A conventional log evaluation method for detection of lithology and hydrocarbons in the Danish North Sea well M–1x

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In the Danish North Sea well M–1x several types logs have been used for obtaining data on petrophysical characteristics in strata penetrated in order to find possible reservoir rocks and hydrocarbons.

From the log evaluation the gas zone was found to be 258′ thick, the oil zone 401′ thick. Average porosity for the whole zone was 29 per cent, and average water-saturation 18.8 per cent. The log-derived lithology was found to be clean limestone and subsidiary dolomitized limestone; however, the presence of dolomite was not confirmed by X-ray analyses. The porosity of the chalk not only correlated with depth of burial but correlated with overpressure as well.

Following zones were found to constitute the chalk reservoir, characterized by different average porosities and water-saturation:

Danian "Porous Zone":	Φ : 36.6 per cent
	S_w : 14.0 per cent
Danian "Tight Zone":	Φ : 28.0 per cent
	S_w : 28.7 per cent
Maastrichtian:	Φ : 28.5 per cent
	S_w : 17.7 per cent

The upper part of Maastrichtian was found to be highly porous, with decreasing porosities at greater depths.

In 1977 the Geological Survey of Denmark started evaluation of petrophysical logs (made available by Danish Underground Consortium), using conventional and basic methods which in this paper are exemplified in the well M–1x in the Dan field. For this investigation only basic data as those obtained from logs and published data have been used. All depths are in feet below Kelly Bushing; elevation of this was 110′ above Mean Sea Level. (A list of abbreviations is given on p. 128.)

Logs used

1) Compensated Formation Density Log (FDC), shows rock porosity, and is used for lithology determination.
2) Sidewall Neutron Porosity Log (SNP), for porosity; cross-plotted with FDC-log, used for determination of lithology and gas zone.
3) Laterolog (LL7), used for determination of resistivity of formation water, and for detection of hydrocarbons.
4) Induction Electrical Log (IES), used for resistivity of formation water, and detection of hydrocarbons. Cross-plotted with porosity it is used for calculation of water-saturation.
5) Borehole Compensated Sonic Log – Gamma Ray (BHC – GR), used for defining the carbonate sequence. With the Gamma Ray Log the amount of clay in the chalk can be determined.

The above-mentioned logs are compiled on plate 1.

Methods

Composite log

A composite log was made for the section of interest. In M–1x the LL7 was chosen as basic log, and the FDC-, SNP-, and IES-logs were normalized with this log in order to honor all logs simultaneously; logging tools often "yo-yo" a few feet up and down during measuring, and two different runs do not always measure the same event exactly at the same depth (plate 1). Events were selected in intervals of clean formation where Gamma-Ray (GR) read almost no clay content. Events were of such a length that maxima and minima of all the different logs were honored (fig. 1). At great shifts between maxima and minima, at a curve, smaller events were chosen, and an average reading selected.

Detection of Hydrocarbons

The hydrocarbon zones were detected from LL7- and IES-logs. LL7 showed approximately 0.5–1.0 ohm-m in the water-bearing shales above the chalk reservoir. In the hydrocarbon-bearing chalk immediately below, the log showed rapid fluctuations to as much as 55 ohm-m, while water-saturated carbonate near the bottom of the section showed approximately 1 ohm-m. The conductivity log showed as low as 10 mmhos/m in the hydrocarbon zone, and between 2000 and 3000 mmhos/m in the water zone of the chalk, as seen on plate 1.

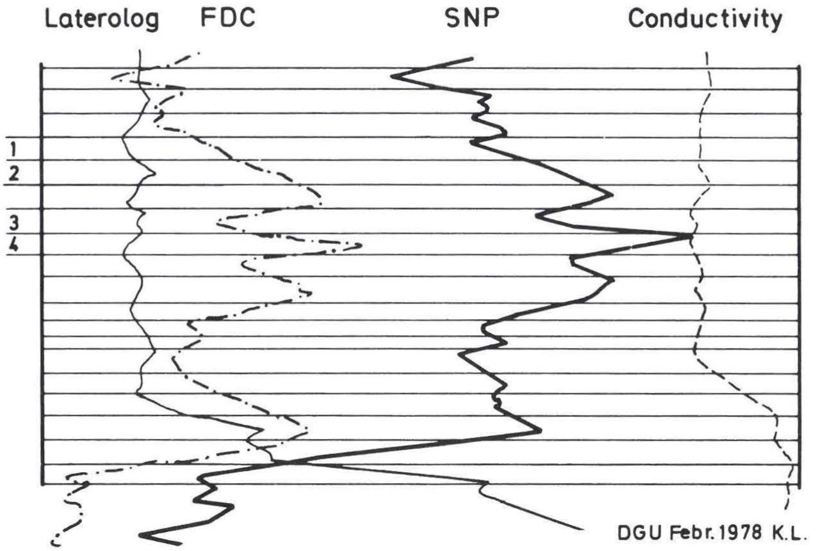

Fig. 1. Example of selection of events. Events 1 and 2 divide a greater shift at the curves, and average readings are selected. Event 3 honors a maximum, event 4 a minimum at the curves, and highest and lowest values were taken.

