point on the basis of wireline logs alone, but it is defined by the occurrence of marls and limestones, or mudstones with reddish coloration above the boundary.

Distribution: The Formation is present in the Danish O-1, A-2, G-1, M-1, M-8, E-1, E-3, and I-1 wells. It is widely distributed in the central North Sea outside structural highs, in the southern part of the Danish-Norwegian Basin, and south of the Ringkøbing-Fyn High.

Geological age: On the basis of foraminiferal faunas, the Formation is invariably dated Albian and occasionally also referred to parts of the Aptian (? Late Aptian).

Depositional environment: Marine shelf.

Source rock potential: Poor. The content of organic material is too low to give any source rock potential.

Reservoir potential: Unknown.

Sealing potential: Fair, but this cannot yet be evaluated further.

3.6 Late Cretaceous and Danian limestone

By Kirsten Lieberkind, Inger Bang, Naja Mikkelsen & Erik Nygaard

At the termination of the Early Cretaceous period, the sea transgressed large earlier land areas. The transgression, the reduced relief of the continents, the generally diminished tectonic activity, the climatic change, and the enormous production of calcareous nannoplankton in the oceans profoundly changed the gross facies pattern in the North Sea region. The clastic sedimentation was replaced during Late Cre-

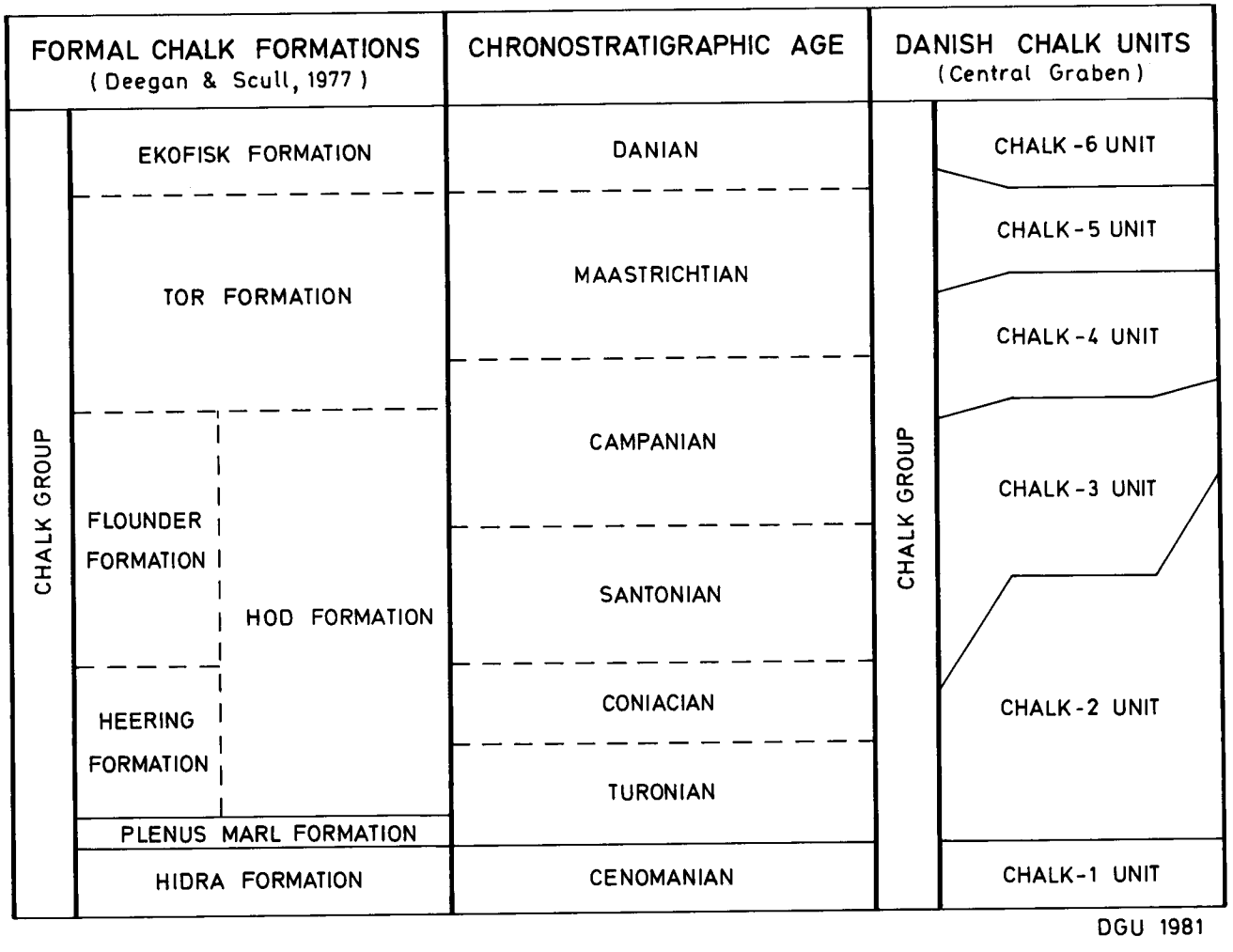

Fig. 25: A correlation between Chalk Units in the Danish Central Graben, the chronostratigraphic time table, and the formal Chalk Formations established by Deegan & Scull (1977) for the Northern and Central North Sea area.

taceous time by offshore relatively deep water carbonate sedimentation.

This resulted in the deposition of a chalk sequence reaching a thickness of 1-2 km in the Danish Subbasin and the North Sea area.

Chalk Group (Deegan & Scull 1977)

The chalk interval in the North Sea has been described as the Chalk Group by Deegan & Scull (1977).

Type section: The type area of the Chalk Group is the North Sea basin. A formal type section has not yet been established.

Reference sections: A thickness estimate based on a compilation of thicknesses of units from a number of wells in the type area suggests a thickness in the order of 1500 m.

A similar estimate for the Danish Central Graben is 1000 m, but the figures show a wide variety.

Lithology: The Chalk interval in the North Sea is represented by white limestone which shows wide variations in induration, colour, chert, clay, shale, and glauconite content. The term 'chalk' is used here as in Scholle (1977a).

