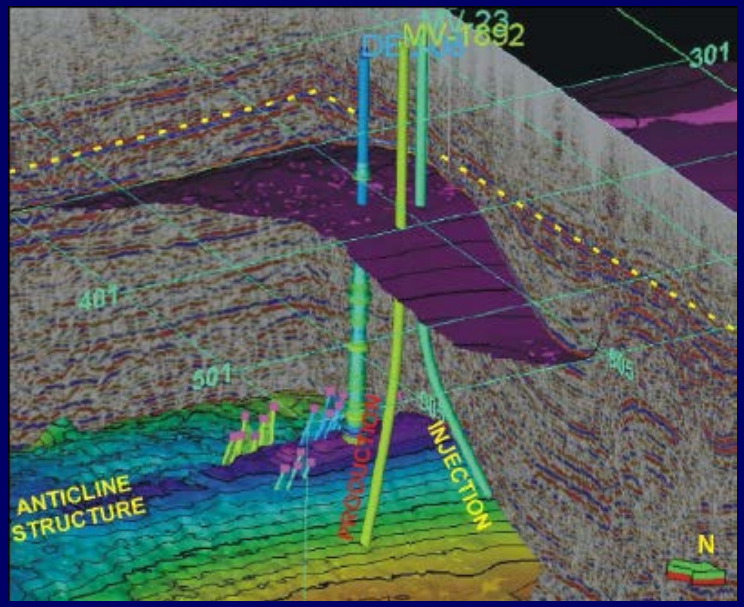
Bachelor Project

The layers and there properties inside the Delft sandstone formation

By

Jeroen van Eldert



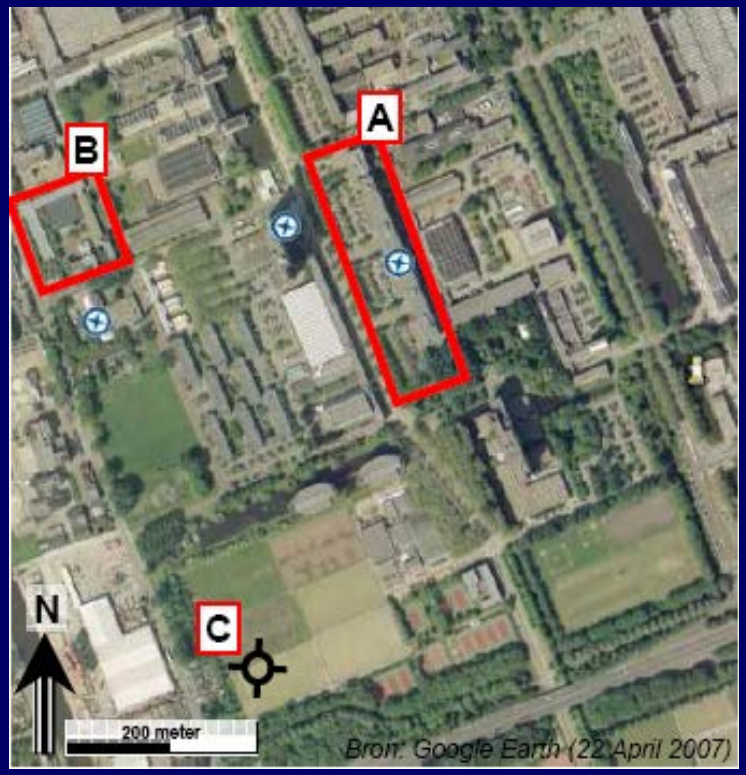
DAP

TU Delft

Delft University of Technology

Introduction

- The Delft Aardwarmte Project (Delft Geothermic Project)
  - History
  - Planning
  - location
- Objective: Extracting Heat form an underground water reservoir

