

## ***Das Mont Terri Felslabor: Organisation, Geologie & Übersicht Experimente***

**Medienreise Nuklearforum**

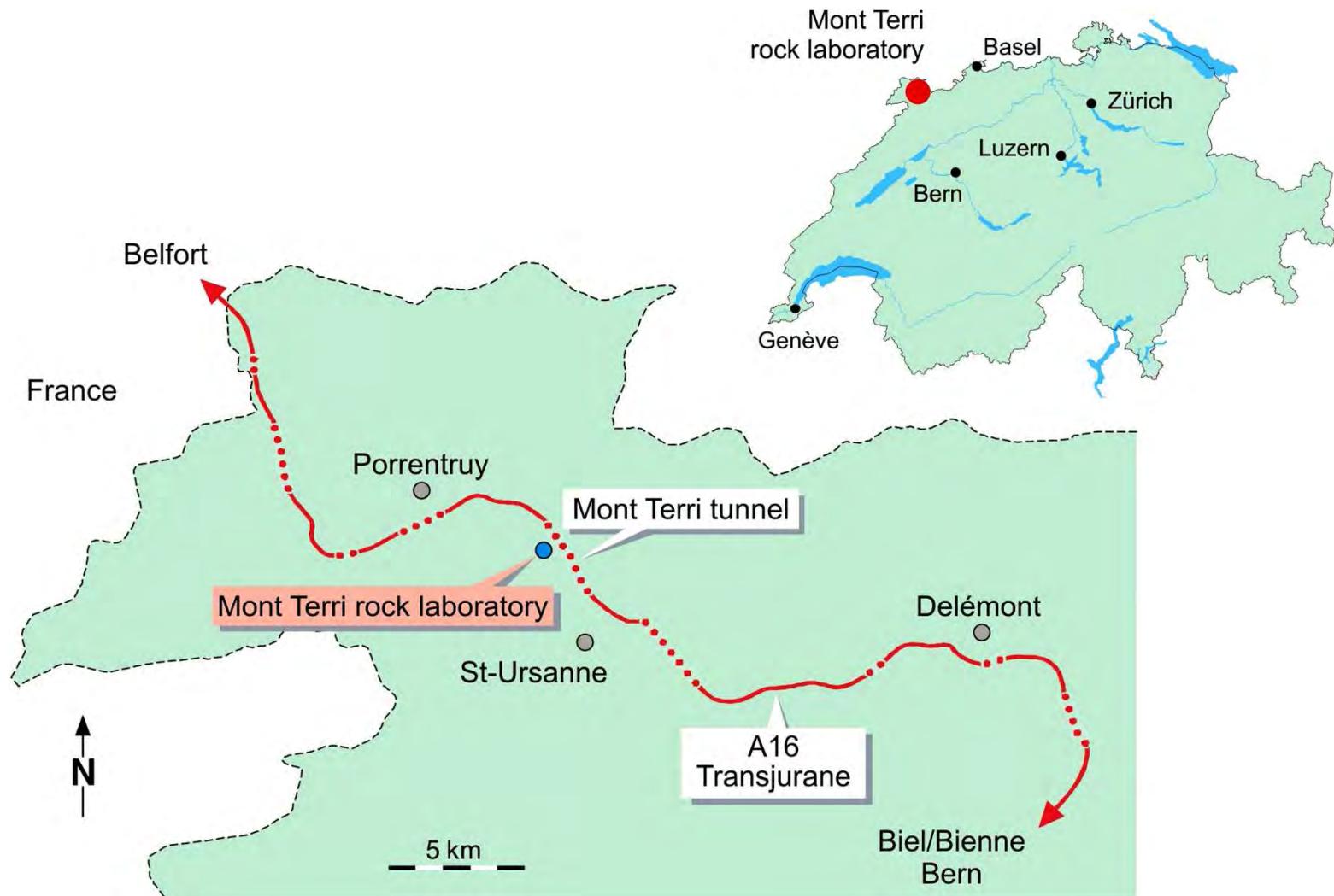
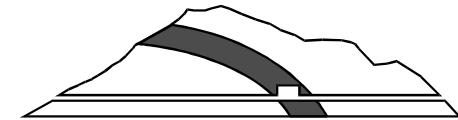
**31.10.2014**



[www.mont-terri.ch](http://www.mont-terri.ch)

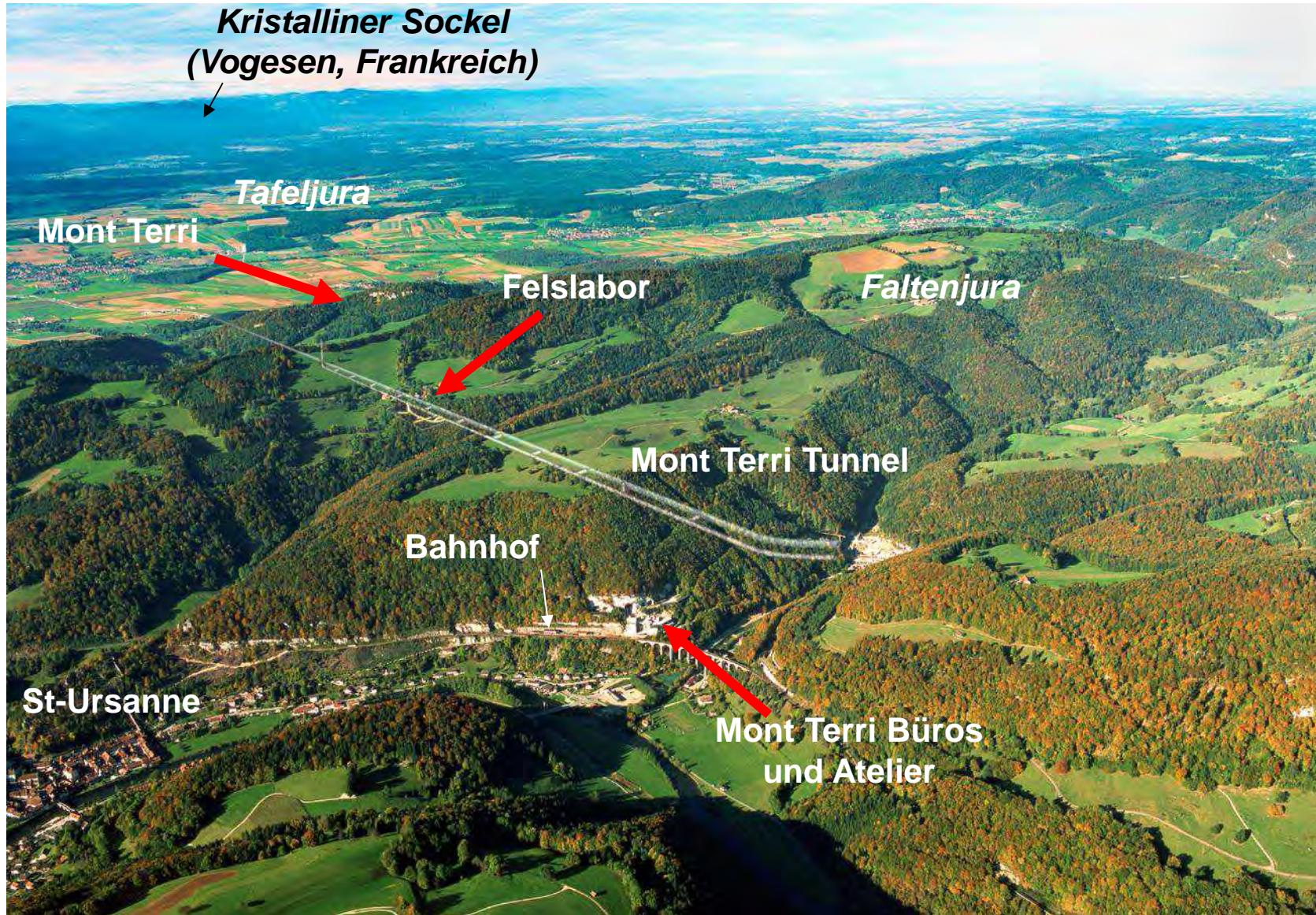
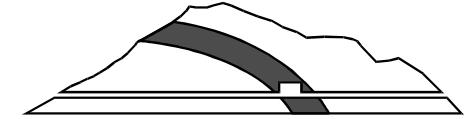
**Paul Bossart**

# Wo sind wir?



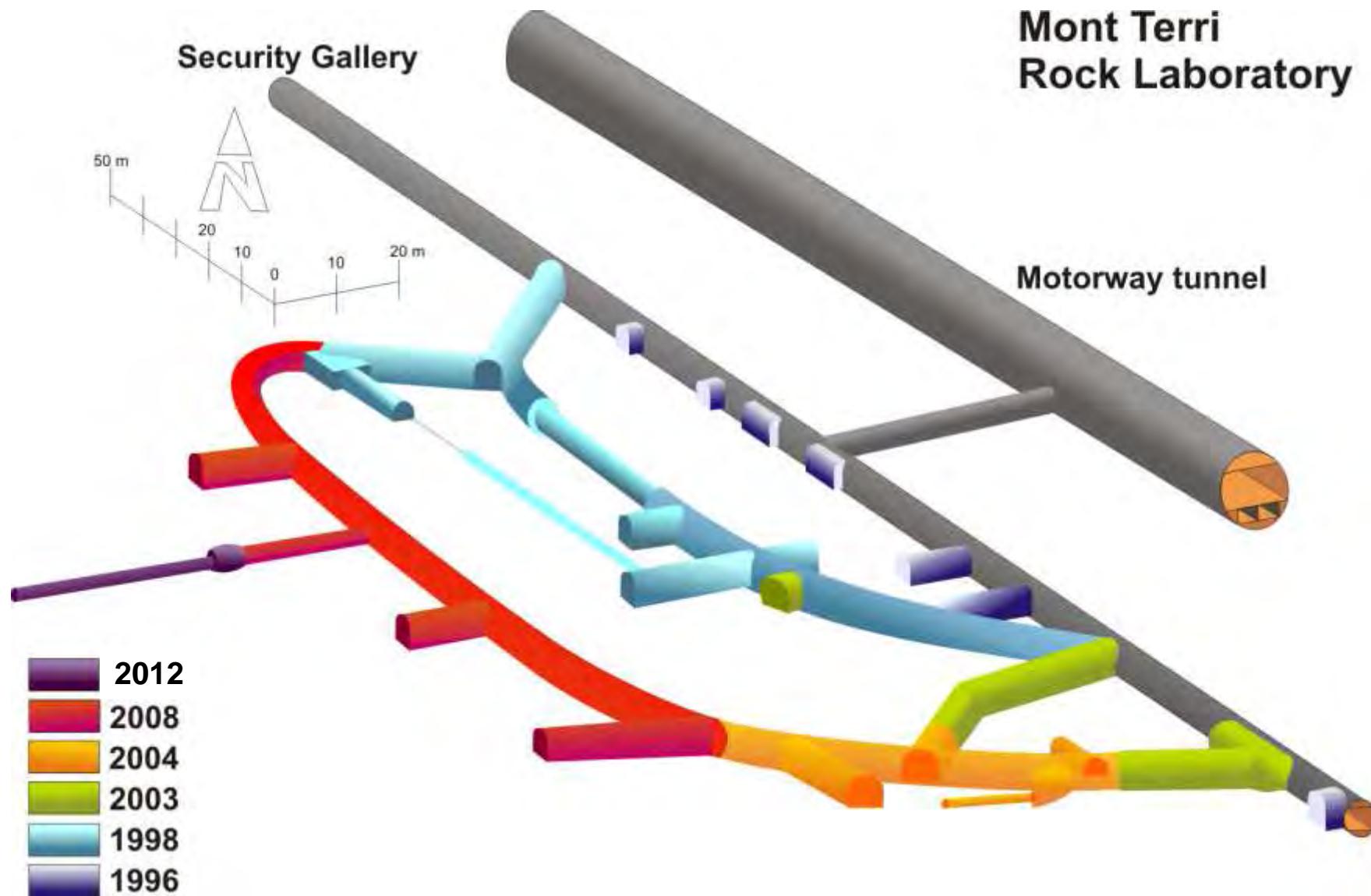


# Lage des Felslabors





# Das Felslabor



# Die Partner



**swisstopo**  
**nagra.**  
**ENSI**

**swisstopo** Bundesamt für Landestopografie  
**NAGRA** Nationale Genossenschaft für die Lagerung von radioaktivem Abfall  
**ENSI** Eidgenössisches Nuklearsicherheitsinspektorat



**ANDRA** Agence Nationale pour la Gestion des Déchets Radioactifs  
**IRSN** Institut de Protection et de Sûreté Nucléaire



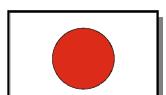
**BGR** Bundesanstalt für Geowissenschaften und Rohstoffe  
**GRS** Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) mbh



**ENRESA** Empresa Nacional de Residuos Radiactivos, S.A.



**SCK•CEN** Studiecentrum voor Kernenergie, Mol



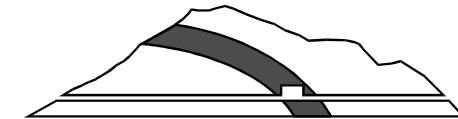
**JAEA** Japan Atomic Energy Agency  
**OBAYASHI** Obayashi Corporation  
**CRIEPI** Central Research Institute of Electric Power Industry



