Global perspective of Engineered Geothermal System and how it can be brought to the market place in Europe

by

Roy Baria [1,2] & Susan Petty [2]

[1] MIL-TECH UK Ltd, Woking UK

[2] AltaRock Energy, Seattle, WA

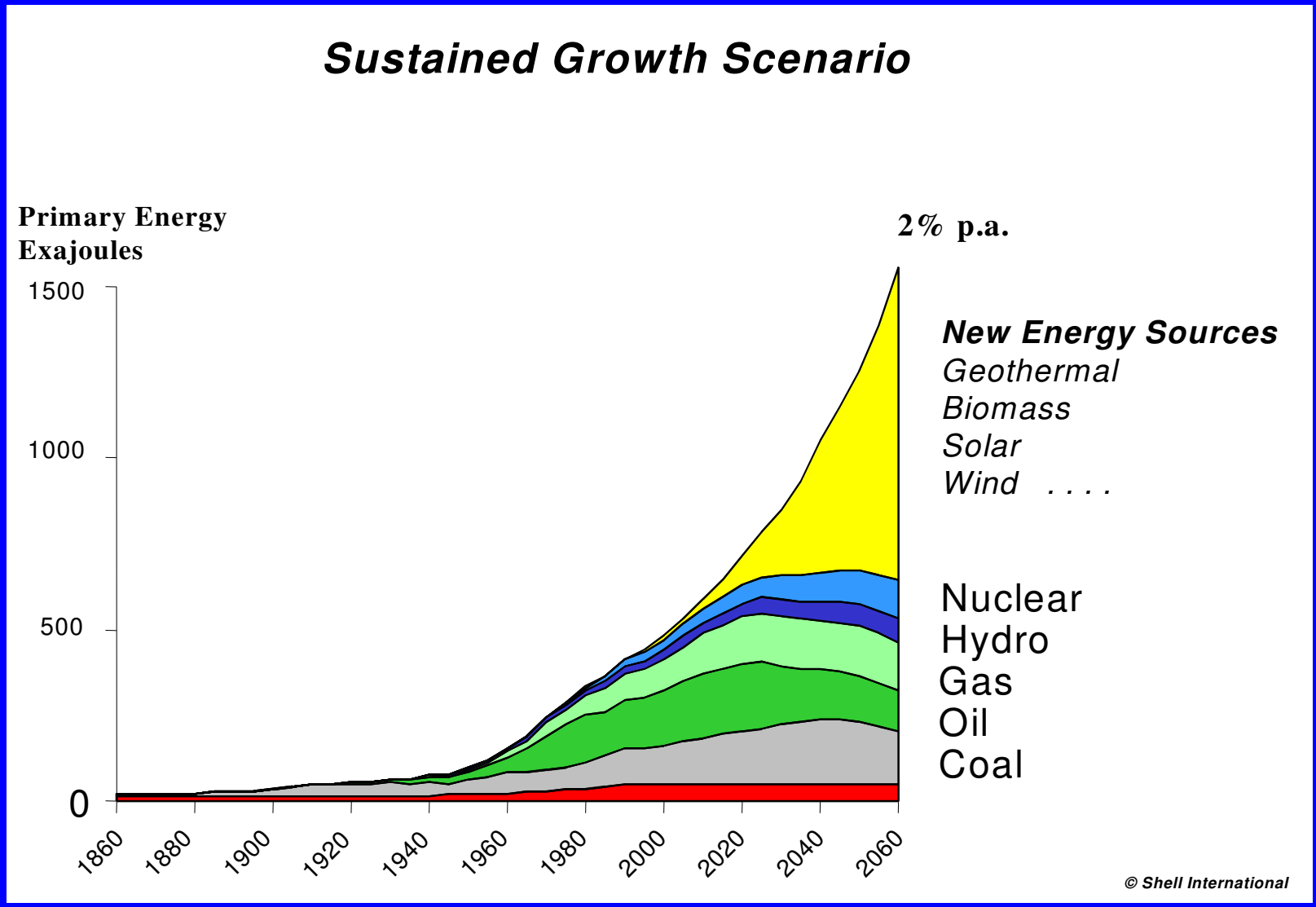
Talk overview

1. Why the interest in EGS ?
2. What type of geothermal energy
3. Current status of EGS technology
4. What next (after ENGINE)

1. Why the interest in EGS ?

a. Future trend: Demand for the energy will outstrip the supply
b. Concern with climate change: reduction of CO_2
c. Extremely large resource
d. Fairley widely available
e. Strategic resource
f. Environmental friendly

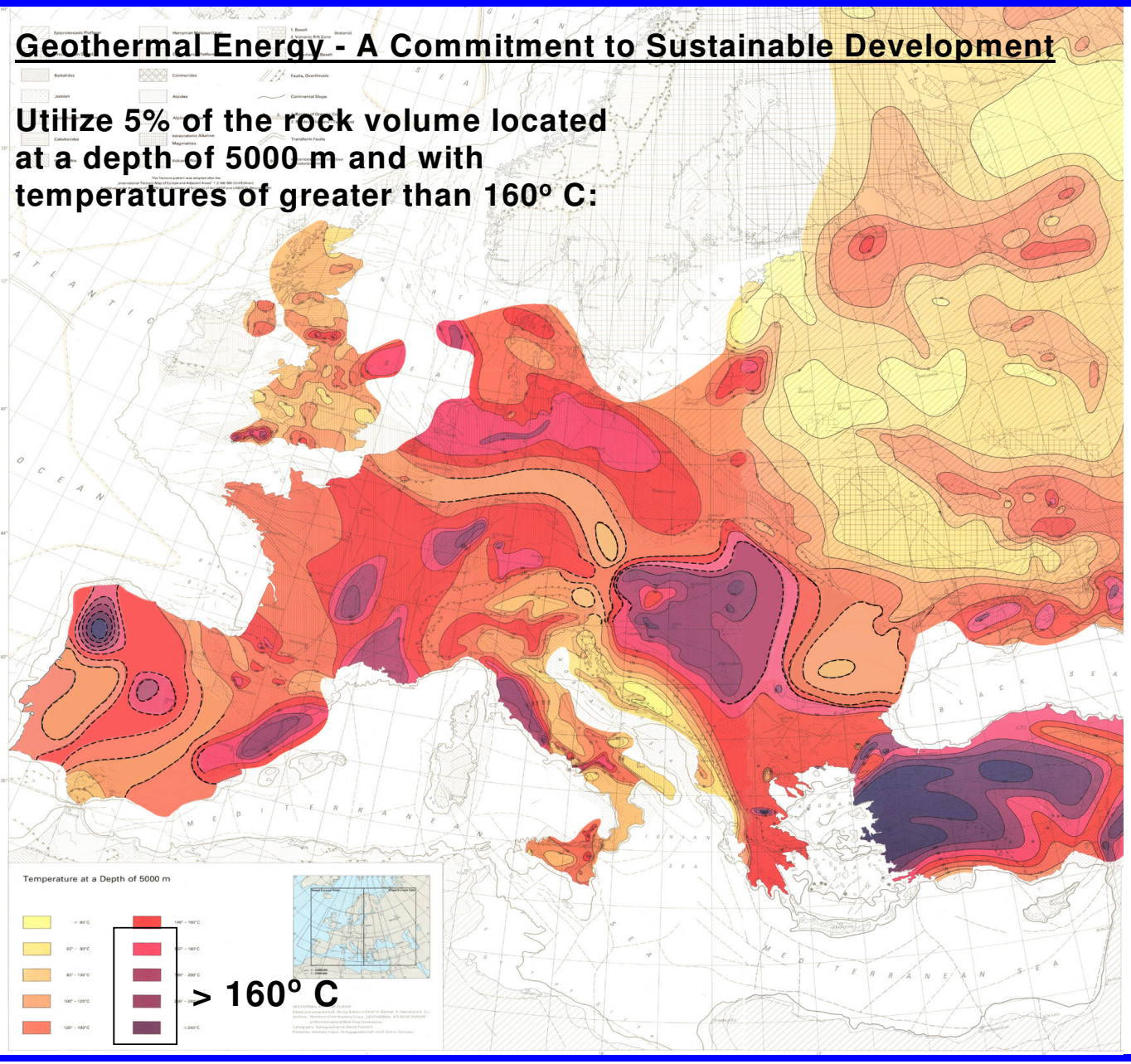
1a. Future world energy demand and supply trends



1c. POTENTIAL RESOURCE IN W. EUROPE

Geothermal Energy - A Commitment to Sustainable Development

Utilize 5% of the rock volume located at a depth of 5000 m and with temperatures of greater than 160º C:



EU resources could :

*** support 130 GWe of power generation capacity**

*** generate ~900 TWh (E 45 bln/yr - market)**

*** similar to 1995 electricity generation of Europe's nuclear capacity.**

*** 35% of current EU consumption.**

1d. GEOTHERMAL SYSTEMS

NATURAL

HYDROTHERMAL
(LIMITED RESOURCE)

Conditions:

HIGH PERMEABILITY

ABUNDENT INSITU FLUID

CHEMICALLY ACTIVE

Total world generation ~ 7GWe

MAN MADE

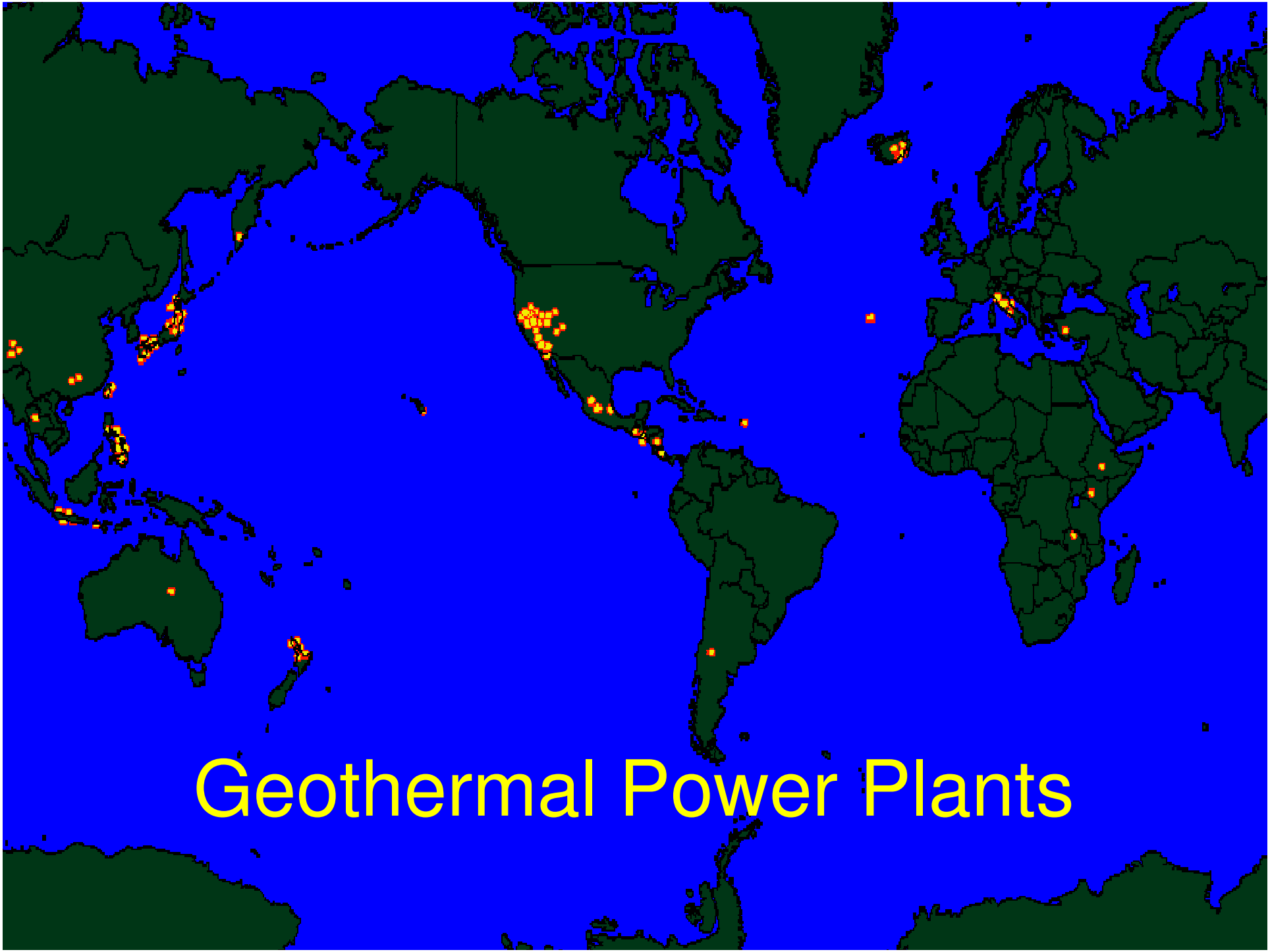
ENGINEERED **G**EOTHERMAL **S**YSTEMS (EXTENSIVE RESOURCE)

Conditions:
IGNEOUS ROCKS ???

