Power production from Enhanced Geothermal Systems (EGS)

Lessons from the Basel project and the future of EGS

CUEPE, Université de Genève, 8. Nov. 2007

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Geothermal Explorers Ltd

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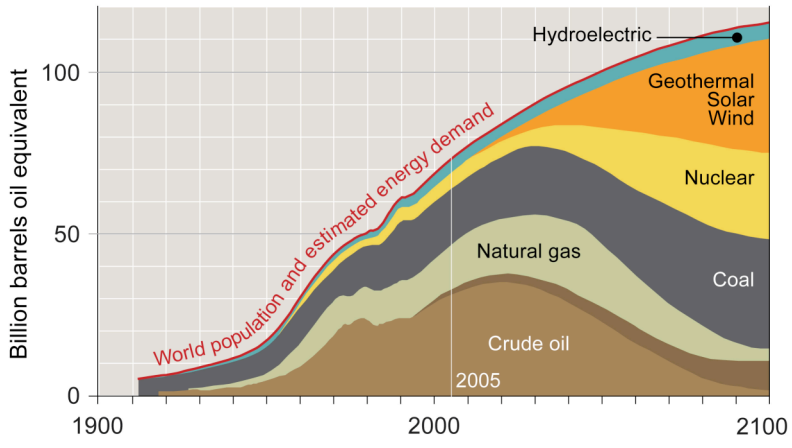
Conventional resources are limited



Source: Edwards, AAPG, 1997

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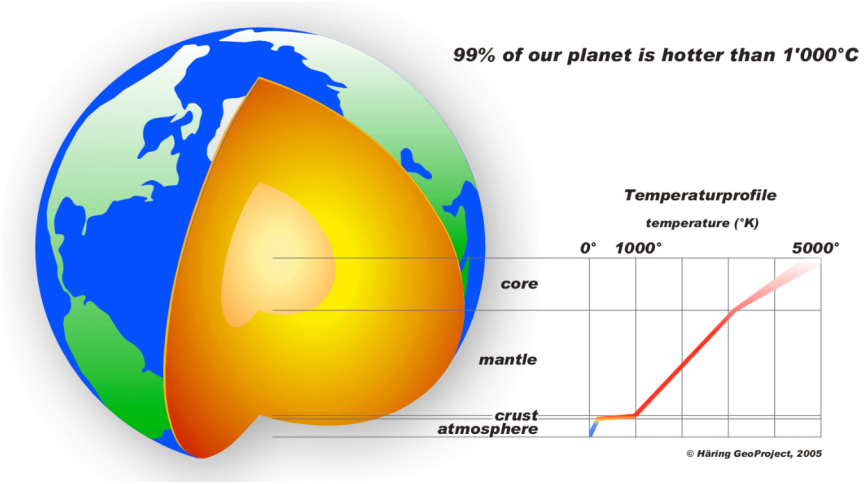
Sustainable Resource



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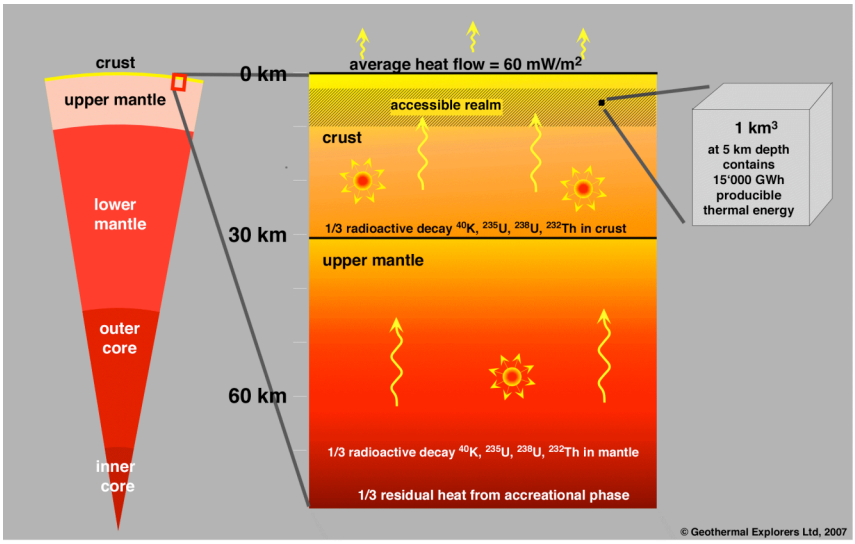
Origin of heat



