

## RESERVOIR GEOLOGY, STRUCTURAL FRAMEWORK AND PETROPHYSICAL ASPECTS OF THE DE WIJK GAS FIELD<sup>1</sup>

J. E. GDULA<sup>2</sup>

### ABSTRACT

Gdula, J. E. 1983 Reservoir geology, structural framework and petrophysical aspects of the De Wijk gas field. In: J. P. H. Kaasschieter & T. J. A. Reijers (eds.): Petroleum geology of the southeastern North Sea and the adjacent onshore areas (The Hague, 1982) – Geol. Mijnbouw 62: 191-202.

The De Wijk gas field is situated near the town of Meppel in the Dutch province of Drenthe. It produces gas from Carboniferous, Triassic and Tertiary. The largest gas accumulation is contained within a system of Triassic reservoirs and is trapped in a broad salt induced structure some 10 by 11 km. Within this structure Triassic sediments, ranging from the Lower Muschelkalk Member in the east to the Main Claystone Member in the west, subcrop with marked angularity on the Late Kimmerian erosion surface. Vertical sealing is provided by Lower Cretaceous shales and marls which unconformably overlay the Triassic sediments.

So far economic gas production has been established from the shallow Basal Dongen Tuffite Member in the lower part of the Tertiary, from the Triassic Rogenstein oolite, Volpriehausen Sandstone and Lower Muschelkalk members, as well as from a small Carboniferous reservoir. The fact that gas is produced from the Basal Dongen Tuffite, Rogenstein oolite and Lower Muschelkalk makes the De Wijk field unique among Dutch gas fields; nowhere else in The Netherlands are any of these reservoirs gas productive. The reservoir properties of the Triassic reservoirs are due to diagenetic effects; in particular to leaching of anhydrite during the Kimmerian erosional phases.

### INTRODUCTION

The De Wijk gas field (Fig. 1) is unique amongst Dutch gas fields as it produces from a series of lithologies that do not act as reservoirs anywhere else in The Netherlands. It is the most easterly of a series of three gas fields, the other two are collectively called the Wanneperveen field.

Within the De Wijk field itself gas is produced from a system of Triassic reservoirs, from the shallow Basal Dongen Tuffite reservoir in the lower part of the Tertiary and from a small Carboniferous accumulation. The largest gas accumulation is contained within the Triassic reservoir system where Ultimately Recoverable gas reserves are estimated to be some  $7.6 \times 10^9$  m<sup>3</sup>. To date, within the Triassic, economic gas production has been established from the Volpriehausen Sandstone, Rogenstein oolite and Lower Muschelkalk members. In addition, the Triassic Upper Röt Claystones within the De Wijk field and the Main Claystone Member in the nearby Wanneperveen field are also gas productive, although

only at marginally economic rates. With the exception of the Volpriehausen Sandstone none of these horizons are found to be gas productive anywhere else in The Netherlands.

The field was discovered in 1949 by the well WIJK-1 which proved the presence of economic gas accumulations in what was then termed the 'Triassic weathered claystone reservoir'

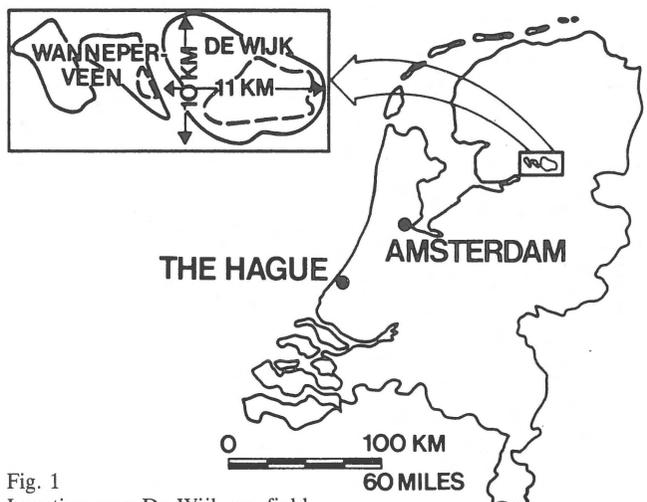


Fig. 1  
Location map De Wijk gas field.

<sup>1</sup> Manuscript received: 1982-11-27.

<sup>2</sup> Nederlandse Aardolie Maatschappij B.V.,  
P.O. Box 28, 9400 AA Assen, The Netherlands.

and in the Basal Dongen Tuffite reservoirs in the lower part of the Tertiary. Subsequent appraisal in the period 1951-1953 delineated the areal extent of the field and one well, WIJK-6, discovered a small gas accumulation in the Carboniferous. In addition two wells in this early round of appraisal drilling obtained some weak gas flows from the Zechstein-2 Carbonate. The field was further appraised in the early 70's when it was noted that a discrepancy existed between material balance and volumetric estimates of reserves in the Triassic reservoirs. This later round of appraisal led to the discovery of the Triassic Volpriehausen Sandstone reservoir but failed to

confirm the presence of Zechstein-2 Carbonate of sufficient reservoir quality. A further round of appraisal drilling was concluded in early 1982. During this last round of appraisal drilling the opportunity was taken to core the productive Triassic reservoirs and the shallow Basal Dongen Tuffite. These cores have aided greatly in the evaluation of the field and have given some insight in the origin of the reservoir properties in the producing Triassic horizons. It is the aim of this paper to discuss the origin of these reservoir properties and to show that they mainly arise from diagenetic processes associated with the Kimmerian erosion phases.

