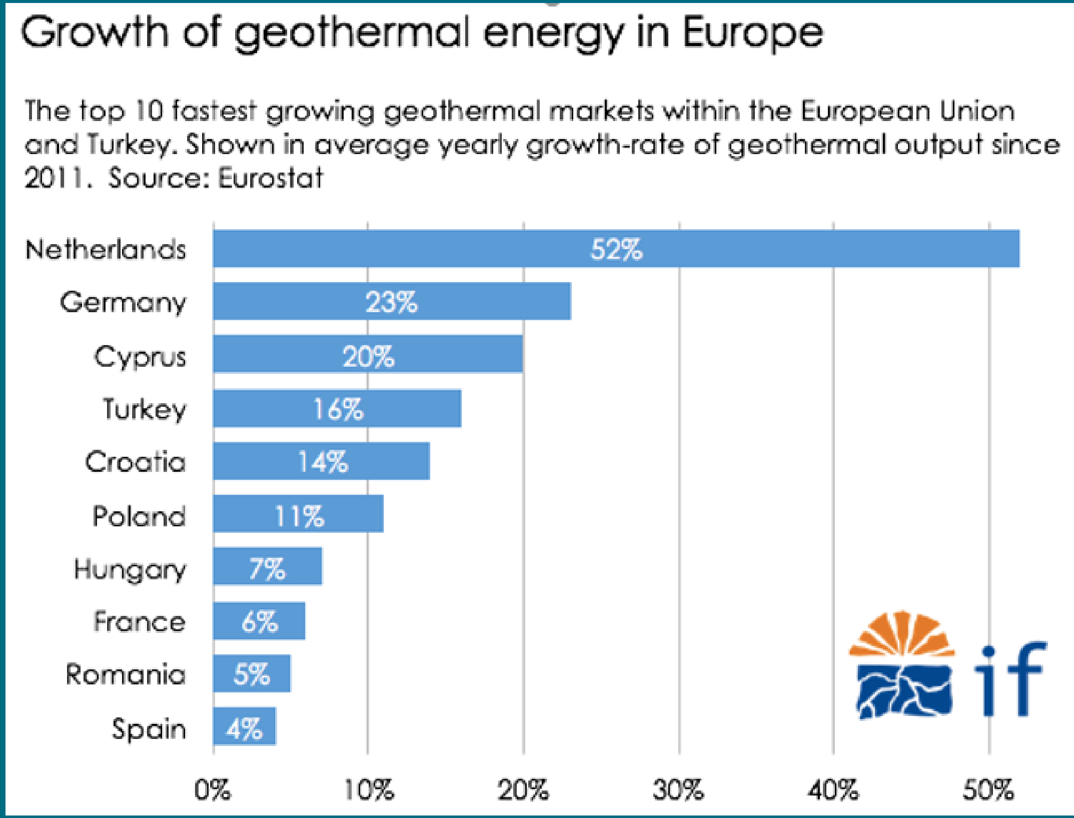
Geothermal energy in the Netherlands



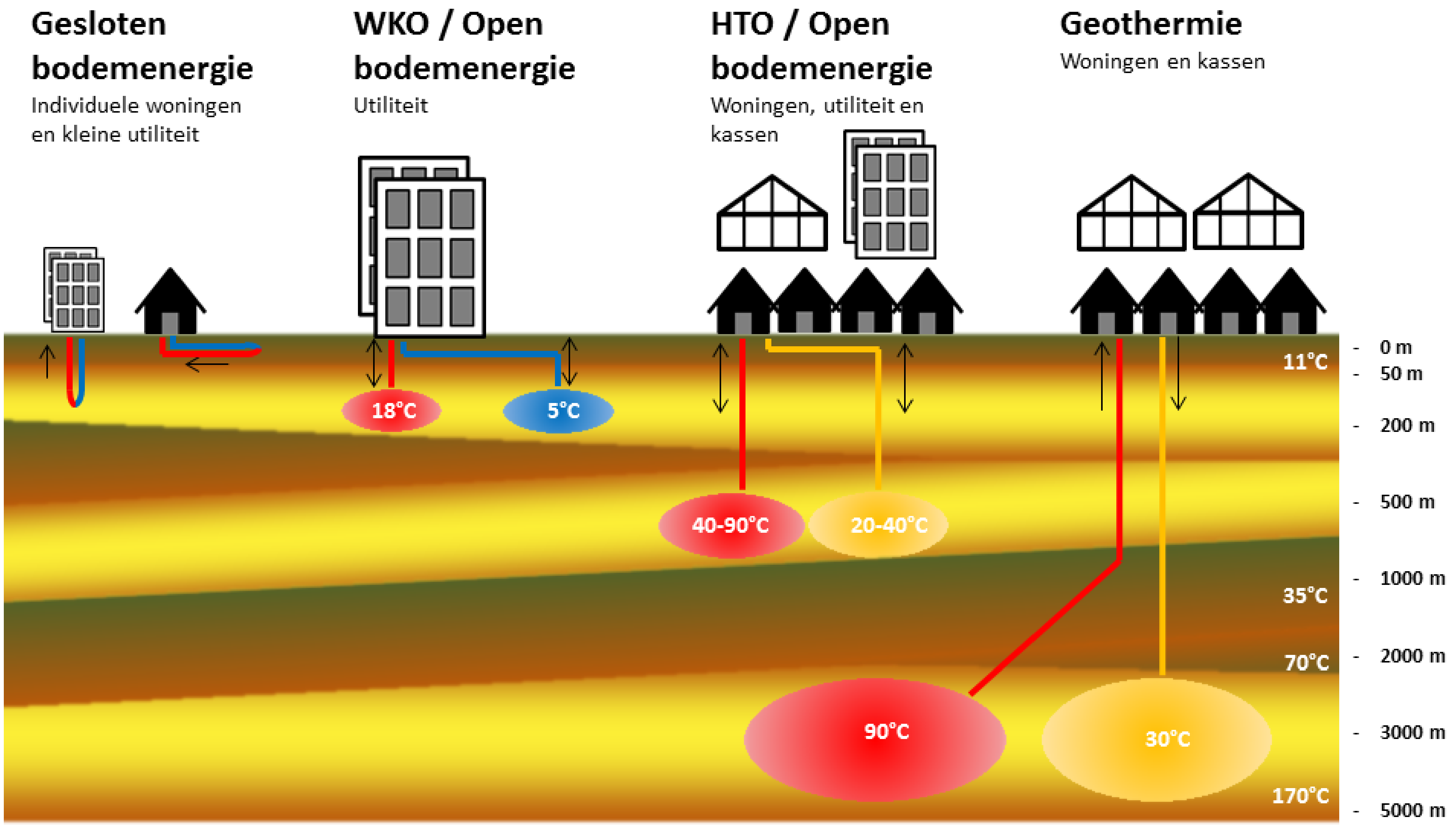
Introduction

- Nick Buik, reservoir engineer at IF Technology in Arnhem
- IF Technology is a consultancy company in Arnhem:
    - Renewable energy in which the subsurface and/or ground(water) plays a role

Content

- Overview geo-energy systems
- What is geothermal energy
- Current state and what are the future ambitions and contributions to the “klimaat doelstellingen”
- Realization of a geothermal system in practice
- Some figures
- Uncertainties and risks

Overzicht bodemenergiesystemen



https://www.h2owaternetwerk.nl/

Geothermal Energy in the Netherlands

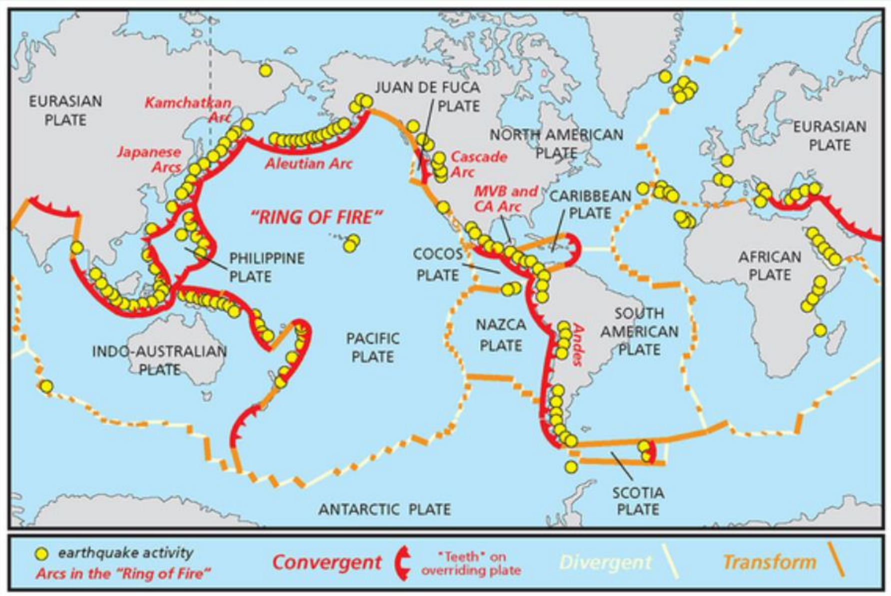
Geothermal Energy in the Netherlands

ENEA — Desire - Net Project — UNESCO

Geothermal systems

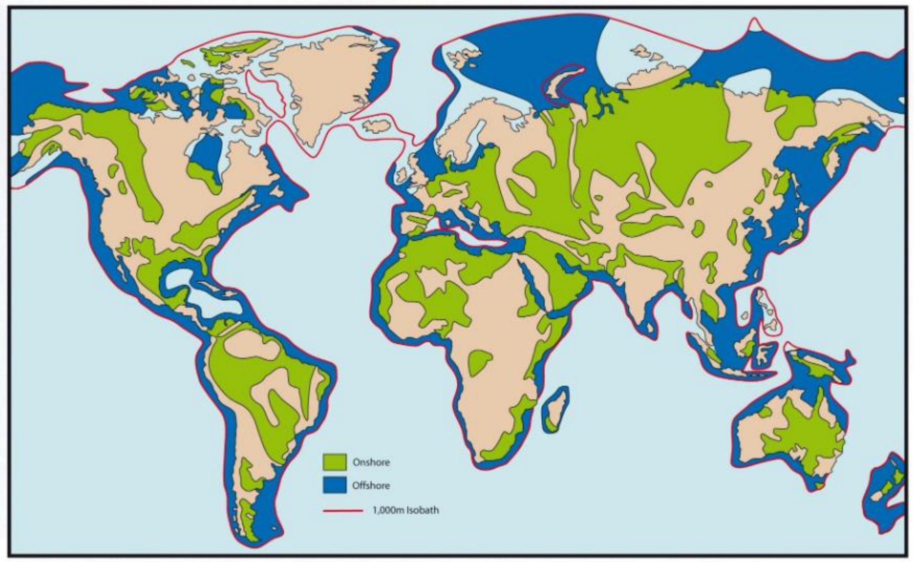
Reservoir Temperature	Reservoir Fluid	Common Use	Technology commonly chosen
High Temperature >220ºC (>428ºF).	Water or Steam	Power Generation Direct Use	▪ Flash Steam ▪ Combined (Flash and Binary) Cycle ▪ Heat Exchangers ▪ Heat Pumps
Intermediate Temperature 130-220ºC (266 - 428ºF).	Water	Power Generation Direct Use	▪ Binary Cycle ▪ Direct Fluid Use ▪ Heat Exchangers ▪ Heat Pumps
Low Temperature 50-130ºC (122- 266ºF).	Water	Direct Use	▪ Direct Fluid Use ▪ Heat Exchangers ▪ Heat Pumps

Enel ENERGY IN TUNE WITH YOU.



Map of Tectonic Plates by National Park Service (CC0)

WORLD'S MAJOR SEDIMENTARY BASINS



Oil Field Review, Spring 2005

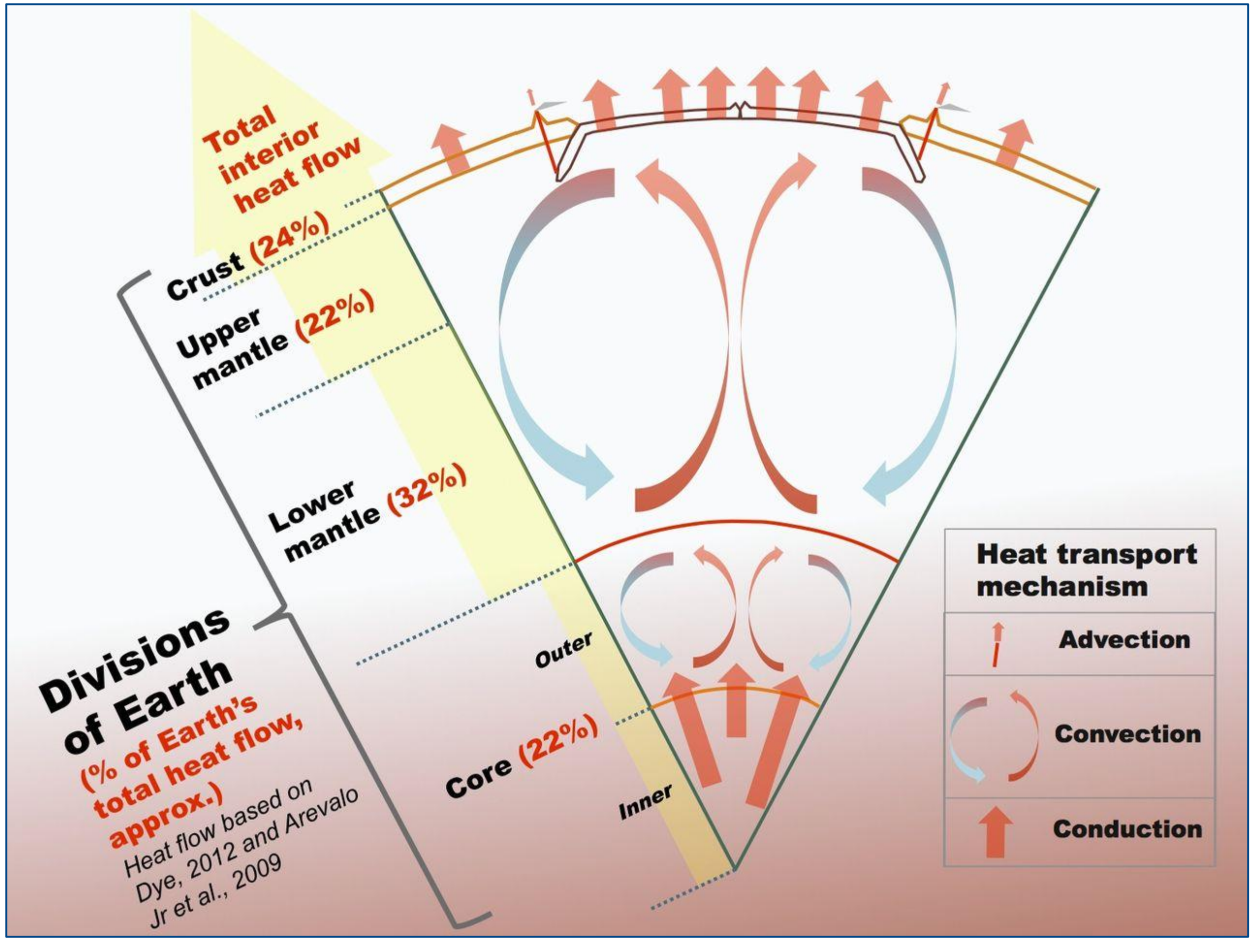
Where does the heat come from

Core temperature: 2,000-12,000°C
1) **heat** from when the planet formed and accreted, which has not yet been lost;