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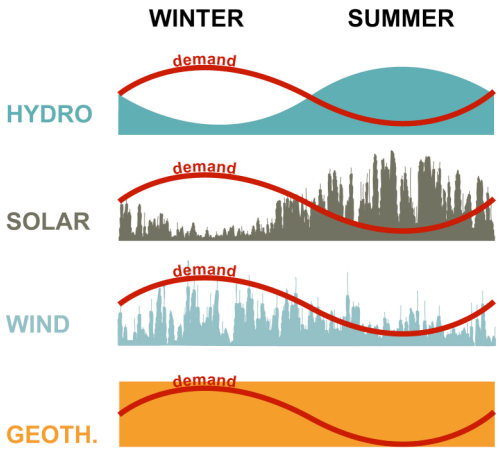
Characteristics of geothermal energy



- CO_2-free
- baseload energy
- sustainable
- locally available
- inconspicuous
- cheap

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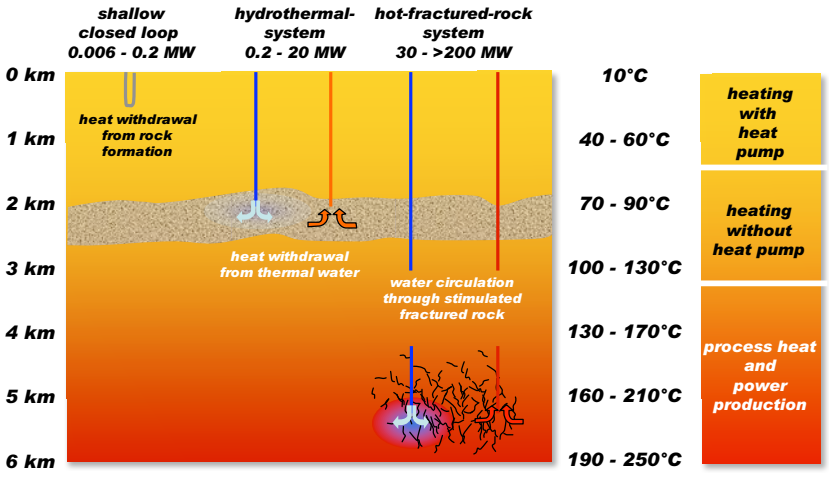
Methods to produce geothermal energy



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Installed geothermal capacity

Country	1990 MWe	1995 MWe	2000 MWe	2005 MWe
USA	2'775	2'817	2'228	2'544
Philippines	891	1'227	1'909	1'931
Mexico	700	753	755	953
Indonesia	145	310	590	797
Italy	545	632	785	790
Japan	215	414	547	535
New Zealand	283	286	437	425
Iceland	45	50	170	322
Costa Rica	0	55	143	163
El Salvador	95	105	161	151
Kenya	45	45	45	127
Russia (Kamchatka)	11	11	23	79
Nicaragua	35	70	70	77
Papua New Guinea	0	0	0	39
Guatemala	0	33	33	33
China	19	29	29	28
Turkey	21	20	20	20
Portugal (The Azores)	3	5	16	16
France (Guadeloupe)	4	4	4	15
Ethiopia	0	0	9	7
Austria	0	0	0	1
Thailand	0	0	0	0
Australia	0	0	0	0
Germany	0	0	0	0
Argentina	1	1	0	0
Total	5'832	6'833	7'974	9'064

Quelle: http://iga.igg.cnr.it/geoworld/

Development 1995 - 2005

USA:	-10%
Phillipines:	+57%
Mexico:	+27%
Indonesia:	+157%
Italy:	+25%
Japan:	+29%
New Zealand:	+49%
Iceland:	+544%
Costa Rica:	+196%
El Salvador:	+43%