Log characteristics: A number of formal chalk forma-

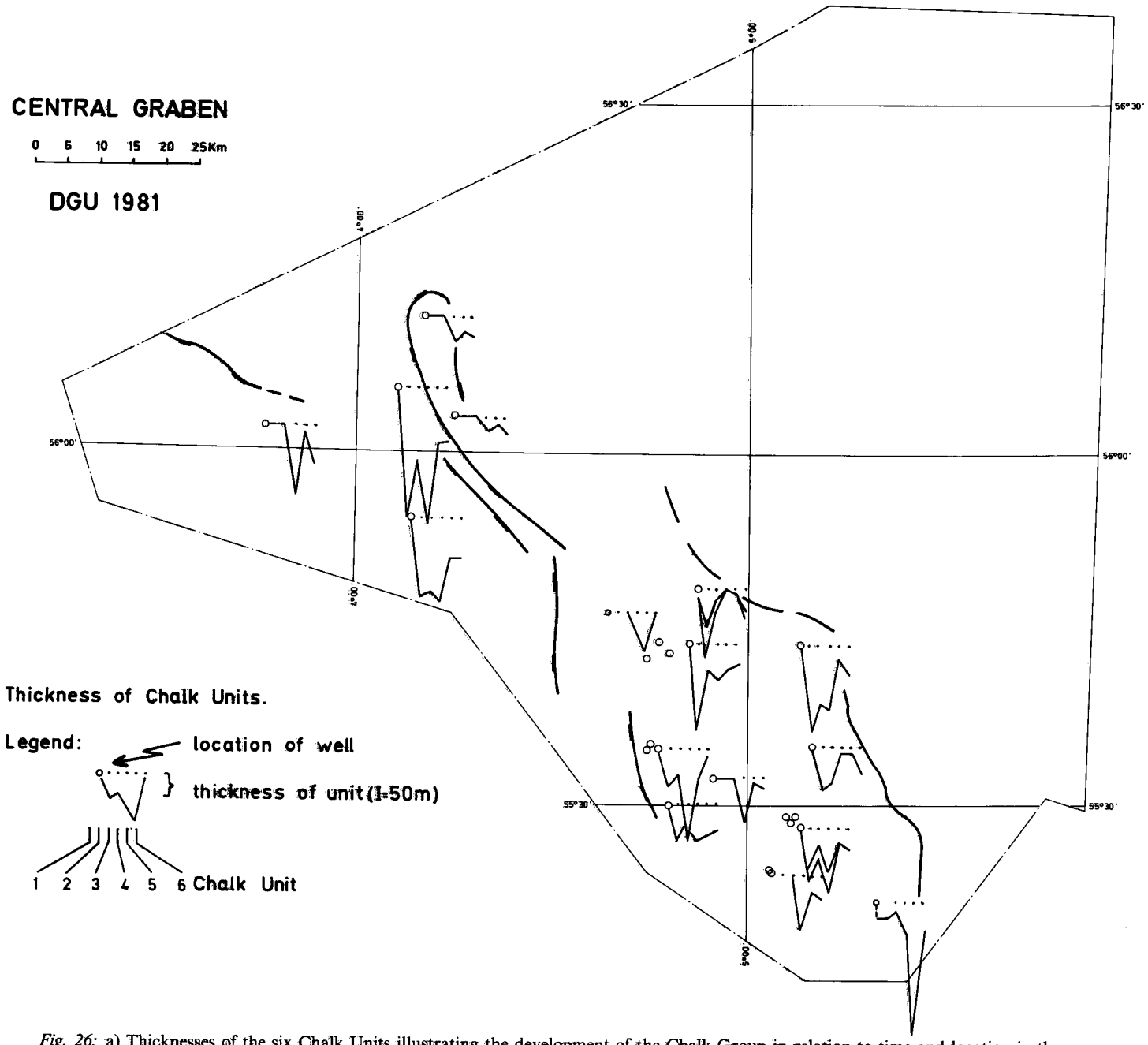

Fig. 26: a) Thicknesses of the six Chalk Units illustrating the development of the Chalk Group in relation to time and location in the Graben area.

tions have been established in the Norwegian sector by Deegan & Scull (1977).

In the Danish sector of the Central Graben, a total number of six log units have been established (see below). These units are mainly defined by gamma ray and sonic velocity responses. The units are labelled Chalk-1 Unit to Chalk-6 Unit, where the first represents the older sequence and the Chalk-6 Unit the younger.

The above mentioned units have not been given the rank of formal formations, as work remains before the definitions can be verified. The correlation between the formal chalk formations of Deegan & Scull (1977) and the proposed Danish chalk units (fig. 25) is therefore tentative.

Boundaries: The Chalk Group in the type area overlies the Early Cretaceous calcareous mudstone of the Cromer Knoll Group and, in the Danish sector, the Rødby Formation or older deposits. The boundary in both cases is only distinct if a hiatus is present.

The upper boundary to the overlying clastic sediments of the Tertiary may be sharp or gradual through the calcareous 'North Sea Marl' unit.

Distribution: The Group has a wide distribution in the central North Sea. It is present in the southern part of the Viking Graben, in southeast England, in the Dutch and German parts of the North Sea, and in the Danish onshore and offshore areas. At least a part of

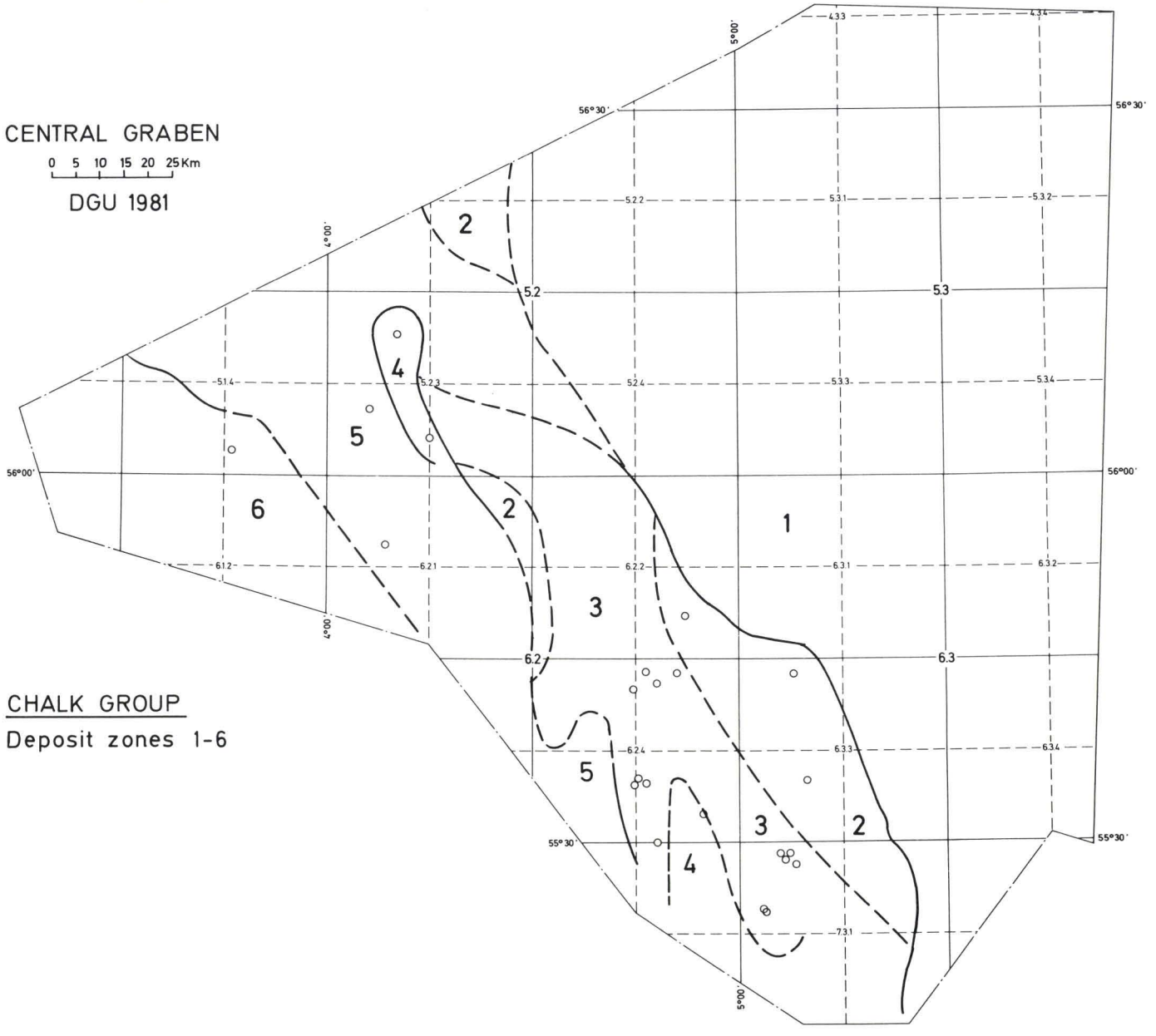

Fig. 26: b) Areal distribution of the chalk deposit zones 1 to 6 deduced from the chalk depositions.

the Chalk Group has been recognized in all wells from the Danish Central Graben. Based on the presence/absence and thicknesses of the single chalk units (figs. 27 to 29), and the generalized isopach map (fig. 16) a set of six deposit zones is suggested (fig. 26). Wells situated within the same zone show a gross similarity in the chalk development (fig. 31).

