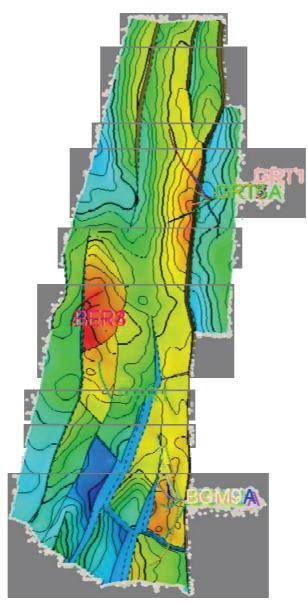
### Bergermeer

### **UGS Subsurface Modelling Study**









Nengti Borkhataria **Suzanne Castelein Birgit Dietrich Guillaume Maillet Hans Martens** 

February-June 2007

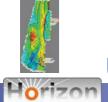


#### **Horizon Energy Partners BV**

Prinses Margrietplantsoen 81 2595 BR The Hague The Netherlands Phone: +31 (0) 70 312 4960 Fax: +31 (0) 70 3124961

http://www.horizon-ep.com





# Bergermeer UGS Subsurface Modelling Study



#### **Table of Contents**

LIST	OF TA	BLES	6
LIST	OF FIG	GURES	8
EXEC	UTIVE	E SUMMARY	16
1 II	NTRO	DUCTION	17
PAR1	ΓΙ \$	STATIC MODELING	22
2 (	SENER	RAL GEOLOGY	23
2.1	GE	OLOGICAL BACKGROUND	23
2	2.1.1	Regional Sedimentology	
2	2.1.2	Facies Interpretation for the AOI; Discussion of cores	23
2	2.1.3	Regional Structural Geology	31
2	2.1.4	Structural style in the area of interest	32
2.2	WE	ELL TOP PICKS	32
3 F	PETRO	PHYSICS	40
3.1	INP	PUT DATA OVERVIEW	40
3.2		ROSITY LOG QUALITY ISSUES	
3.3	Po	ROSITY LOG QUICK-LOOK RE-EVALUATION	41
3.4	От	HER PETROPHYSICAL RESULTS	42
3	3.4.1	Salinity	
3	3.4.2	Por/Perm relation	42
3	3.4.3	Reservoir Temperature	43
3	3.4.4	Contact picks; Saturation vs. Height	43
3	3.4.5	Petrophysical Averages	
4 8	STATIC	MODELING	59
4.1	INP	PUT DATA OVERVIEW	59
4.2	Wo	DRKFLOW	59
4.3	Da	TA QC & PROCESSING	60
4	1.3.1	Surface & Faults	60
4.4	STA	ATIC MODELLING	61



# Bergermeer UGS Subsurface Modelling Study

Horizon Energy Partners B.V.

APPENDIX	(I.A PETROGRAPHIC EVALUATION SUMMARY	119
REFEREN	CES	117
4.4.7	Volume Calculation	65
4.4.6	Structural Sensitivities	65
4.4.5	Property upscaling to the simulation model	65
4.4.4	Property Modelling	63
4.4.3	Facies Modelling	62
4.4.2	Top and Base reservoir, Zonation and Layering	62
4.4.1	Fault Model and Pillar Gridding	61

Part II DYNAMIC MODELING



#### **List of Tables**

Table 2-1	Well tops availability in Bergermeer, Groet and Bergen Fields The nomenclature	
	(based on [11]): Top ROSLU = Upper Slochteren Sandstone Member, Upper	
	Rotliegend super group Top DCCR = Ruurlo Formation, Limburg super group	
	(Carboniferous) TD = total depth of penetration	33
Table 3-1	List of logs provided. The source of the logs is the work reported in [1]. The	
	composite logs were loaded from the TNO/NITG DINO website. Core analysis	
	results (conventional) was only available for well BGM1	44
Table 3-2	Overview of wells in the project, with length of Rotliegend penetration (only	
	BER1, BGM1 and BGM8A penetrate the base), as well as porosity (PHIE) log	
	handling. Note that GRT porosity logs cannot be used as is, since no fluid fill	
	correction was applied, not because they are based on the sonic log	49
Table 3-3	Petrophysical averages [1] of several fields in the Bergen concession. BGM and	
	GRT are marked yellow; BER averages are not given	53
Table 3-4	GWC picks from the various wells in the model. Swc averages obtained over	
	the pay zone are also quoted [note that the Sw averages are not weighted with	
	porosity or otherwise].	56
Table 4-1	Use of well data for facies and property distribution ('Properties'), and for	
	structural modelling ('Structure')	66
Table 4-2	List of faults used for pillar gridding. Fault 2b is separating between BGM7 and	
	other wells in Bergermeer. The pressure data showed BGM7 well has different	
	pressure data from the rest of the wells. Therefore it is a modelling requirement	
	to have fault physically included (no offset = non-active). Fault 9 is excluded	
	based on longer computing time in flow simulation problem towards unequal	
	grid block. Hence, fault 9 is not the project area. Fault 18 and fault 19 were	
	created for segment separation purposes and should be set as non-active faults	
	(no offset).	67
Table 4-3	List of the help data points (pseudo well tops) constraining the 'Make Horizons'	
	process for the Top ROSLU (=Top Reservoir) horizon	68
Table 4-4	Well report from making the horizon "Horizon after" is the depth (MD) of the	
	horizon surface intersection with the well; "different after" is the difference to the	
	corresponding well top.	69