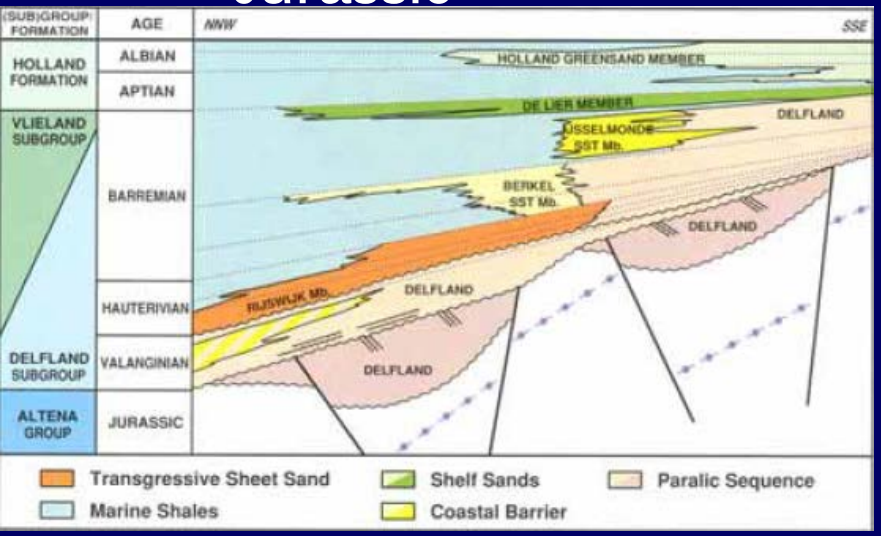


DAP

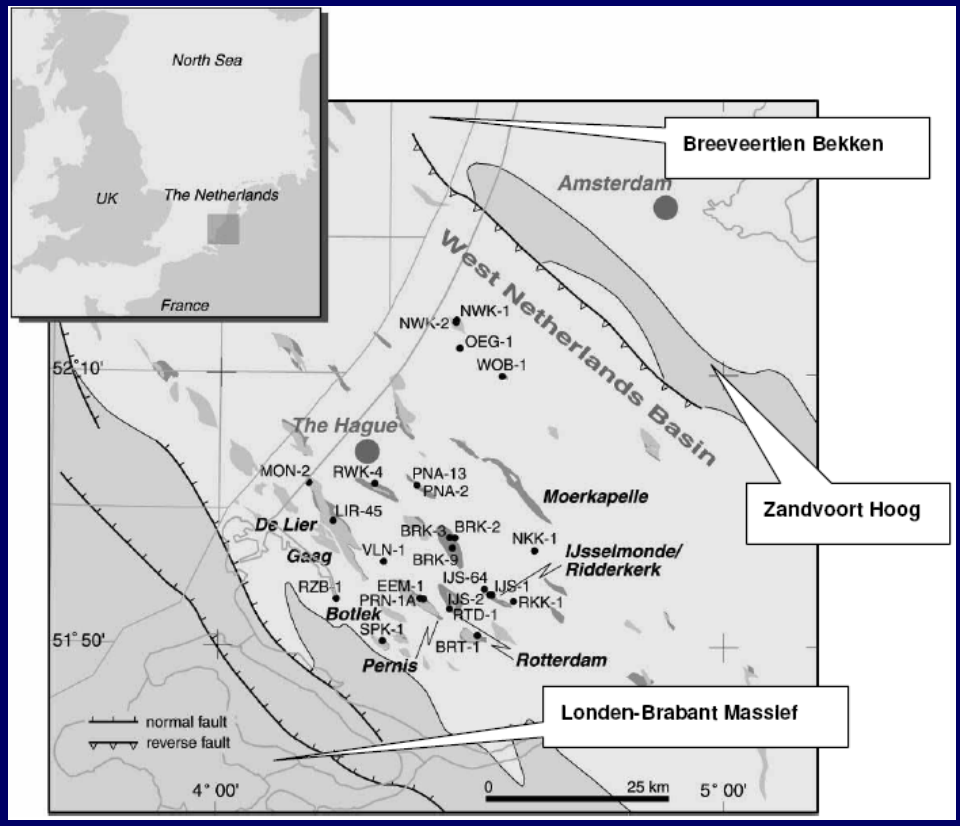
TU Delft

Geology

- Braided river system
- Deposit in the Late Jurassic



Racero-Baenr & Drake, 1996



Source: TNO report, 2007-U-R1118/B

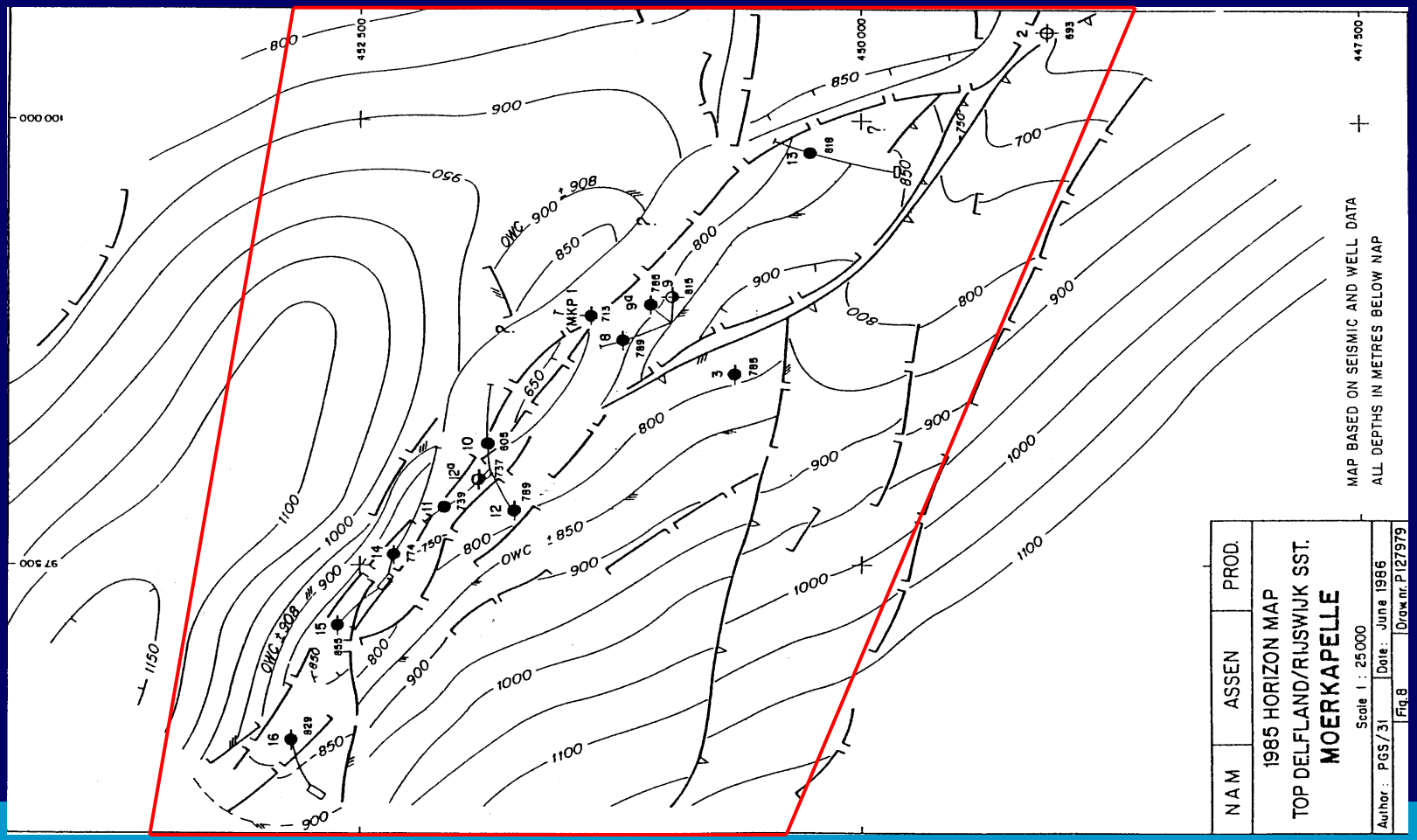
TU Delft

Data Source

- No data, concerning the Delft sandstone available in the Delft area
- Well data from the Moerkapelle Field
  - NAM
  - www.nlog.nl
- Extrapolation of the MKP to the Delft area

Moerkapelle Field

- MKP Well locations



Data (1)