**NWMO** Nuclear Waste Management Organisation, Toronto

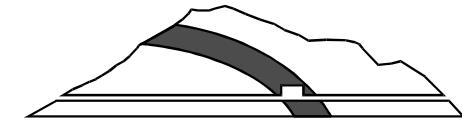


**U.S. DOE** Department of Energy, Washington DC  
**Chevron** Chevron Energy Technology Company, Houston





# Organisation



Convention 2009

Agreement 2001

## Überwachung

RCJU

Commission de suivi

## Leitung

swisstopo

Landesgeologie

## Forschungspartner

ANDRA BGR CHEVRON CRIEPI  
US DOE ENRESA ENSI GRS IRSN  
JAEA NAGRA NWMO OBAYASHI  
SCK•CEN SWISSTOPO

Président  
Experts

## Jährliche Bewilligungen

Direktor  
Projekt Manager

Ingenieur  
Örtlicher Leiter

Wissenschaftlicher Mitarbeiter

Techniker

Sekretariat & Accounting

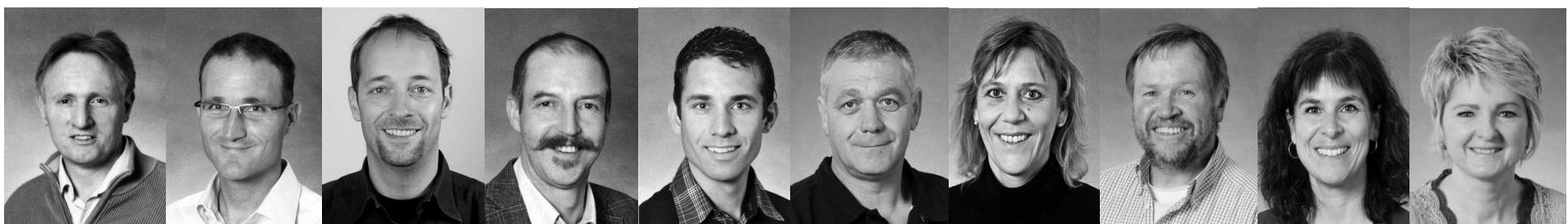
Besucherkordinator

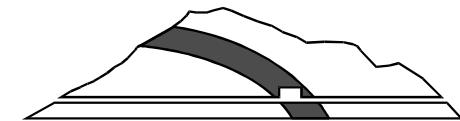
Besucherbetreuerin & Sicherheit

## Steering Committee

(1 Delegierter per Partner)

## VersuchsleiterIn

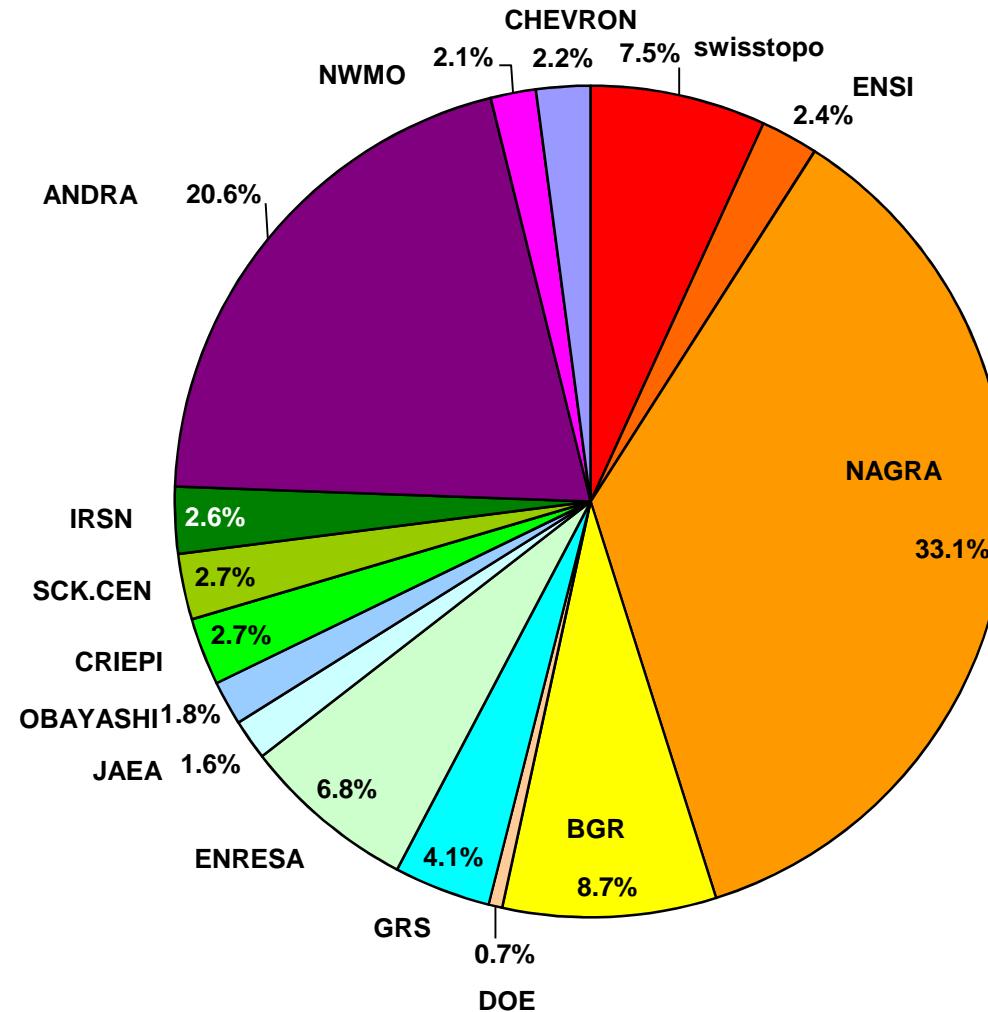




1996-mid 2015

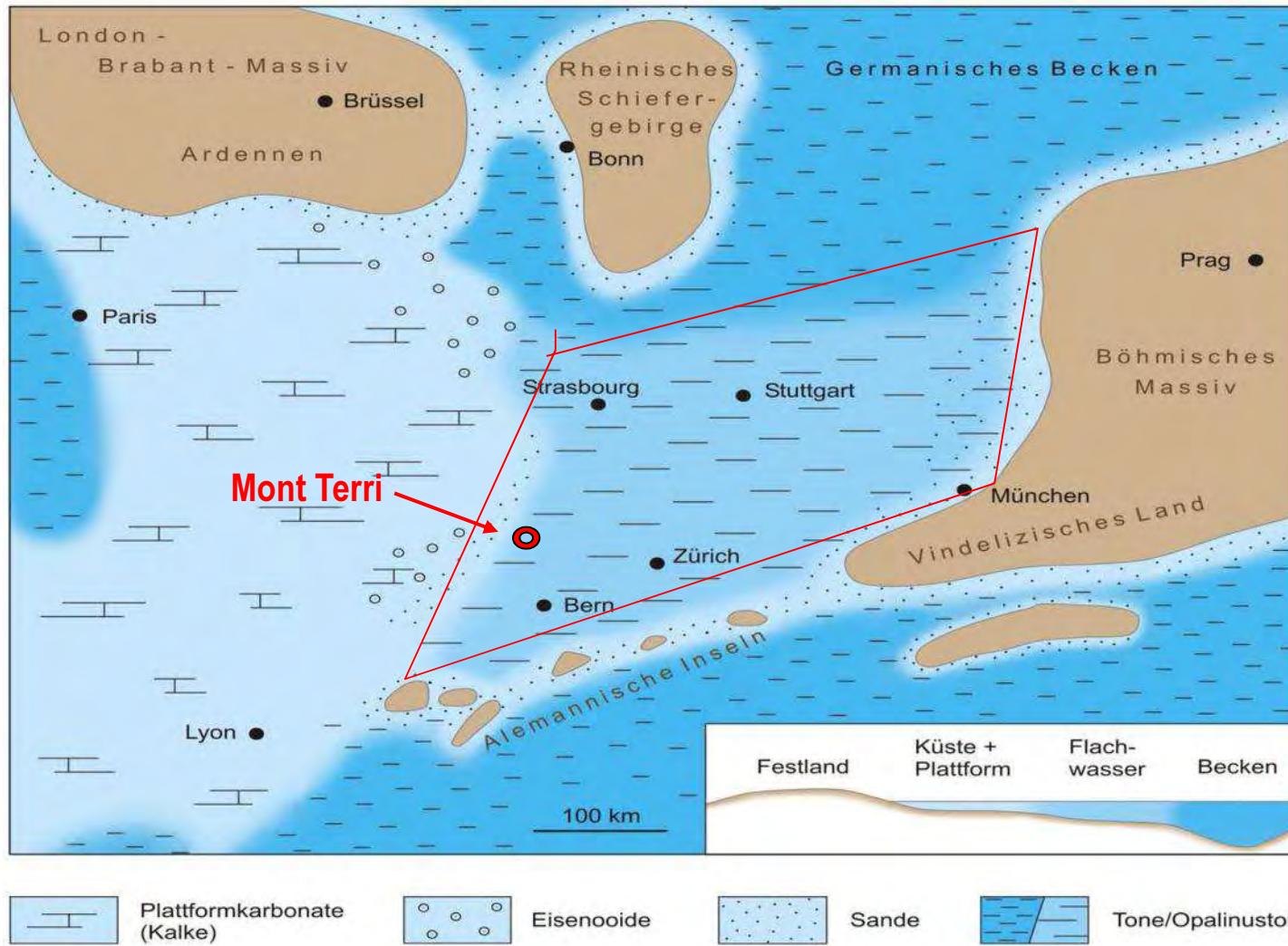
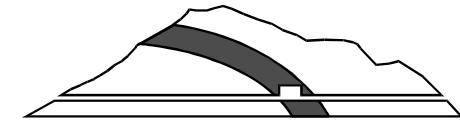
**73.5 Mio. CHF**

**20% remain in  
Canton of Jura**





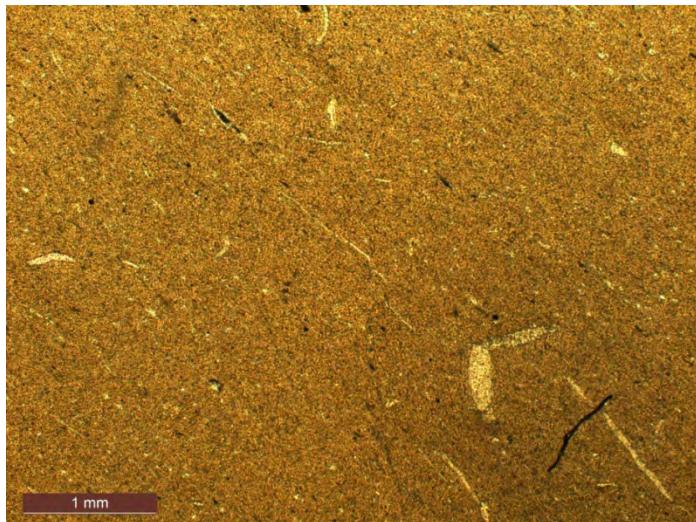
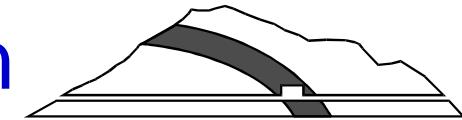
# Geologie - Paläogeografie