TO ENHANCE IN-SITU PERMEABILTY BY X20 OR MORE by stimulations

CREATE LARGE HEAT TRASFER AREA

LOW PARASITIC LOSSES


Geothermal Power Plants

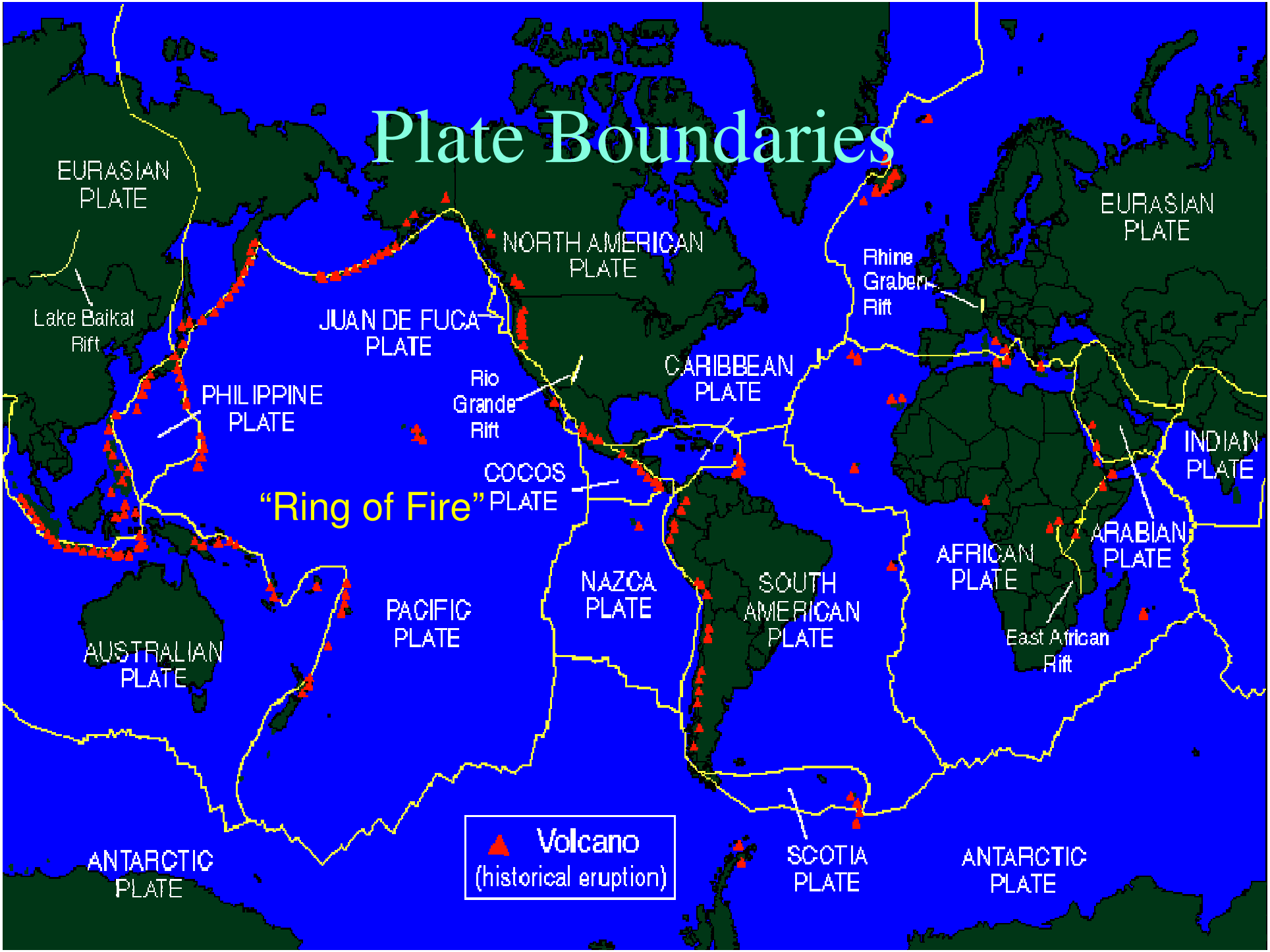


Plate Boundaries
EURASIAN PLATE
Lake Baikal Rift
NORTH AMERICAN PLATE
JUAN DE FUCA PLATE
PHILIPPINE PLATE
Rio Grande Rift
CARIBBEAN PLATE
Rhine Graben Rift
EURASIAN PLATE
INDIAN PLATE
COCOS PLATE
"Ring of Fire"
ARABIAN PLATE
AFRICAN PLATE
NAZCA PLATE
SOUTH AMERICAN PLATE
PACIFIC PLATE
East African Rift
AUSTRALIAN PLATE
Volcano
(historical eruption)
ANTARCTIC PLATE
SCOTIA PLATE
ANTARCTIC PLATE

Sweden handed toughest green target

By Tony Barber in Brussels

Under the European Commission's proposals, each European Union state has its own legally binding target for increasing the share of renewables, such as wind and solar power, in its energy mix.

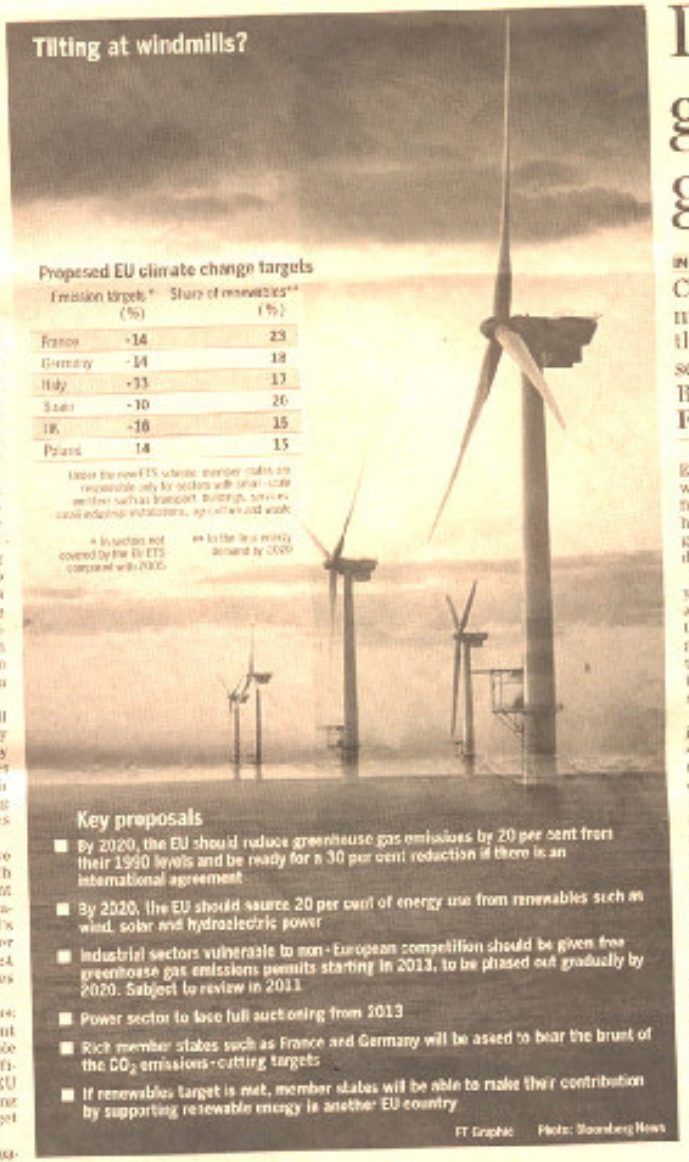
At the top of the scale, Sweden, which already generates most of its electricity from nuclear and hydroelectric power, is being asked to raise renewables to 49 per cent of the country's overall energy use. At the lower end of the scale, Belgium, Cyprus, the Czech Republic and Hungary are each being asked to meet a 13 per cent target.

As long as the EU's overall target of renewable energy accounting for 20 per cent by 2020 is met, member states will be allowed to make their contribution by promoting production of renewables outside their borders.

Such an option may prove attractive in the UK, which generates a mere 2 per cent of its energy from renewables – the lowest of the EU's biggest economies. Under the proposals, the UK must increase its renewables share to 15 per cent.

The Commission estimates that, by shifting investment to places where renewable energy can be most efficiently produced, the EU could cut the cost of meeting its overall 20 per cent target by €13bn ($18bn, £11bn).

A more controversial feature of the Commission's plan is its demand that biofuels account for 10 per cent of transport fuel by 2020. Critics say that, given the current state of technology, large-scale biofuel production risks damaging the environment and does not



Proposed EU climate change targets

	Emission targets* (%)	Share of renewables** (%)
France	-14	23
Germany	-14	18
Italy	-13	17
Spain	-10	20
UK	-16	15
Poland	14	15

Under the new ETS scheme, member states are responsible only for sectors with small-scale emitters such as transport, buildings, services, waste-reducing installations, agriculture and waste.

* Reduction not covered by the EU ETS compared with 2005

** As to the final energy demand by 2020

Key proposals

- By 2020, the EU should reduce greenhouse gas emissions by 20 per cent from their 1990 levels and be ready for a 30 per cent reduction if there is an international agreement
- By 2020, the EU should source 20 per cent of energy use from renewables such as wind, solar and hydroelectric power
- Industrial sectors vulnerable to non-European competition should be given free greenhouse gas emissions permits starting in 2013, to be phased out gradually by 2020. Subject to review in 2011
- Power sector to face full auctioning from 2013
- Rich member states such as France and Germany will be asked to bear the brunt of the CO_2 emissions-cutting targets
- If renewables target is met, member states will be able to make their contribution by supporting renewable energy in another EU country

FT Graphic Photo: Bloomberg News

Warning of trade war over carbon import taxes

OBSERVATION & CONCLUSION:

- Hydrothermal has an important role to play but is limited to margins of continental plates & thus has limited resource and availability worldwide.

- **E**ngineered **G**eothermal **S**ystem can enhance the resource ***significantly*** but sophisticated technology is needed to exploit it.