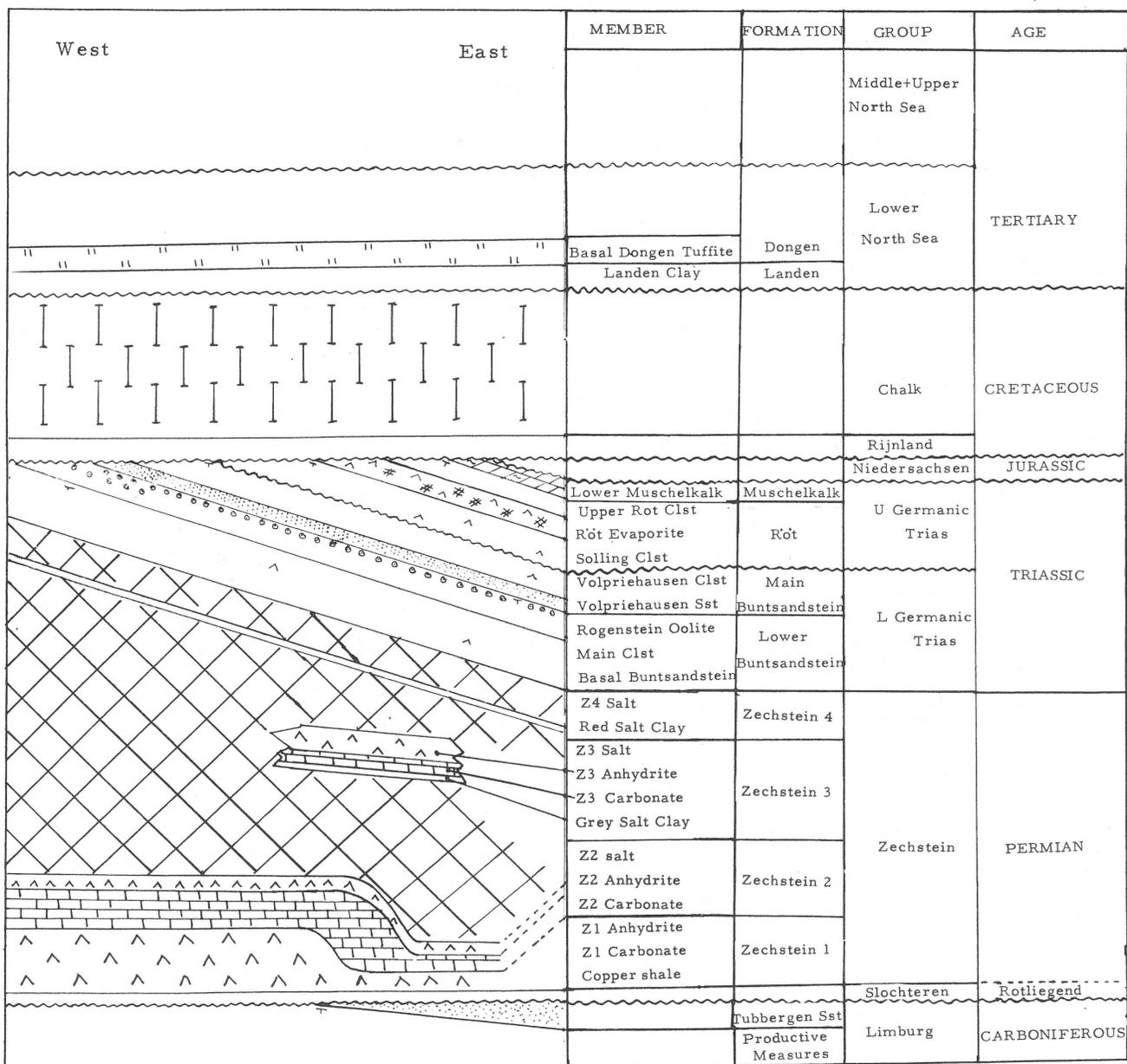


Fig. 2 Stratigraphy and stratigraphic relations in the De Wijk gas field.

## STRATIGRAPHY

## Zechstein Group

*Carboniferous and Rotliegend*

The oldest gas producing horizon in the De Wijk field is a 30m thick shaly sand sequence of Carboniferous age. Palaeontological evidence and regional correlation suggest that this sand is the basal part of the Tubbergen Sandstone Formation. Seismic and well data indicate that the Carboniferous strata in the De Wijk field have an overall gentle dip to the east with respect to the Saalian Unconformity surface and that the base of the Tubbergen Sandstone subcrops against the Saalian Unconformity in the western part of the field (Figs. 2 and 3). The Productive Measures, which directly underlie the Tubbergen Sandstone do not, in general, contain rocks of reservoir quality.

At top Carboniferous (Saalian Unconformity) level regional dips are to the southeast. However, block faulting to some degree obscures this regional picture (Fig. 3).

The Carboniferous is overlain unconformably by a thin (circa 5-10 m thick) Rotliegend conglomerate which is also of reservoir quality. Despite several appraisal wells only one small gas accumulation has been found to date in these conglomerates and the Carboniferous sequence of the De Wijk field. The Ultimately Recoverable reserves for this accumulation are estimated to be  $0.14 \times 10^9 \text{ m}^3$ .

The Rotliegend is overlain by the Upper Permian Zechstein sequence which consists predominantly of evaporites. All four cycles of Zechstein evaporite deposition are recognisable within the field although the original pattern of evaporite deposition has been markedly distorted by halokinesis. At the Triassic and Tertiary reservoir levels salt pillowing has created dip-closed structures (Figs. 4 and 5). On the crest of the pillow, the Zechstein reaches a maximum thickness of some 1000 m.

On the flanks of the De Wijk structure the Zechstein thins rapidly and to the west, in the Wanneperveen field, a progressive thinning of the salts takes place which coincides with a thickening of the anhydrites of the Zechstein-1, -2, and -3 cycles (Fig. 6). In the extreme west of Wanneperveen the Zechstein salts are absent and only a remnant anhydrite/carbonate package is found. The thickening of the Zechstein anhydrites is due to two factors. Firstly, the thickening of the Zechstein-1 Anhydrite is purely a depositional feature. This follows from a consideration of the facies of the Zechstein-2 Carbonates which directly overlie the Zechstein-1 Anhydrite. The thickest Zechstein-1 Anhydrite was deposited as thick wedges and mounds of gypsum along the rim of the early Zechstein Basin. Subsequently, shallow marine Zechstein-2 Carbonates were developed on and along the edge of these

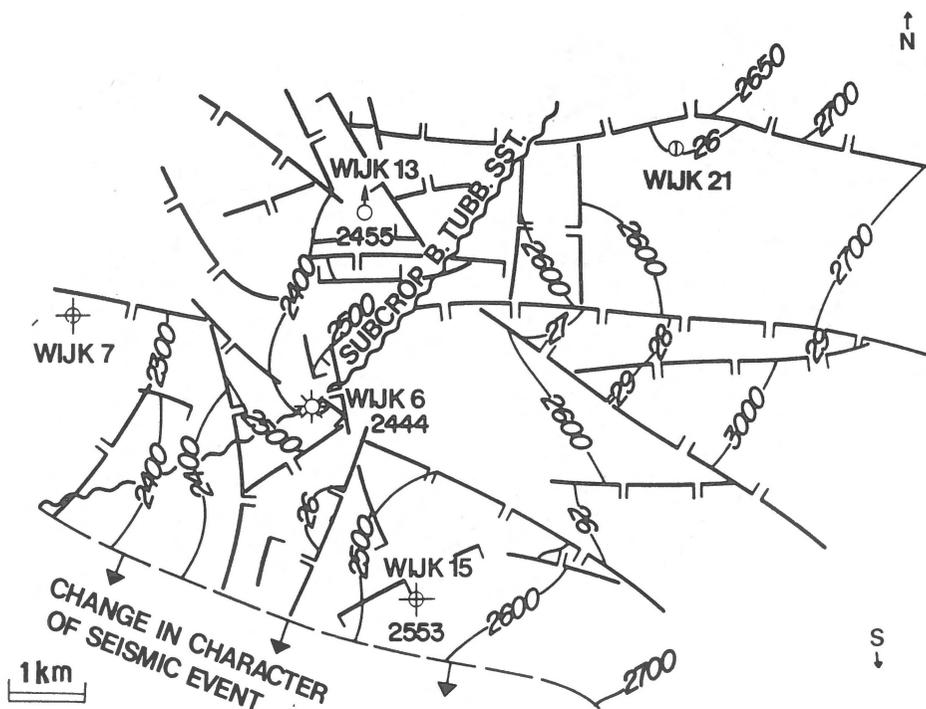


Fig. 3  
Top Carboniferous contour map.

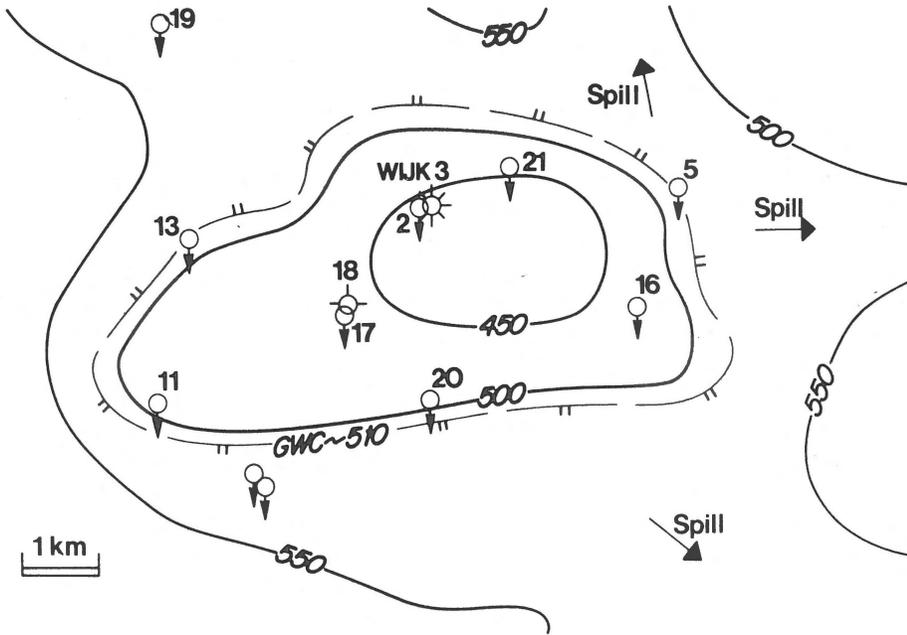


Fig. 4  
Top Basal Dongen Tuffite contour map.