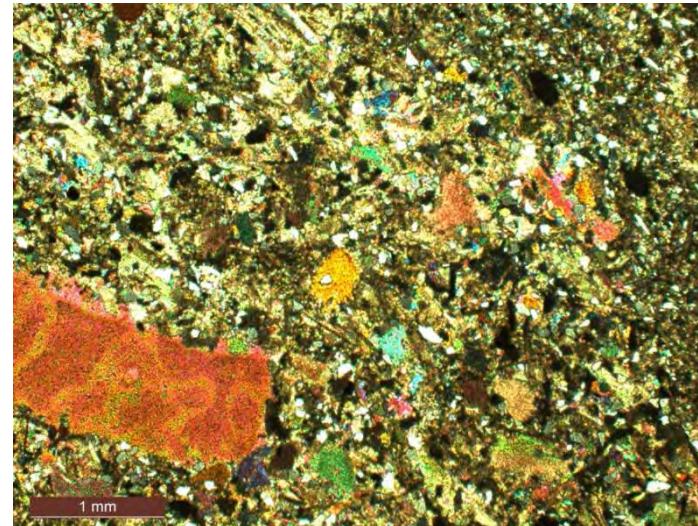
Mitteleuropa vor 174 Mio Jahren



# Geologie- Ton ist nicht gleich Ton



Tonige Fazies



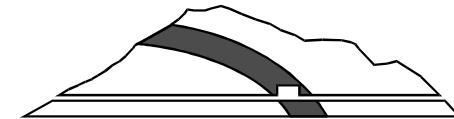
Sandig Karbonatreiche Fazies



Sandige Fazies

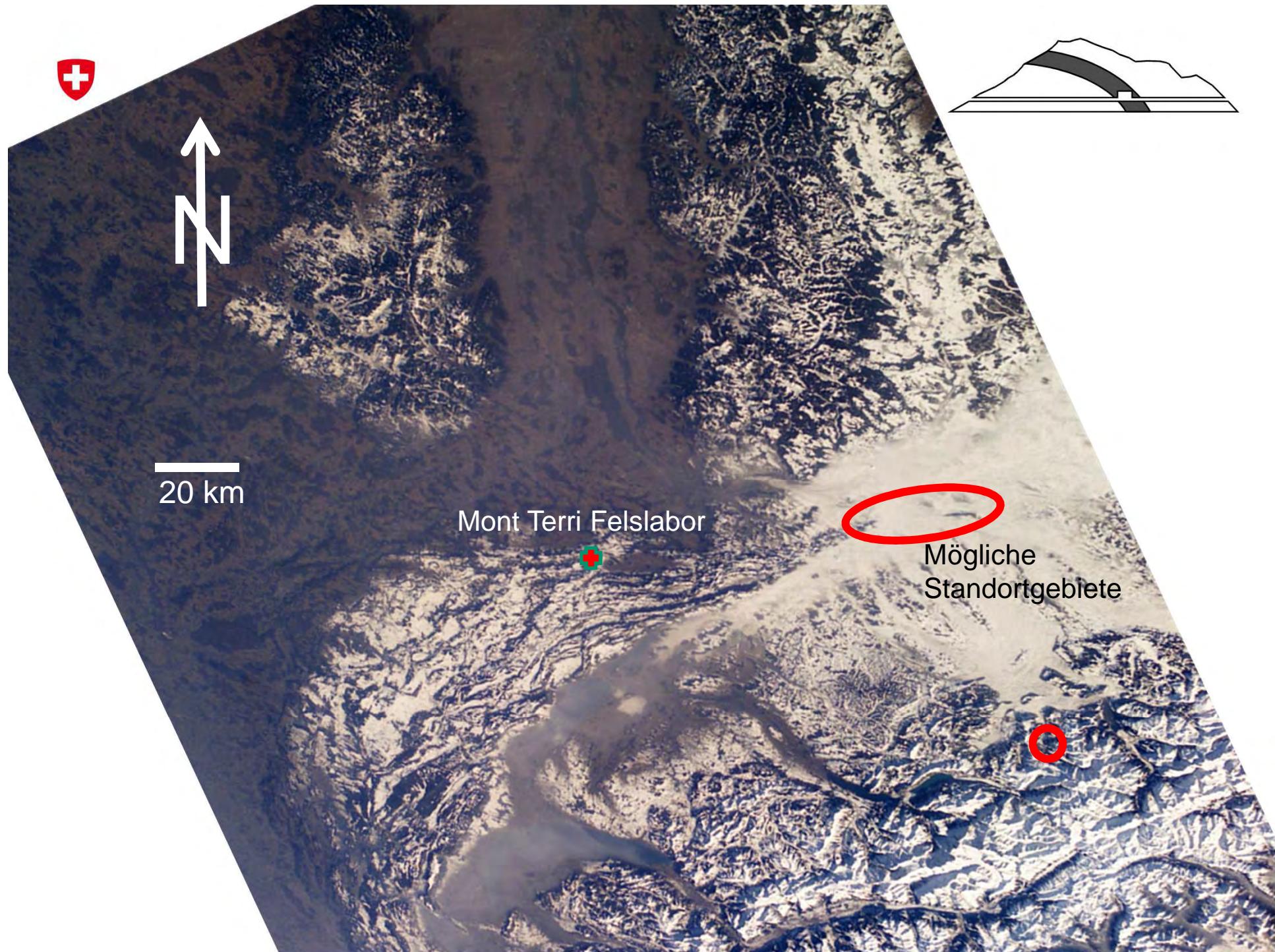


# Geologie – 3 Faziestypen



	Tonige Fazies	Sandige Fazies	Sandig-karbonatreiche Fazies
Ton	28-93	6-62	8-30
Quarz	10-32	21-52	22-36
Kalk	4-29	7-66	33-49

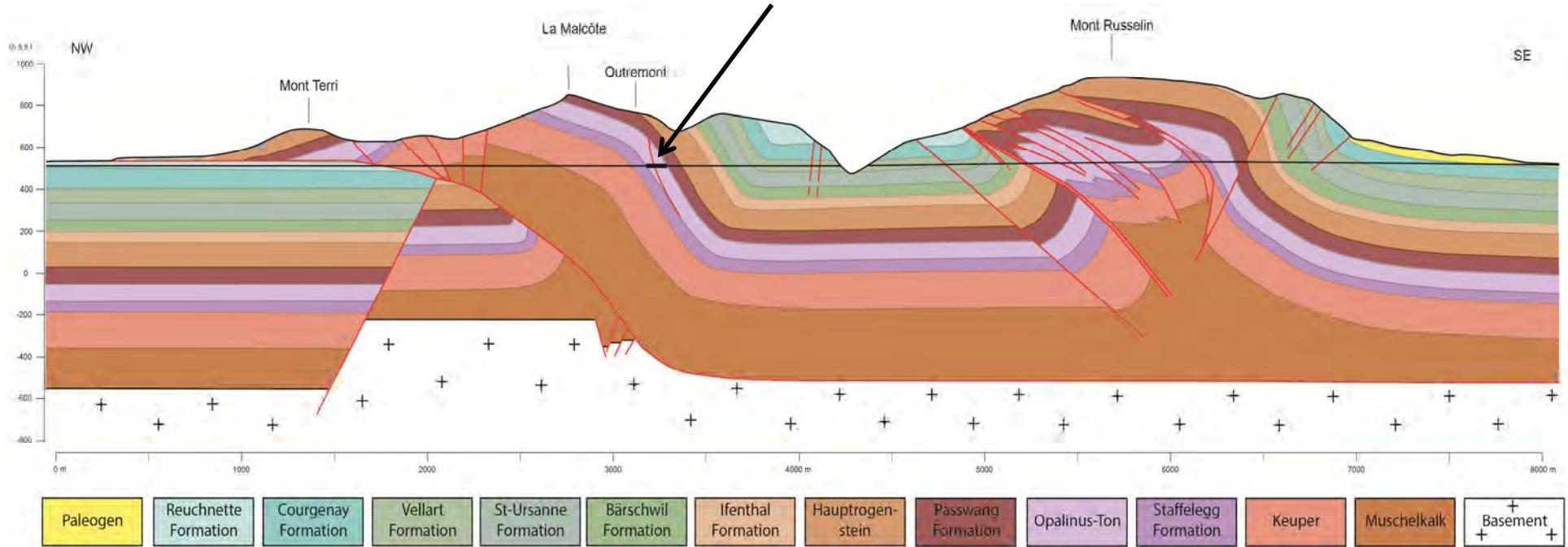
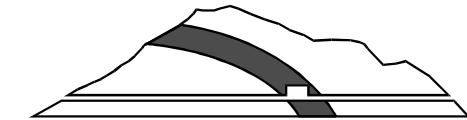
Tonminerale	Illit, Illit-Smektit-mixed-layers, Chlorit, Kaolinit
Kalkminerale	Kalzit, Dolomit, Ankerit, Siderit
Weitere Mineralien	Feldspat, Coelestin, Barit, Pyrit und organisches Material





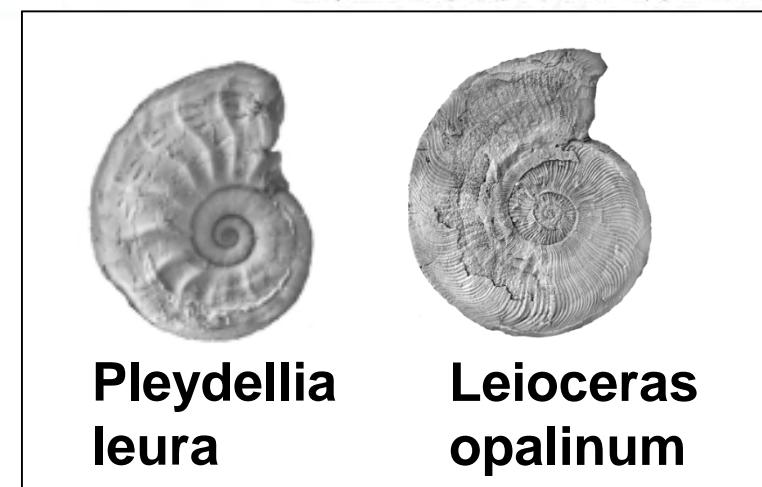
# Geologisches Profil

## Felslabor

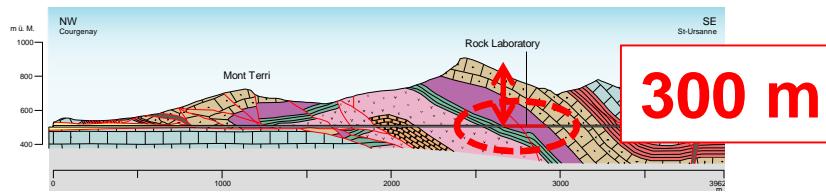
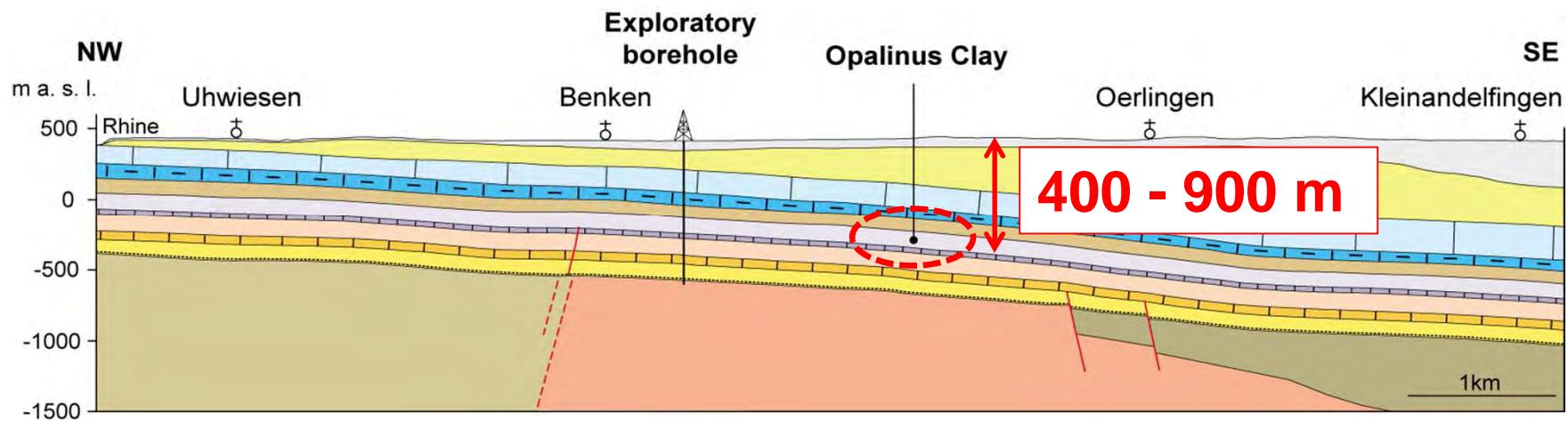
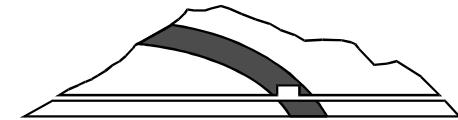


drawn by N. Kern after Freivogel & Huggenberger (2003), Caer (in preparation) J. Norbert & B. Schindler (1988) and J. Norbert (1992)