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MAN MADE

(History & experience)

ENGINEERED **G**EOTHERMAL **S**YSTEMS (EXTENSIVE RESOURCE)

Conditions:

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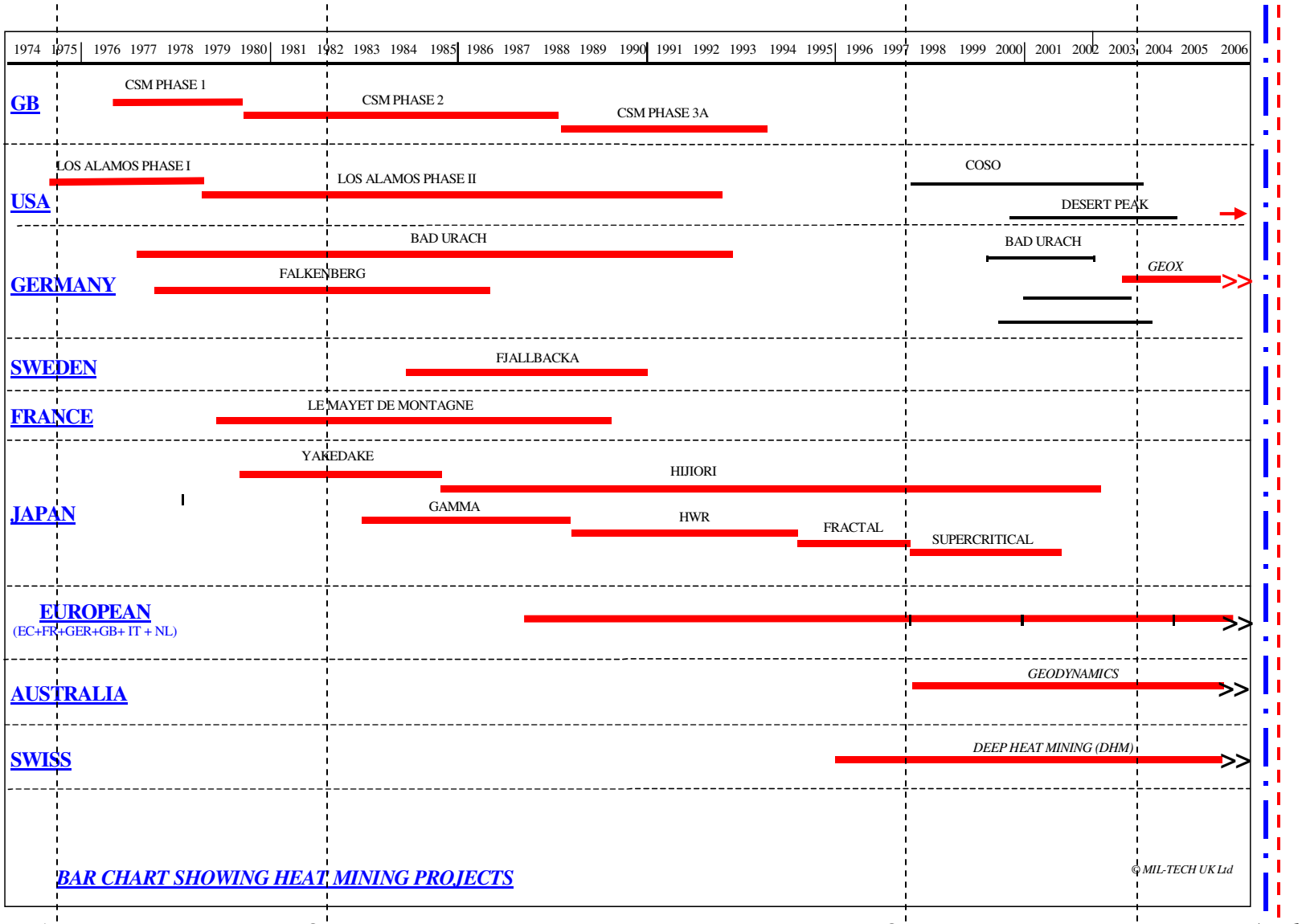
THE KNOWLEDGE IS DERIVED FROM EXPERIENCES GAINED FROM VARIOUS PROJECTS IN THE WORLD



EVOLUTION IN CONCEPTS

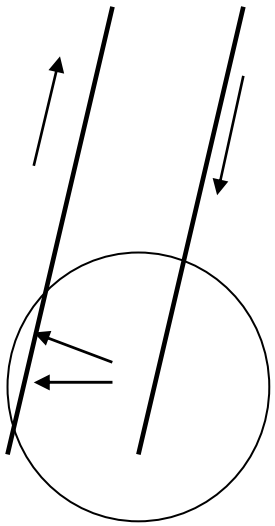


Fig 1A
Penny shaped

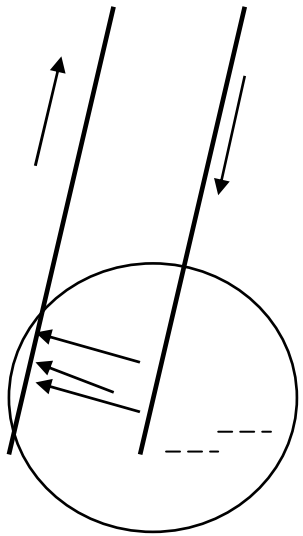


Fig 1B: Shear on
Natural Joints

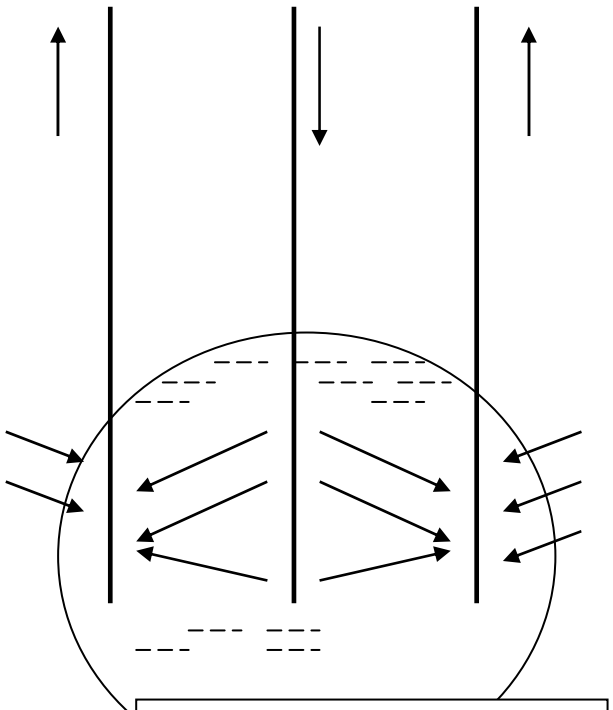
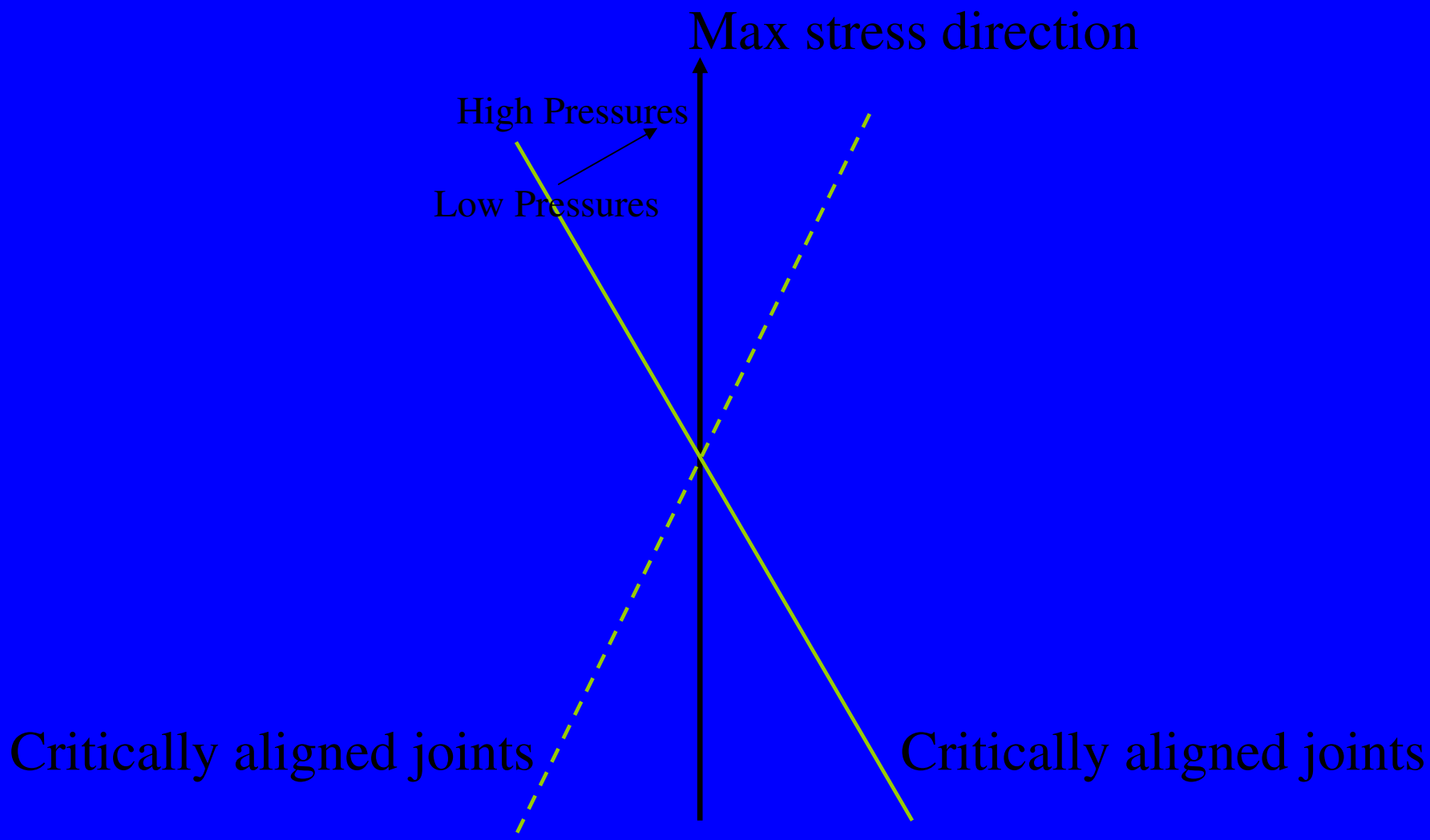