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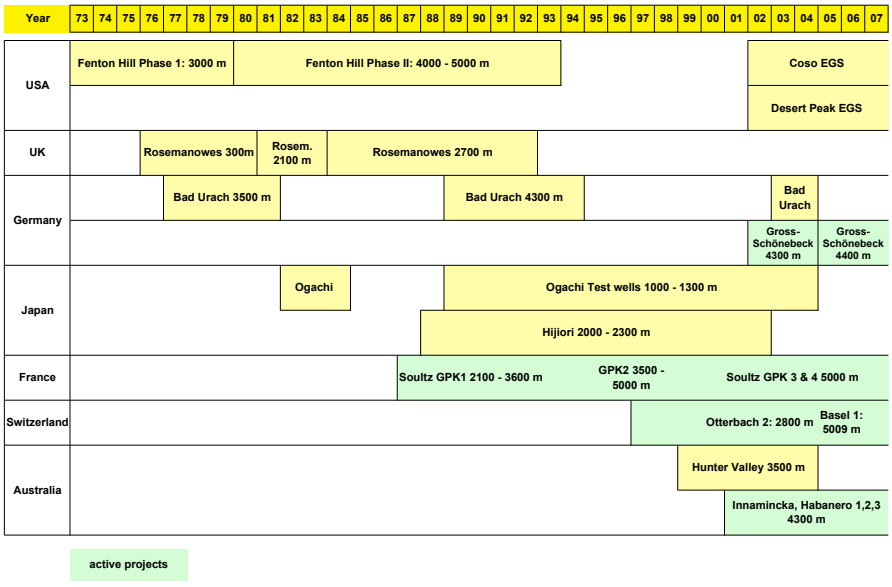
History of EGS research



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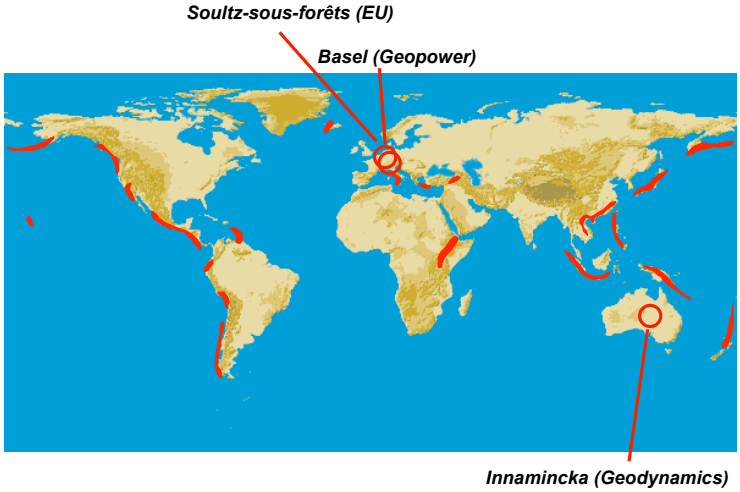
Active EGS projects around the world



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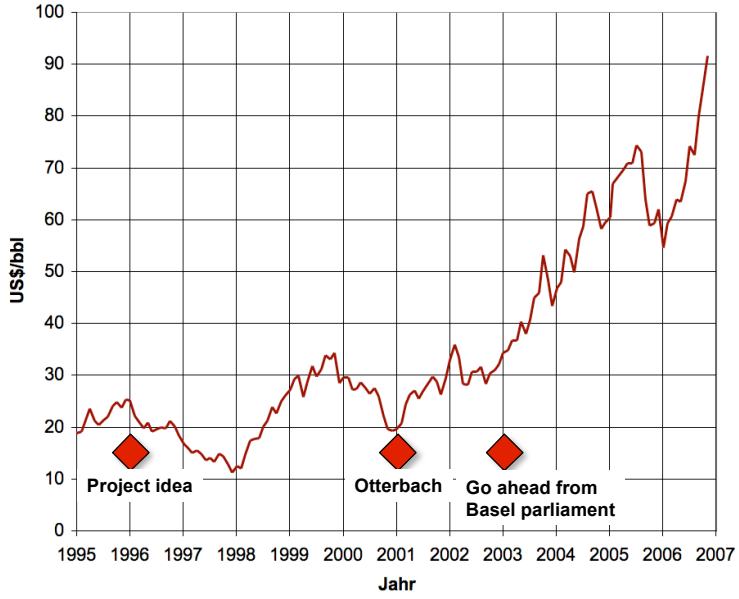
Long term strategy for EGS in Switzerland



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Exploration target: Circulation through an enhanced geothermal system (EGS)

in: 50 kg/s **out: 50 kg/s**

pressure impedance determines success or failure

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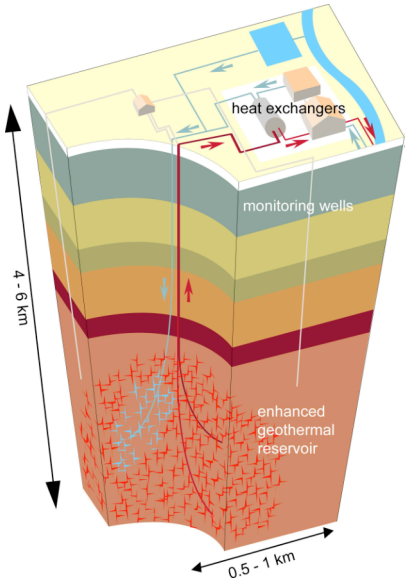
Project Deep Heat Mining Basel