Geological age: The dating of the Chalk Group in the North Sea is essentially based on micropalaeontological studies of foraminifera. The Chalk Group is referred to the stratigraphic interval from base Late Cretaceous to top Danian.

From palaeontological studies it is evident that Danian limestone is present in nearly all Central Graben wells. Chalk of Maastrichtian age is also recorded in all wells. Chalk of Campanian age is present in most wells, whereas the older chalk of Cenomanian to Santonian age has a rather scattered occurrence in the area.

Depositional environment: Open marine conditions dominated during the deposition of the Chalk Group. The general picture of the chalk sedimentation, however, seems to indicate rather disordered pre-Maastrichtian deposits in the Central Graben. The distribution pattern of these deposits is affected by folding, salt movements, and non-deposition or erosion, especially in the southern part. The Maastrichtian-Danian chalk deposits tend to be less affected by these processes, and they unconformably overlie the older chalk units on most piercement structures.

The chalk sequence is often bounded by two unconformities - a minor at the Cretaceous-Tertiary boundary and a major at the base of the chalk. The unconformity at the base of the chalk is diachronous. However, it clearly indicates a conspicuous change in the depositional environment between the chalk sequence and the older sediments. The unconformity is pronounced in the northern part of the Danish Central Graben and less striking in the middle and southern part. The most complete chalk sequences are recorded in deposit zones 2 and 3 (fig. 26) of the Central Graben. This area presumably subsided during the entire Late Cretaceous and Early Tertiary period.Indirect evaluations suggest a similar evolution in the western end of the Ringkøbing-Fyn High area. On the contrary, the older chalk sequence (from Cenomanian to Coniacian) is missing in deposit zones 4 to 6, creating the major hiati in these areas.

Source rock potential: The Chalk Group is in general considered to have a low source rock potential.

Reservoir rock potential: The primary porosity and fractures of the Chalk Group in general makes it a fair reservoir rock despite its low matrix permeability. Oil and gas have been located within the Chalk Group and production has been started in a few fields of the Danish part of the North Sea.

Sealing potential: Clay lamina, stylolites, and diagenetic horizons within the Chalk Group represent sealing possibilities. However, the Chalk Group in general is considered to have a poor sealing potential.

Chalk-1 Unit *(informal name)*

Type section: The Danish Adda-1 well (7420-7512' b.KB), thickness 28 m.

Reference section: The Danish O-1 well (7500-7580' b.KB), thickness 22 m.

In the Danish Central Graben, the Chalk-1 Unit is also present in the E-1 well, the data of which are given in chapter 8.

The Unit may furthermore be present in the A-2, B-1, and H-1 wells, where the sections are very condensed.

Tentative correlations: The Chalk-1 Unit may be correlated with the Hidra Formation.

Thickness: The Chalk-1 Unit is only recognized with certainty in three wells in the middle and southern part of Central Graben. The maximum thickness of the Unit is recorded in Adda-1 (28 m) (fig. 27).

Lithology: The Chalk-1 Unit is dominated by hard to moderately hard chalk. The colour is white to light grey and occasionally slightly pink. The chalk is often interbedded with greyish and light green marl and shale. Thin beds of calcisiltite may be present (O-1) and in places the chalk is slightly dolomitized (Adda-1).

Log characteristics: The Chalk-1 Unit is defined by the gamma ray and sonic velocity, which have constant low and high values respectively. In some wells the logs have an irregular curve pattern reflecting clayey and marly intercalations in the chalk.

Boundaries: The lower boundary between the Rødby Formation and the Chalk-1 Unit is often gradual. The boundary is defined where for the first time constant, low gamma ray and high sonic velocities are encoun-

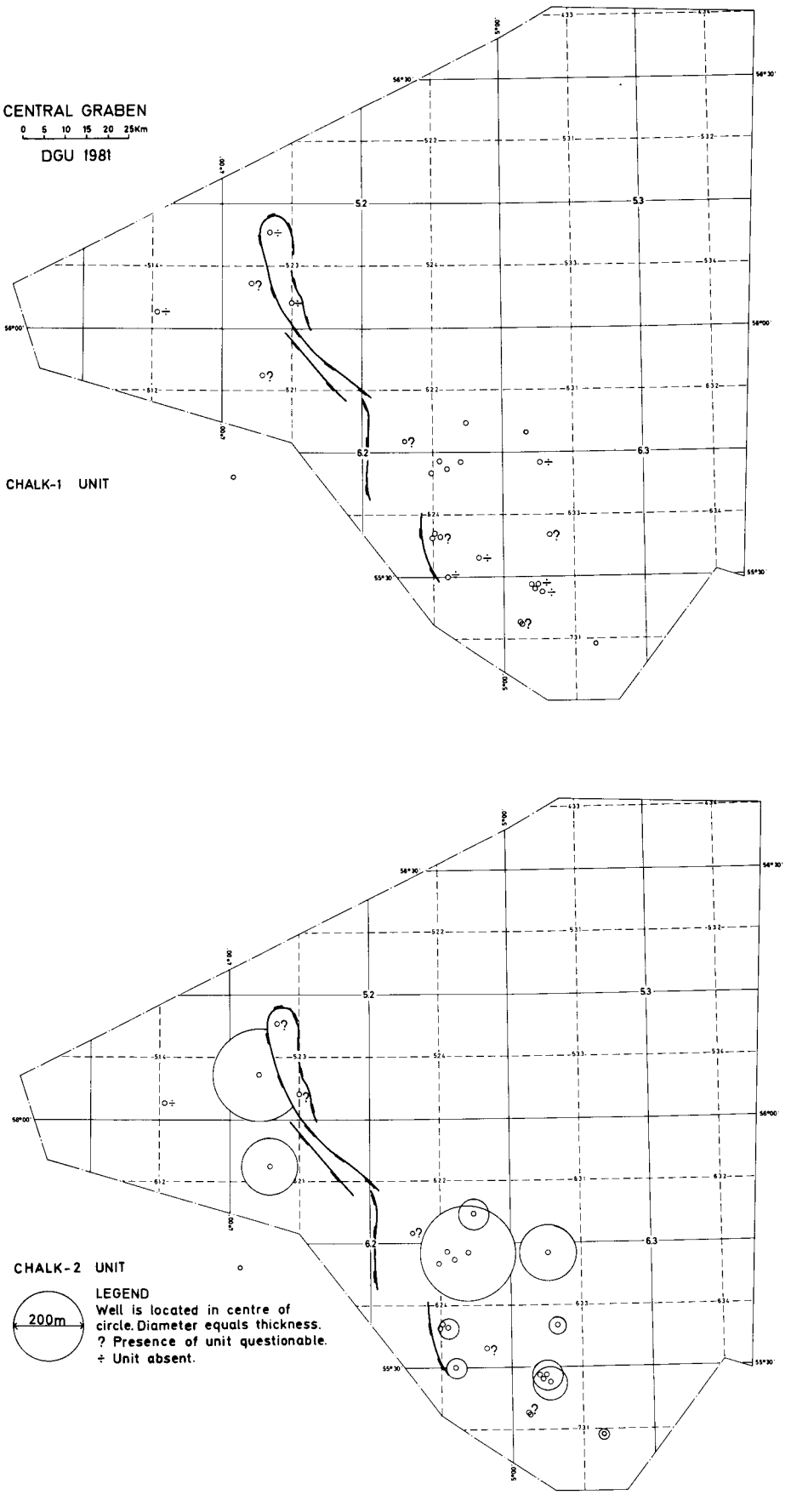

Fig. 27: Distribution and thickness of a) Chalk-1 Unit and b) Chalk-2 Unit.

