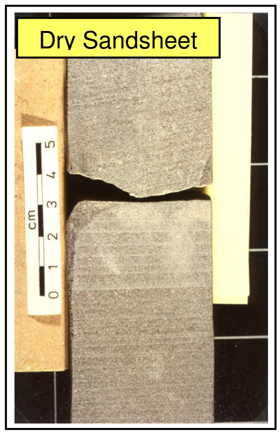
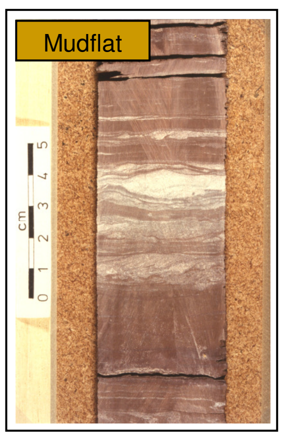
Symposium and Core Workshop

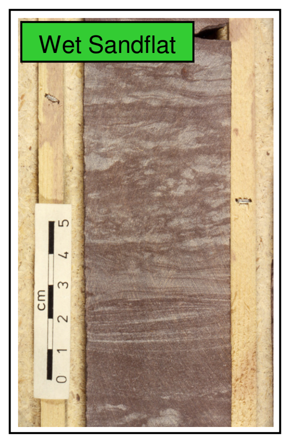
"Fifty years of petroleum exploration in the Netherlands after the Groningen discovery"

Organised by EBN and TNO Geo-Energy

In cooperation with the PGK to commemorate their 30th anniversary
15 & 16 January 2009, Utrecht







Panamint Valley USA – A Present Day Equivalent of the Rotliegend Depositional System

Photo Harmen Mijnlieff

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Symposium and Core Workshop

"Fifty years of petroleum exploration in the Netherlands after the Groningen discovery"

Conveners F.F.N. van Hulten & J.E. Lutgert

Organised by EBN and TNO Geo-Energy in cooperation with PGK
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Day 1: Exploration Symposium 15 January 2009

After the landmark discovery of the Groningen field in 1959, with the well Slochteren-1,
petroleum exploration in the Netherlands changed profoundly. The exploration in the years after the first discoveries has only been documented in part. Fifty years geologists have been busy finding new plays in the Dutch subsurface. Now in this "year of the earth " and 50 years after the discovery it is a good moment for reflection on these exploration activities. Exploration in the Netherlands became part of the search for oil and gas in the larger North Sea basin area. The workshop will touch on a number of detailed examples. Many play concepts have been forgotten over time. The symposium will allow ample time for the early explorationists to bring them back in order to help the professionals active today. In a number of lectures examples of plays that were explored the last fifty years will be shown. Some background material will be available on CD-ROM.

Day 2: Rotliegend Core Workshop 16 January 2009

On Friday a dedicated core workshop will be held focused on the Permian Rotliegend,
Summarizing 50 year of research in the Netherlands. The core workshop will bring together a unique display of Rotliegend cores demonstrating the complexity of this depositional system. Lectures are planned to introduce key topics and their impact on the gas fields in the subsurface:

1. **Stratigraphy**
2. **Depositional Environment**
3. **Paleogeography**
4. **Diagenesis**
5. **Structural Geology**
6. **Field Studies**

The proceedings from the workshop will be published in the SEPM special publications series edited by R. Gaupp & J. Grötsch.

Program Day 1

Symposium “Fifty years of petroleum exploration in the Netherlands after the Groningen discovery”

Thursday, January 15th 2009

Coffee 9.30 Registration

Session 1
10.00 Welcome (TNO/EBN)
10.10 KEN GLENNIE (University of Aberdeen) – [presented by Jaap Breunese - TNO] Desert interpretation of the Permian Rotliegend Sandstone, Groningen.
10.30 Questions/discussion
10.35 RIEN HERBER (NAM - Assen) – NAM's exploration history and outlook in the Netherlands
10.55 Questions/discussion

Coffee 11.00

Session 2
11.35 JEAN-JACQUES BITEAU (Total - Paris) – The TOTAL Group (Total, Fina, Elf and former parent companies)
‘E & P in the Netherlands, a 45 years success story’
11.55 Questions/discussion
12.00 SANDER KABEL (NAM - ASSEN) – ‘Triassic in the Northern Offshore’
12.25 Questions/discussion
12.30 PHILIPPE DRIJKONINGEN (GdF–Suez - Paris) – ‘Unexpected plays and discoveries’
12.50 Questions/discussion

Lunch 12.55

Session 3
13.45 BERT DE WIJN (Wintershall Noordzee B.V. – Rijswijk) – ‘Wintershall 40 years of exploration and production history’
14.10 Questions/discussion
14.15 BERT MANDERS (Fugro – Robertson Leidschendam) – ‘Dutch Offshore Rounds: Be early and hope for luck’
14.35 Questions/discussion

Tea 14.40

Session 4
15.15 JACQUES VAN VEEN (retired NAM) – ‘The frontal area of the London-Brabant Massif - 3D exploration since the mid-eighties along the River Maas lineation’
15.45 Questions/discussion
15.50 PETER ROSENKRANZ (EBN) – ‘Model approach to future offshore exploration’
16.15 Questions/discussion
16.20 Closing Remarks

Drinks 16.30

Program Day 2

Core Workshop “The Permian Rotliegend in The Netherlands”

Friday, January 16th 2009

Coffee 9.30 Registration
10.00 Welcome by EBN/TNO

Session I
10.05 J. GRÖTSCH (NAM - Assen): ‘The Groningen gas field: 50 years of history’
10.20 H.F. MIJNLIEFF (TNO – Utrecht): ‘Stratigraphy of the Permian Rotliegend’
10.35 R. GAUPP (U. of Jena, Germany): ‘Rotliegend depositional environments’

Session II
10.50 Introduction to core sessions (LUTGERT/GRÖTSCH)
11.00 Core sessions in 6 groups (2 * 30 min)

1. The Groningen gas field
2. Regional correlation and sequence stratigraphy
3. Rotliegend feather edge - Lower Slochteren
4. Rotliegend feather edge - Upper Slochteren
5. Diagenesis
6. Fractures

Lunch 12.00

Session III
13.00 Core sessions in 6 Groups (2 * 30 min)

Tea 14.00

Session IV
14.45 J.C. DOORNENBAL (TNO - Utrecht): ‘Paleogeography of the Permian Rotliegend’
15.00 R. GAUPP (U. of Jena, Germany): ‘Diagenesis in Rotliegend reservoirs of the Netherlands’
15.15 H. LIGTENBERG (NAM – Assen): ‘Some notes on Structural Geology from Rotliegend cores’
15.30 J. STEENBRINK (NAM - Assen): ‘The Groningen gas field – managing a giant’
15.45 EBN/TNO: Closing Remarks

Session V
15.50 Core sessions in 6 Groups (2 * 30 min)

Drinks 17.00

Day 1 - Symposium

Early interpretations of the Groningen Gas Field, pre-1965

Ken Glennie (University of Aberdeen)

Abstract: Once the size of the Groningen discovery was realised in 1963, NAM's (Eppo Oomkens') interpretation of the reservoir cores indicated possible desert sands - but of what type. I was ordered to study deserts to find out. After Eppo & I returned from a trip to Libya, early 1964, NAM arranged a one-day in-house conference at a neutral site near the German border (Enschede) with Shell's partners Esso. Esso's own academic 'guru' (Harold Fiske) was convinced that the reservoir was of deltaic type, possibly Mississippi, Ganges, Indus or Mackenzie River, but certainly not desert. The desert interpretation won 'hands down'.

NAM's exploration history and outlook in the Netherlands

RIEN HERBER (NAM - Assen)

C.V.: Rien Herber (1954) graduated as a geophysicist in Utrecht University in 1979 and started his Shell career in that same year in the research lab in Rijswijk in the seismostratigraphy group. Following assignments as production seismologist in Brunei and exploration team leader in Thailand for Shell's onshore concession, Rien assumed a position in the NAM in the Netherlands as exploration team leader for the offshore in the early 90's when the big 3D seismic campaigns took place. He then moved northward to Norway as exploration manager for Norske Shell, during which period the deep water Atlantic Margin was opened. In 1998 he moved back to NAM as exploration manager. Still based in Assen, he was appointed in 2003 as Vice President Exploration for Shell in Europe. In this capacity he is responsible for the Shell operated exploration activities in the UK, Netherlands, Norway, Ukraine, Sweden and Ireland, non-operated Shell interests in Germany, Denmark and Italy as well as new exploration opportunities outside these countries. In addition to these responsibilities he is deputy to the General Manager in NAM (a joint Shell/ExxonMobil EP venture in the Netherlands).