Projected capacity

Power	approx. 6	MW
Heat	approx. 17	MW

Projected production

Power	approx. 31	GWh/y
Heat	approx. 48	GWh/y

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Project consortium

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IWB	IWB (Industrielle Werke Basel)
Bau- und Verkehrsdepartement des Kantons Basel-Stadt Amt für Umwelt und Energie	Amt für Umwelt und Energie des Kantons Basel-Stadt
ebl	Elektra Baselland (EBL)
axpo gibt Energie.	AXPO
GVM Gasverbund Mittelland AG	Gasverbund Mittelland AG
Bau- und Umweltschutzdirektion Kanton Basel-Landschaft Amt für Umweltschutz und Energie	Amt für Umweltschutz und Energie Basel-Landschaft
ewz Die Energie	ewz (Elektrizitätswerk der Stadt Zürich)
ED ENERGIEDIENST	Energiedienst Holding AG
AET Azienda Elettrica Ticinese	Azienda Elettrica Ticinese
SIG	Service Industrielle de Genève
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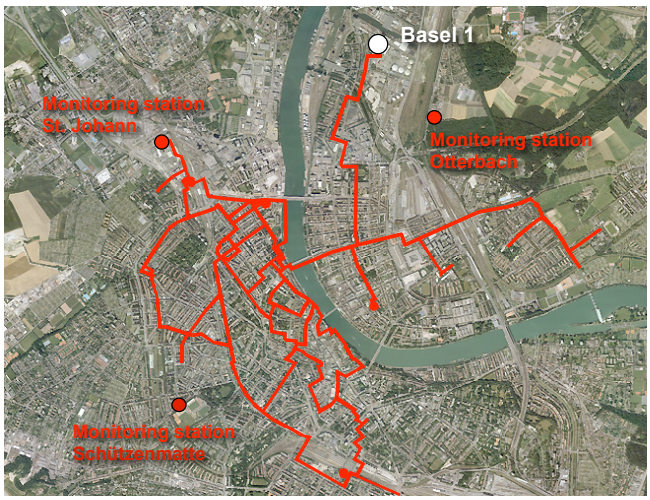
DHM sites in Basel



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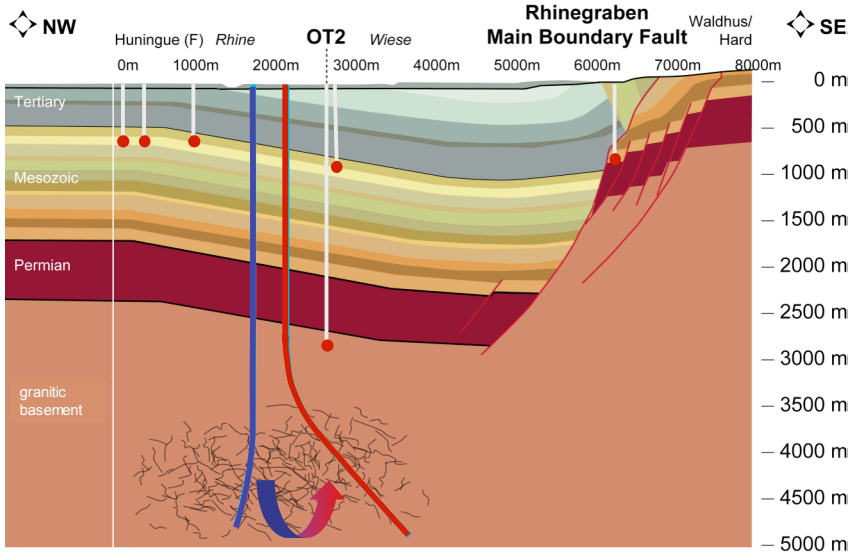
Exploration concept



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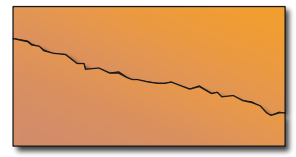
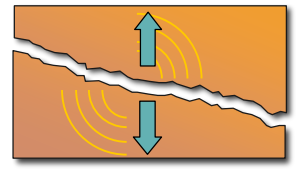
Hydraulic fracture stimulation