Alter  
Opalinus-Ton  
174 Millionen Jahre



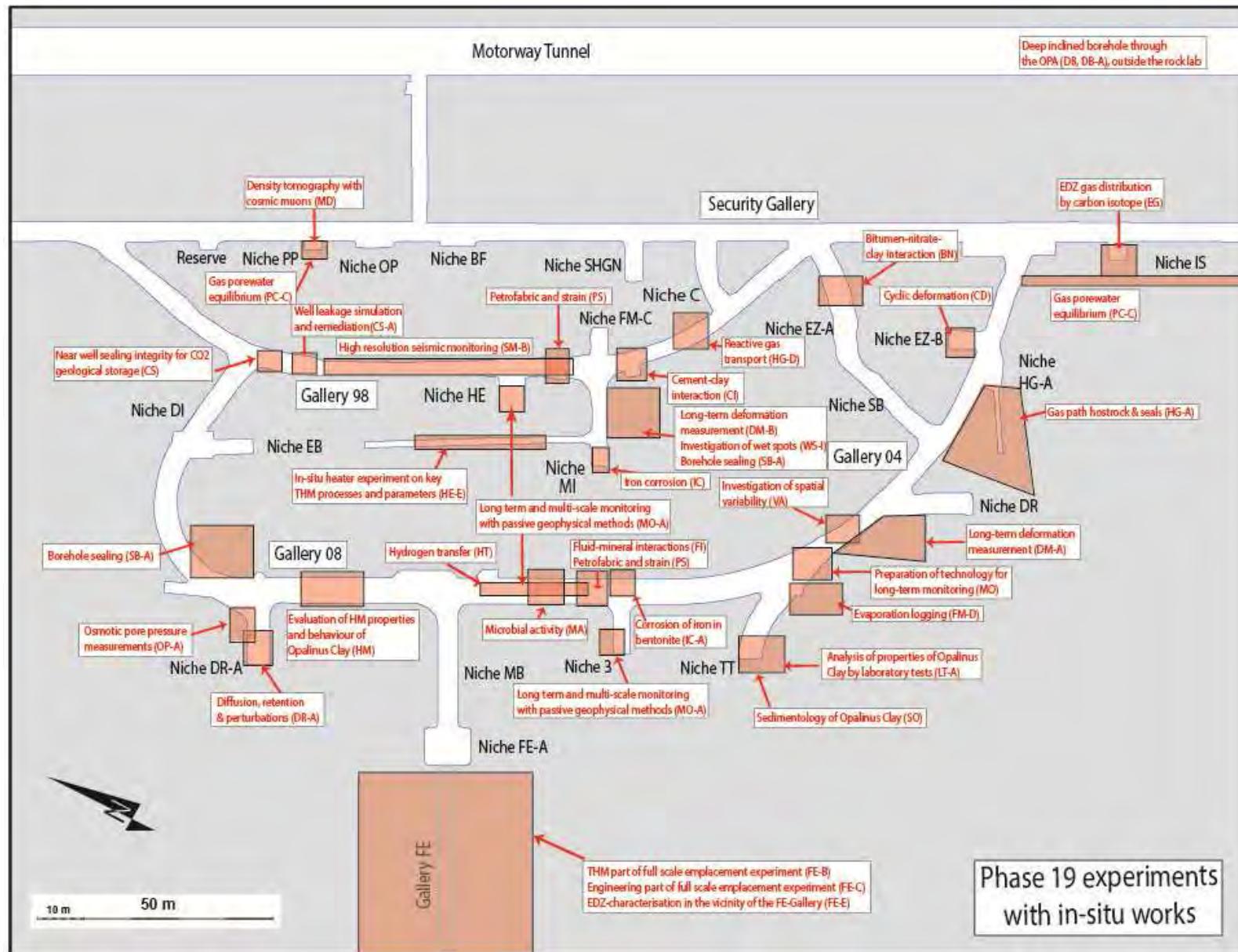
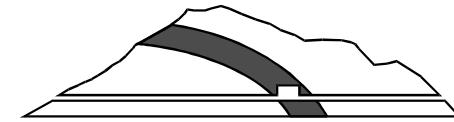
# Geologie – Vergleich zu potentiellen Standorten



1 km

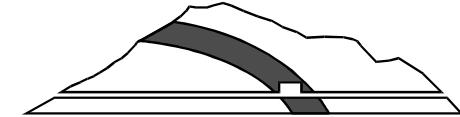


# Aktuell 46 laufende Experimente





# Ziele der Experimente



- **Evaluierung von Technik und Methodik**

Bohrmethoden, Exkavierungsmethoden, Ausbauarten  
Probennahme und Druckmessungen bei Porenwasser  
Konvergenzmessungen  
Mechanische und hydraulische Versuche

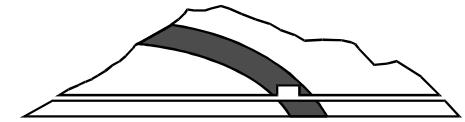
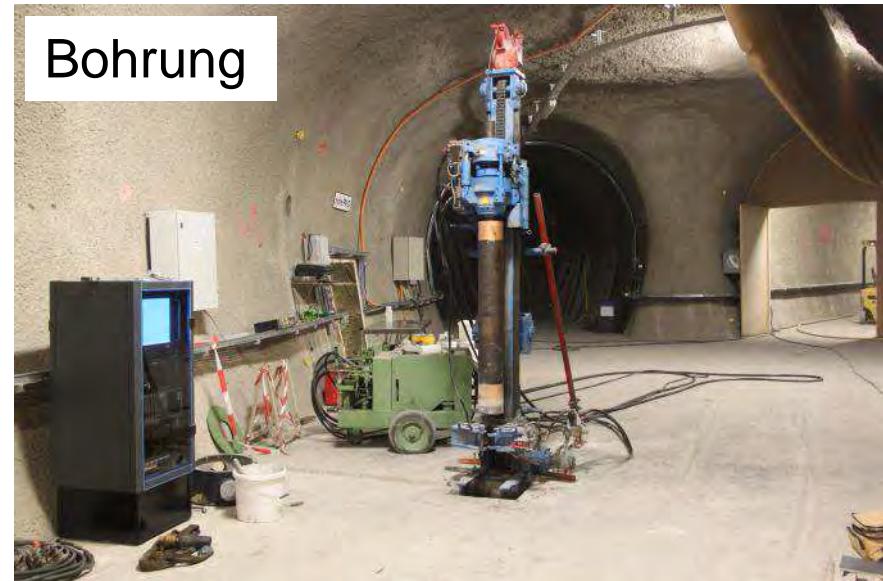
- **Charakterisierung eines Tons (Opalinuston)**

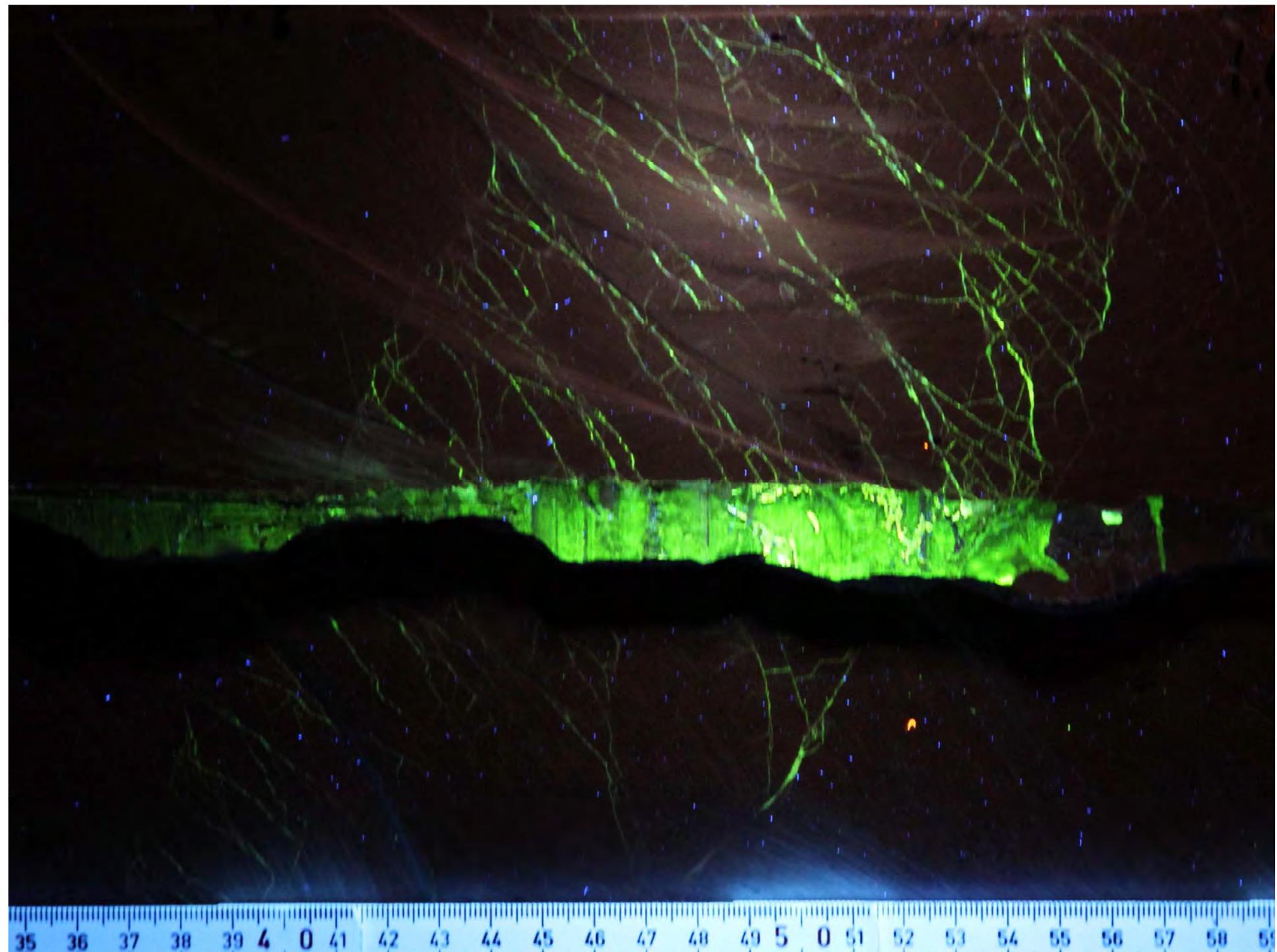
Identifizierung der Prozesse (z.B. Stofftransport, Deformationen)  
Schätzung von Parametern (hydraulisch, mechanisch, chemisch)  
Thermische Eigenschaften  
Entstehung und Verhalten der Auflockerungszone (EDZ)  
Selbstabdichtung von Klüften innerhalb der EDZ

- **Demonstrations-Experimente**

Technische Barrieren (Stahlbehälter, Bentonit), Performance Tiefenlager  
THMC (Thermo-Hydraulische-Mechanische-Chemische Koppelung)

# ✚ Evaluierung von Technik und Methodik (1/4)

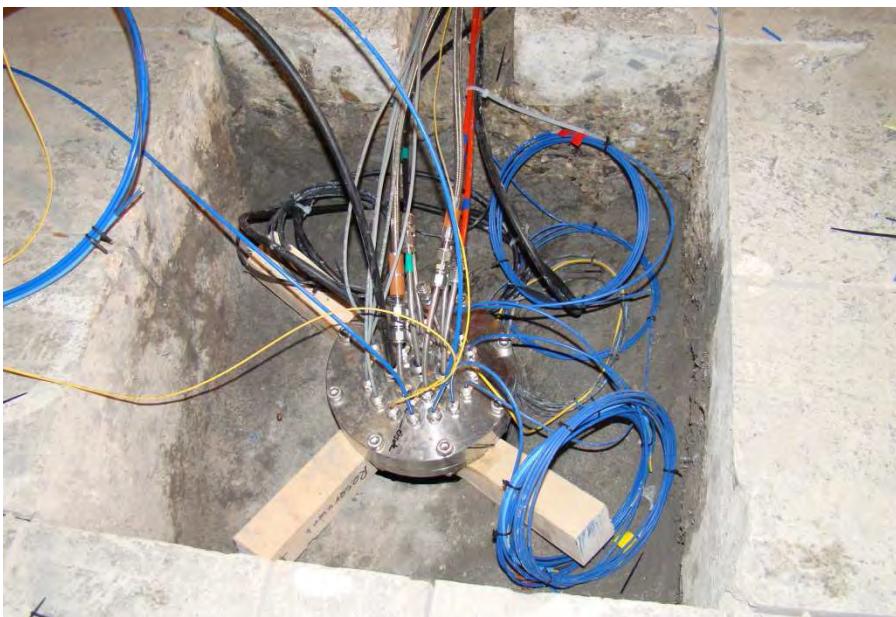
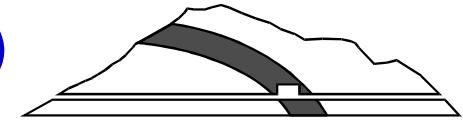






## Evaluierung von Technik und Methodik (2/4)

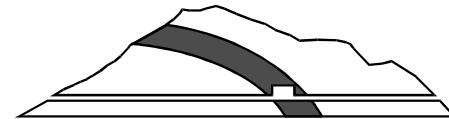
### Langzeit-Monitoring: Alterung Fiberoptischer Leiter