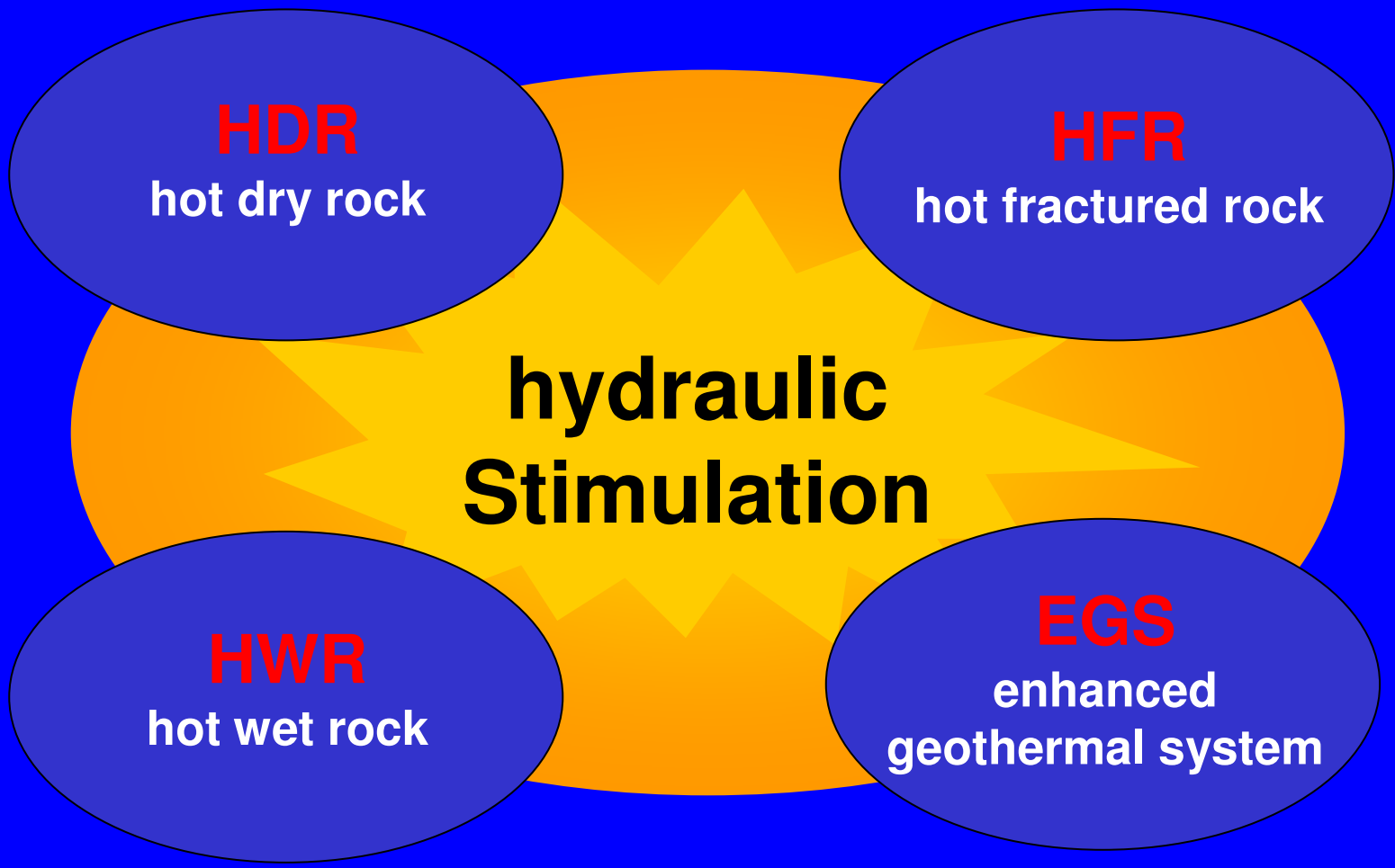
Fig 1C:Graben Concept

RESERVOIR CREATION MECHANISMS

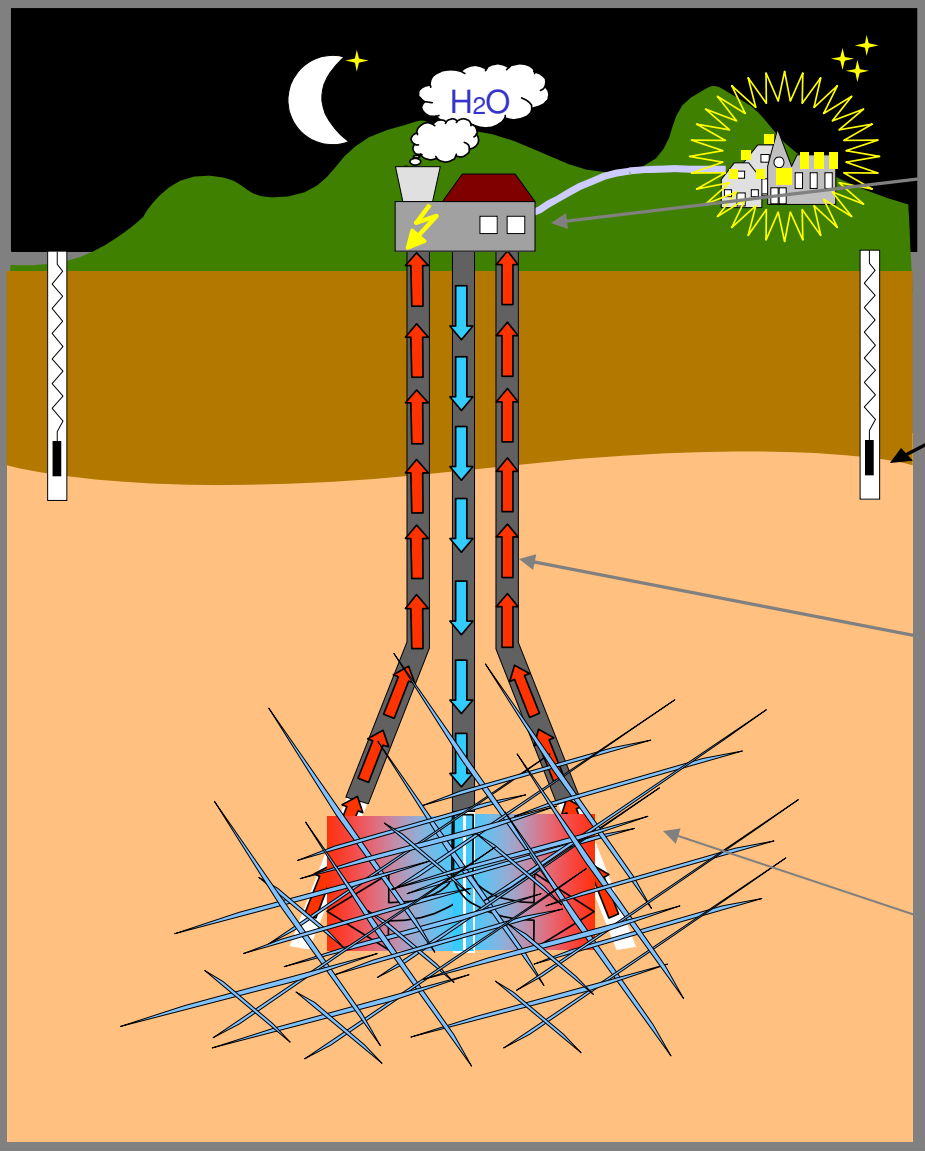
PREDOMINANT MODE DURING STIMULATION IS *SHEAR*



