mohr- Concept

- Earthquakes occur if stresses exceed strength of a fault
- Stresses on the fault depend on the fault orientation
  $\tau = \mu \cdot (\sigma_n(P(r,t))-P(r,t))$





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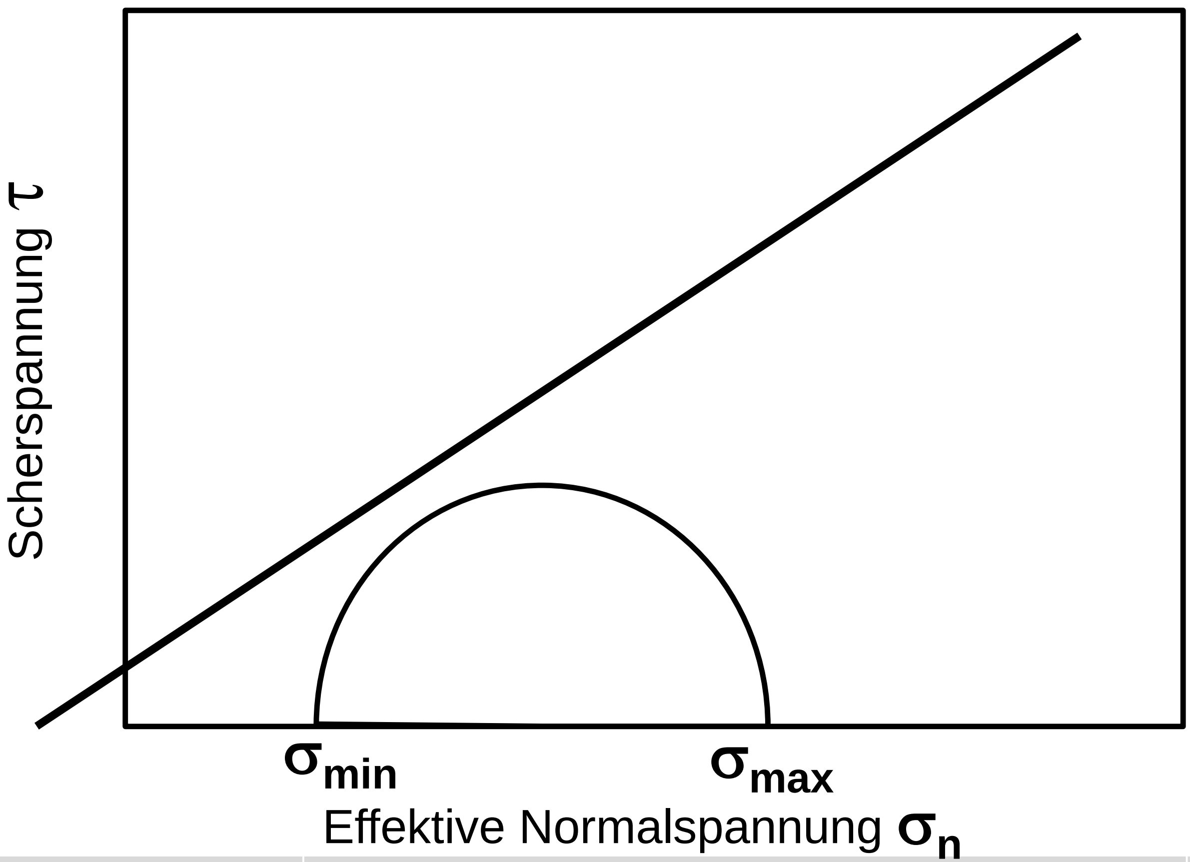
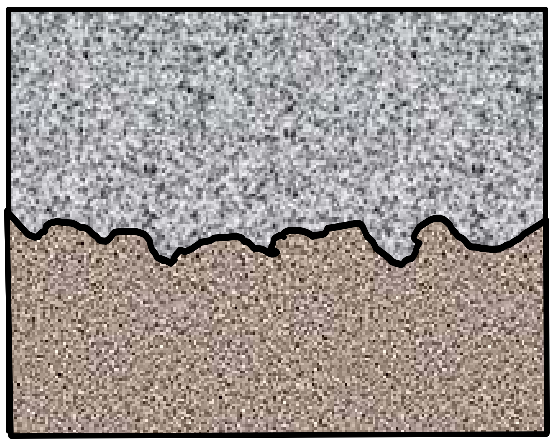


Decreasing Pore Pressure



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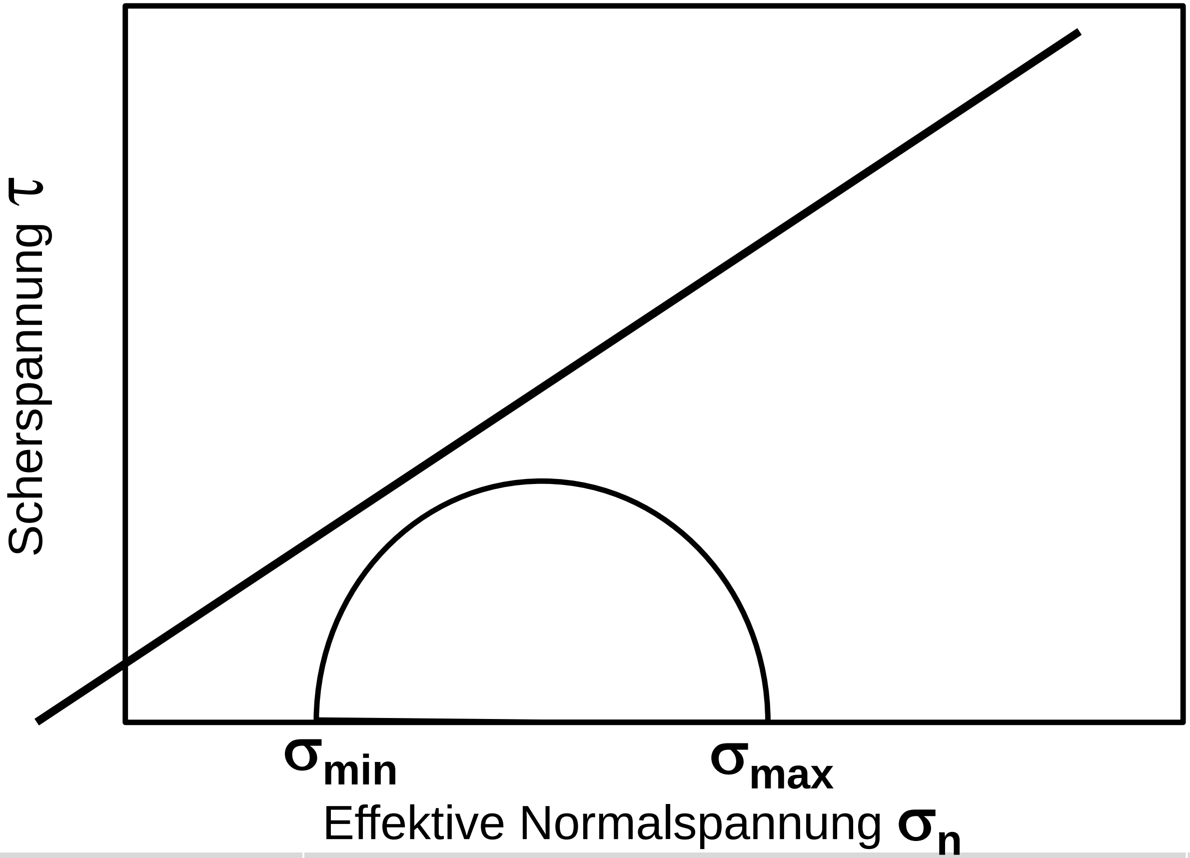
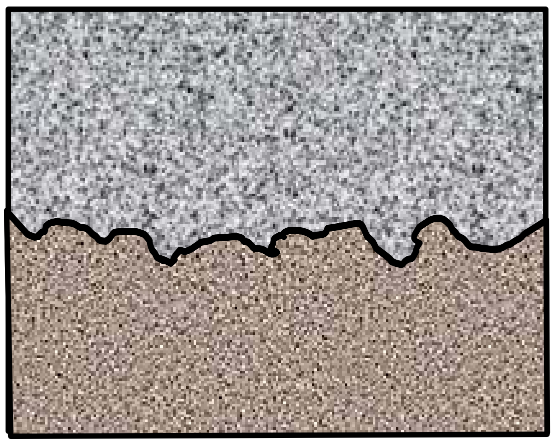


