

THE DEVELOPMENT OF THE ZECHSTEIN IN THE NETHERLANDS¹

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ABSTRACT

Van Adrichem Boogaert, H. A. & W. F. J. Burgers 1983 The development of the Zechstein in The Netherlands. 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: 083-092.

The Zechstein Group can be divided into four, locally five, evaporitic cycles. The margin of the Zechstein basin passes through the southern Netherlands and adjacent offshore area. It is characterized by fringing carbonates and clastics. In the southern offshore area a strong influx of sand is evident. The Zechstein is absent by erosion on the Late Kimmerian Texel-IJsselmeer High. A few indications suggest that part of this High was a positive area during Zechstein times.

The first evaporitic cycle forms an E-W trending anhydrite platform in the central Netherlands and offshore continuation with a thickness of over 250 m. Halite is locally developed in this platform region. The major basinal halite sequences of the second and third cycle lie north of the platform. The carbonate members of these cycles have their main development along the basinward edge of the first cycle anhydrite platform. The fourth and fifth cycles are of modest dimensions and contain no carbonates.

INTRODUCTION

The Zechstein is a group of formations of evaporitic origin. It is of interest for the petroleum industry because it comprises reservoir rocks, cap rocks and source rocks.

The Zechstein is well known from Germany (regional studies of, amongst others, RICHTER BERNBURG (1955, 1957), who introduced the well known division in four wide-spread evaporitic cycles), from the United Kingdom (SMITH, 1970, TAYLOR 1981; TAYLOR & COLTER, 1975), from Denmark (CLARK & TALLBACKA, 1980) and from the eastern Netherlands (BRUEREN, 1959; VISSER, 1963).

From the Netherlands offshore data have now become available from 10 year old released wells. For the Netherlands onshore area an agreement has been reached between the oil companies operating in The Netherlands and the Geological Survey of The Netherlands which allows the Survey to use externally, under certain conditions, 5 to 10 year old exploration data (Fig. 2).

It is the purpose of this paper to complete the published regional Zechstein picture in the central and western part of The Netherlands and the adjacent offshore area.

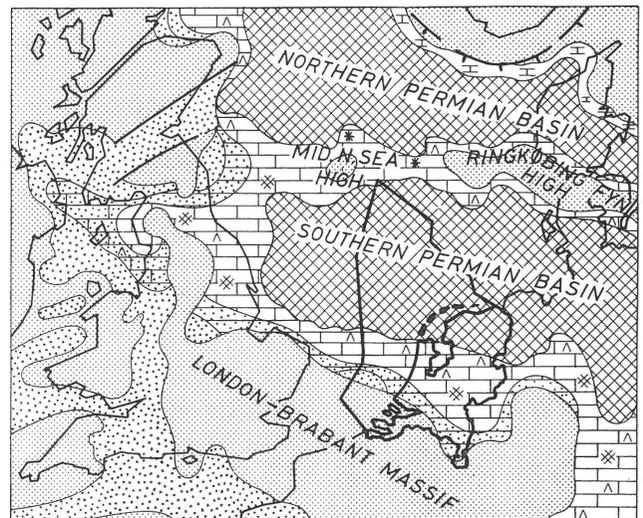


Fig. 1
Position of The Netherlands in the Zechstein Basin. Palaeogeography mainly after Ziegler (1975).

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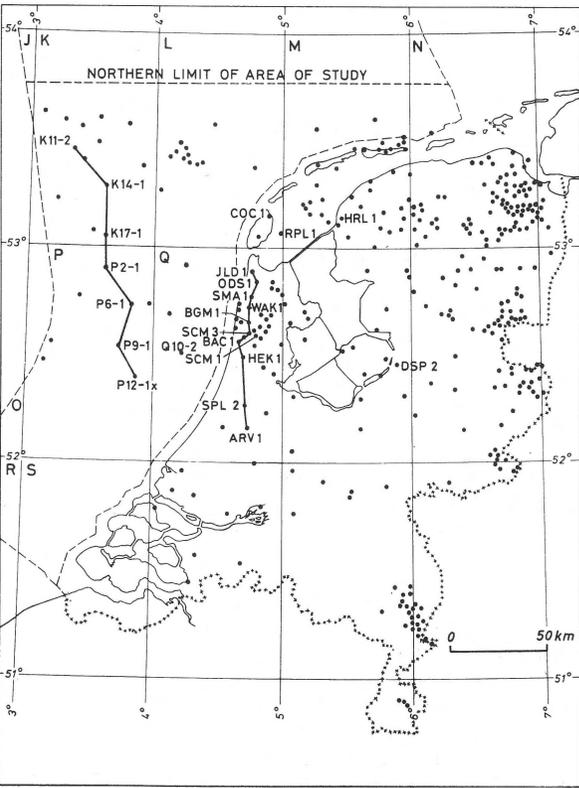


Fig. 2 Available wells that reached the Palaeozoic. The lines of the cross sections of figures 12 and 13 are indicated. For abbreviations see Table I.