## Bergermeer UGS Subsurface Me

### **UGS Subsurface Modelling Study**

Table 4-5	Geometry setting used for the low porosity streaks in the modelling area The	
	orientation of the porosity streaks is based on the minimum, mean and	
	maximum value of the dipmeter value in BGM2 (see Table 4-6). The thickness	
	of the low porosity streaks are based on the facies logs reading. The minor	
	width of the three different facies scenarios are meant to bracket, rather	
	overestimate than underestimate, the range of the possibilities.	70
Table 4-6	Dip/azi values from BGM2 dipmeter log	70
Table 4-7	Facies modelling statistics result of low porosity streaks for different scenarios.	
	Type of facies is discontinuous, either good porosity (0) or low porosity streaks	
	(1). Therefore, mean value is not available. Number of defined value (N) for well	
	logs and upscaled based on 1D well sample data point, and property based on	
	3D (more points). No filtered assigned for facies modelling.	71
Table 4-8	Property (porosity) modelling scenarios in the modelling area. Parameter	
	combinations were chosen to emphasize the range (Table 4-9); nomenclature	
	refers to the porosity variogram length relative to the poor streak body size	72
Table 4-9	Variogram setting used for property modelling; All units are in meter, except	
	azimuth (degree).	72
Table 4-10	Property modelling statistics results of five different low porosity streaks	
	scenarios in the modelling area of Bergermeer, Groet and Bergen Fields	
	Property type is varies (continuous) between 3-39% upscaled porosity. Mean	
	and Standard deviation (Std) of 3D property are match with the 1D upscaled	
	value	73
Table 4-11	List of gas water contact (GWC) per segment in the modelling area of	
	Bergermeer, Groet and Bergen Fields (cf. Figure 4-41).	74
Table 4-12	Volume calculation parameter used for different scenarios	74
Table 4-13	GIIP volumetric results Por/facies scenarios as in Table 4-8. The 'fault2' trace	
	used is the west-trending one, which gives too-low BGM7 volumes (see chapter	
	5)	75



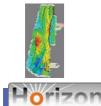
#### **List of Figures**

Figure 1-1	Location of Bergen concession fields that were part of the study: Bergen (BER),	
	Groet (GRT) and Bergermeer (BGM). The latter field is the main focus of this	
	study. The indicated well positions are the top reservoir intersections	18
Figure 1-2	Cumulative production of the three fields in the area of interest (AOI).	19
Figure 1-3	Pressure history of the three fields in the area of interest (AOI)	19
Figure 1-4	Location of BGM wells. Points plotted are top Rotliegend (ROSLU) reservoir	
	picks. Well BGM4 is a water injector, in a fault block S of the main BGM block.	
	Pressures in BGM4 are much higher than in the main BGM block.	. 20
Figure 1-5	Location of GRT wells. Points plotted are top Rotliegend reservoir picks. Wells	
	GRT5 and GRT7 are drilled into a different fault block than the main GRT block,	
	with a different pressure regime.	20
Figure 1-6	Location of BER wells. Points plotted are top Rotliegend reservoir picks	21
Figure 2-1	Palinspastic map of the Permian Basins with the recent-continent contours	
	Bergermeer (see blue star for position) was situated in a proximal position (with	
	regards to the land-mass) and therefore consists predominantly of sandflats and	
	dunes, which is a very favorable depositional setting with regards to the quality	
	of the reservoir properties.	25
Figure 2-2	Sketch of the depositional setting within the Permian Basin. The depositional	
	system of Bergermeer would be located within the 'dry sandflat and dunes'	
	area	26
Figure 2-3	Facies distribution at the onset of the Lower Slochteren Formation, which	
	comprises the reservoir unit of Bergermeer, Groet and Bergen. The blue star	
	marks the position of Bergermeer	27
Figure 2-4	Sketch visualizing the sand dune and interdune (=sandflat) depositional	
	environment. The dark orange area corresponds to the sandflat area, the lighter	
	orange to the dunes.	28
Figure 2-5	Recent analogue example for a desert environment with dunes and interdune	
	areas Note, that the envisaged environment for Bergermeer is supposedly more	
	arid than the shown desert	28
Figure 2-6	GRT3 core - contact cross-bedding with horizontally layered section. [Scale is	
	in cm.]	29