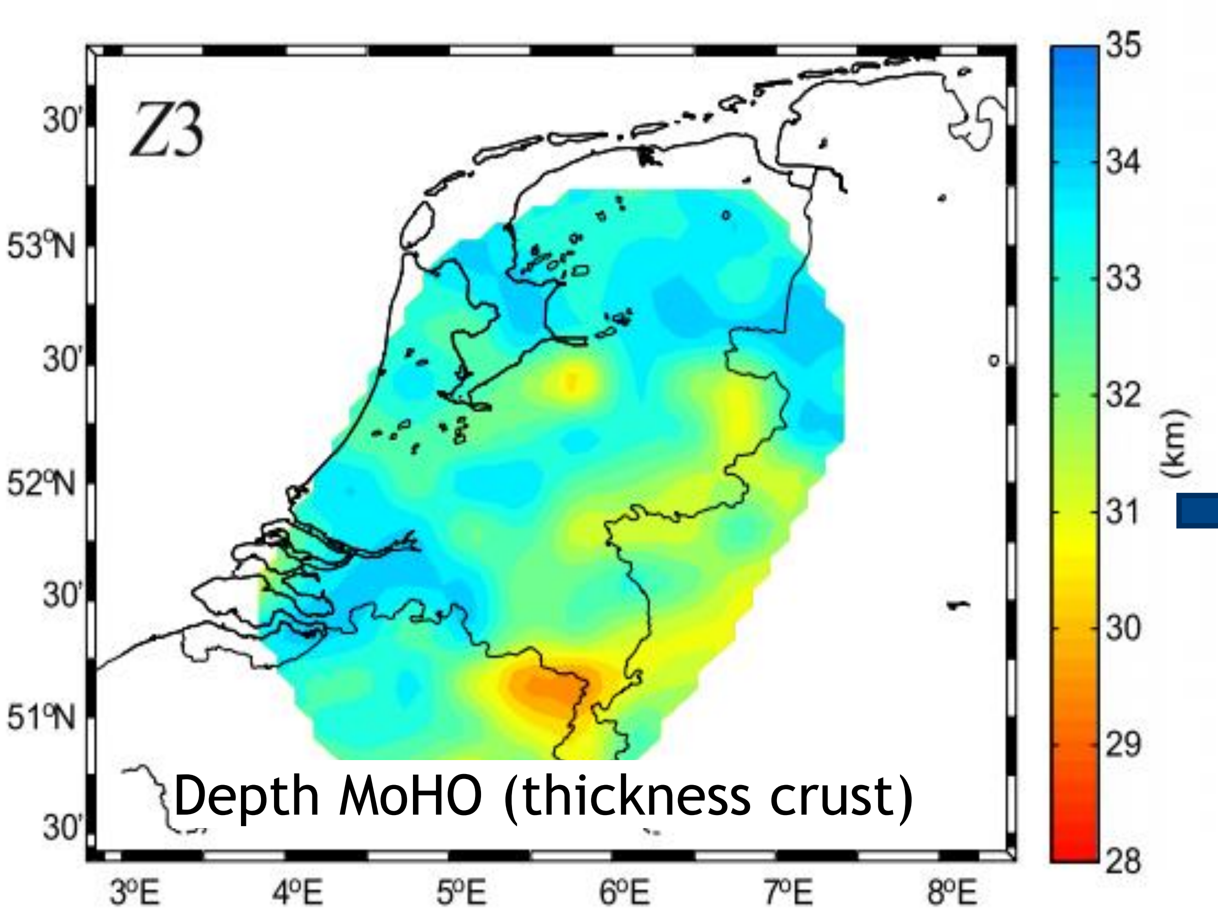
2) frictional **heating**, caused by denser **core** material sinking to the centre of the planet;

3) **heat** from the decay of radioactive elements.

Outer 6 km:
50.000 times the energy of the worlds total amount of oil and gas



Heat Flow



The crustal structure beneath The Netherlands derived from ambient seismic noise

Tedi Yudistira[a,b], Hanneke Paulssen[a,*], Jeannot Trampert[a]

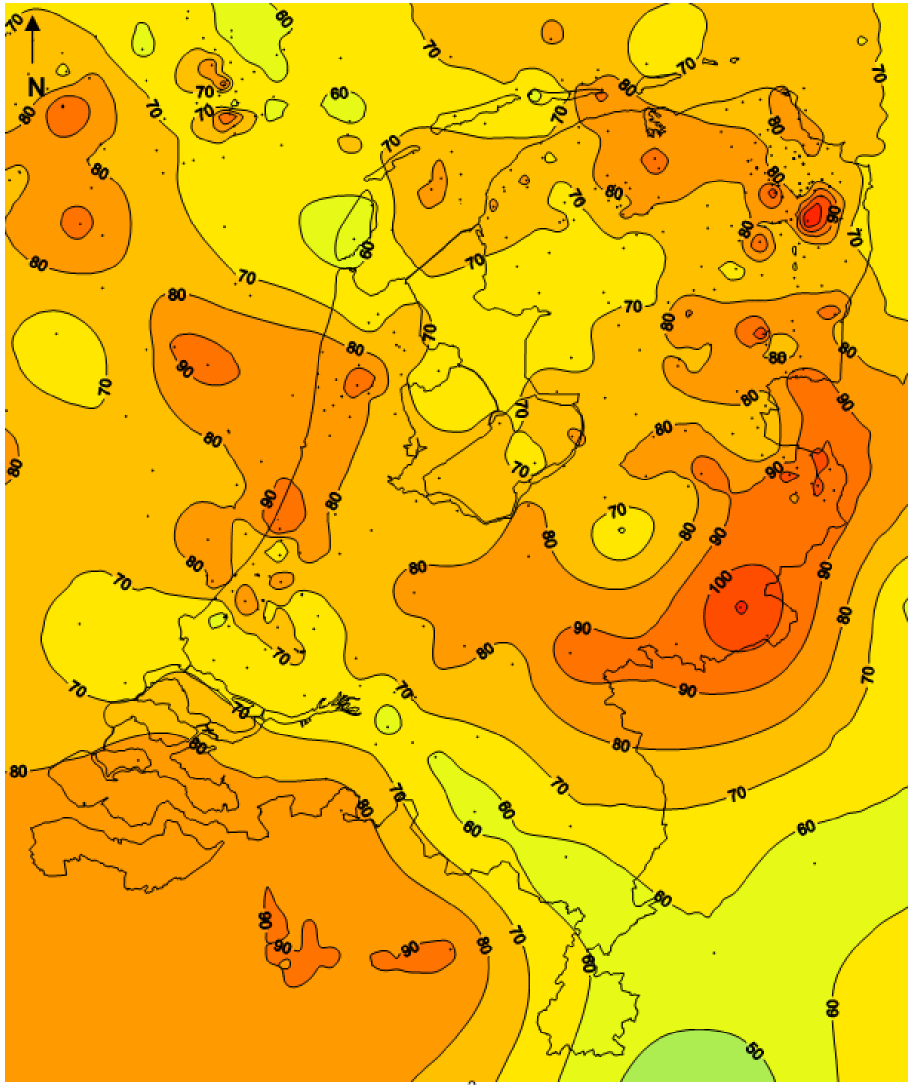
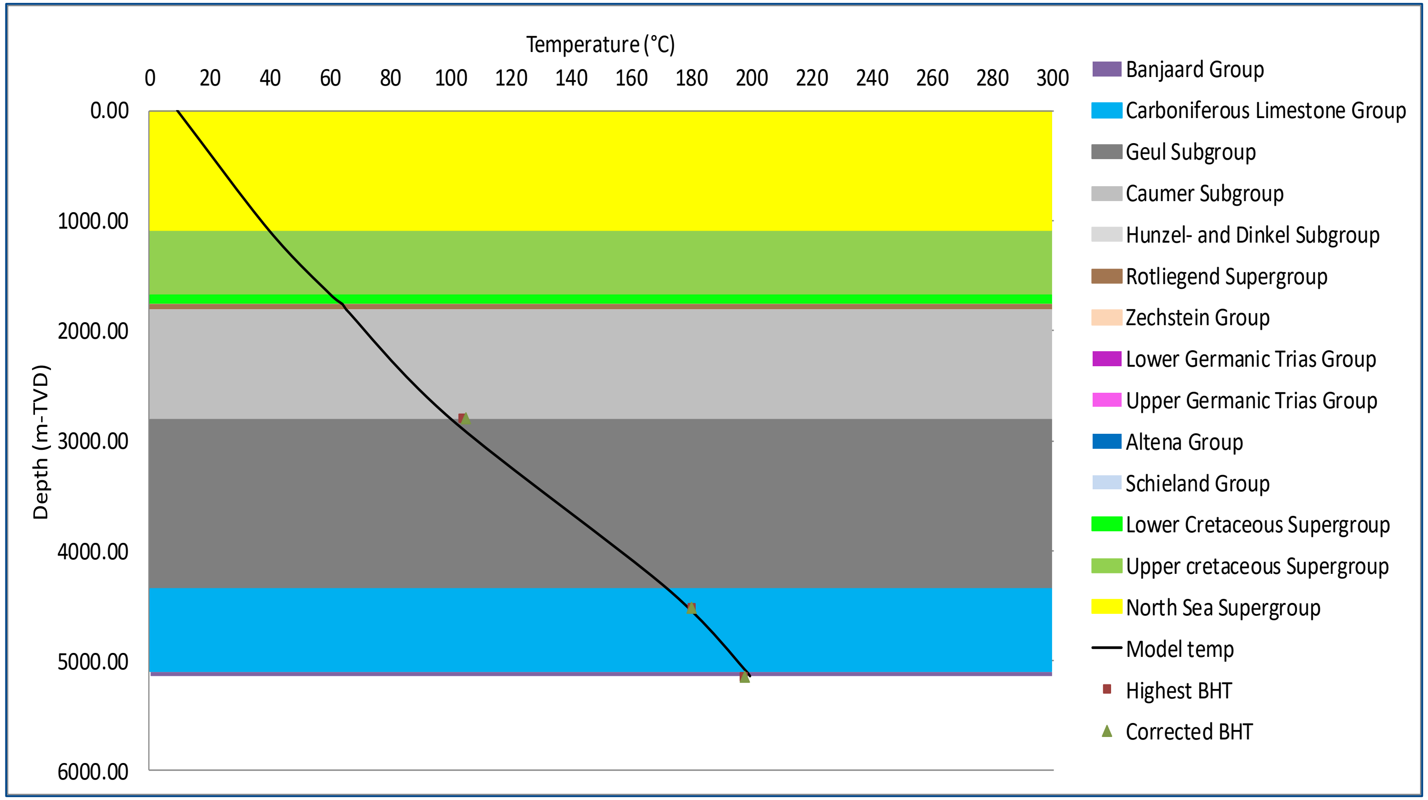


Figure 5.1: Heat-flow density map in mW/m^2 of the Netherlands. The dots are the data points (based on data of Hurter and Haenel, 2002; Hurtig et al., 1992).

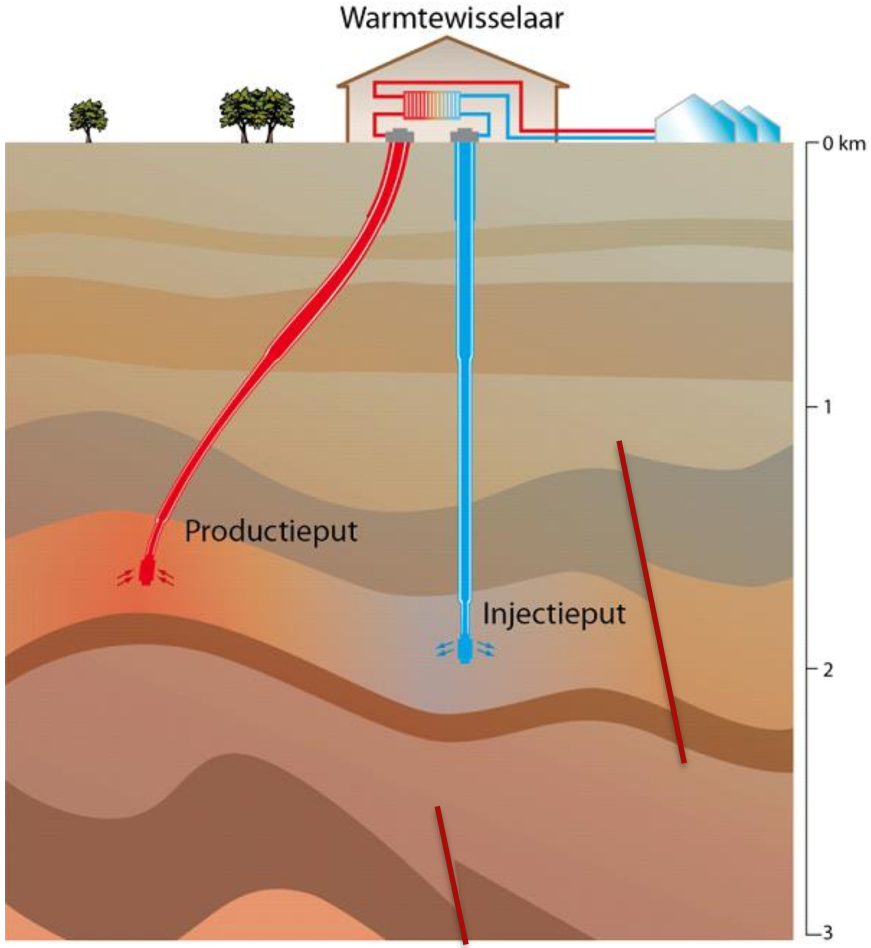
Geothermal Gradient



T = 0,03 * diepte + 10

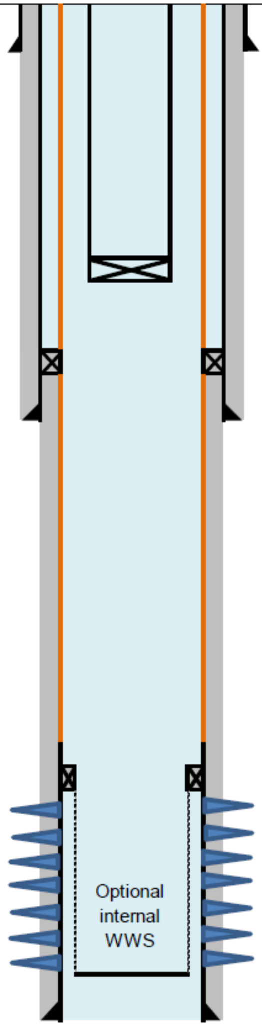
Gradient depends on lithology (thermal conductivity)