GEOGRAPHIC SETTING AND STRATIGRAPHIC NOMENCLATURE

The Netherlands straddle the southern edge of the Southern Permian basin (Fig. 1). Thus, both basin centre and basin fringe facies are present in this area. The lithostratigraphic subdivision of the Zechstein Group in four formations, each consisting of a more or less complete evaporitic cycle is shown in figure 3. Diverging from the classification formulated in the Stratigraphic Nomenclature of the Netherlands (NAM & RGD, 1980) the basin fringe clastics and minor evaporites of Late Permian age have been assigned to the Zechstein instead of to the Bunter in order to be able to construct isopach maps showing the facies development of certain selected time intervals.

HYDROCARBON ACCUMULATIONS

The first Zechstein gas discovery in The Netherlands dates from 1948 by the Coevorden 2 well in Drenthe in the eastern Netherlands (DORSMAN, 1954). Further south, in the Twente area, gas was first struck in 1951 by the Tubbergen 4 well. Continuing exploration led to the discovery of numerous gas

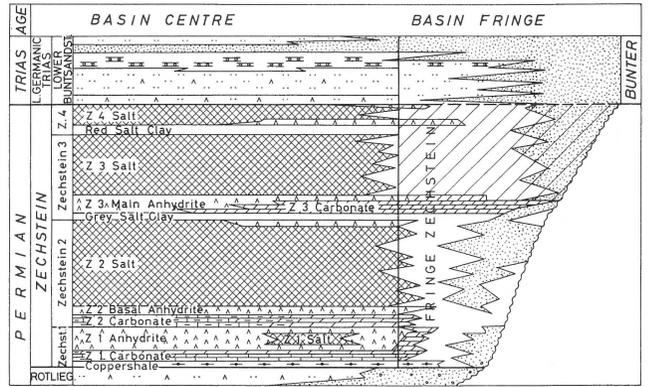


Fig. 3 Rock stratigraphic diagram of the Zechstein Group, modified after the Stratigraphic Nomenclature of The Netherlands (NAM & RGD, 1980). The obliquely hatched zone is assigned to the Zechstein in this paper.

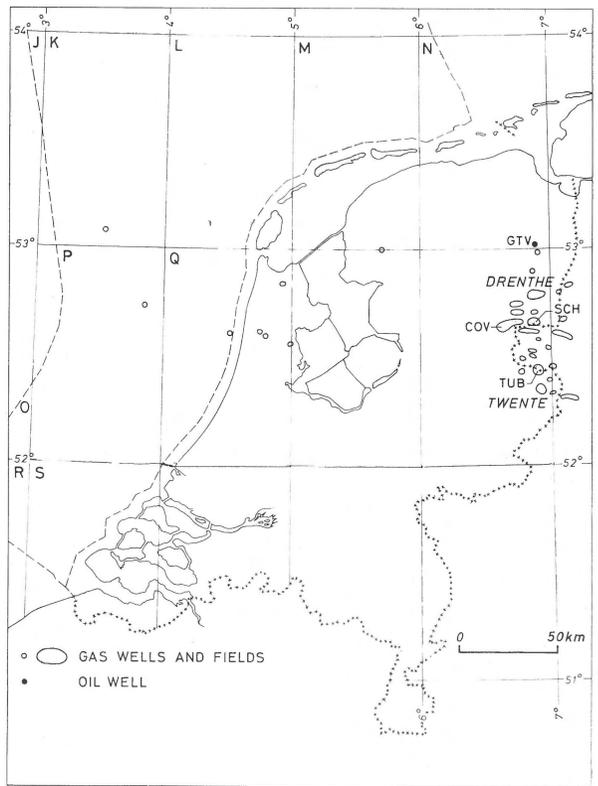


Fig. 4 Hydrocarbon accumulations in the Zechstein. For abbreviations see Table I.

fields and a remarkable oil occurrence in Gieterveen-Oost 1 in the eastern Netherlands (Fig. 4).

Production in the Drenthe area is from the Zechstein 2 Carbonate and in the Twente area from the Zechstein 2 and 3 Carbonates. The Zechstein gases in these parts of the country

Table 1 Legend to abbreviations of wells on Figs. 2 and 4.

code	well	company
ARV	Aarlanderveen	NAM
BAC	Bakkum-Castricum	NAM
BGM	Bergermeer	Amoco
COC	De Cocksdorp	Petroland
COV	Coevorden	NAM
DSP	Doornspijk	NAM
GTV	Gieterveen-Oost	NAM
HEK	Heemskerk	NAM
HRL	Harlingen	Petroland
JLD	Julianadorp	Phillips
ODS	Oude Sluis	Petroland
RPL	Riepel	Petroland
SCH	Schoonebeek	NAM
SCM	Schermer	Amoco
SMA	St. Maarten	Phillips
SPL	Schiphol	Amoco
TUB	Tubbergen	NAM
WAK	Warmenhuizen-Krabbendam	Amoco

are H₂S-bearing, with the exception of those from the Coevorden (east) and Schoonebeek fields.