The gas zone was found in the following manner: the FDC- and SNP-logs were superimposed and depth-matched in the water-saturated lower part of the reservoir, and as seen on plate 1 the two logs read nearly equal porosity (notice the scale difference for the two logs). The gas zone was characterized by separation of several porosity units between the two logs, with the FDC reading the highest porosities.

Porosity and lithology

Evaluation of porosity was made from FDC-log calibrated to limestone units, and from SNP-log.

The log readings had to be corrected. The SNP-log was corrected for mud cake thickness, using Por-13a (Schlumberger 1972 [a]). This gave a porosity correction from zero to minus five porosity units.

Borehole correction at FDC-log for a 12½ inches borehole from Schlumberger chart Por-5b (Schlumberger 1972 [a]) was found to be –1.5 per cent porosity units.

In this case Caliper Log showed no caving in the investigated interval, and consequently no borehole-effect to show false pay zone.

An SNP-FDC cross-plot on Schlumberger chart CP-la (Schlumberger

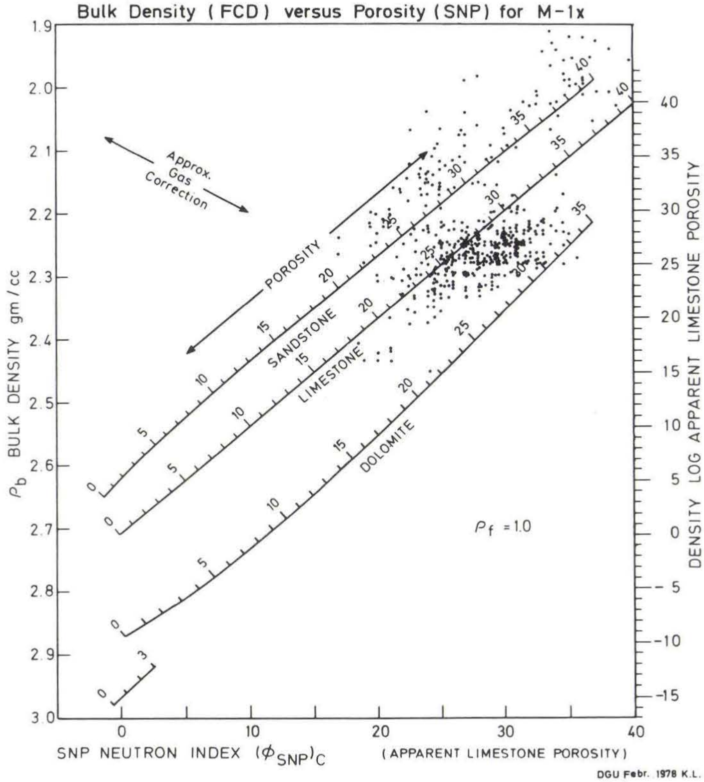

Fig. 2. Bulk density versus neutron porosity cross-plot for Upper Cretaceous-Danian carbonate interval, for freshwater (<100.000 ppm), liquid-filled holes (Schlumberger 1972[a], chart CP-1a).

1972 [a]) was made in order to correct porosities for gas effect, and to check lithology. As seen in fig. 2, some points plotted along the limestone line ensuring the lithology to be clean limestone. Points plotting above and to the left of the limestone line were affected by gas. These points derived from the gas zone. Points plotting to the right and below the limestone line could have been affected by dolomite or clay. These points derived from the lower part of Maastrichtian. Corrected porosities were established with the aid of iso-porosity lines between the limestone- and dolomite lines, and along lines parallel to the gas correction line. The percentile amount of dolomite should be equal to the percentile distance to the dolomite line.

Water-saturation

The 100 per cent water-saturation was determined from the water zone in the reservoir, and was found where LL7 read constant low values, in this case below 1 ohm-m, where FDC- and SNP-porosities had almost identical readings. Assurance was made that GR-log had low readings, i.e. that the interval had no clay content.

Conductivity readings were corrected from Schlumberger chart Rcor-4 (Schlumberger 1972 [a]) with respect to stand-off and mud-resistivity. Conductivity readings (mmhos/m) were converted to Resistivity (ohm-m).

Normally, the IES-log should be used in the water zone, the LL7 in the oil zone (Schlumberger 1972 [c], p. 82). A check on the most preferred log to be used in this case was made from Schlumberger (1972[c]), chart, p. 83; and by cross-plotting porosity versus R_{mf}/R_w it was found that IES-log was to be preferred.

The porosity-resistivity cross-plot was used to mark the 100 per cent water-saturation line, using the Archie saturation equation:

$$S_w = \left(\frac{A \times R_w}{\Phi^m \times R_t}\right)^{\frac{1}{n}} \qquad \text{(Schlumberger 1972 [c])}$$

where S_w = water-saturation in the formation, R_w = resistivity of the formation water, R_t = true resistivity in the formation, Φ = porosity, A = a coefficient, m = a cementation exponent, and n = a saturation exponent. Points did not indicate a trend of the 100 per cent S_w-line, but plotted in a cluster (fig. 3). A 100 per cent water-saturation line was then calculated, using the above equation for the water zone, with S_w = 1 for 100 per cent water-saturation, A = 1, m = 2, and n = 2.