Geothermal wells



- Pumping depth
- Shoe depth
- Inclination
- Kick-off point (KOP)
- End of Built (EOB)
- Diameters

Nr.	Item Description (Depths from NAP, GL = NAP + 2,2 m)	Wellhead and X-mas tree **HAG-GT-03** (Producer)	Depth (m, TVD)	Depth (m, AH)	Hole ID (in)	Pipe OD (in)	Pipe ID (in)
1	26" welded conductor / stove pipe		60	60		26,000	25,000
	13-3/8", GRE-Lined, Premium					13,375	11,750
	7-5/8", coated, Premium *10-3/8" ESP*		700	700	-	7,625	6,875
	Liner hanger 13Cr 18-5/8"x 13-3/8" + packer		1050	1050			
2	18-5/8", Non-premium		1150	1150	24,000	18,625	17,755
	Kick-off Point 1		1610	1610			
	End of build 1 to 45°		2124	2180			
	13-3/8", GRE-Lined, Premium X-over 13-3/8" GRE-lined x 13-3/8" CRA		2195	2281		13,375	11,750
			2280	2401	*Top Perforations*		
			Optional: CRA tubing perforated with optional internal WWS				
			2409	2584	*Bottom perforations*		
3	13-3/8", CRA, Premium		2441	2629	16,000	13,375	12,415

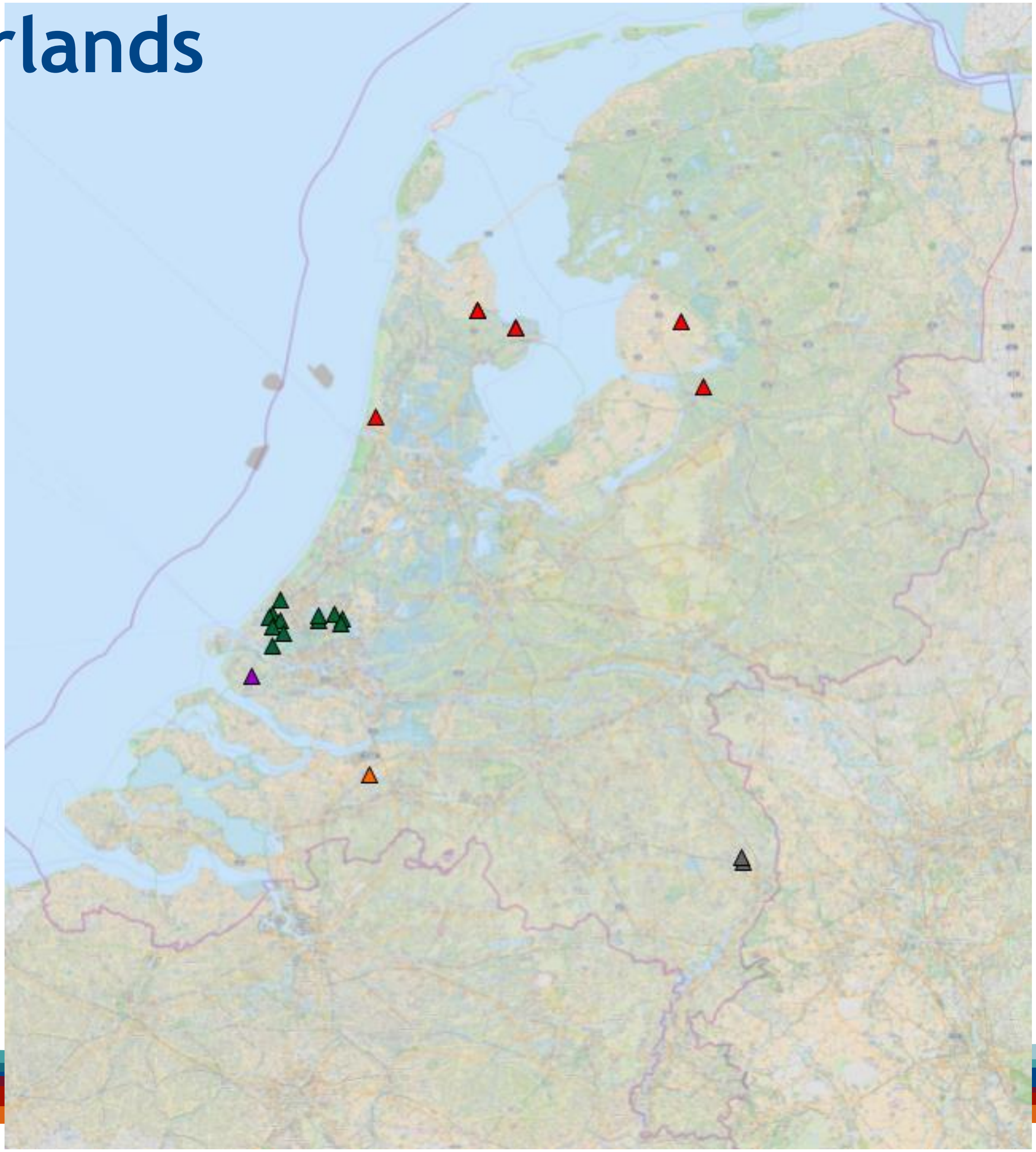


*Not in scale.

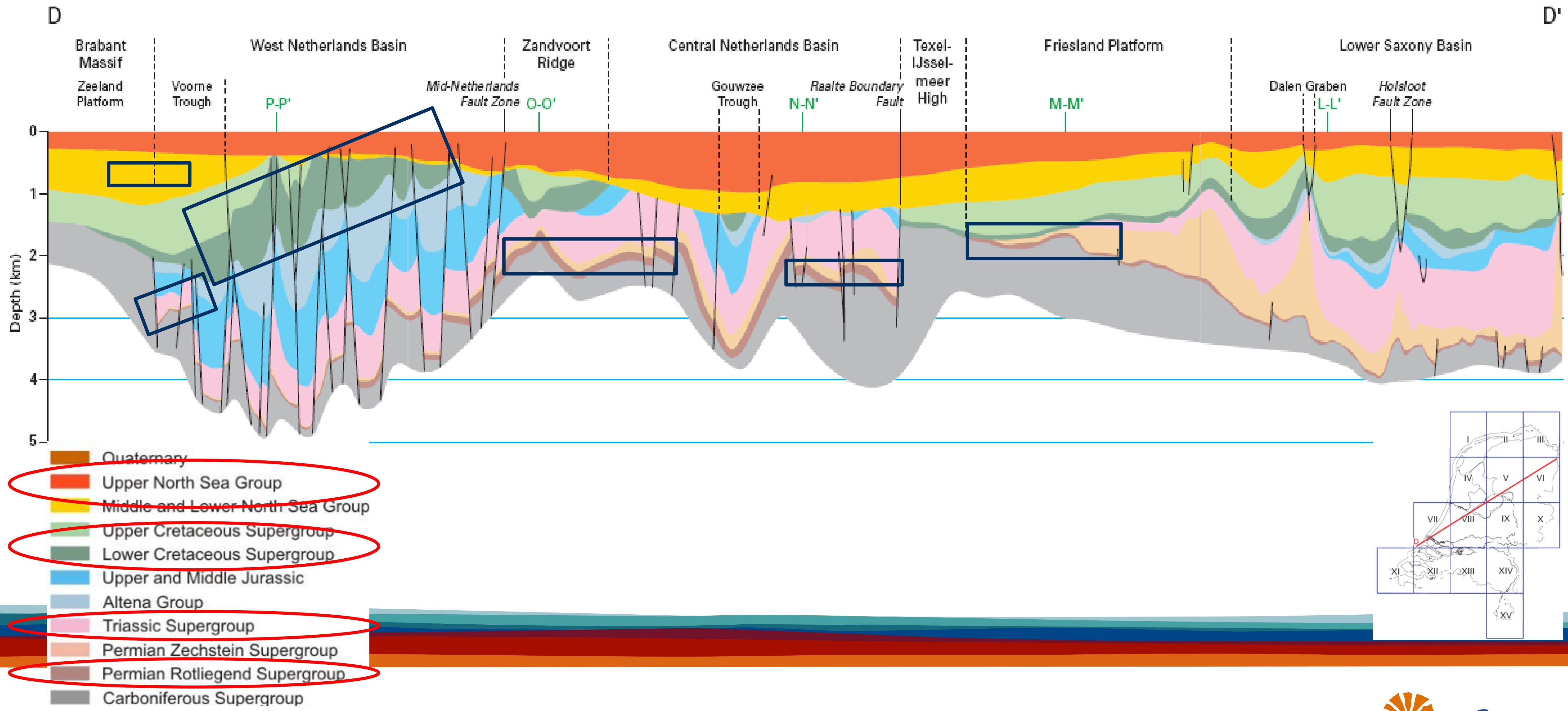
Geothermal systems in the Netherlands

Geologische tijdtabel
met stratigrafische kolom van Nederland

Tijd [MJ]	Hoofdtijdperk	Periode	Tijdvak	Groep of Formatie	Productieve eenheden
2.4	Kenozoïcum	Kwartair		Boven-Noordzee	Formaties van Maassluis, Oosterhout, Breda
		Tertiair	Neogeen		
			Paleogeen	Midden-Noordzee	Voortzand, Veldhoven, Bergzand
65				Onder Noordzee	Brusselssand, Meerssand
	Mesozoïcum	Krijt	Laat-Krijt	Ommelanden	
				Texel	
			Vroeg-Krijt	Holland	Holland Groenzand
				Rijnland	De Lier, IJsselmonde, Berkel en Rijswijk zanden
143				Schieland	Nieuwerkerk Formatie
		Jura	Laat-Jura		
			Midden-Jura	Altena	
208			Vroeg-Jura		
		Trias	Laat-Trias	Boven-Germaanse Trias	
245			Midden-Trias		
251			Vroeg-Trias	Onder-Germaanse Trias	Hoofd-Bontzandsteen
		Perm	Laat-Perm	Zechstein	Z3 Carbonaat
					Z2 Carbonaat
271				Boven-Rotliegend	Slochteren
290			Vroeg-Perm	Onder-Rotliegend	
			Silesian: Stephanien	Limburg	diverse zandstenen
			Westphalien		