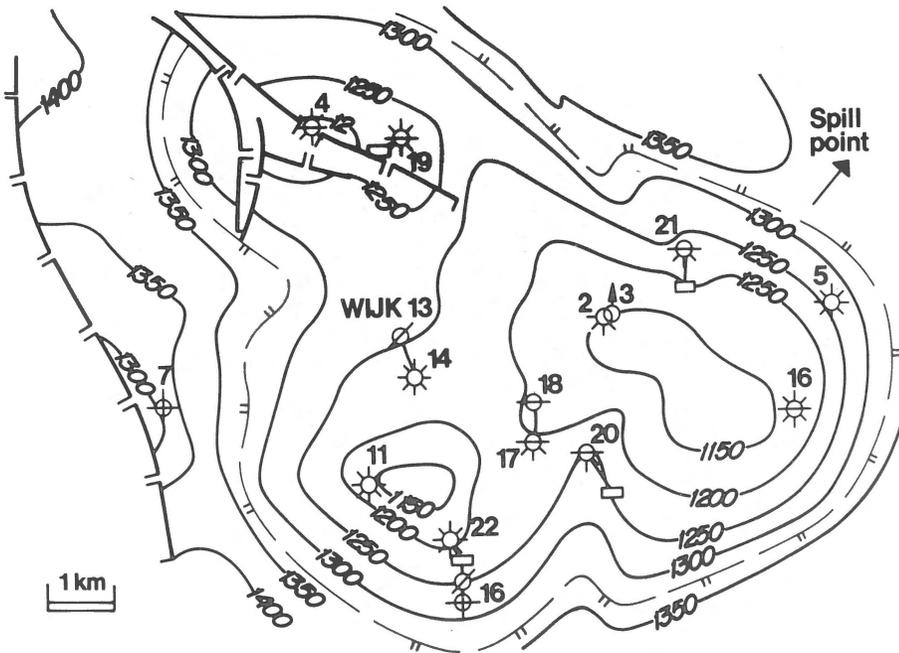


Fig. 5  
Base Cretaceous contour map.

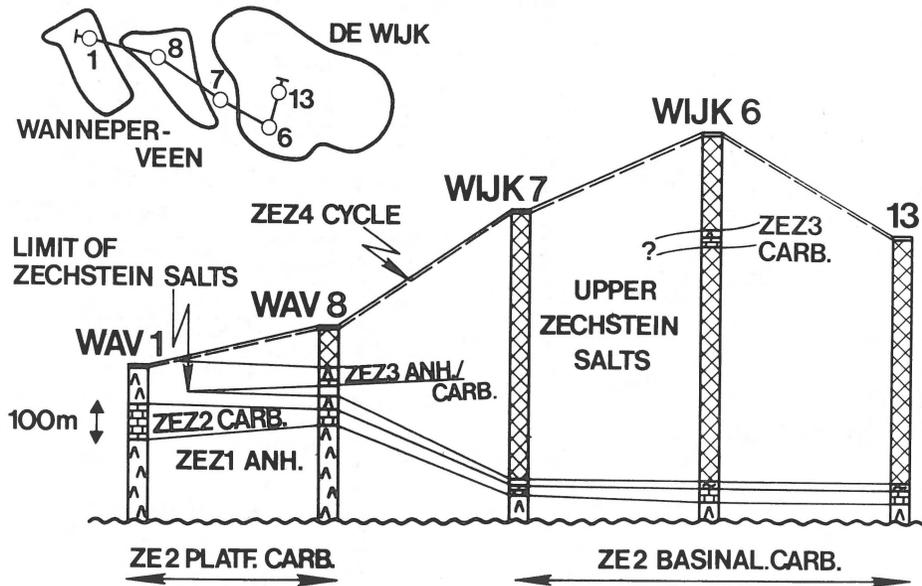


Fig. 6  
Stratigraphic section of the Zechstein sequence De Wijk/Wanneperveen gas fields.

thick anhydrite mounds. On the other hand deeper marine carbonates were deposited in the basin itself and are underlain by thinner Zechstein-1 anhydrites. This pattern of carbonate deposition is seen throughout the area with platform carbonates being found on the thick anhydrite in Wanneperveen and deeper marine carbonates being found on the thin anhydrite in De Wijk.

Secondly, the thickening of the Zechstein-2 and -3 anhydrites is due to salt leaching associated with the Kimmerian erosional phases. Evidence for this comes from consideration of the thickness of the overlying Triassic sequence, which thins markedly due to Kimmerian erosion proceeding westwards over the Wanneperveen field. To the west of Wanneperveen the Triassic is completely eroded and Lower Cretaceous directly overlies residual Zechstein. As such the Zechstein salts have been subjected to Kimmerian erosion, the effect of which is leaching of the salt leaving residual anhydrites. These anhydrites could have accreted on the Zechstein-2 and Zechstein-3 carbonate masses and lead to the thick anhydrites observed (a mechanism similar to that which forms anhydritic cap rocks on present day salt domes).

### Triassic

The Zechstein sequence is followed conformably by the continental Germanic Trias sequence. This in turn is overlain unconformably by Lower Cretaceous shales in most of the De Wijk field, although in the extreme eastern flank of the field a

thin onlapping Jurassic sequence is also present. The field at the Base Cretaceous Unconformity level is a broad salt induced structure some 10 by 11 km. The Triassic reservoirs have a common GWC at 1330 m TV NAP\* which is controlled by a spill point in the northeast of the structure (Fig. 5). In the eastern part of the field the truncated Triassic reaches a maximum thickness of some 700 m and the complete Buntsandstein, and part of the Lower Muschelkalk are preserved from the Kimmerian erosion phases (Fig. 7). Within the Main Buntsandstein erosion associated with the Hardegsen Unconformity has removed most of the sands and only the Volpriehausen Sandstone Member remains.

The Triassic formations subcrop with marked angularity against the Kimmerian erosion surface so that, proceeding in a westerly direction over the field, the Muschelkalk, Röt, Main Buntsandstein and Rogenstein are successively truncated. In the western extremity of the field the Trias has been reduced to a thickness of some 200 m, and the Main Claystone Member of the Lower Buntsandstein subcrops against the unconformity surface.

### Jurassic

In the extreme east of the field the Upper Jurassic Niedersachsen Group onlaps the Lower Muschelkalk. Seismic data clearly indicates that the Jurassic thickens rapidly to the east, and that the Lower Jurassic Altena Shales are also present downflank on the De Wijk structure.