Increasing Pore Pressure

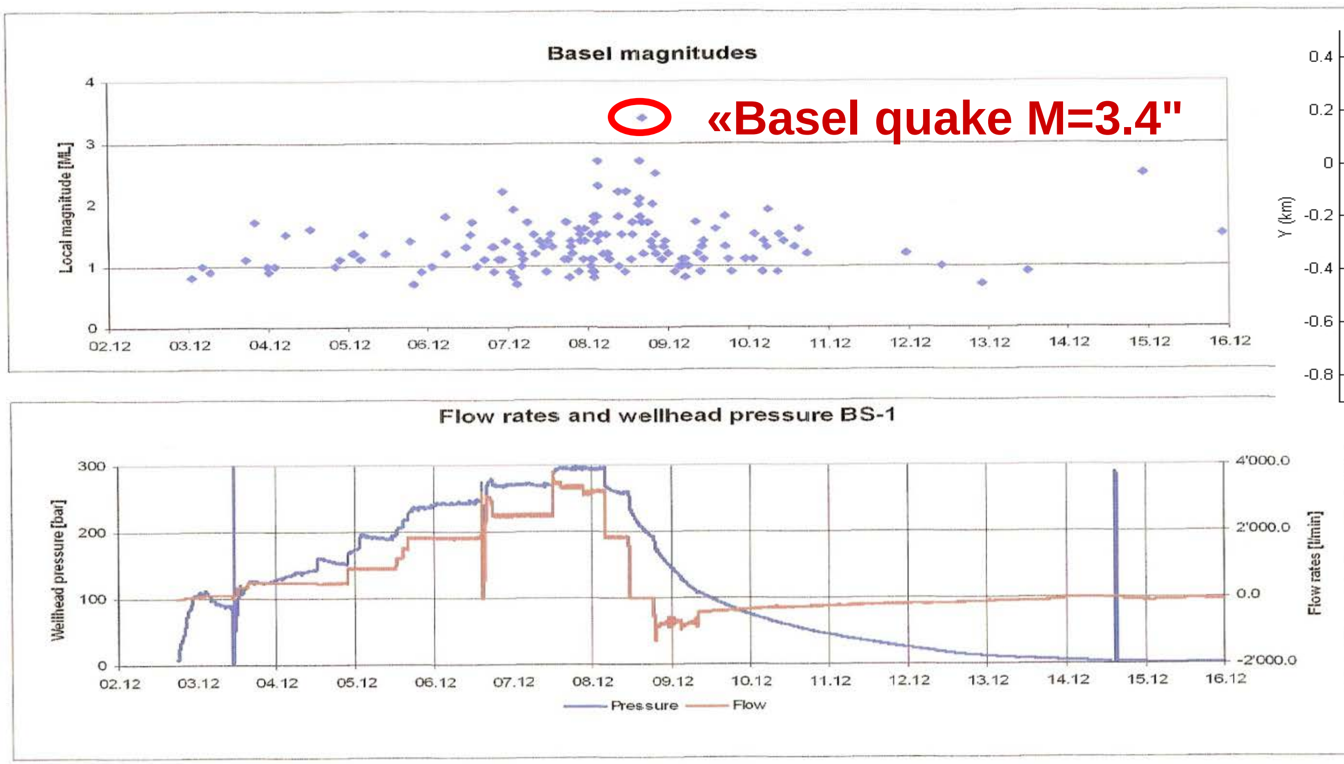


INJECTION INDUCED SEISMICITY

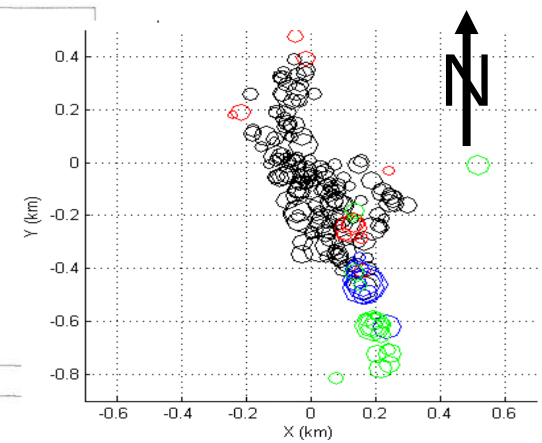
Hydraulic Stimulation

Karlsruhe Institute of Technology

- High Injection rates/pressures can cause seismicity

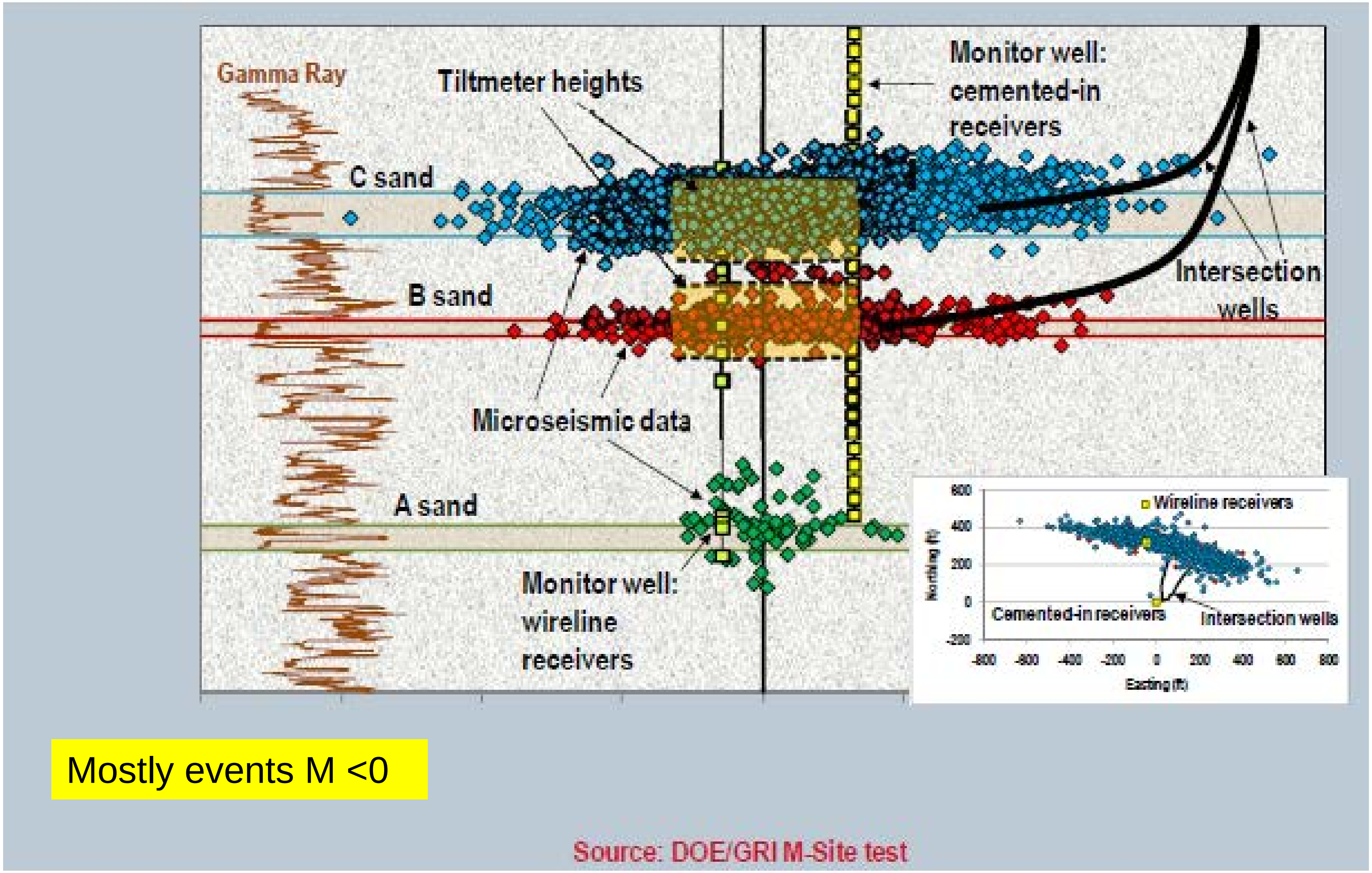


Häring et al., 2008



Deichmann, SED

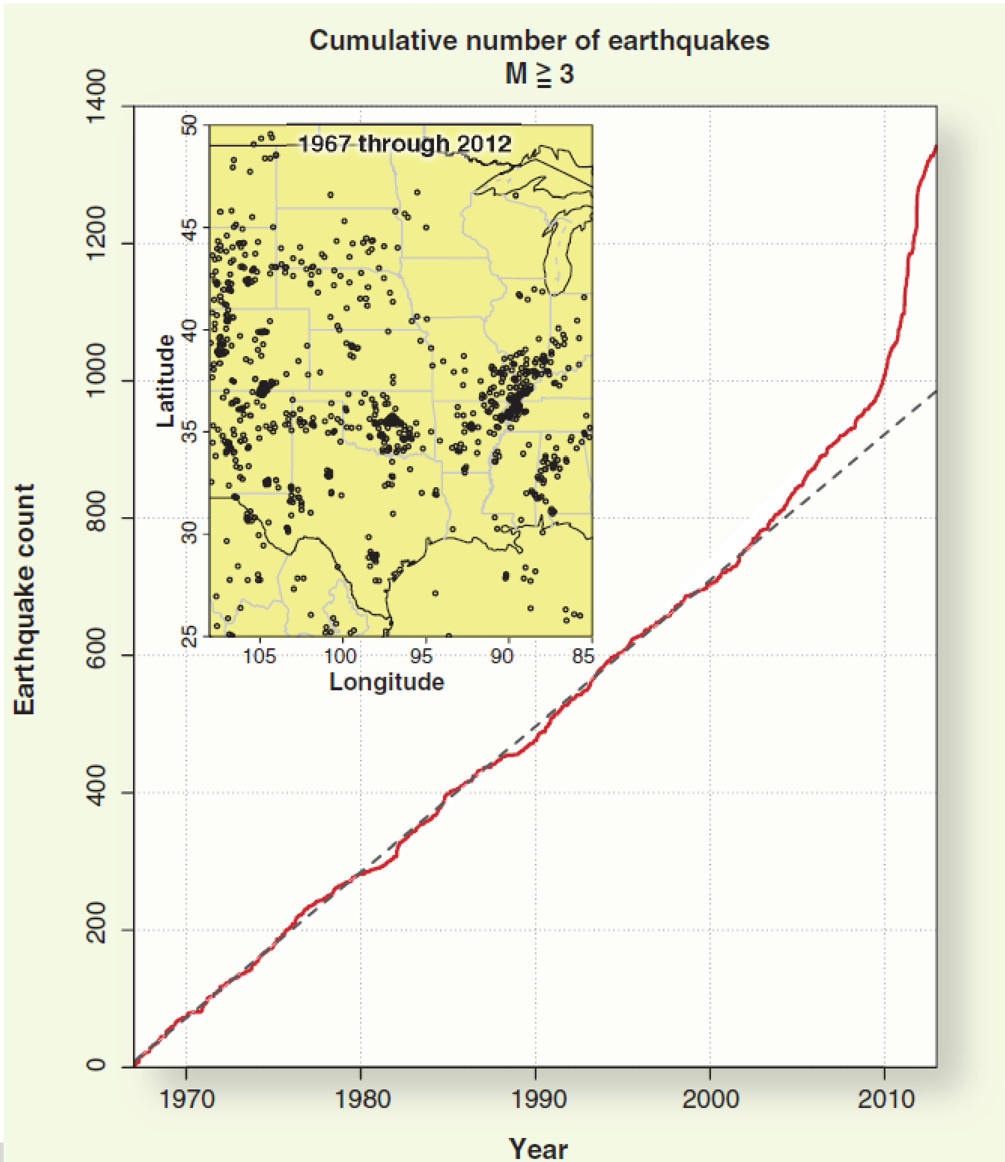
Fracture Monitoring



Mostly events M <0

Increase of Earthquake Activity in US $M_L \geq 3$

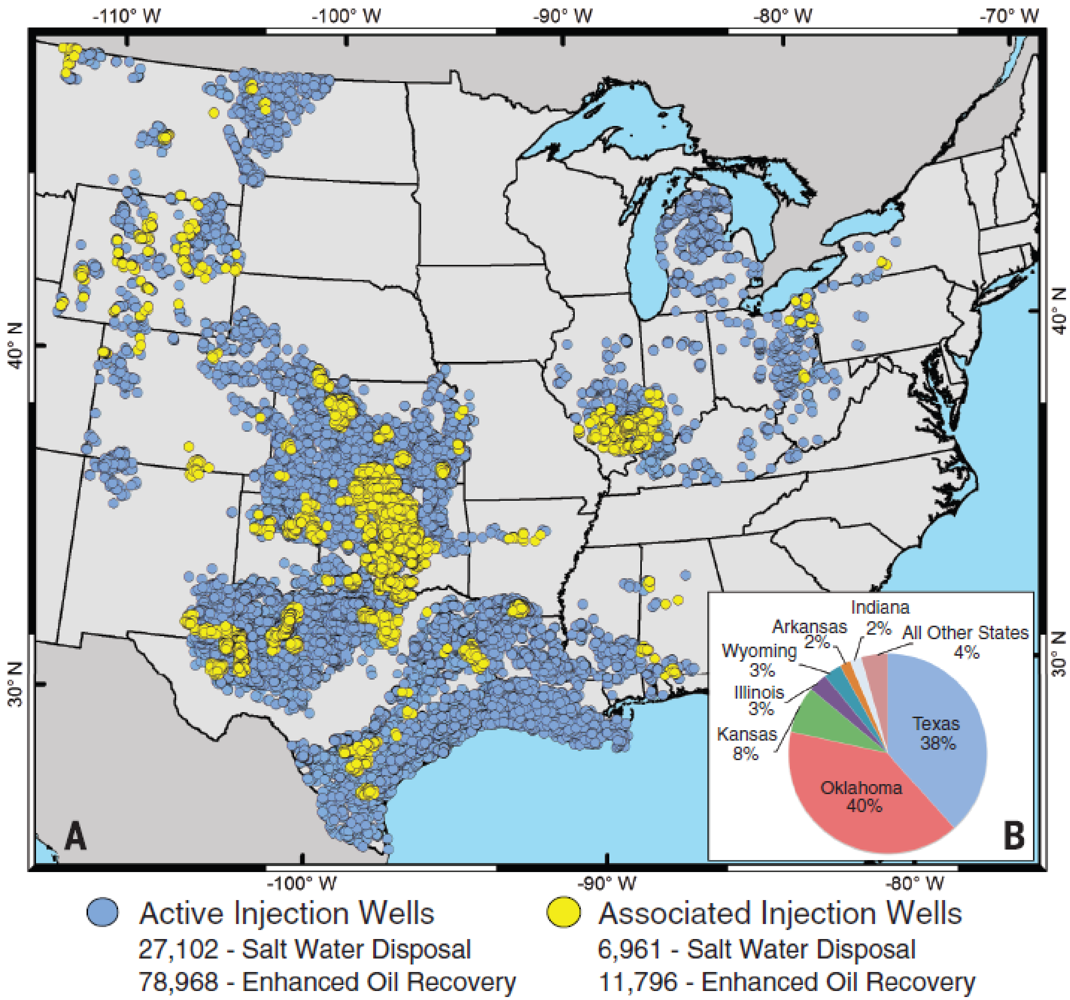
KIT
Karlsruhe Institute of Technology



What is the reason ?

Ellsworth, 2013

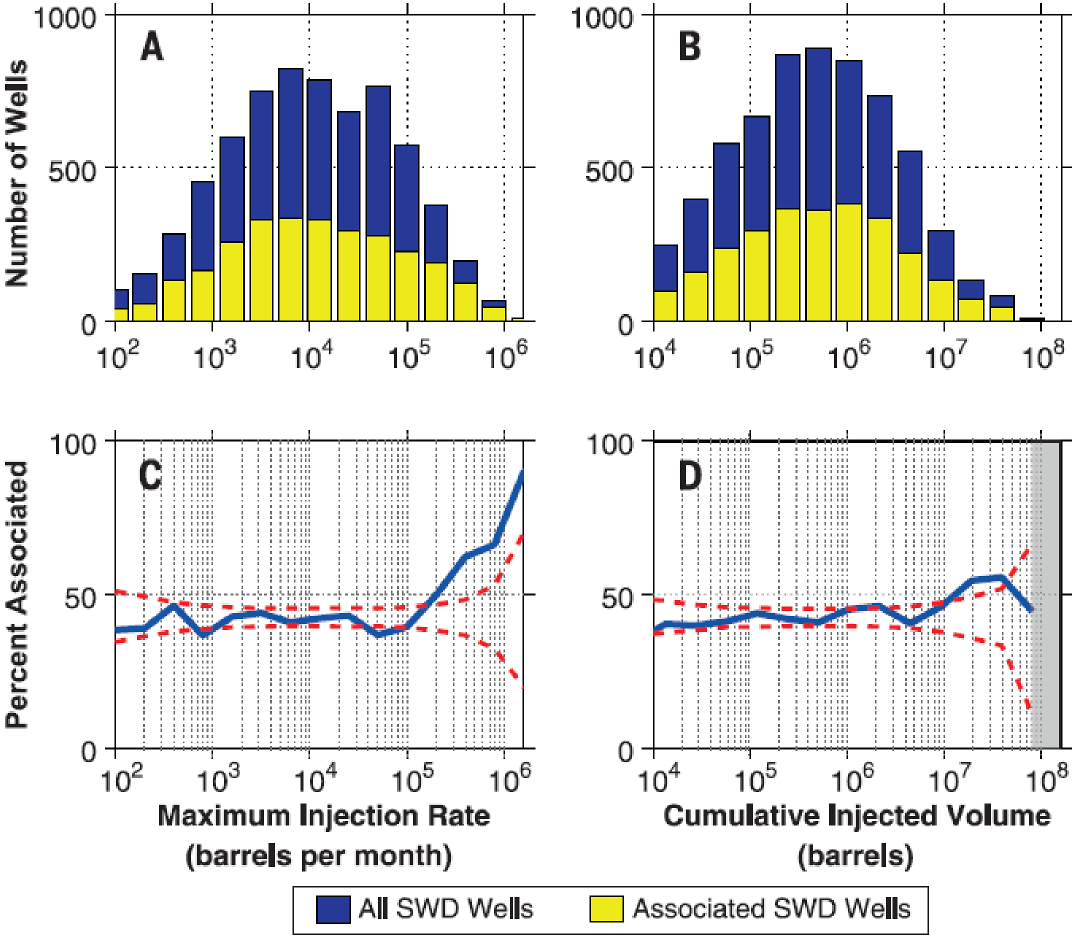
What is it about ?



Location of active class II injection wells in the CEUS. Active injection wells from the database are shown as blue circles. Spatiotemporally associated injection wells, defined as those within a 15-km radius and active at the time of an earthquake, are shown as yellow circles.

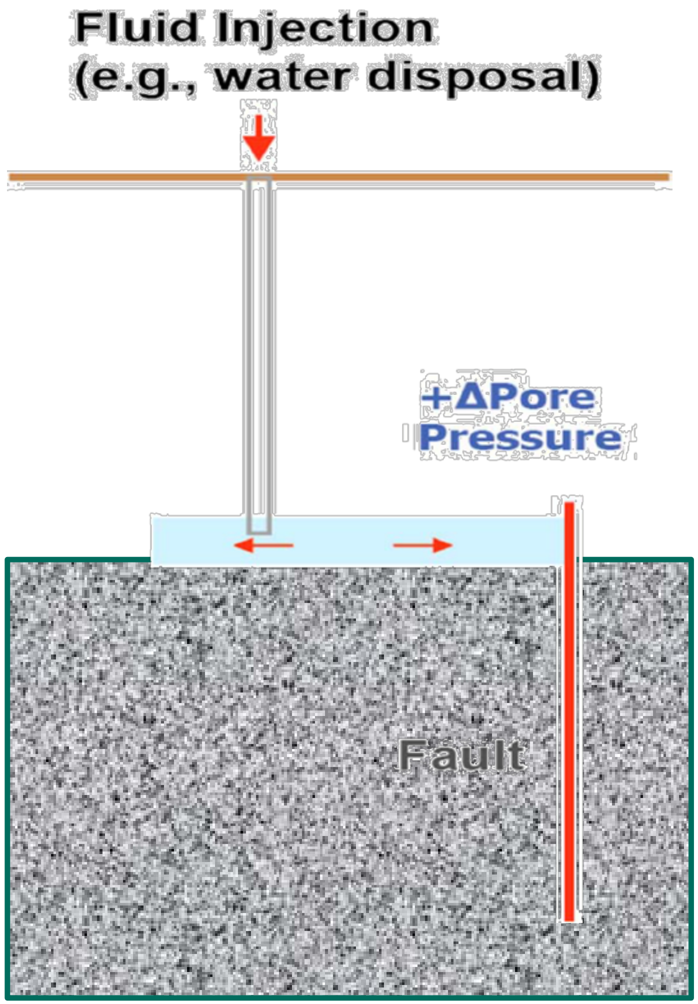
M. Weingarten et al., 2015

- High-rate injection wells (>300,000 barrels per month) are much more likely to be associated with earthquakes than lower-rate wells.
- a well's cumulative injected volume, monthly wellhead pressure, depth, and proximity to crystalline basement do not strongly correlate with earthquake association.
- Managing **injection rates** may be a useful tool to minimize the likelihood of induced earthquakes.



M. Weingarten et al., 2015

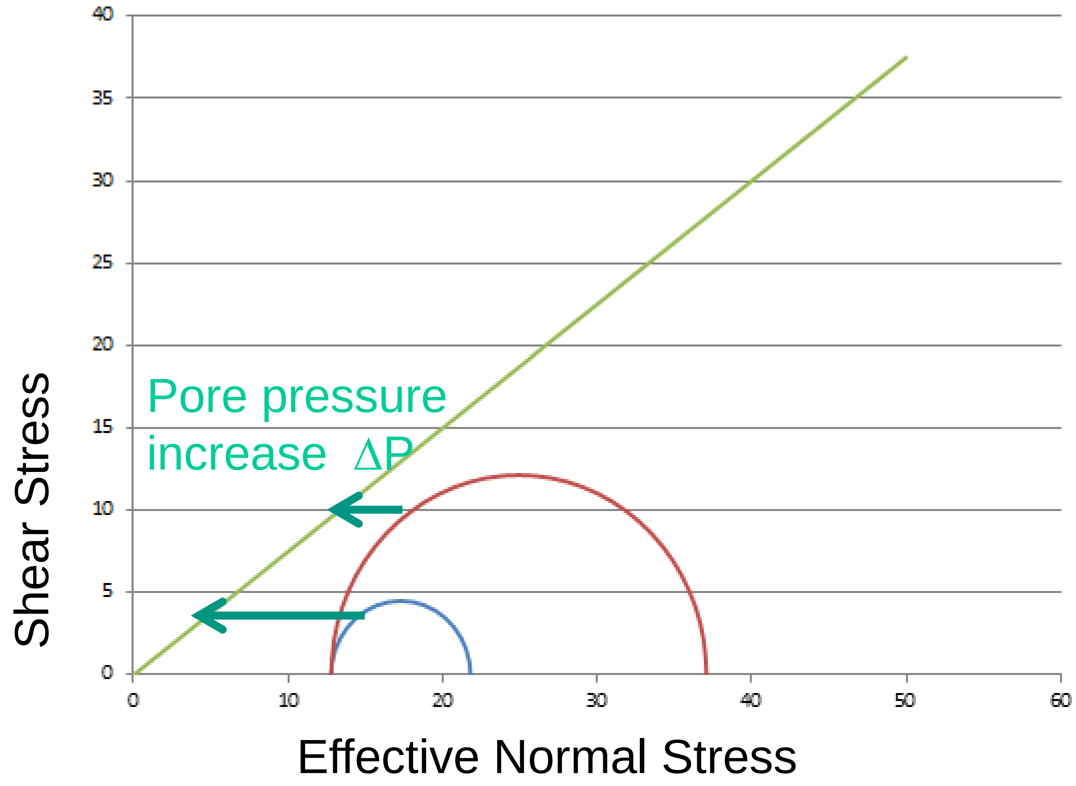
Conceptual Model Walsh and Zoback (2015)



Formation of injection is in hydraulic connection to critically stressed faults
→ Small pressure changes lead to triggered events.
→ Potentially active faults in crystalline basement are also hydrologically active.