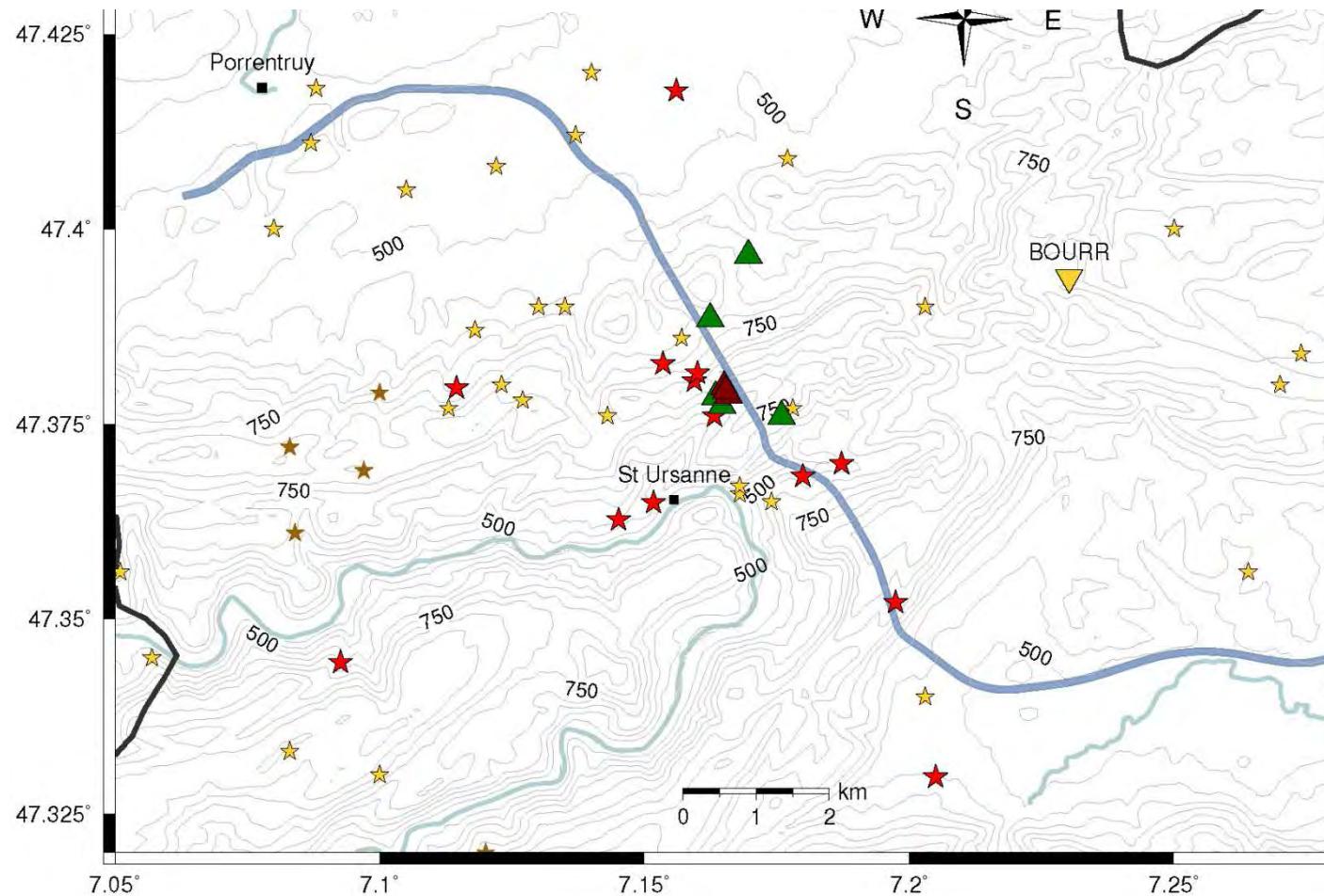


# Evaluierung von Technik und Methodik (3/4)

## Neues Experiment: Nanoseismic Monitoring

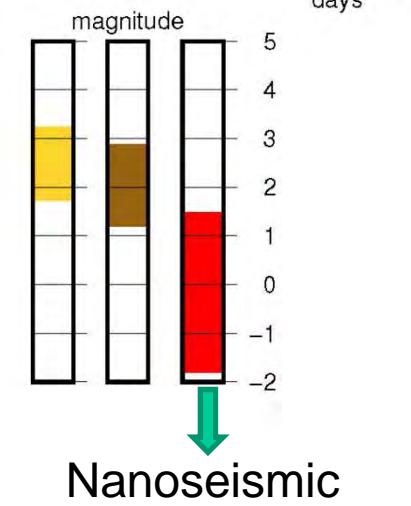
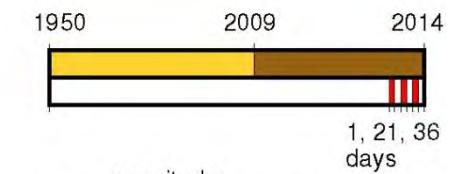


47.45°  
Local seismicity in the Mont Terri region recorded by SED (microseisms: 30 events in 30 years) and Uni Stuttgart (nanoseisms: 13 events in 4 weeks)



- ▼ SED 3C
- ▼ RéNaSS 3C
- ▲ NSM surface SNS
- ▲ NSM underground SNS
- ★ NSM events CI, CII, CIII
- ★ SED 1950–2009 ECOS-09
- ★ SED 2009–2013/09 from [www.seismo.ethz.ch](http://www.seismo.ethz.ch)

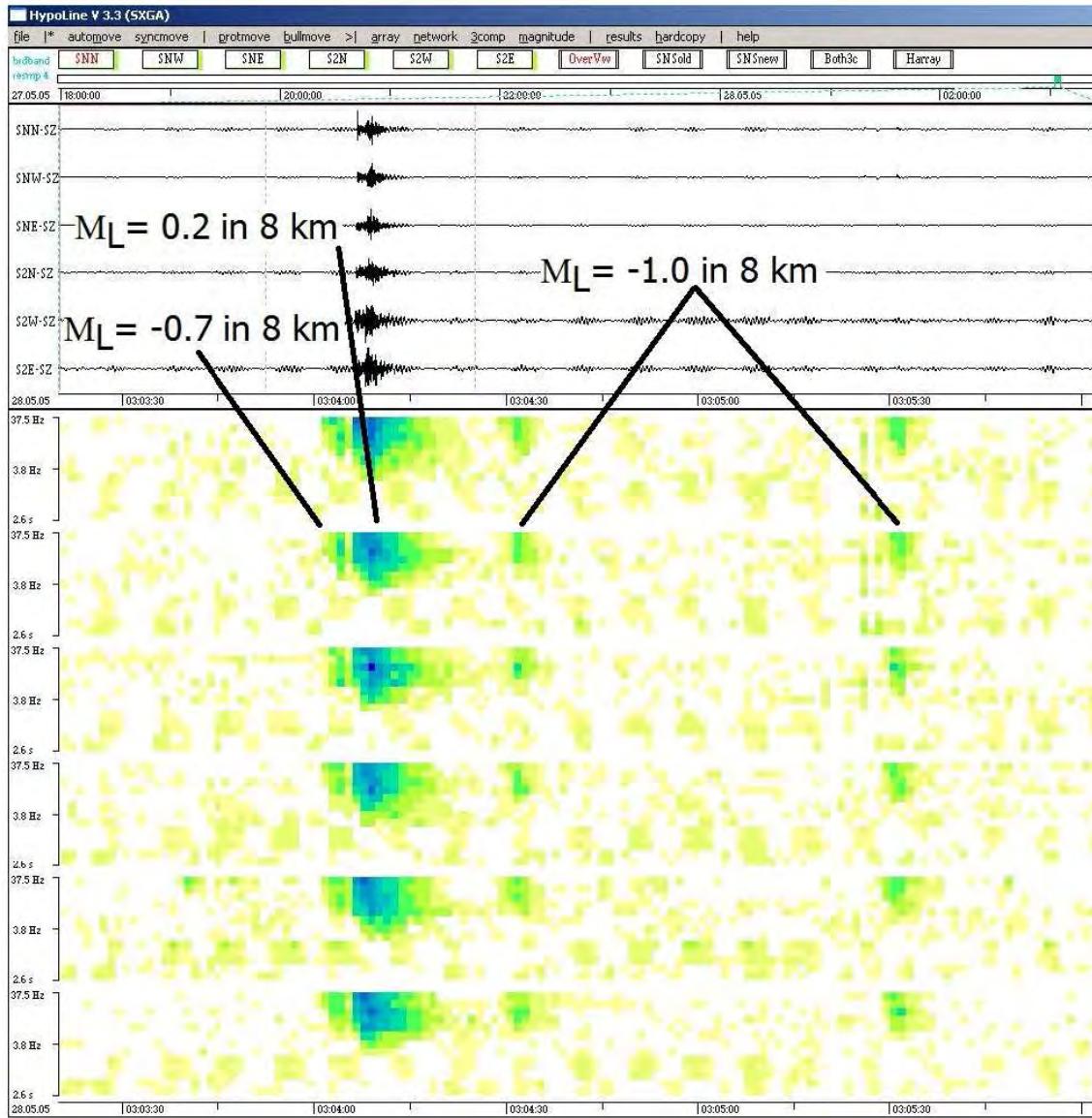
- Highway
- Rivers



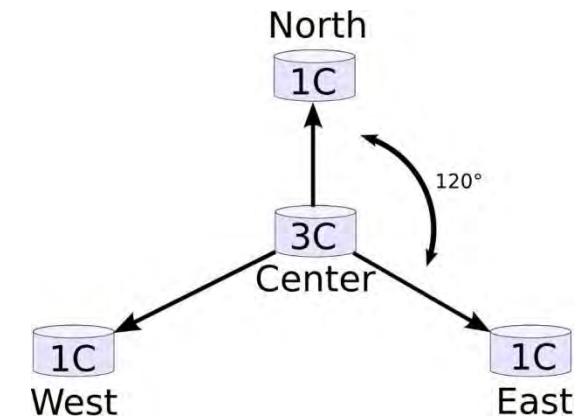


# Evaluierung von Technik und Methodik (4/4)

## Neues Experiment: Nanoseismic Monitoring



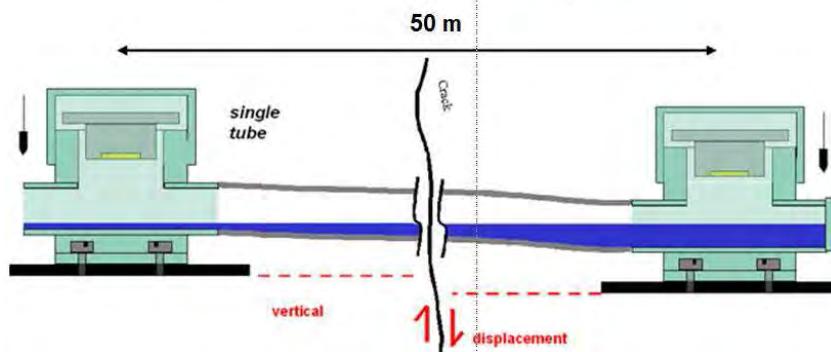
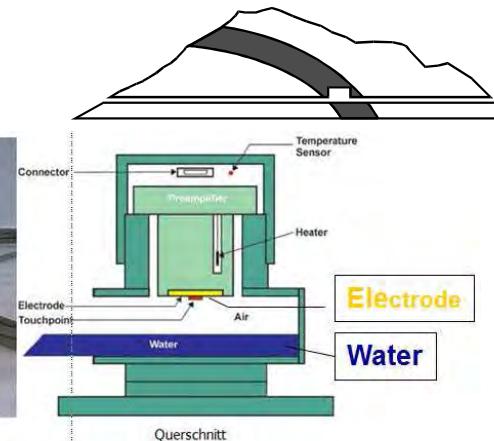
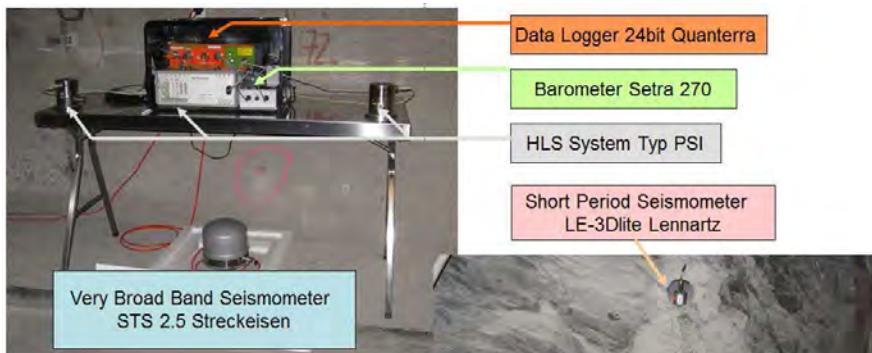
**Seismogram vs.  
Sonogram: detection  
of real events of very  
low magnitudes  
(nanoeartquakes)**