$$S_w = \frac{A \times R_w}{\Phi^m \times R_t} = 1$$

Water-resistivity was calculated for the water zone, for point *A* in fig. 2, using equation:

$$R_w = \frac{\Phi^m \times R_t}{A}$$

True resistivity was then calculated for point *B* for a given porosity, using equation:

$$R_t = \frac{R_w}{\Phi^m \times S_w{}^n}$$

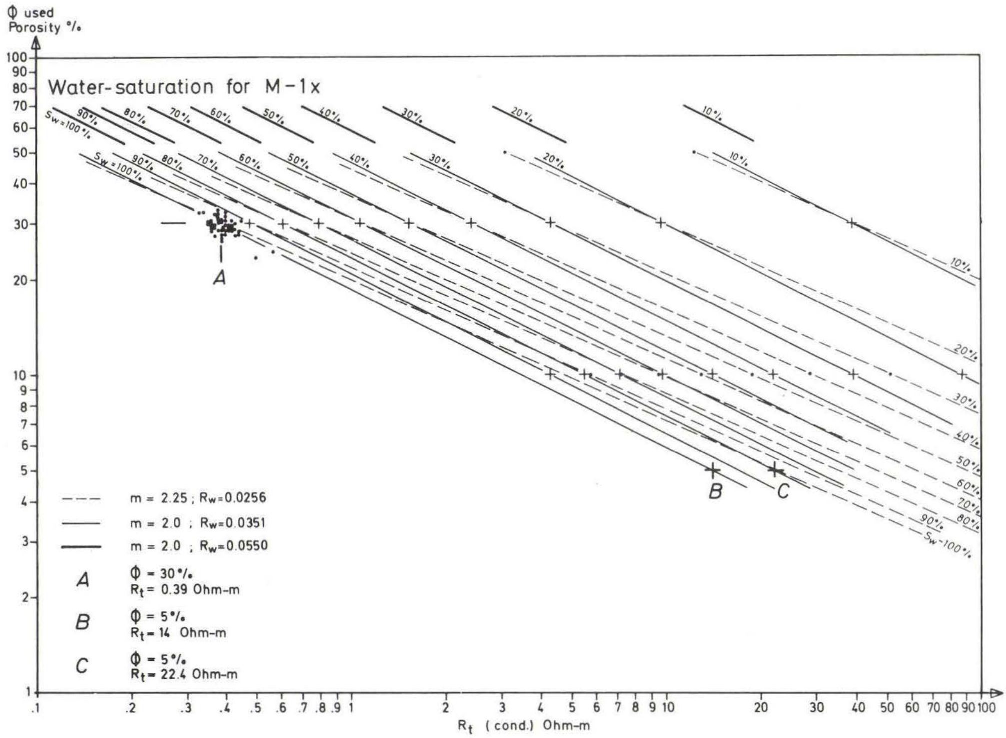

Fig. 3. Porosity versus true resistivity cross-plot from water zone. Examples are given for water-saturation at different values water-resistivity and for different cementation factors. (Method after Pickett 1966, Oduolowu 1977.)

A line representing 100 per cent water-saturation could then be drawn through point *A* to *B*.

Water-saturation in the hydrocarbon zone was found from equation:

$$S_w = \sqrt[n]{\frac{A \times R_w}{\Phi^m \times R_t}}$$

Water-saturation lines corresponding to S_w = 100 per cent, 90 per cent, 80 per cent ... to 10 per cent were drawn (fig. 3).

By plotting Φ- and R_t- readings from events in the hydrocarbon zone, water-saturation could be read direct from the figure. However, it was more accurate to calculate S_w for every event, and easily done with the use of a programmable calculator.

Pay Zone

An average net pay zone was estimated by neglecting events with $S_w \geqq 60$ per cent and $S_w \geqq 50$ per cent within the gas- and oil zones, respectively. These values are normally used for cut-off. A higher value is often used for gas, as relative permeability is higher for gas than for oil.

Weighted average porosity in pay zone was found, using equation:

$$\bar{\Phi} = \frac{\Sigma h \times \Phi}{\Sigma h}$$

Weighted average water-saturation in pay zone was found, using equation:

$$\bar{S}_w = \frac{\Sigma h \times \Phi \times S_w}{\Sigma h \times \Phi}$$

Discussion

Porosity and lithology

As seen from porosity versus depth cross-plot in fig. 4, good correlation between log-derived porosities and measured porosities from cores was found. Core-measured porosities averaged over ten feet intervals (Childs and Reed 1975) were plotted together with highest and lowest log-derived porosities at every ten feet.

As indicated in fig. 2 parts of the chalk should be dolomitized.

Lithology plotting of more than 75 per cent dolomite in fig. 2 was indicated with an asterisk in fig. 4. The dolomitized chalk was within the range of highest porosities throughout the section, but did not rise above porosity range for clean limestone, and as such did not show any evidence of the 10–13 per cent porosity gain normally seen with dolomitization (Murray 1960). However, Murray (1960) found a relation between degree of dolomitization (replacement dolomite) and porosity, with a decrease in porosity below 50 per cent dolomitization and an increase in porosity above 50 per cent.

Childs and Reed (1975) did not report any dolomite in their core-descriptions, and X-ray diffractometry of four samples from the interval 6359′–6393′ showed less than 5 per cent dolomite and close to clean calcite. As such, the cross-plot indicating dolomitized chalk is not valid.