- Logs, taken a MD
- Thickness of the layers (“ put info.xls”)
  - TVD

Well number	MKP 16	MKP 15	MKP 14	MKP 13	MKP 12A	MKP 12	MKP 11	MKP 10	MKP 9A
Top Delft sandstone (m below NAP)	-976	-	-774	-863	-778	-857	-761	-628	-805
Bottom Delft sandstone (m below NAP)	-1097	-	-796	-909	-828	-958	-800	-678	-845

Data (2)

Well	Gamma-Ray [API units]	Bulk Density [g/cc]	Neutron Porosity	Resistivity (total) [Ωm]	Hydrocarbon content (NAM)
MKP 16	V	V	V	V	V
MKP 15	V	V	V	V	V
MKP 14	V	V	V	V	V
MKP 13	V	V	V	V	V
MKP 12A	V	V	V	V	V
MKP 12	V	V	V	V	V
MKP 11	V	V	V	V	V
MKP 10	V	V	V	V	V
MKP 9A	V	V	X	V	X

DAP

TU Delft

Gamma-Ray (1)

- Calculation of the Vshale from the Gamma-Ray log
- Formula:

$$Vshale = (GRmeasured - GRmin) / (GRmax - GRmin)$$

V_{shale}: Shale content
$GR_{measured}$: The GR (in API units) measured
GR_{min}: The minimum GR value (API units)
GR_{max}: The maximum GR value (API units)

Gamma-Ray (2)

well	MKP 16	MKP 15	MKP 14	MKP 13	MKP 12A	MKP 12	MKP 11	MKP 10	MKP 9A
Total max	158,49	145,85	173,25	269,81	199,24	134,13	134,13	158,21	297,25
Total min	14,28	16,47	15,04	9,54	13,94	14,3	17,3	17,94	10,77
Max in clay/shale	122,26	-	129,88	182,05	155,09	134,13	132,26	110,09	173,22

Porosity

- Neutron porosity from the log data
- Neutron porosity to effective porosity
- Formula:

$$\Phi_{effective} = \Phi_{neuton} - V_{shale} * \Phi_{shale}$$

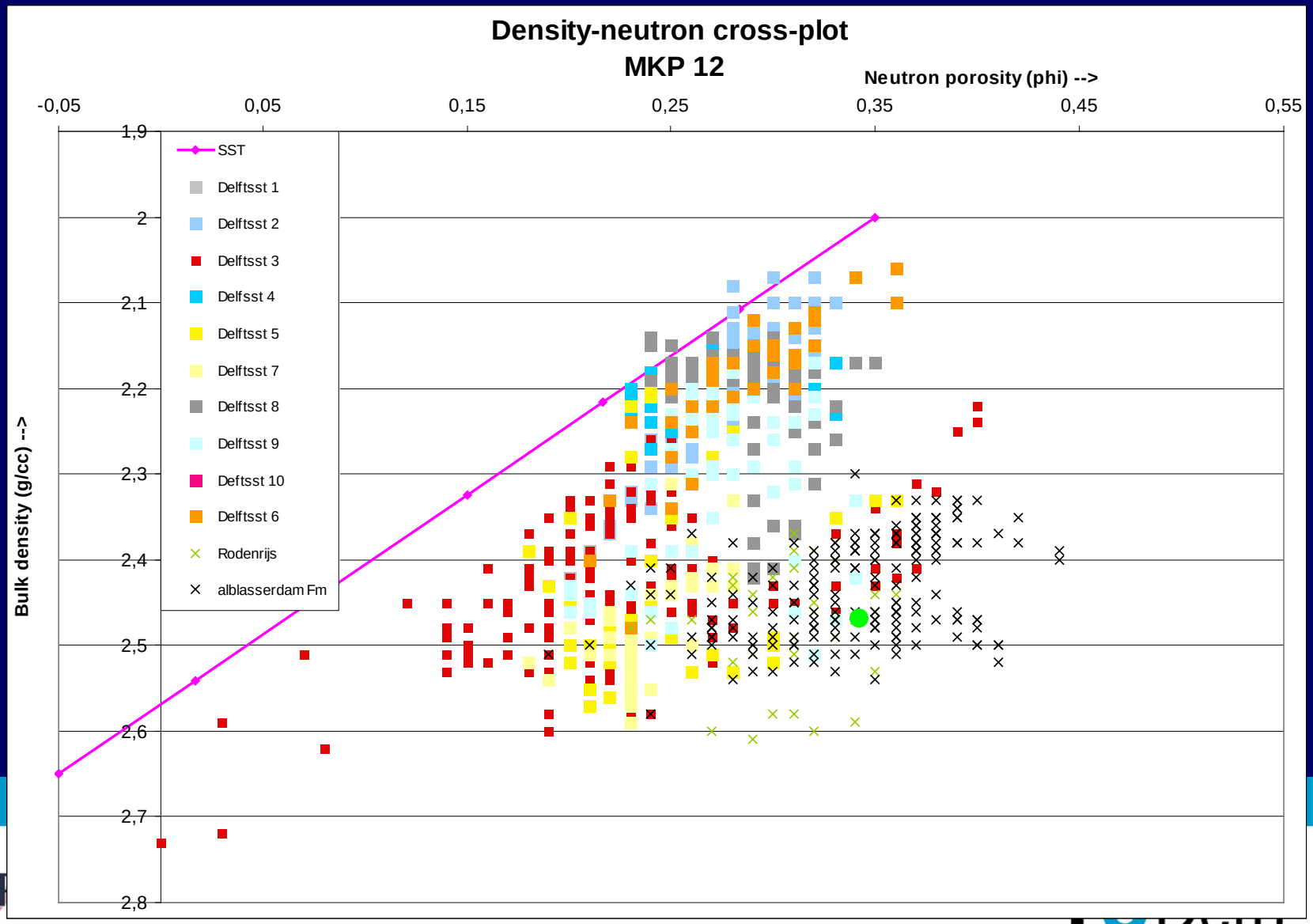
$\Phi_{effective}$: Effective porosity
Φ_{neuton}: Neutron porosity
V_{shale}: Shale content
Φ_{shale}: Shale porosity