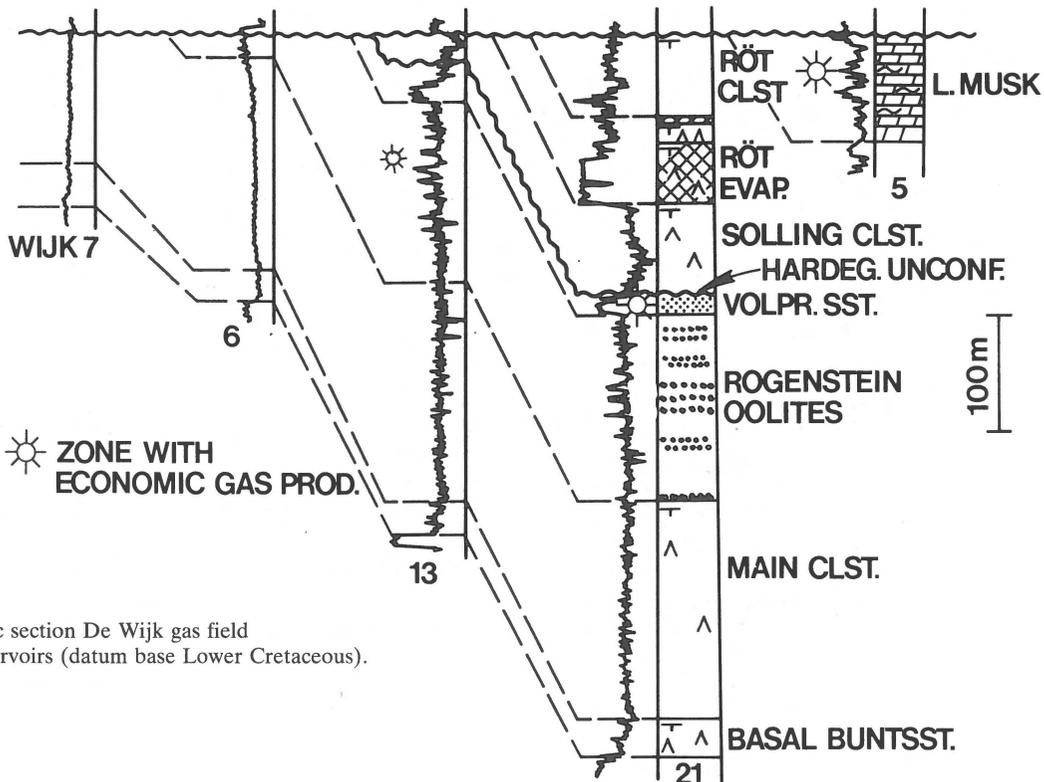


Fig. 7  
Stratigraphic section De Wijk gas field  
Triassic reservoirs (datum base Lower Cretaceous).

#### Lower Cretaceous

The Lower Cretaceous Vlieland Shale unconformably overlies the Triassic in most of the De Wijk field. These shales provide the vertical seal to gas migration for the Triassic reservoirs. Isopachs of the Vlieland Formation define a N-S trending zone of minimum thickness passing through the western part of De Wijk and the most easterly block of the Wanneperveen field. This coincides with the axis of salt diapirism. To the east and west of this ridge the Vlieland Formation thickens quite rapidly and in the western part of the Wanneperveen field some 30 m of Vlieland Sandstone of excellent reservoir quality is found lying on the Triassic Main Claystone Member. Within the De Wijk field the Vlieland Sandstone is generally absent although some wells have penetrated a thin (circa 5 m thick) sequence of this formation. These units are generally associated with local depressions at the level of the unconformity surface which probably formed preferential deposition sites during the Early Cretaceous transgression.

The Vlieland Formation is overlain conformably by the marls and shales of the Holland Formation. These sediments exhibit the same thickness pattern as the underlying Vlieland.

#### Upper Cretaceous Chalk

The Upper Cretaceous Chalk conformably overlies the Lower Cretaceous Holland Formation. Together they are in the order of 450 m thick in the De Wijk field. Chalk deposition was terminated by the Laramide tectonic phase which removed much of the Upper Chalks in the area.

#### Tertiary

After the deposition of the Chalk Group clastic sedimentation prevailed in the Tertiary, starting with the deposition of the Landen Clay Member in the Paleocene. In the De Wijk area this Member is overlain by the Basal Dongen Tuffite which is a producing gas reservoir. The reservoir is some 20 m thick and is composed predominantly of tuffaceous silts. The Tuffite itself is overlain by the Ieper Clay which provides the vertical barrier to gas migration. The structure of the field at the top Tuffite levels is very similar to the structure observed at Base Cretaceous level. The GWC is at 520 m TV NAP and like the Base Cretaceous structure is controlled by structural spill.

Fig. 8 (facing page)  
Geological history of the De Wijk gas field.

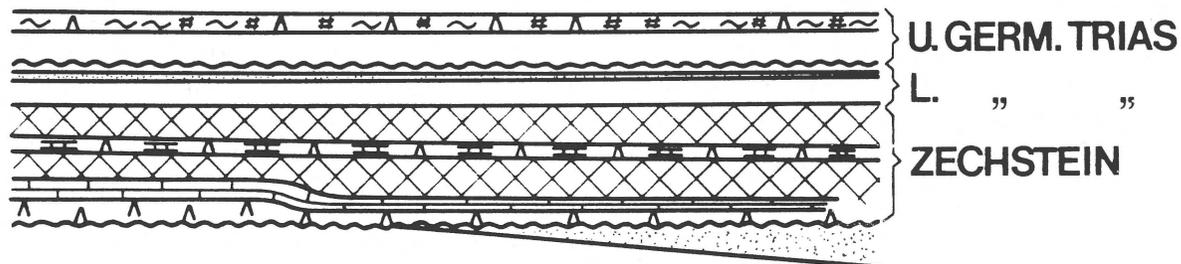
\* NAP = Dutch Ordnance Level.