McGarr, 2015

Remember the Mohr Diagram

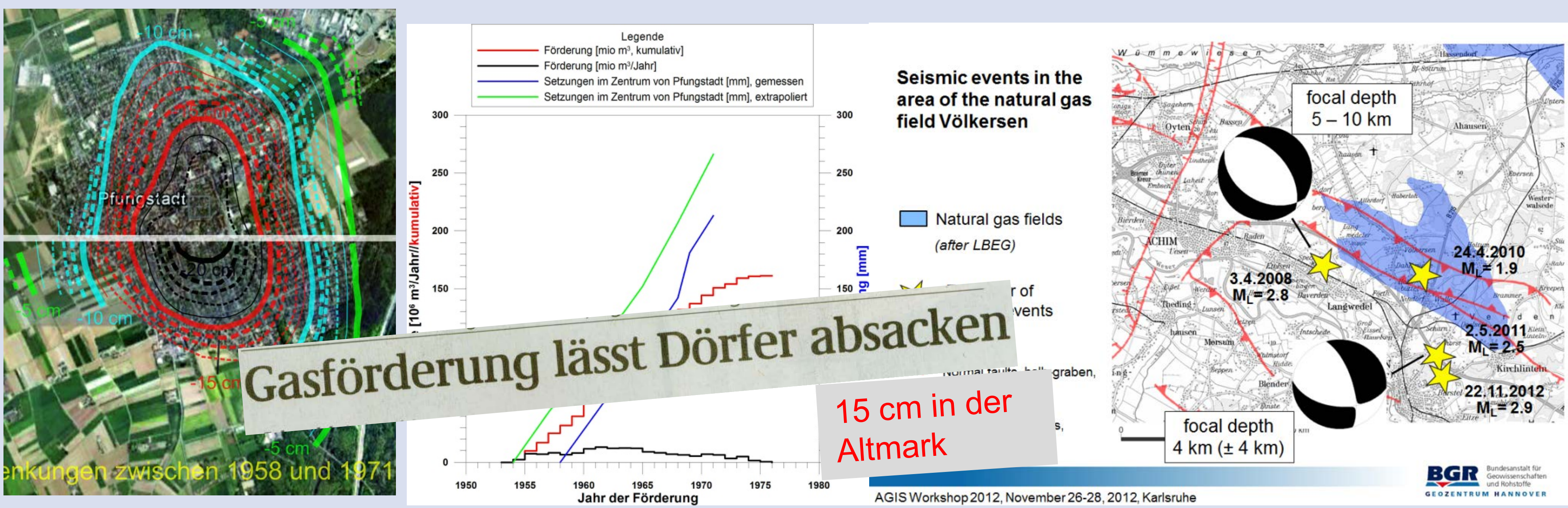


PRODUCTION INDUCED SEISMICITY

LANDES FORSCHUNGS ZENTRUM GEOTHERMIE

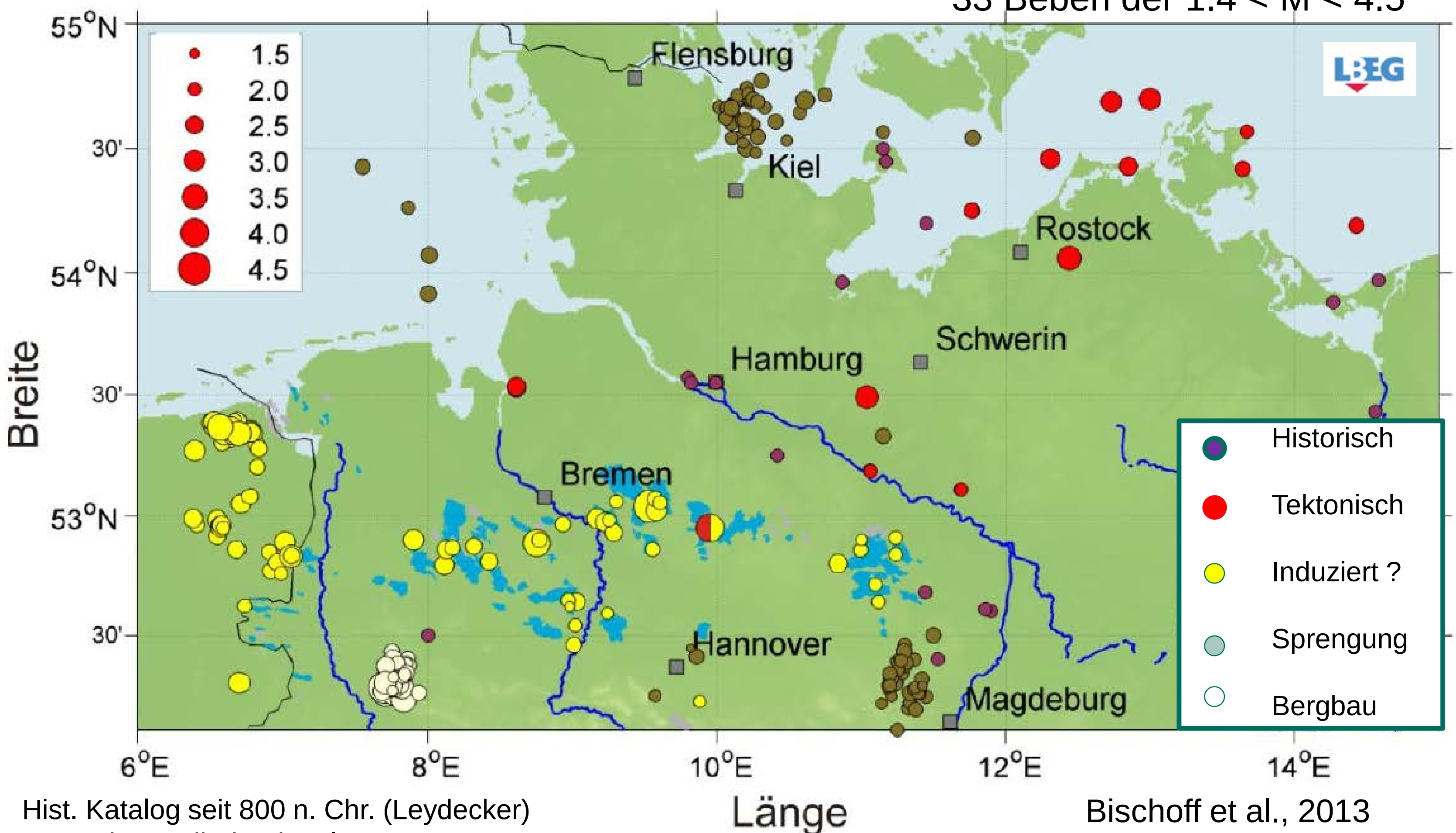
ReservoirManagement & Seismicity

*T. Röckel, **B. Müller**, F. Schilling,*
K. Zippelt, C. Lempp, C. Scheffzük, M. Westerhaus



Seismizität in Norddeutschland

33 Beben der 1.4 < M < 4.5



Hist. Katalog seit 800 n. Chr. (Leydecker)
Deutscher Erdbebenkatalog 1977-2012

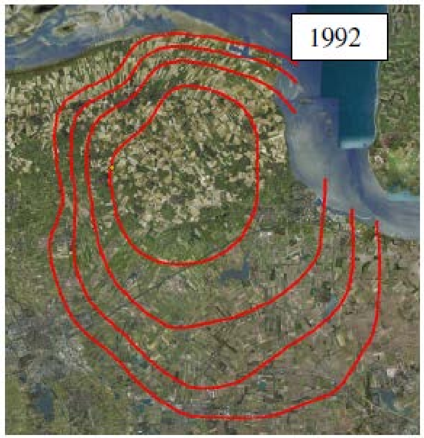
Bischoff et al., 2013

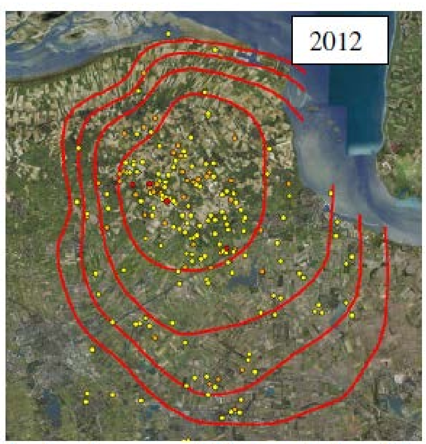
Herausforderung

- Beobachtung: Subsidenz & Erdbeben

Subsidenz 2008

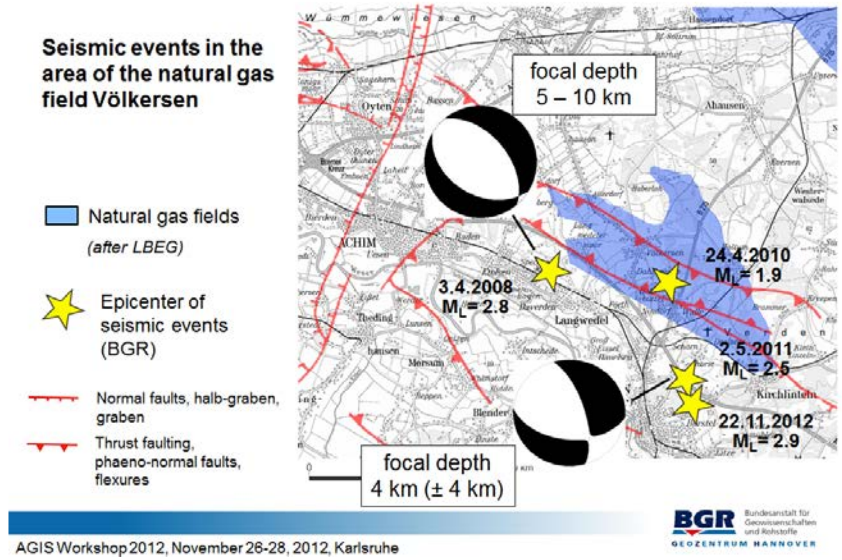
- 1.5<M<2
- 2<M<3
- M>3



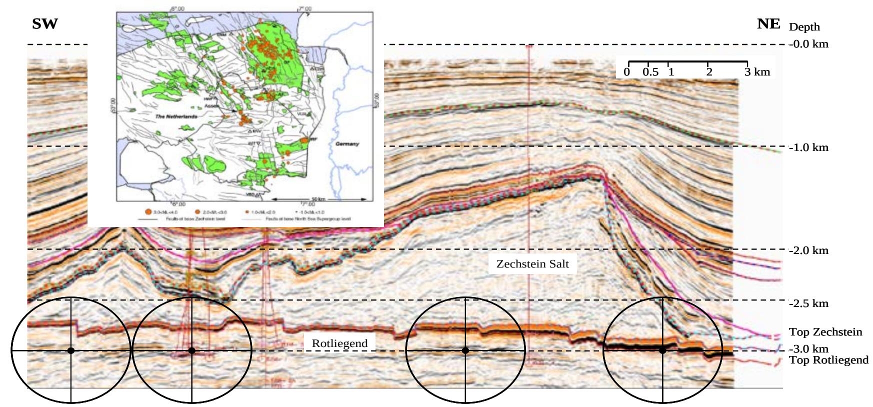


Muntendam-Bos & de Waal, 2013, State Supervision of Mines Report on Groningen

- Beobachtung: Erdbeben

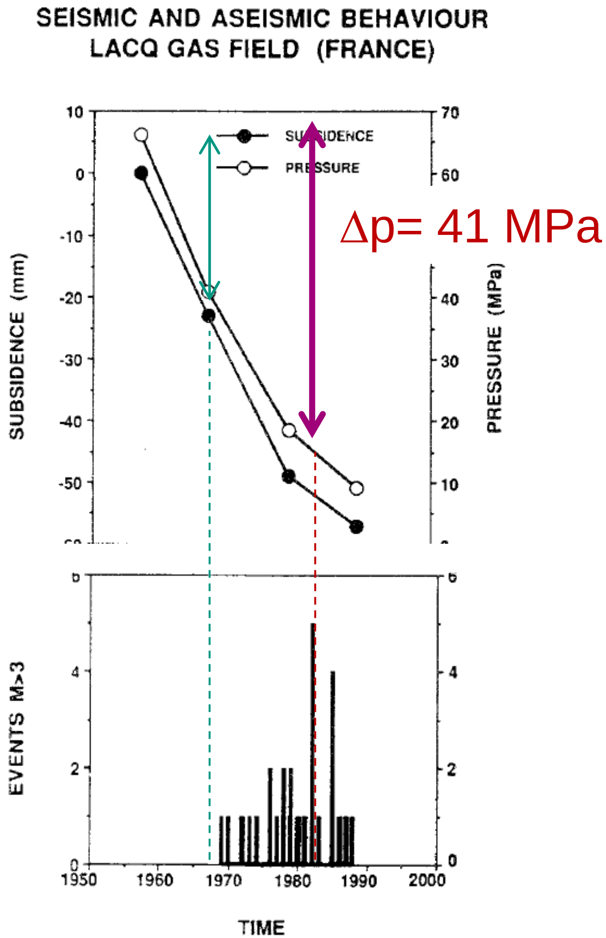


Plenefisch (2012)



(van Eijs, NAM, KNMI)

Zeitabhängigkeit der Seismizität

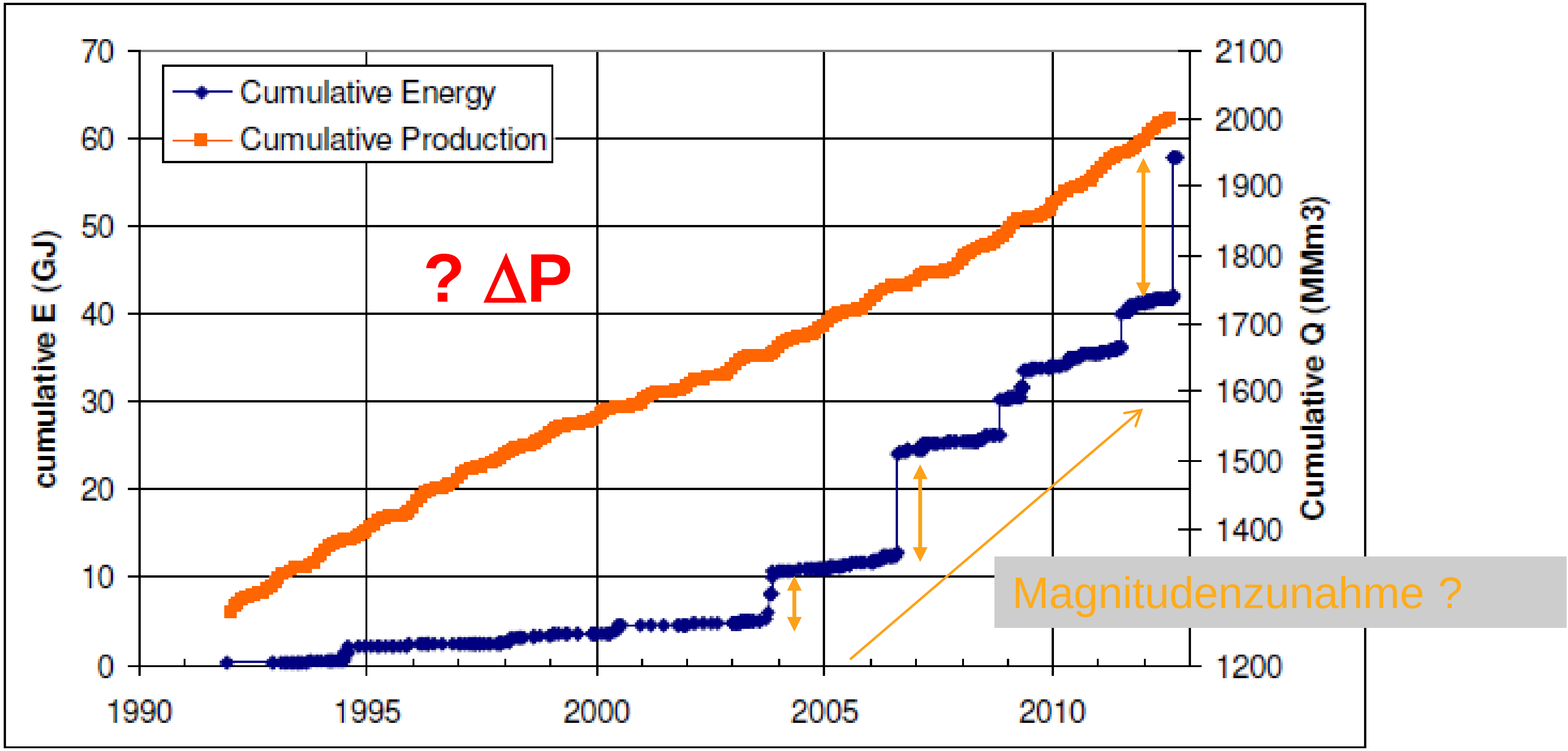


Grasso (1992)

Feldname	Beginn der Produktion	Beginn der Seismizität mit *ML* >2.0	Verzögerung [Jah	ΔP [bar]
Roswinkel	1980	1992	12	212
Bergermeer	1972	1994	22	168
Bergen	1972	2001	29	188
Groninen	1978	1991	13 (28)	197
Eleveld	1975	1986	11	217
Annerveen	1973	1994	21	266
Roden	1976	1996	20	203
Dalen	1974	1996	22	287
Appelscha	1999	2003	4	173
Emmen	1977	1991	14	211

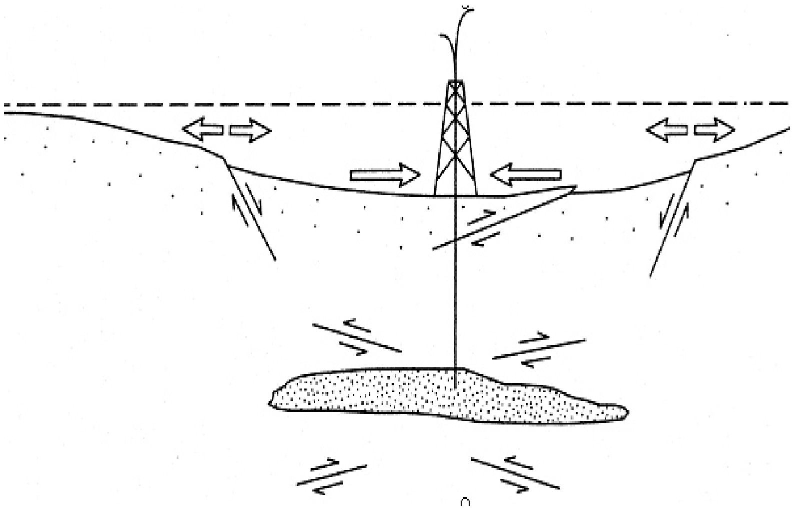
vanEck et al. (2004)

Seismische Energiefreisetzung & Gasproduktion

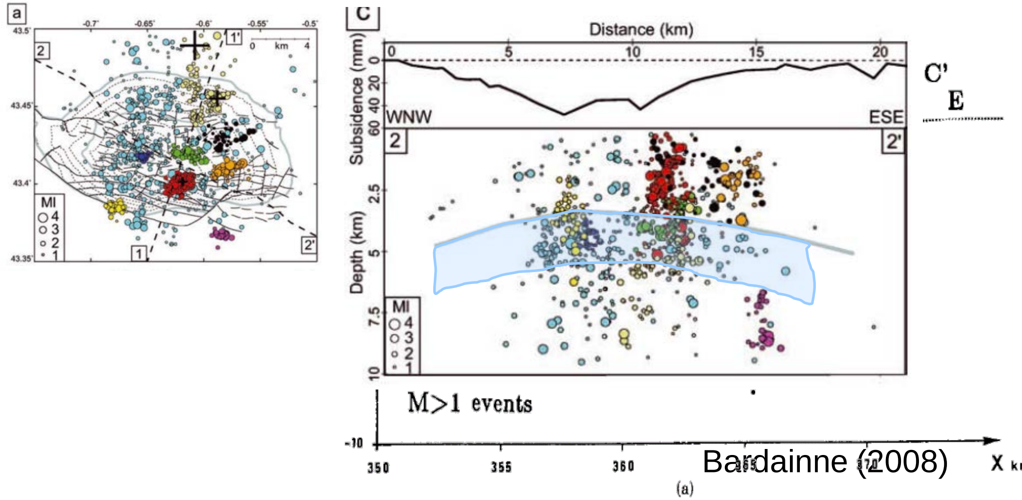


Muntendam-Bos & de Waal, 2013, State Supervision of Mines Report on Groningen

Erklärungsansätze

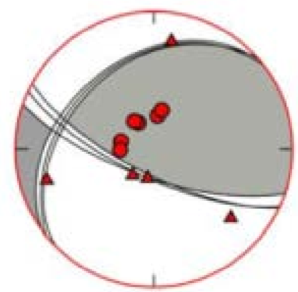


Segall (1989)