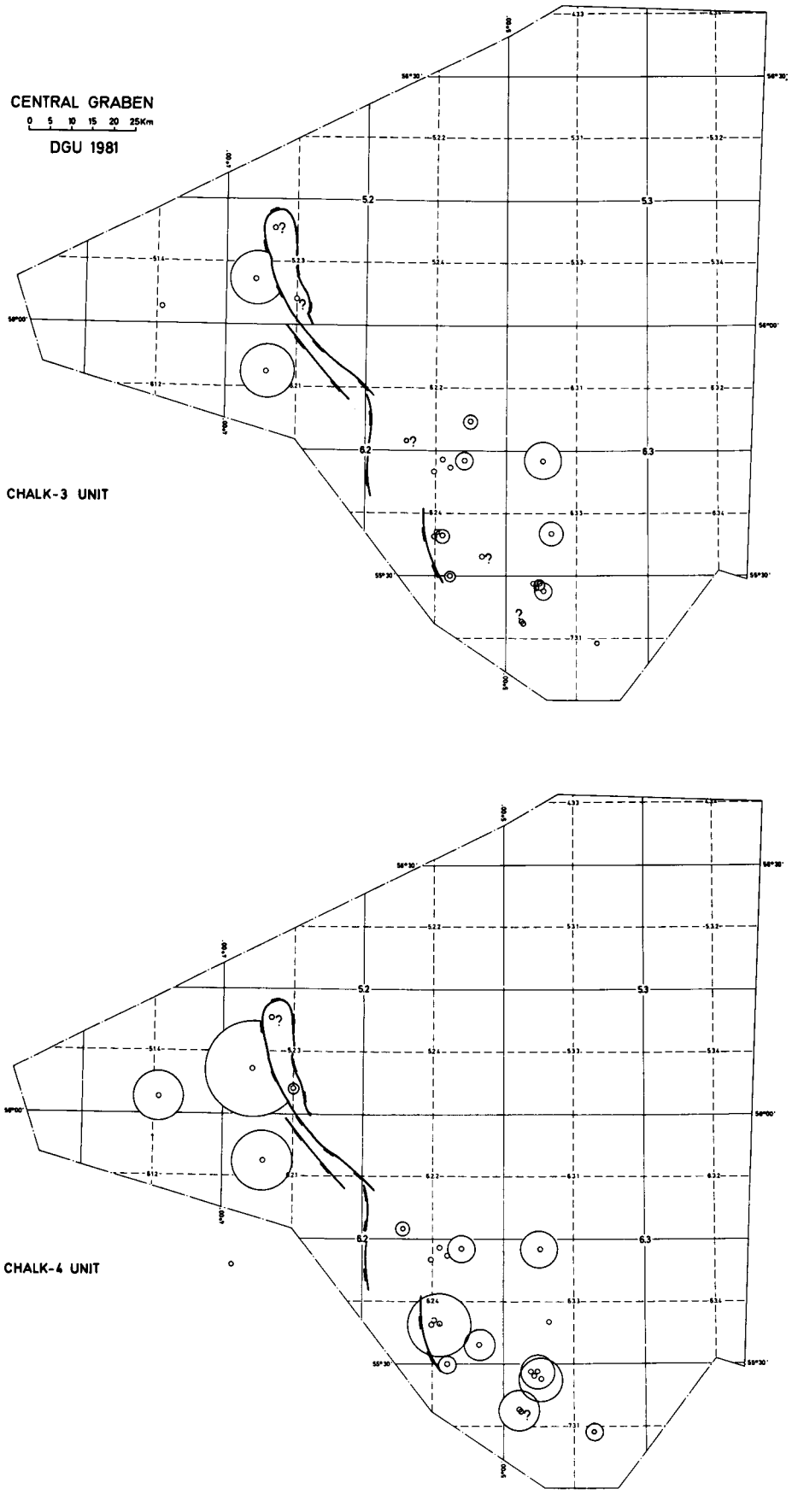

Fig. 28: Distribution and thickness of a) Chalk-3 Unit and b) Chalk-4 Unit. – For legend, see fig. 27.