A deflection of points to the right of the limestone line could also be caused by clay content. All points situated near the dolomite line were from

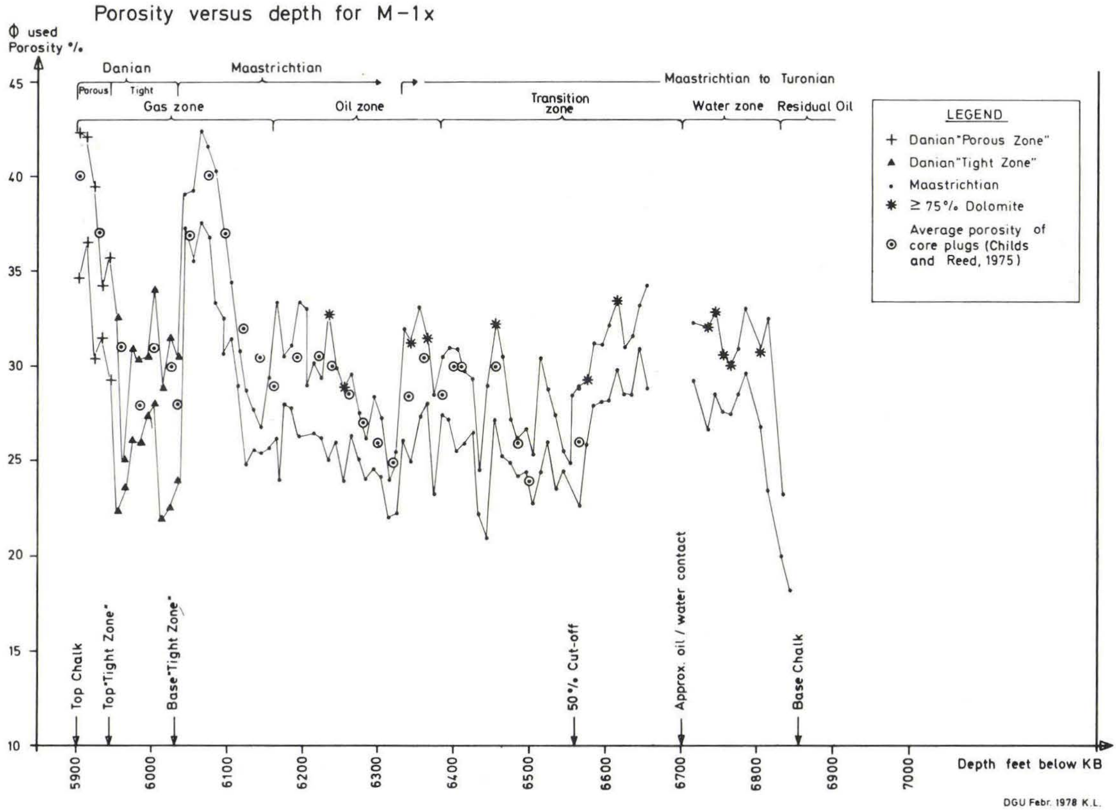

Fig. 4. Porosity versus depth cross-plot. Porosity values were obtained from cross-plot (fig. 1). Highest and lowest porosity readings at every ten feet were plotted. Porosity values obtained from lithology with more than 75 per cent dolomite from cross-plot (fig. 1) are marked with asterisks. Core-porosities, averaged over ten feet intervals, were obtained from Childs and Reed (1975).

Maastrichtian to Turonian. This interval was characterized by almost clean chalk, as clay content was found to be less than 5 per cent, as calculated from equation:

$$V_{clay} = \frac{Gr - Gr_{clean}}{GR_{clay} - GR_{clean}} \quad \text{(Schlumberger 1974 [b])}$$

A clay content of five per cent and less was considered too slight to cause the great deflection away from the limestone line.

Dispersal of the plotting might have been due to poor calibration or correction of the logging tools. However, the correlation between core- and log-derived porosities indicated reasonable log-readings.

Porosity versus depth from the entire carbonate section was plotted at fig. 4. From porosity distribution the section may be divided into several litho-zones.

Danian was divided into an upper "Porous Zone", with high porosities ranging from 29 to 42 per cent, with average porosity at 30.9 per cent; and a lower "Tight Zone" with low porosities ranging from 23 to 32 per cent, with average at 28.5 per cent. The low porosities in "Tight Zone" may be due to a higher degree of cementation, and to as much as 20 per cent dispersed clay, calculated from GR-log.

The upper part of Maastrichtian down to 6120' was highly porous, ranging from 29 to 42 per cent porosity, with average at 35.9 per cent. From 6120' to Turonian the chalk was found less porous, ranging from 22 to 34 per cent, with average at 28.5 per cent. The lowermost 50 feet had as low porosities as 17 per cent. The lower part of the section may be more compacted and diagenetically altered, with a higher degree of cementation, as seen from the lower porosity reading at FDC- and SNP-logs on plate 1. At the BHC-log the Interval Transit Time decreased with depth also indicating that the chalk had become more tight and hardened. This same was indicated by common stylolites formed by pressure solution (Childs and Reed 1975). As clay content was low, it contributed only slightly to low porosities in this zone.

Overpressure

With depth of burial porosity does not decrease normally. The high porosities, especially in Danian "Porous Zone" and upper part Maastrichtian, were probably caused by overpressure preventing normal compaction (Scholle 1977).