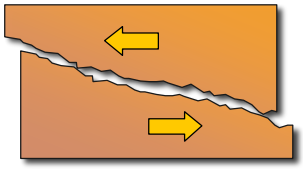


closed fracture
= weak zone



hydraulic injection opens fracture

seismic signal used for location tracking



stress induced slipage

displaced interfaces do not match anymore
= fracture remains open

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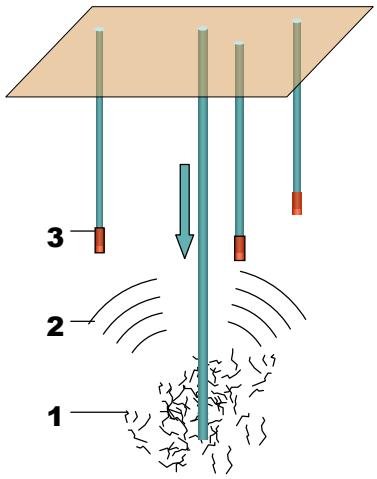
Fracture / reservoir mapping



1. hydraulically stimulated fractures
2. seismic signal
3. geophones

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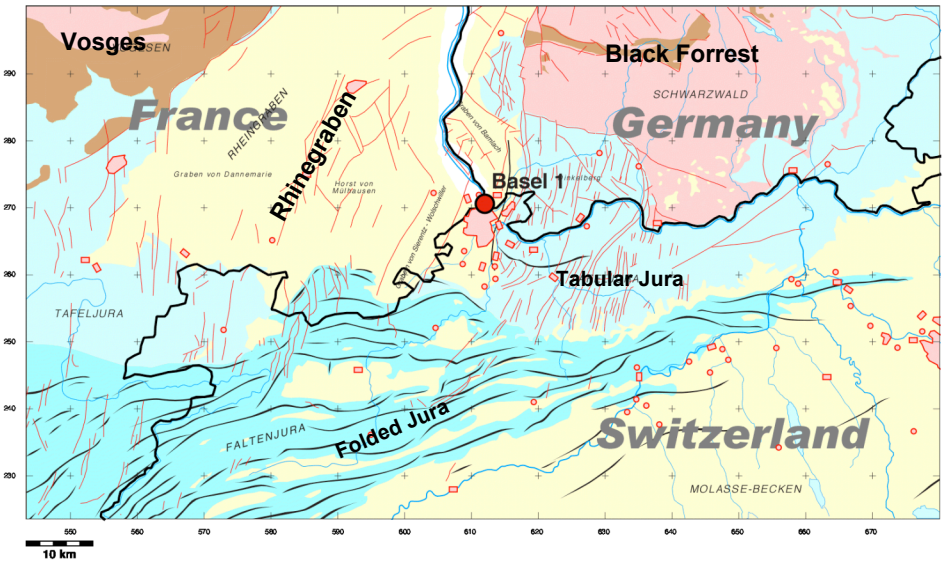
Location Map



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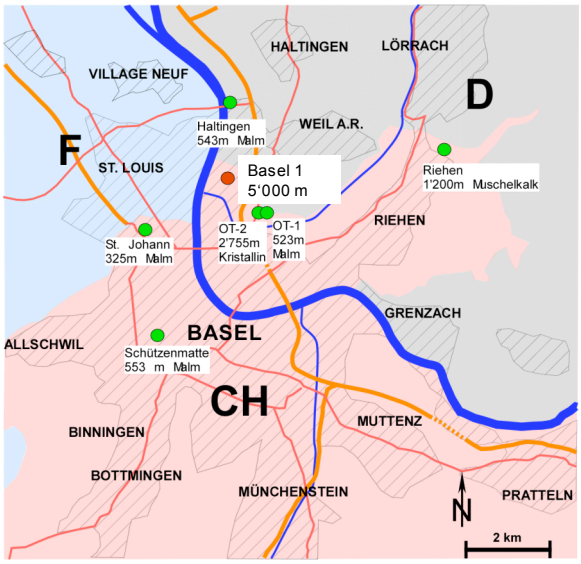
Monitoring Stations



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Deployment of a seismometer

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Exploration well Basel 1 TD 5‘009 m