EnGINEERED GEOTHERMAL SYSTEM



BASIC EGS CONCEPT



SURFACE POWER PLANT

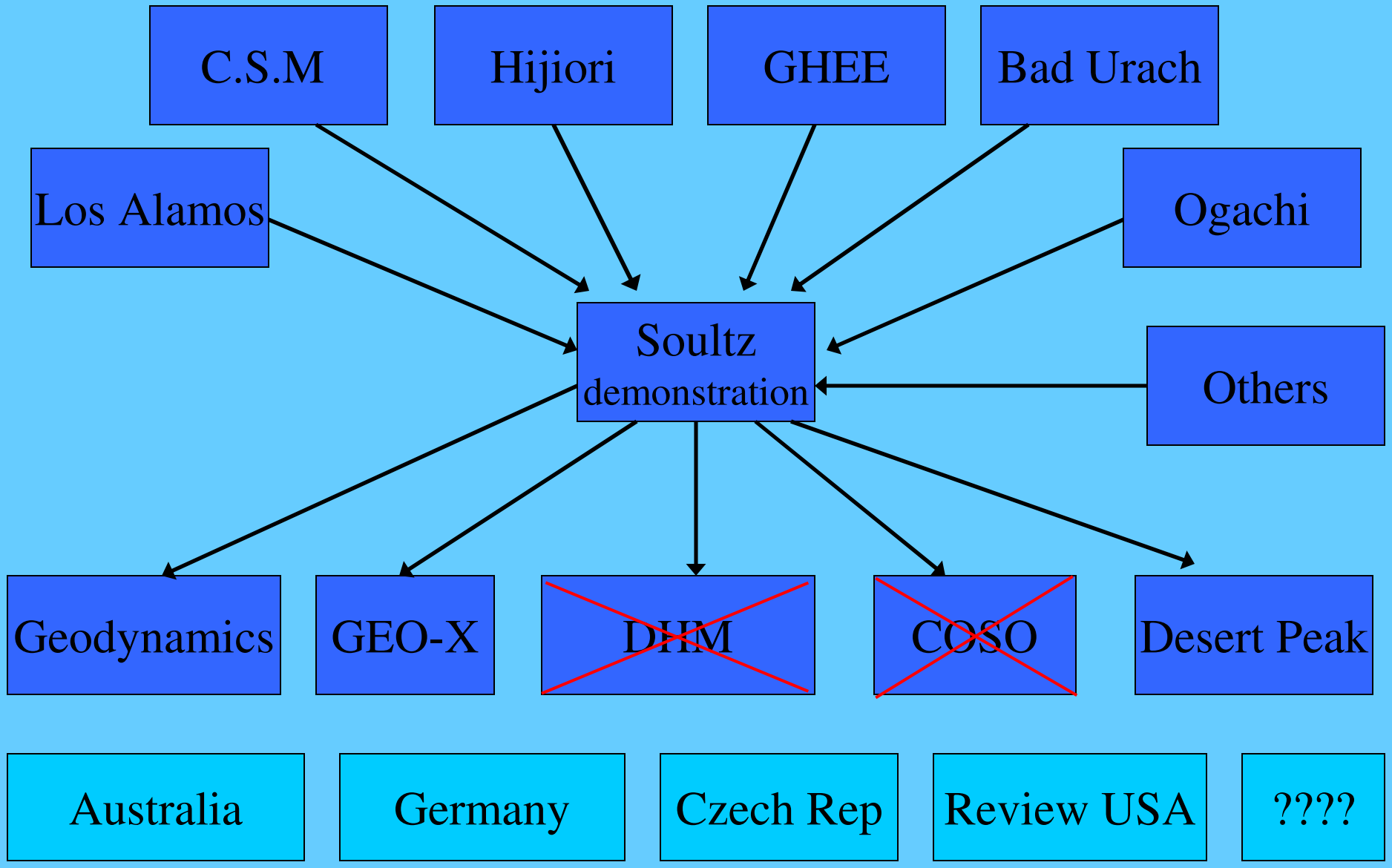
Microseismic monitoring

Deep wells

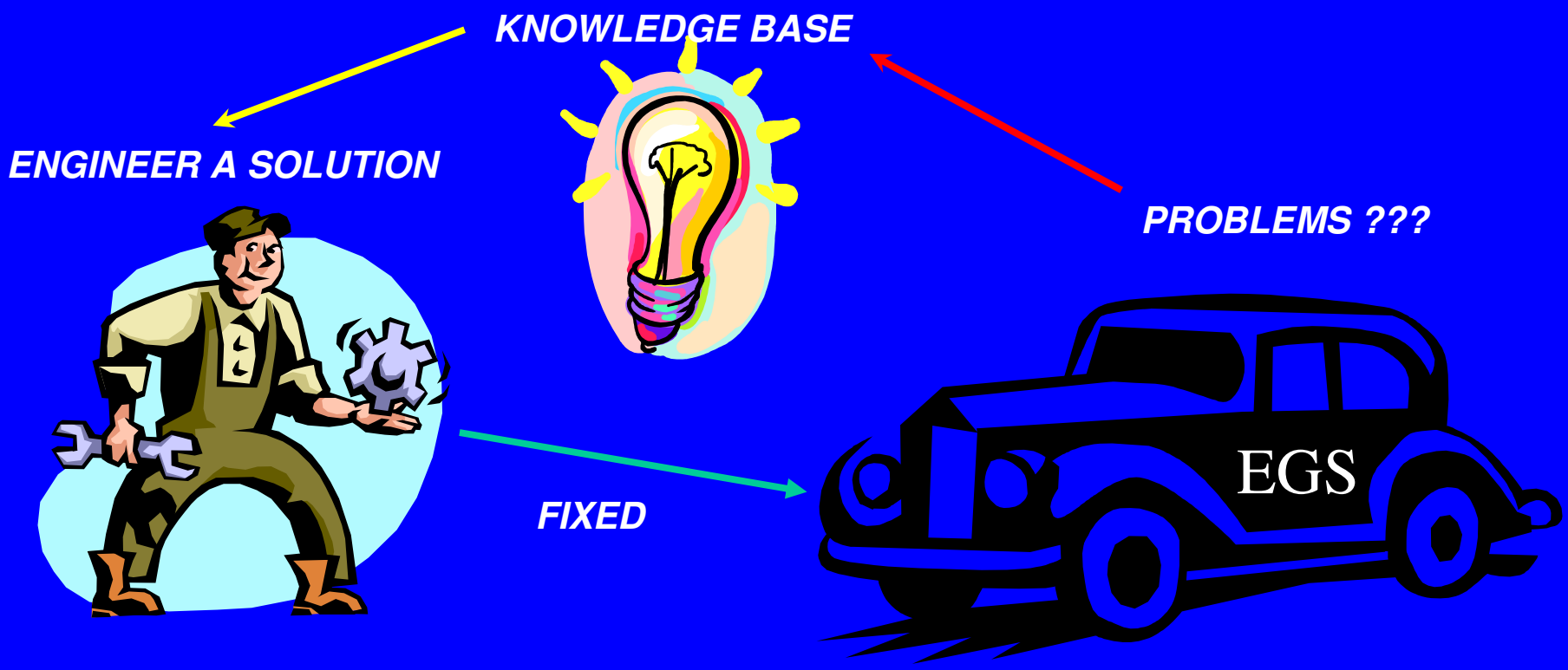
Enhanced natural permeability

ACCUMULATION OF KNOW-HOW

1987-2007 Soultz European Project ?



ACQUIRED ENOUGH KNOWLEDGE TO BE ABLE TO SOLVE DIFFICULTIES



COMMERCIAL DEVELOPMENT REQUIRES:

1. RESOURCE IDENTIFICATION

2. ***ENGINEERING EVALUATION & PLANNING***

3. **ECONOMIC EVALUATION**

4. RAISE CAPITAL

ECONOMIC ASSESSMENT

1. **HOW MUCH POWER CAN BE PRODUCED**

   (Temp, flow, density of the hot fluid and power conversion efficiency)

2. **HOW LONG WILL IT LAST**

   (Heat transfer area, Heat exchange volume, production flow and injection temp.)

3. **WHAT REVENUE CAN BE GENRATED**

   Gross power – (parasitic losses + maintenance) = net power

   Parasitic losses: Energy required to drive the flow

   Water losses

   Management

   Reservoir life

   Interest rate

4. **REVENUE OR PROFIT RELATED TO NET POWER OUTPUT**

ENGINEERING PARAMETERS:

1. DRIVEN BY ECONOMICS: **Target 5-6 MWe /module**

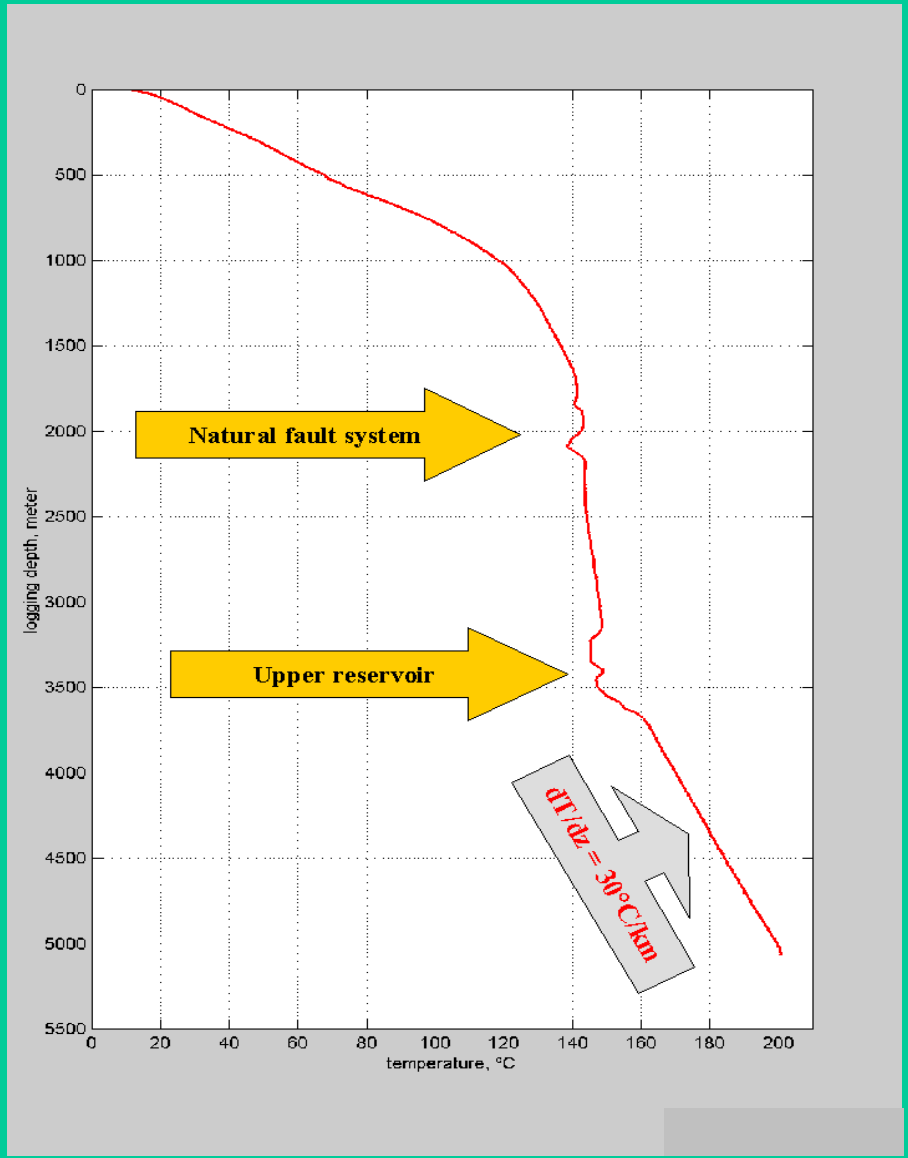
- LIFE OF THE SYSTEM: ~20 Years
- TEMP/DEPTH OF THE WELLS: ~ 200° C
- SEPARATION BETWEEN WELLS: ~600 m
- PRODUCTION FLOW RATE: ~75 Kg/s
- FLOW IMPEDANCE: ~ 0.1MPa/l/s
- WATER LOSS: ~ 10% MAX
- THERMAL DRAWDOWN ~ 10%
- CONTACT SURFACE AREA: ~ 10 million m^2
- RESERVOIR ROCK VOLUME ~ 300 million m^3
- INTEREST RATE FOR THE CAPITAL: ~ 5%
- SUPPORT : No CO_2 levy support etc

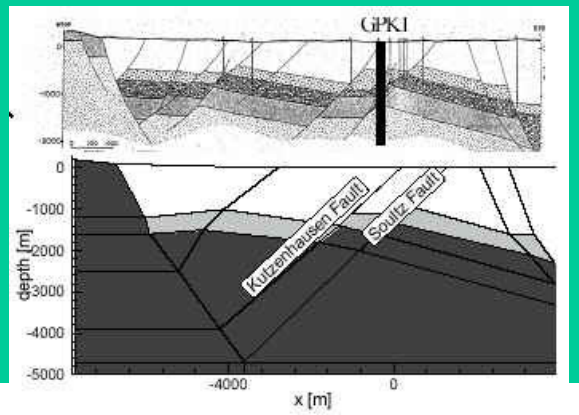
Economic study by Shock ~1986 for UK DoE

Best achieved in the world so far

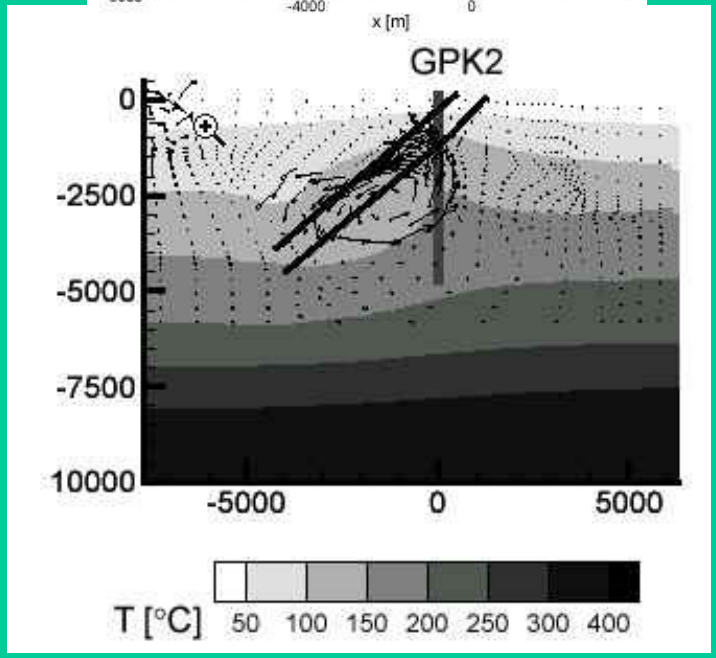
TOPIC	Econ. TARGETS	BEST SO FAR
System life	**20 years**	5 years Rosemanowes
Drilling cost	**10m** € for 6km well	5 m € for 5 km (GPK3)
Temperature	**200°C+**	270°**C** @ **2.2km Hijiori**
Separation between wells	600m	600 m @ Soultz
Flow-rate	**~ 75 l/s**	26 l/s @ Soultz
Flow Impedance	**0.1 MPa/l/s**	0.29 @ Soultz
Water loss	**10 %**	0 % @ Soultz
Thermal drawdown	**10 % after 20 years**	?????
Contact surface area	**10 million m2**	?????
Reservoir rock volume	**300 million m3**	?????
Interest rate	**~ 5%**	?????