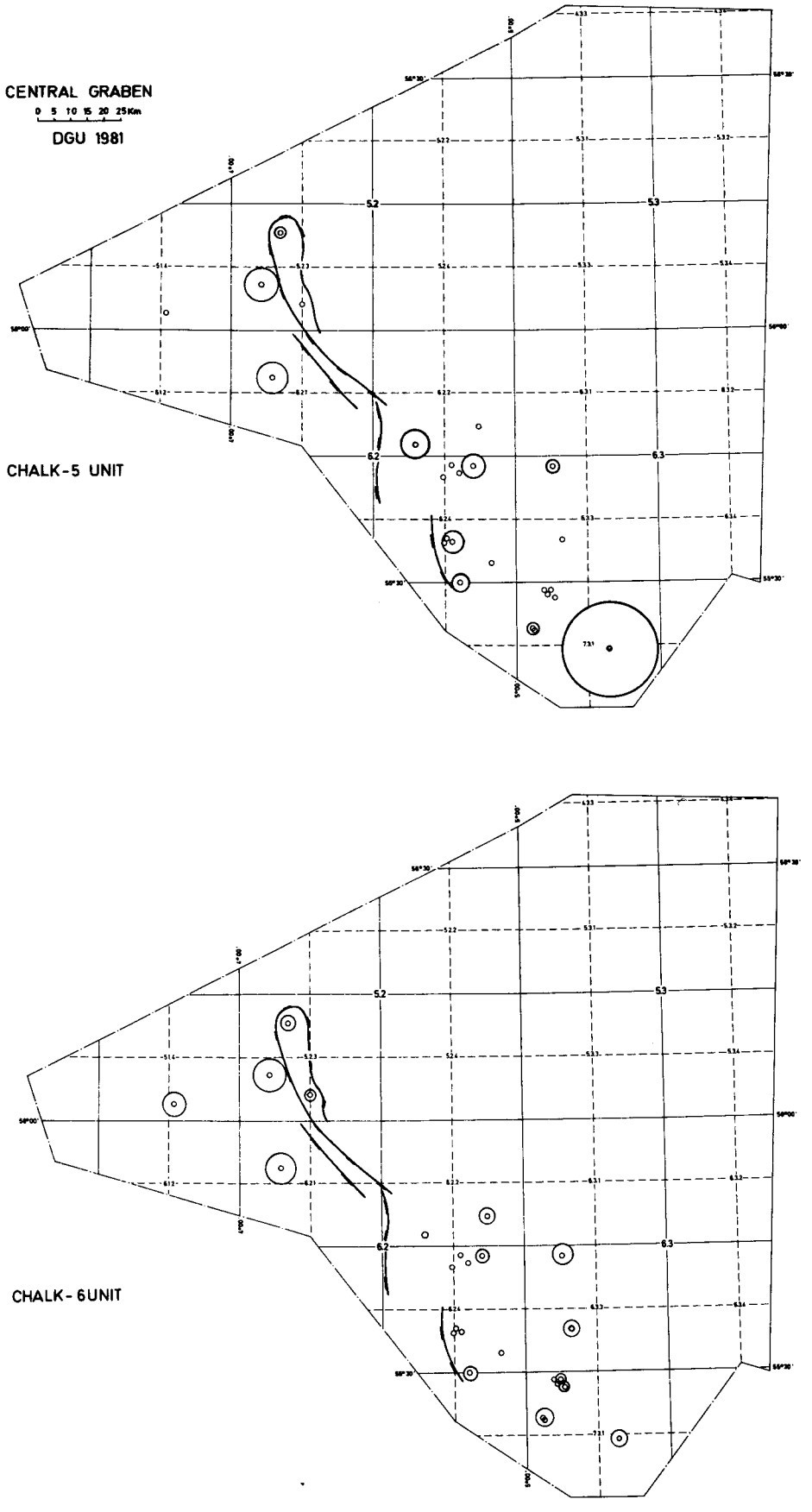

Fig. 29: Distribution and thickness of a) Chalk-5 Unit and b) Chalk-6 Unit. – For legend, see fig. 27.

tered. Where the Rødby Formation is missing the log pattern changes very abruptly.

The upper boundary to the Chalk-2 Unit can only be defined where the 'Turonian Shale' is present. In these cases the boundary is defined where the gamma ray and sonic velocity change abruptly to much higher and lower values respectively.

Distribution: The Chalk-1 Unit has been identified only in wells from the middle and southern part of the deposits zones 2 to 3 (fig. 26). The Unit is missing from wells in all zones of the northern part, and it has not been recorded in wells drilled on top of salt structures, which points to erosion during syn-sedimentary halokinesis.

The Hidra Formation is widely distributed in the southern and central parts of the North Sea. It is likely that the Danish equivalent, the Chalk-1 Unit, is present in the deposit zones 1 to 3 in the Danish Central Graben.

Geological age: All biostratigraphic datings of the Chalk-1 Unit point to a Cenomanian age. The Hidra Formation in the Norwegian sector is also of a Cenomanian age.

Depositional environment: The foraminiferal data indicate an open marine environment of deposition with neritic conditions. The shale and marl lamina within the chalk might indicate a stronger periodical influx of terrestrial materials.

Source rock potential: The Unit is not known as a source rock.

Reservoir potential: The Chalk-1 Unit is fairly tight (chapter 9) and it is probably not a good reservoir rock, unless fractured.

Sealing potential: Only the shale lamina within the Unit would have a good sealing potential. The shales, however, are only a minor constituent of the Unit. The Unit may therefore be characterized as having a poor sealing potential.

Chalk-2 Unit *(informal name)*

Type section: The Danish E-1 well 7500-8115' b.KB, thickness 188 m.

Reference section: The Danish V-1 well 8375-8940' b.KB. In the Danish sector of Central Graben the Chalk-2 Unit is present in the wells given in chapter 8.

Tentative correlations: The 'Turonian Shale' at the base of the Chalk-2 Unit in the Danish sector is probably equivalent to the lower part of the Plenus Marl Formation in the Norwegian sector (fig. 25).

The 'Turonian Shale' is, in this presentation, considered to be the base of the Chalk-2 Unit. However, it may be defined as a separate unit at a later stage, when more information on the shale is available.

The chalk sequence of the Unit seems to correlate with the lower part of the Hod Formation (fig. 25), or with the Heering and the lower part of the Flounder Formations which are homotaxial to the Hod Formation.

The 'Turonian Shale' and the rest of the Chalk-2 Unit have also been recognized in the Danish onshore area.

Thickness: The thicknesses listed in chapter 8 show a wide scatter which apparently is related to the depositional subdivision of the Graben area. The maximum thicknesses are found in the wells of the northern and middle parts of the Graben, i.e. deposit zones 2, 3 and 5, whereas the Unit is thin or absent above the salt structures of deposit zone 4 in the southern part (figs. 26 and 27). This pattern appears to be enhanced by syn-sedimentary growth of the salt piercement structures.

In the Danish type section the 'Turonian Shale' is approximately 2 m thick.

Lithology: The base of the Unit is represented by the distinct 'Turonian Shale', which is in general a black non-calcareous shale.

Above the basal shale there is a white to light grey chalk sequence which is hard with moderately hard intercalations. The chalk is often dominated by numerous stylolites seams, and sometimes horse-tail solution structures. Occasionally marly intervals or fine clay lamina are present in the chalk (e.g. the E-1 well).

Log characteristics: At the base of Unit-2 both gamma ray and sonic velocities show peaks, corresponding to the 'Turonian Shale'. Upwards in the rest of the Unit the gamma ray and the sonic velocity read constant low and high values respectively. The sonic velocity is generally lower than in Unit-1. However, the sonic velocity pattern is rather nervous, with high amplitudes. With greater depth of burial, this feature becomes less distinct, as seen in the Q-1 well.

Boundaries: The lower boundary is identical to the upper boundary of the Chalk-1 Unit. The upper boundary to the Chalk-3 Unit is defined where the

gamma ray changes to a constant and slightly lower level, and the sonic velocity reads higher values.

Distribution: The Chalk-2 Unit is known from wells in deposit zones 2, 3, 5, and 6 in the Central Graben (fig. 27). The Unit is likely to be present in between the salt structures of the deposit zone 4.

Geological age: The age of the shale at the base of Unit-2 is unknown but it is assigned a Turonian age. The datings of the overlying chalk sequence indicate the nature of the Unit to be diachronous. In the middle part of deposit zones 2 to 3 of the Graben area, the Unit seems to be of Turonian-Coniacian age. In the southern part it is difficult to make log- and age-interpretations. However, the Chalk-2 Unit in the less structurally affected well 0-1 is of a Turonian-Coniacian age.

In deposit zone 6 and the mid- northern part of zone 2, the micropalaeontological dating of the Chalk-2 Unit points to an overall Santonian age. The change from a depositional environment influenced by terrestrial sources (as recognized in the lithology of the Chalk-2 Unit), to an environment with less terrestrial influence (as recognized in the lithology of the Chalk-3 Unit) thus occurred at a later stage in the northern than in the middle and southern part of the Danish Central Graben.

Depositional environment: Apart from the basal part the Unit is deposited in an open marine neritic environment. A number of hypotheses have been proposed for the depositional history of the 'Turonian Shale'. It has been suggested that the Unit represents weathered volcanic detritus since it has a high content of montmorillionite and a wide distribution despite its relative thinness.Another hypothesis proposes that deposition occurred during a regression period with anaerobic conditions. The Chalk-2 Unit is widely distributed in the Central Graben, and unconformably overlies older rocks of Early Cretaceous and Jurassic ages in the northern part of the area. In deposit zones 2 and 3, the shale conformably overlies the Chalk-1 Unit. In deposit zone 4 halokinetic movements have disturbed the depositional pattern. During the deposition of Unit-2, subsidence must have increased considerably since the younger part of the Unit is also found in deposit zone 5.

After the deposition of the Turonian Shale, pure chalk of a basinal character was deposited, and stable outer marine conditions seem to have prevailed.

Source rock potential: The Turonian Shale might be considered a possible source rock. It may have a fairly high organic content, but is presumably immature. The source rock potential of the remaining part of the Chalk-2 Unit must be characterized as poor, due to a rather low organic matter content.