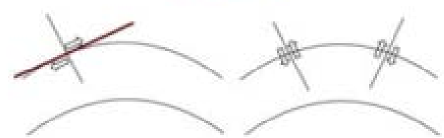


Bardainne (2008)

1. Compaction
2. Reactivation of Normal Fau
3. Poroelastic Stress Changes



Roswinkel
1997

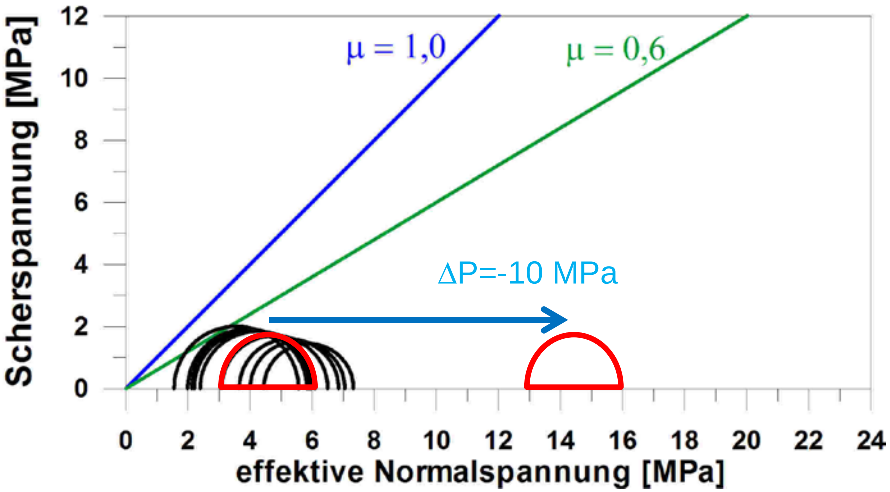


Van Eck et al. (2004)

Consider Stress and Pore pressure

- Example Valhall

σ_{diff} = 4 MPa → $\Delta\sigma_{diff}$ = 0 MPa



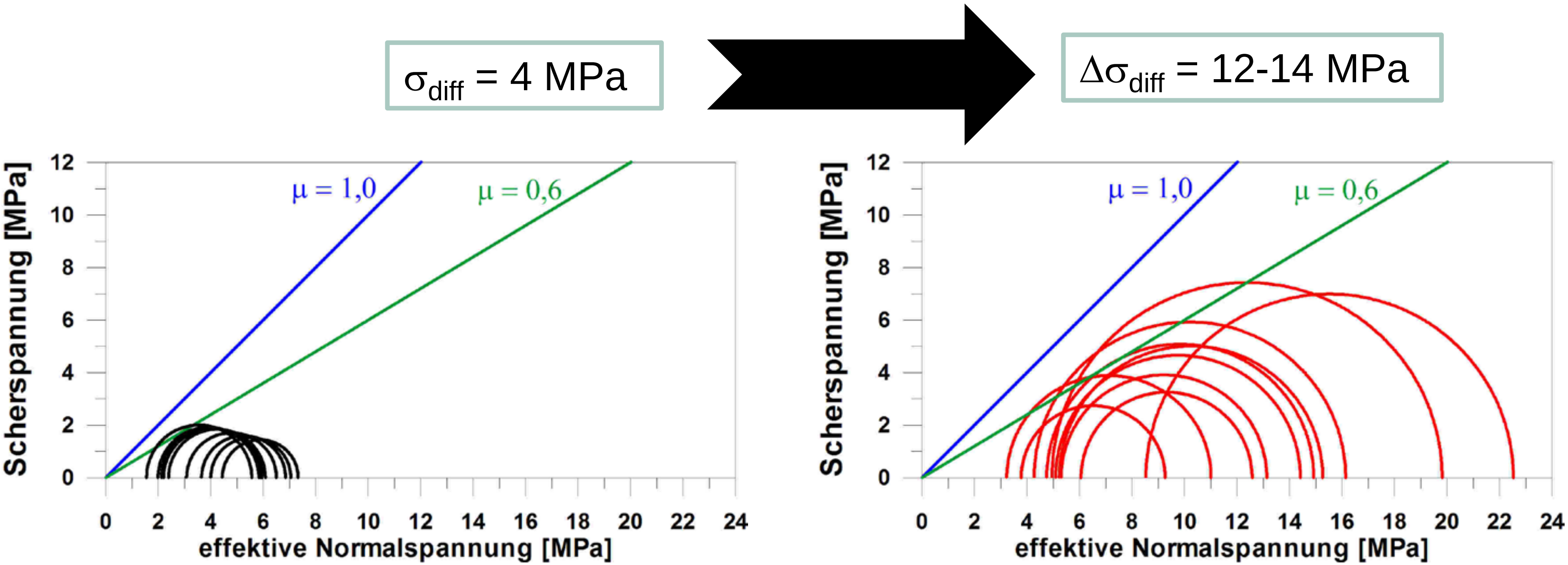
Stress State Valhall
Begin of Production

Röckel (2013)

Spannungszustand Valhall
während der Produktion

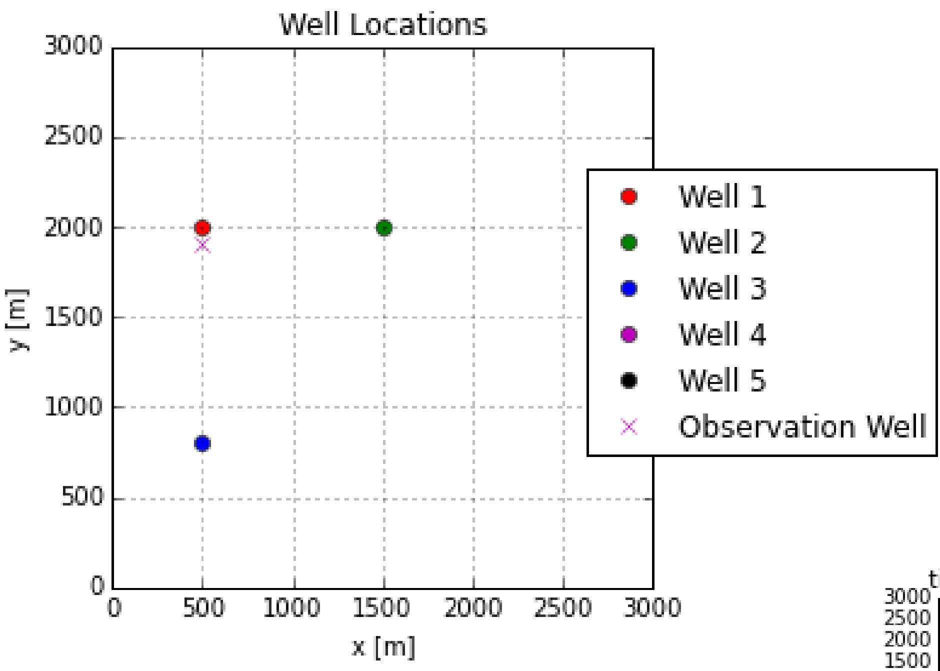
Consider Stress and Pore pressure

- Example Valhall

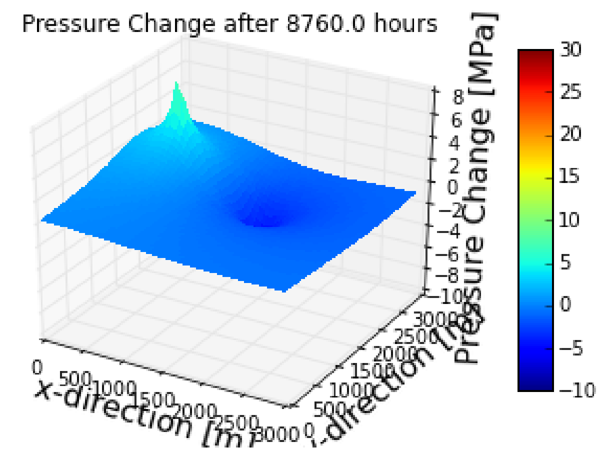


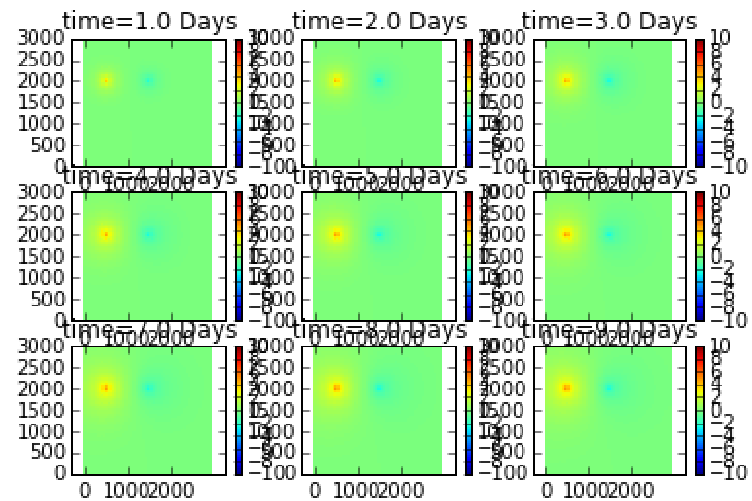
Röckel (2013)

Was rechnen wir ?



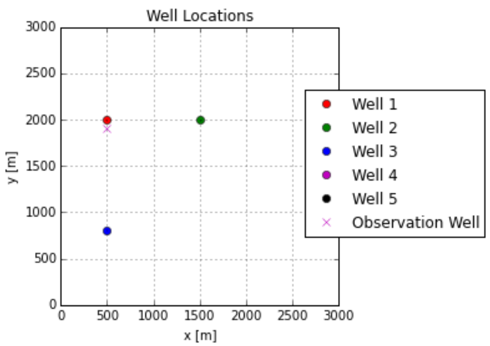
Porendruckänderung mit der Zeit

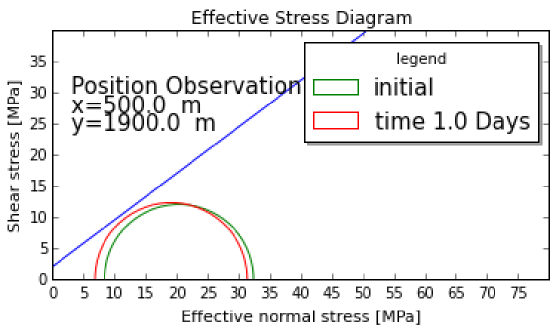


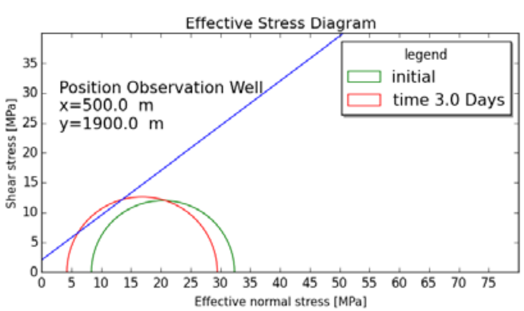


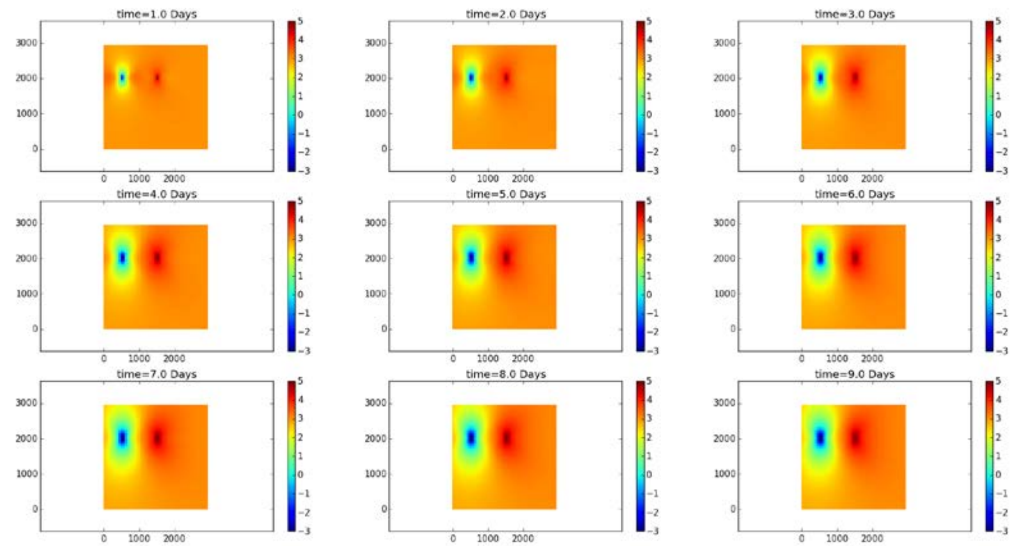
Was rechnen wir ?

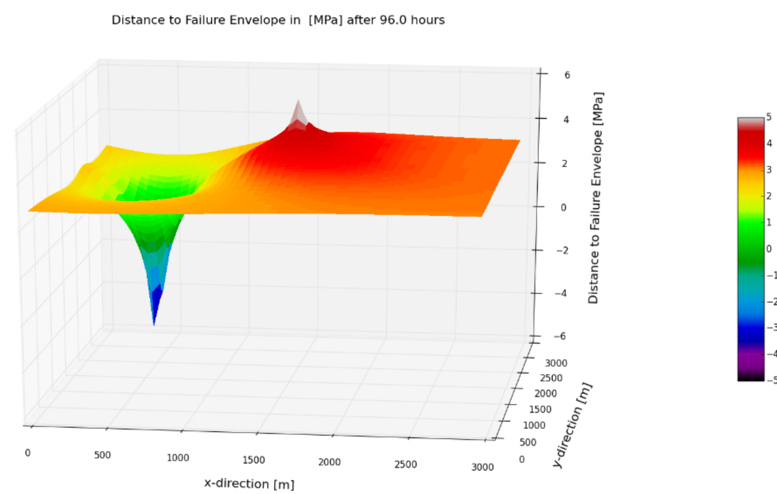
Änderung des Spannungszustands mit der Zeit