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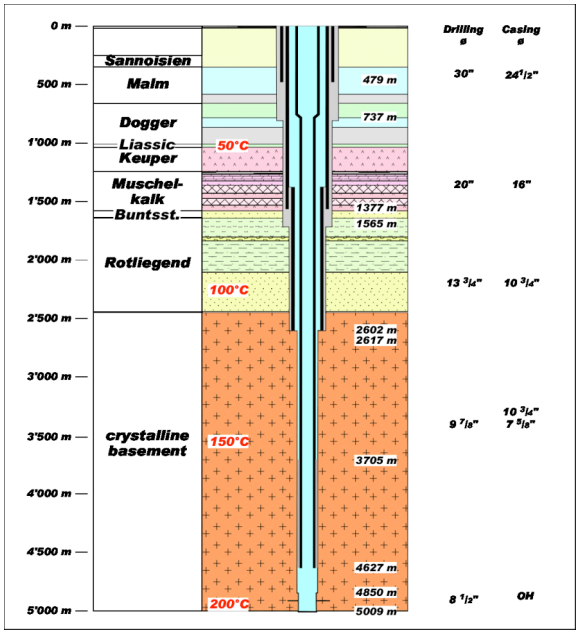
Basel 1



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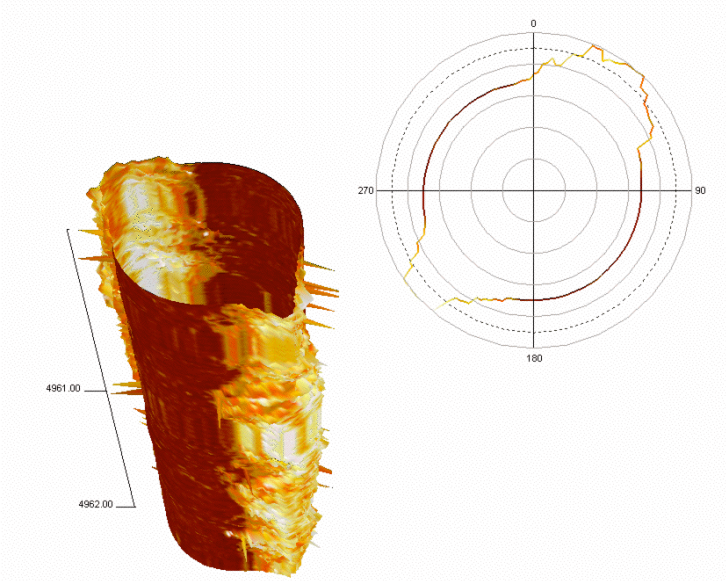
Borehole Images with Ultrasonic Borehole Imager (UBI)



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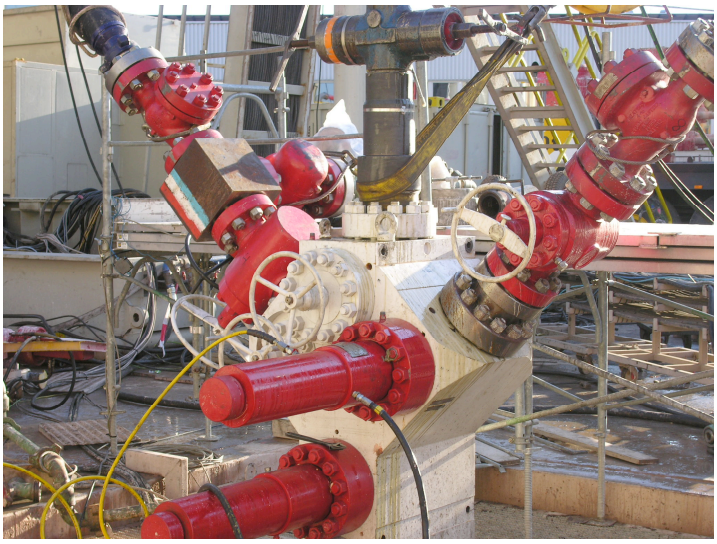
X-mas Tree Basel 1



