Brief history of petroleum exploration in the Netherlands

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Most of the Netherlands is covered by a thick sequence of Pleistocene and Holocene deposits and it took a while before the deeper subsurface of the Netherlands was explored. In the nineteenth century a few wells were drilled that revealed parts of the deeper subsurface in the eastern and southern part of the country, where layers of Mesozoic and locally even of Paleozoic age come close to the surface or can be studied in outcrops. Modern exploration started in 1902, when a primarily coal and salt exploration program was set up by the government. Systematic petroleum exploration began after 1934, the year BPM, a predecessor of Shell, started looking for oil in the country. In the 25 years before the Groningen discovery there was active exploration activity in the country after a string of discoveries in the West Netherlands Basin in the west and discoveries at the southern edge of the Lower Saxony Basin, including the landmark Schoonebeek oil field discovery, in the east. Exploration after the Groningen discovery however is of a totally different magnitude. In this summary a brief overview is given of the most important petroleum exploration developments in the country. The history expands the review of Knaap & Coenen (1987), which has a more detailed account with respect to the older periods.

1.0 The first wells to the deeper subsurface in the Netherlands

At the start of the twentieth century hydrocarbon discoveries were few in Western Europe. The major discovery was the Wietze oil field (1859) north of Hannover. Some natural gas shows with a high content of hydrogen sulphide were encountered between 1904 and 1907 in boreholes in formations of Late Jurassic age in the Bentheim area in Germany. Drilling was carried out after the mapping of outcrops of Lower Cretaceous asphaltic layers and bituminous claystones. The first oil shows in the Netherlands were found a few years later, in a 1902-1924 drilling campaign by the State Service for Exploration of Mineral Resources (ROD), in boreholes in the southern flank of the Peel Horst. They were reported to occur in mid Oligocene bituminous clays. In the well 'America', spudded in April 1909, brownish clay with oil traces was found at 425 m. Between 428 and 429 m oil stained shale was encountered. There is some doubt whether these shows represent natural oil or grease used for drilling. The first flowing natural oil in the Dutch subsurface was found during another test by the ROD at the farm Vleerkemper, near Corle, west of the town of Winterswijk. Approximately 240 liters of oil were drained on February 23 and 24, 1923 from Zechstein anhydrites and Carboniferous sandstones (Knaap & Coenen, 1987).

Two days earlier some gas flow was reported. In total 1.5 barrel of oil was recovered after a mishap with explosives. The oil was reported at a depth between 1066 and 1083 m. The 1924 Gelria-1 and -2 wells at Lichtevoorde and Groenlo, north of Winterswijk, had oil shows as well.

1.1 The first systematic exploration in the early twentieth century

At the beginning of the twentieth century coal exploitation became attractive and the government became interested in systematic exploration outside South-Limburg. In 1902, supported by Law in 1903, gave the government a temporary monopoly on exploration of coal, (potassium) salt and after 1908 all other minerals including oil as well. Drilling started in the central eastern and south-eastern parts of the country. The national organization (ROD) was founded in 1902 to investigate possible mineral resources in the country for the state. After the drilling of a number of exploration wells that gave the first systematic insight in the deeper geology of the country, the organization was dismantled after 1924 when the freedom of exploration was restored as foreseen in the 1903 law.
The result of this first systematic investigation of the deep subsurface was the discovery of the horst and graben structure of the southern Netherlands. The successful coal exploration well Helenaveen-5a, proved the Peel Horst, where the Carboniferous was found at a depth of 940 m. The well found six workable coal seams (Stheeman & Thiadens, 1969). Carboniferous was also proven by the well Plantengaarde-1 in the Achterhoek in 1908. The main unconformities were discovered and even tectonic inversion was noted for the first time (Klein, 1913). The better understanding of the east of the Netherlands resulted in the local salt exploitation there. The Buurse salt mining concession was granted in 1918 and the Twente Rijn concession in 1933. The coal and salt finds together with the Zechstein oil-shows and the Corle oil find resulted in 1926 in an application “Gelria” for a combined coal, salt and oil concession. A concession was granted, without the oil, because the viability of the oil was not demonstrated. Gelria never became successful for various reasons. One of the reasons of the failure being the obsessive interest in the remote possibility of petroleum prospects.