E

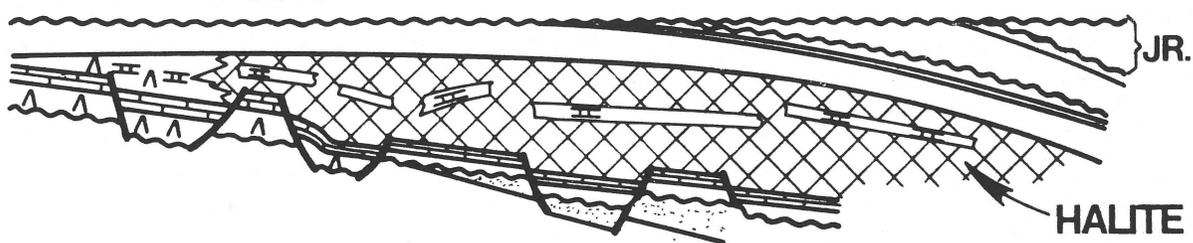
1. END CARBONIFEROUS



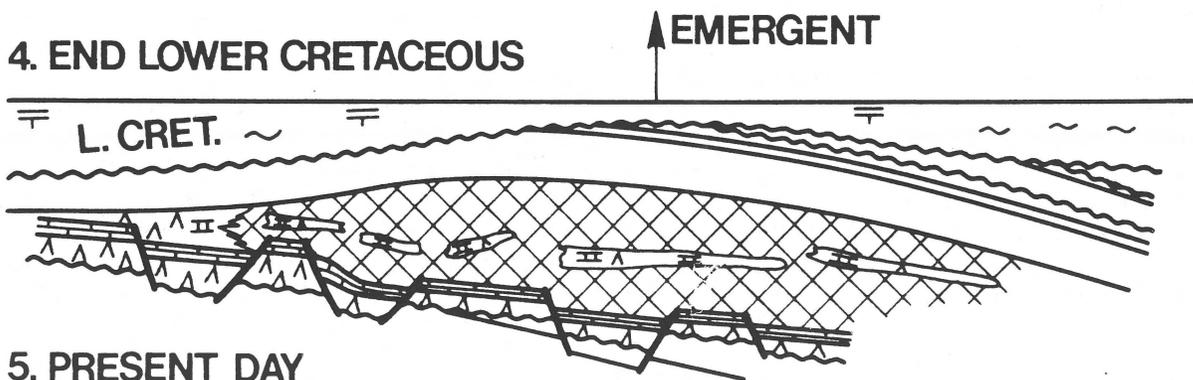
2. END TRIAS



3. END JURASSIC

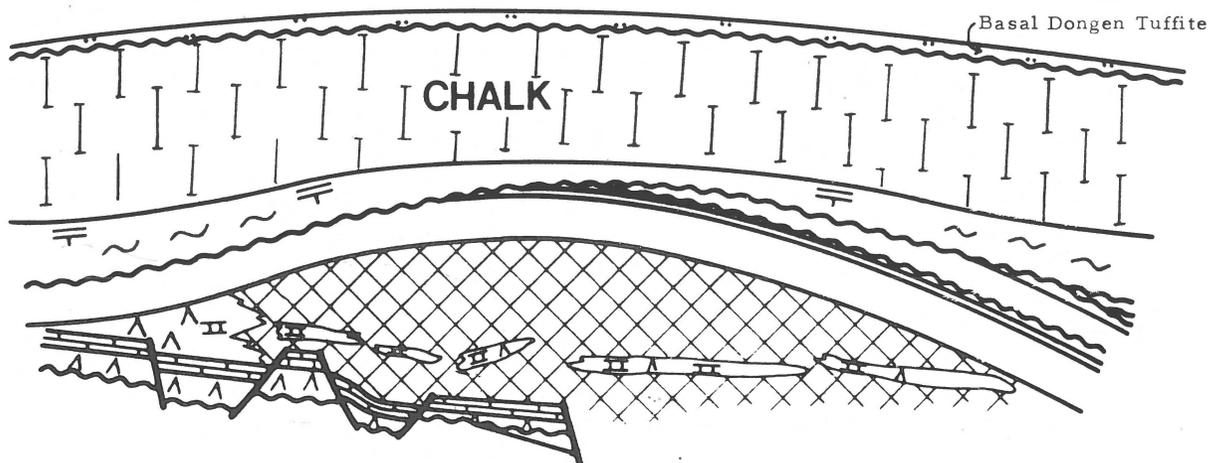


4. END LOWER CRETACEOUS



5. PRESENT DAY

TERTIARY



## STRUCTURE AND STRUCTURAL GROWTH OF THE DE WIJK FIELD

An understanding of the stratigraphy of the De Wijk field enables a simple structural model for the geological history. It successfully accounts for the unique distribution of the reservoirs by highlighting a structural development for the field which is not seen elsewhere in The Netherlands.

At the end of the Carboniferous the area of the present De Wijk field was a peneplain, beneath which the Tubbergen Sandstone and Productive Measures subcropped angularly (Fig. 8.1). Sedimentation was almost continuous throughout the Permian and Triassic with only one minor phase of erosion which resulted in the intra-Triassic Hardegsen Unconformity. Deposition commenced with the thin Rotliegendes conglomerate and was followed conformably by the deposition of the Zechstein evaporites and Triassic Buntsandstein sequence (Fig. 8.2). In the Jurassic the first period of major tectonic activity took place. At this time the De Wijk field lay in a tectonic transition zone (Fig. 9). To the west the Texel IJsselmeer High was being uplifted. In the De Wijk area, which lies on the flank of this major feature, the basement was uplifted, the highest uplift having occurred nearest to the Texel IJsselmeer High. This resulted in the generally easterly tilted top Limburg topography. Basement faulting, causing numerous small fault blocks, was also initiated at this time. To the east of De Wijk subsidence was taking place as the Lower Saxony Basin was being formed. Under the increasing overburden load the Zechstein salts, which underlay this basin, were mobilised and moved in a westerly direction into the De Wijk area (Fig. 8.3). In the extreme west of the area, however, the Zechstein salts were being leached and eroded and only a remnant residual anhydrite/carbonate package was left. This residual Zechstein could have formed an effective wall so limiting the westerly movement of the salt. The salt, unable to move west, would then pillow and result in the uplift of the

Triassic in the De Wijk structure. This, combined with Kimmerian erosion, led to the present day subcrop pattern of the Triassic at the Base Cretaceous unconformity surface.

The isopachs of the Lower Cretaceous (Fig. 5) indicate that in the Early Cretaceous the western part of the De Wijk field and the eastern part of Wanneperveen were still being uplifted as salt diapirism continued (Fig. 8.4). Following this, the Chalk was deposited and ended with the Laramide erosion phase. Continued Zechstein salt pillowing throughout the Cretaceous and Tertiary gave rise to the present day structure of the field at the Base Tertiary reservoir level (Fig. 8.5).

## RESERVOIR GEOLOGY AND PETROPHYSICAL ASPECTS OF THE TRIASSIC RESERVOIRS

### *Productive horizons and the origin of reservoir properties*

The most productive reservoirs in the De Wijk field are the Triassic Volpriehausen Sandstones, Rogenstein oolites and the calcareous dolomites of the Lower Muschelkalk. In addition gas is produced, albeit at marginally economic rates from the Upper Röt Claystones and, in the nearby Wanneperveen field, from the Main Claystone Member. It is important to appreciate that only the Volpriehausen Sandstone has primary reservoir properties. All the other lithologies owe their reservoir properties to leaching effects associated with the Kimmerian erosion phases. To understand the importance of these leaching effects in the creation of reservoir properties it should be realised that the Triassic was deposited in a hot arid climate in extensive playa lakes and inland sabkhas. The presence of pure evaporite beds (e.g., the Röt Evaporite) indicates periods when these lakes dried out completely. Under such conditions anhydrite commonly occurs. The removal of this syndepositional anhydrite by the Kimmerian erosion phases created many of the reservoir properties seen in the De Wijk field today. This will be illustrated in the following sections.

### *Rogenstein Oolite Reservoir*

The complete Rogenstein Oolite Member is some 165 m thick. Of this only some 40 m are of the oolitic grainstone facies, which are the main reservoir objective. Figure 10 shows the type log for the Rogenstein Oolites in the field. The oolites themselves occur in numerous thin beds up to a maximum of 5 m thick and are interbedded with sandy and silty claystones. They are readily correlatable throughout the field and reservoir continuity is excellent. Based on log character a five fold subdivision of the oolites into the  $\alpha$ ,  $\beta$ ,  $\gamma$ ,  $\delta$ , and  $\epsilon$  beds is currently used within the field.

To date production test data are only available for a well completed on the  $\alpha$  and  $\beta$  beds. The data indicate that these beds have a deliverability at 50 bar drawdown of some 450 000 m<sup>3</sup>/d.

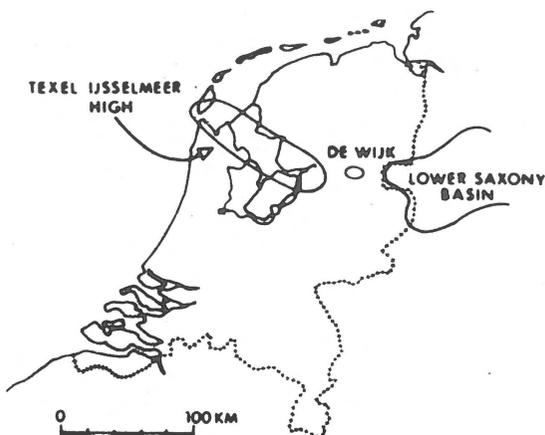


Fig. 9  
Relationship of the De Wijk field to major regional tectonic features.