The TOTAL* Group: E & P in the Netherlands, A 45 years success story…

Jean-Jacques Biteau*, Christian Mathieu*, Hans-Lo Ten-Haven**, Patrick Sorriaux*

*: TOTAL E&P Paris La Defense, France **: TOTAL E&P NEDERLAND, The Hague, Netherlands

Abstract: In 1962, several French state owned companies decided to unite their efforts to explore for hydrocarbons in the Dutch acreage: the Régie autonome des pétroles (RAP), the Compagnie Française des Pétroles (CFP), the Bureau de Recherches Pétrolières (BRP) and the REX small companies; all forming the so-called “French Group”.

1-The early onshore adventure

After several field geological studies that were carried out on outcrops in northern Germany, and correlations built from the Heibaart-1 Belgian well data in which the BRP was a partner, different 2D seismic surveys were acquired in Friesland-Noord Holland, Drente, in the Waddenzee and on Texel Island (i.e on the non-leased areas between the producing Hague Basin and the Groningen discovery).

The exploration targeted three main plays: the Lower Cretaceous sandstones already corresponding to the producing layers of the Schoonebeek field (discovered during the Second World War), the Zechstein dolomites and the Rotliegendes sandstones, famous reservoirs of the giant Groningen field, subject of this conference celebration.

It is worth pointing that in the Netherlands petroleum prospecting was ruled at that time by the Napoleonic code (written in French!) which allowed exploration drilling to be carried out everywhere but in the production concessions. When discovered after drilling, accumulations automatically became the property of the company that operated the well. Before the new Mining Law in 1967, this generated a frenetic hunt for hydrocarbons and in as early as 1964, the French group succeeded in discovering the Slootdorp field in the Zechstein Dolomites and the Harlingen field in the Vlieland Lower Cretaceous Sandstones. Production concessions were applied for in 1964 and 1965. This was the beginning of the Total group success story in the Netherlands…

The phase 1 development of the Leeuwarden gas field was completed in 1970 and it came on stream in 1971.

2- The offshore harvest

In 1968, offshore blocks were granted to different companies including the Petroland group (acting as the operator of the French group which at that time comprised Elf, CFP, SNPA and REX). After drilling dry well P5-1 in 1968, Petroland discovered a small gas accumulation in well K6-1 well in 1969.

In 1970, the Zuidwal field was discovered in the Waddenzee. The gas bearing accumulation was evidenced in a Vlieland sandstone section deposited around a volcano. The production of this field was authorized only in 1984 owing to environmental restrictions and the first gas was produced in 1989 from an unmanned platform, a world first at that time, strictly adhering to numerous original Nature protection guidelines.

In 1971, well L7-1 found the first offshore commercial discovery operated by Petroland.

A huge exploration effort during the eighties and nineties was concluded by the discovery of several other offshore fields located mainly in the Rotliegendes of the K4-K5-K6-L4-L7 blocks. After a farmout issued from BP, Petroland also discovered the F15A gas condensate field in 1986 in the Volpriehausen Sandstones, followed in 1998 by the discovery of F15B in Upper Jurassic Scruff spiculites.

Development of the offshore and onshore discoveries boosted the shared production (operated & non operated) to reach a peak of 26.8 millions barrels oil equivalent in 1996.

Since 2000, the Total group attempted to find deeper, frontier or extrapolated petroleum plays both offshore and onshore, but unfortunately none of its efforts proved fruitful.

In 2003, the Total operated onshore producing licences were sold to Vermillion.

Today, the efforts of the Total Netherlands subsidiary are focused mainly on enhancing the value of production and resources of its assets.

Unexpected Plays and Discoveries

PHILIPPE DRIJKONINGEN, GdF–Suez – Paris

Wintershall - 40 Years of Exploration and Production History

BERT DE WIJN, Wintershall Noordzee B.V. – Rijswijk

C.V.: Bert de Wijn is Chief Geologist at Wintershall Noordzee. He graduated in 1978 from the University of Utrecht in Structural Geology and Geophysics. Following two years of research in the mechanical behaviour of salt, he joined Pennzoil in 1981 and embarked on a twenty eight year career in exploration, development and production geology, wellsite geology and petrophysics. He is an active member of the SPE-NL and previously served on the board for many years. His main interests are the generation of formation pressure, formation gas and water analysis and the diagenesis of reservoir rocks.

Abstract: The history of Wintershall in the North Sea area is two fold, first from 1963 as a partner in the German Deutsche Nordsee Gruppe (DNG) which drilled B1, the very first offshore well, and later in 1968 as part of the Noordwinning Group in the Dutch North Sea. A successful economic history commenced following the discovery in 1972 of the Triassic Main Buntsandstein sandstone of the K13-A Field and the subsequent discoveries in both in the Triassic and Rotliegend in the K13/K10 area. After taking over of Pennnzoil's operatorship in the Dutch waters in 1988, Wintershall effectively explored and developed the L8 and L5 deep Rotliegend area, the Main Bunter reservoir of the P14-A Field, the D15 and D12 Carboniferous Fields and the F16 Rotliegend Featheredge. The German A6-A Field, which had been discovered in 1974, was put on production in the year 2000 after Wintershall took over the operatorship of BEB in the German offshore (DNG). Subsequent to acquiring Clyde Petroleum in 2002, Wintershall developed the Q1 Main Buntsandtstein discovery. Current North Sea area exploration efforts are continuing in the Dutch and German sectors while being extended towards the UK and Danish sectors.

Dutch Offshore Rounds: Be Early and Hope for Luck

BERT MANDERS, Fugro - Leidschendam

Abstract: Three quarters of the cumulative hydrocarbon production originates from exploration licences that were awarded during the first two years of offshore permitting. This is the main conclusion from our review of licence activities since the start of the First Round in 1968. In the last forty years 56 operators and 163 partners received 472 exploration licences. Sixty such permits were converted into producing licences, which generated about 690 bcm gas up to the end of 2008. This volume includes oil recalculated to the gas equivalent.

First and Second Round: As seismic imaging was poor and offshore drilling had not yet started, the geological know-how must have been mediocre in the late 1960's. Success or failure was mainly a matter of luck. Highly contested blocks, for example K17, turned out to be meager, while massive Rotliegend reserves were discovered in the uncontested K15 and L10 blocks.

Still, it is remarkable that the permits that were issued in 1968 and 1970 represent 500 bcm or 72% of today's cumulative output. Operators that were lucky in the early days or purchased good acreage from other operators (Signal>NAM and Richfield>Placid), have stayed, although some changed their names a few times. Companies that received the highest number of blocks in the First Round were NAM and Mobil. NAM seems to have been lucky and became the largest producer. Mobil's victories, on the other hand, were marginal. Other unlucky operators like BP, Phillips, Chevron and Tenneco acquired numerous blocks in the early rounds as well, but most of their acreage remained dry and they left the Dutch scene eventually.

Third to Ninth Round: Exploration licences that were awarded in the next 38 years, have contributed only 28% of the total hydrocarbon production. The best discoveries in the later rounds were in P15/P18 by Amoco, Rotliegend gas in K4/K5 by Elf Petroland, and the 'Fat Sands' in L9 by NAM. Clyde found beautiful Bunter reservoirs in the relinquished Q4 block during Round Nine, while substantial Carboniferous gas was discovered by Wintershall in F16 recently. However, ultimate recoverable reserves in these young permits are small compared to the older 'Super' blocks. The list below shows the Top 10 of best producing blocks. Some permits have been joined because they were awarded in combination or because of historic production data.

TOP 10 PRODUCING BLOCKS

	Permit or Block	<2009 bcm	year award	Round	operator then	operator now
1	K8+K11	56	1968	1	Signal	NAM
2	L10+L11a	55	1968	1	Placid	GDF
3	K15	53	1970	2	NAM	NAM
4	L7+K6	48	1968	1	Petroland	Total
5	K4+K5	36	1985	5	Bow+Elf	Total
6	P15+P18	32	1979	4	Amoco	TAQA
7	L9	30	1978	4	NAM	NAM
8	K12	28	1968	1	Richfield	GDF
9	K13	25	1968	1	Amax	open
10	K14	23	1968	1	NAM	NAM

DON'T FORGET THE FIRST ROUND

The discovery of the Groningen gas giant is now fifty years ago. We should not forget, though, that forty years ago, this year, the First Round licences were awarded in the Netherlands offshore.

Drilling in the Dutch offshore had been delayed because new mining legislation had to be written, by which time the UK sector had seen about 100 wells already. Out of the 331 applications for the First Round, 100 licences were awarded to 56 operators and partners in March 1968.

The most successful companies in the First Round were NAM and mainly US multi-nationals like Mobil, Tenneco, Pennzoil, Amoco, Union Oil and Placid. The French and the British had Petroland and BP, while German and Dutch partners were linked to construction yards, shipping firms, coal traders, and to the Hoogovens steel mill. Even aircraft manufacturer Fokker took a share in one of the permits.

As a result of numerous name changes, mergers, takeovers and possibly bankruptcies, only four out of the 56 pioneers are still active in the Netherlands under their original name. These are: NAM, Total, Dyas and Oranje Nassau.