Temperature Profile Well GPK-1



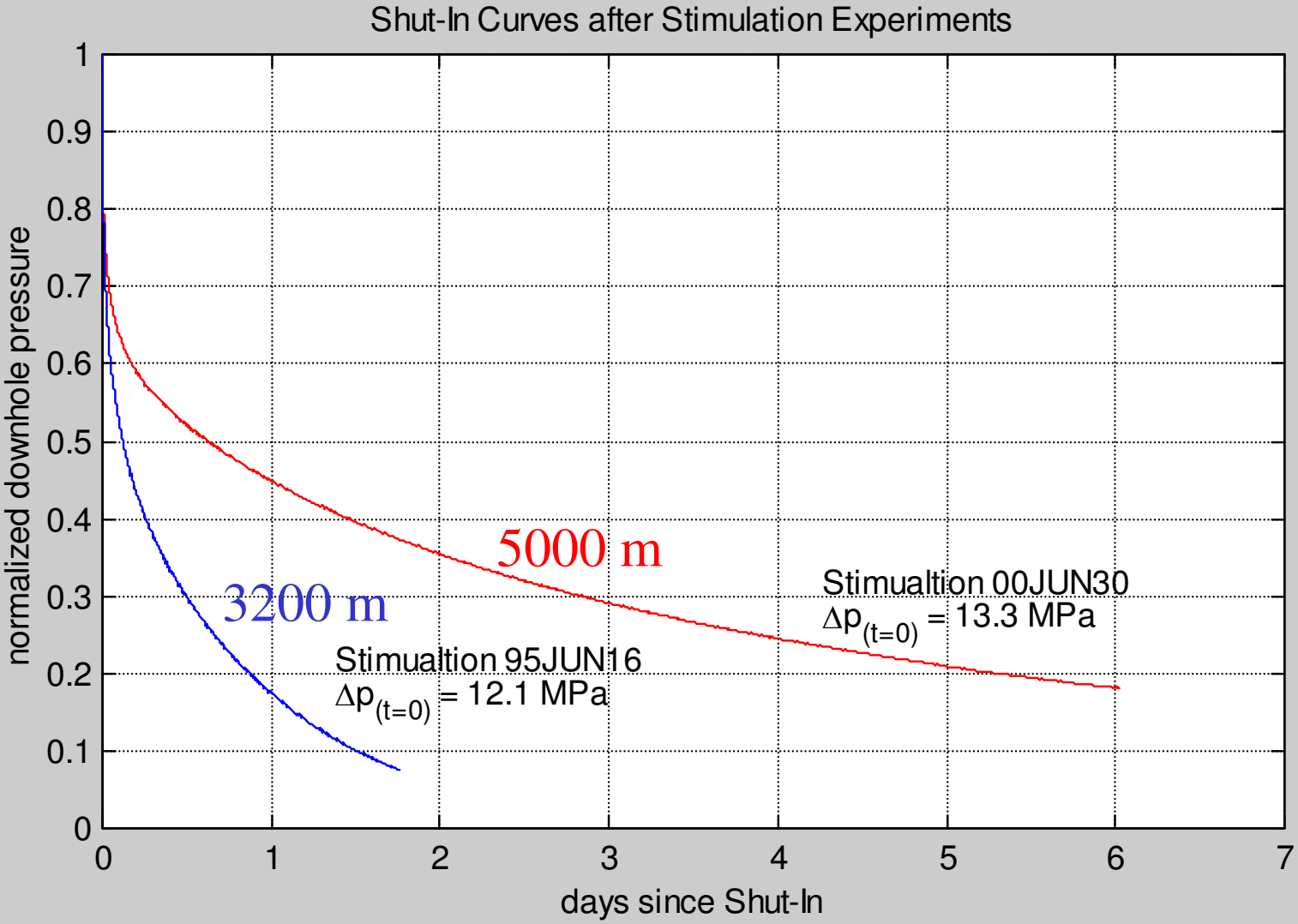


Cross section



Forward modelled temperature illustrating the convective region

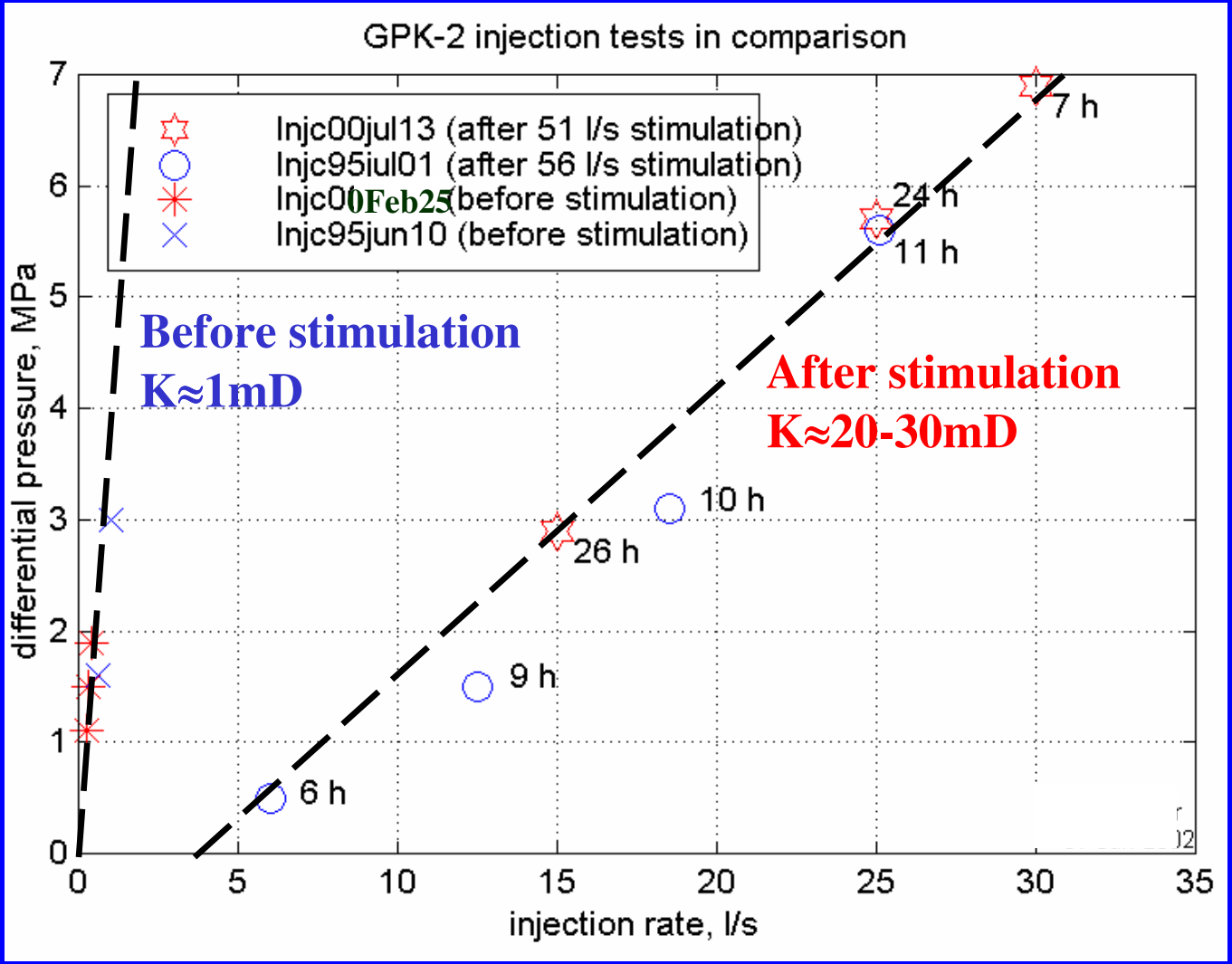
Shut-in curve demonstrates if open or closed system



4 months Circulation Test in 1997

- Duration : 4 months
- Separation of wells: 450 m
- Injection in GPK1 : 25 l/s
- Injection Pressure 4 MPa-> **2MPA**
- Production in GPK2 : 25 l/s
- 142°C output temperature
- 244 000 m^3 fluid circulated
- 250 – 220 kW used
- Production 10-11MWth
- Impedance 0.23 MP/l/s
- Control corrosion & precipitation
- Zero water loss

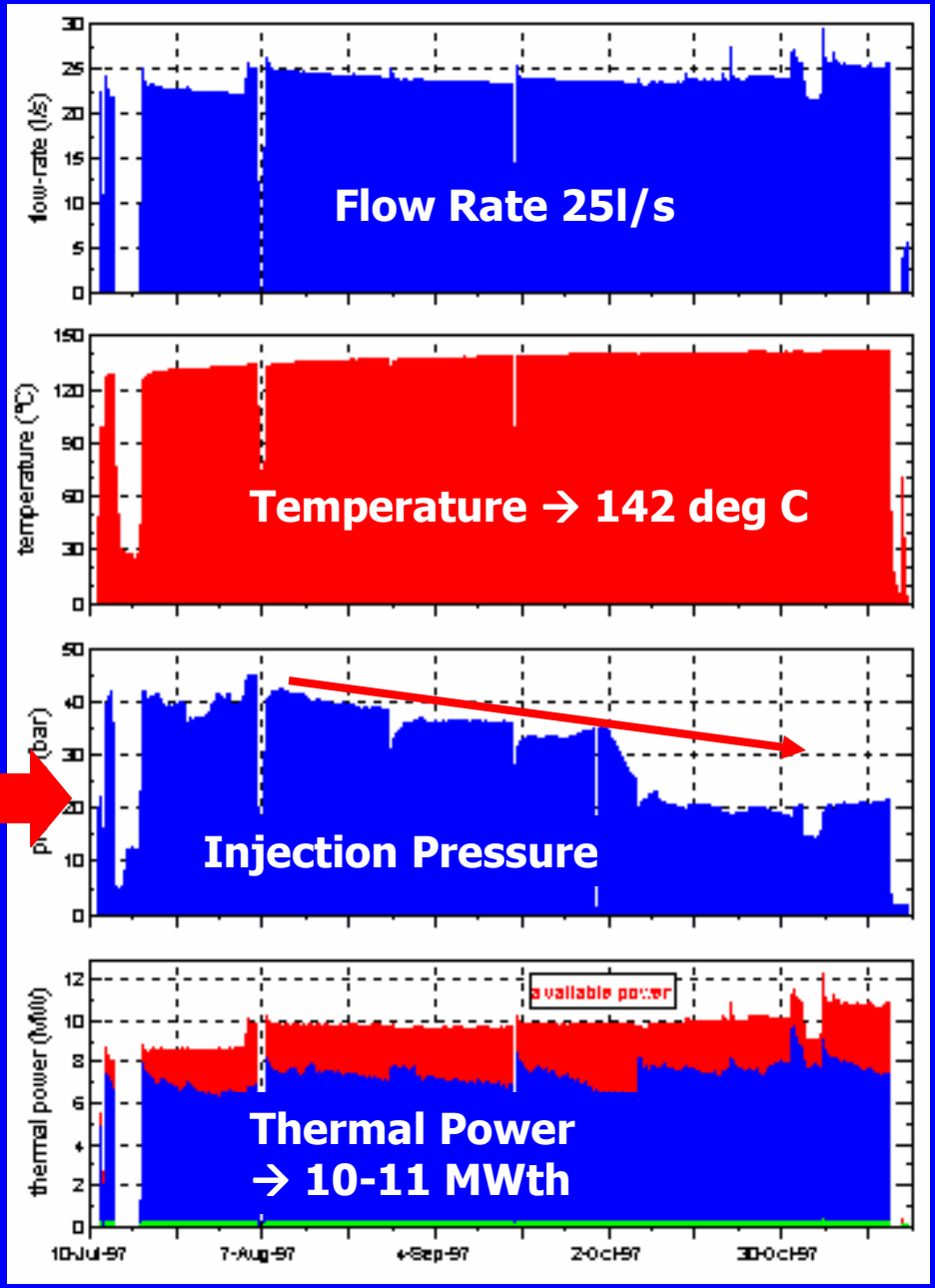
Injection test overpressures: 1995 & 2000