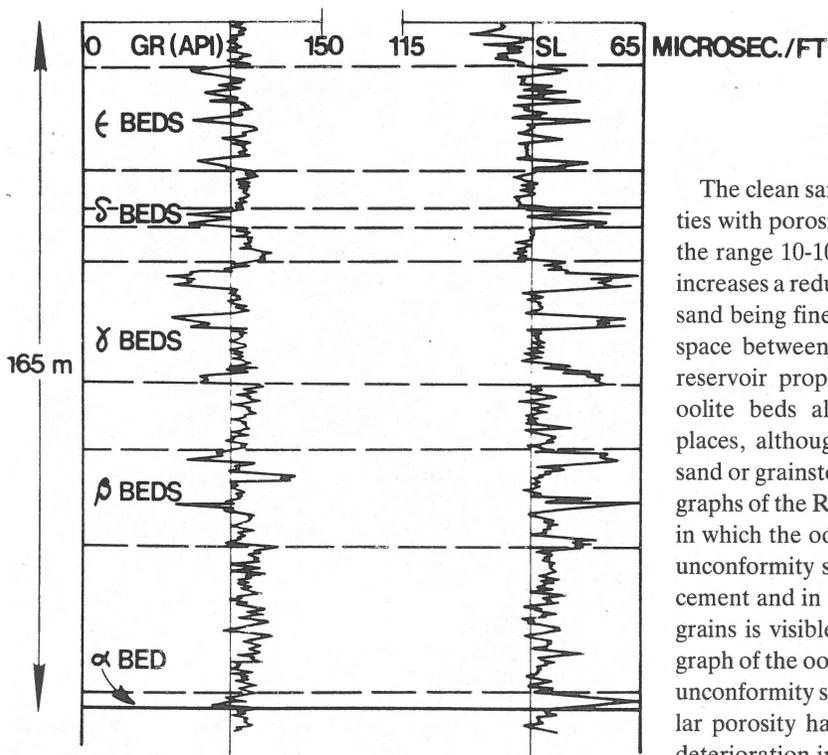


Fig. 10 Type log Rogenstein Oolites De Wijk field.

Although calcitic ooids dominate within the oolite beds, quartz sand is also an important constituent. In places the sand dominates and pure sandstones are found. The best reservoir properties are found in the clean oolites with porosities as high as 30% and permeabilities of over 1 Darcy (Fig. 11).

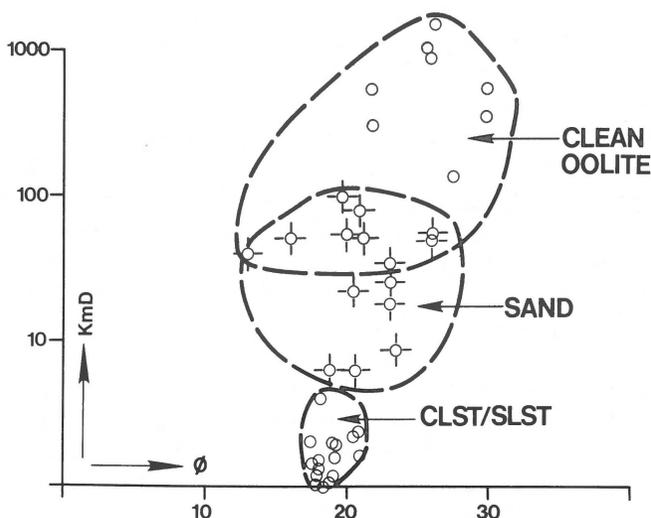


Fig. 11 Rogenstein Oolites Ø-K plot.

The clean sand beds also have reasonable reservoir properties with porosities in the order of 25% and permeabilities in the range 10-100 mD. Where the sand content of the oolites increases a reduction in porosity and permeability results. The sand being finer grained than the oolite tends to fill the pore space between the ooid particles leading to a reduction in reservoir properties. The siltstones which lie between the oolite beds also have favourable reservoir properties in places, although they are poorer reservoirs than either the sand or grainstone facies. Plates 1B and 1C show photomicrographs of the Rogenstein oolites taken from the well WIJK-22 in which the oolites subcrop directly on the Base Cretaceous unconformity surface. Notable is the total lack of interstitial cement and in one of the samples leaching of the actual ooid grains is visible. By contrast Plate 1A shows a photomicrograph of the oolite taken in the same well but 100 m below the unconformity surface. It can be seen that all of the intergranular porosity has been destroyed by anhydrite cement. This deterioration in reservoir properties due to anhydrite infill is observable on logs. Figure 12 gives the gamma rays and sonic log responses from well WIJK-22. The depth of leaching (palaeoground watertable) can be determined directly from the core data. Overlain on the sonic log from WIJK-22 (Fig. 12) is the sonic log of a well where the top of the Rogenstein oolite was penetrated some 100 m underneath the unconformity surface and was not therefore subjected to leaching. A decreasing separation of the two sonic logs is evident with increasing depth from the unconformity surface, indicating the increasing amount of anhydrite filling the pore space.

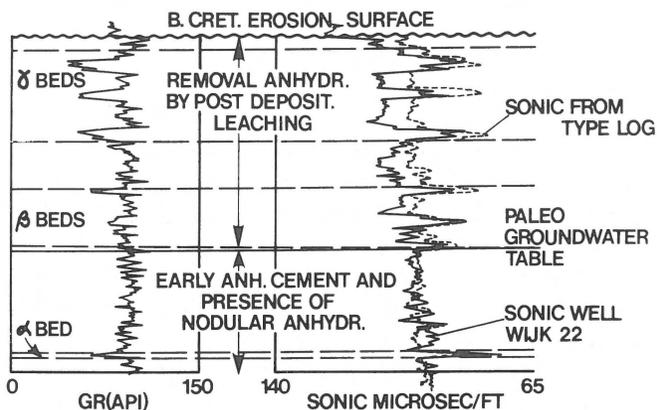


Fig. 12 GR and sonic logs of WIJK-22. The sonic log is overlain by a well with the same interval 100 m below the Base Cretaceous unconformity.

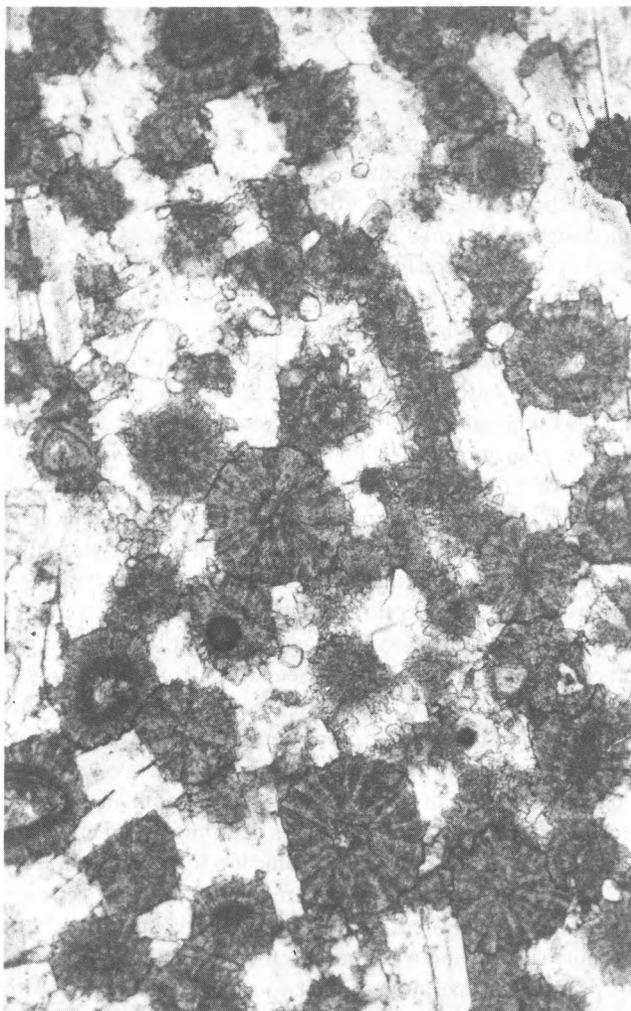


Plate 1A  
Photomicrograph; Rogenstein Oolite Member, De Wijk gas field (magnification x80). Thin section taken from  $\alpha$  bed in well WIJK-22. In this well the oolite was penetrated some 100 m away from the Base Cretaceous unconformity surface. Note total destruction of porosity by anhydrite.