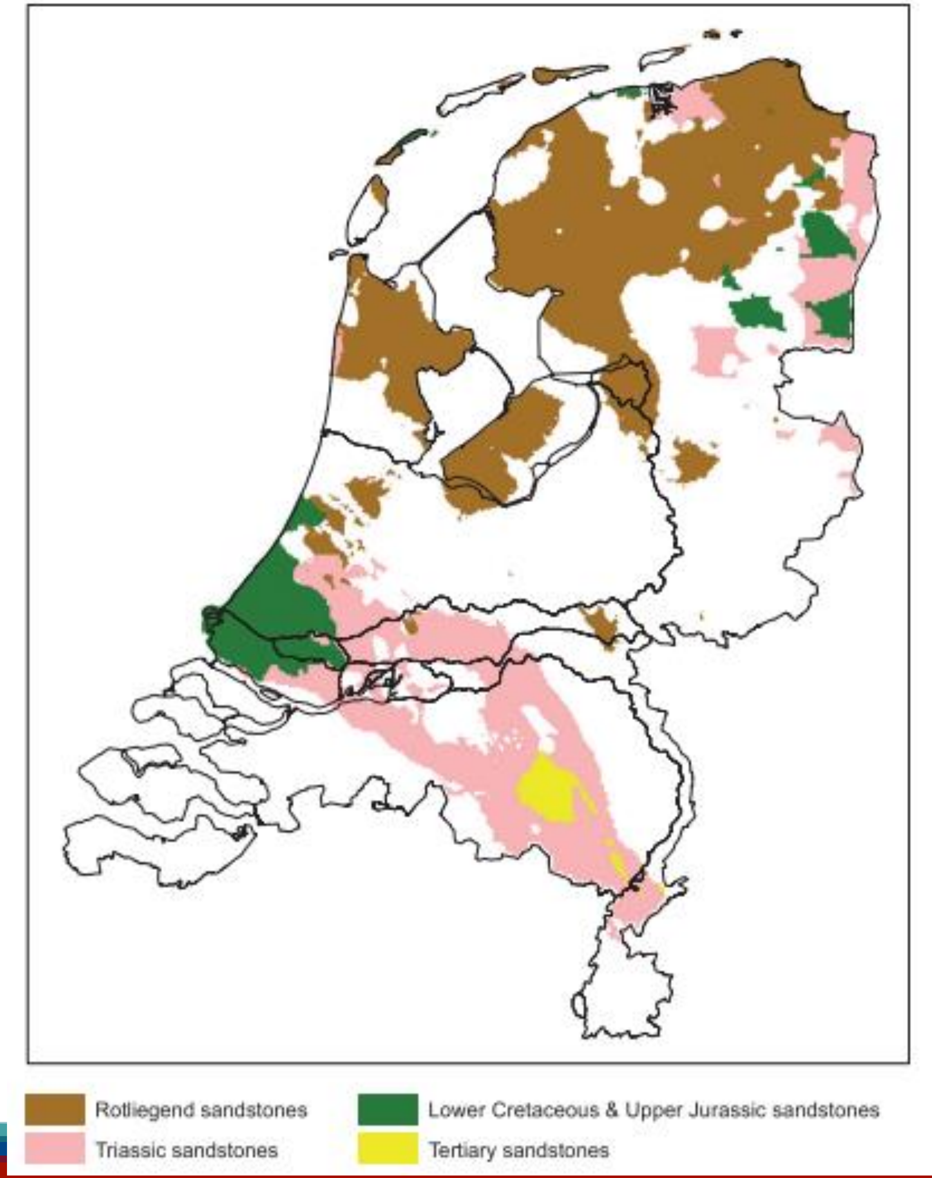


Geological cross section



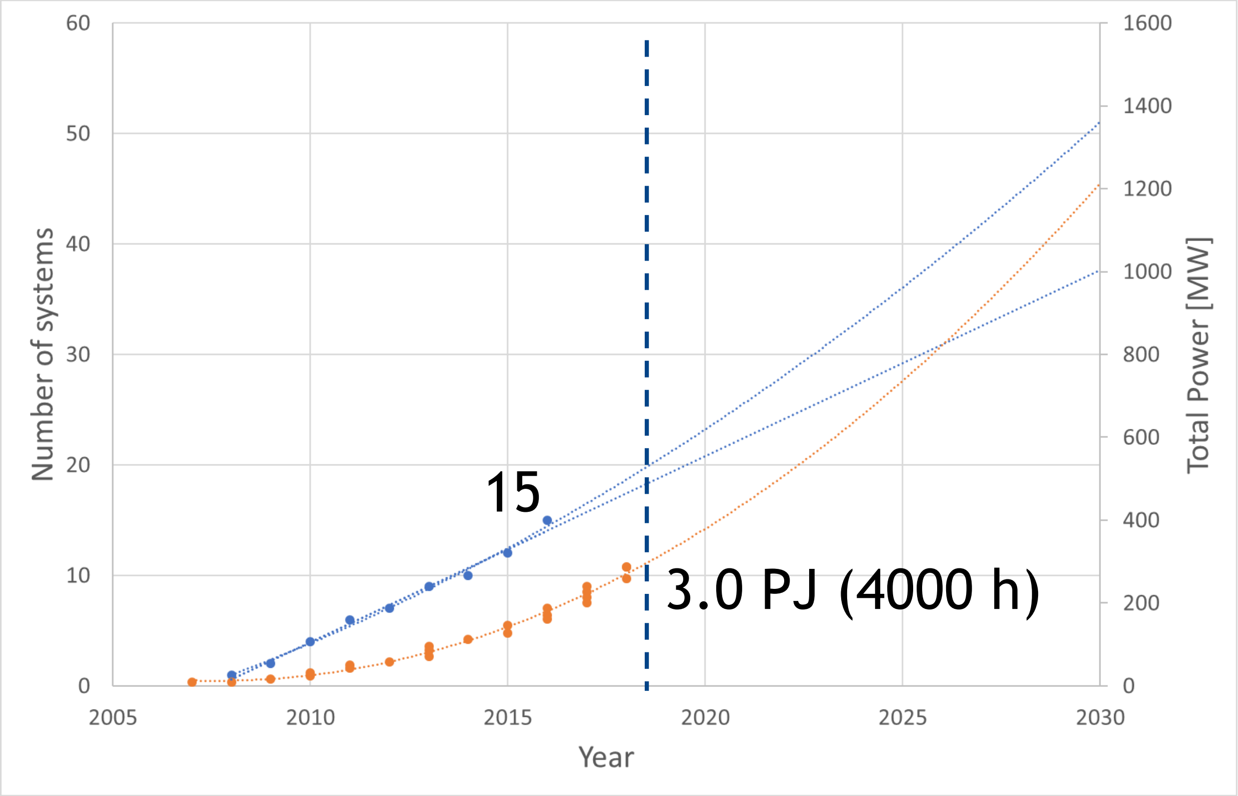
Suitable layers in the Netherlands

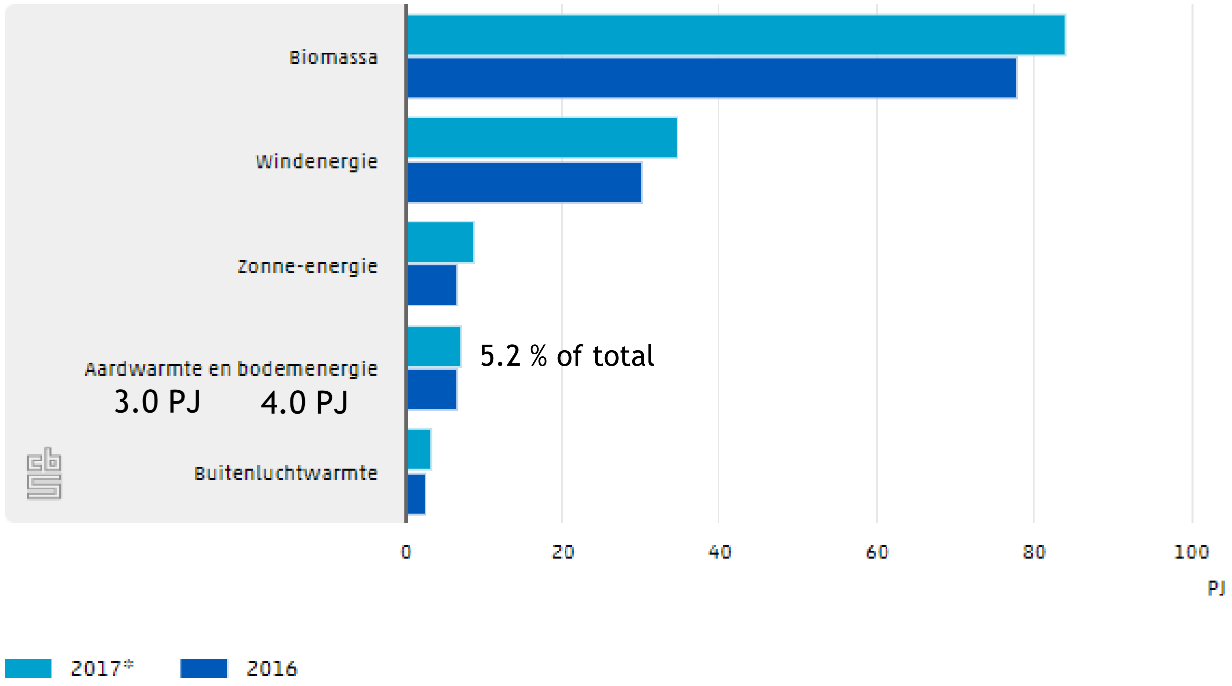
- Rotliegend sandstones (Slochteren)
- Triassic sandstones
- Lower Cretaceous and Upper Jurassic sandstones
- Tertiary sandstones



Pluymaekers et al. (2012)

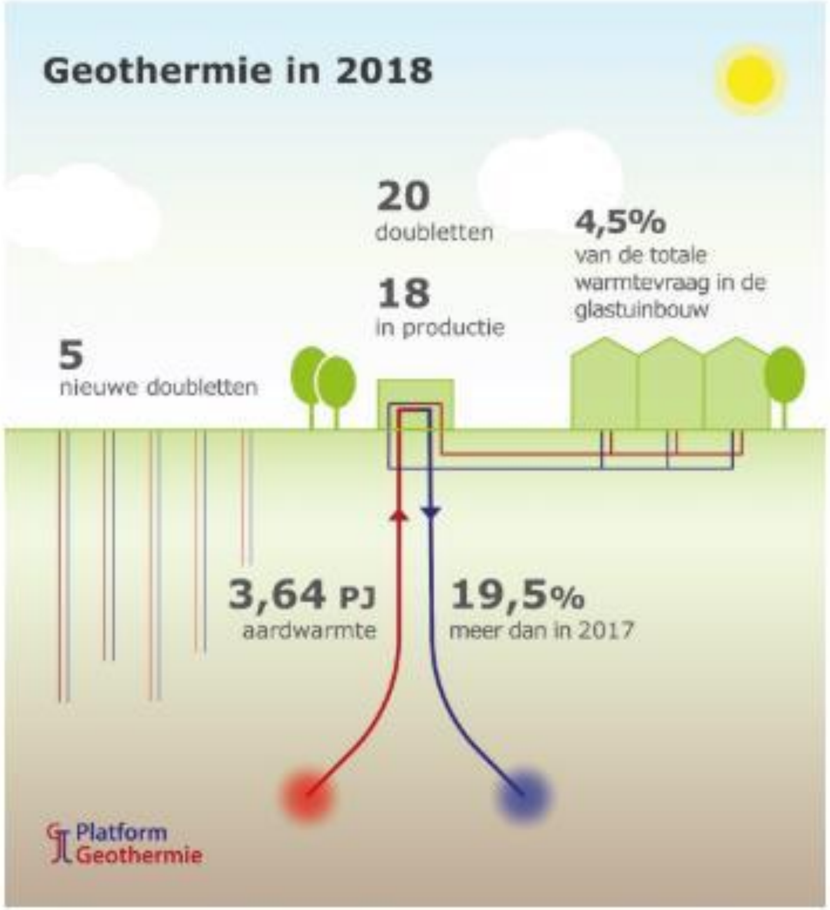
Geothermal contribution to renewable energies (2017)





Increase of geothermal systems in past 10 years

Status 2018



Huidige benutting geothermie (2018)

Van 2006 tot 2017 3.0 PJ

Drilling Rigs

Koekoekspolder

Haagse Aardwarmte Leyweg, Den Haag

Nature’s Heat, Kwintsheul

Bron afbeeldingen: website Platform Geothermie

Preparations

Koekoekspolder

Koekoekspolder

Voorbeelden winningsfase

© Guido J. Van Den Elshout

Haagse Aardwarmte Leyweg, Den Haag

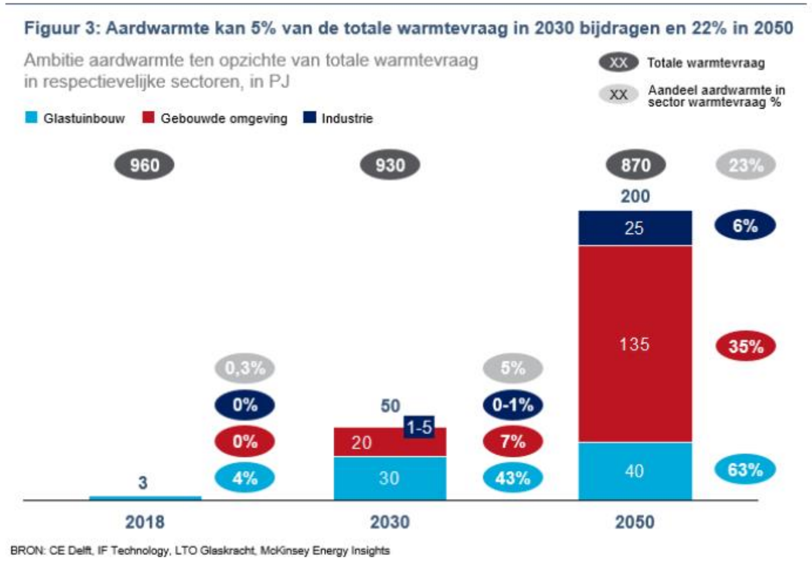
Nature’s Heat, Kwintsheul

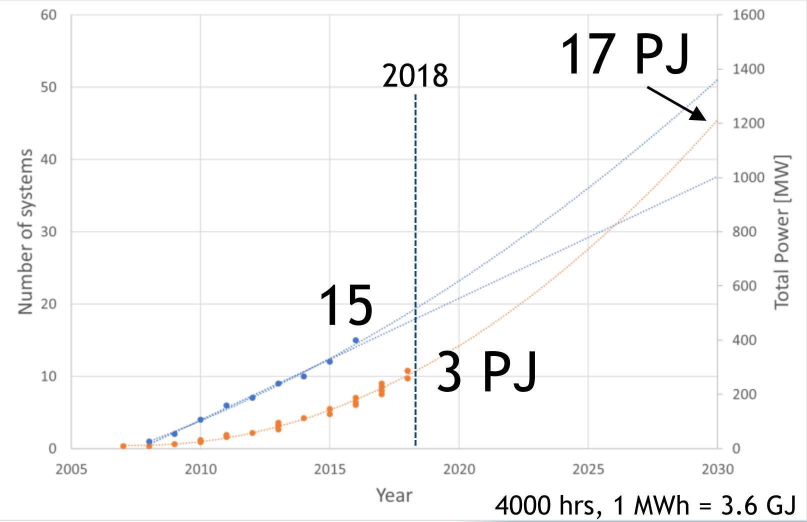
Bron afbeeldingen: website Nature’s Heat

Ambitie aardwarmte in Nederland

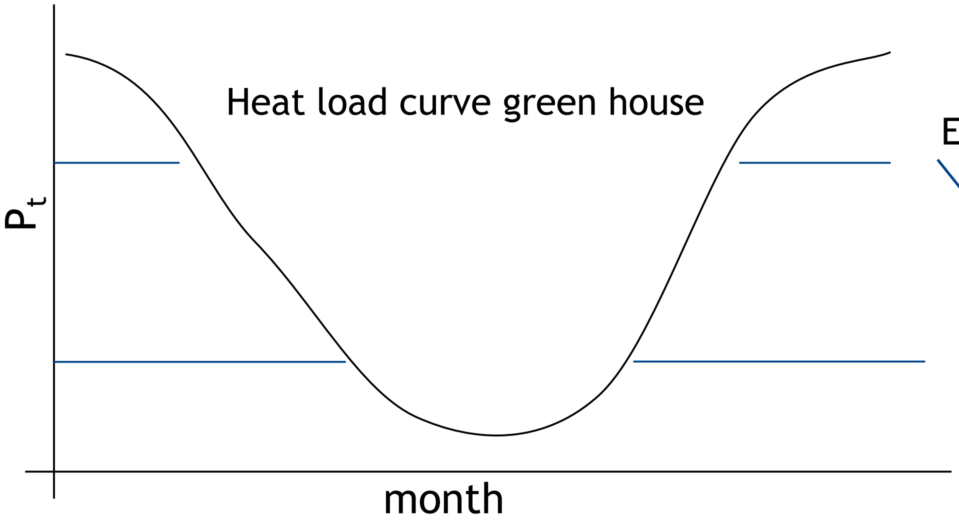
- Ambitie aardwarmte geformuleerd in rapport "Masterplan Aardwarmte in Nederland"
- Warmtevraag neemt af van 960 PJ in 2018 naar 870 Pj in 2050 (door efficientie, isolatie en verwachte afname bevolkingsgroei).
- Aandeel aardwarmte in totale warmtevraag stijgt van 0.3% in 2018 naar:
  - 5% in 2030 = ~50 PJ
  - 23% in 2050 = ~200 PJ
- Huidige trend (oranje lijn) voorspelt slechts 17 PJ in 2030 = ~2%!!
- De verwachting is dat het aantal aardwarmte systemen dat per jaar gerealiseerd wordt (~2/jaar) significant moet toenemen om ambitie te halen.
- Van 17 gerealiseerde systemen in 2018 naar ~175 systemen in 2030, en vervolgens naar ~700 in 2050 (Op basis van een gemiddeld vermogen van 0,3 PJ per jaar per doublet).