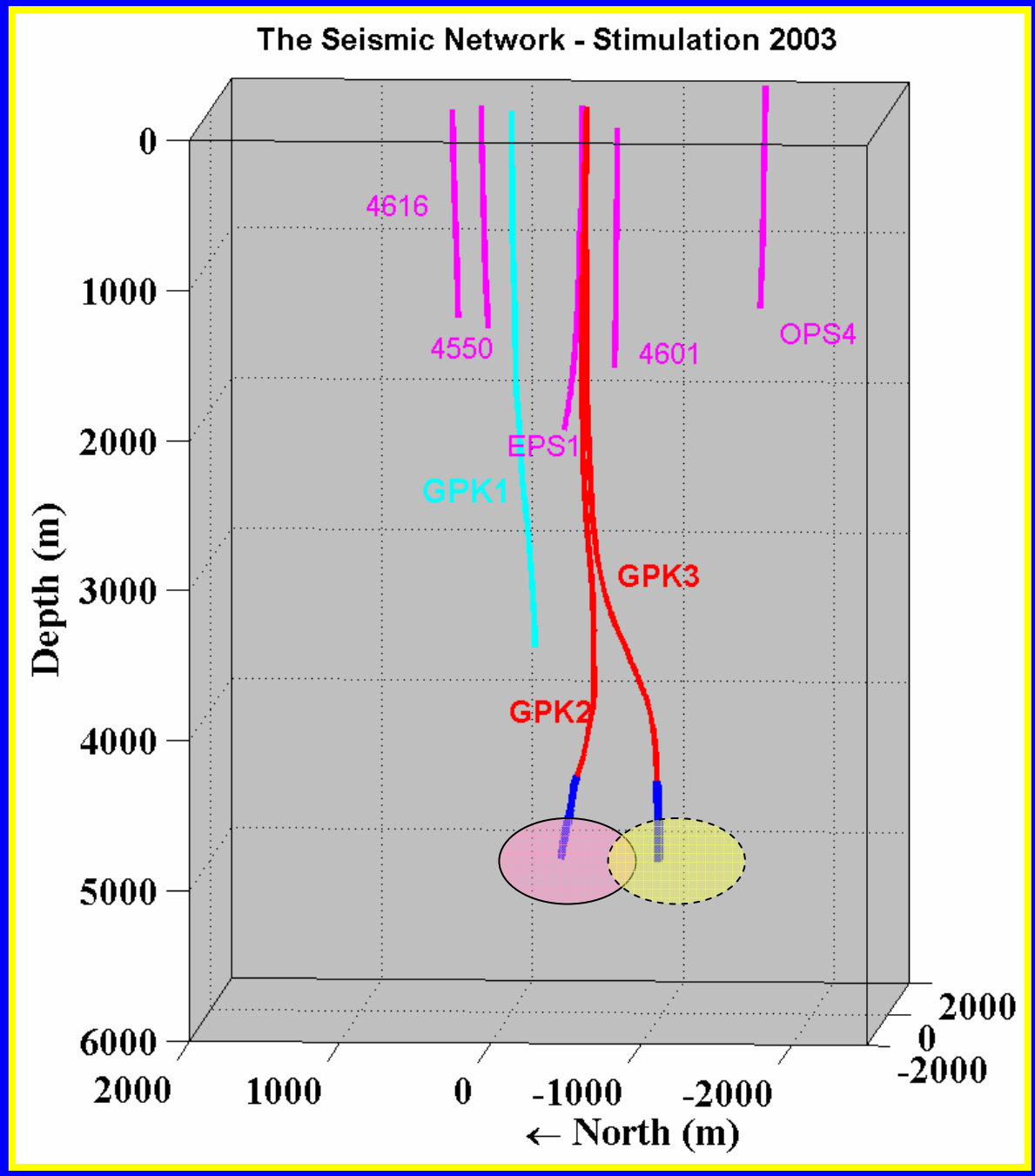


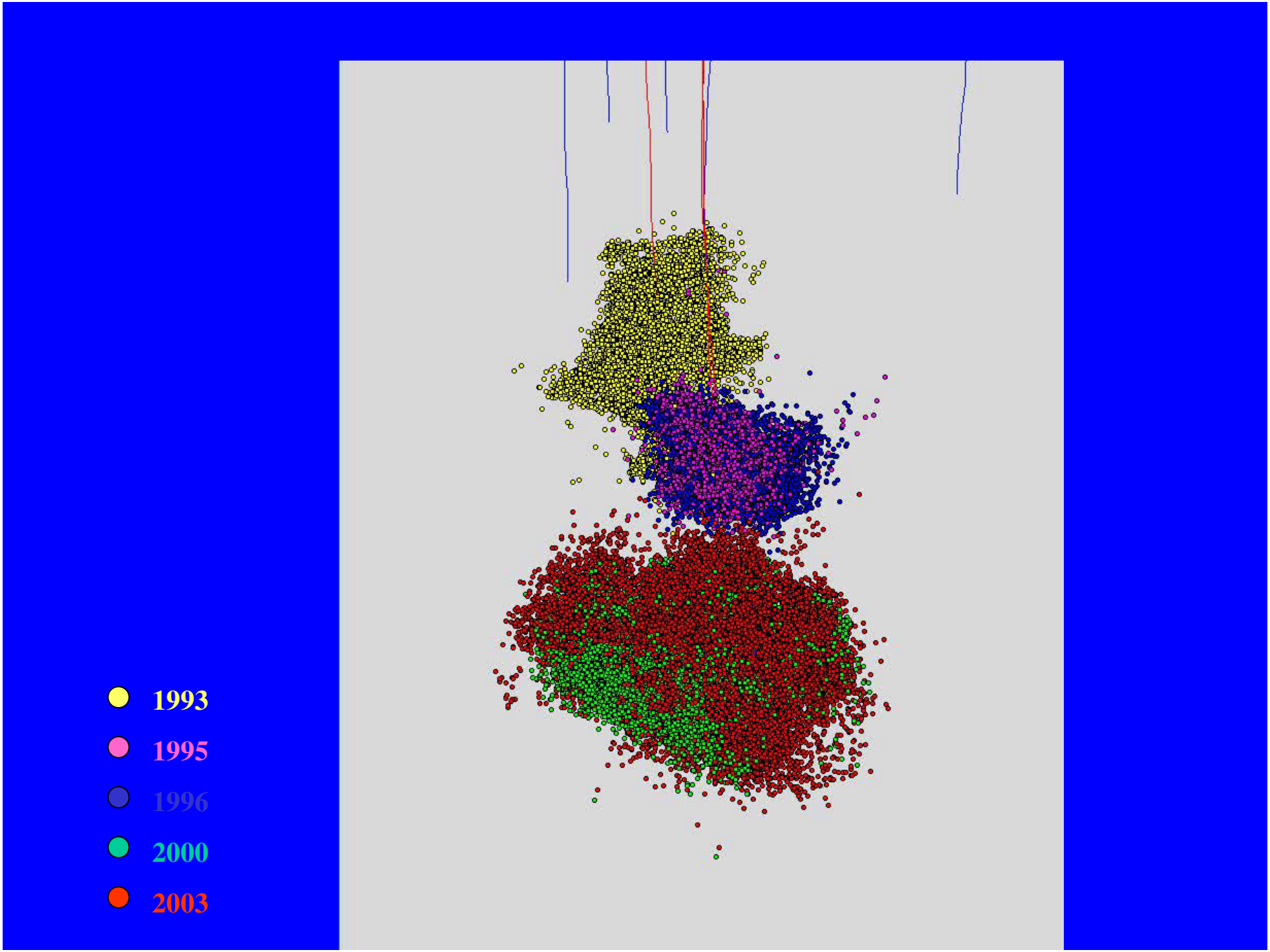
>> internal reservoir permeability was strongly enhanced (x20-30)

The 4 Month Circulation Test at 3200 m

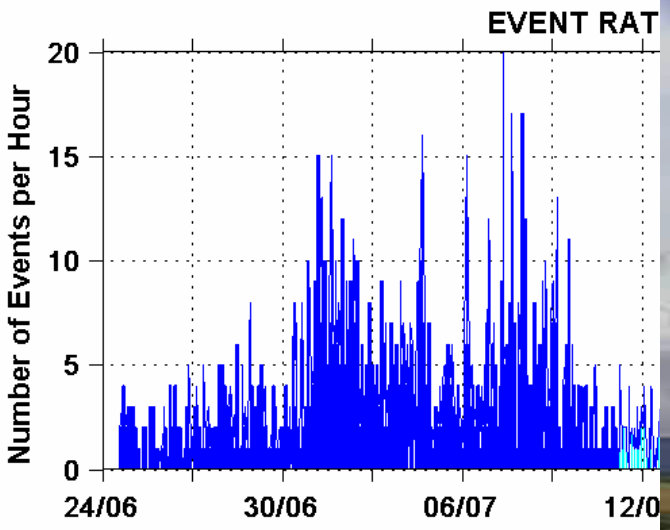
Injection pressure drop
4 → 2 MPa
⇒Thermal cracking
+
⇒ stop injection of flocculent (Aquaprox)

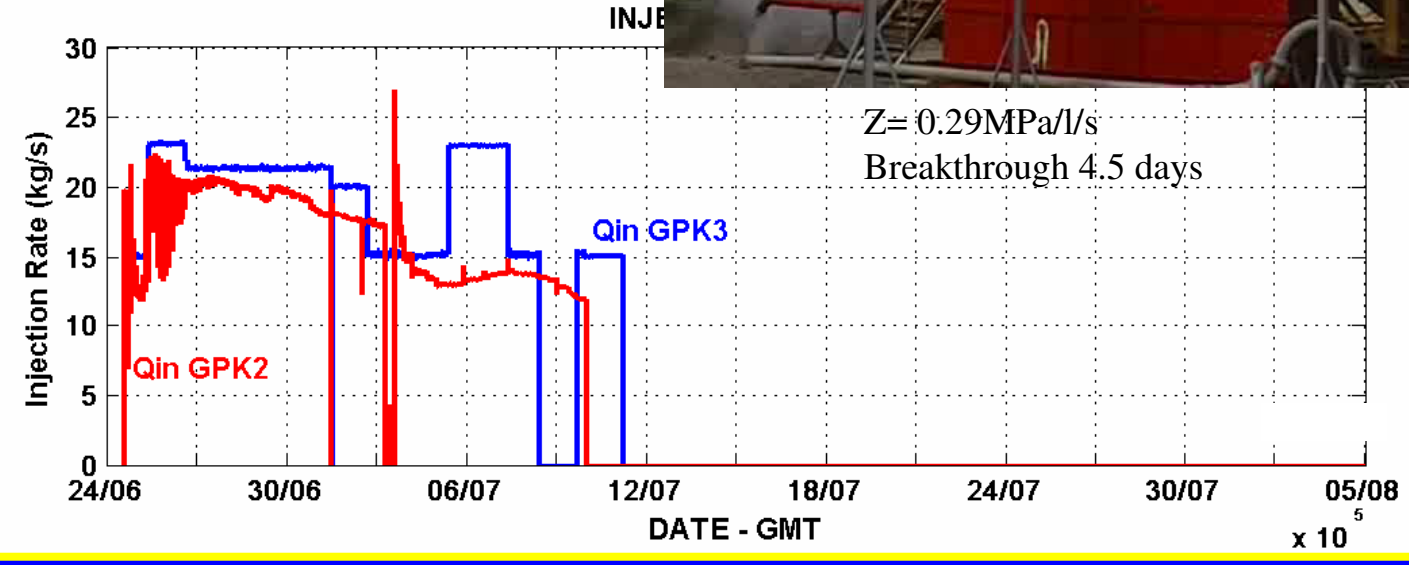



The Seismic Network - Stimulation 2003
Depth (m)
0
1000
2000
3000
4000
5000
6000
4616
4550
4601
OPS4
EPS1
GPK1
GPK3
GPK2
2000
1000
0
-1000
-2000
← North (m)
2000
0
-2000