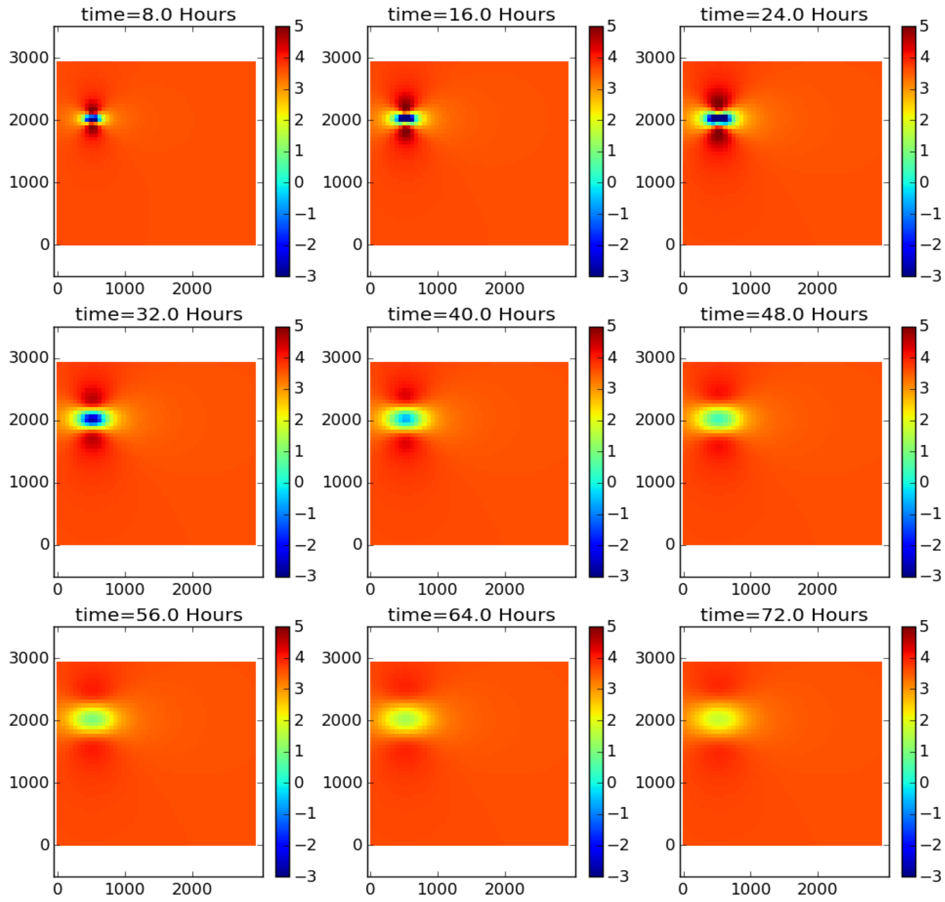








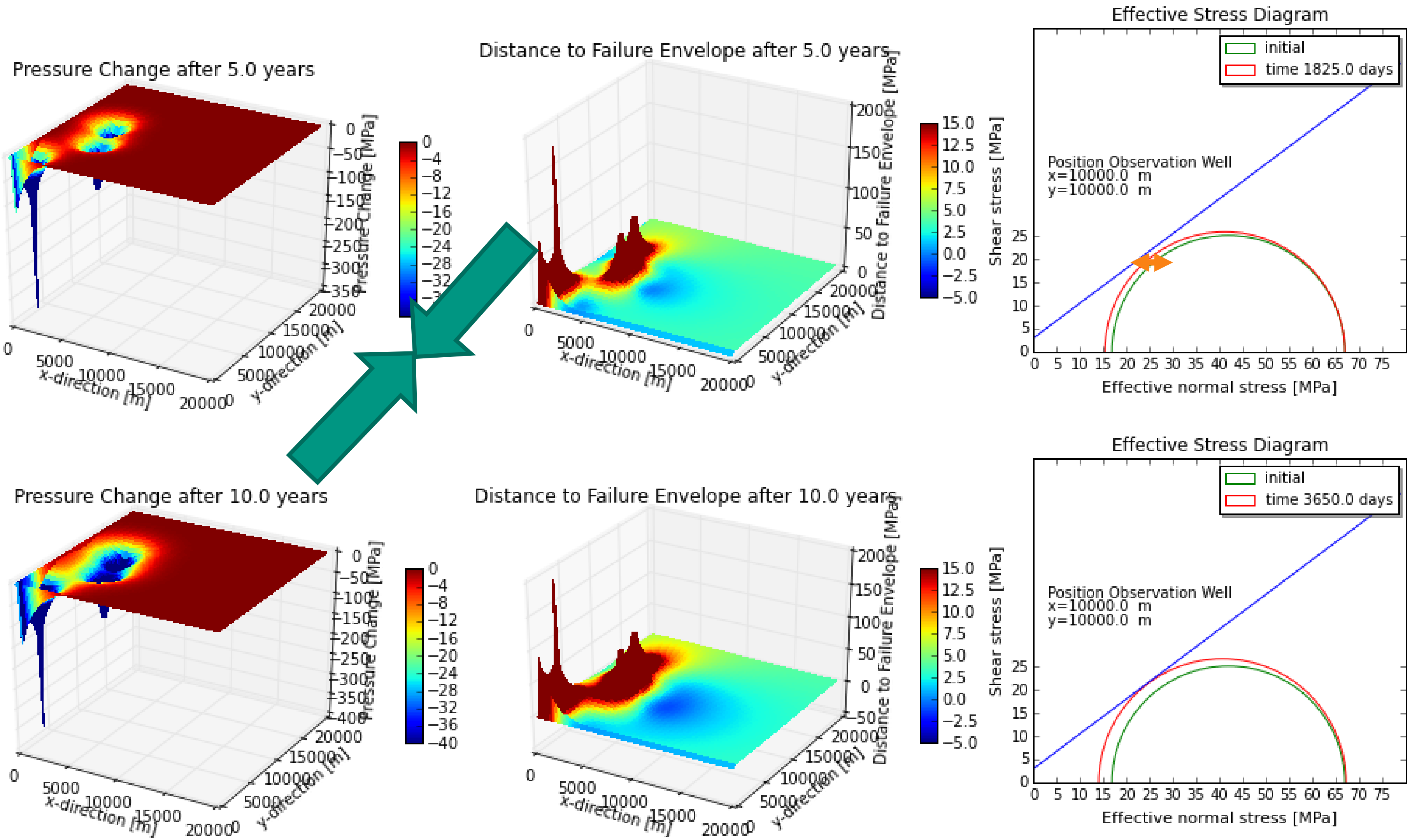
Petrothermal Case: 12 hours injection



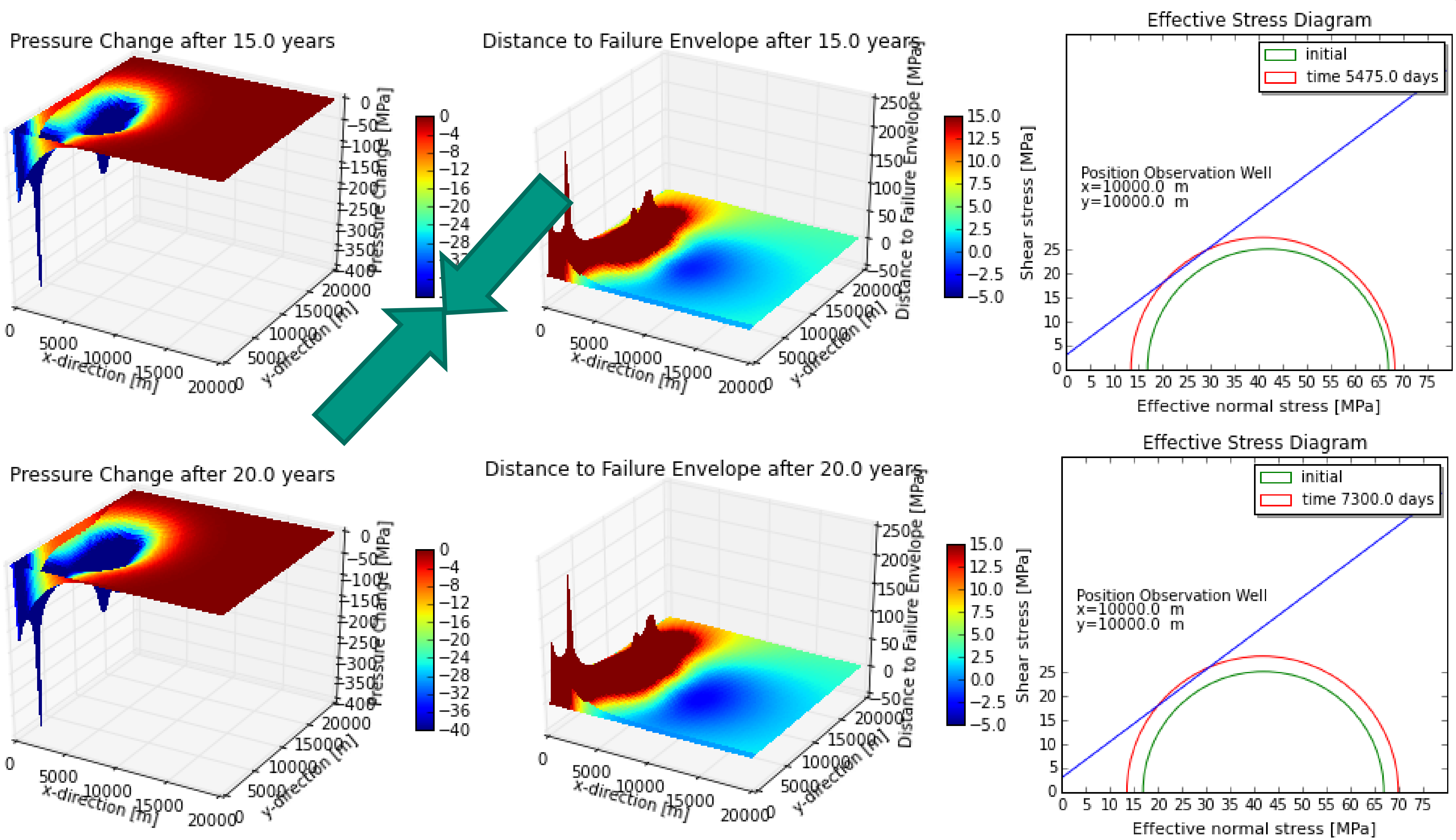
Depth 5 km
Permeability 30 mD
Bulk Modulus 98GPa
12 hours injection 150 l/s
Stress Orientation is EW

Critically stressed area (and eq) appear already during injection.
Maximum extent of critically stressed area (maxquake) is reached after ca. 24 hours, is aligned with stress.

Pore Pressure and Shear Stress Evolution during a 20 years producton



Porendruck und Spannungs-Entwicklung der Scherspannungen über 20 Jahre



Summing up induced seismicity

- Injection induced seismicity occurs soon in the vicinity of the well
- Greatest magnitudes occur during shut-in
- Production induced seismicity occurs after years and at greater distance





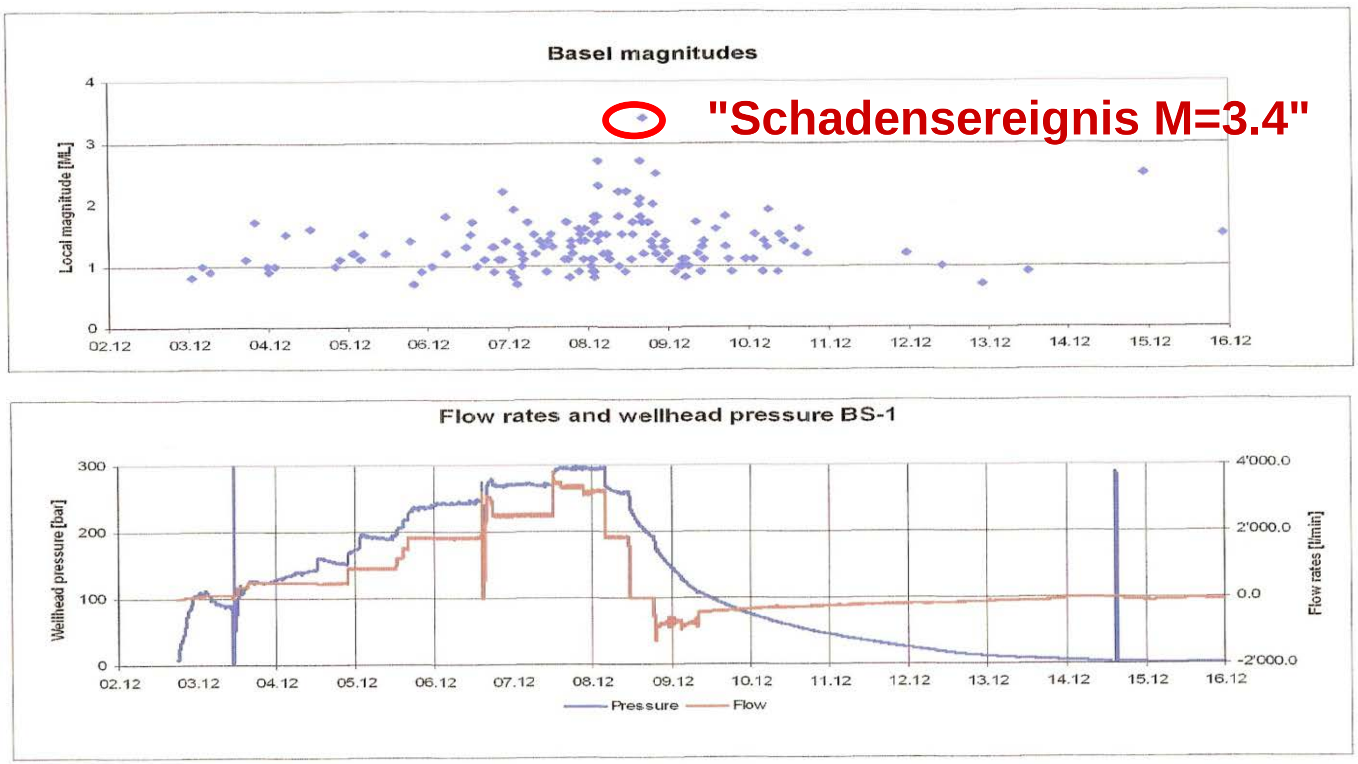


Most resources are limited !

Tiefe Geothermie: Erdbebengefährdung

- Problematik bei hydraulischer Stimulation:

  Bei hohen Injektionsdrücken kann spürbare Seismizität verursacht werden



Karlsruhe Institute of Technology

HYDRAULIC FRACTURING

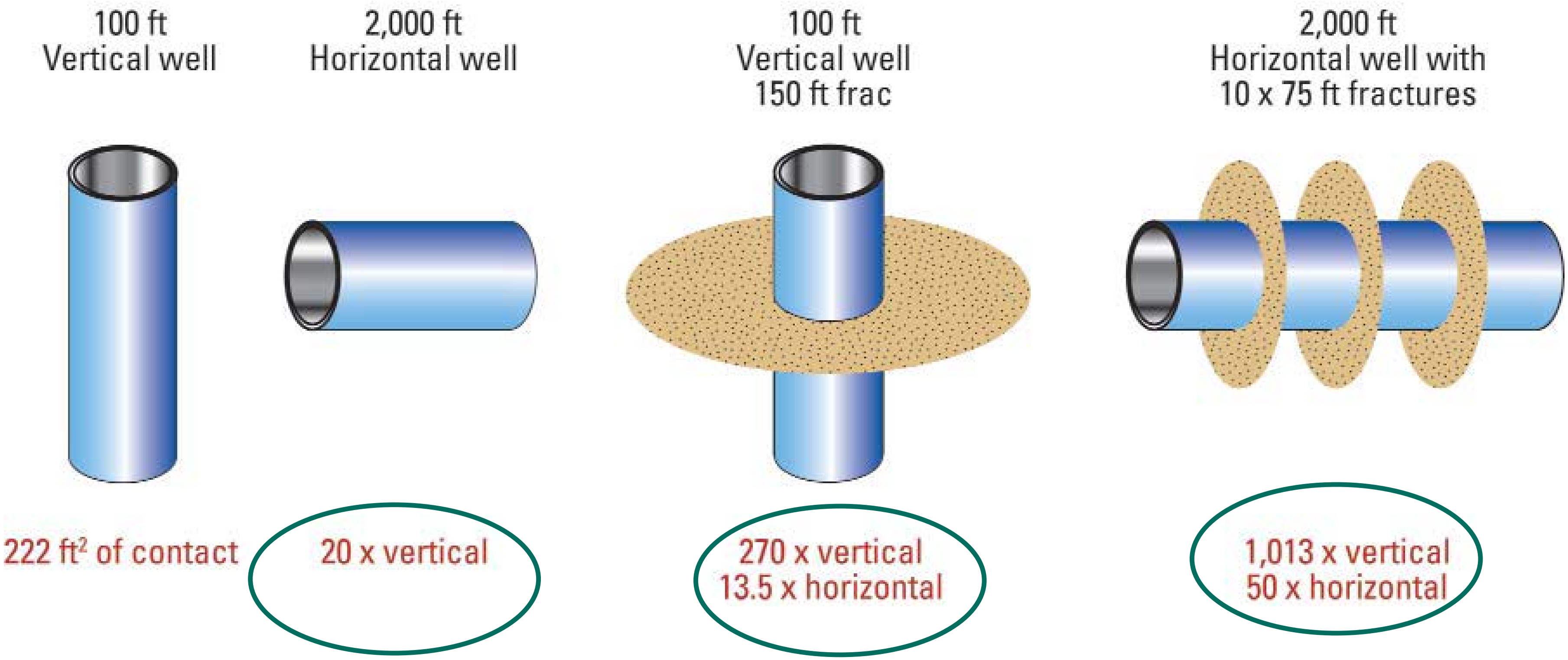
WARUM WIRD „GEFRACT“?

Warum wird gefract ?

- Öl und Gas befinden sich **nicht** in unterirdischen Seen

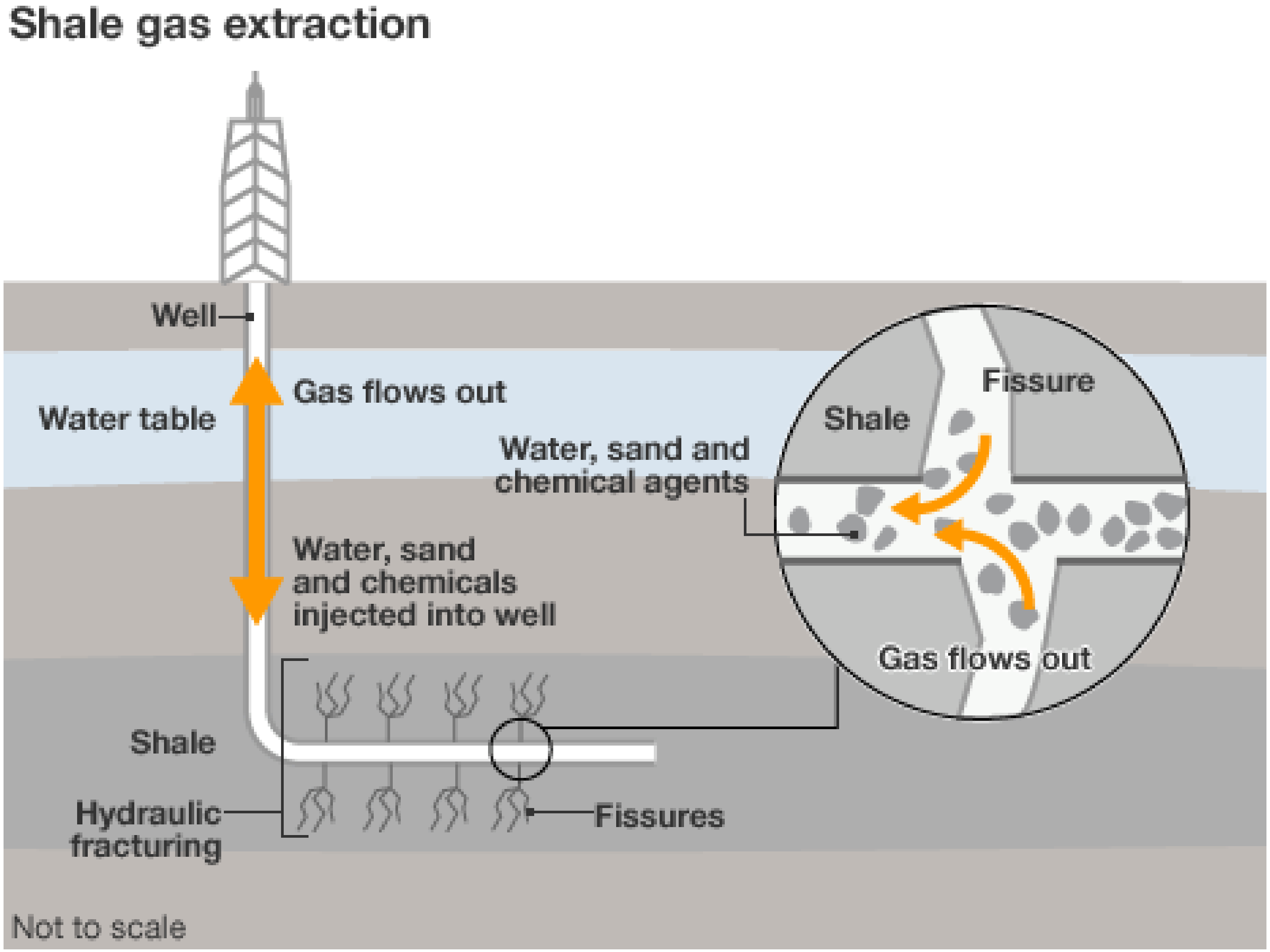
Warum wird gefract ?