The Zechstein 3 Carbonate has proven to be gas-productive in the western Netherlands, although in a more modest scale and free of H₂S. Offshore, it is again this carbonate member which has demonstrated to have gasbearing potential (Fig. 4).

ZECHSTEIN DEVELOPMENT

The Zechstein isopach map (Fig. 5) demonstrates the position of The Netherlands along the margin of the basin. Strong halokinesis took place in the northern part of the area, where a thick series of basal halite is developed, which makes small scale contouring impracticable. Areas where the Zechstein was removed by later erosion are indicated. The Texel-IJsselmeer High, of Late Kimmerian origin, is the most conspicuous zone of erosion. To the south little erosion occurred, but the area north of this High, forming the culmination of a large Late Kimmerian uplift in the northern Netherlands, was subjected to erosion and subsrosion which affect the contour pattern. An exception forms the area around Harlingen, where the Zechstein is complete and overlain by a thick Lower Buntsandstein. The geological map of the Pre-Cretaceous by HEYBROEK (1974) shows clearly where the Permian subgroups and where it is covered and protected by Triassic deposits.

A strong influx of siliciclastics is noted in the southern offshore (Fig. 6). The percentage of clastics decreases rapidly to the north. An aberrant development forms the sequence in the Doornspijk 2 well, where the Zechstein consists of an anhydrite-shale alternation with a minor amount of carbonates and a shale fraction of over 50%. Sandstones are restricted to the basin fringe in the P and Q quadrants, and diminish rapidly into the adjacent UK area. No clear evidence

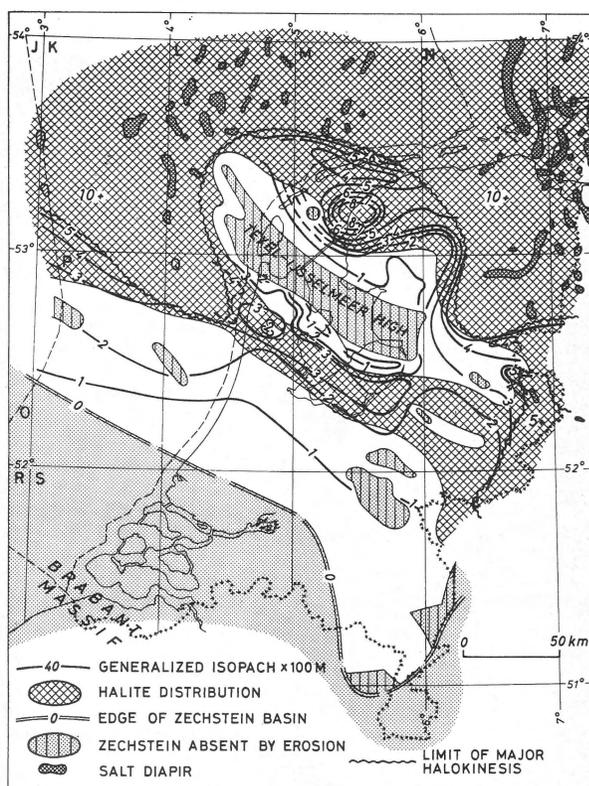


Fig. 5
Generalized isopach map of the Zechstein Group.

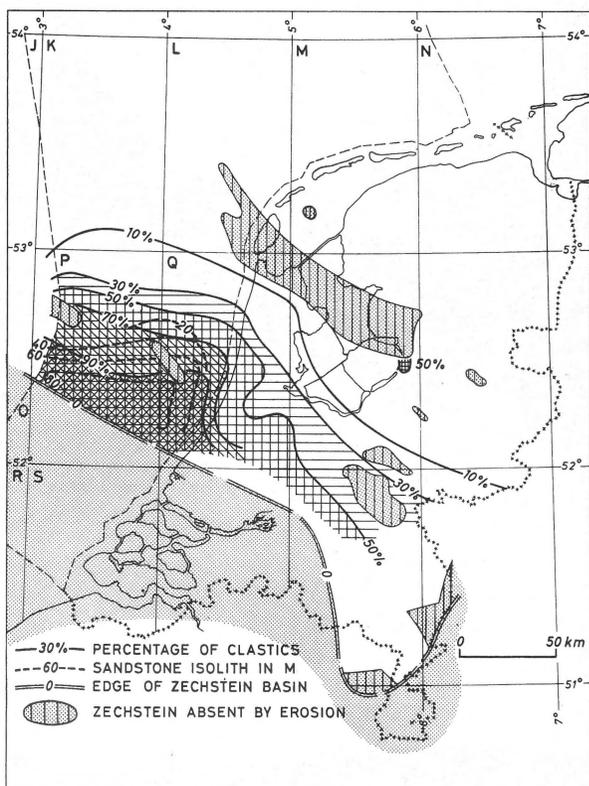
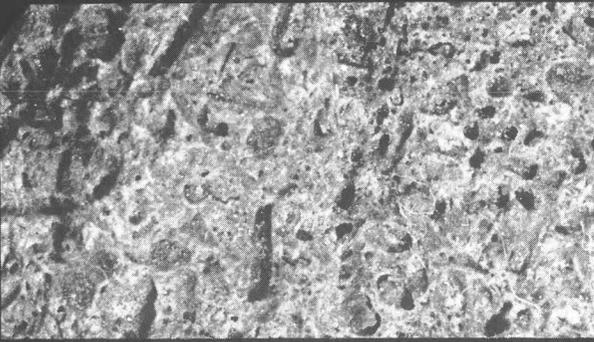


Fig. 6
Siliciclastics in the Zechstein Group.