1993
1995
1996
2000
2003

DEMONSTRATION: 3 weeks of circulation between GPK2 & GPK3

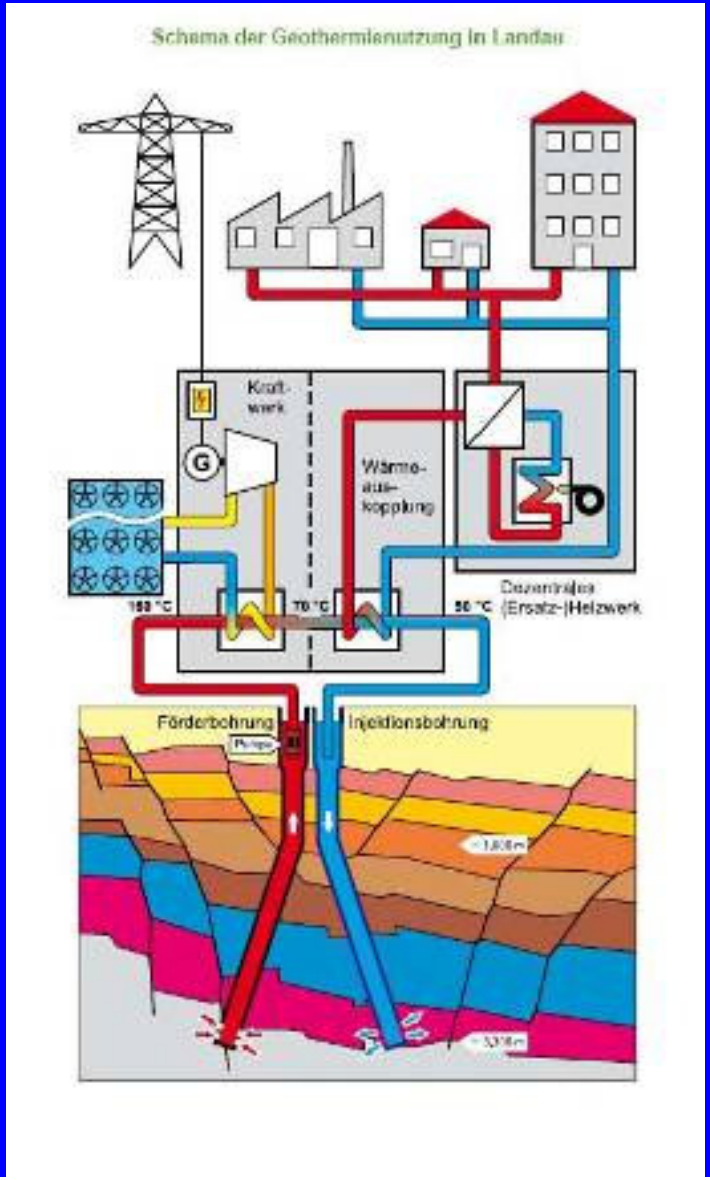




Z= 0.29MPa/l/s
Breakthrough 4.5 days

INDUSTRIALLY FUNDED

project in Landau, Germany



(GEOX) PROJECT

First operational Engineered Geothermal System in Landau (Germany)

1. Constructed in ~3.5 years
2. Surface temp. 145 °C, Flow 60-80 l/s
3. Depth 3.8 km
4. Cost 15 M€
5. Generate power in Feb 2008 (~2.0MWe; ORMAT plant)
6. Conference 29-31 Oct. in Mainz (www.bestec-for-nature.com/fegr2007/)

What next:

Research: (Develop toolbox)

1.Stimulations in different stress regime
2.Determine stress profile
3.Determine the life of reservoir (heat transfer area & volume)
4.Forward modeling of stimulations.
5.Method of increasing flow rates
6.Develop downhole tools (packers , sealants etc)
7.Reduce seismic risk: stress migration
8.Scale up to 25 to 200MWe
9.USA & EC Coop agreement
10.IEA/GIA agreement

Commercial involvement:

1. **Resource assessment (MIT report)**
2. Liberalise Energy market
3. Provide licensing procedures for EGS exploration
4.Seek preferential tariff to reflect CO2 reduction
5.Train EGS staff
6.Initiate risk insurance
7.Improve drilling technology
8.Power conversion cycle
9.Reduce the time for planning permission

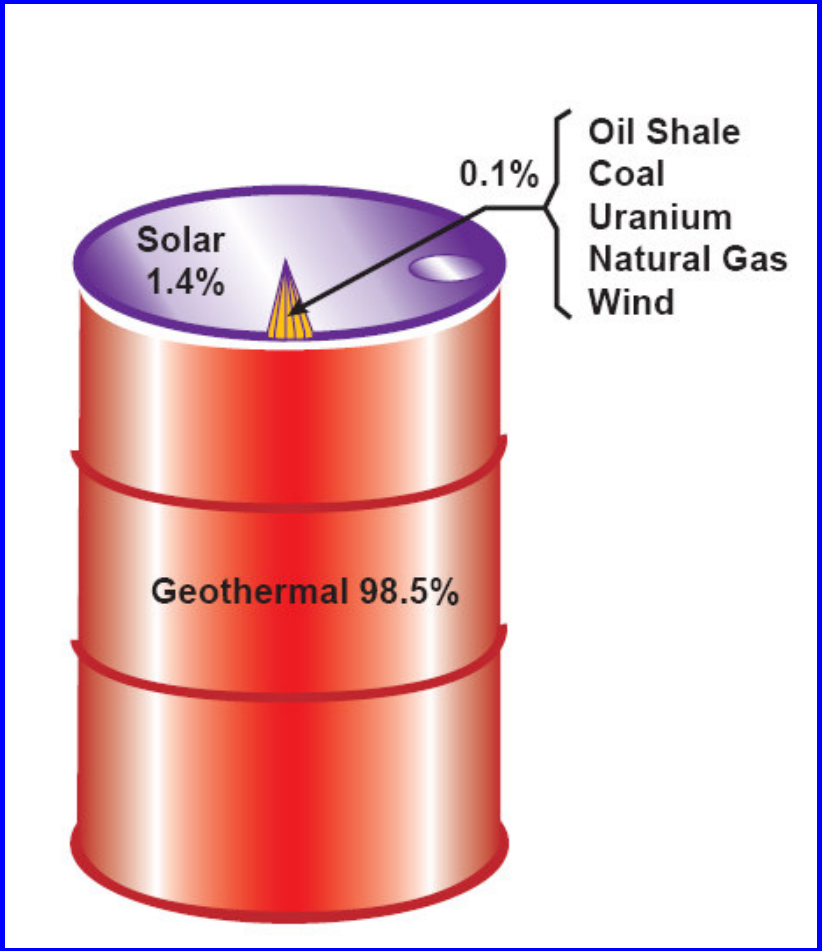
Resource & Technology review for the EU area (~MIT):

1. Select a highly respectable organization to coordinate the study
2. The study to cover up to 2020, 2030 & 2050.
3. **Resource –** estimating magnitude and distribution of the EU EGS resource (a) 0-5km depth, b) 0-10km)
4. **Technology –** establishing requirements for extracting and utilizing energy from EGS reservoirs including drilling, reservoir design and stimulation, and thermal energy conversion to electricity
5. **Economics –** projecting costs for EGS supplied electricity as a function of invested R&D and deployment in evolving energy markets
6. MIT report discusses what it takes for EGS to provide **100,000 MWe** of base-load electric generating capacity by 2050.

Effect of the report in the USA:

1. Drew attention of the politicians, general public and the Industry
2. Gave geothermal (EGS) high profile it deserves
3. Has persuaded the US Senate & Congress to support improvements in the technology to achieve these goals
4. Has persuaded capital venture and other companies to seek the benefit from investing in the technology.
5. Some of these companies are:
   - Altarock Energy Inc
   - Ormat Industries
   - Two leading oil companies
   - One oil & gas service companies
6. Being considered are two major by DoE and run by national labs.

US Energy Resource Base



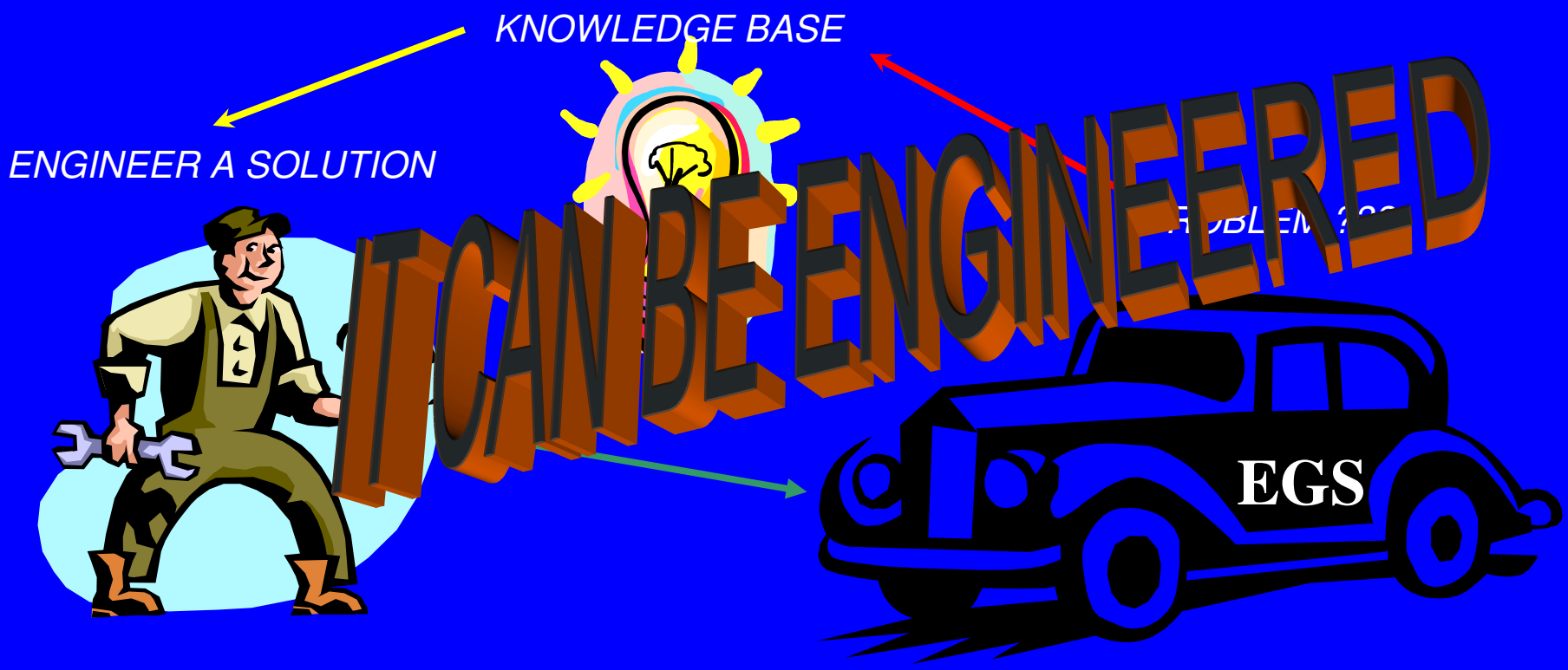
Sources:

Geothermal: MIT Report
Solar: "Characterization of U.S. Energy Resources and Reserves", Meridian Corporation 1989
Wind: "An Assessment of the Available Windy Land Area and Wind Energy Potential in the Contiguous United States", PNL 1991
Uranium: "Forward-Cost Uranium Reserves by State", EIA 2003
Coal: "International Energy Annual", EIA 2003
Natural Gas: "International Gas Reserves and Resources", EIA 2006

What are the alternatives:

- The centre of gravity will move from Europe to USA & Australia
- Loose scientists and engineers (30 years experience lost)
- Will have to import the technology in the future
- Will not be able to develop our strategic energy resource

THINK POSITIVE
THIS YOUR FUTURE



ONLY POSSIBLE BECAUSE OF THE DEDICATION OF SCIENTIST & ENGINEERS OVER THE LAST 30 YEARS