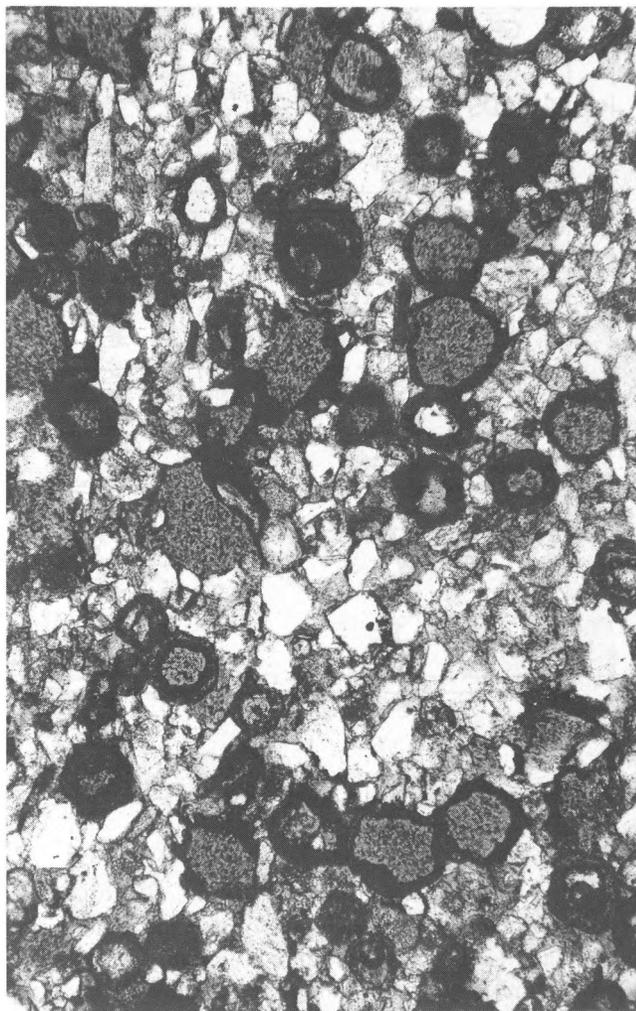


Plate 1B  
Photomicrograph; Rogenstein Oolite Member, De Wijk gas field (magnification x80). Thin section taken in sandy oolite from uppermost  $\gamma$ , well WIJK 22. Thin section has been impregnated with plastic to show up porosity which appears on this photograph as a grainy grey colour. Note high degree of intergranular porosity and in this sample leaching of the actual oolite grains is visible.

### *Lower Muschelkalk*

The Lower Muschelkalk Member subcrops against the Base Cretaceous Unconformity in the east of the field. It reaches a maximum thickness of over 100 m on the eastern flank of the structure before being progressively overlapped by Jurassic sediments. The interval consists of fine crystalline dolomite layers interbedded with more marly horizons. The main porosity type is a very fine intercrystalline porosity created by dolomitisation (Plate 1D). However, the leaching of nodular anhydrite has also been important in the creation of mouldic porosity. In some places these moulds have been enlarged to vugs due to progressive leaching. In addition cores show the common presence of fractures and collapsed breccia structures which also enhance the productivity of the unit. Well test

data indicates that the Lower Muschelkalk behaves like a system of coarse fissures in a very low permeability matrix. This is in agreement with the reservoir geology of the unit, the coarse fissures being the vuggy and fracture porosities and the low permeability matrix being the finely crystalline dolomite layers.

The core measured porosities are illustrated in Figure 13. The porosities are generally quite high; however, permeabilities are generally low and very variable. Of the 50 samples measured 42 had permeabilities too low to measure and the highest permeability measured was only some 26 mD. These low permeabilities are largely due to the very fine nature of the sucrosic porosity. However, post-depositional diagenesis and in particular the growth of late diagenetic clays (Plate 1D) has also reduced the permeability considerably.

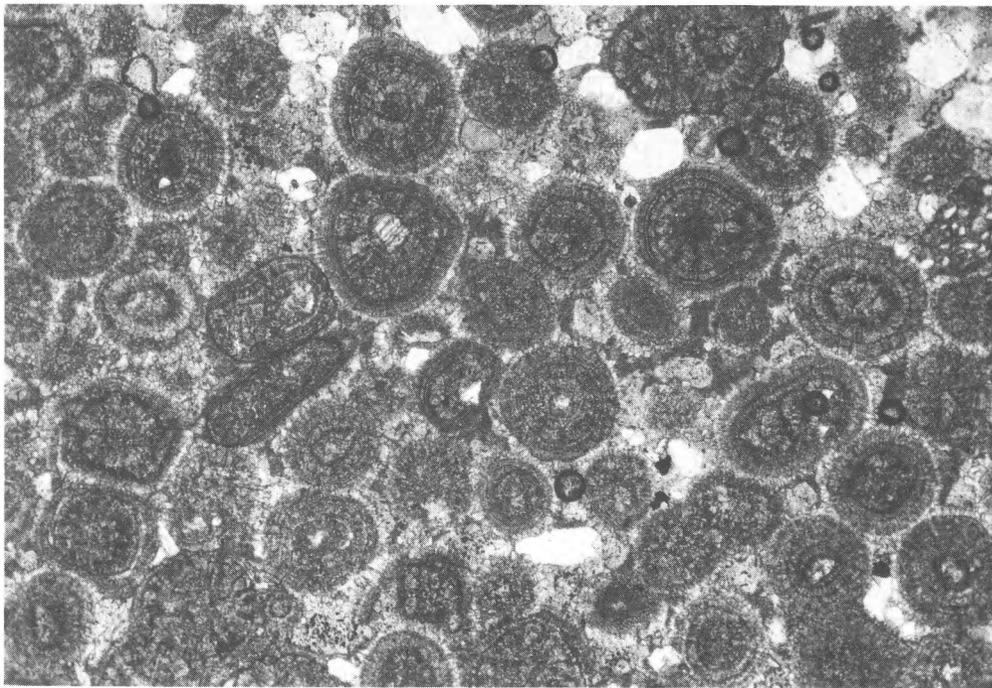


Plate 1C

Photomicrograph; Rogenstein Oolite Member De Wijk gas field (magnification x80). Thin section taken in oolitic grainstone facies  $\beta$  beds well WIJK 22. Thin section has again been impregnated with blue plastic to show up porosity. Intergranular porosity remains high although no leaching of the actual oolite grains is visible.