Depth versus Δt (Interval Transit Time) plotted for shaly intervals (fig. 5) showed normal compaction, i.e. a normal pressure trend down to 3750'. Below this level the shales were not compacted normally and became overpressured. Even Lower Cretaceous shales at 6700'-8000' were not pressured normally (fig. 5).

Pressure was measured to 3800 psi at 6200' below Mean Sea Level (Childs and Reed 1975); normal hydrostatic pressure at this depth should have been about 2880 psi, i.e. 920 psi in overpressure, as the hydrostatic pressure normally increases with 46.5 psi per 100' depth.

Water-saturation

Water-saturation was calculated for the whole carbonate section. Top of the hydrocarbon zone was found at 5902', a 50 per cent cut-off (for S_w= 50 per

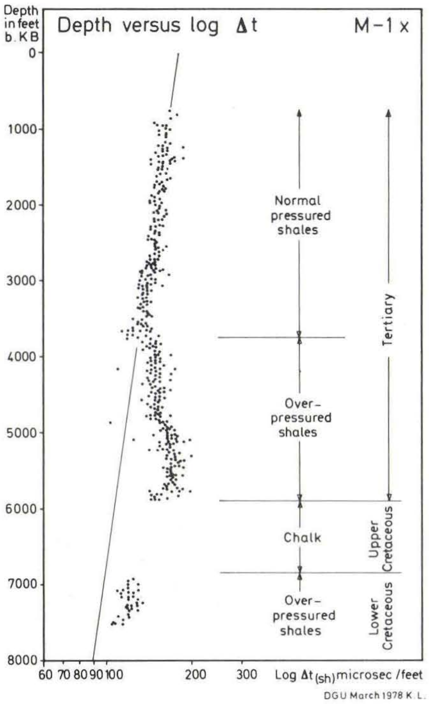

Fig. 5. Depth versus logΔt_{shale} cross-plot for Tertiary and Lower Cretaceous shales shows normally pressured and over-pressured zones.

cent) at 6561′, and top water zone (for S_w = 100 per cent) at approximately 6700′. Gas/oil contact was found at 6160′ from FDC- and SNP-logs. Each lithological zone in the reservoir was found to have different values averaged water-saturation: Danian "Porous Zone" showed an average S_w at 14 per cent, Danian "Tight Zone" an average S_w at 28.7 per cent, and Maastrichtian an average S_w at 17.7 per cent, calculated from top Maastrichtian to cut-off at 50 per cent water-saturation. This would give a net pay zone of 659′, with 258′ net gas zone and 401′ net oil zone.

A cementation factor equal to two is normally used for carbonates. The m-value defines the slope of the 100 per cent water-saturation line; with a higher value the slope will be less inclined. Using m = 2.25, as exemplified by the stippled lines in fig. 3, would only cause deviation of ± 2 per cent S_w in the range of 25 to 35 per cent porosity. In the range of very high and low porosities deviation would be more than ten per cent water-saturation, causing the high porosity interval to have lower value water-saturation, and the low porosity interval to have higher values water-saturation. This again affects the calculated pay zone, as the level for 50 per cent cut-off, using m = 2, would be placed 20′ deeper than if m = 2.25 was used.

Resistivity of formation water

The m-value affects the calculation of water-resistivity, which in turn affects water-saturation, thus the calculated amount of oil in a formation. At fig. 3 an example of two different R_w-values at 0.0550 ohm-m and 0.0351 ohm-m, respectively, are shown, both with m-values equal to 2. The 100 per cent water-saturation line for R_w = 0.0550 ohm-m corresponds to the 80 per cent water-saturation line for R_w = 0.0351 ohm-m, deviation decreasing at a lower per cent S_w. For R_w = 0.0351 ohm-m in M-lx, a 50 per cent cut-off was found at 6561′. With R_w = 0.0550 ohm-m the cut-off would be placed higher, thus diminishing the oil zone. As R_w is a main factor controlling the calculation of S_w, i.e. the thickness of the pay zone, it is important to get this value as correct as possible. R_w may be calculated as in the example, or from SP-log, or obtained direct from water samples from the aquifer below the hydrocarbon-bearing zone.

Irreducible water-saturation

A cross-plot of porosity versus water-saturation (fig. 6) showed upper part of Maastrichtian to be the most favorable part of the reservoir, with the lowest water-saturation, "Tight Zone" the poorest part of the reservoir, with high water-saturation. For a constant lithology or a formation with a constant grain size, the product of porosity and water-saturation will generally be a constant, for points within the zone of irreducible water-saturation, where $S_w = S_{w\ irr}$. The equation $\Phi \times S_w = C$ where C is a constant (Φ and S_w in fractional units) will plot along a hyperbola (Lavers *et al.* 1975; Morris and Biggs 1967). Points from the transition zone will plot above and to the right of the hyperbola. Hyperbolae drawn for points within the zone of irreducible water-saturation reflect the different lithological zones in the reservoir; for "Porous Zone" in Danian some points plotted to the right of the curve, indicating moveable water. Points from "Tight Zone" plotted along the curve, almost fitting the hyperbola of irreducible water-saturation, indicating no moveable water. The upper part of Maastrichtian followed several closely-spaced hyperbolae for irreducible water-saturation, indicating a gradual change in lithology down into the transition zone. The remaining part of Maastrichtian plotted to the right of the curve and indicated movable water in the transition zone.