The frontal area of the London-Brabant Massif – 3D exploration since the mid-eighties along the River Maas lineation

JACQUES VAN VEEN (retired NAM)

C.V.: Dr. J.(Jacques) van Veen is a geologist who studied at Leiden University. He joined Shell in mid 1962 and worked in various EP disciplines in Shell Rijswijk, Italy, Algeria, Nicaragua, NW Borneo, Gabon, NW Borneo, Shell The Hague and NAM Assen. He retired in 1989 and worked till the autumn of 2007 as an independent adviser in international EP ventures.

Abstract: In autumn 1985 an extensive 3D "mixed" seismic exploration campaign was initiated by the NAM in the wider Rotterdam town and harbour areas. It was a clearly innovative follow-up operation after two encouraging 1984 discoveries, i.e. gas in Botlek-1(Triassic) and oil in Rottedam-1(U.Jurassic-L.Cretaceous). This new seismic fieldapproach became possible because at that time the three contrasting seismic signatures from Vibroseis(town), Airgun (harbour/river waters), and Dynamite (open country) could become satisfactorily tied together and harmonised through the rapidly progressing computer and seismic processing state of the art. The success of this well prepared and executed Rotterdam 3D survey and the achieved transparency of EP prospects quickly enabled to also introduce in the offshore the expensive 3D seismic as an exploration tool, instead of only limiting it to production field refinement purposes. The drilling success ratio became more than doubled and towards the late eighties at least one in two exploration wells was a discovery. This accuracy rate also helped to highlight the creative Small Gas Fields Policy of the Dutch Government (1973) as becoming remarkably succesfull. For instance in the early nineties, out of ca 275 gasfields, about fifty percent were in the order of only c.a. 2 mrd. cubic meters. This harvest of small fields could not have been pursued economicly with the old pre-3D drilling succes

ratio of one in four to five. NAM`s extensive 3D seismic approach became quikly followed by other Dutch operators and was also strikingly succesfully followed up by other Shell Opco`s in the world.
Talking about the Triassic in the River Maas orientation, we look today upon a long chain of onshore and offhore gas(cum oil!) fields, stretching from Waalwijk in the SSE, via the Rotterdam harbour region, towards offshore P-6 in the NNW. It marks a prolific achievement, mainly by operators Amoco, Mobil, NAM, and Wintershall. Very illustrative:an impressive percentage of the Dutch onshore/offshore territories, h been surveyed by 3D seismic coverages.

Model approach to future offshore exploration

PETER ROSENKRANZ, EBN

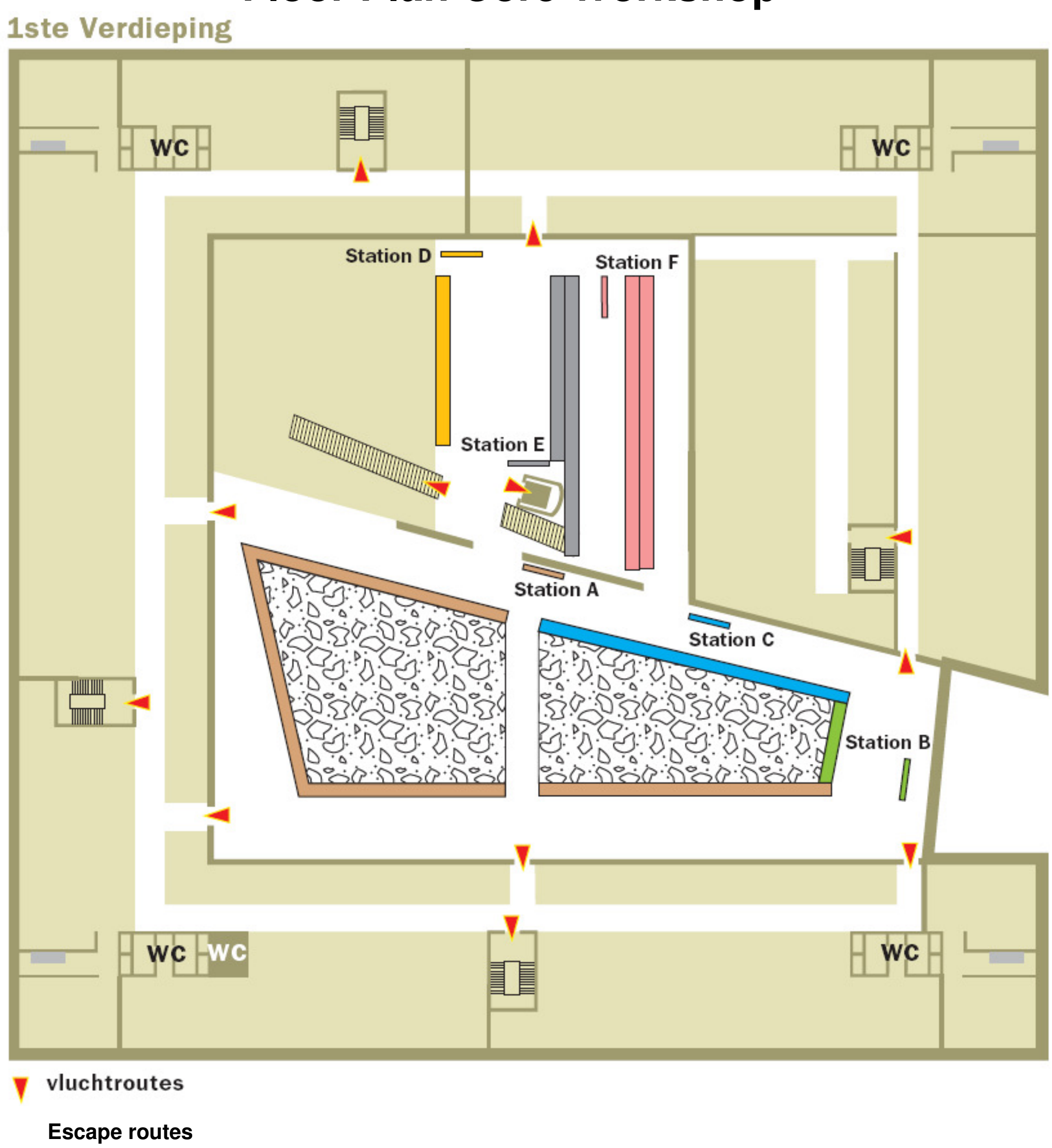
Abstract: An Excel based Monte Carlo model has been made to simulate the offshore exploration process and to calculate the exploration results. Input is TNO's offshore prospect database, the offshore platform database and exploration and development cost parameters. The program simulates the annual exploration drilling results by taking into account the limited availability of the existing host platforms. In case of successful 'drilling' the model generates new platforms which are available for the remaining prospects. The drilling decision is based on cash-flow calculations including full tax calculations. Output is, under given conditions, future reserves, production and cash-flow profiles. The model may be used to define an optimal exploration effort that ensures that no gas is left behind. The model can also be used to calculate the effect of (fiscal) stimulation measures.

Day 2 – Core Workshop

Starting time and location for each of the six groups

Time	Station A	Station B	Station C	Station D	Station E	Station F	Auditorium
10:00-11:00							All Groups
11:00	Group-1	Group-2	Group-3	Group-4	Group-5	Group-6	
11:30	Group-2	Group-3	Group-4	Group-5	Group-6	Group-1	
12:00 - lunch							All Groups
13:00	Group-3	Group-4	Group-5	Group-6	Group-1	Group-2	
13:30	Group-4	Group-5	Group-6	Group-1	Group-2	Group-3	
14:00 - Tea							All Groups
15:50	Group-5	Group-6	Group-1	Group-2	Group-3	Group-4	
16:20	Group-6	Group-1	Group-2	Group-3	Group-4	Group-5	
Drinks			17:00 hrs				

Floor Plan Core Workshop



The Groningen Gas Field: 50 years of History

J. Grötsch & J. Steenbrink

The Groningen Gas Field is the largest gas accumulation in Western Europe with initial recoverable reserves of close to 2800 x109 m3 gas. It represents two thirds of the total recoverable proven gas volumes in The Netherlands. To date approx. 1750 x109 m3 gas has been produced.

The field was discovered in 1959 by well Slochteren-1, however, it's actual aerial extend (862 km2) was initially not recognised. The original target of the discovery well was the basal Zechstein carbonates in a relative small structural closure, mapped on 2D seismic. However, the underlying Rotliegend sandstones turned out to be gas bearing as well. Only several wells later, it was realised that the small prospect targeted initially forms part of a much larger structural closure.

Start of gas production was in 1963. The initial field development took some 15 years during which 29 production locations were build and some 300 wells were drilled. The development of the field was geared towards production capacity generation in order to provide the swing capacity for North West Europe. By the late eighties, with 50% of the gas resources recovered, two major investment projects were kicked-off. The first project involved the installation of some 20 compressors by 2010. The second project was initiated to realise Underground Gas Storages (UGS) for optimum depletion of the Groningen Field.

Looking to the future, additional stages of compression will need to be installed in order to effectively deplete the field. It is planned to install second stage compression in the period 2015 till 2025 and third stage compression thereafter. Additional working volume and capacity will be realised via UGSs.