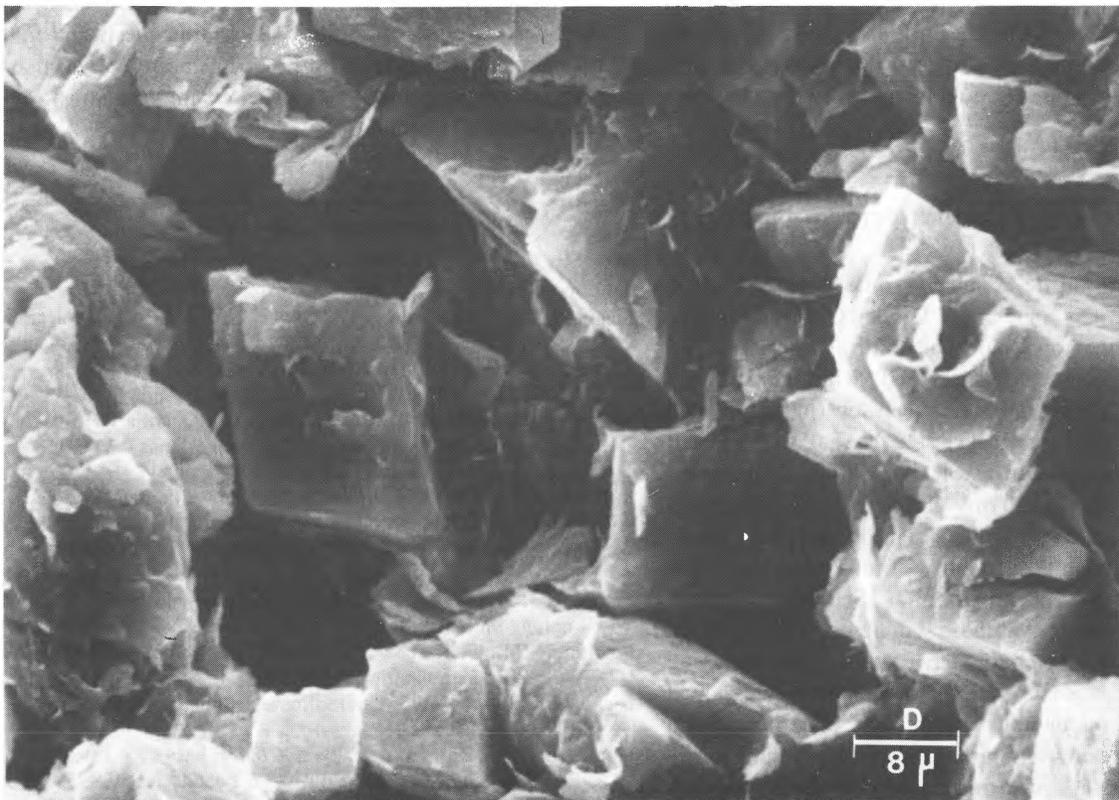


Plate 1D

SEM Photograph; Lower Muschelkalk Member De Wijk gas field. Note: fine crystalline sucrosic dolomite and development of intercrystalline porosity. Also shows detrital and authigenic clayminerals between and on the dolomite crystals.

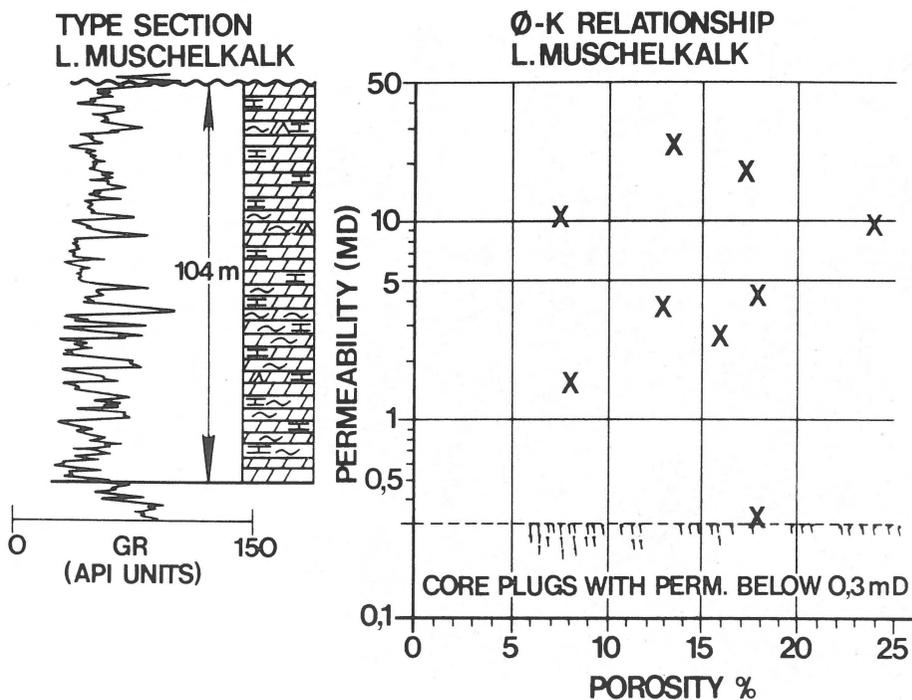


Fig. 13  
Core measured porosity and permeability values of the Lower Muschelkalk reservoir.

The productivity of the reservoir is quite low (ca. 9 000 m<sup>3</sup>/d at 9 bar THP); however, it does respond well to stimulation, and test data indicates a productivity at 50 bar drawdown of some 110 000 m<sup>3</sup>/d after acidization. Further diagenetic effects which locally reduced the porosity are the recalcitisation of dolomite and the infill of mouldic porosity by celestine cement.

1. The very well sorted nature of the silts;
2. A striking lack of diagenetic products, such as, in particular authigenic quartz. This results in a fairly loose packing of the quartz grains. In addition clay authigenesis and the presence of detrital clay is only of local importance, so that plugging of pore throats is not as common as might be expected in a siltstone.

### TERTIARY BASAL DONGEN TUFFITE RESERVOIR

The Basal Dongen Tuffite Member is some 20 m thick in the field. It is underlain by some 5 m of Landen Clay. This in turn rests directly on the top Chalk Unconformity surface. The Tuffite has been in production since 1955 through the well WIJK-3. The production rate is relatively low (initially 50 000 m<sup>3</sup>/d at 0 bar THP) due in part at least to the shallow depth and hence low pressure of the reservoir. An Ultimately Recoverable reserve of  $1.05 \times 10^9$  m<sup>3</sup> of gas is assigned to this reservoir. Both the Basal Dongen Tuffite and the Landen Clay are composed predominantly of siltstones and some unconsolidated clays and minor sands. Sedimentary structures and fauna indicate that these sediments were deposited in a shallow marine low energy environment. However, the presence of pyroclastic material, such as angular sickle shaped quartz grains and ferruginous volcanic ash, is fairly common and gives rise to the name Tuffite. Although the sediments are predominantly arenaceous core measured porosities are high (average 30%) and permeabilities range between 10 and 100 mD. These good reservoir properties arise mainly from two factors, viz.:

### BIBLIOGRAPHY

- Jacqué, M. & J. Thouvenin 1975 Lower Tertiary tuffs and volcanic activity in the North Sea. In: A. W. Woodland (ed.): Petroleum and the Continental Shelf of North West Europe, I Geology – Applied Sc. Publ. for Inst. of Petroleum, London: 455-465.
- Nederlandse Aardolie Mij. B.V. & Rijks Geologische Dienst 1980 Stratigraphic Nomenclature of The Netherlands – Verh. Kon. Ned. Geol. Mijnbk. Genootschap 32: 77 pp.
- Lutz, M., J. P. H. Kaasschieter & D. H. Van Wijhe 1974 Geological factors controlling Rotliegendes gas accumulations in the Mid European Basin – Proc. 9th World Petr. Congr. (Tokyo), 2: 93-103.
- Patijn, R. J. H. 1964 Die Entstehung von Erdgas infolge der Nachinkohlung im Nordosten der Niederlande – Erdöl Kohle 17.
- Pegrum, R. M., G. R. Rees & D. Naylor 1975 Geology of the North-West European Continental Shelf, Vol. 2.
- Richter-Bernburg, G. 1955 Uber saline Sedimentation – Z.dt. geol. Ges., 105: 843-854.
- Sanneman, D., J. Zimdars & E. Plein 1978 Der basale Zechstein (A2-T1) zwischen Weser und Ems – Z.dt. geol. Ges. 129: 33-69.
- Schlager, W. & H. Bolz 1977 Clastic accumulation of sulphate evaporites in deep water – Jl. Sed. Petrology 47: 600-609.
- Ziegler, P. A. 1978 North-West Europe: Tectonics and basin development – Geol. Mijnbouw 57: 589-626.