FDC-CNL plots (1)

- Neutron porosity and Bulk density from the logs
- Plotting both parameters (FDC-CNL plot)
- Plotting clean sandstone line
- Determine shale point

Well number	Shale porosity
MKP 16	0,25
MKP 14	0,32
MKP 13	0,30
MKP 12A	0,24
MKP 12	0,32
MKP 11	0,43
MKP 10	0,32

FDC-CNL Plots (2)



Water Resitivity (1)

- De Lier and The Hague lower cretaceous
  - Estimation of the range (0.04 Ωm)
- Corrected Archie
  - Corrected for the shale content
  - 100 % water saturation
  - Indication of the value
- Log(Rt)-$\Phi_{Neutron}$ Plot
  - Determination of the Rw from that plot

Water resistivity (2)

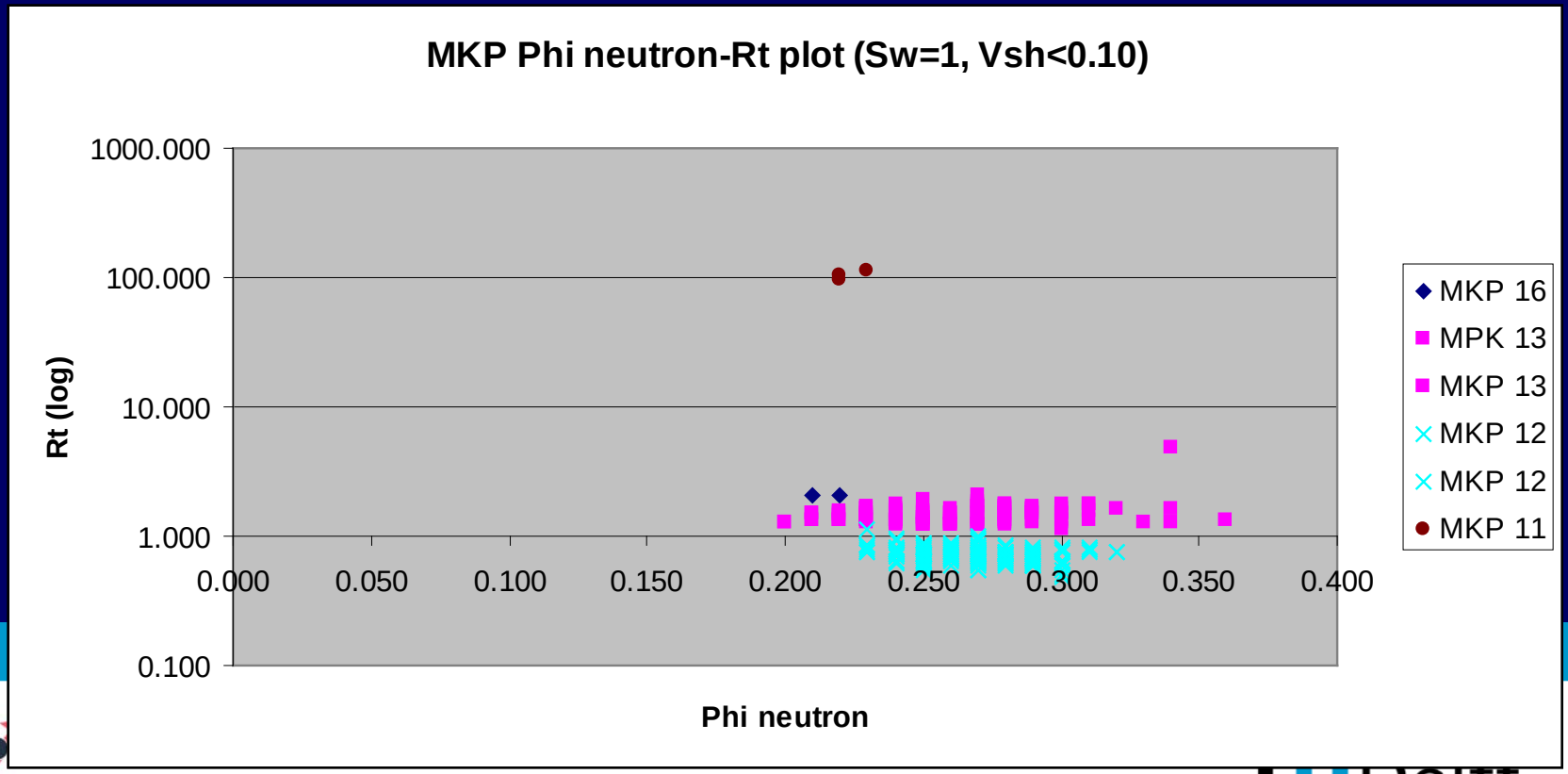
- Corrected Archie

Rw= (Rt-Vshale*Rshale)*Φeff.m

Rw:	Water resistivity (Ωm)
Rt:	Measured resistivity (Ωm)
Vshale:	Shale content
Rshale:	Shale resistivity, 100% shale (Ωm)
Φeff.:	Effective porosity