1.2 The first petroleum exploration after 1935

The Bataafse Petroleum Maatschappij attracted by oil discoveries in Germany near Hannover and perhaps enticed by the Gelria application (Stheeman & Thiadens, 1969), commenced a systematic search for oil and gas in the Netherlands after 1934. In 1933 a law had been presented to parliament that restricted exploration freedom in five eastern and northern provinces to the benefit of BPM. Exploration freedom was restored in 1947. A gravity and magnetic survey over the eastern Netherlands was acquired. Drilling started in Meppel and Coevorden in 1937. The second oil discovery in the Netherlands was

serendipitous. In 1938 during an exhibition of "living in the Dutch East Indies" in the gardens on 'De Mient' in The Hague oil was found (Bodenhausen & Ott, 1981). The demonstration of a light rotary rig intended to drill a hole down to 500 m, spudded June 13 and discovered oil unintentionally. The show of asphalt-like oil, in De Mient-1 at 464 m in the Eocene, had no economic value or follow up, but stimulated exploration in the western parts of the Netherlands.

Important gas discoveries were made in Germany near Bentheim close to the Dutch border in 1938. In particular the Zechstein discovery well Nord Deutschland-1, caught the imagination. The well was drilled in 1938 and had a blowout that came under control after three months. The discovery sparked an extensive exploration campaign in the area.

Thereafter in the period 1935-1943 twenty-five exploration wells were drilled in the Netherlands. The deepest was just over 1000 m. Prior to the German occupation of the Netherlands in 1940, 12 dry holes were drilled. The main target were anticlines similar to the structures in the German Lower Saxony basin (Stheeman & Thiadens, 1969). Finally in February 1943 the Schoonebeek oil field (Visser and Sung, 1958) was discovered. Oil had been encountered in the Jurassic of the well Coevorden-2 (1942) but missed the lower Cretaceous sands that were known from Germany. The first to strike Cretaceous oil was Wintershall on the German side of the border. The BPM well Coevorden-3 close to the town of Schoonebeek made the discovery in 1944, on the Dutch side, at a depth between 803 and 828 m. August 1946, at the request of the Schoonebeek community, the field name Coevorden-East was changed to Schoonebeek (Reimering, 1948). The Schoonebeek heavy oilfield turned out to be the largest onshore oilfield of Western Europe.

The 1938 oil find of 'De Mient' activated exploration in the West Netherlands Basin (Bodenhausen & Ott, 1981). Drilling in 1944 and 1947 near Delft and 1952 near Berkel by NAM, did not find economic quantities of oil. An extensive seismic campaign initiated in 1947 together with a gravimetric survey gave an indication of potential hydrocarbon bearing structures and already in 1953 the first economic quantities were found in the Rijswijk field (Rijswijk-1) and Pijnacker (1955), with light oil in Early Cretaceous sandstones. A concession was granted in October 1955 and was expanded in 1957 covering large parts of the Zuid-Holland province after discoveries in De Lier (1955, gas), IJselmonde (1956, gas/oil) and Wassenaar (1956, oil). The Rijswijk concession led to production from ten oil fields with a total production in 1994 of 200 mln bbls (Racero-Baena & Drake, 1996), peaking in 1960. In 1947 the successor of BPM
NAM was founded as a joint Shell and Standard Oil co. of New Jersey (now Exxon Mobil) venture.
In the eastern part of the country, in the provinces Drenthe and Overijssel, seismic acquisition between 1947 and 1952 covered 67,000 km. This led to the discovery of a number of gas wells. The first major gas find was the second well west of Coevorden called Coevorden-West-2. The well showed in July 1948 gas at

the depth of 2785 m in the Zechstein. It was the deepest well in the Netherlands at that time. This first gas find represented a major new reservoir.
Noticeable in that period are the other gas discoveries in the Zechstein like Tubbergen (Zechstein 2, 3) in 1951. In 1955 gas was found in Twente near Rossum and a year later in De Lutte. Hydrocarbons were found in other formations as well. In De Wijk gas field a unique multi reservoir stack was discovered with gas in Tertiary, L. Cretaceous, Triassic, Permian (Zechstein and Rotliegend) and Carboniferous horizons. The discovery well was drilled in 1949 (Gdula, 1983; Bruijn, 1996). The nearby Wanneperveen field (Lower Cretaceous) was discovered in 1951.
Prior to the discovery of Groningen ninety eight exploration wells with a total of 257,653 m were drilled. The deepest well Dwingeloo-1 in 1955 reached a depth of 3,800 m. Improvements in seismic acquisition made it possible after 1955 to record reflections below the Zechstein salt (Stheeman & Thiadens, 1969).