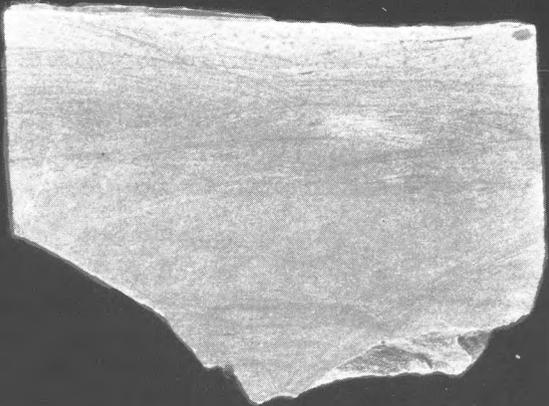
49



4a



2



3



1

has been found for a fluvial depositional environment of these pink and off-white sandstones, intercalated with some red shale. One could visualise a river system, probably ephemeral, flowing from the London-Brabant Massif into the Zechstein basin, and supplying sand and shale that were redistributed in a shallow marine coastal area.

Zechstein sandstone has been cored in the Q10-2 well (Plate 1 photo 3). In the favourable parts porosities of 16 to 19% and permeabilities to 65 of 111 mD were observed.

THE TEXEL-IJSELMEER HIGH

As mentioned before, the Texel-IJsselmeer High in its present extension resulted from Late Kimmerian positive movements. Dissolution features occur in a number of wells close to this High. Photo 2 depicts a collapse breccia from De Cocksdorp 1.

The Late Kimmerian erosion has removed most evidence for a possible positive expression of the High during Zechstein times. A few observations, however, point to the possible existence of such a contemporaneous high, probably not extending north of the island of Texel:

1. The thinning of the Zechstein south of the High;
2. The occurrence of the basal Zechstein carbonates instead of the Zechstein 1 Anhydrite in Riepel 1;
3. The aberrant shaly sequence in Doornspijk 2.

Apart from the not fully understood Doornspijk 2 development, there is no evidence that the postulated early Texel-IJsselmeer High acted as a source for clastics (see Fig. 6). One could expect this area to be a shallow zone, bordered at the basinward side by a thick Zechstein 1 Anhydrite rim like the configuration in the east of Drenthe (Fig. 7). To date such a rim has not been found, but well control north of the Texel-IJsselmeer High is too scanty to really disprove its existence.

ZECHSTEIN 1

The Zechstein 1 Formation comprises the first evaporitic cycle. It features an anhydrite platform with a thickness of over 250 m along the margin of the basin (Fig. 7). In Drenthe a remarkable protrusion occurs around a shallow, south-north trending sill in the basin (after MAUREAU & VAN WIJHE, 1979; VAN WIJHE, 1981). Basinwards the thickness decreases over a short

Plate 1 (facing page)

- 1: P6-1, 3115 m: Zechstein 3 Carbonate, dolomite with vugs, x 3/4.
- 2: De Cocksdorp 1, 2371 m: Collapse breccia from upper part of Zechstein, x 3/4.
- 3: Q10-2, 2265 m: Zechstein sandstone with small scale crossbedding, x 3/4.
- 4a: Schermer 1, 2108 m: Zechstein 3 Carbonate, leached algal dolomite, x 3/4.
- 4b: Detail of figure 4a, x 4.

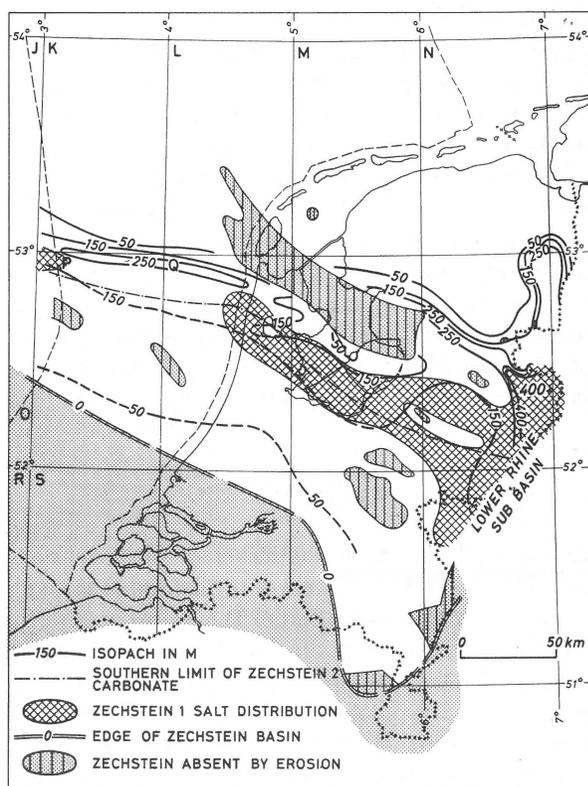


Fig. 7
Zechstein 1 isopach map.