Stratigraphy of the Permian Rotliegend, an introduction.

H.F. Mijnlieff

The Rotliegend is a very well known and studied stratigraphic interval as a result of its enormous economic significance. An overview of the Rotliegend is given in the work of Mark Geluk 2007 the chapter of the Permian in “Geology of the Netherlands”. The Rotliegend sediments are situated between two well known horizons: KupferSchiefer and the base Permian unconformity (BPU). The wedge between these two horizons is filled with, primarily, three lithologies: Sandstones, Claystones and Evaporites. Start of sedimentation varied. It is thought first Rotliegend sedimentation within Netherlands started some 263 MMa ago and ended quite abruptly when the SPB was flooded some 258 MA ago. Thus the Upper Rotliegend Group is presently thought to be of middle Permian age. The BPU is an amalgamation of at least 4 unconformities related to the different tectonic events at the end of the Variscan orogeny. Moreover, BPU has a lot of different faces. Base Rotliegend consists roughly of three different kind of lithologies Claystone, Sandstone or Conglomerate most commonly in red but in some cases grey. At Top Carboniferous the same lithologies may subcrop which means 9 different permutations on the character of the unconformity on only lithology.
Defining the exact location of the BPU is in some cases difficult task; Where to put the golden spike?

The lithostatigraphy subdivision is excellently illustrated bij the litho-chronostratigraphic chart of Adrichem Boogaert et al. 1994. The Upper Rotliegend comprises predominantly claystone and sandstone. The lithostratigrapic subdivision follows this. The Sand prone Formation => Slochteren Formation and the Clay prone Formation => Silverpit Formation. The Formations have been subdivided in various Members on basis of location within the basin and relative to under- and overlying members.

On a basin scale the Rotliegend series gradually onlaps. Consequently, Lower Slochteren, Ameland should note have time equivalent sediments of the pinchout line of the Ameland Claystone. However, on a regional scale interpretations differ, wedge type of stratigraphic correlations are presented.

There is relative little debate on the recognition/interpretation of lithostratigraphic units in the Rotliegend. Although the subdivision is relatively thorough and usable it is extremely difficult definine/interprete timelines. Lot of roposals prove to be non-unique. Various workers have proposed a “sequence stratigraphical” approach by using cyclostratigraphy, definition of drying or wettening upward cycles. In a broader view it is striking that most workers define some 7 cycles in the Dutch part of the Rotliegend Basin.

Of all lithostatigraphic units examples on display. Additionally, typical sequences and lateral facies changes are illustrated.

Rotliegend depositional evolution

Reinhard Gaupp   Friedrich-Schiller-University of Jena, Germany

General setting, Palaeogeography

Rotliegend deposition in the Southern Permian Basin (SPB) started within regionally restricted basins, mainly located in Northern Germany. From these fault-bounded small basins sedimentation progressively onlapped the Variscan (Saalian) unconformity towards the East and West. During the Late Wordian and Early Wuchiapingian, up to 2,000 m thick Upper Rotliegend sediments, containing most of the gas reservoir facies, were deposited from England to Poland, whith the basin centre still located in Northern Germany. Continental siliciclastics and evaporites were predominantly deposited within a large ephemeral to perennial saline lake, before the marine Zechstein transgression flooded the basin.

In the basin centre a perennial saline lake existed since Dethlingen Fm. which was surrounded by belts of saline mudflats, sandflats and small ergs (aeolian dune fields). Although deposition in this continental basin was influenced by short termed marine ingressions (Legler & Schneider 2008), it became not fully marine until Zechstein transgression.

Wadi systems at the southern border of the SPB focussed the influx of clastic material, from where sand and fines were redeposited by aeolian action. A general westward migration of clastics by east-west directed winds from voluminous sources in the Polish sub-basin can be assumed.

Control factors on deposition

Rotliegend clastic deposition was mainly controlled by climate and structural setting. Major factors sontrolling deposition were:

1. Structural position
2. Sediment supply
    a. supra-regional: aeolian clastics (quartz, fsp., mature lithics)
    b. regional, local: alluvial / fluvial (often volcanic lithics)
3. Fixation potential
    a. basinal accommodation potential always in excess
    b. local preservation of sediment highly variable

ad.1: Extensional tectonics with graben/horst formation influenced facies and thickness distribution untill late Rotliegend deposition (Gast 1988, van Wees et al. 2000)

ad 2: Under semiarid (to hyperaride) climates a sediment-starved deposition has been dominated by clastic supply. Accommodationn potential has always been in excess, taking the marine base level as reference. However, local deposition/ preservation was controlled by the sediment fixation potential with processes like adhesion (capillary ground water rise to surface), fixation of aeolian clasts by salt efflorescences (wind shadow, sticky salt surfaces etc.) or microbial structures, structural or morphological capture of aeolian sand, or flash flooding. The water budget of the saline lake, associated with surface run-off from the South (Variscan upland), appears to be a predominant control of sand deposition during the late Rotliegend.

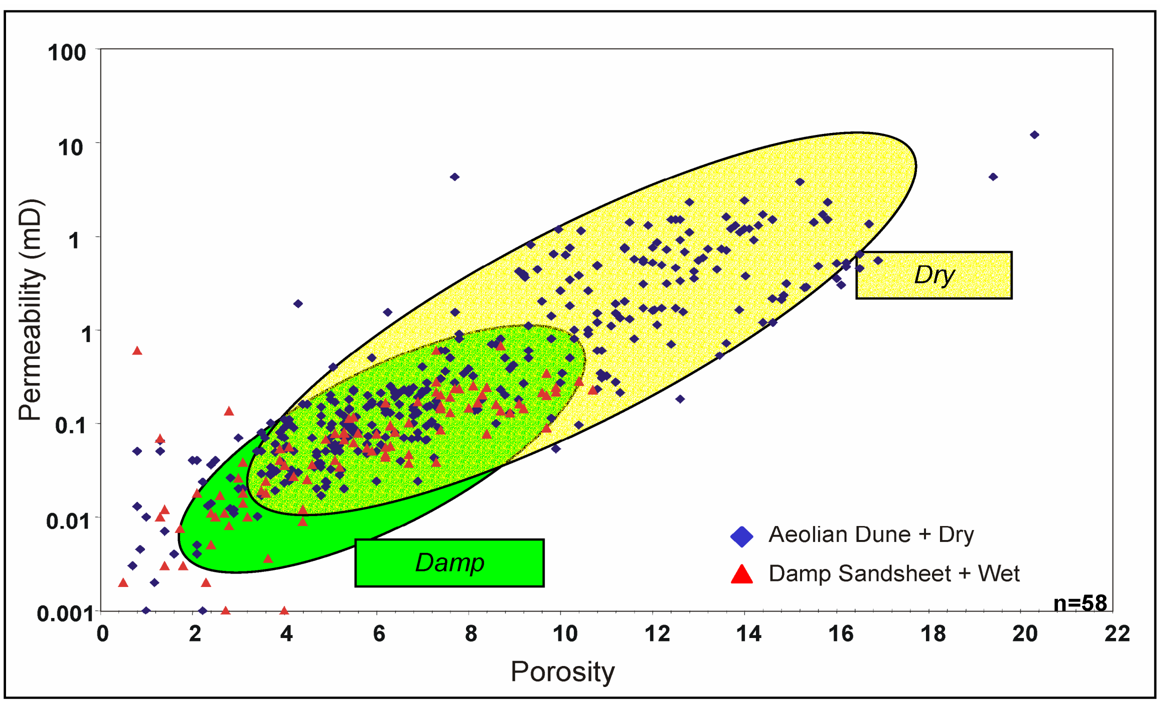
The vast volumes of fines in the SPB are likely to be at least in parts of aeolian origin, silt wind-blown into a vast shallow saline lake. Also aeolian drift of mud pellets was accumulating structureless mudstones. Real lacustrine pelites/clays appear to be rare even close to salt layers.

Climate-controlled lake level fluctuations on different temporal
scales (orbital Rhythms?) are assumed to have controlled the cyclicity as evidenced within almost all margina to central areas of the SPB. Although the chronostratigraphic significance of the diverse depositional cycles is still poorly understood, they provide the only feasible means of regional to basin-wide correlation. Climatic cycles, bounded at the point of lowest aridity were defined by different authors. These climatic cycles have been correlated between different, co-existent depositional environments. They are also the base for subdivision of the Slochteren Sandstones into reservoir units. Phytolite-stratigraphy (TNO) could bring progress in Rotliegend stratigraphic interpretation.