Reservoir potential: The Unit normally displays a rather moderate porosity (chapter 9) which reduces the reservoir potential of the Unit, unless it is fractured. However, in the Adda-1 well, high porosity oil-bearing zones have been encountered within the Unit.

Sealing potential: The Turonian Shale at the base of the Unit might provide a seal. The upper part of the Unit has a low sealing potential due to the porosity of the chalk.

Chalk-3 Unit *(informal name)*

Type section: The Danish V-1 well, 8357-8737' b.KB, thickness 107 m.

Reference section: The Danish Q-1 well, 11,240-12,128' b.KB, thickness 149 m.

The Unit has furthermore been recognized in the Danish wells noted in chapter 8.

Tentative correlations: The Chalk-3 Unit is tentatively correlated to the middle part of the Hod Formation, and a part of the homotaxial Flounder Formation (fig. 25). The Chalk-3 Unit may also be recognized in the Danish offshore area northeast of the Central Graben, as well as in the Danish onshore area.

Thickness: The thicknesses listed in chapter 8 show a wide range, from 18 m in the O-1 well to 157 m in the W-1 well. The Unit is well developed in deposit zone 5 as well as in zones 2 and 3 along the western margin of the Ringkøbing-Fyn High (fig. 26). In deposit zone 4 of the southern salt dome province of the Central Graben, the thickness of the Unit is only about 25 m (fig. 28).

Lithology: The Chalk-3 Unit consists of a white to light grey crypto- to microcrystalline hard chalk with a very low clay content ($<2\%$).

Log characteristics: The gamma ray is characterized by constant low values. The sonic velocities are high, especially in the bottom and top parts, giving the general curve trend a concave shape. The sonic curve also has a somewhat serratic pattern with low ampli-

tudes. In this Unit the sonic velocity shows often the highest values found in the entire Chalk Group.

Boundaries: The lower boundary is identical to the upper boundary of the Chalk-2 Unit. The upper boundary to Unit-4 is defined where the sonic velocities change abruptly to a constant lower level. Normally the boundary is indistinct on the gamma ray log. However, the gamma ray sometimes changes to slightly higher values in Unit-4.

Distribution: The Chalk-3 Unit is present in almost all wells drilled within the Danish Central Graben, except for deposit zone 6 and the southern part of zone 4 (figs. 26 and 28).

Geological age: The age datings based on foraminiferal analyses of the Chalk-3 Unit show ages ranging from Coniacian to Early Maastrichtian, but most datings of the Unit fall within the time interval of Early Campanian to Late Santonian. A time transgressive nature of the Unit may be illustrated by the apparent younger age of the Chalk-3 Unit in depositional zones 5 and 6 (Late Santonian-Campanian) than in zones 2 and 3 (Santonian-Coniacian).

Depositional environment: The palaeontological data point to an open marine type of deposition. The subsidence, which started during the deposition of the Chalk-2 Unit, seems to have continued but apparently at a reduced rate. The overall thickness of the Unit is thus reduced compared to the previous interval. The salt dome and piercement structures of deposit zone 4 were presumably active in the depositional period of the Chalk-3 Unit, since the Unit is thin or absent on these structures.

The apparent time transgressive nature of the Unit may illustrate regional changes in the history of deposition. The Unit thus covers a much longer time span in deposit zones 2 to 3 than elsewhere. This may indicate a slower rate of change in the depositional environment of deposit zones 2 to 3 than in the remaining areas. Compared to the depocentres of the Chalk-2 Unit, the depocentre of the Chalk-3 Unit has moved north within deposit zones 2 to 3 (figs. 27 and 28).

Source rock potential: The Unit in general has a very low content of organic material and is generally a poor source rock.

Reservoir potential: The porosity and permeability of the chalk is fairly low (chapter 9). The Unit may therefore be considered a poor reservoir rock in general. Fractures occur occasionally above salt structures and thereby provide some reservoir potentials for the Unit.

Sealing potential: The Unit may have a moderate sealing potential due to the fairly low porosity.

Chalk-4 Unit *(informal name)*

Type section: The Danish M-1 well, 6118-6471' b.KB, thickness 108 m.

Reference section: The Danish Q-1 well, 10,730-11,640' b.KB, thickness 227 m.

The Unit, which is known as the 'Maastrichtian Tight', has been recognized in the wells given in chapter 8.

Tentative correlation: The log pattern of the Chalk-4 Unit may allow a correlation to the uppermost part of the Flounder Formation and the lower part of the Tor Formation in the Norwegian sector of Central Graben (fig. 25).

As with the above described chalk units, a correlation is possible between the chalk section in the Danish Central Graben and the Danish onshore, as well as the Danish offshore area to the northeast.

Thickness: The thicknesses listed in chapter 8 show a wide range (fig. 28), which again reflects the structural development of the Graben area. The maximum thicknesses are found in deposit zone 5 along the eastern flank of the Dogger High, whereas the Unit is totally missing in the Adda-1 well. It is relatively thin above the salt structures in the northern part of deposit zone 4, and thin or absent in deposit zone 2.

Lithology: The formation consists of a white to light grey chalk. The upper part of the Unit is sometimes referred to as 'Calcisphere Chalk' as allochems of calcispheres make up 20-30% of the rock. The induration of the Chalk-4 Unit may vary, but it is generally less firm than the older units. Stylolites are common. Flint, chert beds, and clays are unevenly distributed.

Log characteristics: The gamma ray values are low and fairly constant throughout the Unit. The sonic curve pattern is either open or densely serratic, with a small amplitude. The sonic velocity values are generally high in the lower part of the Unit and decrease steadily upwards. In the middle of the Unit a distinct

high velocity peak is seen. This is referred to as the 'Maastrichtian Hard Strike' which, when cored in the M-1 well, proved to be a flint bed with a thickness of one foot. When present, this peak is an excellent marker. The marker is developed in the middle part of the Central Graben.

Boundaries: The lower boundary is identical to the upper boundary of the Chalk-3 Unit. The upper boundary to Unit-5 is defined at an abrupt change in the sonic velocity from generally high to generally lower values. This point corresponds to a change from a steep to a low inclination of the general trend of the curve from Unit-4 to Unit-5 respectively.

Geological age: The palaeontological age datings point to a Late Campanian-Early Maastrichtian age for the Unit, and it seems to be less time transgressive than the previous units.

Depositional environment: The Chalk-4 Unit has been deposited under open marine conditions, whereas the Calcisphere content in the upper part of the Unit suggests a shallowing upwards situation. The primary productivity of the rock forming coccoliths has been high and the sediments show only minor terrestrial influence.

Except for deposit zone 2 and the northern part of zone 4, the rate of subsidence in the Graben area increased during the deposition of the Unit, and the depositional environment of the remaining deposit zones was equivalent to the older periods of the chalk deposition. The halokinetic movements were reduced, although the fact that the Unit is slightly condensed, or shows intraformational unconformities above salt structures, indicates that they did not entirely cease.

Source rock potential: The Unit contains very small amount of organic matter, and therefore it is considered to have only minor source rock potential.

Reservoir potential: The primary porosity is good and the permeability is fair (chapter 9) The Unit acts as a reservoir in several fields of the Central Graben.

Sealing potential: The high porosity of the Unit gives it in general a poor sealing potential.

Chalk-5 Unit *(informal name)*

Type section: The Danish M-1 well, 6032-6118' b.KB, thickness 26 m.