**Mini-array composed  
of 4 seismometers**

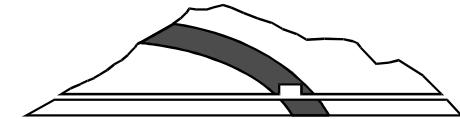


# Seismic Equipment





# Charakterisierung OPA (1/4)



## Kennwertermittlung, Abschätzung der Unsicherheit

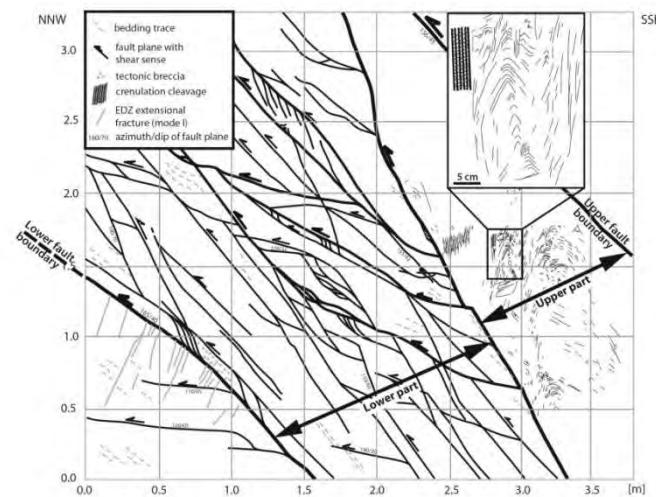
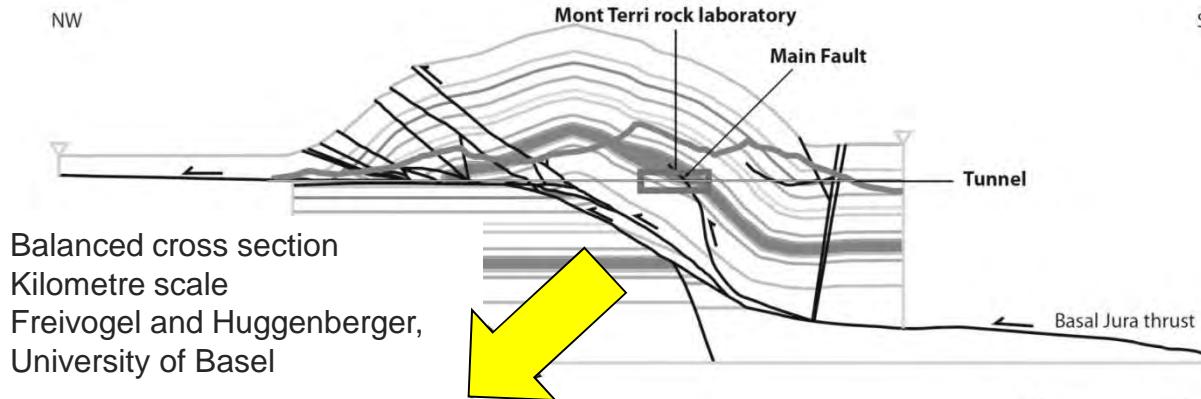
PARAMETRES	RANGE	BEST ESTIMATE
Bulk density, sat. (g cm <sup>-3</sup> )	2.40 – 2.53	2.45
Water content (wt%)	5.5 – 8.9	6.6
Total (physical) porosity (vol%)	14 – 25	18
Water loss porosity at 105°C (vol-%)	13 – 21	16
Hydraulic conductivity (ms <sup>-1</sup> )	*2E-14 – 1E-12	2E-13
Thermal Conductivity (Wm <sup>-1</sup> K <sup>-1</sup> )	*1.0 – 3.1	1.7
Heat capacity (J Kg <sup>-1</sup> K <sup>-1</sup> )	750 – 1000	860
Total dissolved solids in pore water (g/l)	5 - 20	12
Uniaxial compressive strength (MPa)	*4 – 28	11
Young's modulus (MPa)	*6000 – 12000	9000
Poisson's ratio (-)	*0.16 – 0.38	0.25
Shear modulus (MPa)	*800 – 1600	1200

\* Values are dependant on bedding anisotropy



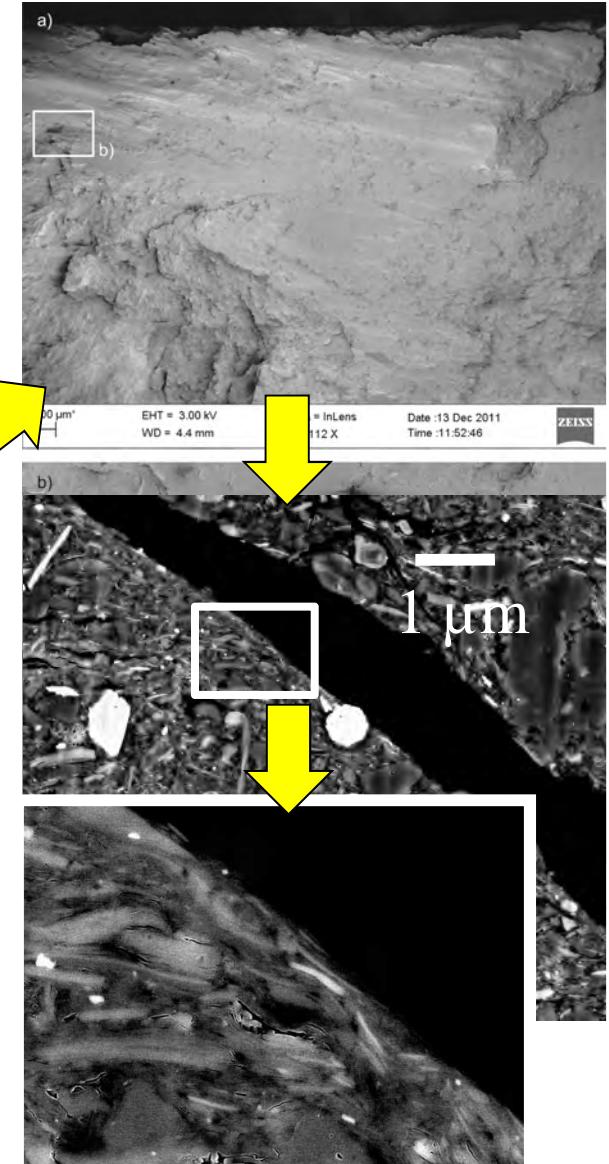
## Charakterisierung OPA (2/4)

### Sind Störzonen im Ton dicht?



**Chevron, swisstopo**  
B. Laurich, Ph.D., Uni Aachen

Illite foliation in main fault  
Micrometre scale

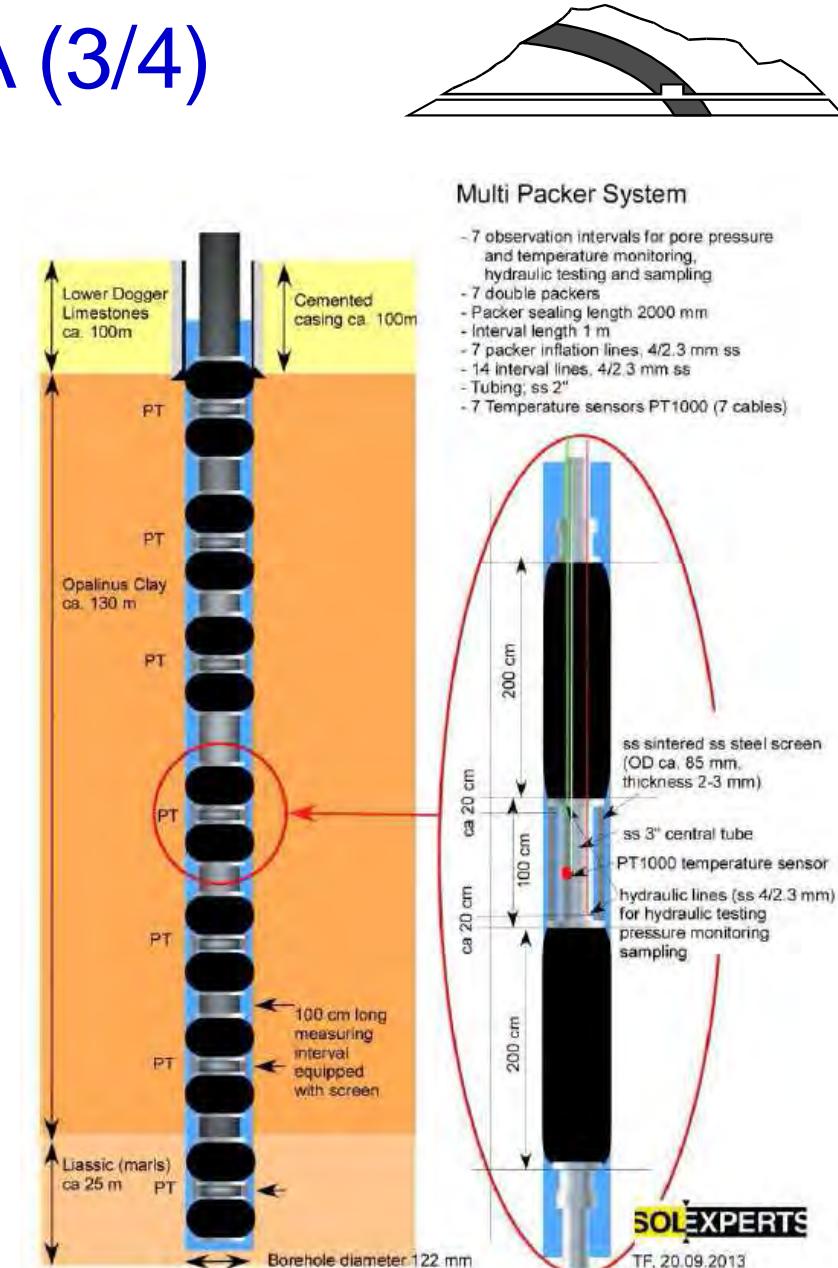




# Charakterisierung OPA (3/4)

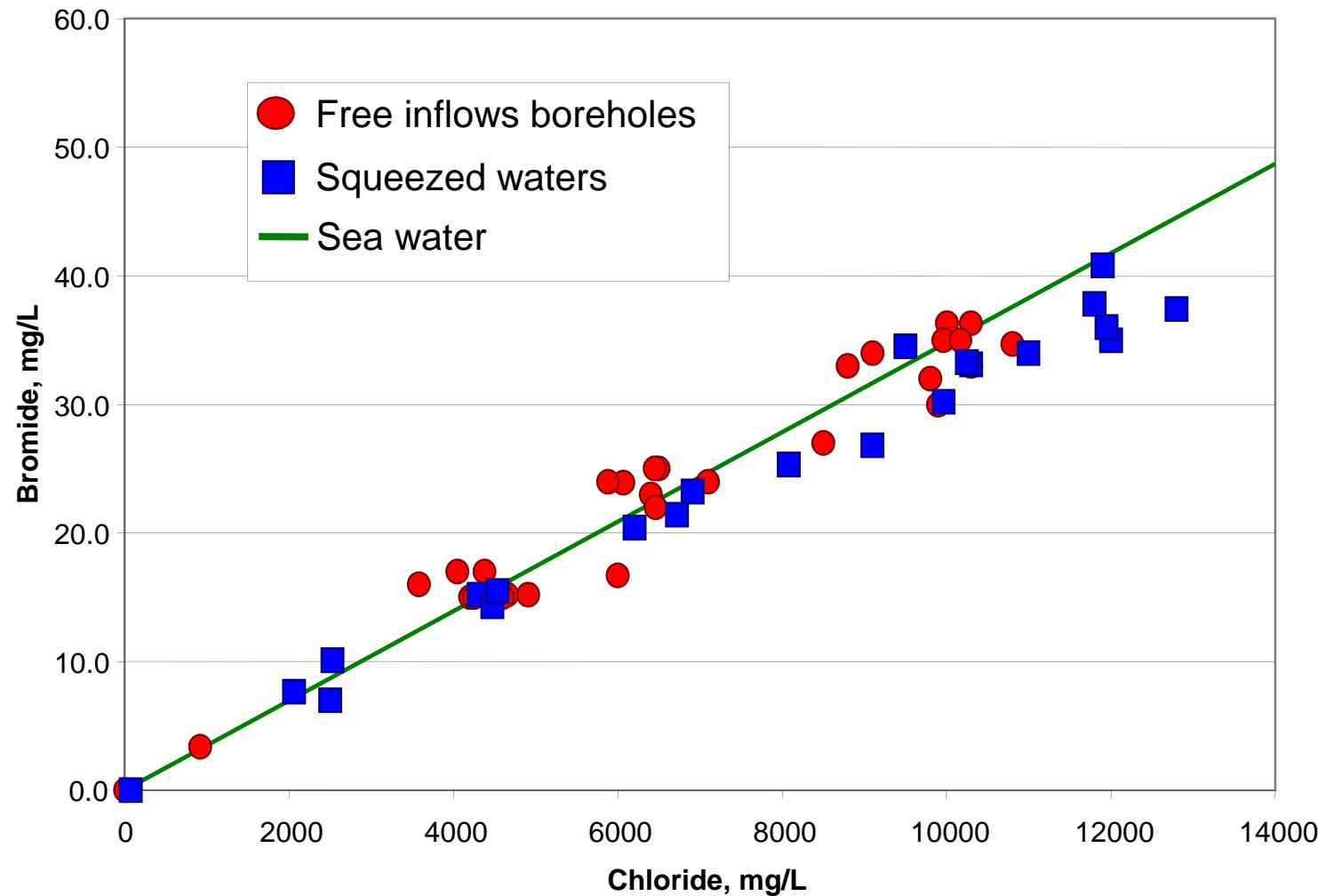
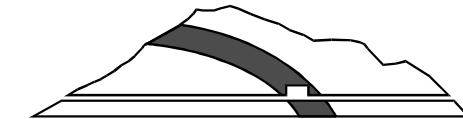


- 6 Doppelpacker, Einfachpacker, Intervallport
- Intervalldruck, Intervalltemperatur, Packerdruck
- Systemlänge 5 m, Ø 88 mm
- 27 Leitungen und Kabel (total ca. 4 km)
- Totale Systemlänge 250 m