1 PJ ~ 30 miljoen m^3 gas

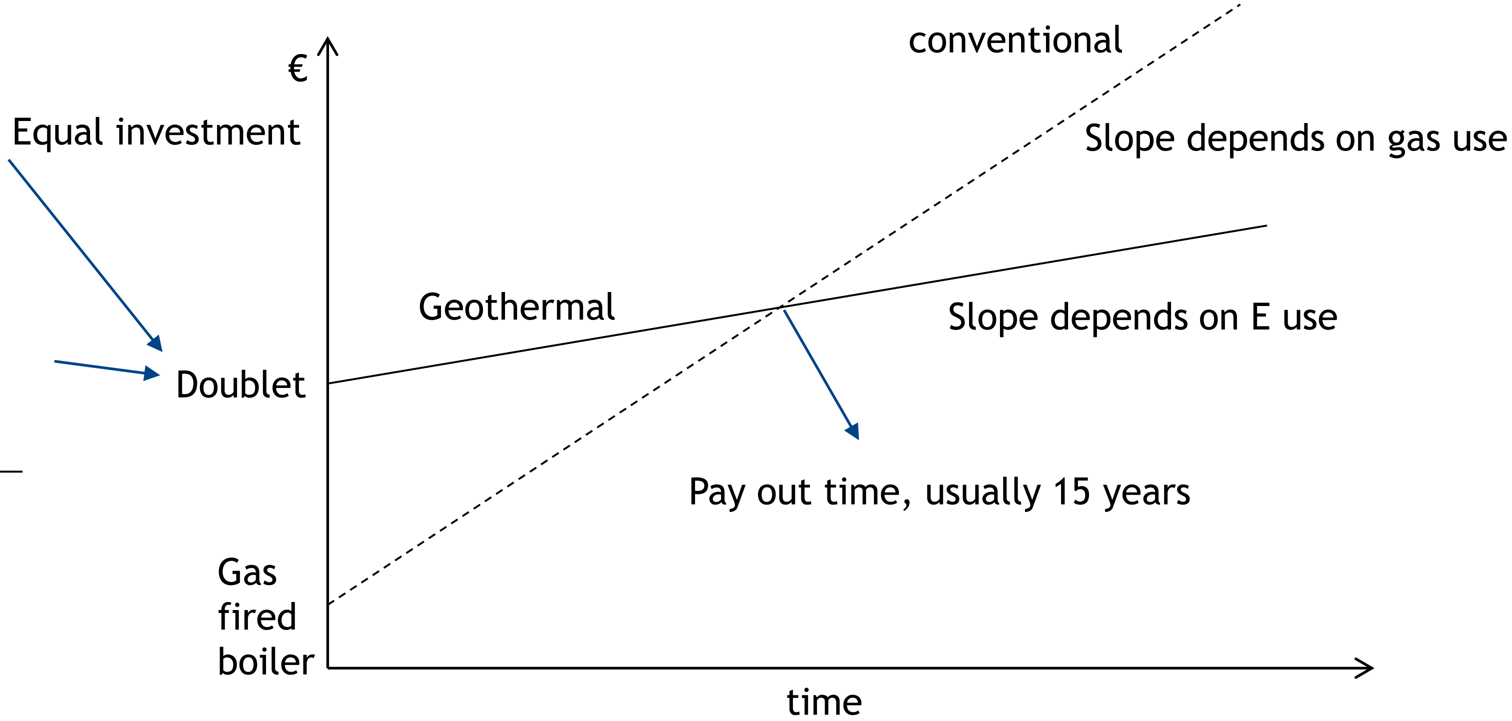




Realization in Practice



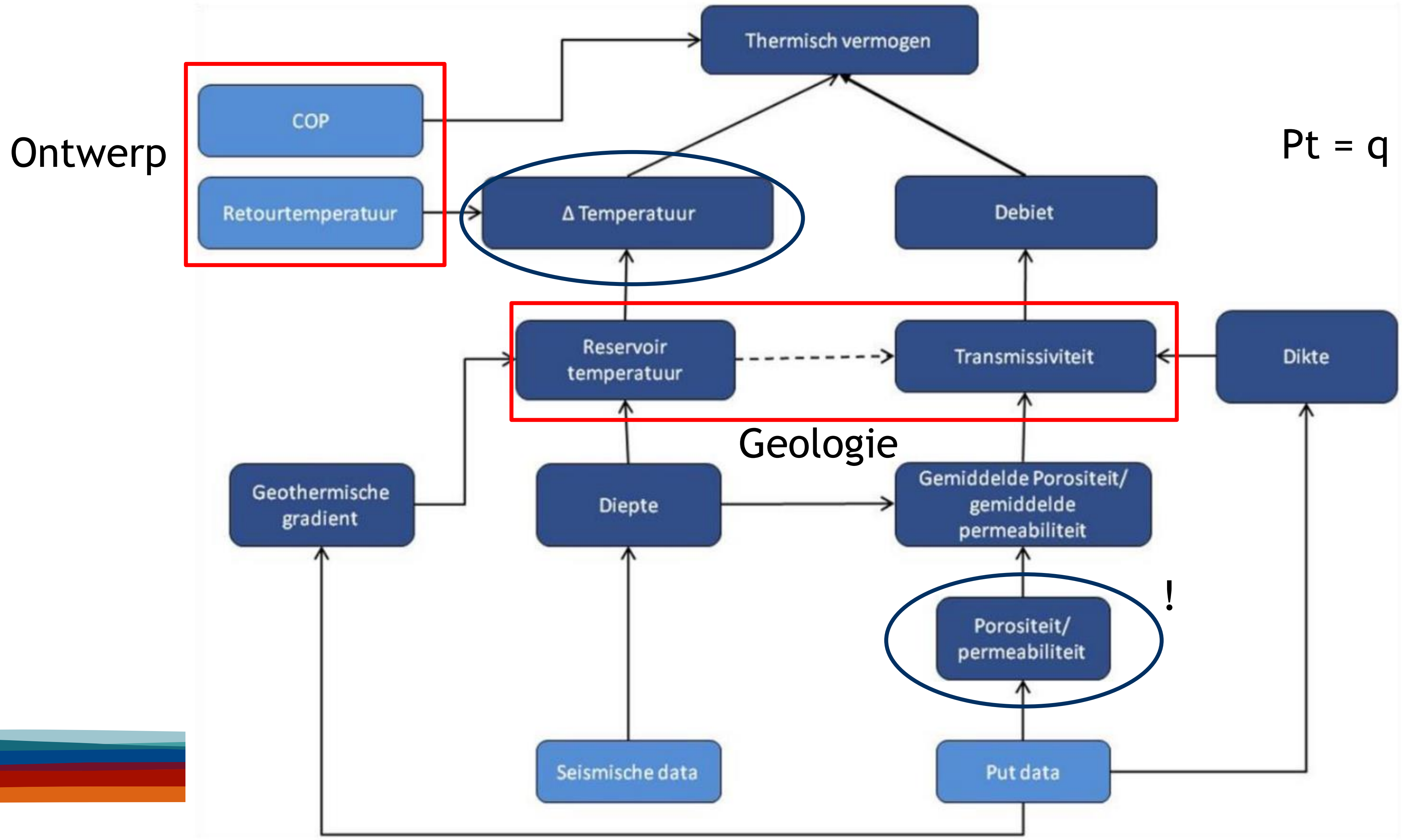
Capacity (m3/h) of a doublet defines Pt [MW]



Kentallen Geothermie

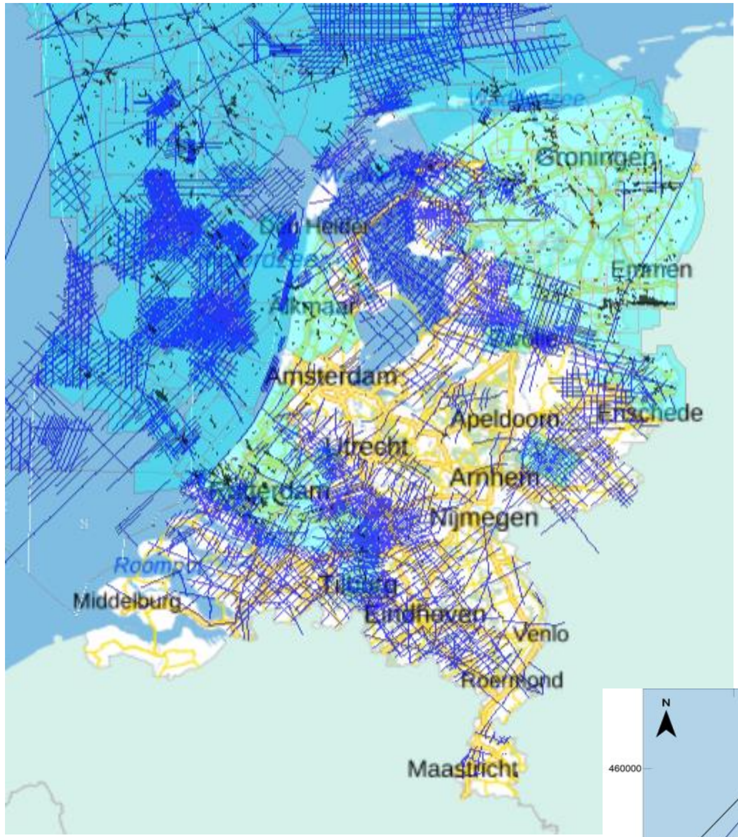
- Meeste doubletten produceren 7 tot 15 MW aan warmte (gemiddeld 10 MW)
- Temperatuur 70 tot 80 °C
- Gemiddeld systeem bespaard ongeveer 7.000.000 m^3 aardgas
- Investering 10 tot 15 Meuro (~ 1 Meuro/MW)
- > 1000 huizen

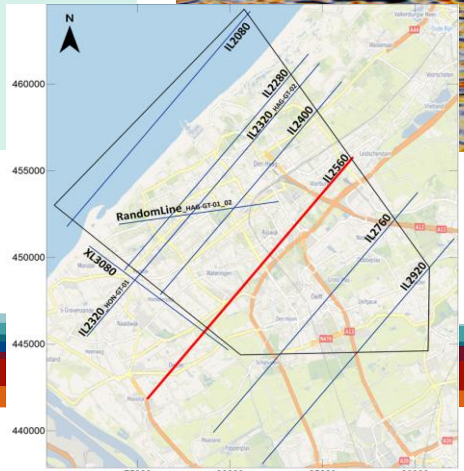
How to determine thermal Power a doublet