Reference section: The Danish 0-1 well, 6264-7187' b.KB, thickness 281 m.

In the Danish Central Graben this Unit, often referred as the 'Maastrichtian Porous', has been recorded in all wells (chapter 8).

Tentative correlations: The Unit seems to correlate to the upper part of the Tor Formation in the Norwegian sector (fig. 25). It can also be correlated to the Danish onshore, as well as the Danish offshore area to the northeast. The layer of clay which in some wells has been found at the boundary between the Chalk-5 and Chalk-6 Units has in all investigated wells proved to be younger than the 'Fish-clay' described from the cliff at Stevns in eastern Denmark.

Thickness: The thicknesses of the Unit show a wide range in the drilled sequences. The greatest thickness is found in the O-1 well with more than 200 metres of sediment.

The average thickness of the Unit seems to be around 20 to 80 m in the remaining part of the Graben area, except for the salt and upheaval structures and the Dogger High where the minimum thicknesses are recorded (fig. 29).

Lithology: Unit-5 is clean biogenic chalk, white to off-white or tan in color, rarely light grey. The chalk is moderately hard with soft intercalations. The clay content is low (2-8%). Clay lamina are rare except for a layer occasionally present at the top of the Unit. Flint and chert may occur, and stylolites are common.

Log characteristics: The gamma ray reads generally constant low values. The sonic velocity pattern is rather nervous with high amplitudes. The sonic values are highest at the base of the Unit and decrease gradually towards the top of the Unit. The upper part of the Unit noramlly yields the lowest sonic velocities encountered within the entire Chalk Group.

Boundaries: The lower boundary is identical to the upper boundary of the Chalk-4 Unit. The upper boundary to Unit-6 is often marked by a slight increase of gamma ray values. The sonic velocity defines the boundary by a distinct change from low to considerably higher values, creating a double velocity peak just above the boundary.

Distribution: The Chalk-5 Unit is widely distributed in the North Sea area. It has been recorded in all Danish offshore wells (fig. 29) and it has a considerable thickness in the Danish onshore area. In the

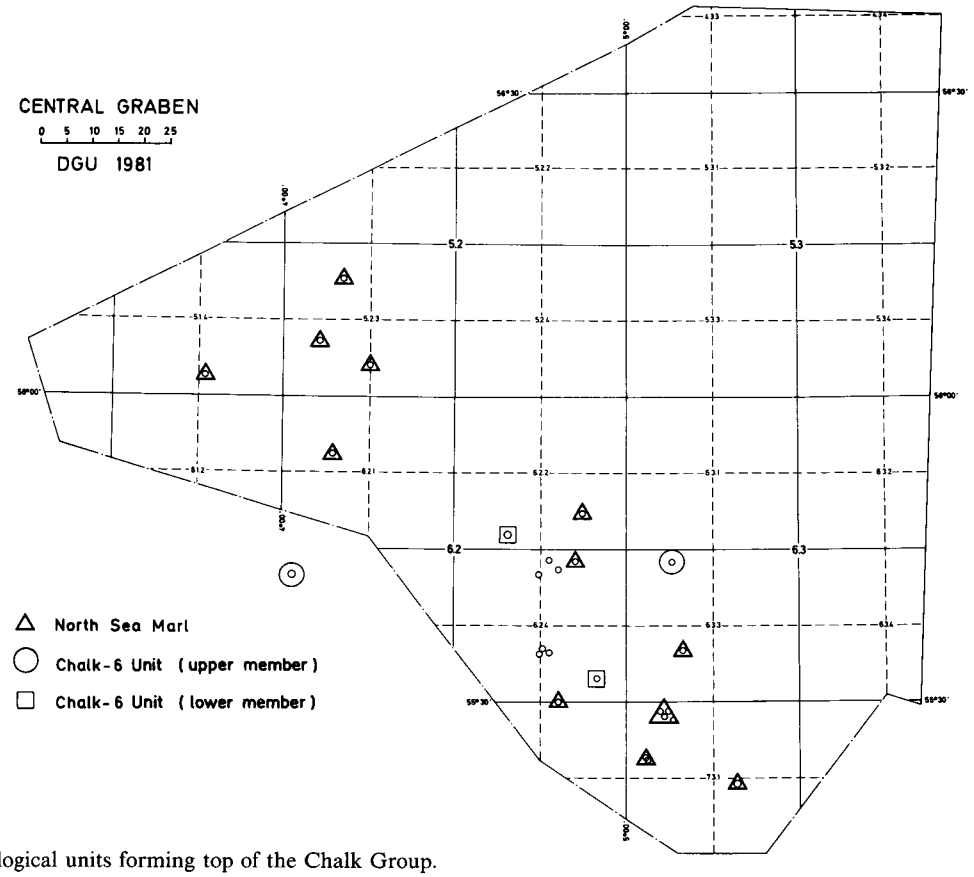

Fig. 30: Lithological units forming top of the Chalk Group.

Norwegian and British sectors, the equivalent formation is well developed in the central parts of the North Sea. To the north it passes into a sequence of interbedded pure limestones and shales in the Norwegian Viking Graben.

Geological age: The micropalaeontological dating of the Chalk-5 Unit points to a general Late Maastrichtian age. The upper boundary of the Unit in most cases is identical to the Maastrichtian-Danian boundary. Despite the fact that the upper boundary apparently straddles the Maastrichtian-Danian boundary in a few wells, the Unit seems to be rather contemporaneous in the North Sea area.

Depositional environment: The general pattern of sediment distribution which was initiated during the deposition of the Chalk-4 Unit presumably continued during the deposition of the Chalk-5 Unit. An exception is shown by the O-1 well which follows a separate pattern. The foraminiferal content of the Chalk-5 Unit points to an open marine depositional environment with outer shelf conditions. The increasing amount of benthonic foraminifera from the bottom to the top of the Unit might indicate a gradual shallowing of the water depth towards the top of the Maastrichtian Chalk-5 Unit. Halokinesis was active in Late Maastrichtian time, as illustrated by the reduced thickness of the Unit on top of salt structures. As indicated by the logs, it is often the uppermost highly