# **Bergermeer**UGS Subsurface Modelling Study

Figure 2-7	Pleistocene eolian deposits from Oman. A: small-scale example of vertical	
	changes from strongly dipping, dune strata and horizontally laminated interdune	
	areas. B: large-scale outcrop example for lateral and vertical juxtaposition of	
	dune and interdune strata.	29
Figure 2-8	Fluvial water ripples in GRT3. The core sample is from 2462m MD, the overall	
	thickness of this fluvial interval is about 15cm.	30
Figure 2-9	Mud flakes suggest fluvial influence in the upper part of the GRT3 cores	31
Figure 2-10	Mesozoic structural geology map of the Netherlands and SW North Sea. The	
	colors outline the extension of the major sedimentary basins. The blue star	
	marks the position of Bergermeer.	34
Figure 2-11	Overview of structures in the Netherlands during the Late Jurassic to Early	
	Cretaceous. Note that the ridges/platforms not necessarily existed during	
	deposition of the reservoir unit.	35
Figure 2-12	Map view of the base reservoir horizon (=Top Carboniferous). The three	
	greenish lines correspond to the position of the intersections shown in Figure	
	2-13 below. White gaps in the horizons represent faults. For direction of fault	
	offset, please refer to the figure below. Note, that the middle part of the model is	
	hardly faulted, whereas the southern and northern area are offset by horst-and-	
	graben-structures.	36
Figure 2-13	View from the south onto the base reservoir horizon (=top Carboniferous).	
	Faults are filled with light blue color. The three intersections $(1 - 3)$ dissecting	
	the model show the reservoir unit in dark blue and faults in white. BGM1,	
	BGM7, BER1, and GRT1 are displayed to indicate the location of the referring	
	fields Bergermeer, Bergen, and Groet. See also Figure 2-14. Intersection 1:	
	Northern domain: NE-dipping half-grabens. Intersection 2: Transfer zone: less	
	deformation in the eastern part of the Intersection, which is located in direct	
	extension of the Groet and Bergermeer Fields. Intersection 3: Southern domain:	
	direction of displacement is opposed to the one in the northern domain	37
Figure 2-14	Azimuth map of the to Rotliegend. The change from E-dip to W-dip as we move	
	from BGM to GRT is apparent	38
Figure 2-15	Anhydrite-healed small-scale faults in core 11 of BGM1	39
Figure 3-1	Por/Perm crossplot for BGM1 conventional core analysis	45
Figure 3-2	Core vs. log porosity (Figure 17 from ref. [1])	45
Figure 3-3	Crossplot of PHIE vs RHOB for BGM2 (left) and BGM1 (right). Trend lines	
	plotted are for fluid densities 0.7 (purple), 1.05 (yellow), 1.1 (cyan), respectively.	
	All trends use matrix density 2.65 g/cc	46



### Bergermeer UGS Subsurface

**UGS Subsurface Modelling Study** 

Figure 3-4	BGM1 cross-plot of core porosity (no attempt was made to achieve a core $\rightarrow$	
	log shift) vs. RHOB log values (last sample point preceding core plug depth).	
	Various fluid density trends are superposed	46
Figure 3-5	RHOB/PHIE crossplot for GRT1	47
Figure 3-6	PHIE- $\rho_f$ relation used in section 3.3 to model lower apparent fluid density at	
	higher porosity	47
Figure 3-7	Density/porosity crossplot with adapted transform (left: GRT1, right: BGM1)	47
Figure 3-8	Core/log crossplot of BGM1 with adapted density porosity log. Coefficients	
	plotted are for a forced fit through (0,0). Note that the cloud of points around .18	
	is below the line (possibly suggesting higher matrix density), whereas the cloud	
	around .28 is above the line (suggesting lower fluid density). The fit is of a	
	similar quality than if we would have multiplied the input PHIE log (which was	
	derived from porosity) by 0.9	48
Figure 3-9	BGM1 log plot. The light yellow track shows the core porosity vs. the original	
	PHIE (blue) and the adapted PHIE (black). The latter has generally slightly	
	lower values, as well as more pronounced low-porosity streaks. The circle	
	indicates an example of likely core/log depth mismatch	. 50
Figure 3-10	Partially (see Table 3-2) re-computed PHIE log plots for BGM8 (left) to BGM1	
	(right). PHIE scale is 0-0.34 for all logs. The BGM6 and 6A wells (which are not	
	used for property interpolation; cf. section 4.4.4) are the third and fourth from	
	the left (light yellow background)	51
Figure 3-11	Por/Perm correlation wit linear and quadratic trend. The top plot shows core por	
	vs. core perm, the bottom plot shows log por vs. core perm. The linear trend is	
	fitted for the two graphs separately; the formulas are indicated in the graphs.	
	The quadratic trend is fixed, as in the text.	52
Figure 3-12	Log plot of well BGM1 across the Rotliegend (ROSLU) from [1]	. 54
Figure 3-13	Log plot of well BGM7 across the Rotliegend (ROSLU) from [1]. The circle	
	highlights the HC zone on the Sw track, with Sw's (visually) between 0.2 and	
	0.4	55
Figure 3-14	Log plot of well GRT1 across the Rotliegend (ROSLU) from [1]. The circle	
	highlights the HC zone on the Sw track, with a ramping profile suggesting a	
	transition zone.	55
Figure 3-15	Saturation vs. height above free water level (FWL) for BER. Color is PHIE_HEP	
	(0.03-0.39).	57
Figure 3-16	Saturation vs. height above FWL for GRT. Color is PHIE_HEP (0.03-0.39)	57