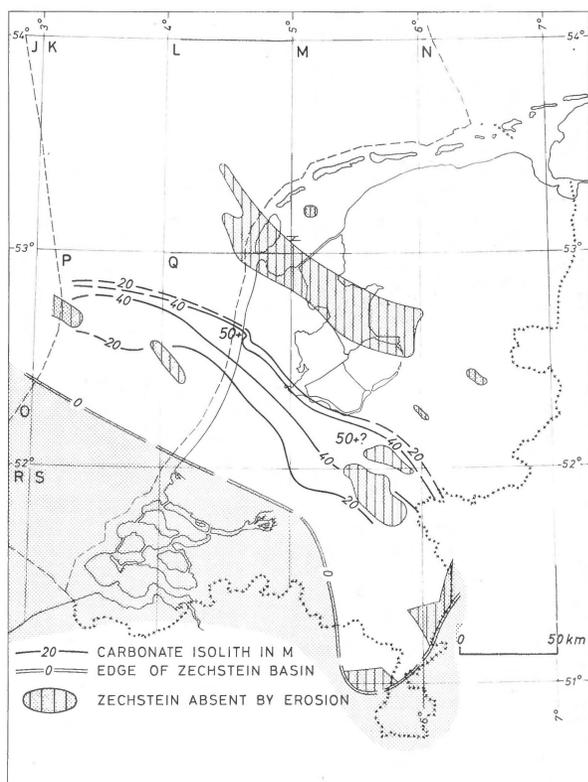


Fig. 8
Zechstein 1 Carbonate; carbonate isolith map.

distance to less than 50 m. At the time of deposition a steep slope along the northern edge of the platform existed. Behind the main anhydrite development (probably originally deposited as gypsum), halite was precipitated in places. A thickness of several hundreds of meters was reached in the separately subsiding Lower Rhine subbasin (Fig. 7).

Further to the south and close to the basin edge, fringe carbonates are present. Figure 8 shows that the net carbonate thickness rarely exceeds 50 m. The rather thin development in the offshore area, where many shale intercalations occur, is attributed to the earlier-mentioned clastic influx from the London-Brabant Massif. The UK area, a little further west, shows again a much stronger carbonate development.

ZECHSTEIN 2 AND 3 CARBONATES

The Zechstein 2 Carbonate has its thickest development along the slope of the Zechstein 2 Anhydrite platform. The major accumulation is in the eastern part of The Netherlands with a thickness of over 150 m (Fig. 9). This carbonate member is developed within the reach of the platform edge in a shallow water facies. This Hauptdolomit or Main Dolomite consists of light coloured, oolitic, bioclastic and pelletoidal grainstones (CLARK, 1980a). Slightly more basinwards a deeper water facies is developed, the Stinkdolomit or Stinking Dolomite, consist-

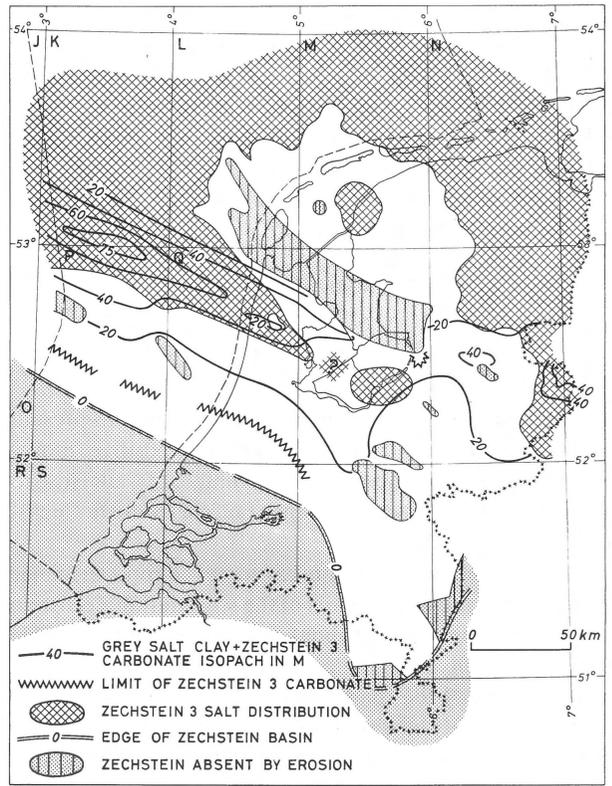


Fig. 10
Zechstein 3 Carbonate + Grey Salt Clay isopach map.