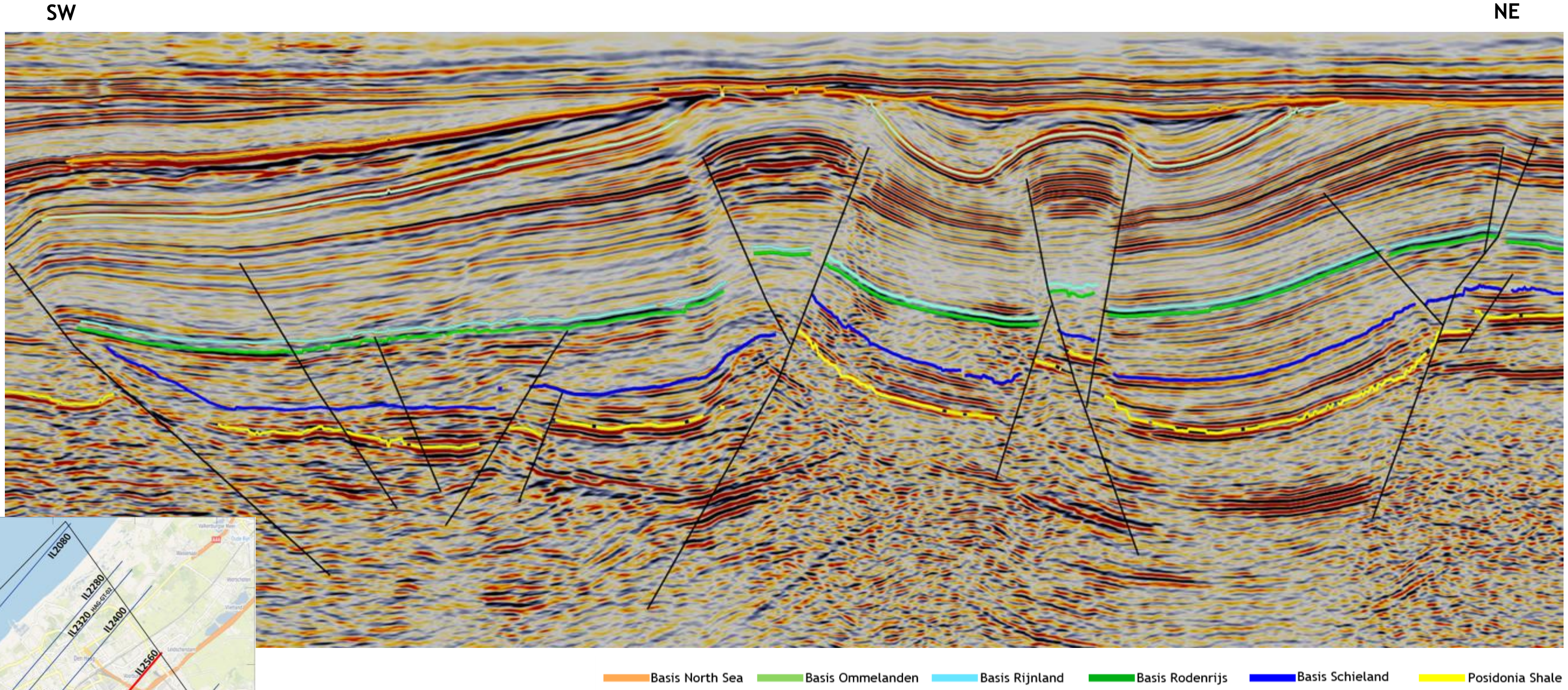


Pt = q * dT * factor

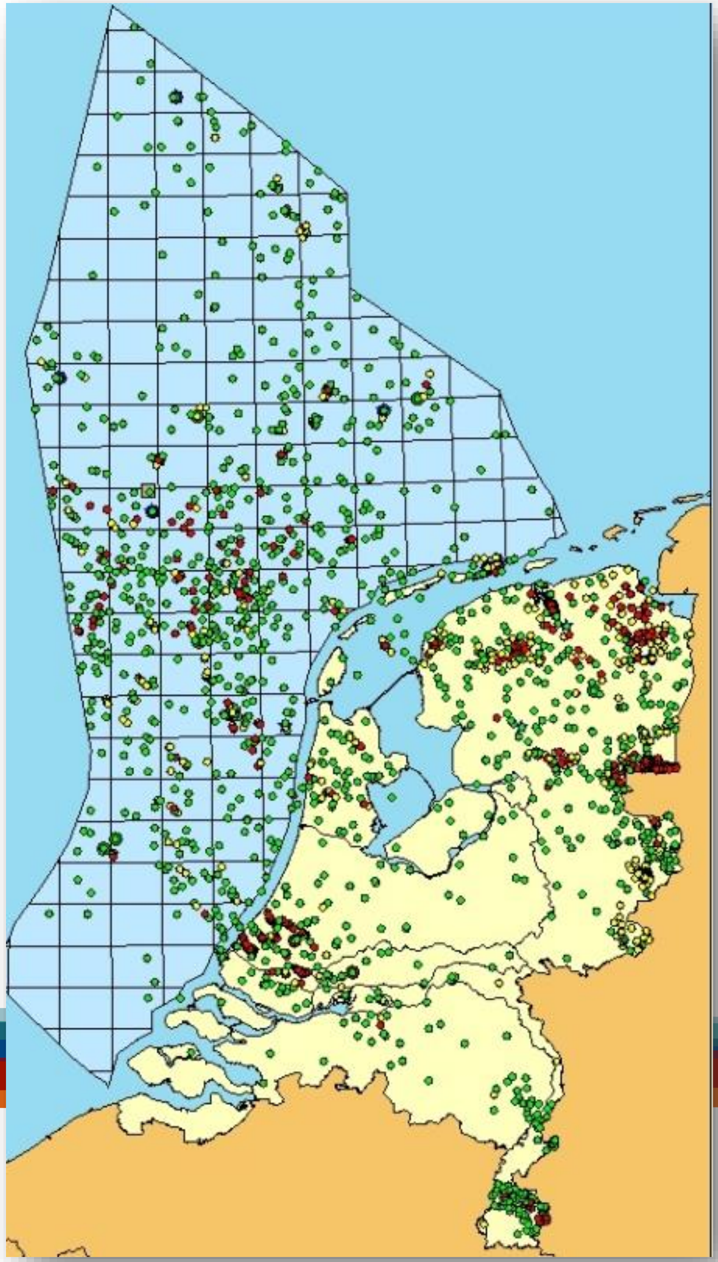
Seismic data

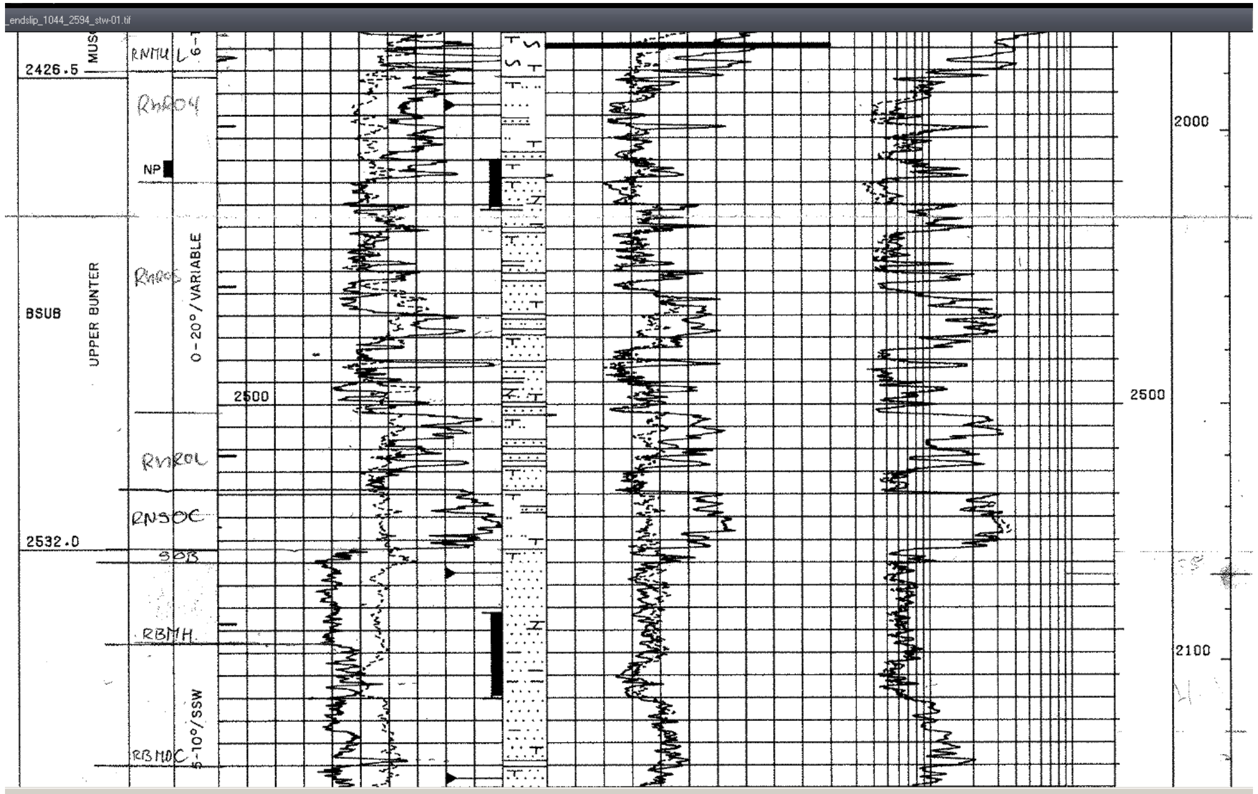






Well data (porosity logs)





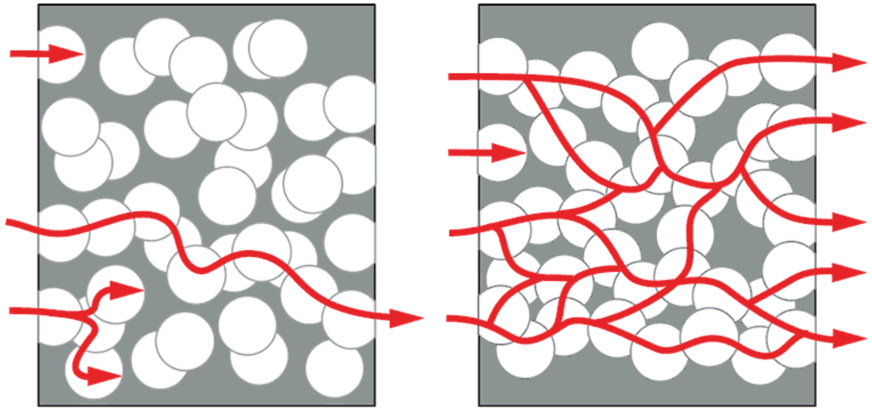
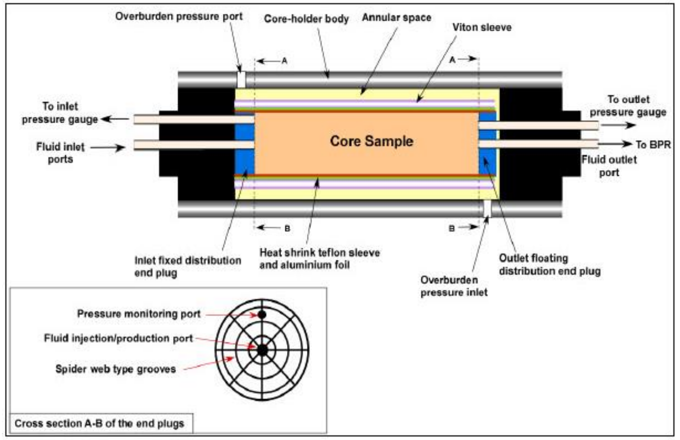


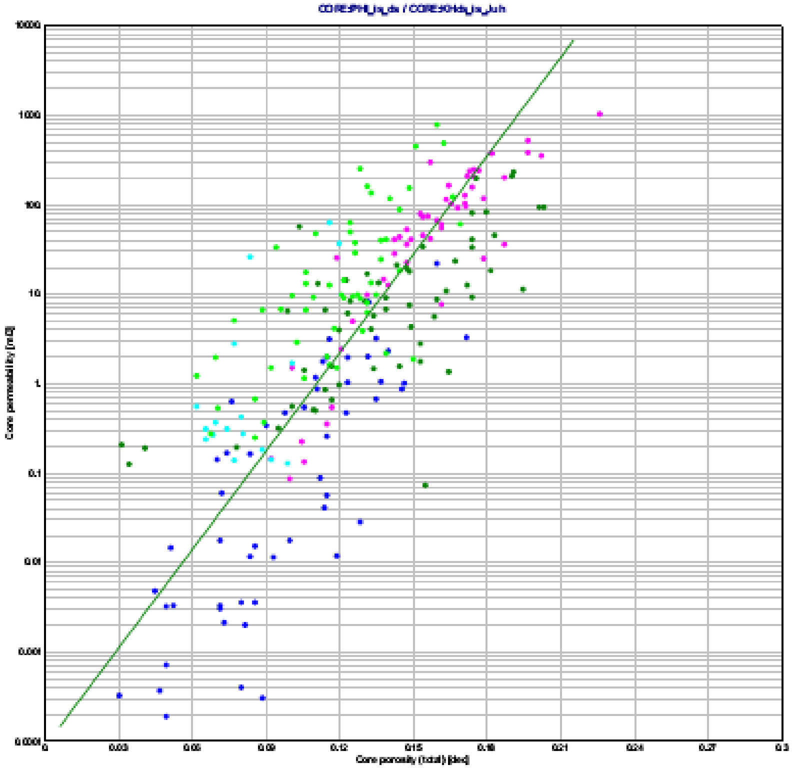
Figure 1. Good Porosity but Poor Permeability.

Figure 2. Good Porosity and Good Permeability.

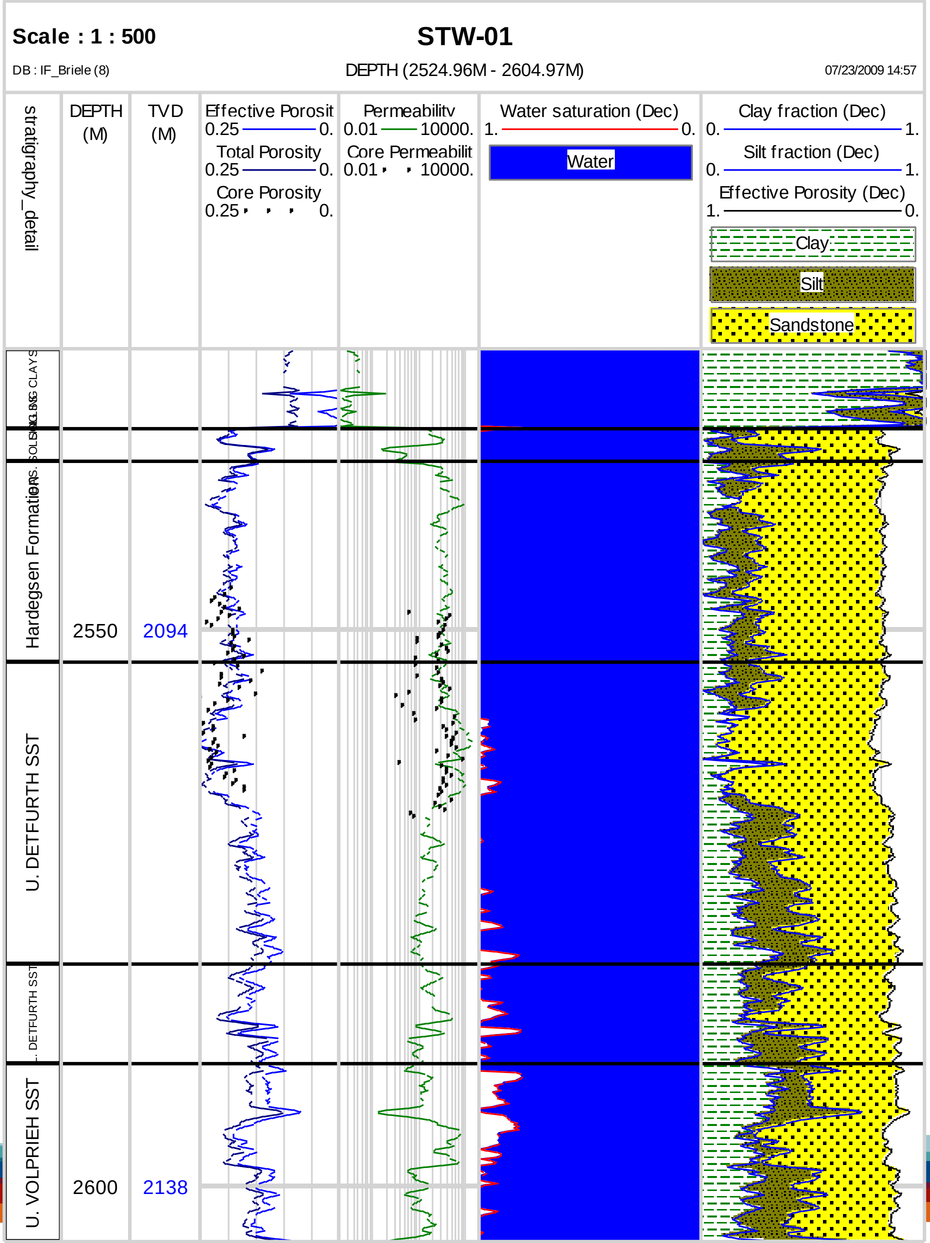
Core data



Overburden pressure port
Core-holder body
Annular space
Viton sleeve
To inlet pressure gauge
Fluid inlet ports
Core Sample
To outlet pressure gauge
To BPR
Fluid outlet port
Inlet fixed distribution end plug
Heat shrink teflon sleeve and aluminium foil
Overburden pressure inlet
Outlet floating distribution end plug
Pressure monitoring port
Fluid injection/production port
Spider web type grooves
Cross section A-B of the end plugs



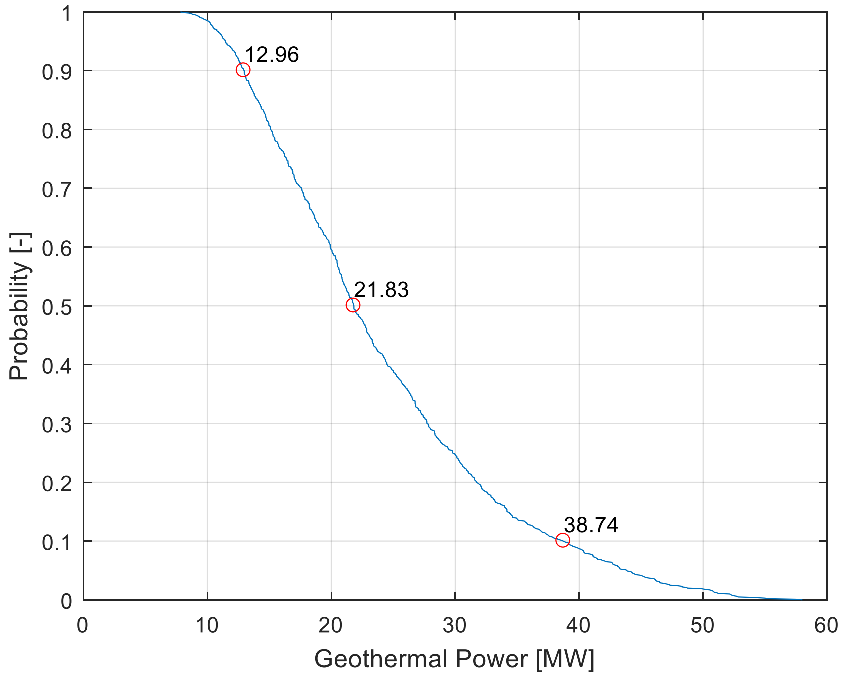
Core permeability [mD]
Core porosity (total) [dec]
10000
1000
100
10
1
0.1
0.01
0.001
0.0001
0
0.03
0.06
0.09
0.12
0.15
0.18
0.21
0.24
0.27
0.3