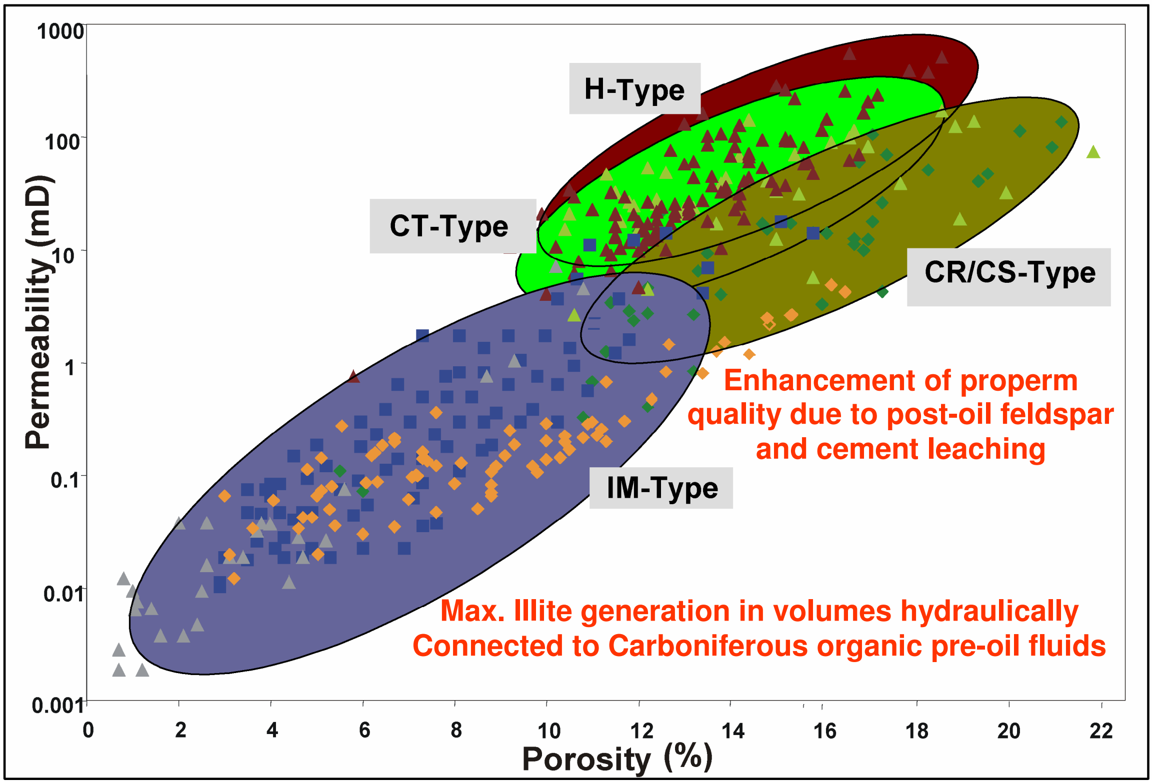
Sandstones at the Southern fringe of the SPB show an onlap on Base Permian palaeotopography. Alternative models suggest stratigraphic convergence or successive erosional truncations toward highs or basin margin.

Lake marginal sand belts (wet, damp, dry aeolian sandflats) and small sand seas were flooded during lake level highstands (e.g. Ameland, Bahnsen intervals). During the late Rotliegend, the depositional area increased steadily with successively more fine clastic accumulation, which is interpreted as evidence for increasing climatic humidity towards the base of Zechstein.

Rotliegend depositional environments comprise alluvial, fluvial, lacustrine / playa, mud- and sandflat, and diverse aeolian sub-environments and lithotypes. Good reservoir quality is encountered within aeolian, particularly dry aeolian and within fluvial facies. Under shallow burial conditions even poorly sorted coarse alluvial clastics can be reservoirs.



Gaupp Fig. 1 Depositional controls on Reservoir Quality



Gaupp Fig. 2 Diagenesis types (diagenetic facies) depend on fluid compositions and strongly control RQ in deep basinal settings

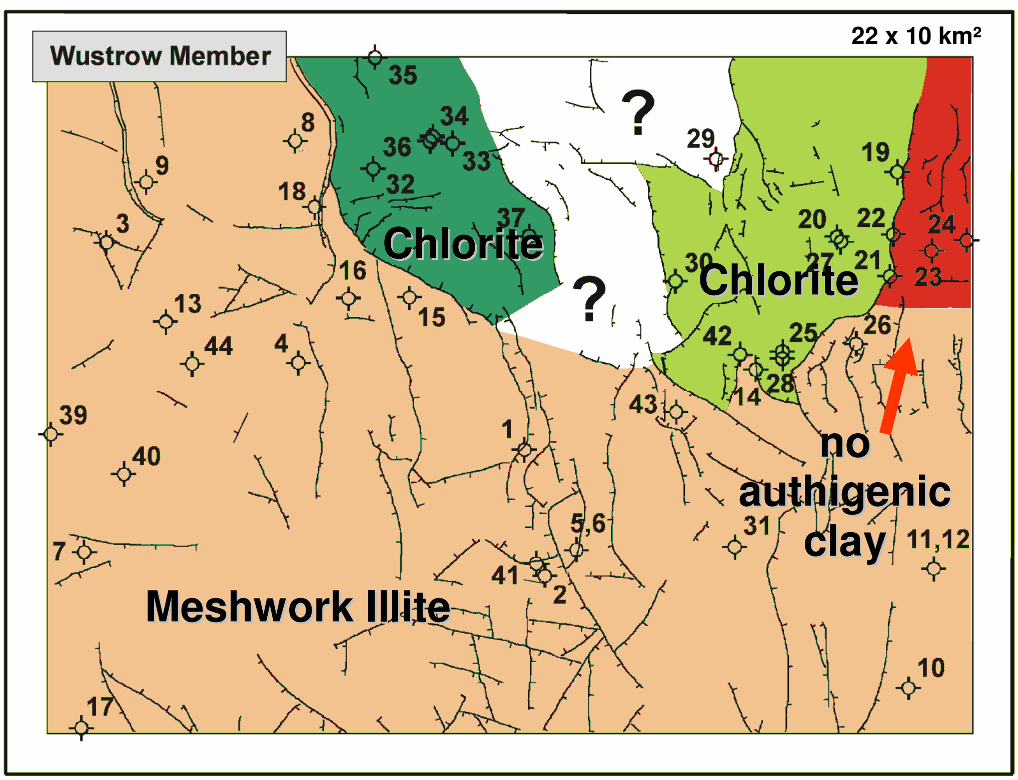
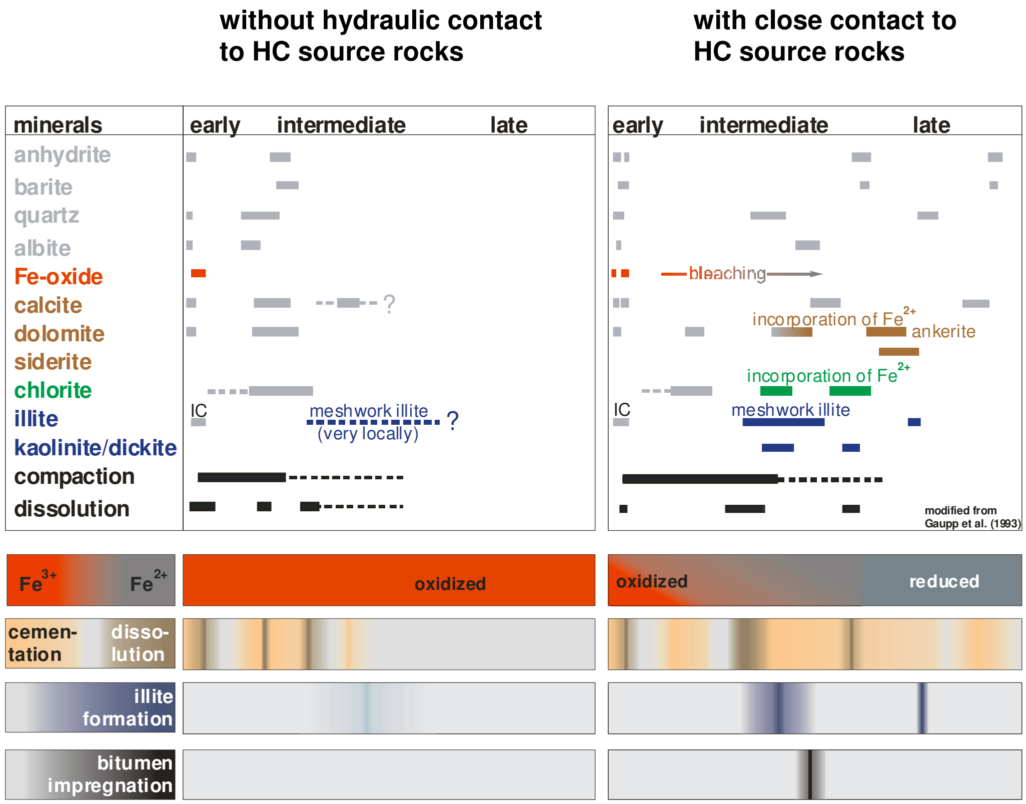
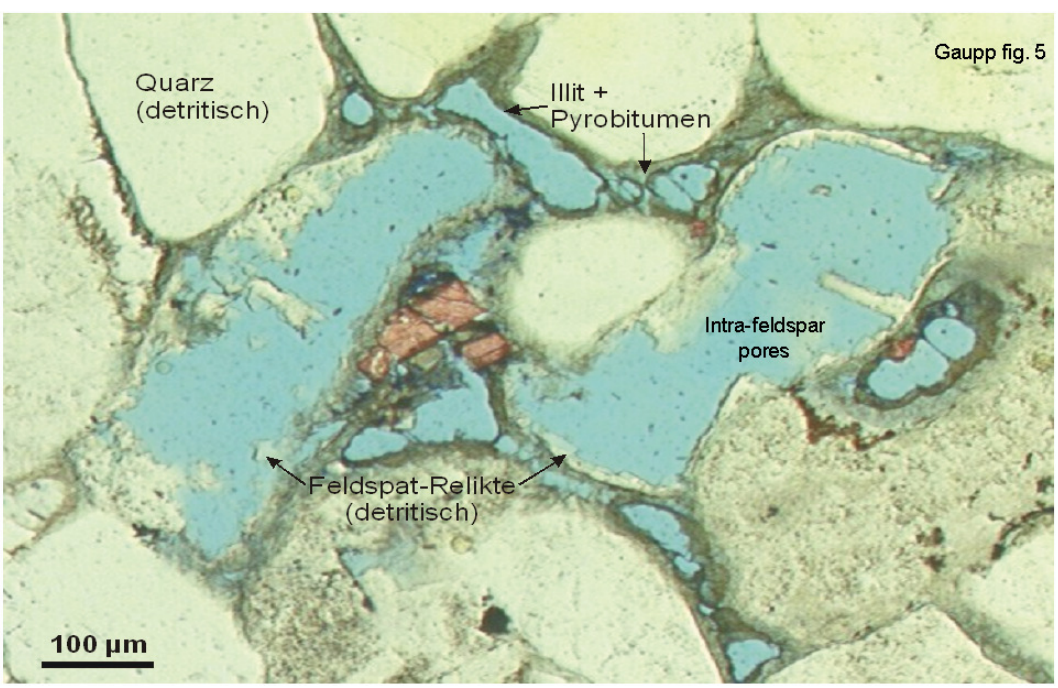