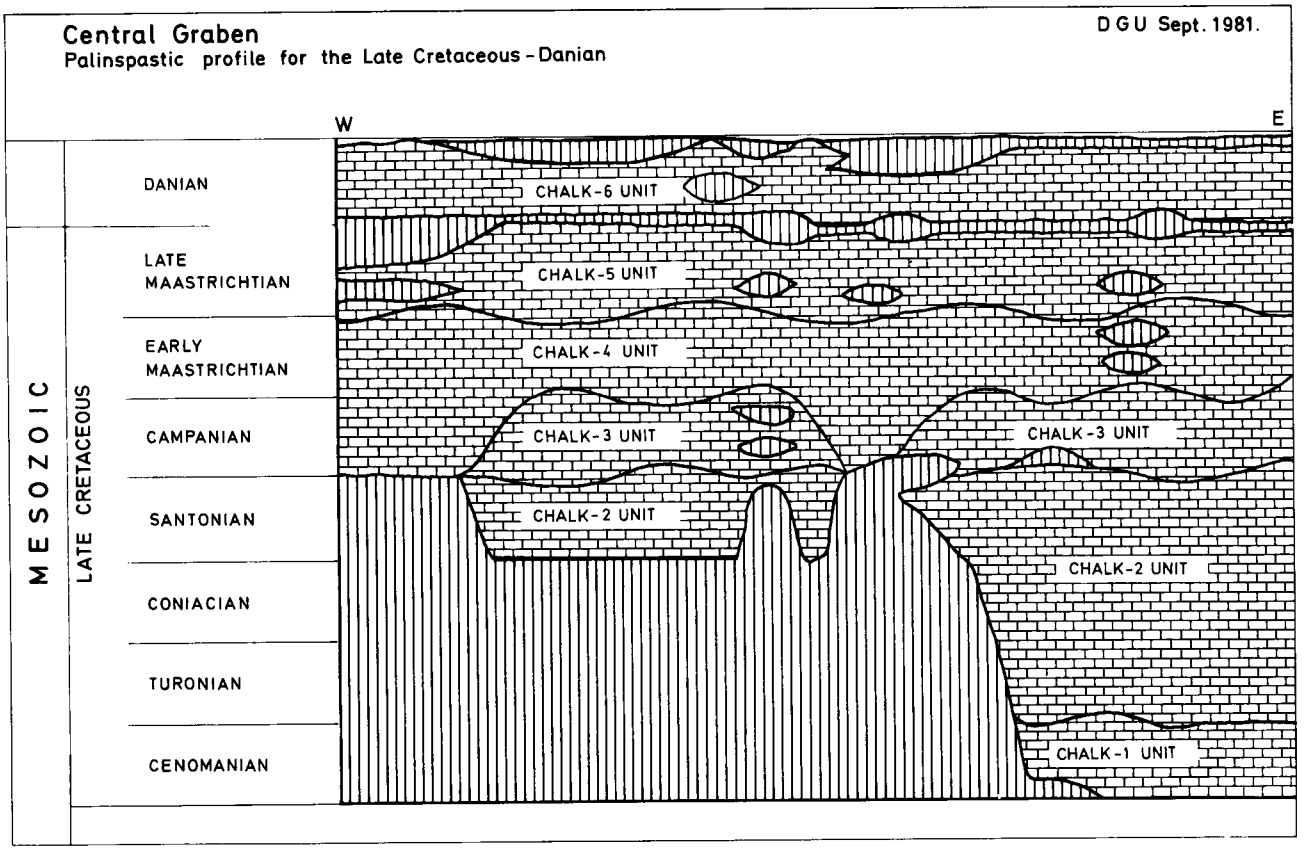

Fig. 31: Palinspastic profile of the Late Cretaceous-Danian deposits. – For legend, see fig. 3.

porous part of the Unit which is preserved on the salt structures whereas the lower part may be missing.

Source rock potential: The Unit is almost devoid of organic material and hence a poor source rock.

Reservoir potential: The primary porosity and permeability data (chapter 9) are generally good and point to fair reservoir characteritics for the Unit. A number of oil reservoirs have been proven within the Unit in both the Danish and Norwegian sectors.

Sealing potential: The high porosity of the Unit gives it a very poor sealing potential.

Chalk-6 Unit *(informal name)*

Type section: The Danish G-1 well, 6620-6790' b.KB, thickness 52 m.

The Unit is divided into a lower member, often referred to as 'Danian Tight' and an upper member, often referred to as 'Danian Porous'.

Reference section: The Danish W-1 well, 10135-10413' b.KB, thickness 25 m.

In the Danish Central Graben the Unit has further been recorded in the wells mentioned in chapter 8.

Tentative correlation: The Chalk-6 Unit may be correlated with at least a part of the Ekofisk Formation.

In the Danish onshore area, the Chalk-6 Unit is equivalent to the informal unit 'Danske Kalken'.

Thickness: On a regional scale the thickness of the Chalk-6 Unit is larger in the northern than in the southern part of the Central Graben (fig. 29). The maximum thickness is recorded in deposit zone 6 and in the mid-northern part of deposit zone 2. The thickness is rather uniform in the remaining area. The smallest thickness is found on an inversion structure in the H-1 well (10 m).

Lithology: The lower member is chalk, white to greyish or cream colour, moderately-hard to hard. The clay content is fairly high (15-20%), and thin clay lamina, flint beds, and chert are commonly found.

The upper member is a pure, white to cream and

buff coloured chalk, which is soft to moderately hard and in which the occurrence of flint and chert is common. The clay content is generally lesser than in the lower member.

Log characteristics: The Chalk-6 Unit is divided into two distinct intervals: a lower member and an upper member.

The gamma ray generally reads slightly higher values in the lower member than in the upper one. The sonic curve shows numerous high velocity peaks, reflecting the numerous flint beds throughout the entire unit. In the lower member the sonic values are considerably higher than in the upper member, which normally reads values equally low as in the upper part of Unit-5.

Boundaries: The lower boundary is identical to the upper boundary of the Chalk-5 Unit.

The upper boundary to the 'North Sea Marl' is gradual, showing an increase from constantly low gamma ray values and a decrease in the sonic velocities. Where the 'North Sea Marl' is missing, the change is very abrupt. The boundary is defined at the point where the gamma ray and sonic values change to higher and lower values respectively.

Distribution: The Chalk-6 Unit has been recorded in all Danish wells (fig. 29) and, together with the equivalent Ekofisk Formation, this chalk sequence has a wide distribution, being recognized in the Dutch, German, English, Norwegian, and Danish sectors of the central North Sea.

Geological age: The Chalk-6 Unit has recently been dated by means of planktonic foraminifera. These datings point to a Danian age exclusively. Previous datings pointed to a slight time transgressive nature for the Unit.

Detailed studies of the Chalk-6 Unit show that the boundary between the upper and the lower member falls within the *G. daubjergensis* Zone. The upper member may be divided into three subzones, one of which is apparently related to a characteristic log marker. The age of the top of the Chalk-6 Unit varies due to erosion of the chalk (fig. 30).

Depositional environment: The planktonic foraminifera point to outer neritic marine conditions. The recorded thickness of the Chalk-6 Unit in the Central Graben points to a slightly higher rate of subsidence in the northern part (fig. 29). Local variations seem to be less pronounced than in previous periods and the effect of halokinesis has decreased, as verified by a relatively thick sequence of the Chalk-6 Unit on top of salt structures.

Source rock potential: The upper member contains only a small amount of organic matter and is immature. Although the lower member may contain relatively more organic matter, it has never reached a mature stage.

Reservoir potential: The lower member has a fair primary porosity and a fairly low permeability (chapter 9), but it is nevertheless a reservoir rock. The fairly high clay content causes poor production characteristics due to fairly low permeability, unless fractured. The upper member has a good reservoir potential, and high hydrocarbon saturations have often been encountered within this member.

Sealing potential: The presence of clay lamina and chert beds within the lower member may occasionally render the Unit a sealing potential.

3.7 Cenozoic excl. Danian limestone

By Finn Nyhuus Kristoffersen & Inger Bang

During the Quaternary and Tertiary a regional subsidence took place resulting in a large depositional basin, the axis of which coincides with the central part of the present North Sea. Thick Tertiary and Quaternary series were deposited, consisting mainly of clays with an increasing amount of sand upwards. The upper part of the series is particularly uninfluenced by deeply seated structures or by major tectonic activities (fig. 36).

North Sea Marl *(informal name)*

The North Sea Marl may be correlated to the unnamed marl unit in the Norwegian Central North Sea mentioned as an equivalent to the Maureen Formation of the Montrose Group (Deegan & Scull 1977), in the Norwegian Central North Sea.

Type section: The Danish E-1 well, 6725-6735' b.KB.

Reference sections: In the Danish Central Graben the following wells characterize the Unit: N-1 (6839-6897' b.KB), P-1 (9504-9580' b.KB), Q-1 (9971-10072'