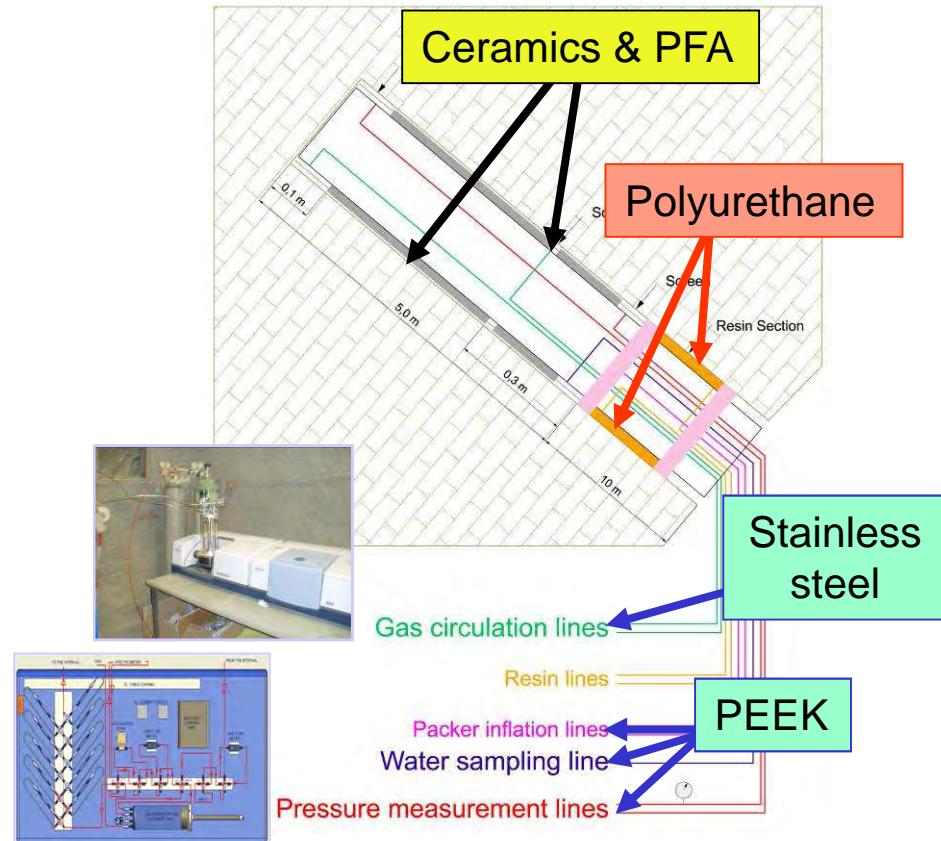
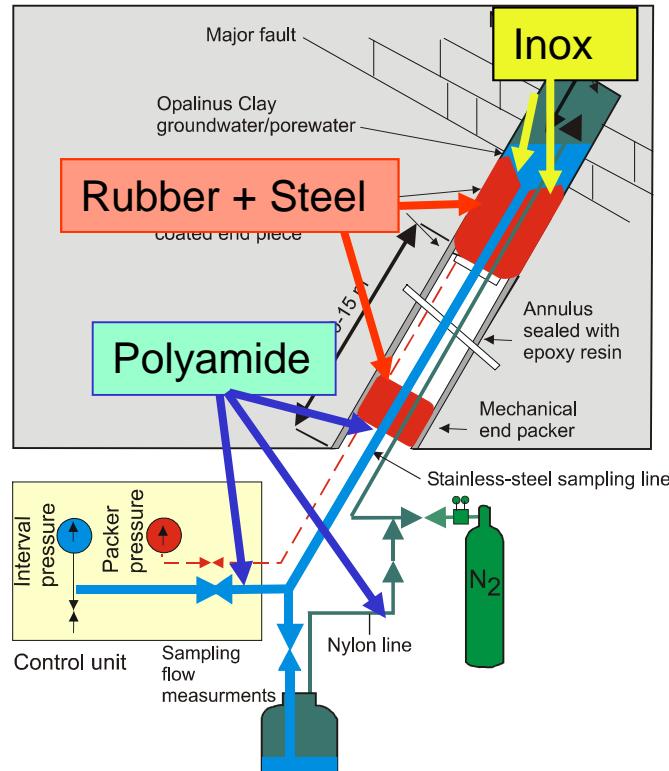
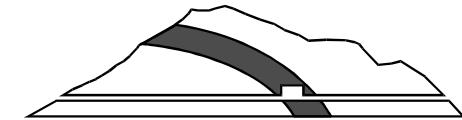


# Charakterisierung OPA (4/4)





# Water sampling Equipment



Water sampling  
(einst...)

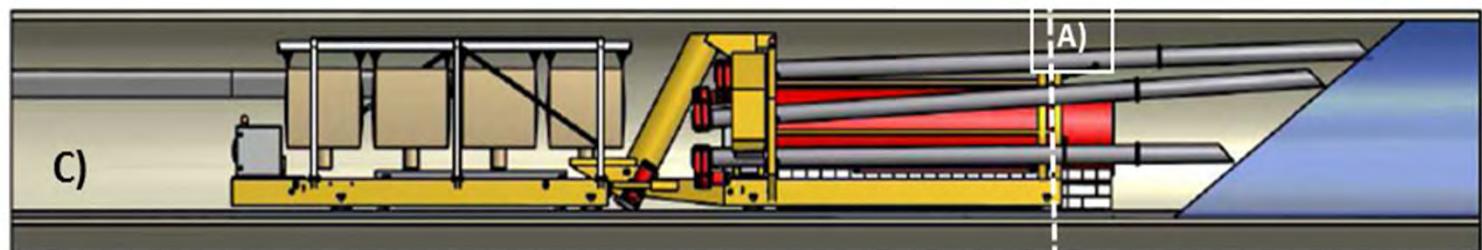
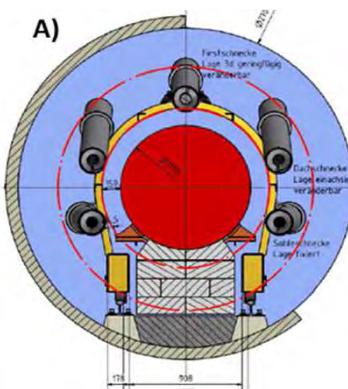
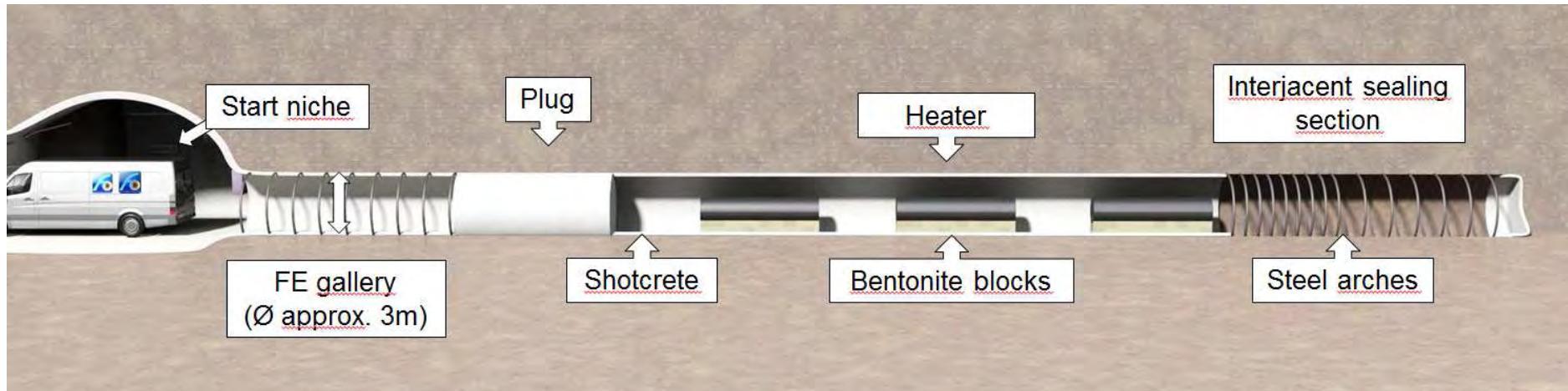
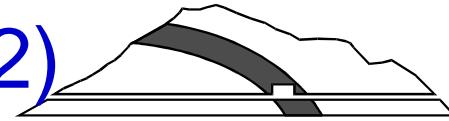
15'000 Euros

Pore water and gas equilibration  
(und heute)

200'000 Euros



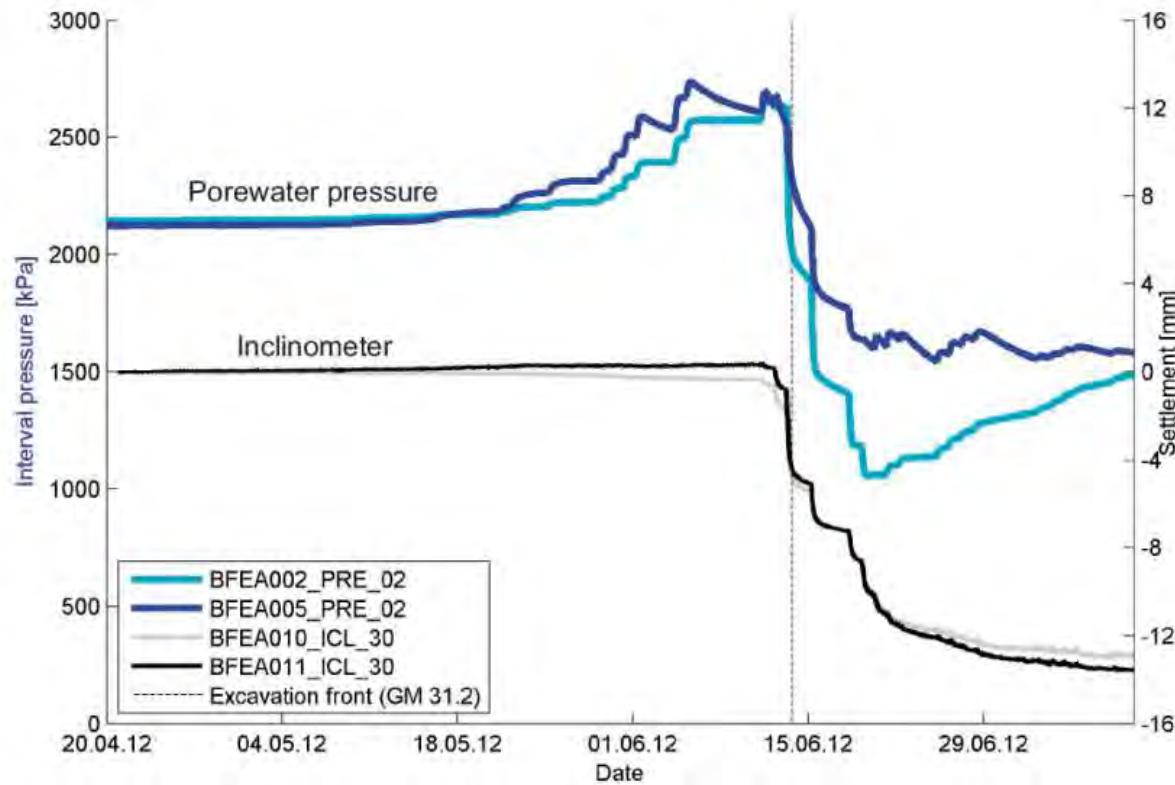
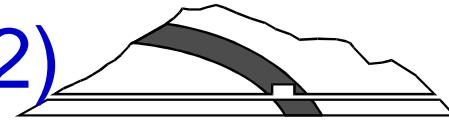
# Demonstrations-Experimente (1/2)



- 1:1 full-scale Experiment, 3 m ø , 50 m Länge
- 3 Heizer à 1500 W (T an Bentonit-OPA-Grenze <90°C)
- THM (thermisch, hydraulisch, mechanisch)-gekoppeltes System
- Experimentdauer > 15 Jahre



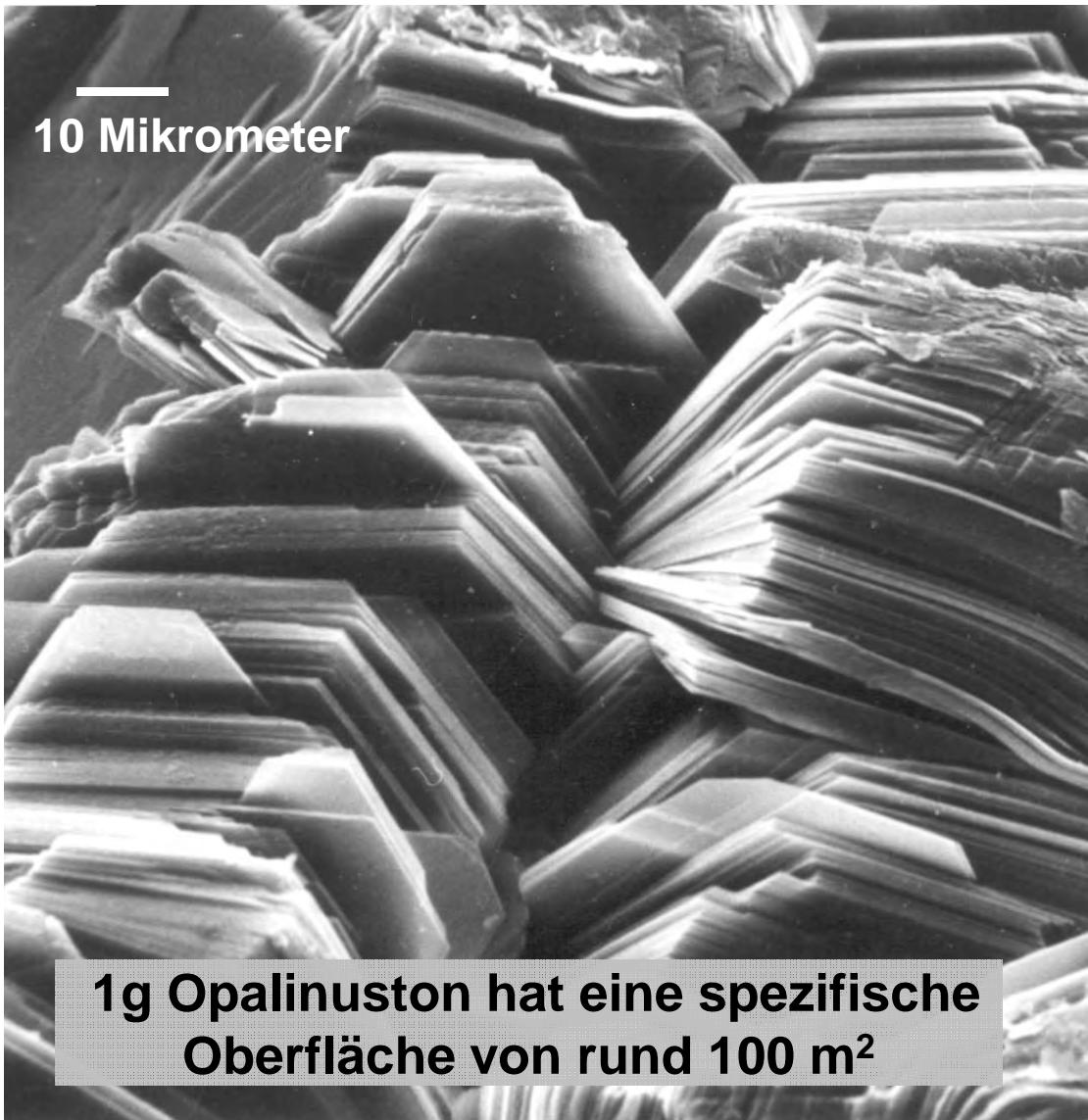
## Demonstrations-Experimente (2/2)