m:	Formation cementation factor (1.8)

Water Resistivity (3)

- Value draw from plot
  - Rw: 0.137 Ωm



Water Saturation (1)

- Indonesia Formula:

$$Ct^{0.5}=\Phi eff^{(m/2)}*Sw^{(n/2)}*Cw^{0.5}+Vshale^{(1-Vshale/2)}*Sw^{(n/2)}*Cshale^{0.5}$$

Ct:	Measured conductivity (Ωm^{-1}) (1/Rt)
Φeff.:	Effective porosity
Sw:	Water saturation
Cw:	Water conductivity (Ωm^{-1}) (1/Rw)
Vshale:	Shale content
Cshale:	Shale conductivity (Ωm^{-1}) (1/Rshale)
m:	Cementation factor (1.8)
n:	Saturation exponent (2)

Water Saturation (2)

- Rewriting the Indonesia formula

$$S_w = \left(\frac{C_t^{0.5}}{\phi_{eff}^{m/2} * C_w^{0.5} + V_{shale}^{(1-V_{shale}/2)} * C_{shale}^{0.5}} \right)^{2/n}$$

- Sw with the Sw measured by NAM

Well	Sw	Sw NAM
MKP 16	0.621	0.855
MKP 14	0.390	0.383
MKP 13	0.817	0.961
MKP 12A	0.331	0.277
MKP 12	0.771	0.984
MKP 11	0.361	0.523
MKP 10	0.096	0.434