2.0 The discovery of Groningen

The Rotliegend was hardly known in the Netherlands before the Groningen gas find. The first well drilled to marginal facies of the Permian Rotliegend is one of the first ROD wells, Helenaveen-5A [1905] (Geluk, 2005). The first exploration well in the province of Groningen went down in 1952. The target, of this well Haren-1, were the Permian Zechstein carbonate rocks, which were found in an anhydritic, tight basinal facies. The well was deepened and for the first time showed the 200 m -water bearing -Lower Permian Rotliegendes sandstone and thus proved the existence of an important reservoir below the Zechstein evaporites (Te Groen & Steenken, 1968). It was not the Rotliegend but the Zechstein that justified the important follow-up (Stheeman & Thiadens, 1969). They recall that the exploration concept for the next well based on a high near the “Hondsrug” lineament, a Pleistocene ridge, which has a “Variscan” direction i.e. parallel to the edge of the Russian Platform (sic), analogous to the situation in Rumania.
This follow-up well Ten Boer-1, spudded September 1, 1955, was stopped for technical reasons (a safety valve malfunction shut down operations) in the predominantly shaly upper section of the Lower Permian, just short of being the formal discovery well. These shale facies of the Rotliegend later called “Ten Boer Member” almost killed the Rotliegend as exploration target. Stheeman &Thiadens (1969) suggest that swabbing during pullout of the drill pipe gave enough gas production to justify later investigations in the Rotliegend. The well Ten Boer-1 at that time was completed as a small Zechstein producer.
Two additional wells at structural highs near Delfzijl and Slochteren were deferred in 1956 when the Suez crisis shifted attention to development drilling (Stäuble & Milius, 1970) in proven oil fields. It was not until the Slochteren-1 well (spudded May 29, 1959, near the village Kolham), positioned on the highest position on the culmination, found the Lower Permian Rotliegendes sands gas

bearing on July 22, 1959. The next well Delfzijl-1 (Te Groen & Steenken, 1968) that was spudded 26 January 1960, revealed only the upper part of the sequence to be gas bearing on what was thought to be a separate structure.

Seismic detailing, additional appraisal wells and the use of improved velocity data led to drastically improved maps, showing one giant field. The Groningen concession, covering the whole province of Groningen, was issued by Royal Decree (KB) May 30, 1963.

In the Groningen concession, some 27 smaller fields in addition to Groningen, have been discovered since 1963. The second largest onshore field is the Annerveen field, straddling the Groningen Drenthe provincial boundary, with about 75 mrd m^3 of initial in place volume (Veenhof, 1996).

2.1 Exploration policy changes

The Groningen gas find of 22 July 1959 changed Dutch energy policy and led to a new exploration phase onshore and offshore some years later.
The giant accumulation of 2,800 mrd m^3 gas changed also the conditions for concessions profoundly. The legal framework could hardly handle the interest of the international oil industry. The 1947 exploration freedom concept created chaos in 1959, after the competition heard of the gas find. Between May 1963 and December 1965, eight different companies applied for eighteen overlapping concessions in the Northern provinces. This complicated situation was brought to an end in 1965 with new legislation. It introduced an exclusive drilling permit, which does not guarantee the granting of a concession in case of succes. After December 1965, when the proposal was tabled, until the moment a new bill (Mineral exploration law 1967) became operational, companies actually postponed drilling.

3.0 Rotliegend exploration onshore after Groningen

The emphasis of exploration for oil after the discovery of Schoonebeek, shifted to gas after the Groningen find. Despite the fact that Groningen is situated at the Dutch-German border it was the United Kingdom that benefitted the most from the discovery. At first, the Rotliegend play hardly extended to the east. In Germany only a limited number of commercial Rotliegend fields were discovered (Groothusen, Wustrow). Many finds there showed very high nitrogen content. Much later, exploration based on modern seismic yielded more than 100 mrd m^3 reserves in northern Germany.
It was towards the west where the play really became successful. A large number of onshore discoveries and later even more successful exploration in the offshore area. For example the Grootegast field on the west side of the Groningen province was discovered at the end of 1960. The drive to the west was after 1964 supported by Rotliegend discoveries in the UK southern North Sea as well.

It is interesting to note that companies immediately started sedimentological research of the Rotliegend (Glennie, this workshop). K. W.Glennie, recalls his first steps in becoming an expert in desert sedimentation in 1963 when he was pulled off a study of turbidites because the discovery of the Groningen gas accumulation. Initially the sedimentological model of reservoir sand was not clear. There were discussions of the desert/playa model vs. a delta model. Glennie (this workshop) credits Eppo Omkens to be the first geologist to realize that the cores showed desert sediments.