Fig. 3 Clay Provinces in a Rotliegend reservoir unit, N. Germany



Gaupp Fig. 4 **Rotliegend Reservoir Sandstones**



Gaupp Fig.5 **Late porosity enhancement after illite & paleobitumen Cement and feldspar leaching after illite-bitumen (+ 2-5% porosity)**

Diagenesis of Rotliegend Reservoirs

Reinhard Gaupp Friedrich-Schiller-University of Jena, Germany

Deeply buried reservoirs show more complex diagenetic histories and thus more complex patterns of reservoir quality. This is particularly true for the Rotliegend Gas Plays of Western/Central Europe.

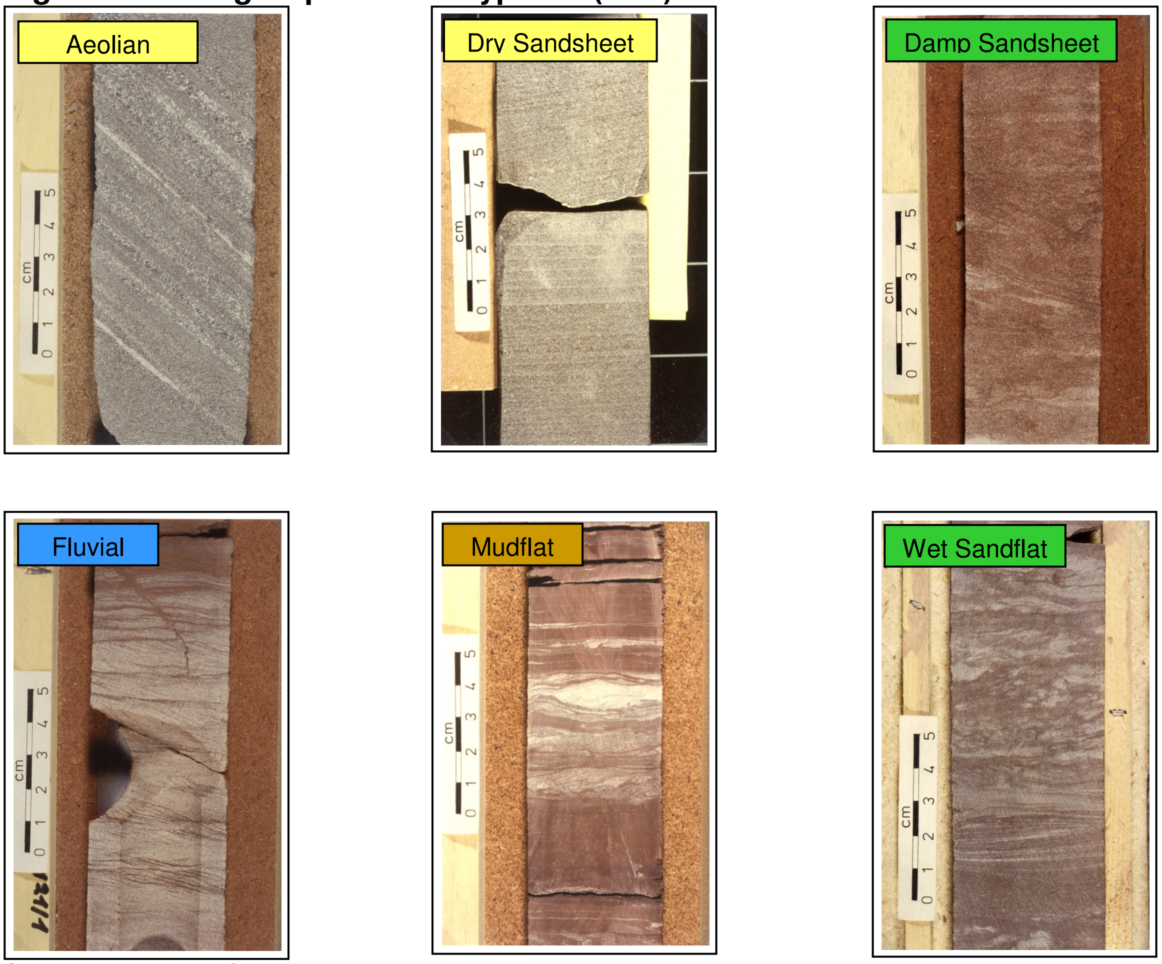
1. Major Factors controlling Rotliegend Sandstone Diagenesis

With increasing depth, the influence of primary depositional control on reservoir properties of Rotliegend sandstones diminishes. However, in the deepest reservoirs still the best porosities and permeabilities are encountered in dry aeolian sandstones. For more than 30 years diagenesis studies were performed with the aim to support reservoir quality assessment in E&P. Fundamental progress has been achieved in the understanding of diagentic histories and their impacts on reservoir quality (Glennie et al. 1978; Drong 1979; Almon 1981; Seemann 1982; Gaupp et al. 1993, 2004; Lanson et al. 1996; Leveille et al. 1997, Zwingmann et al. 1998, 1999). Still, several aspects of Rotliegend diagenesis are explained with alternative models like causes of contrasting diagenetic evolution in different compartments of Rotliegend gas fields (particularly authigenic clay growth and enhanced porosities).

The diagenetic processes and products in Rotliegend sandstone reservoirs are basically comparable within the entire Southern Permian Basin (from UK offshore, the NL off- and onshore sectors, north German Basin, Polish Basin). Early diagenetic cementation evolution has many common features within the basin, depending on paleogeographic / paleomorphological position and distance to ground water. Burial related aspects of diagenetic evolution show regional or local patterns (e.g. clay provinces), according to structural, thermal, or fluid flow evolution. For instance the meteoric (telodiagenetic) influence related to inversion uplift, is restricted to limited areas in Northen NL. The more pronounced transformations of the initial detrital composition, advanced mechanical compaction, and intensive illitisation are due to extended residence times in deep burial regimes.

The most abundant authigenic minerals in Rotliegend sandstones from the southern basin margin (as in other parts of the play from UK to southern Poland) are quartz, various carbonates, sulphates, clay minerals (illite, chlorite, rare kaolinite), and ferric oxide. Traces of bitumen witness the former presence of liquid HC and are widespread in many Rotliegend sandstones. HC fluids from organic-rich source rocks are a major control on red bed sandstone diagenesis. Comparative studies demonstrated that red-bed diagenesis may evolve very differently in neighbouring basin compartments depending on the availability of organic-rich rocks and the timing of organic maturation and migration (Burley 1986, Gaupp et al. 2004, Schöner & Gaupp 2005).