Layers in the Delft sandstone (1)

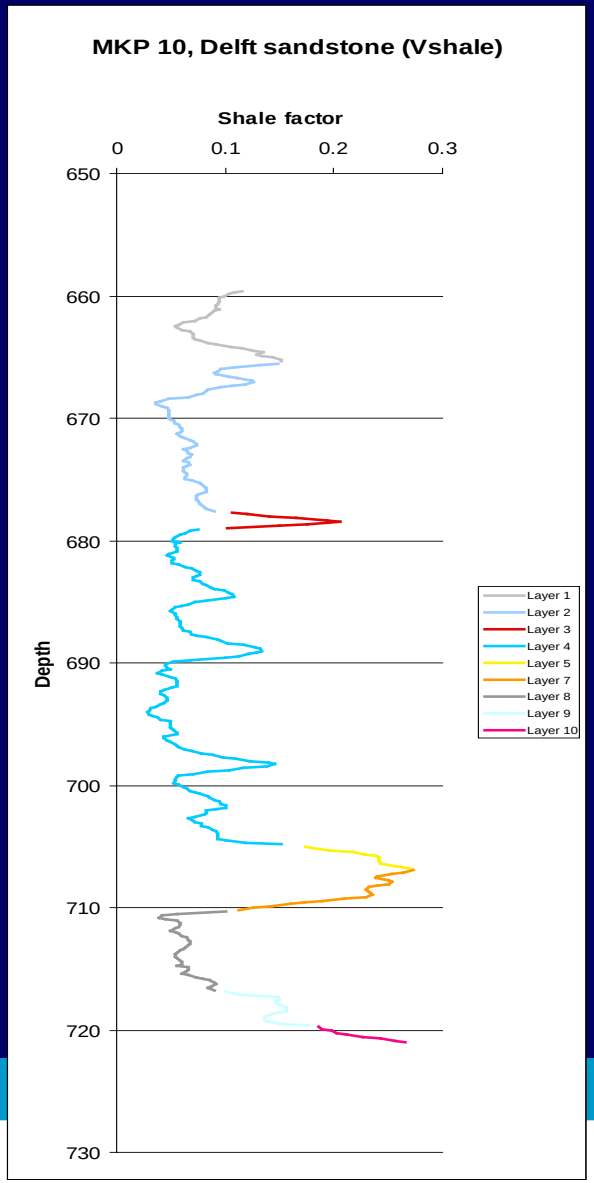
- Different layers in the formation, 10 layers
- Differences in the Gamma-Ray log
- Checked with Neutron log

Layer #	color		Definition (by shale content)
1		gray -25%	top of Delft sandstone
2		pale bleu	first measurement of <0,15 after measurement with a value >0,15
3		red	>0,10
4		sky bleu	<0,10
5		yellow	>0,156 if progress to >0,23
6		orange	<0,202
7		light yellow	>0,202
8		gray -40%	<0,10
9		light turquoise	>0,10
10		pink	>0,18

DAP

TU Delft

Layers in the Delft sandstone (2)



Volume evaluation

- 10-15.3 cm spacing between data points
- Converting MD to TVD
- V_{shale} cut-off 20%, 40% and 60%
- Concession area (16.94 km^2)

Vshale Cut-off	Average thickness(MD) (with MKP 14 and MKP 15)	Standard deviation (MD) (with MKP 14 and MKP 15)	Phi $_{effective}$	Rock volume (10^9 m3)	water volume (10^6 m3)
20%	28.7 m (22.3 m)	11.3 m (16.0 m)	0.219	0.486	78 (60)
40%	51.5 m (38.3 m)	17.5 m (25.5 m)	0.184	0.874	140 (104)
60%	59.8 m (48.3 m)	30.8 m (35.4 m)	0.162	0.920	160 (126)