For NAM a race started to keep the lead they obtained with the discovery (Interview Van Tellingen). A major goal was to apply for more concessions in order to secure acreage. Their aim was to find as fast as possible more commercial hydrocarbons to maintain the inside track they had with respect to the Rotliegend play. The major Annerveen accumulation, discovered by Annerveen-Anloo-1 in 1962, led to the concession application of Drenthe (granted in 1968).
In 1962 only three companies besides NAM were performing seismic surveys onshore and offshore, the next year six operators were active. Amoseas started seismic acquisition in the south, in Brabant and the southern part of Zuid-Holland. Soon acquisition shifted to the tidal flat area of the Waddenzee in the north where also Mobil was active. Acquisition of 2,860 km seismic in 1963 increased to 10,992 km during 1964. The number of wells mounted from four (1963) to thirty one (1964). The drilling was mainly concentrated in the northern regions of the country, Noord-Holland, Friesland and the Wadden area. The gas rush was demonstrated dramatically in 1964 on the Frisian tourist island of Ameland where 5 rigs were active between May and June. The Ameland field was discovered in that year with the well Ameland-East-1 drilled by Mobil in this period, but Nam was active on the island as well and drilled a successful gas well (Hollum-2).

3.1 Exploration in Friesland

The successes on Ameland were no measure for the rest of the Friesland province. There were certainly some Rotliegendes discoveries by NAM like Blija-Ferweradeel (1963), Tietjerk (1965), Ureterp (1965) and Suawoude (1966). These discoveries were mostly in the eastern part of the province close to the Groningen Friesland boundary. In the western part Zechstein salt seal was missing (see Van Wijhe *et al*., 1980) and Rotliegend exploration was not successful. Here discoveries were made in the Lower Cretaceous (Cottençon *et al*., 1975). Fields like Oudega-Akkrum (Amoseas, 1964), Harlingen (Petroland, 1964) and Warga (Petroland, 1964). The drilling of the larger Leeuwarden field followed after the discovery of the Warga accumulation. Follow-up wells in Eernewoude-1 and Nijega-1 (both Petroland, 1965), confirmed the Lower Cretaceous Vlieland play over the large Leeuwarden Field area. In 1966 drilling came to a halt and no wells were drilled after 14 December 1965 till 1968 because

of the new mineral exploration law. The Leeuwarden Concession was granted in February 1969 after some delineation wells had been drilled. In 1970 in a follow-up to the west, the Lower Cretaceous Zuidwal field was found in the Waddenzee (Perrot & Van der Poel, 1987).

A discovery without follow-up was the Harlingen Chalk discovery in 1964. Late Cretaceous Chalk can be found underneath large parts of the country, however the Harlingen gas accumulation is one of the few producing fields in the Chalk in the Netherlands. The structure was formed in the Oligocene, suggesting late charge (Van den Bosch, 1983).

3.2 Exploration in Noord Holland

In the Noord Holland province, a race was going on between Amoco, Phillips Petroleum and NAM. In February 1964 NAM had made a gas discovery in the Bunter of the well Wimmenum-Egmond-1. The other companies tried to diminish the relative advantage of NAM. In 1964 seismic acquisition of Amoco and Phillips reached a length of over 687 and 463 km. These companies spudded their first wells almost at the same time July 1964 only a few days before NAM, based on a discovery in the well Middelie-1, filed an application for a production concession which covered almost the whole province including a part of the IJsselmeer. Amoco found in 1964 gas in its first well Schermer-1 in the Zechstein-3. After a dry hole in Warmenhuizen-Krabbendam-1, gas was found in Heiloo-1 in the Bunter. The production test in the wells warranted commercial production and an application for the Bergen concession was filed immediately after the production test. Subsequent exploration resulted in the Rotliegend discoveries of the Groet (Groet-1) and Bergen fields (Bergen-1A) shortly after in 1965 (Van Lith, 1983). Amoco applied deviated drilling in the sensitive dune nature area.

The Middelie concession, now reduced in size, was granted to NAM in 1964. The Bergen concession surrounded by Middelie was granted to Amoco in 1965. The Bergermeer Rotliegend field was found in 1969.

Phillips had not been as lucky. A string of dry holes ended their exploration. Exploration attempts of Mobil were unsuccessful in Noord Holland as well.

In the northern tip of the province Petroland shot only 95 km seismic. After two dry holes on the island of Texel, gas was found on the mainland. The well Slootdorp-1 was spudded November 1964 by Petroland. It resulted in a Zechstein discovery and the concession Slootdorp in the north of the province.

3.3 The Sleen-2 blow out

The frantic drilling came at a price in 1965 (Van Tellingen, Interview). A blow-out of the exploration well Sleen-2 caused the rig to disappear in a crater lake created by the mishap (Milius & Van der Vlugt, 1967). The well had spudded November 2 1965 and on November 18 the first high pressure formations of the Triassic had been reached at 1840 m. The high pressure warranted a mud weight adjustment and about 100 m more were drilled into the Triassic. While pulling the drill bit in order to run the casing, gas outflow made the borehole unstable. The drill string was lowered again, but got stuck at 930 m at an obstruction. Circulation started but new problems arose because mud losses became increasingly serious in a shallow formation by December 1. By that date the bit had reached 1070 m but this was too shallow to avoid the high pressure gas flowing into the younger formations and small craters were forming around the derrick at the surface. Three o'clock that afternoon the first eruption took place and water fountains of 8 to 9 m marked the beginning of the end for the rig. Less than an hour later the drilling equipment had disappeared in a large crater lake. A relief well Sleen-3 was drilled 600 m of the original hole. That well reached 18 February the Sleen-2. February 21 the well was under control. Today a small lake remains.