Reservoirkontaktflächen bei verschiedenen Bohrverfahren mit und ohne Hydraulic Fracturing



Schlumberger 2013

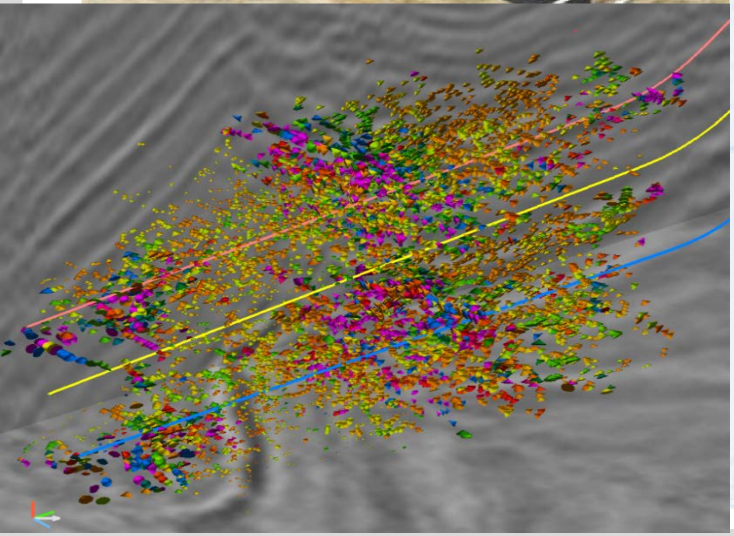
Prinzip der Schiefergasförderung mit Hydraulic Fracturing

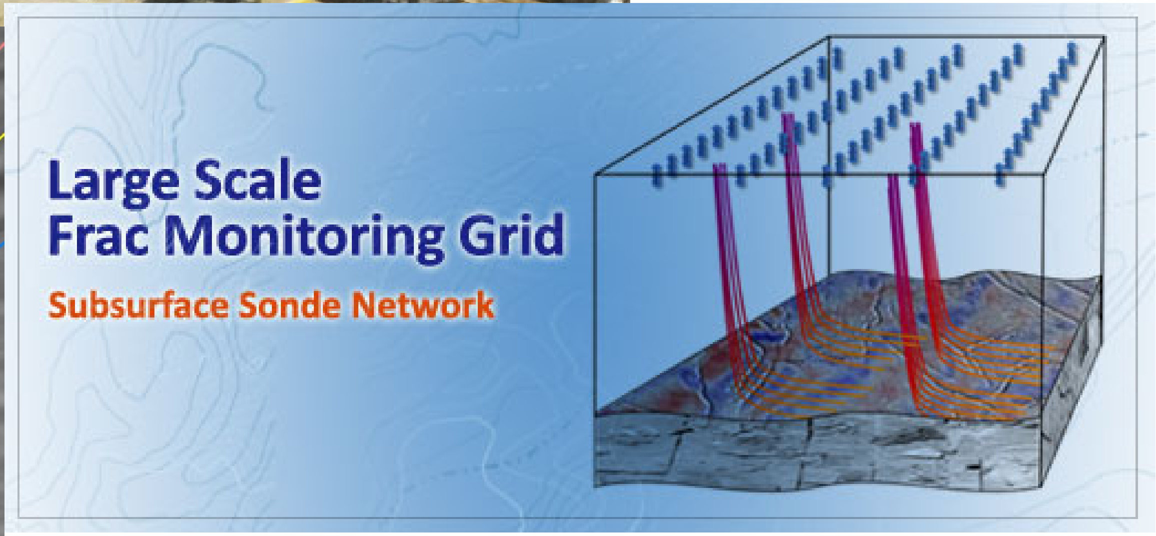


BBC News 2011

Fakultät für Bau-, Geo-, Umweltwissenschaften
Prodekan Geowissenschaften

Fracing On Site





2013 04 10 www.oilandgaslawyerblog.com, www.terraspark.com, www.globalgeophysical.com

Fracking Fluide für unkonventionelle Lagerstätten

Chemischer Name	CAS Nummer	WGK	Gefahrstoff-einstufung	Minimum	Maximum
Wasser	-	-	-	73,6 Gew.%	84,1 Gew.%
Quarz (SiO_2)	14808-60-7	0	-	15,6 Gew.%	26,0 Gew.%
Butyldiglycol	112-34-5	1	Xi	0,06 Gew.%	0,10 Gew.%
Cholinchlorid	67-48-1	1	-	0,15 Gew.%	0,16 Gew.%
Ethylendioxydimethanol	3586-55-8	1	Xi	0,07 Gew.%	0,15 Gew.%

Gesamtgemisch

- nicht umweltgefährdend
- nicht giftig
- biologisch leicht abbaubar
- WGK 1

Quelle: Schlumberger: Vortrag Fracking Dialog 2013

Fracking Fluide für Shale Gas
Funktion der verschiedenen Bestandteile

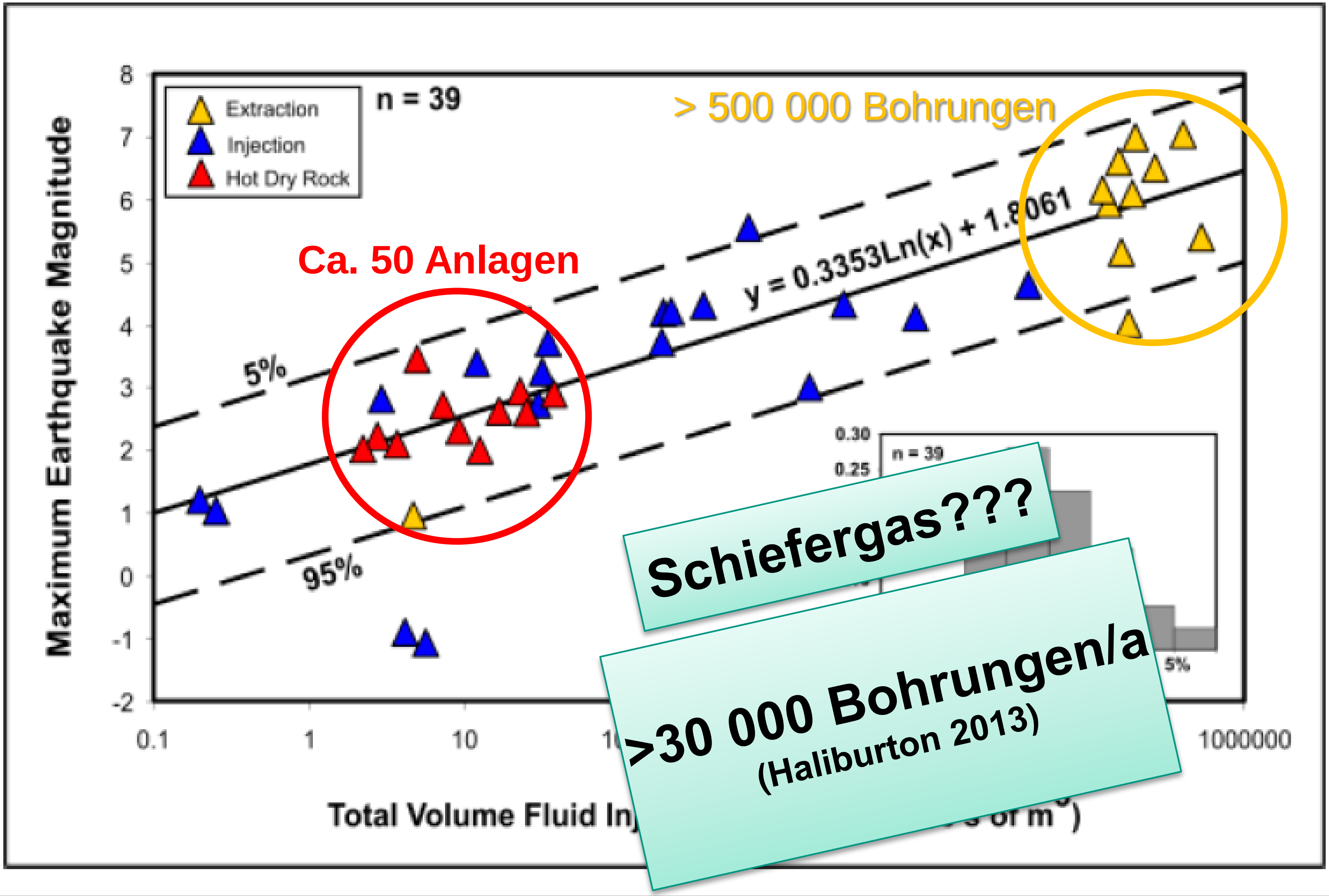
Chemischer Name	CAS Nummer	WGK	Gefahrstoff-einstufung	Minimum	Maximum
Wasser	-	-	-	57,2 Gew.%	74,3 Gew.%
Bauxit (Propant - Stützmittel)	66402-68-4	1	-	25,1 Gew.%	41,8 Gew.%
Polymer	-	1	-	0,17 Gew.%	0,28 Gew.%
Natriumhydrogencarbonat	144-55-8	1	C	0,02 Gew.%	0,03 Gew.%
Butyldiglycol	112-34-5	1	Xi	0,06 Gew.%	0,10 Gew.%
Cholinchlorid	67-48-1	1	-	0,15 Gew.%	0,16 Gew.%
Ethylendioxydimethanol	3586-55-8	1	Xi	0,06 Gew.%	0,12 Gew.%
Natriumthiosulfat	10102-17-7	1	-	0,02 Gew.%	0,03 Gew.%
Zirkonylchlorid	13520-92-8	1	Xn/C	0,01 Gew.%	0,02 Gew.%
Natriumbromat	7789-38-0	1	Xn/Xi/O	0,03 Gew.%	0,05 Gew.%
Diammoniumperoxodisulfat	7727-54-0	1	Xn/Xi/O	0,01 Gew.%	0,02 Gew.%

Gesamtgemisch

- nicht umweltgefährdend
- nicht giftig
- biologisch leicht abbaubar
- WGK 1

Quelle: Schlumberger: Vortrag Fracking Dialog 2013

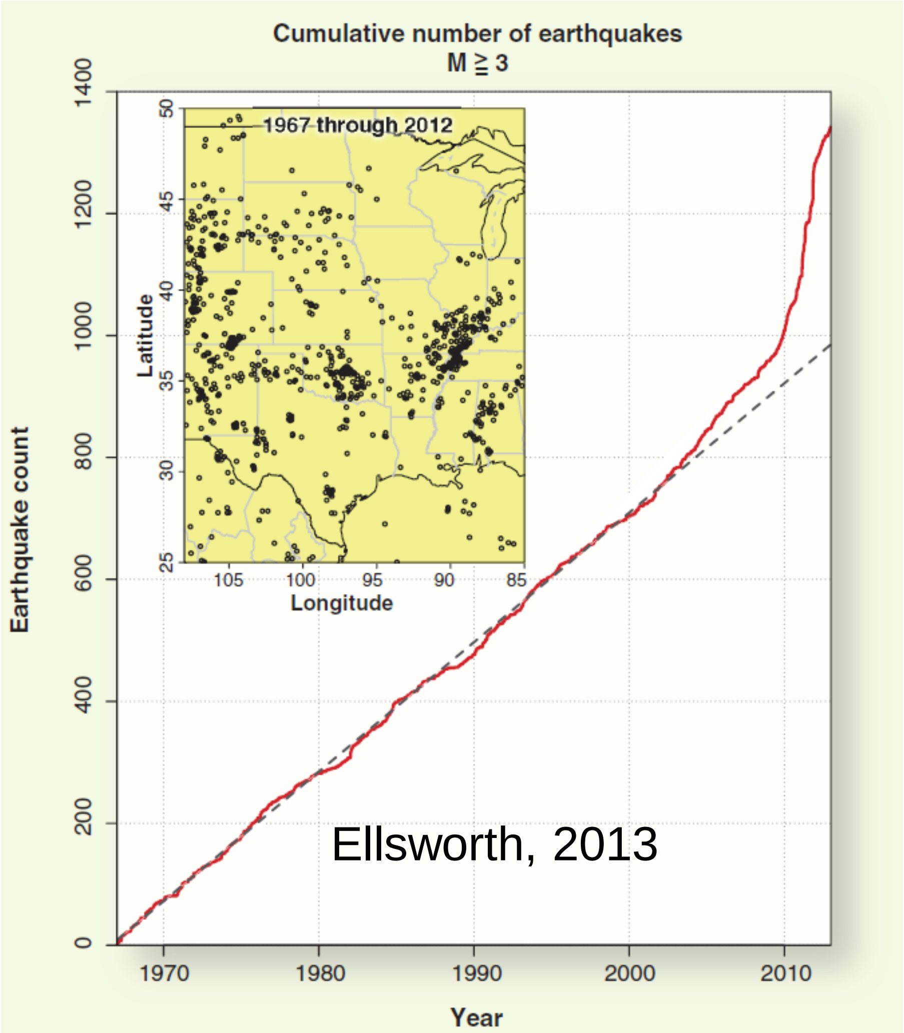
Maximale Bebenmagnituden bei Fluidinjektion bzw. -extraktion



Nicol *et al.*, 2011

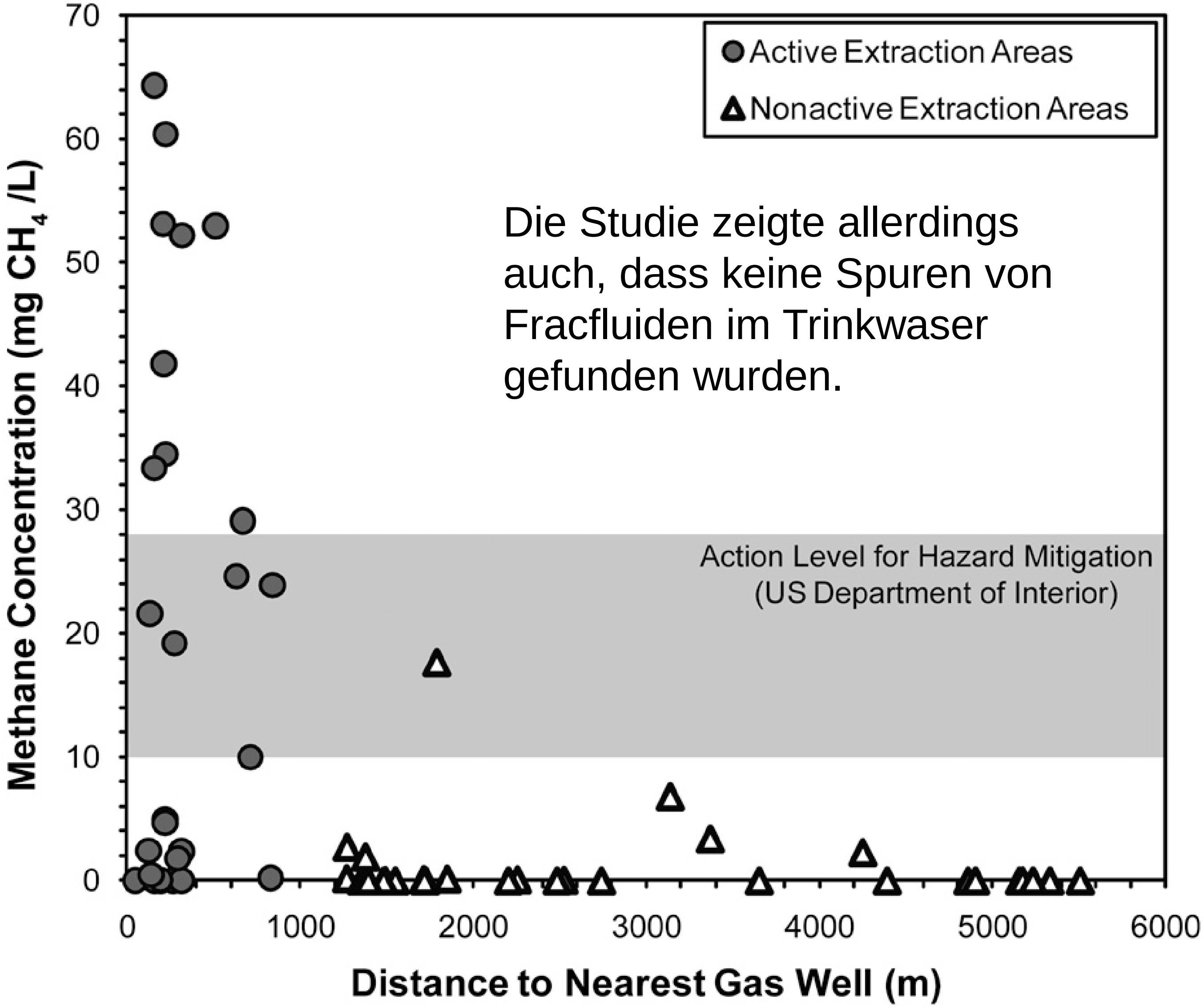
Einführung: Erdbebenaktivität in N-Amerika $M_L \geq 3$