Figures: Basic groups of Lithotypes & (Sub)-Environments



Solms/Baunack in Gaupp et al. (2004)

2. Diagenesis and Reservoir Quality

Besides advanced mechanical compaction, Illitisation is the major factor of quality deterioration in the deeply buried Rotliegend reservoirs. Samples affected by meshwork illite show moderate to low porosities and varying intergranular volume, but largely reduced permeabilities. Authigenic illite is widespread and not limited to a certain sedimentary facies, but is particularly abundant around major fault zones (Gaupp et al. 1993, 2004) with close hydraulic contact to Carboniferous Coal Measures. Many “Tight Gas” Rotliegend sandstones contain abundant authigenic illite. Dense coarse plates of kaolin minerals, mainly dickite, occur in close proximity to Carboniferous Coal Measures, and are strongly related to feldspar leaching preceeding or synchronous with the time of illitisation (Gaupp et al. 1993). Bleaching of red beds, illitisation, bitumen impregnation, and late stage porositiy enhancement (intragranular pores) are a successive set of diagenetic features often present in Rotliegend gas reservoirs. The best permeabilities appear to be present in those parts of fields that were not accessible for illitising fluids during late Triassic to Mid / Late Jurassic times.

3. Rotliegend Diagenesis in cores

Most diagenetic phenomena relevant in the evolution of reservoir quality are not visible in cores. This particularly applies for authigenic clay minerals with varying effect on reservoir quality deterioration. Some important diagenetic aspects can be visualised in core material and will be discussed in the core workshop:

a) Primary red versus bleached (grey) facies
b) Bitumen impregnation along flow conduits
c) Evaporite mineral cementation (friable halite cemented sandstones, anhydrite-carbonate cementation)
d) Fractured lithologies with cementation, deformation bands etc.

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Some notes on Structural Geology from Rotliegend cores

H. Ligtenberg, J. Okkerman, M. de Keijzer, NAM Assen

A quick glance on the fault patterns at Rotliegend interval mainly shows a quite regular, simple fault pattern in many places, in between zones of more complex faulting. Although at first glance it appears simple, most of these fault systems have already formed at very early stage in the structural tectonic history of the region and have been reactivated at most, if not all subsequent tectonic phases. Observing the fault patterns in more detail, a clear distinction can be made between different fault types and regions with (slightly) different fault systems, suggesting presence of different structural domains. These may have an effect on fault zone properties and may cause inconsistencies when comparing faults from different structural domains when you are not aware of their existence.

Three major tectonic events have affected the region, which include the Carboniferous Variscan orogeny; the Mesosoic break-up of Pangaea and related opening of the Atlantic; and the mid-Cretaceous to Miocene deformation, associated with the Alpine orogeny. Variation in deformation style and intensity exists between the different regions of the Netherlands on- and offshore. For example, the Alpine inversion was very significant in the Broad Fourteens Basin, in contrast to the northern part of the Netherlands onshore.

This symposium and workshop focuses on exploration activities. In exploration we are predominantly interested in the prospect-bounding faults and their properties: are they open, closed (sealing) or are they behaving as baffles? Their properties depend on many factors, including: the amount of shale in the system (N/G); the orientation, strike of faults; the tectonic history, i.e. has the fault been reactivated or not? In the Rotliegend we observe different fault seal types: predominantly cataclastic sealing faults and shale gouge sealing faults. A brief overview and examples will be provided of the different fault seal types and their elements. 'Unfortunately', we do not often drill through faults, such that we can obtain an improved insight in the fault properties. However, studying faults in outcrops and cores assists in improving our understanding of Rotliegend faults. We should be aware that faults we observe in seismic are not single fault planes, but are actually complex zones consisting of a fault core (with sharp fault planes, breccia, etc.) and a fault damage zone (with deformation bands). We will study cores from different wells in the same field that show variation away from a major fault and will give us some insight in fault damage zone width, properties and variation, for example in fracture density.

An element in fracture style is the type of lithology (Zechstein carbonates, Ameland shales and Upper/ Lower Slochteren sandstones). Several cores will show different styles of fractures depending on lithology type and will illustrate fracture propagation and fracture arrestment. We will evaluate different fracture types, including: cataclastic fractures; clay-rich fractures, syn-sedimentary fractures; open fractures; cemented fractures; and reactivated fractures. Capturing the style and occurrence of fractures remains difficult, but is crucial in unlocking the tight gas areas in the Netherlands on- and offshore. Discussion at the symposium and around the cores will hopefully lead to interesting ideas and new suggestions to improve our understanding of fractures and detection of densely fractured zones.

The Groningen Field: Recent and Future Development

Joris Steenbrink, Hermann Priebe, Arnoud Sluijk and Niels Dijksman

The giant Groningen Field (100 TcF) provides swing capacity, volume and ramp up for the Netherlands and large parts of NW Europe in a changing and liberalising market. After more than 40 years of production, an integration of latest technologies in all subsurface disciplines is more than ever an essential part of current production strategy and future field development plans.

In 2003, a major integrated Groningen Field review was completed, covering long term field development as well as dedicated operational aspects. Existing 3D-seismic was reprocessed leading to significant overall data improvement. Together with the re-described cores and updated facies model, the new seismic data set has been used to revise the reservoir subdivision and property model, in line with the observed dynamic behaviour. A new field wide geochemical sampling was undertaken, which together with reservoir pressure, gas-water contact and structural data, provided a better insight of compartmentalisation within and at the periphery of the field.

Compartmentalisation is an important driver in further field development. Partly and unconnected blocks provide opportunities for new capacity development and new resource volumes. Current understanding indicates a good chance that the gas quality in these blocks might lie outside the Groningen contractual band and could be sold under more attractive terms. Capacity development from partly connected blocks is being combined with ongoing refurbishment of producing well clusters and compressor installation.

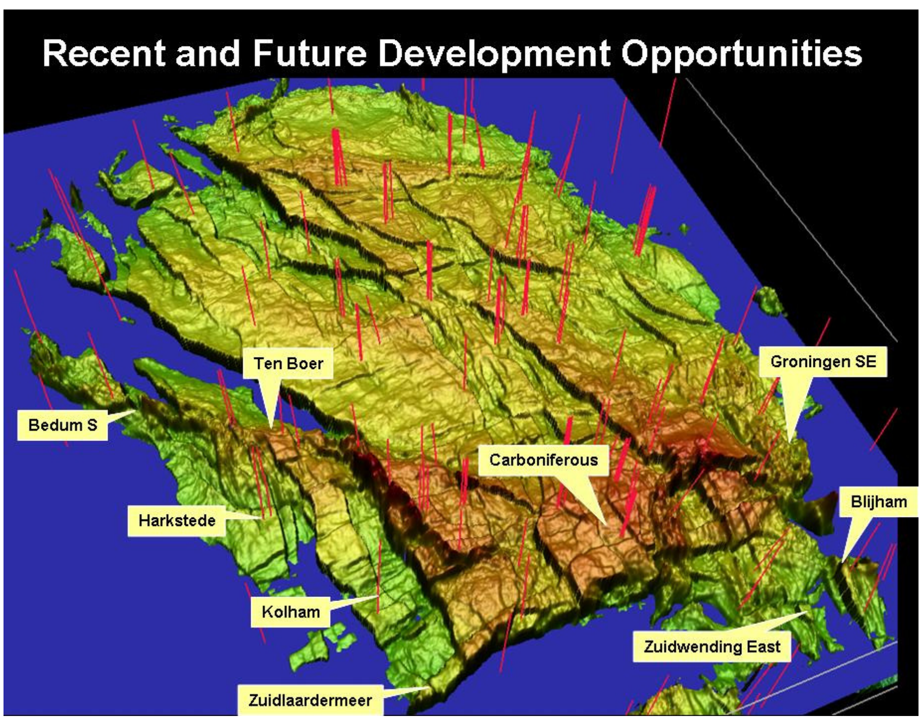

Figure 1: 3D view of the top Rotliegend depth map of the Groningen and peripheral fields (Groningen Field Review, 2003). Also indicated are well penetrations in red (clipped at some 1000m below NAP) and recent developments and future opportunities.

Call for Papers

SEPM Special Publication Series

The Permian Rotliegend in the Netherlands

Following up on the core workshop a publication is planned in the Special Publication Series of the Society of Economic Paleontologist and Mineralogists (SEPM). The main objectives of this publication are:

- To provide a summary of the present state of knowledge on the Permian Rotliegend in the subsurface of the Netherlands
- To present a set of reference cross sections in the subsurface illustrating paleogeography, facies and reservoir quality development
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The publication will for the first time present a comprehensive summary of the Rotliegend in the subsurface of the Netherlands covering sedimentology, stratigraphy, paleogeography, diagenesis, structural deformation and their impact on reservoir development as demonstrated by hydrocarbon field examples. An extensive set of core photographs will illustrate these features in form of an appendix. Target audience are sedimentologists, reservoir geoscientists and explorationists in industry as well as academia.

The call for papers is open to all interested parties in academia and industry and particularly field related studies are encouraged. Deadline for contributions is the 30th of June 2009. For any further information please contact the editors of the volume which are Prof. Reinhard Gaupp from the University of Jena (reinhard.gaupp@uni-jena.de) and Dr. Jürgen Grötsch from NAM (jurgen.grotsch@shell.com). Below, a table of content with confirmed contributors is provided.