For the past fifty years this has been the only blow out of an exploration well.

4.0 Offshore exploration after Groningen

The discovery of offshore oil and gas seemed impossible at the end of the 1950s, when only very little was known of the northwest European continental shelf. Although the oil industry already had considerable experience in developing oil- and gas fields in shallow parts of the offshore – notably in Venezuela, the Arabian Gulf and the Gulf of Mexico – the rather small size of producing oil fields in the Netherlands and Northern Germany did not stimulate exploration in a hostile and higher-cost area offshore. Seismic acquisition in the Netherlands had been started by NAM already in the late 1950s in the area adjacent to the shore between Hoek van Holland and IJmuiden. A few years later this survey was extended 30-50 km off the coastline with a total length of 26,778 km in 1963. The absence of an international agreement establishing sovereignty over the continental seas prevented offshore exploration (Glennie, 1998). Drilling was possible but within the territorial waters or from an island. The first offshore well in the Netherlands drilled -with the rig Triton - is the Kijkduin-Zee-1 well, which spudded September 4 1961, in the territorial waters near The Hague. After this well the rig stayed close to the coast and drilled the dry holes Scheveningen-Zee-1, Noordwijk-Zee-1 and Zandvoort-Zee-1.
These were not the first North Sea wells. From the island of Helgoland, a well was already drilled in 1934 (Reichsbohrung No. 503; Kockel, 1995). These

German and four Dutch wells were not drilled for the Rotliegend play as was developing after the Groningen discovery. Drilling offshore in the Netherlands for the Slochteren play had to wait because of delays in the Mining Legislation. In 1958, the first United Nations International Maritime Law Conference at Geneva resulted in the Treaty on the Continental Shelf, which was ratified by the Netherlands as late as 1968. Based on this treaty the borderline with the United Kingdom was agreed.
The Dutch offshore regime is governed by the Mining Law Continental Shelf 1965 and some important administrative orders concerning the terms and conditions of the permits and mining regulations. The offshore was divided in blocks for which exploration applications could be submitted to the government.
The first offshore concessions were awarded by Denmark in 1963, the United Kingdom and Germany followed in 1964 and Norway in 1965. The slow enactment of petroleum legislation for the Netherlands offshore prevented drilling to take place there until 1968. The Netherlands got its first offshore North Sea exploration license in 1968, five years after Denmark.

It was therefore in the United Kingdom that the first Rotliegend gas was discovered offshore. The first gas strike in the North Sea was initiated on May 20 1964, when a German consortium (Deutsche Nordsee Gruppe, with a.o. Mobil and Wintershall) spudded the first offshore well, Nordsee B-1 in the German sector of the North Sea (De Wijn, this workshop). The well found non-commercial Zechstein gas, with a nitrogen content of over 90%. A spectacular blowout of the well killed itself after a number of days (Knaap & Coenen, 1987). On the UK shelf, the first well was 38/29 with a spud 26 December 1964. The first gas well was drilled a year later by BP in 48/6, 70 km East of the Humber with the West Sole field find. This discovery ended in a tragedy after the rig, a converted barge with ten support legs, called 'Sea Gem' collapsed because of metal fatigue. It capsized, sank and 13 of the 32 crew members died December 27, 1965. This wild start causes safety to be an ongoing important issue in North Sea offshore exploration.

Gas discoveries in the northern regions of the Netherlands combined with information of the neighboring countries, confirmed quickly the extension of the Rotliegend gas play. In the United Kingdom, after the West Sole discovery, Shell/Esso already found in 1966 the giant Leman field (49/26-1, spud December 17, 1965). The United Kingdom information combined with the disappointing results in the German sector provided a better understanding of the geographical limits of the Rotliegend play. In the United Kingdom, the first disappointments with tight reservoir (48/13-1) or valid structures devoid of gas (49/19) because of inversion were found. Despite some disappointments, the early years of exploration in the wider Southern North Sea area are characterized by a high rate of discoveries.