- Besteht ein Zusammenhang mit Bergbauaktivitäten?
- Öl- und Gas- Förderung
- Waste Water
- Geothermie
- Schiefergas-Förderung
- CO_2-Speicherung…



Ellsworth, 2013

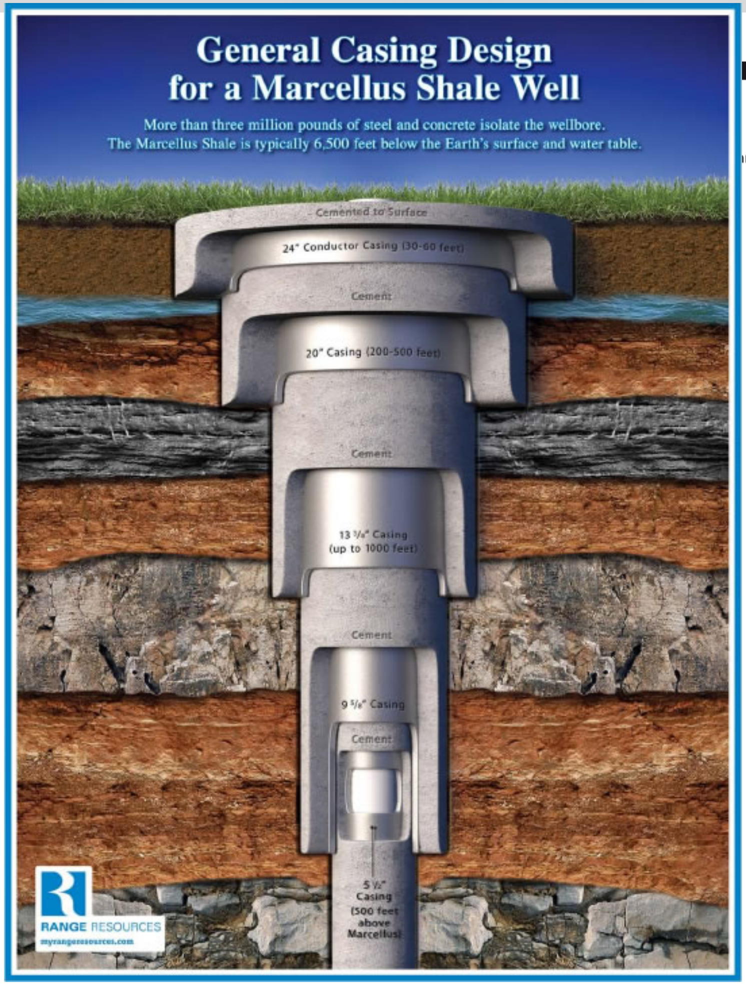
Bohrungen: Methan-Kontamination im Trinkwasser



Die Studie zeigte allerdings auch, dass keine Spuren von Fracfluiden im Trinkwaser gefunden wurden.

Osborn *et al.*, 2011

Erdgasförderung in USA



- 200 000 Altbohrungen allein in Pennsylvania, viele davon nicht „Abandoned“ (verschlossen)!
- Striktere Regeln erst seit 1984 (oil and gas act)

www.rangeresources.com 2013

Zugspitze

http://h-i-g-h.de 2013

Ein Schnitt durch die Erdoberfläche – stark vereinfacht

Grundwasser

Salinares Aquifer

Salinares Aquifer

Zielhorizont

Pedosphäre

Quartär

Rubelton/ Oligozän

„Sinemur“

Kreide/Jura

Keuper

Muschelkalk

Buntsand-stein

Rotliegendes

Karbon

Google.maps 2013 – garantiert überwacht durch NSA

Vorteile von horizontalen Bohrungen

Karlsruhe Institute of Technology

- Weniger Bohrungen
- man trifft mehr targets (s. Channel Sandstones)
- Man kann der Formation folgen
- Früherer Beginn einer Produktion (höhere production rate erlaubt schneller die Installation einer Infrastruktur im Feld)
- Da die Bohrungen bis zur produzierender Formation verrohrt werden beim Bohren der horizontalen Strecke können Drilling Muds geringerer Dichte verwendet werde
- → ´geringerer formation damage

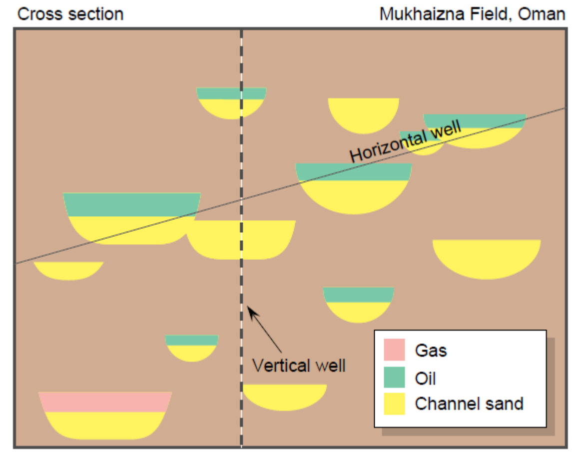


Fig. 1.3: HITTING THE TARGETS: In channel sandstone reservoirs comprising a number of discrete oil and gas accumulations a vertical well may only find one target, while a horizontal or deviated well could find several oil and gas zones. A similar application was used by QGPC for a heterogeneous Arab-C reservoir in Dukhan Field. From J. Bouvier and A. Heward of Petroleum Development Oman. Presented at the1993 AAPG International Conference, The Hague, The

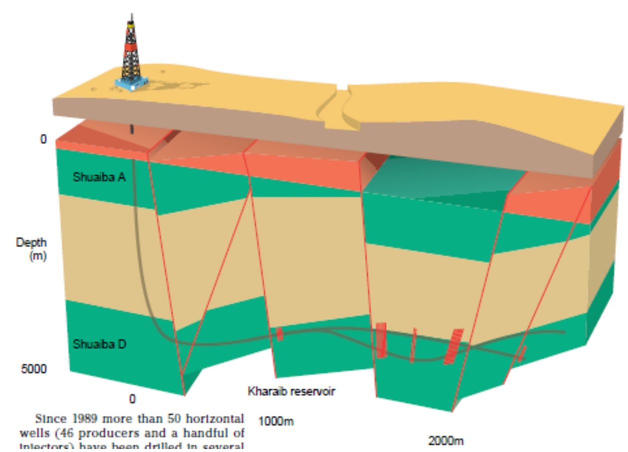


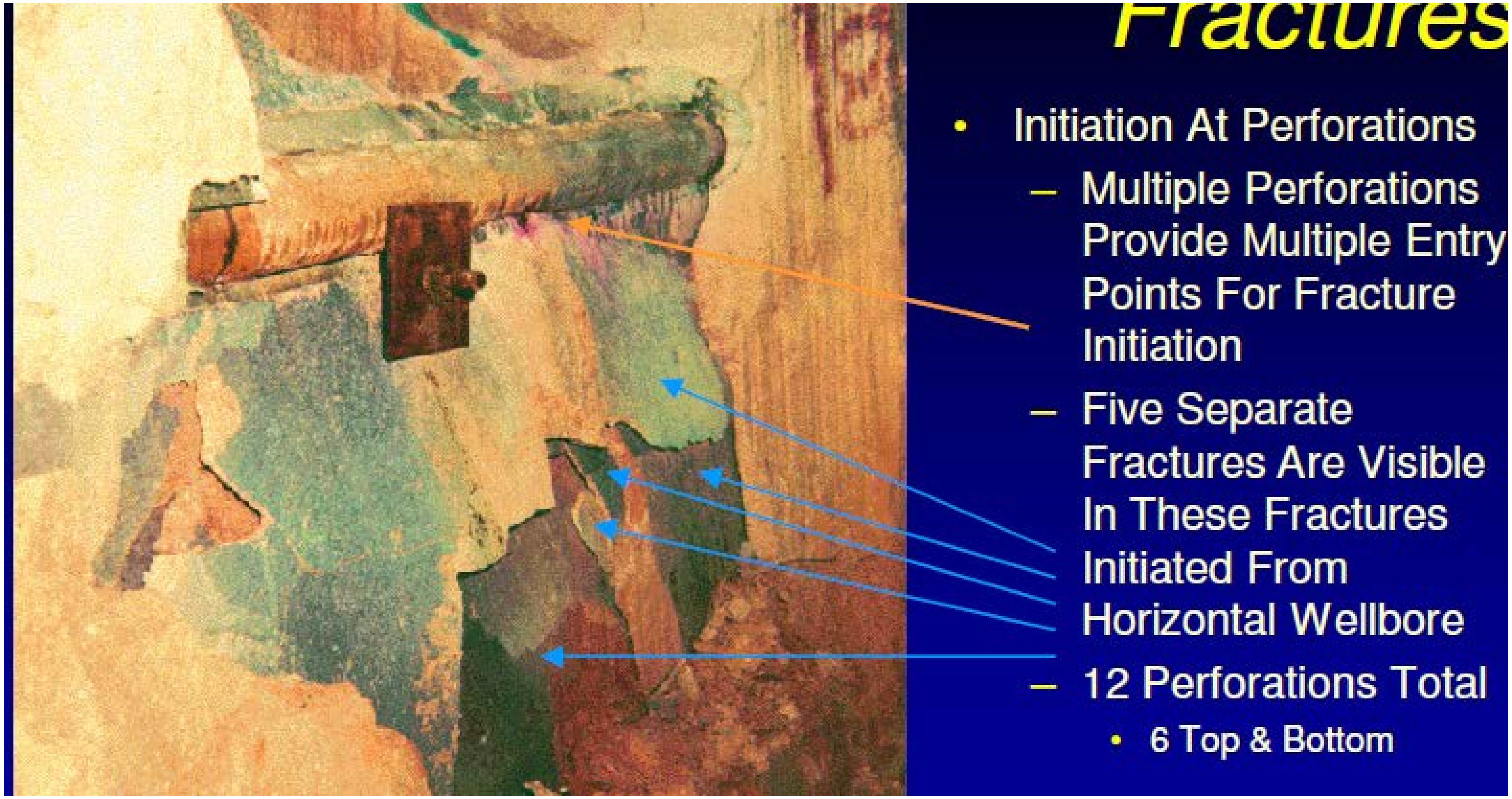
Fig. 1.10: Unexpected faulting made it difficult for two horizontal wells to remain within the target (Kharaib reservoir layer) in Qatar's Idd El Shargi Field. FMS images from both wells revealed that the fractures were closely related to the faults. Exact dip and strike values for the faults were also obtained using the FMS. The use of borehole imagery indicated which faults were open and were responsible for the loss of drilling fluids in the second well. This figure is modified from the GEO 94 paper presented by P. Cosgrove and A.F. Jubralla of QGPC.

Since 1989 more than 50 horizontal wells (46 producers and a handful of injectors) have been drilled in several

WIE SEHEN FRACS AUS ?

Wie sieht so ein Frac aus?

- Multiple Fracs in Mesa Verde

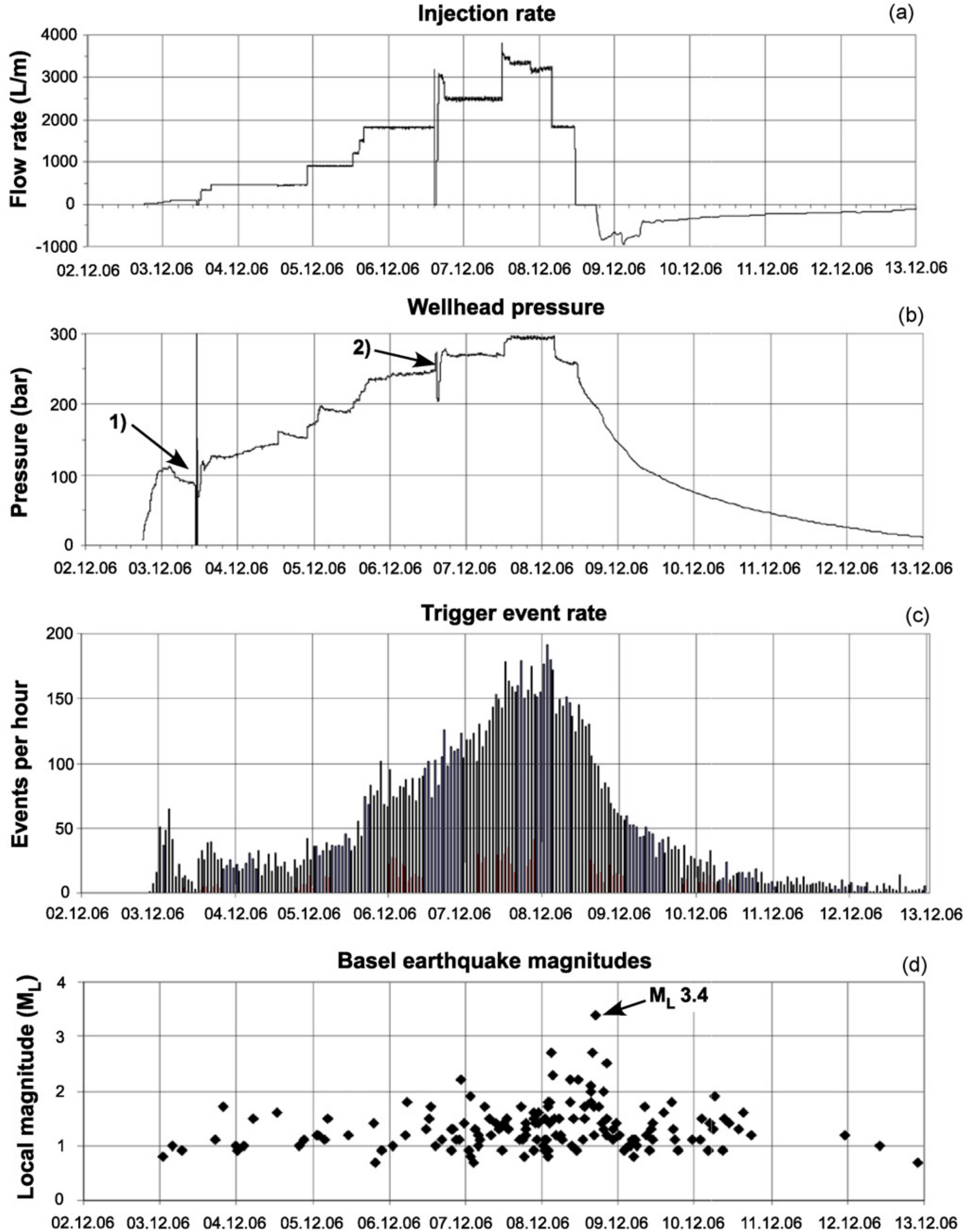


M. Vincent, Fracwell (2010)

Spanish Peaks Volcanic Dikes, Colorado

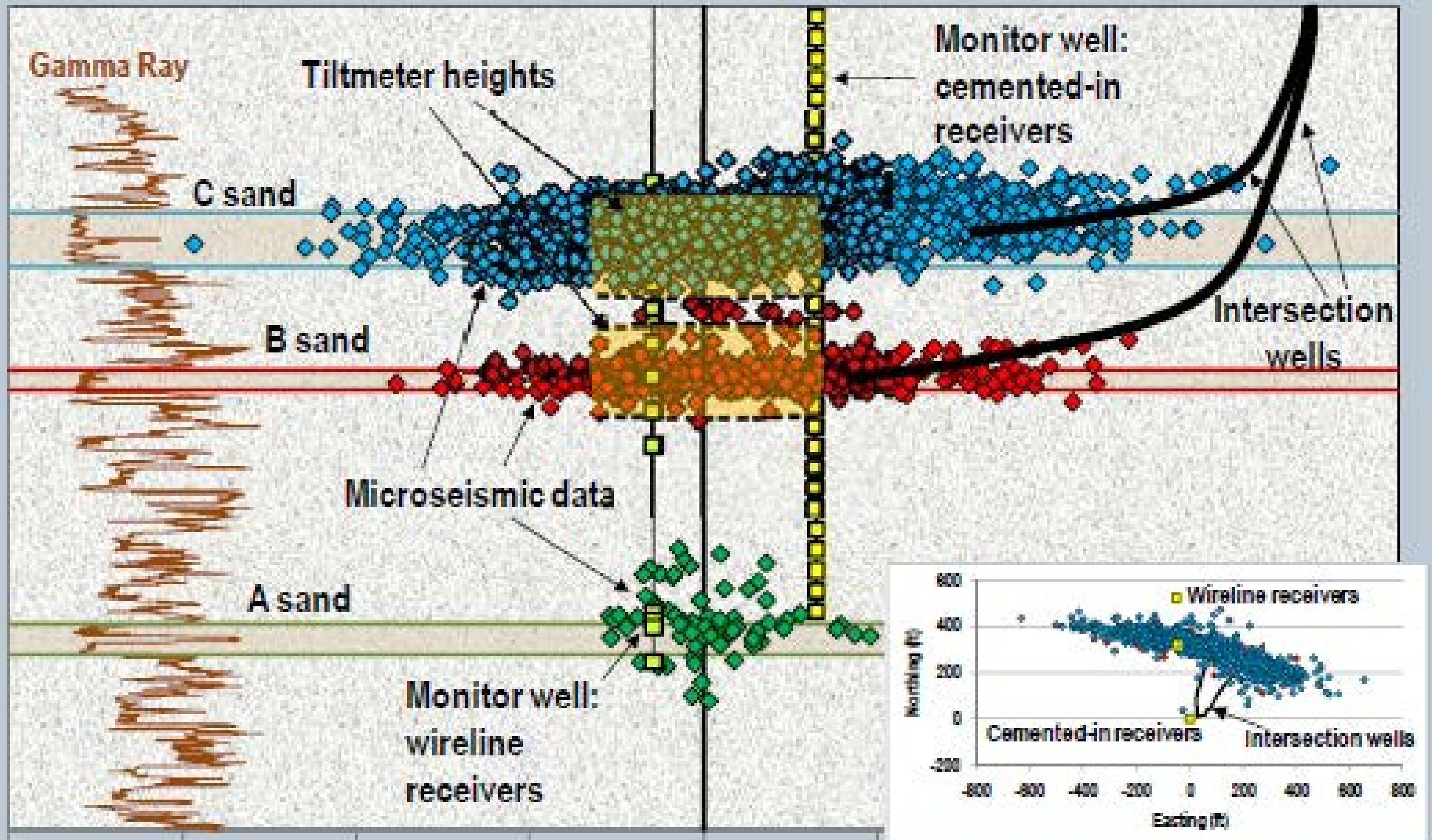
Paul Ellner

Basel



Injection rate
(a)
Flow rate (L/m)
4000
3000
2000
1000
0
-1000
02.12.06 03.12.06 04.12.06 05.12.06 06.12.06 07.12.06 08.12.06 09.12.06 10.12.06 11.12.06 12.12.06 13.12.06
Wellhead pressure
(b)
Pressure (bar)
300
200
100
0
1)
2)
02.12.06 03.12.06 04.12.06 05.12.06 06.12.06 07.12.06 08.12.06 09.12.06 10.12.06 11.12.06 12.12.06 13.12.06
Trigger event rate
(c)
Events per hour
200
150
100
50
0
02.12.06 03.12.06 04.12.06 05.12.06 06.12.06 07.12.06 08.12.06 09.12.06 10.12.06 11.12.06 12.12.06 13.12.06
Basel earthquake magnitudes
(d)
Local magnitude (M_L)
4
3
2
1
0
M_L 3.4
02.12.06 03.12.06 04.12.06 05.12.06 06.12.06 07.12.06 08.12.06 09.12.06 10.12.06 11.12.06 12.12.06 13.12.06