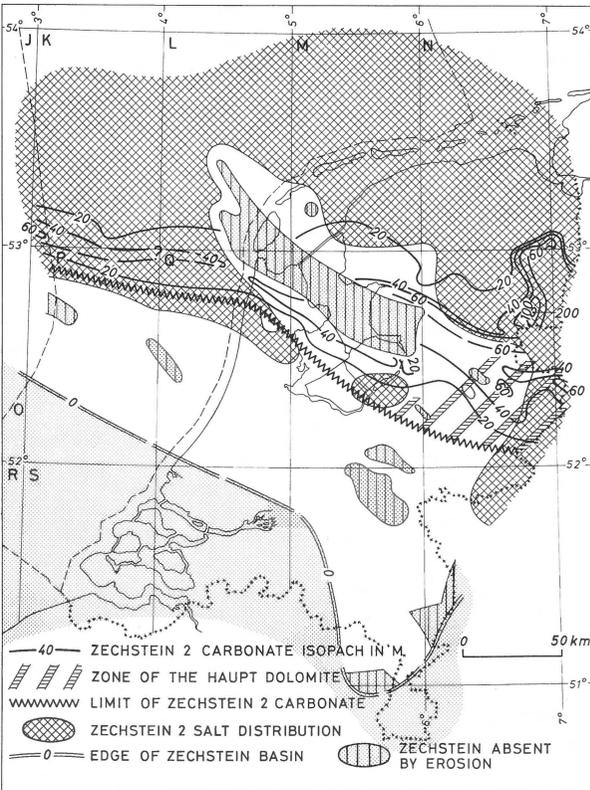


Fig. 9
Zechstein 2 Carbonate isopach map.

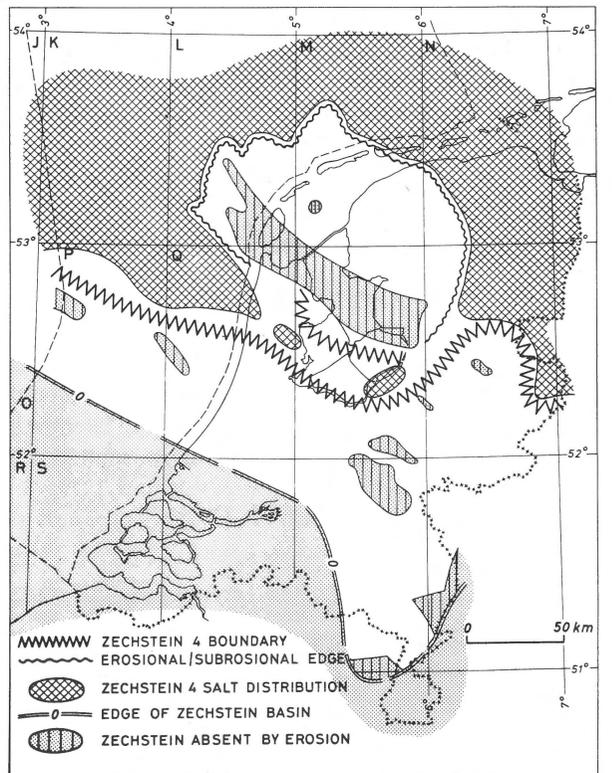


Fig. 11
Zechstein 4 distribution.