4.1 Exploration 1968-1974 The offshore drilling effort

After the enactment of the Mining Law continental Shelf (1967) and the onshore "Search for Minerals Act" six operators were granted onshore drilling permits and offshore licenses were granted to eight companies. An explosive exploration effort ensued, particularly in the offshore. Seismic activities expanded feverishly followed with the drilling of twelve wells in 1968. The first regional seismic lines offshore were shot in the early 1960's by NAM. These lines gave NAM a head-start because they indicated a structural style similar to that present in the northern area of the Netherlands (Oele *et al*., 1981). Extensive regional seismic surveys were shot prior to the granting of the first offshore blocks in early 1968. The initial seismic interpretation showed large fault dip-closed structures at top Rotliegend level. The first true offshore well clearly outside the Dutch territorial waters K17-1 encountered a 275 m thick Rotliegend, a tight gas accumulation. This was a very disappointing start, considering that sixteen companies had applied for the block in the first exploration round (1968). The poor results shifted the exploration to the more northern blocks. The subsequent drilling in the Dutch blocks K7 (NAM, 1969) and L10 (Placid, 1970) were a success and followed by other successes in the K and L quadrants in the succeeding years. NAM had discoveries in K8, K11, K14, K15, K17, L13 (see Oele *et al*., 1981); Placid in K9, K12, L11, Petroland in L4 and L7 and Pennzoil in K10 and L8. The very prolific K15 block was only picked up in the second round of 1970 without competition (Manders, this workshop).

While the commercial limits of the Rotliegend sands appeared to be constrained to a relative narrow east-west-trending zone on the southern flank of the Southern Permian Basin, the Triassic Bunter sands, of excellent reservoir quality, were found to be far more widely distributed. High hopes for a major Bunter play were short-lived, because the Permian evaporites proved in most places to be a barrier to gas migration from the Carboniferous source. In the Netherlands, the significant Triassic gas discoveries were made much later. Offshore the first Triassic discovery was P6-1 (Meilink, 1984) in July 1968 (Mobil). The well encountered gas in the Zechstein as well, but was targeted to the Rotliegend, which was even more tight than K17-1 (d' Engelbronner, 2006). Both fields are situated in the inverted Broad Fourteens Basin. The next major Triassic find of L2 (NAM, 1968) did not get much follow up as did the discovery of the K13-A (1972) and K13-B (K13-2, spud August 1973, Bunter and Rotliegend gas) fields (Roos & Smits, 1983). The Bunter was initially no target in K13 and the Bunter gas was an exceptional case of spill from the Rotliegend in the layers above the salt. An important discovery after 1987 were the substantial Triassic fields by Amoco in the P15 block. The absence of Zechstein salt allowed migration of the Carboniferous gas into the Bunter.

The Zechstein rarely had good reservoir properties comparable to the earlier finds in SW Drenthe (Van Wijhe, 1981) and remained a secondary objective for

gas in selected areas. Few discoveries of Zechstein are commercial. For a long time P6 and Q8 (BP) were the only viable Zechstein discoveries offshore. The Carboniferous find in K4-1 (Tenneco, 1974), triggered interest in the D and E quads in the fourth exploration round (1976-1983).

5.0 Exploration 1974-1986 - More than gas

The first (non commercial) oil offshore was found by Tenneco in 1970 in F18 in the Dutch Central Graben. A flow of 325 m^3 of light (31 API°) oil was measured during flow tests from Jurassic sandstones at a depth of 2,500 m. Other oil accumulations in the Dutch Central Graben area were found in B18 and F17 by NAM in 1982 and in F14 by Statoil in 1986. These finds have not been developed so far, contrary to the oil discoveries in the inverted basins in the southern offshore. There in the Broad Fourteens Basin a number of oilfields in Lower Cretaceous sandstone were discovered in Q1 like Helm and Helder (1979), followed a year later by Hoorn (Roelofsen & De Boer, 1991). This led to oil finds in Kotter (1980), Logger (1982) by Conoco. Amoco had found the Lower Cretaceous Rijn oil field in P15 already in 1975; however the viability of the field was not established until 1982. Horizon (P9-2, Amoco) was found in 1982. Onshore oil discoveries in the West Netherlands Basin continued. In 1984 the well Rotterdam-1 found Cretaceous oil.

Gas exploration in this period was commercially more important than oil. Onshore a number of significant Rotliegend fields were discovered in the NAM production licenses like Marum, Bedum and Warffum (1975 and 1977).Offshore K15-FB (NAM), L12-FB (NAM), K13-C (Pennzoil, 1977), K13-D (Pennzoil, 1977), K15-FC (NAM, 1978), L11b-A (Unocal, 1978) were found.

After the deepening of the De Lier oilfield, Bunter gas was discovered in Monster (1983). A follow up in the Botlek-1 well in 1984 extended the Bunter play to the area south of the Rijswijk concession. Other finds were Papekop in the province of Utrecht.