Fracture Monitoring



Source: DOE/GRI M-Site test

Verschiedene „Hydraulic Fracs“

- „Leak Off Test“ → Sicherheitsrelevant bei Tiefbohrungen
- „Mikro und Mini Fracs“ → Sicherheitsrelevant…

- Hydraulische Stimulation (Erhöhung der Wirtschaftlichkeit)
  - Drucksäuerung
  - Massive hydraulische Fracs
  - Hydraulische Fracs mit Stützmittel

Schiefergasvorkommen in Deutschland

Einerseits könnte man meinen:

- Technologieentwicklung ja
- Schiefergasförderung momentan nur an Testsites (sparen wir das Gas für später auf und lernen aus den Fehlern der anderen)
- Entwicklung nichttoxischer Gels

Andererseits :

- Shale Gas hat die Gaspreise und CO_2 Ausstoß in den USA gesenkt
- Gas wird für die Brückentechnologie der Energiewende benötigt
- Shale Gas Fracturing bei uns verhindert unkontrollierte und hochriskante Abbaumethoden an anderer Stelle (wo sich die Bevölkerung nicht so gut wehren kann).

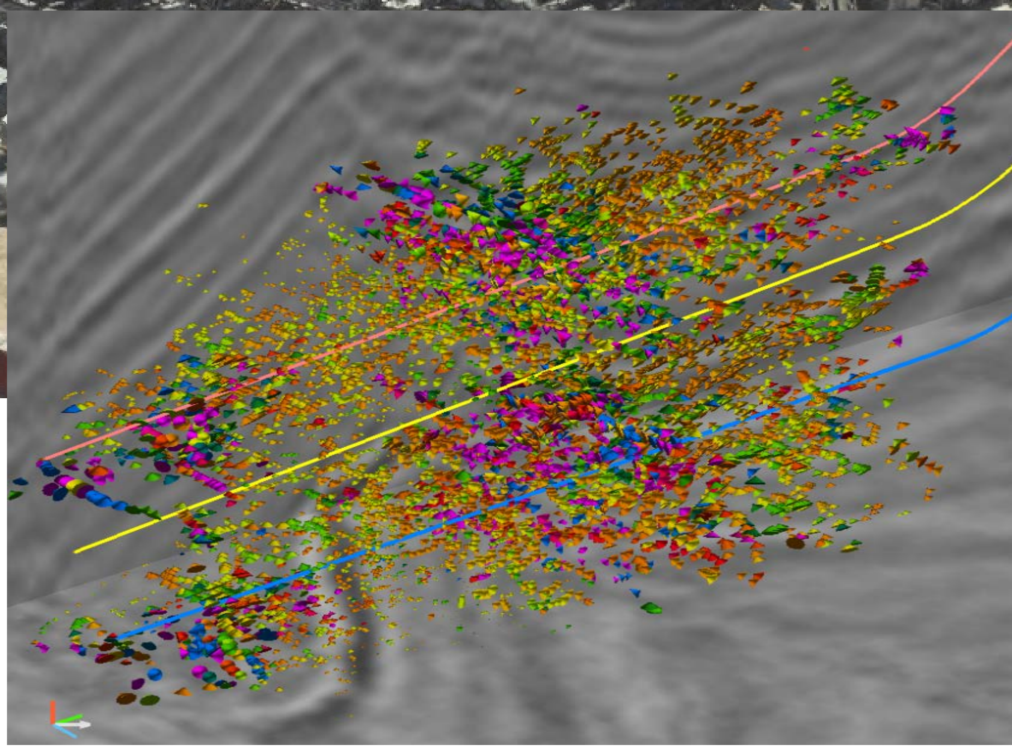
Ähnlich kritische Blicke auf Verpressung oder Lagerung von (nicht nur radioaktiven) Abfällen im Untergrund. Auch das Material der Solardächer wird irgendwann (Sonder)Müll. →Faire Diskussion wird benötigt.

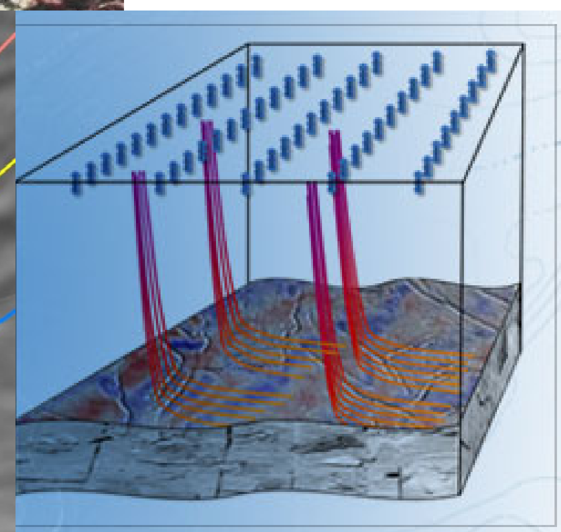
Funktion des „Chemie-Coctails“

- Schonung der Rohre (Korrosionsinihibitor)
- Ggf. Propants
- Einstellung der Viskosität
- Einstellung der Dichte
- Änderung der Viskosität nach Beendigung des Fracs
- Biozide zur „Stabilisierung“ der Frac-Fluide

Fracing On Site

Karlsruhe Institute of Technology





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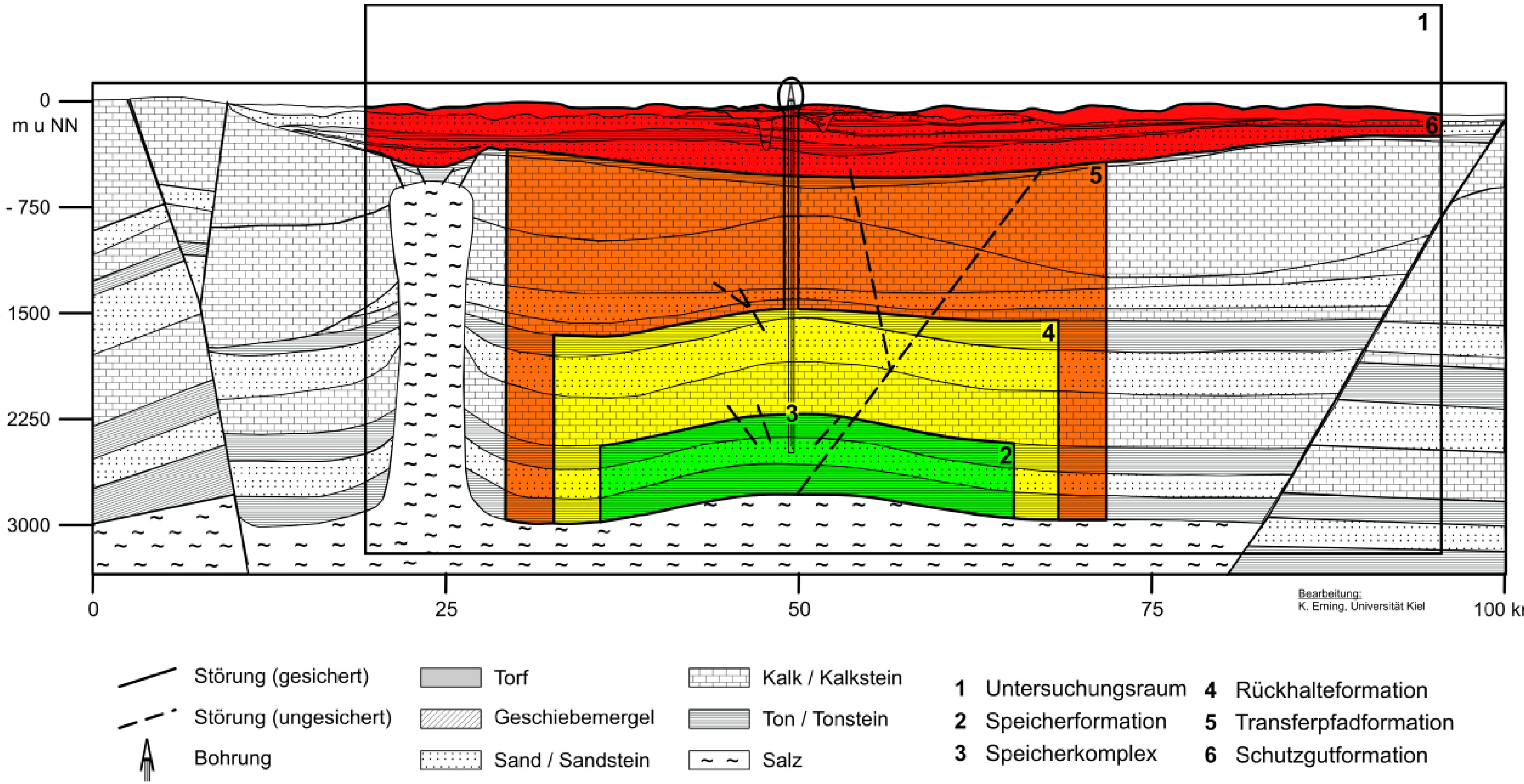
www.terraspark.com, www.globalgeophysical.com

Wann wird es kritisch



Grossmann, Dahmke, Schilling, 2011

Verschiedene „Hydraulic Fracs“

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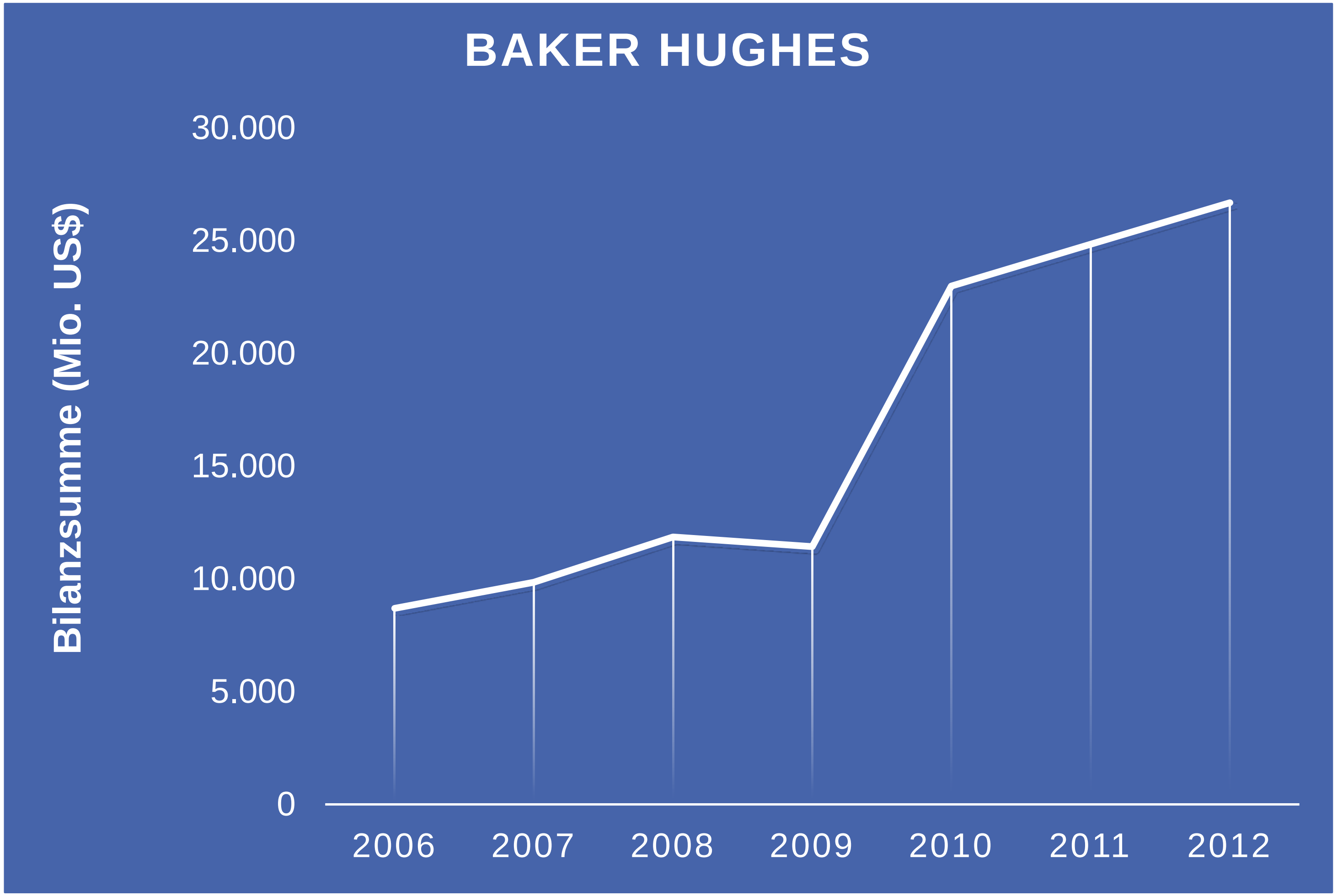
Wer verdient? – z.B. Celle



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No Fracing No Future?

Vielen Dank für Ihre Aufmerksamkeit

Fakultät für Bau-, Geo-, Umweltwissenschaften
Prodekan Geowissenschaften

Literatur:

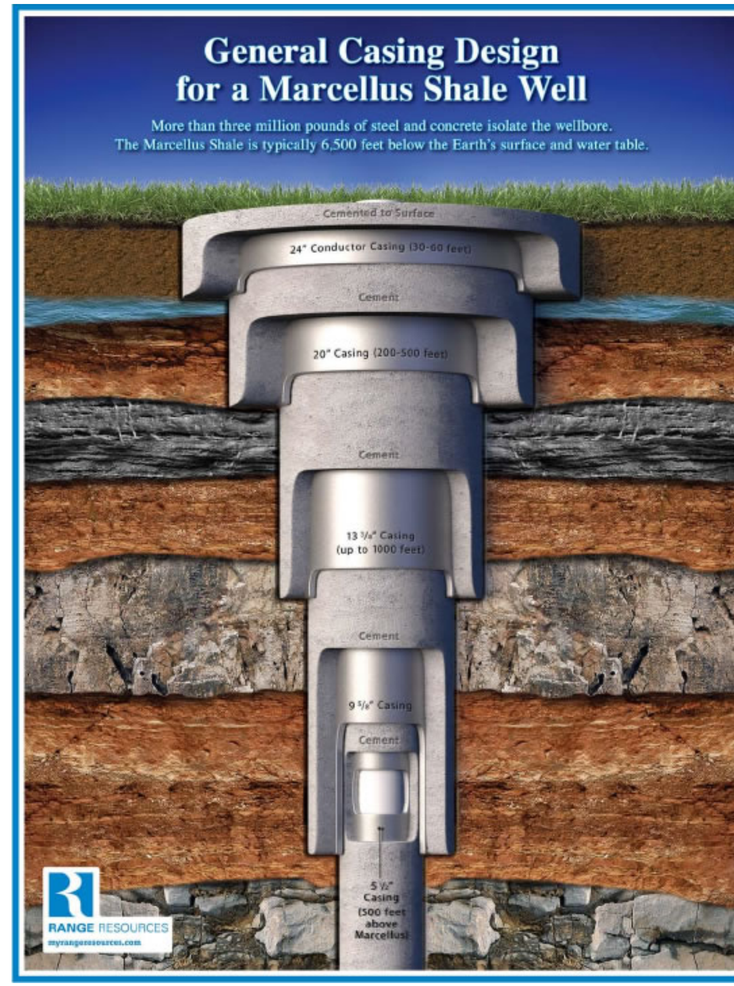
- Stosch: Einführung in die Gesteins- & Lagerstättenkunde
  Kapitel 4., Online Script, 2009
- Schilling (Bohren – in Vorbereitung)

Hausaufgabe

- Lesen GEOTECHNOLOGIENbericht zu CCS → Monitoring

- Prinzip seismisches und elektrisches Monitoring
- Drucküberwachung im Aquifer oberhalb (warum…)

Old Well in USA



- Pennsylvania 200 000 old wells, most are not abandoned
- More strict rules in some States since 1984 (oil and gas act)

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