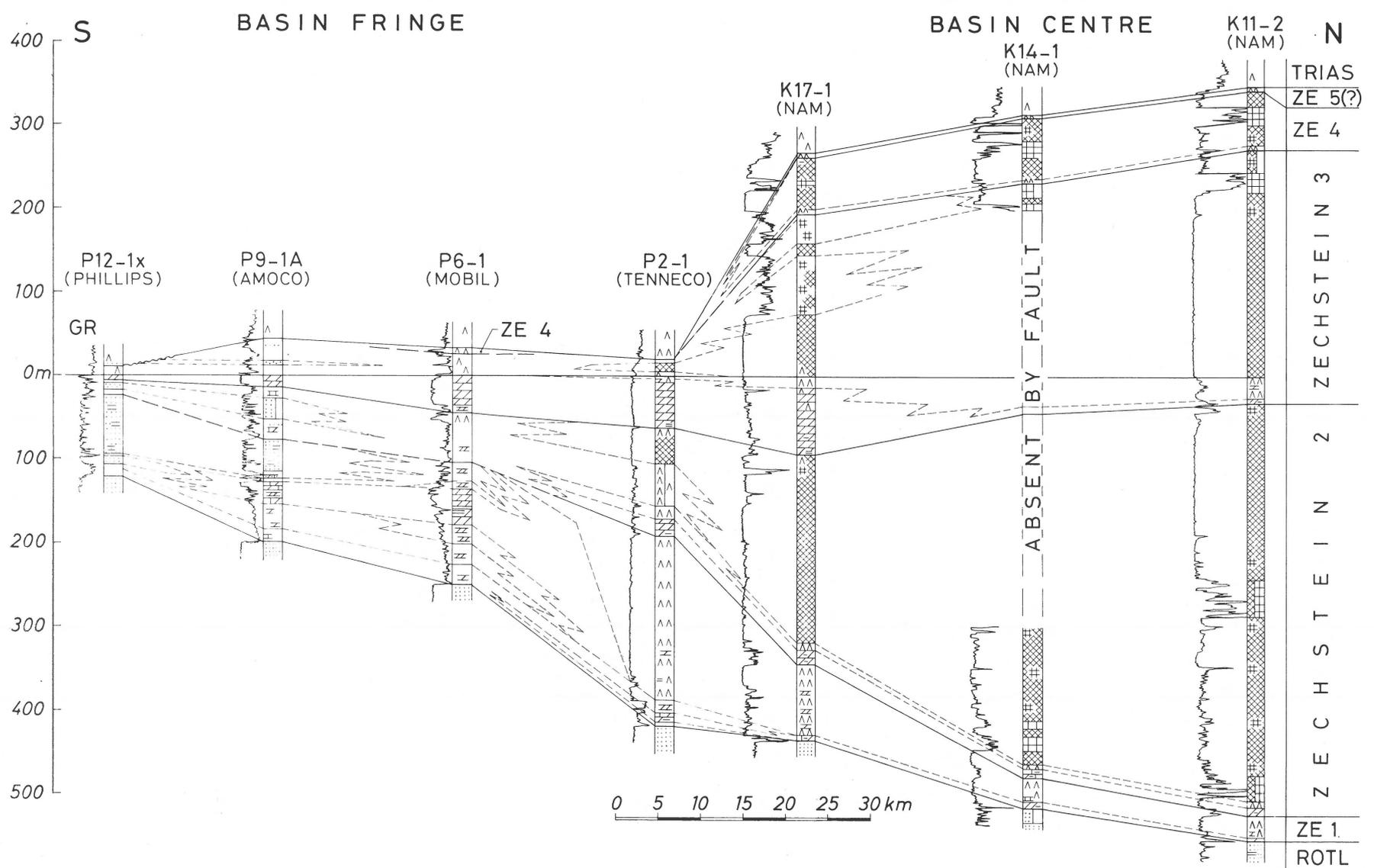


Fig. 12 Well correlation of the Zechstein from P12-1x to K11-2. See figure 2 for well locations. Datum line is base Zechstein 3 Salt or lateral equivalent in fringe area.