Some 544 exploration wells were drilled between 1968 and 1986. Gas was found in 137 wells and 21 wells found oil. The deepest well reached a total depth of 6,011 m. The Rotliegend play was now generally known and detailed publications (Lutz *et al*., 1975, Van Wijhe *et al*., 1980) gave a good insight in the various play areas. Exploration activity was relatively low between 1974 and 1980. The chance to find another Groningen or Annerveen had been diminished and made the Netherlands less attractive. It was not the second oil-shock that caused a renewed interest in exploration. It was the 'small field policy' of the Dutch government that was instrumental in the renewed interest. It guaranteed offtake of the gas

of such fields by 'Gasunie' , whereas the Groningen field was used as swing producer mainly, produced during high demand winter peaks.

6.0 Exploration 1986-1995

Despite the collapse of oil prices in the late 1980's, activity remained high onshore and offshore in the following years. Contrary to other basins in the world, drilling was not down because the Dutch small field policy and also the positive effect of deregulation in the United Kingdom was felt in the southern North Sea Area as a whole. Besides these policy changes, new seismic techniques lowered drilling risk substantially. Exploration in the Rotliegend was highly dependent on quality of structural depth maps and new acquisition techniques and processing could provide this. The period was characterized by the acquisition of 3D seismic that improved the subsurface structural imaging below the Zechstein salt. Not only the entire Rotliegend play trend was covered by 3D seismic, many areas outside the Rotliegend fairway have 3D coverage by the end of the twentieth century as well.

The Rotliegend discoveries onshore get a new impulse after the better than expected gas find of Grijpskerk (NAM, 1990). After this new impulse, a number of gas fields are discovered in the Lauwerszee Trough area, called the 'Dutch Golden lane' (Corona, 2005). Some fields discovered by NAM in this area are Munnekezijl, 1992; Anjum, 1992; Saaksum, 1993; Vierhuizen, 1994; Moddergat, 1995.; Lauwersoog, 1996; Kollum-N., 1997.

Blocks close to the Groningen field contained significant amounts of gas (Zuidwending, 1988; Oude Pekela 1989; Lula/Kiel-Windeweer, 1997).

The discoveries offshore in this period were even more substantial. The number of Rotliegend fields increased with numerous discoveries by Elf Petroland in the blocks K5 and K6 (Biteau, this workshop) like K6-C, 1986; K6-D, 1988; K6-DN, 1989; K6-G, 1990; K5-D, 1991; K6-T, 1991. The discovery of the Rotliegend Markham field in 1987 recieved extra attention because the field straddled the Dutch/UK boundary (Myres *et al*., 1995).

Twenty years after the Bunter discovery in L2, a follow up was found in L5 (L5-5, 1988). In the southern offshore the P15 Bunter play (see Ames & Farfan, 1996) was expanded in P18 (1989). Bunter gas was found in the block P12 (1987) by Mobil as well. Onshore Bunter discoveries followed the Monster and Botlek discoveries. In Pernis-West-1, spud October 4 1987 (Van Veen, this workshop and De Jager *et al.,* 1996), Oud Beijerland Zuid-1 (NAM, 1990), Spijkenisse Oost (NAM, 1990), Spijkenisse West-1 (NAM, 1992) and other smaller discoveries like Andel (NAM) in 1991. Some new Bunter discoveries were made in the Waalwijk area as well. Gas was found

in Waalwijk-1 (BP, 1987) and in Loon op Zand (Waalwijk-Zuid-1, Clyde, 1991).

Bunter discoveries in the block F15 and L9 were also sizable. In 1986 Elf found gas in F15-4 (Fontaine *et al*., 1993), after an earlier unsuccessful attempt by BP (F15-2, 1982). . Gas had been found in 1973 by Phillips in L9-1 in the Rotliegend but it was almost twenty years later that the potential of the Bunter was realized by NAM in a number of L9 Bunter fields (De Jager & Barrio, 2003).

Tertiary (Pliocene) gas in the A&B blocks opened up a new play in the most northern area of the Dutch offshore. The low relief structures with relatively low pressure biogenic gas were very different from the normal gas accumulations (Duyverman *et al*., 1991). The A& B blocks had been already applied for in the first (1968) and third (1972) round. The first wells were drilled to deeper targets (A12-1, Tenneco, 1971; A18-1, NAM, 1974) and did not realize the shallow gas potential. NAM, Clyde and Wintershall found several Pliocene gas accumulations, but development of these finds were not attractive for development for a long time. Shallow gas was seen as a liability, a drilling risk. The first dedicated wells were drilled in 1987 and 1988 with A18-2 and A12-3. In the period 1990-1992 several accumulations were drilled like B13-3 (NAM), B10-3 (NAM), B17-5 (NAM), A15-2 (Clyde), A15-3 (Wintershall).