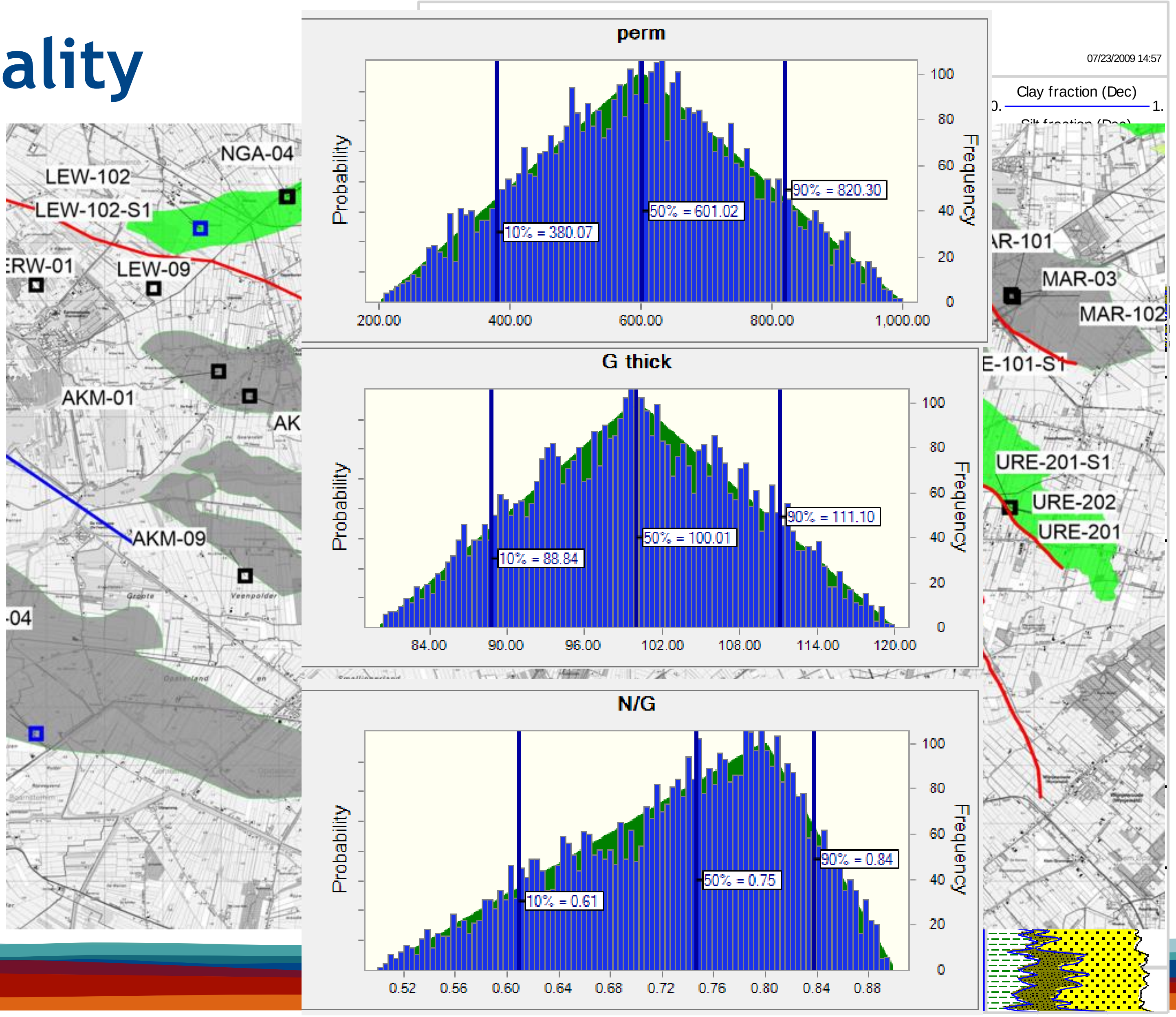


Scale : 1 : 500
STW-01
DB : IF_Briele (8)
DEPTH (2524.96M - 2604.97M)
07/23/2009 14:57
stratigraphy_detail
DEPTH (M)
TVD (M)
Effective Porosit 0.25 0.
Total Porosity 0.25 0.
Core Porosity 0.25 0.
Permeability 0.01 10000.
Core Permeabilit 0.01 10000.
Water saturation (Dec) 1. 0.
Water
Clay fraction (Dec) 0. 1.
Silt fraction (Dec) 0. 1.
Effective Porosity (Dec) 1. 0.
Clay
Silt
Sandstone
Hardegsen Formation
U. DETFURTH SST
U. VOLPRIEH SST
2550
2094
2600
2138

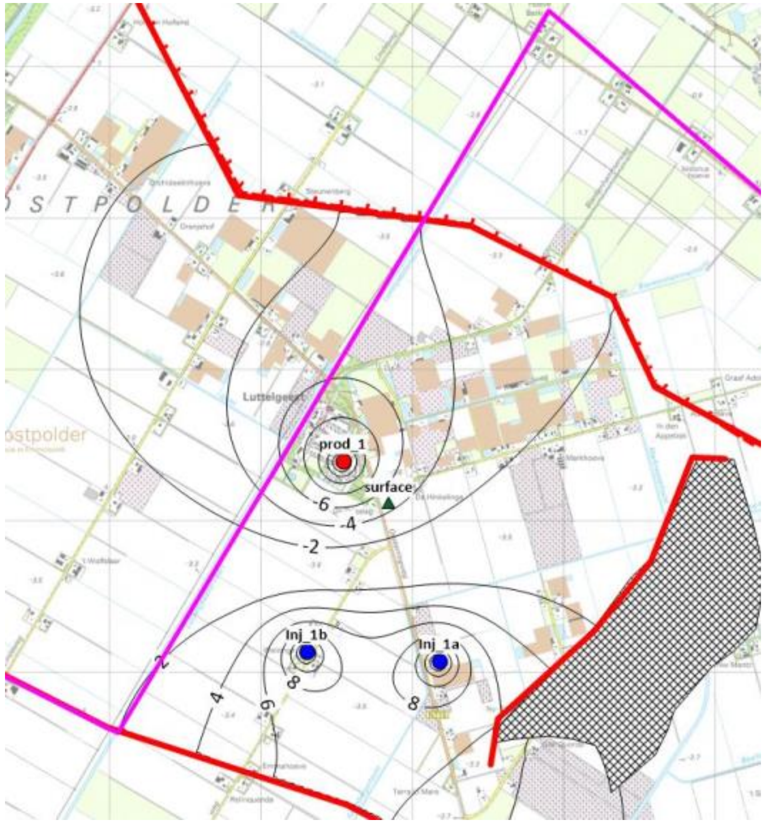
Uncertainties reservoir quality

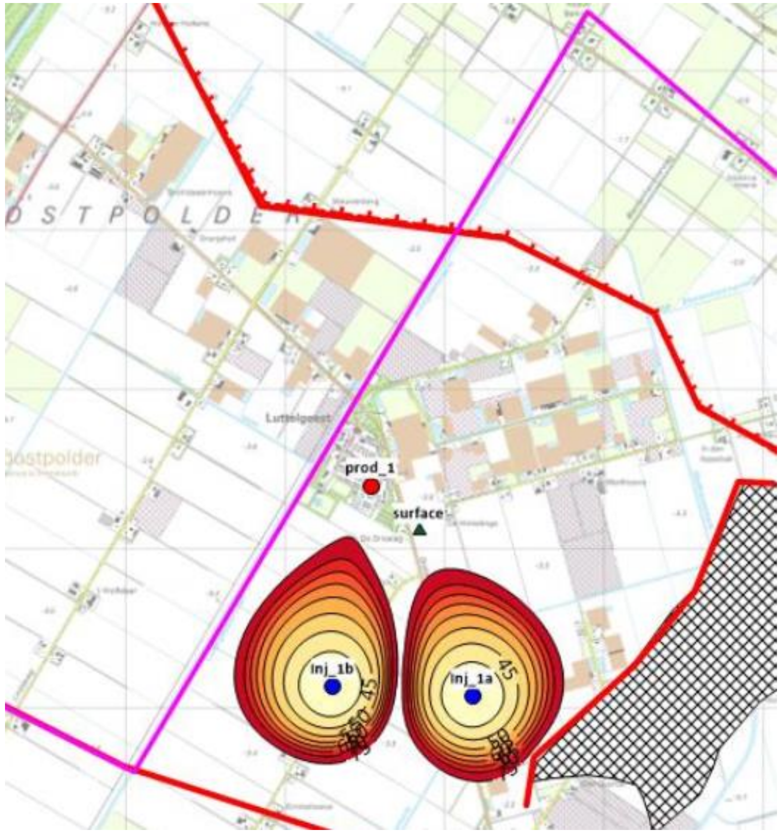
- Core data best part of reservoir (data is biased)
- Core data must be upscaled
- Translation from porosity to permeability
- Translation to project location
- Core data from oil and gas wells