- Ca. 3'000 Sensoren (inkl. fiberoptischen Sensoren)
- Temperaturen, Porenwasserdrucke, Quelldrucke, Deformationen (Inklinometer, Extensometer), Relative Feuchtigkeit, chemische Parameter
- Messbeginn bereits vor dem Ausbruch des Tunnels im Jahre 2012



# Warum Forschung im Ton?

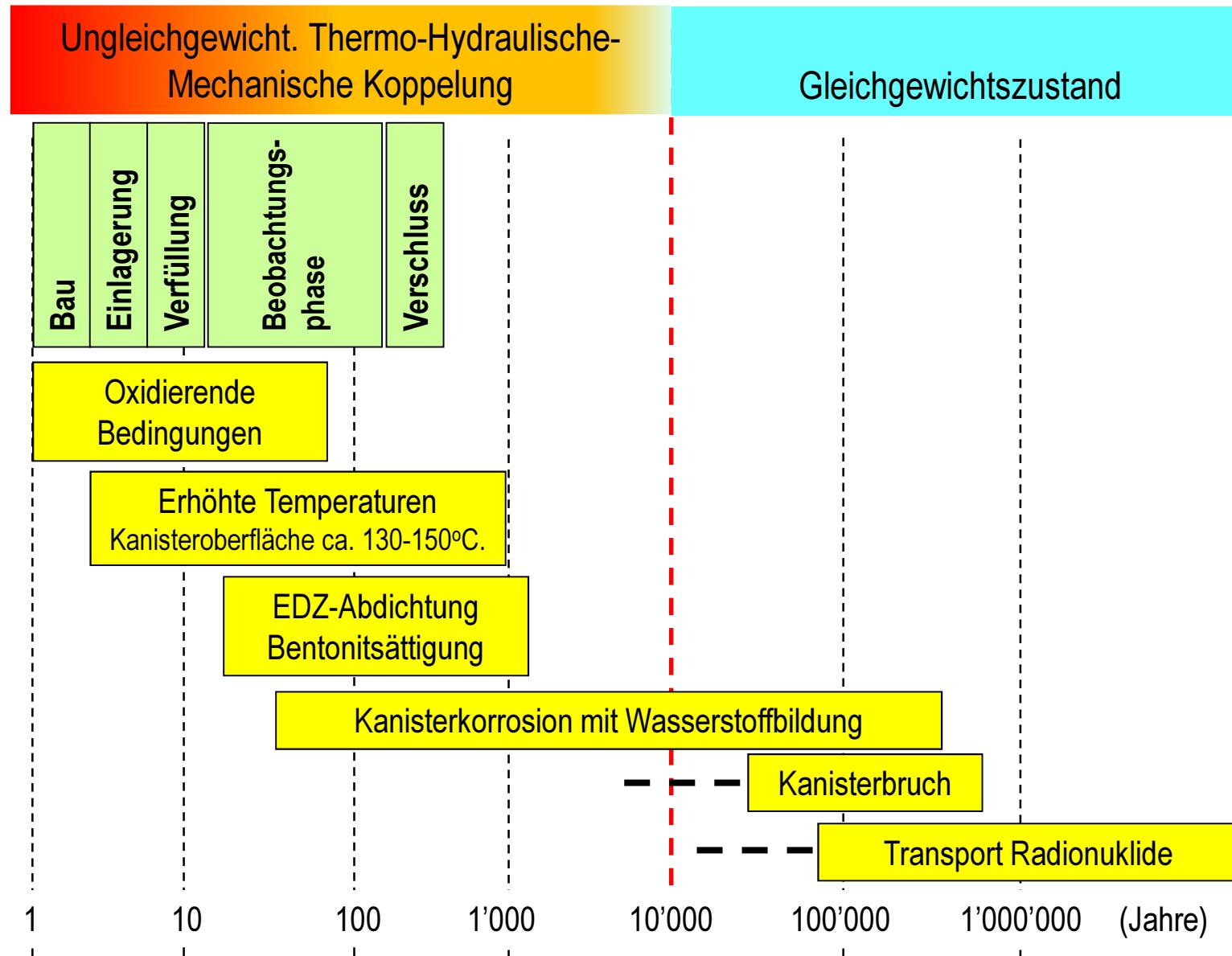
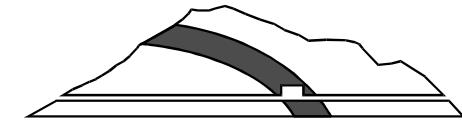


## „Key-Results“

- **Hervorragende Sorptionseigenschaften**
- **Sehr geringe Durchlässigkeit**
- **Porenwasser marinens Ursprungs**
- **Molekulare Diffusion**
- **Selbstabdichtung von Rissen**
- **Bautechnische Machbarkeit**

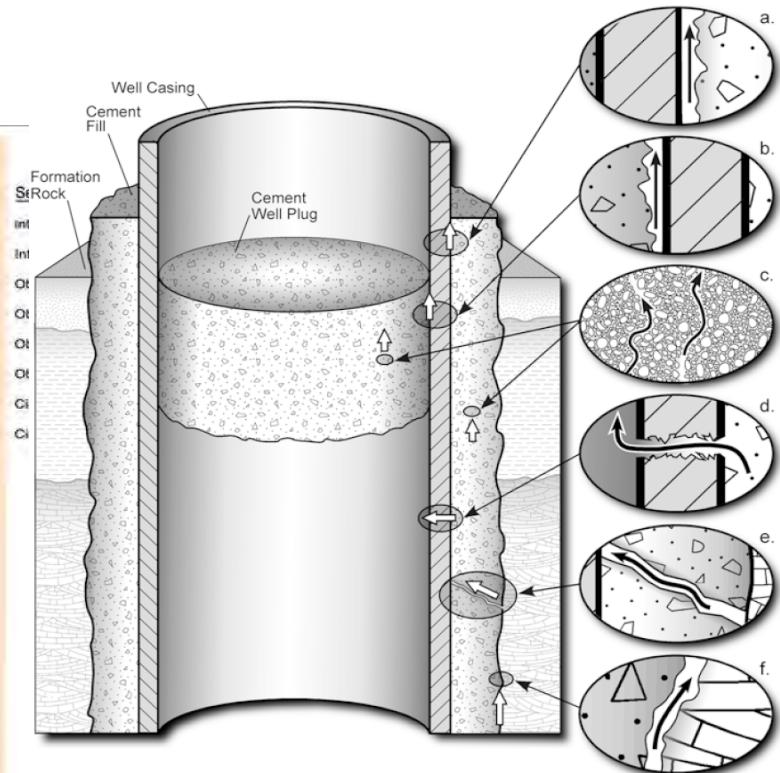
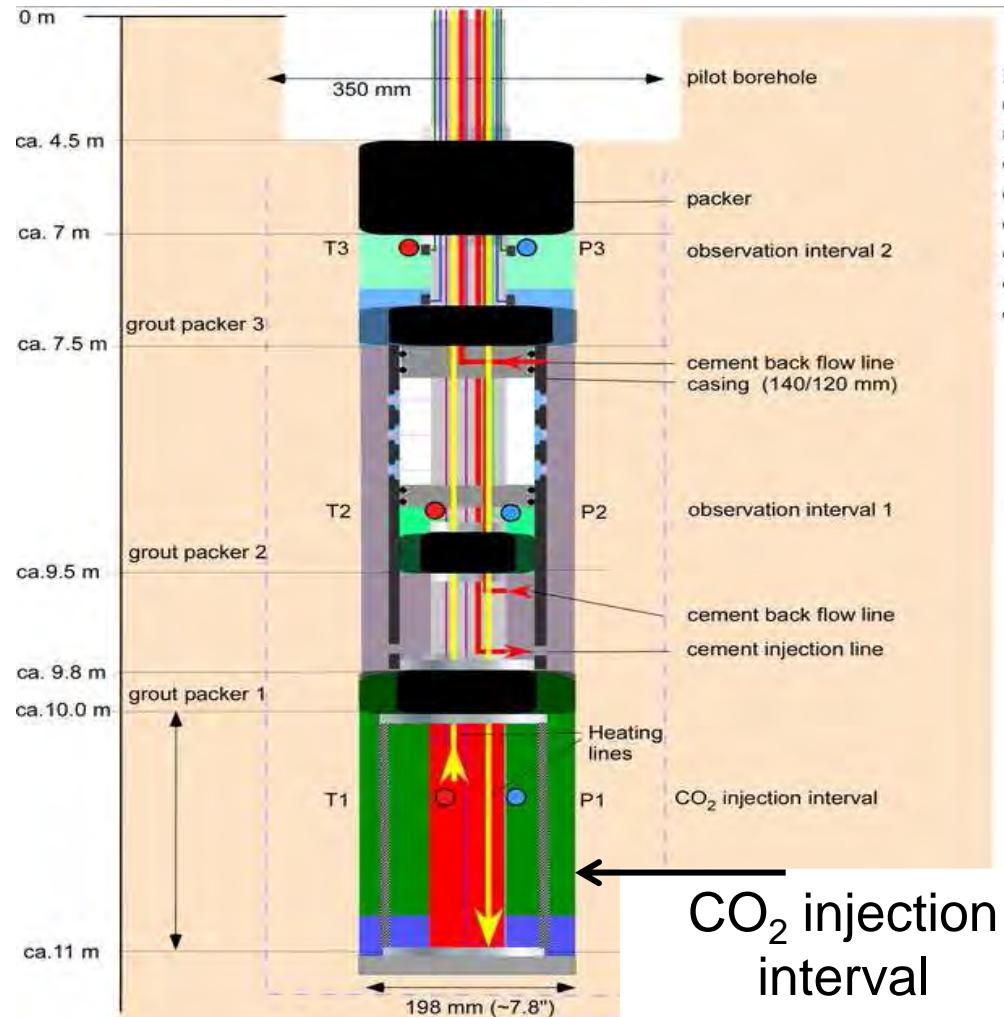


# Verhält sich ein Tiefenlager so wie vorausgesagt?





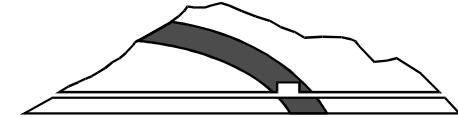
# CO<sub>2</sub> Speicherung



**OBAYASHI, SWISSTOPO  
(BRGM, EC co-financed)**



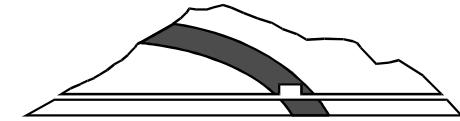
# Auf den Punkt gebracht



- Mont Terri Projekt: International führend in der Tiefenlager Tonforschung.
- 15 Partner aus CH, EU, Japan, Kanada und der USA, unter der Leitung des Bundes (swisstopo). Die Arbeiten werden von 50 Universitäten und Forschungsinstituten sowie von über 50 Spezialfirmen ausgeführt.
- Das Felslabor Mont Terri trägt wesentlich zur Sicherheit und der technischen Machbarkeit eines Geologischen Tiefenlagers im Opalinus-Ton bei. Methodik-Charakterisierung-Demonstration
- Swisstopo führt selber Experimente durch (Beispiel: CO2-Lagerung, Überprüfung der Dichtigkeit von Gestein und Bohrungen).



**Vielen Dank für Ihre Aufmerksamkeit**



Paul Bossart  
Direktor Mont Terri Projekt  
swisstopo  
Fabrique de Chaux  
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