The exploration of the D and E quads yielded only a few commercial gas fields (D15-FA, 1985; K2-A, 1987) contrary to the developments in the adjacent area of the United Kingdom (see Besly, 1993).

Oil exploration in the Netherlands was disappointing and activity was certainly not stimulated by low oil prices. There were some discoveries. The Dutch Central Graben area saw the discovery of a major oil field. A small oil discovery in the Jurassic of the Dutch Central Graben had already been made by NAM in 1971 in the block F3. This F3-FA condensate accumulation was not economic at that time. The F3-FB Jurassic condensate/oil find in 1994 was a major find.

7.0 Exploration after 1995

After the 8th round (1992) it was decided not to have a fixed date for an exploration round. Since April 1 1995 there is a so-called 9th round. In contrast to previous rounds, the Continental Shelf is permanently open for exploration license applications. The results of this round after five years were called disappointing (Alblas, 2001). Also the industry demand to shorten the cycle time for prospect generation has come at a price (Corona, 2005).
There is a general decrease in number of exploration wells (Rosenkranz, this workshop) but the area is not yet creaming (Breunese *et al*. 2005).

Seismic is still the most important source of identifying prospects and 3D acquisition becomes the norm. Increasingly migration modeling is performed (Whitfield *et al*., 2005; Van Lingen, 2003). Increasing computer power makes PreSDM processing affordable. Amplitude anomalies and flat spot analysis becomes a reliable tool, even in sub salt Rotliegend reservoirs.
The last 15 years interesting Rotliegend discoveries were made in K12-13 (K12-G, 2000); F16 -3x (F16-E, 2001 Wintershall) and L5-B & C (De Wijn, this workshop). Near field exploration still yields gas fields in blocks K2, K5, K12 and K15 for the Rotliegend. More fields were producing from the Carboniferous with in K4 combined Rotliegend and Carboniferous and D12-A (D12-6, 2002, Wintershall) Carboniferous (De Wijn, this workshop).
New Bunter discoveries in G14 and G17 opened up a new exploration area north of the Terschelling Basin on the Schill Grund High. After a Bunter gas find in 2000 in G17-4, the well G14-2 in 2002 had gas shows. The subsequent 2003 well G14-2st warranted a development (2005) of the G14-A and G14-B, G14-C and G17-S (Drijkonigen, this workshop). In 2001 Clyde announced an unusual large Bunter gas discovery in the southern offshore Q1/Q4 area (Van der Weerd, 2004). In the P15/P18 area in 2003 three new discoveries for the Bunter were made by BP.
In the southern offshore, oil was found by Amoco in P11-3 (1996) in the Triassic Volpriehausen and in clastic fringe facies of the Zechstein. The oil is now developed as the 'De Ruyter Field' (Blom *et al*., 2008). In the northern offshore area Unocal found with the F2-5 well the first Chalk oil field on top of a Zechstein salt dome. The first well tested mainly water but the well F2-5 drilled by RWE, encountered 76 m oil and they developed the field 'Hanze' with first oil in 2001 (Price *et al*., 2002).

8.0 Conclusions

Exploration of the Dutch subsurface has made the Netherlands an important hydrocarbon producer. The Jurassic source rocks have yielded many oil fields. The Carboniferous source rock gave the country its important position in the energy supply for Western Europe. What started with a gas find in the Zechstein of Coevorden-West in 1948 led to the discovery of Groningen in 1959 and resulted in over 400 smaller gas fields in various formations. The total reserves in these small fields is about halve the reserves of the giant Groningen field.

Most of the "small" fields have been found in the Permian Rotliegend and new finds are still being made particular in the Rotliegend and Bunter. Exploration activity has declined the last decade and the many smaller fields are reaching the tail-end or will stop producing in a few years. This, combined with the aging infrastructure, is a major concern for future exploration. When existing platforms

have disappeared, it will be economically not attractive to explore for small prospects. The estimated undiscovered exploration potential ranges between 165 - 380 mrd m3. (Rosenkranz, this workshop). A part of these prospects are very small or have unfavourable reservoir properties. Nevertheless the question has to be answered how much of this resource will be left behind if there is not sufficient exploration activity. Rosenkranz (this workshop) describes a number of scenarios. It is clear from the calculations that there are enough attractive prospects left that can be drilled economically with current prices. When the announced fiscal measure will materialise, this number is even higher. But time is of the essence and the current exploration activity level seems to be insufficient to explore and develop a large part of the presently known prospects.

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