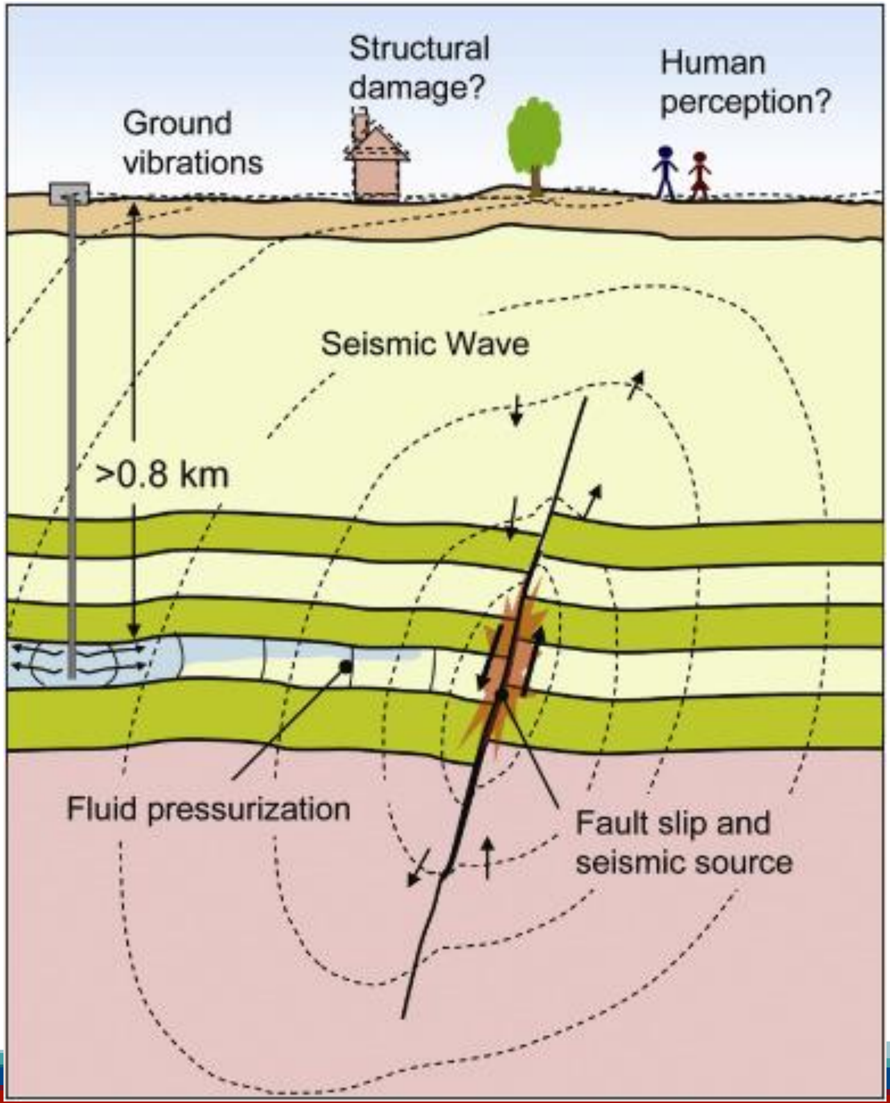




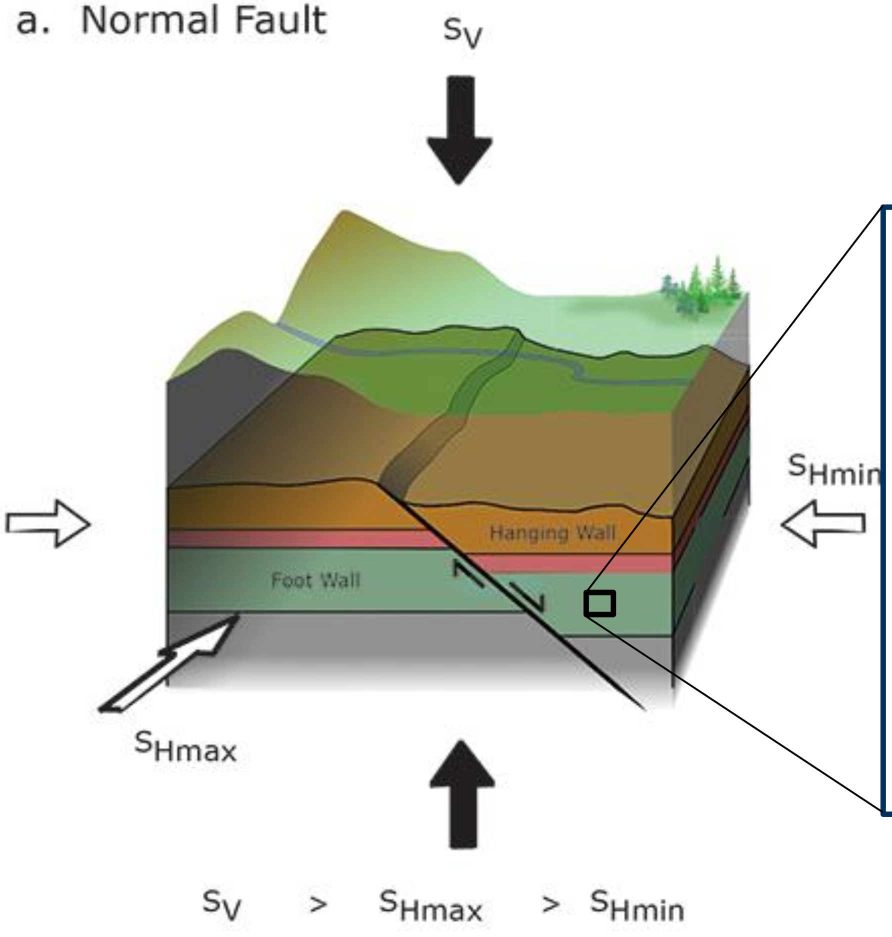
Induced Seismicity

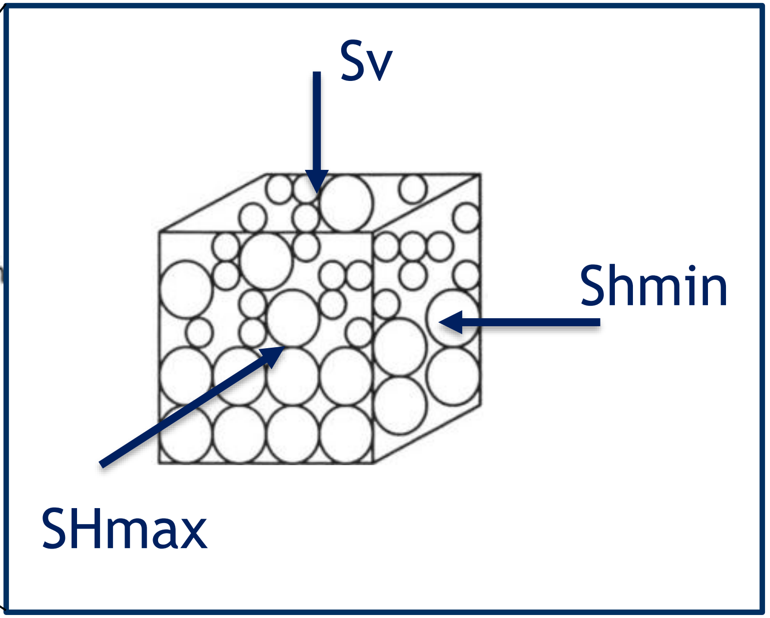


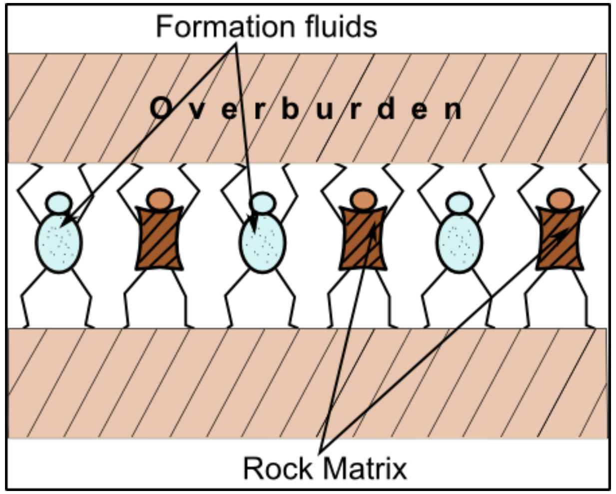




Normal stress and shear stress

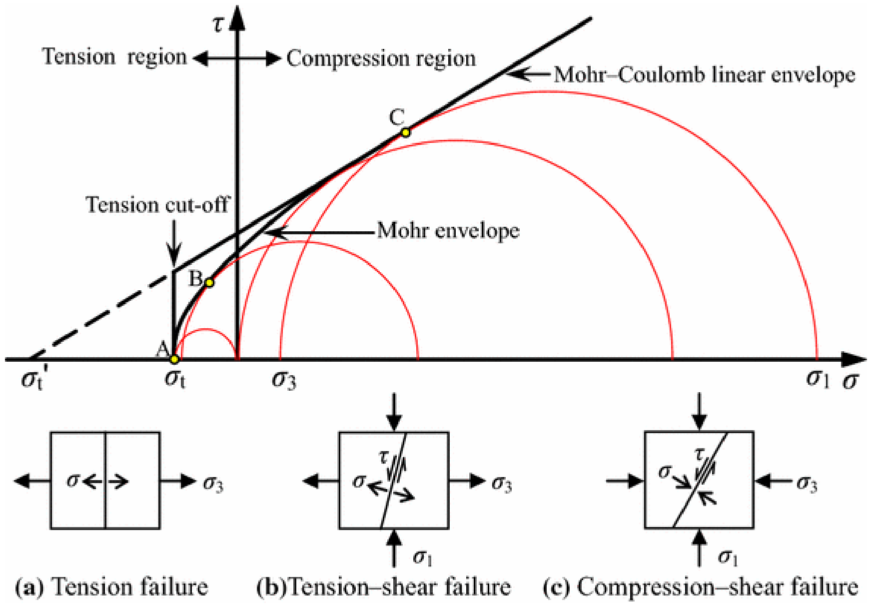


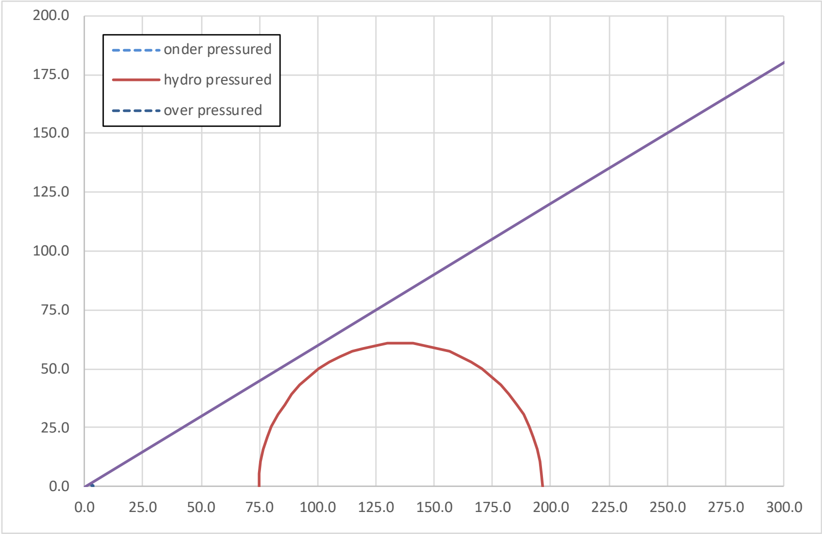


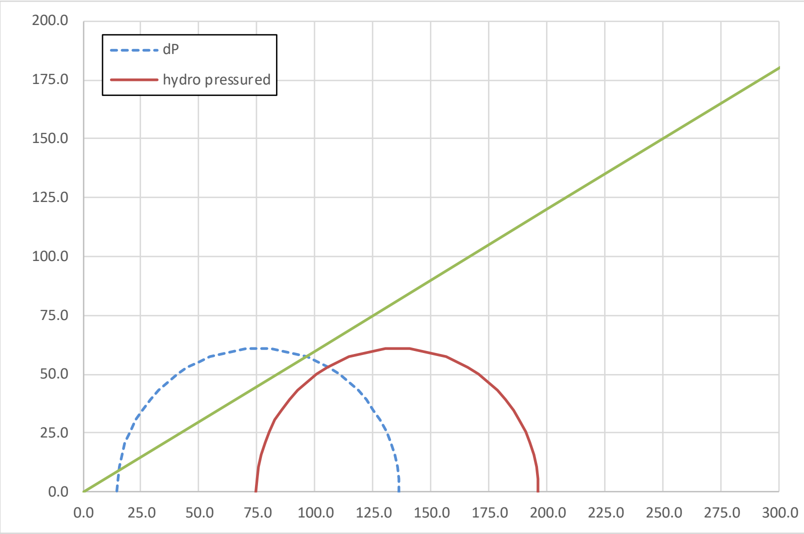


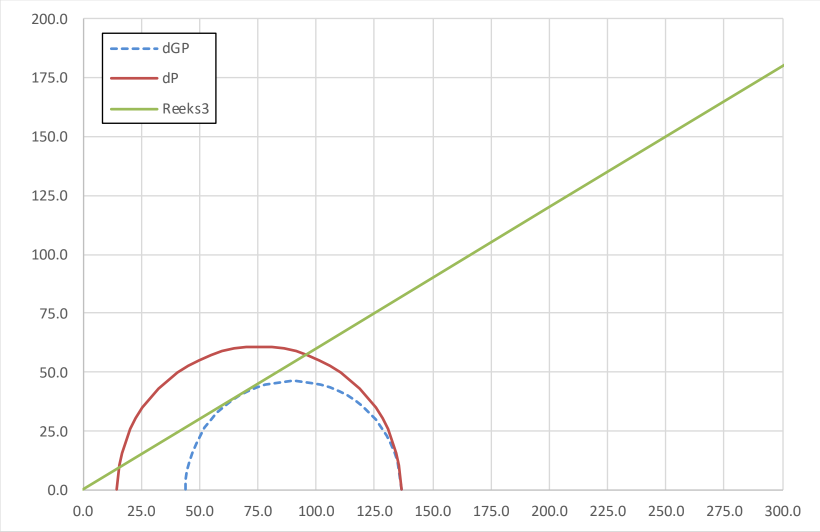
Netto Stress = Stress – Pore pressure
S1 > S2 > S3
Sv > SHmax > Shmin

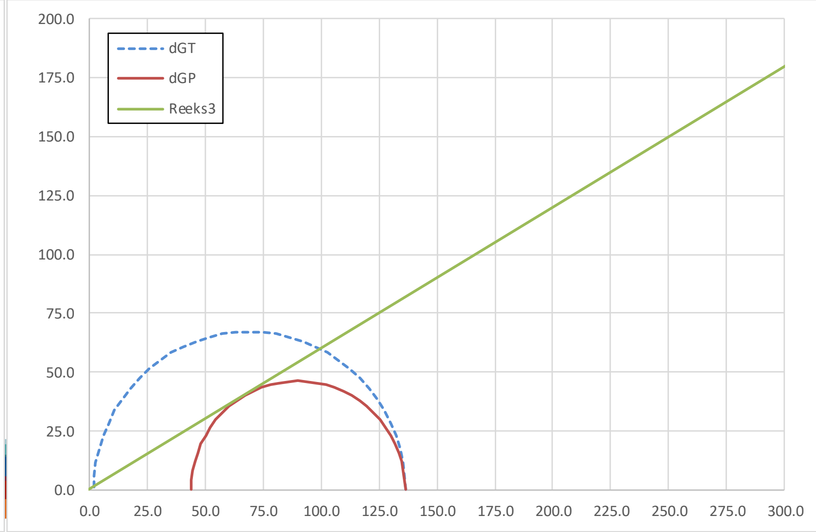
Principle of inducing seismicity



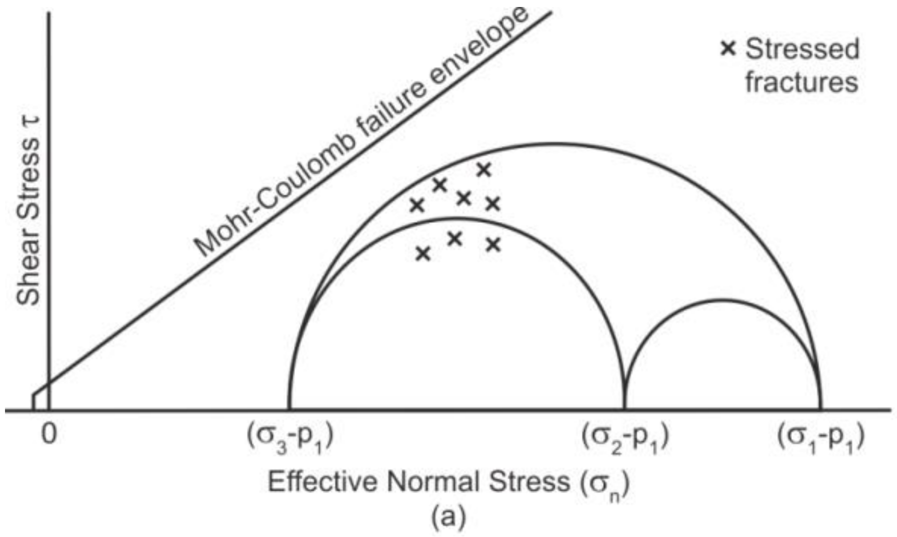


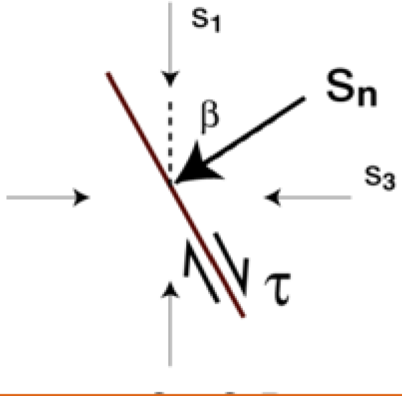






Stress on a Fault plane





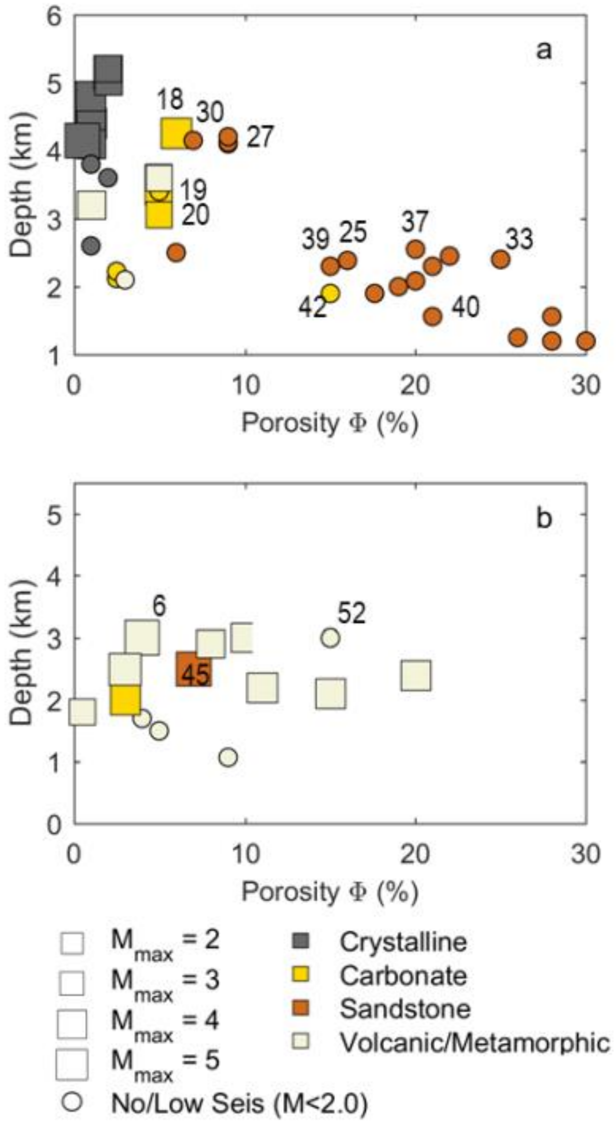


Figure 3 Depth and average matrix porosity of geothermal systems and the occurrence of seismicity. a) hot sedimentary aquifer and EGS, b) geothermal fields. Numbers indicate cases, see Table 1.

IF Technology **Creating energy**