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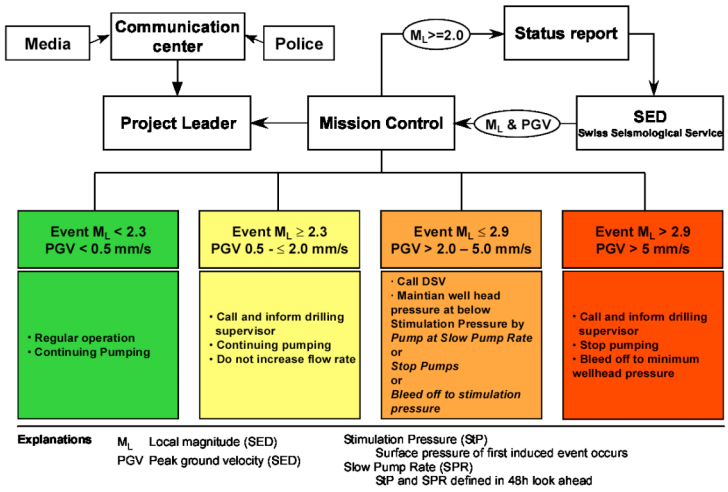
Micro-Seismic Event Response Procedure



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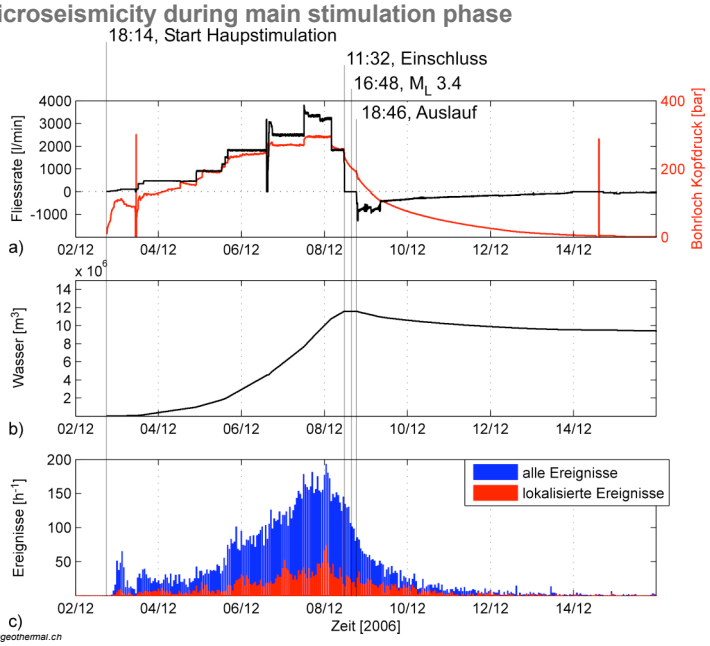
Microseismicity during main stimulation phase



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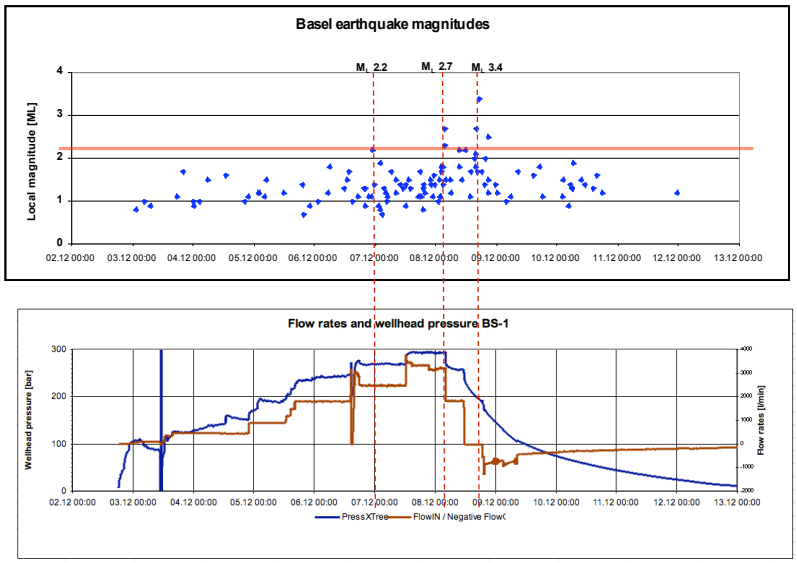
Seismicity during main stimulation phase