Conclusion

- Production rate 150 m^3/h → 1.314 Mm^3/y

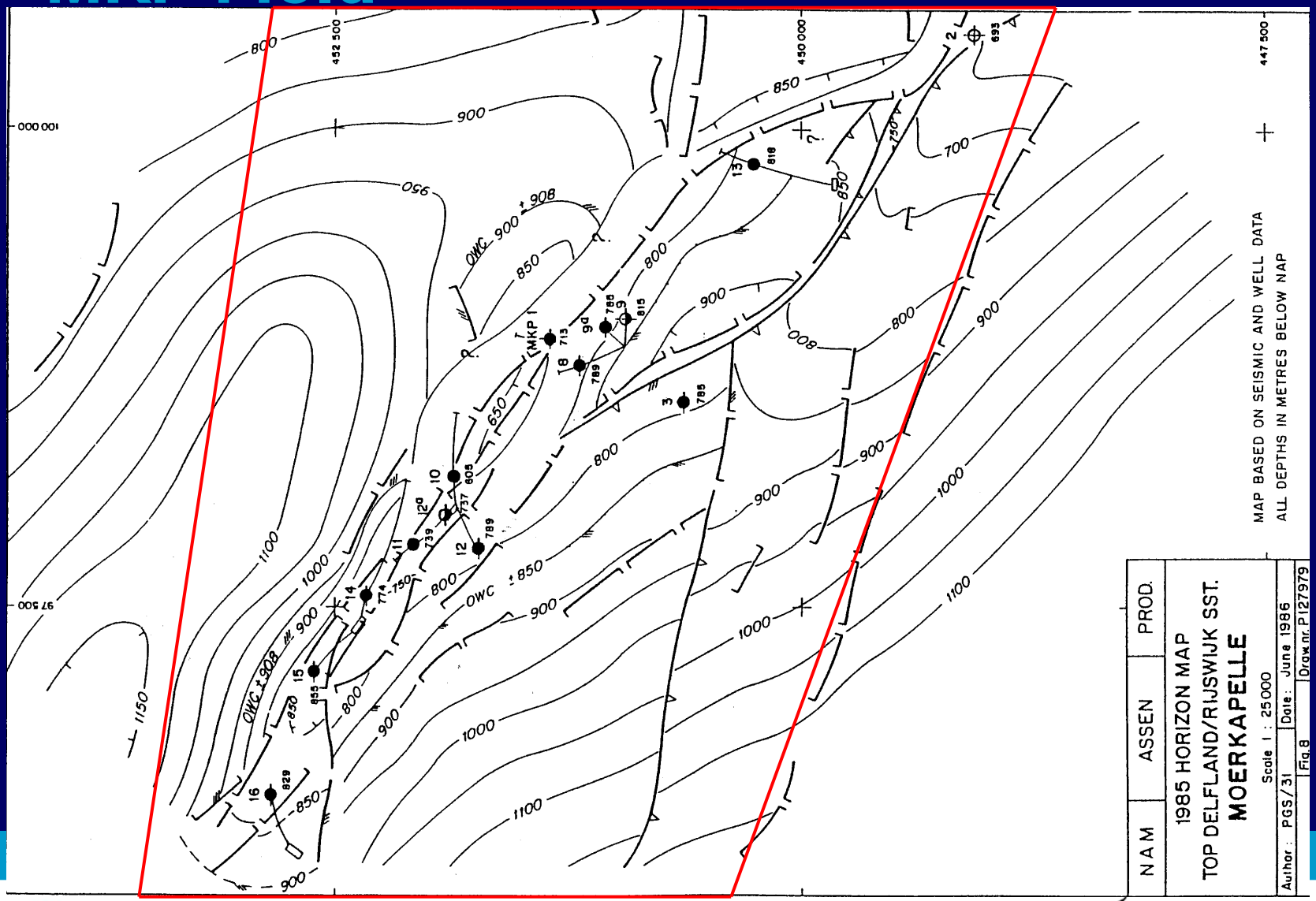
V_{shale} Cut-off	Years before all water used
20%	45
40%	106
60%	123

DAP

TU Delft

Questions

MKP Field



DAP

TU Delft

References

- Dr. K-H.A.A. Wolf, 1999, Petrophysics
- Schlumberger, 2000, Log Interpretation charts
- Dresser Atals, 1972, Log data
- Dr. K-H.A.A. Wolf, 2008, AL EAGE Rome
- www.google.maps.nl
- http://www.geothermie.nl/img/images_inline.php?id=129