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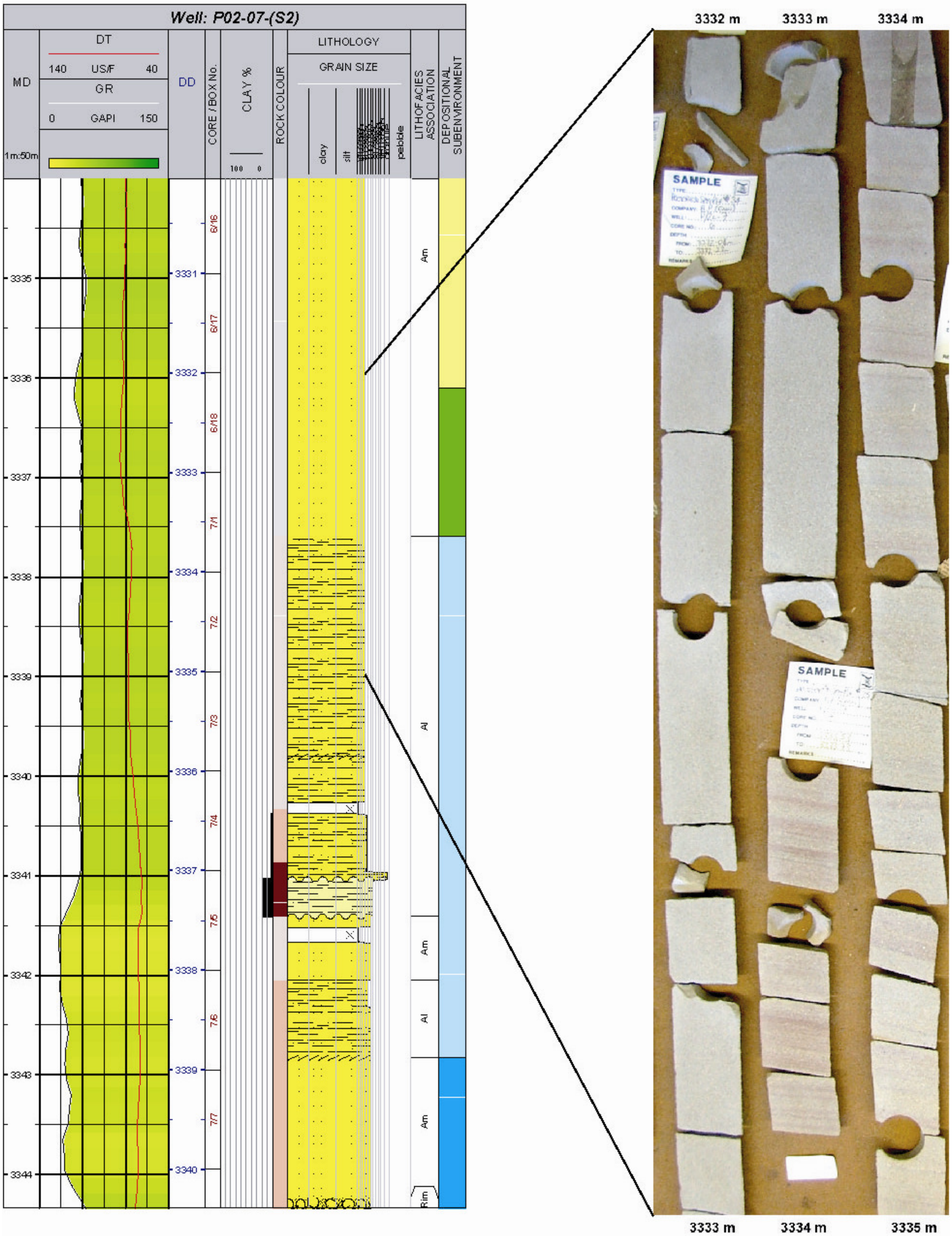
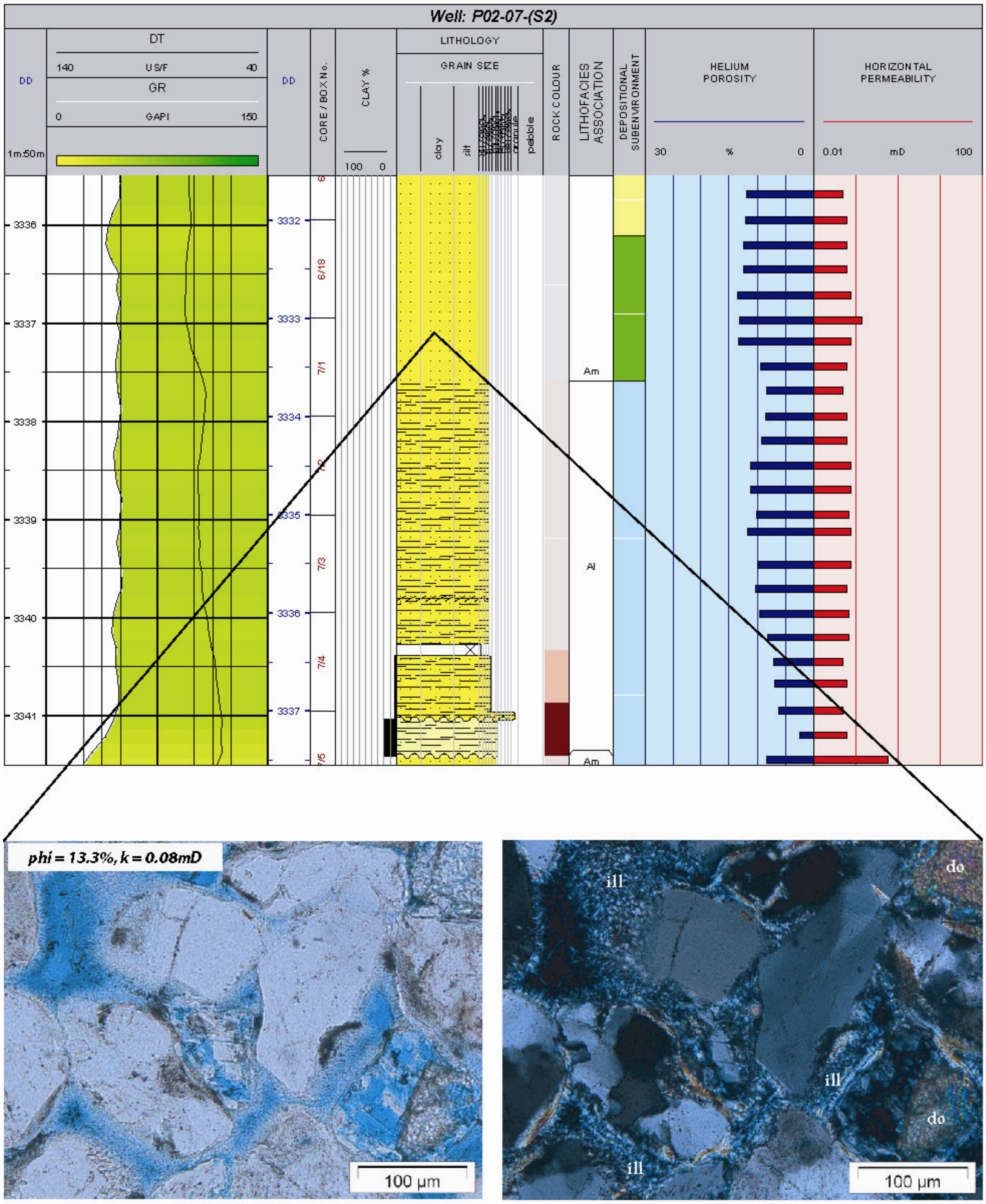


Well: P02-07-(S2): The three metres of core on the right side show the transition from reddish-grey, structured sands into bright-grey, structureless deposits of the uppermost Rotliegend interval (Weissliegend). The "Weissliegend" in Well P02-07 is characterised by fine-grained, moderately-well to well sorted, rounded sandstones. Grain size and thin section analysis indicate that those sands were originally deposited as both aeolian and fluvial facies. The sands of the "Weissliegend" commonly show poor to very poor reservoir properties due to the presence of abundant authigenic cements and clays (see following pages).



Well P02-07-(S2): Thin section of plug number 436 at 3333.20 m (DD), taken from a homogenised aeolian sandflat deposit. The sand is moderately-well sorted, fine- to medium-grained and mainly composed of rounded to subrounded poly- and monocrystalline quartz detritus. Feldspars are subordinate and commonly corroded, resulting in a fair amount of intragranular porosity (see central & lower right of the thin section photomicrographs). In the shown sample area total porosity is fairly high. Permeability is reduced by the high amount of authigenic grain-coating and fibrous illite (ill). The long illite fibrous locally form meshworks and pore bridges, significantly reducing pore-connectivity and therefore permeability. Minor cements are non-ferroan and ferroan dolomite (d).