BASIN FRINGE

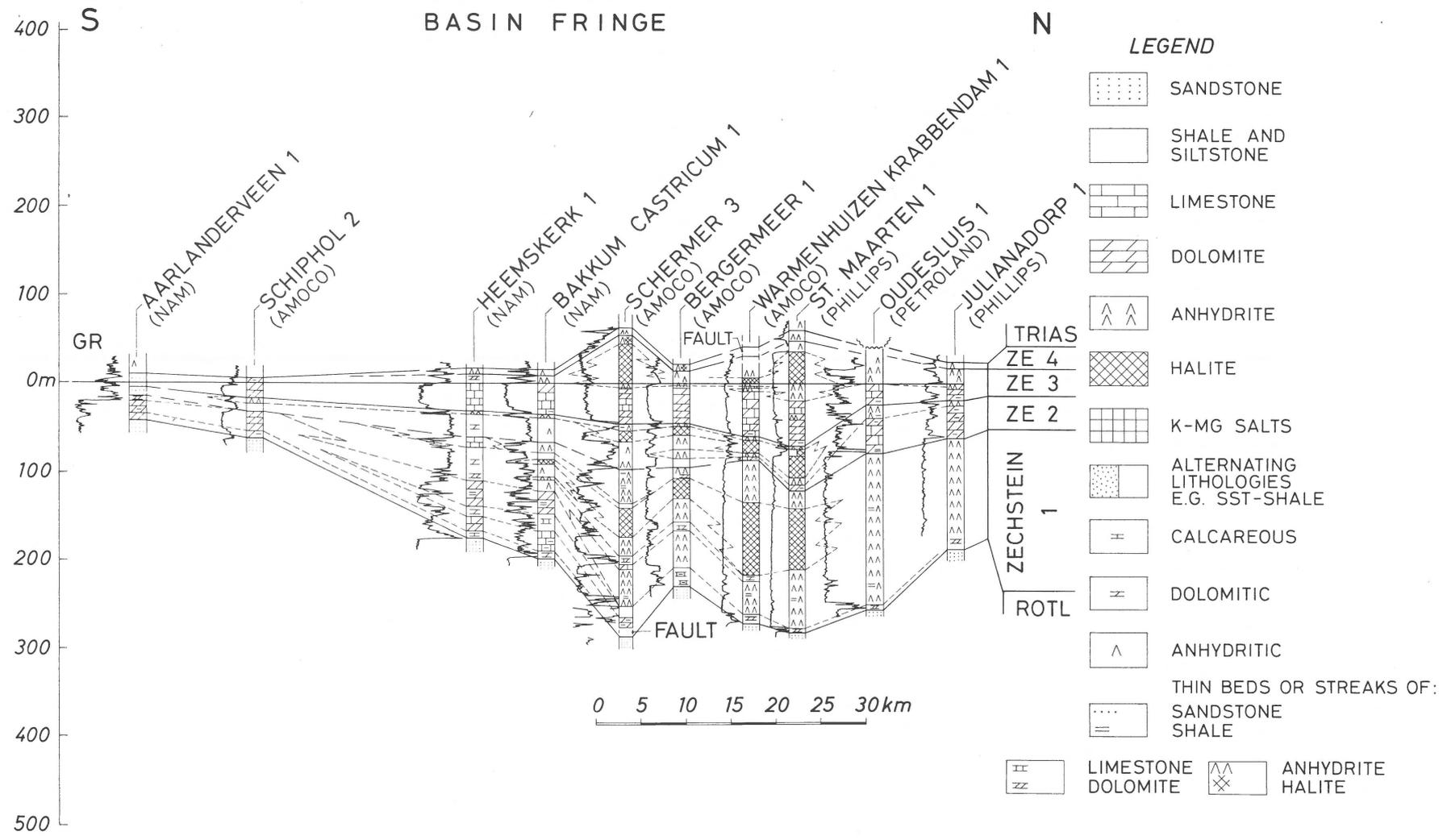


Fig. 13 Well correlation of the Zechstein from Aarlanderveen 1 to Julianadorp 1. See figure 2 for well locations. Datum line as in figure 12.

ing of H₂S-smelling carbonate mudstones, bioclastic wackestones and turbiditic grainstones (CLARK, 1980a). Further basinwards the Zechstein 2 Carbonate becomes more calcareous (Stinkkalk) and decreases rapidly in thickness to ultimately less than 10 m. This thin basinal facies consists of a thinly laminated limestone, the Stinkschiefer or Fetid Limestone (VISSER, 1963).

South of the main development and closer to the basin edge, anhydrite intercalations occur in Zechstein 2 Carbonate in the eastern Netherlands. This dolomite-anhydrite complex is known as the 'Hauptdolomitregion' (HEIDORN, 1949), 'Main Dolomite Zone' (BRUEREN, 1959) or 'Zone of the Hauptdolomite' (VISSER, 1963), which distribution is marked on figure 9. Further south, both in the eastern and western Netherlands, the Zechstein 2 Carbonate grades into dolomitic shales. This implies that establishing the boundary between the Zechstein 1 and Zechstein 2 formations is usually somewhat arbitrary (see Figs. 12 and 13).

The Zechstein 3 Carbonate has, in contrast to the second cycle carbonate, its strongest development in the offshore area of The Netherlands (see Fig. 10), where a thickness of up to 75 m is recorded. The maximum carbonate development, as light coloured dolomites and locally limestones, generally occurs slightly more to the south than that of the preceding cycle. The Zechstein 3 Carbonate extends markedly further southwards. Basinwards this carbonate thins rapidly, grading into the third cycle Hauptanhydrit or Main Anhydrite (Fig. 12). Platy, dark coloured, H₂S-smelling dolomites are developed on the slope towards the basin. This is the actual Plattendolomit of Platy Dolomite (FÜCHTBAUER, 1964).

On the isopach map of figure 10, the Zechstein 3 Carbonate has been contoured in combination with the Grey Salt Clay. As the thickness of the latter rarely exceeds a few meters, this map is in fact representative for the development of the Zechstein 3 Carbonate Member.

In the area north of the Texel-IJsselmeer High, where the Zechstein 3 Salt is missing, the Zechstein is for a large part capped by the Zechstein 3 Main Anhydrite, locally overlain by a minor amount of red, residual shale.

The Zechstein 3 Carbonate has good reservoir properties in the Schermer-Alkmaar area. A core from Schermer 1 (Amoco) shows a leached algal dolomite (Plate 1, photo 4a, 4b) with porosities as high as 20% (\varnothing max 26%; K max 149 mD) but with an average permeability of less than 10 mD. Poorer conditions were found, e.g. in a core from P6-1 (Plate 1, photo 1) with, on average, a porosity of less than 5% and a permeability of less than 1 mD, in spite of locally its vuggy texture (\varnothing max 6.8%; K max 18 mD).

Because of their reservoir potential, the Zechstein 2 and 3 Carbonates have been studied intensively, both on their depositional model (e.g. FÜCHTBAUER, 1968; SANNEMANN ET AL., 1978; CLARK, 1980a; SMITH, 1980b) and their diagenesis (e.g. FÜCHTBAUER, 1964; CLARK, 1980b). Experience has shown that the reservoir properties of these carbonates can change rapidly from place to place, both in horizontal and vertical

sense (MAUREAU & VAN WIJHE, 1969; VAN LITH, 1983).

ZECHSTEIN 4 AND 5

The Zechstein 4 Formation has no basal carbonate. It is a relatively thin unit. To the south it decreases gradually in thickness till it cannot be identified anymore as a separate unit (see Figs. 11 and 12).

An indication for a fifth evaporitic cycle of very modest dimensions is found offshore in a persistent shale-anhydrite sequence in the uppermost part of the Zechstein with a thickness of not more than 5 m. No halite could be traced in this unit.

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