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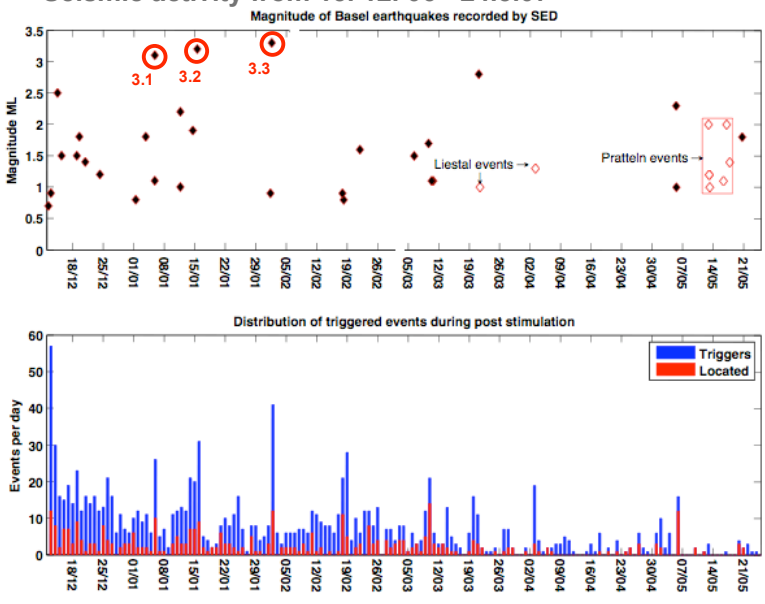
Seismic activity from 13. 12. 06 - 24.5.07



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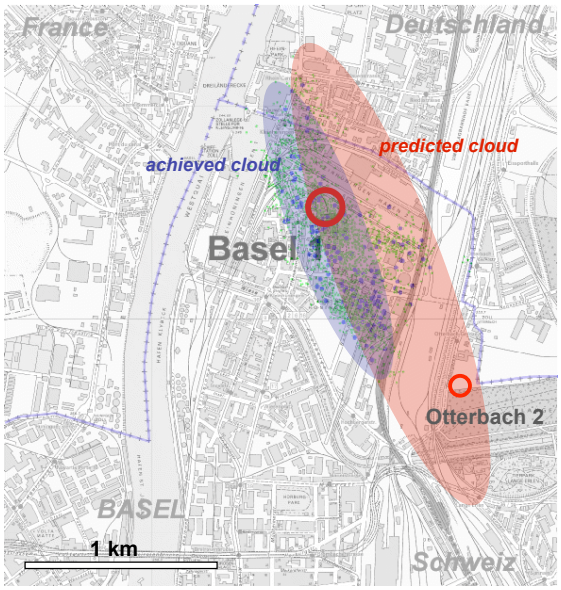
Extent of induced seismic cloud



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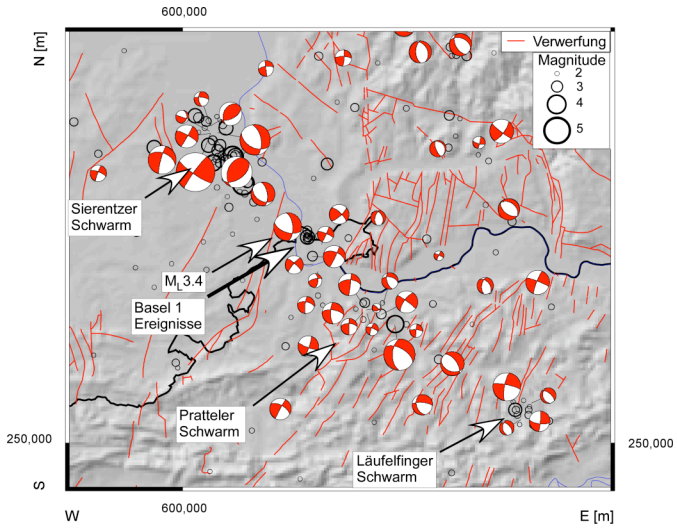
Fault plane solutions of natural events



Impact of „Basel“ for EGS

- More than 85% of the geothermal potential is in crystalline basement. Hydrothermal systems < 10%
- A profound understanding of rock mechanical processes is required to understand the source of induced seismicity with the goal to mitigate and control the magnitude of such events.
- The Basel microseismic data set covering a longterm pre- and post- stimulation period recording provides a crucial key for risk assessment in EGS.

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Fields of Research

1 Induced seismicity mitigation:
   - Seismicity control during stimulation and production
   - Seismic probability prediction
   - Seismic intensity modelling
2 Reservoir stimulation:
   - „soft“ methods
3 Geophysical exploration techniques in hard rocks
   - VSP
   - Tomography
   - hostile environment wireline tools
4 Drilling technology
   - hard rock bits
   - drilling automation
   - monodiameter wells
   - cementing
5 Power conversion
   - Efficiency improvement in low enthalpy power conversion

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To create the possible,
one must try the impossible
again and again.

Hermann Hesse