From cross-plot depth versus water-saturation (fig. 7) the depth for irreducible water-saturation was defined at S_w = 17.5 per cent, where the capillary pressure curve became vertical, at 6380′. It was also found (fig. 7) that the upper part of the reservoir was heterogenous, with each lithological zone

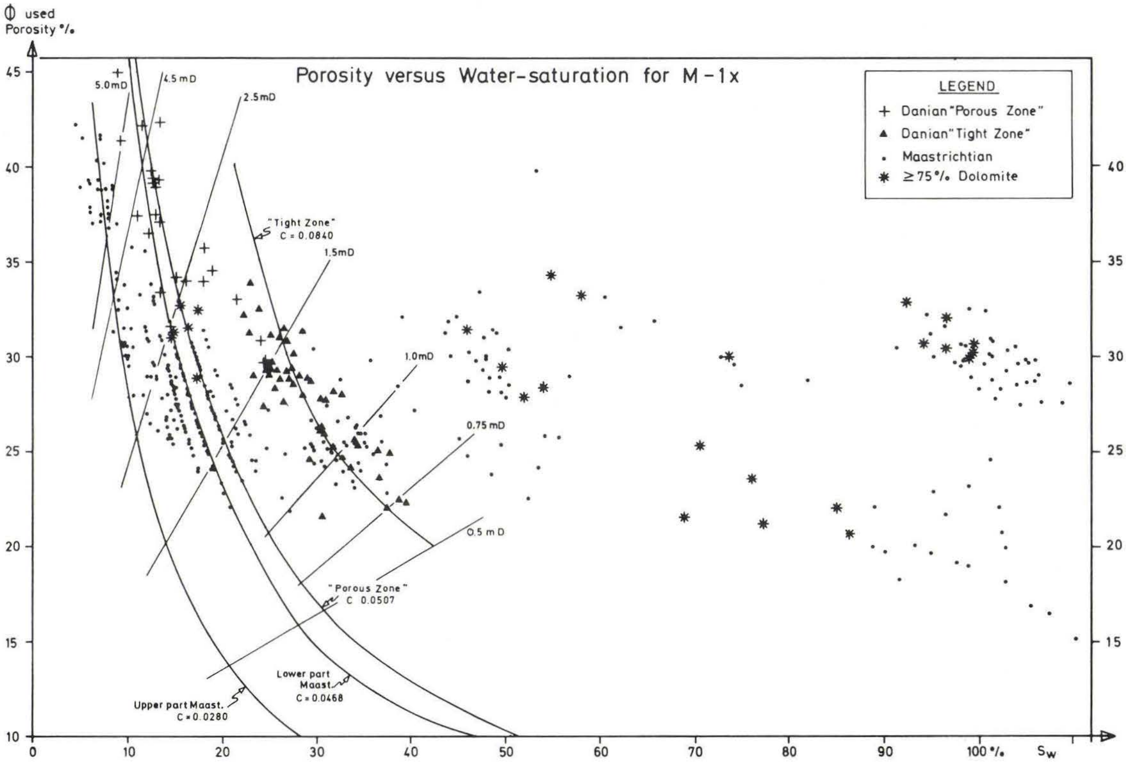

Fig. 6. Porosity versus water-saturation cross-plot, $\Phi \times S_w = C$, calculated for different lithologies for points within the range of irreducible water-saturation. Isopermeability lines were calculated from equation

$$K^{2.5} \times 0.15 = \frac{\Phi^3}{S_{w\ irr}^{\ 2}}$$

Lithology found to contain more than 75 per cent dolomite from cross-plot (fig. 1) are plotted with asterisks.

having different capillary pressure, and the hyperbolae for $S_{w\ irr}$ (fig. 6) ensuring these zones to lie within the range of irreducible water-saturation.

Permeability

Morris and Biggs (1967) have presented a method of calculating permeability from log-derived values of porosity and irreducible water-saturation. This method was modified by Lavers *et al.* (1975) to fit core material from carbonate reservoirs in the North Sea, using the equation:

$$K^{2.5} \times 0.15 = \frac{\Phi^3}{S_{w\ irr}^{\ 2}}$$

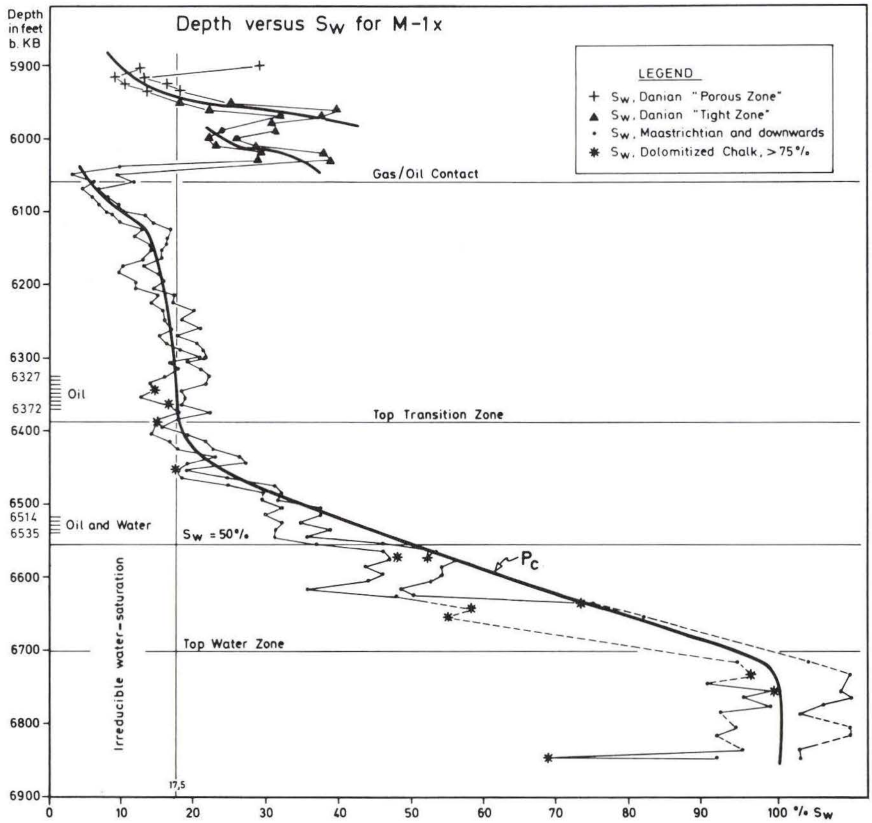

Fig. 7. Depth versus water-saturation cross-plot shows capillary pressure curve P_c, gas/oil contact, top transition zone, and levels for 50 per cent and 100 per cent water-saturation. Perforations for production tests are marked.

where K is permeability. This equation can be utilized within the permeability range of 0.4–5.0 mD. Iso-permeability lines were drawn at fig. 6, and were calculated from the equation above.

The calculated permeability was found in the range of 0.75–6.72 mD, lowest for "Tight Zone" and highest for upper part Maastrichtian. Compared with permeabilities obtained from core measurements (Childs and Reed 1975), calculated permeabilities for "Tight Zone" were about 1 mD higher, those from "Porous Zone" 2 mD lower, whereas calculated permeabilities from Maastrichtian were in the same range as measured permeabilities.

Capillary Pressure

Depth versus water-saturation was plotted at fig. 7. Highest and lowest S_w-values within every ten feet were plotted, and an approximate curve was drawn. The curve reflects the capillary pressure-drop from the oil zone through the transition zone to the free water level at 100 per cent water-saturation, where capillary pressure equals zero. Capillary pressure depends on size of pore-connections, oil gravity, and salinity of formation-water; combinations of these factors influence the height of the transition zone (Arps 1964; Schlumberger 1972 [c]). In M-lx a thick transition zone of approximately 320′ was found, caused by low permeability, i.e. very narrow pore connections, medium gravity oil equaling 30° API (Childs and Reed 1975), and fresh formation-water (<100.000 ppm). The transition zone was defined from the capillary pressure curve as the interval between S_w equaling 100 per cent to the point of irreducible water-saturation, at S_w = 17.5 per cent, defined where the P_c-curve approximates vertical. Above the level for irreducible water-saturation water was held by capillary pressure and would not flow during production. Below this level – in the transition zone – oil and water would flow together. A 50 per cent cut-off is conventionally applied for the lower boundary in commercial oil production, as the amount of produced water often is too great below this level.

At the base of the chalk section, below the top of the free water level, a few feet with water-saturation down to 70 per cent were found; this could be explained as residual oil after oil-migration.

M-lx was tested at two intervals. One perforation at 6327′–6372′ yielded oil (fig. 7), as the perforation was situated above the level of irreducible water-saturation. The second perforation was placed at depth 6514′–6535′ and flowed both oil and water, corresponding to the transition zone of water-saturation at 30–40 per cent (fig. 7). Both tests confirmed the log-evaluations.

Conclusion

From composite log and cross-plots of different log-parameters it was possible to predict lithology and calculate porosity, water-saturation, permeability, and levels for gas-, oil-, transition-, and water zones, all factors of great importance in the development and exploitation of a reservoir.

Lithology was found to be carbonate, with less than 5 per cent dolomite, though log-derived lithology indicated as much as 90 per cent dolomitized chalk. Porosity was found to correspond to measured core-porosities with as much as 43 per cent porosity in "Porous Zone" Danian and upper part

Maastrichtian, and down to 22 per cent porosity in the transition zone. The high porosity was caused by overpressure. Total average porosity for pay zone was found to be 29 per cent, which was close to the 28 per cent porosity found by Childs and Reed (1975).

Calculated permeabilities showed +1 and −2 mD off from core-measured permeabilities.

Average water-saturation for pay zone was found to be 19 per cent, highly differing from an average of 30 per cent, as found by Childs and Reed (1975). This deviation may be due to different values water-resistivity. Still, S_w-calculations in this examination were confirmed by the test-results.

Levels for hydrocarbon-bearing zones:

Top gas zone	5902′
Top oil zone	6160′
Top transition zone	6380′
Cut-off at S_w = 50 per cent	6561′
Top water zone approx.	6700′
Gas net pay zone	258′
Oil net pay zone	401′
Total net pay zone	659′

Childs and Reed (1975) found net gas zone at 263′, net oil zone at 316′, and top water zone at 6675′ b.KB. The minor difference for net gas zone may be due to slightly different picking of top chalk and gas/oil contact. The greater discrepancy in the net oil zone and top water zone could only be caused by different values in water-resistivity, emphasizing the importance of obtaining correct water-resistivity data, as this value is main factor in predictions of oil in place.

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Dansk sammendrag

I boringen Dansk Nordsø M-lx er der foretaget en tolkning af logdata med henblik på bestemmelse af lithologi og kulbrintemængde i gas- og olieførende øvre kridt og danien kalksten, med præsentation af enkelte basale, kendte arbejdsmetoder baseret på porøsitets- og modstandsmålinger. Disse metoder danner grundlag for beregninger af tilstedeværende oliereserver i reservoiret samt for udviklingsforløbet i udnyttelsen af feltet.

Reservoiret blev opdelt i fire lithologiske enheder: Danien i en øvre »Porøs Zone« og en nedre »Tæt Zone«; øvre kridt i en porøs øvre del af maastrichtien og en mindre porøs, nedre del

af maastrichtien. De unormalt høje porøsiteter i den øverste del af kalkstenen skyldtes overtryk i formationen. Beregnede permeabiliteter er meget lave og stemmer overens med data fra kærnemateriale. Beregninger af vandmætning viser »pay zone« ned til 50 procent vandmætning i en dybde af 6561′ under Kelly Bushing. Gas og olie kan kun produceres vandfrit indtil en dybde af 6380′ under Kelly Bushing, da vand er bundet i formationen over dette niveau. 100 procent vandmætning fandtes ved 6700′ dybde. Prøvepumpninger sandsynliggør rigtigheden af disse log-beregninger.

Abbreviations

A	=	coefficient (usually equal to 1)
API°	=	classification of oil density, as defined by the American Petroleum Institute
BHC-GR	=	Bore Hole Compensated Sonic-Gamma Ray Log
C	=	constant in equation: $\Phi \times S_w = C$
CNL	=	Compensated Neutron Porosity Log
Δt	=	Interval Transit Time
Δt_{shale}	=	Interval Transit Time in shale
FDC	=	Compensated Formation Density Log
GR	=	Gamma Ray Log
GR_{clay}	=	Gamma Ray reading in shales
GR_{clean}	=	Gamma Ray reading in clean formation
h	=	thickness of event
IES	=	Induction Electrical Log
K	=	permeability in millidarcy
LL7	=	Laterolog
m	=	cementation exponent (often equal to 2.0, empirically derived)
mD	=	millidarcy; measure for permeability
n	=	saturation exponent (often equal to 2)
ohm-m	=	$\frac{1000}{\text{mmhos/m}}$
P_c	=	capillary pressure in psi
Φ	=	porosity (using FDC- and SNP-logs)
$\bar{\Phi}$	=	average porosity
Φ_{used}	=	porosity (using FDC-SNP cross-plot)
ppm	=	parts per million
psi	=	pounds per square inch
R_m	=	resistivity of mud
R_{mf}	=	resistivity of mud filtrate
R_t	=	resistivity, true; i.e. for uninvaded zone (using IES or Laterolog)
R_w	=	resistivity of formation water (calculated)
Σ	=	summation of
SNP	=	Sidewall Neutron Porosity Log
S_w	=	water-saturation
$\bar{S}_w$	=	average water-saturation
$S_{w\ irr}$	=	irreducible water-saturation
b.KB	=	below Kelly Bushing
V_{clay}	=	volume per cent of clay in a formation

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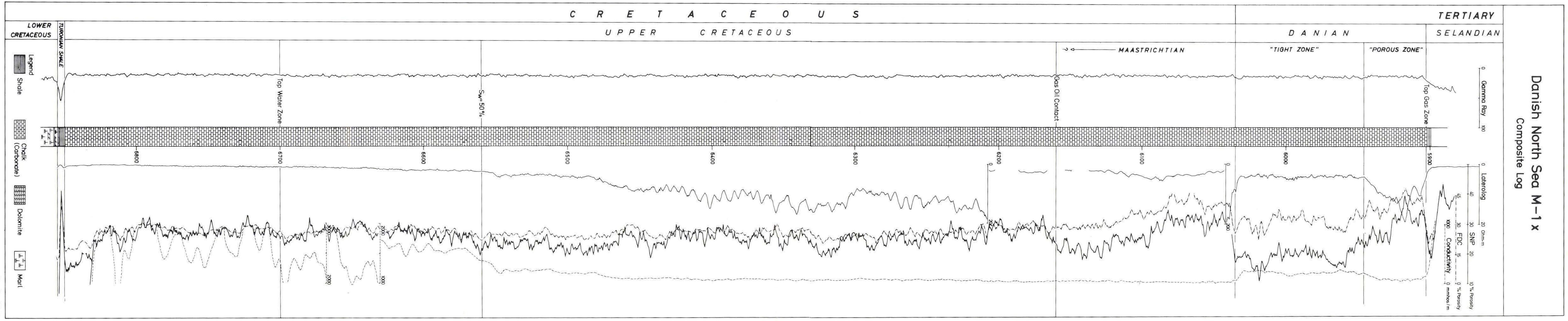

Plate 1. Composite log. LL7 was used as basic log for depth-matching.