Thickness: The thickness of the Zechstein Group within the Central Graben is poorly known, due to halokinesis, to the scarcity of deep wells, and to uncertain stratigraphy above the ?Rotliegendes volcanics in wells P-1, Q-1, and W-1 (see the interpretation in fig. 19). Furthermore, seismic evidence to characterize the Zechstein deposits has not yet been evaluated. For these reasons, thicknesses of zero to several km (in the salt diapirs) are expected.

Lithology and distribution: The lithology of the Zechstein Group varies in accordance with distance to land: the Ringkøbing-Fyn High, Dogger High and Mid North Sea High are fringed by sabkha sediments and lagoonal evaporites dominated by limestone, dolomite, and anhydrite, as in B-1 and L-1 outside the Graben. These marginal deposits grade into the thick basinal facies dominated by rock salt with the basal kupferschiefer, and interbedded with salt, clay, dolomite, anhydrite, and K-Mg salt forming up to four evaporite cycles. Zechstein deposits have not yet been identified with certainty by the wells on the structural highs in the central part of the Danish Central Graben nor by seismic methods in the deeper parts here. Rocks of the marginal facies presumably frame the salt deposits in the northern and southern part of the Graben where the thick salt deposits have formed salt domes and diapirs.

In the idealized profile of the evaporites (fig. 19) in the eastern part of the North Sea, a tentative lithostratigraphic correlation is given. To the south, there is a well established succession controlled by data from several wells. To the northeast, the profile is based on the Danish D-1 well and the Norwegian 17/4-1 well. The differing evolution of the four cycles of evaporites in the two mega-basins is shown: in the South Permian Basin, Z-2 is the major cycle, and in the North Permian Basin, both Z-1 and Z-2 and partly Z-3 are major cycles and Z-4 subordinate.

3.3 Triassic

By Finn Jacobsen

Deposition during the Triassic continued in the basinal areas developed during the Permian, but in Early Triassic the highs were also gradually covered by sediments. The pattern of sedimentation in the two mega-basins is analogous to that of the Rotliegendes,

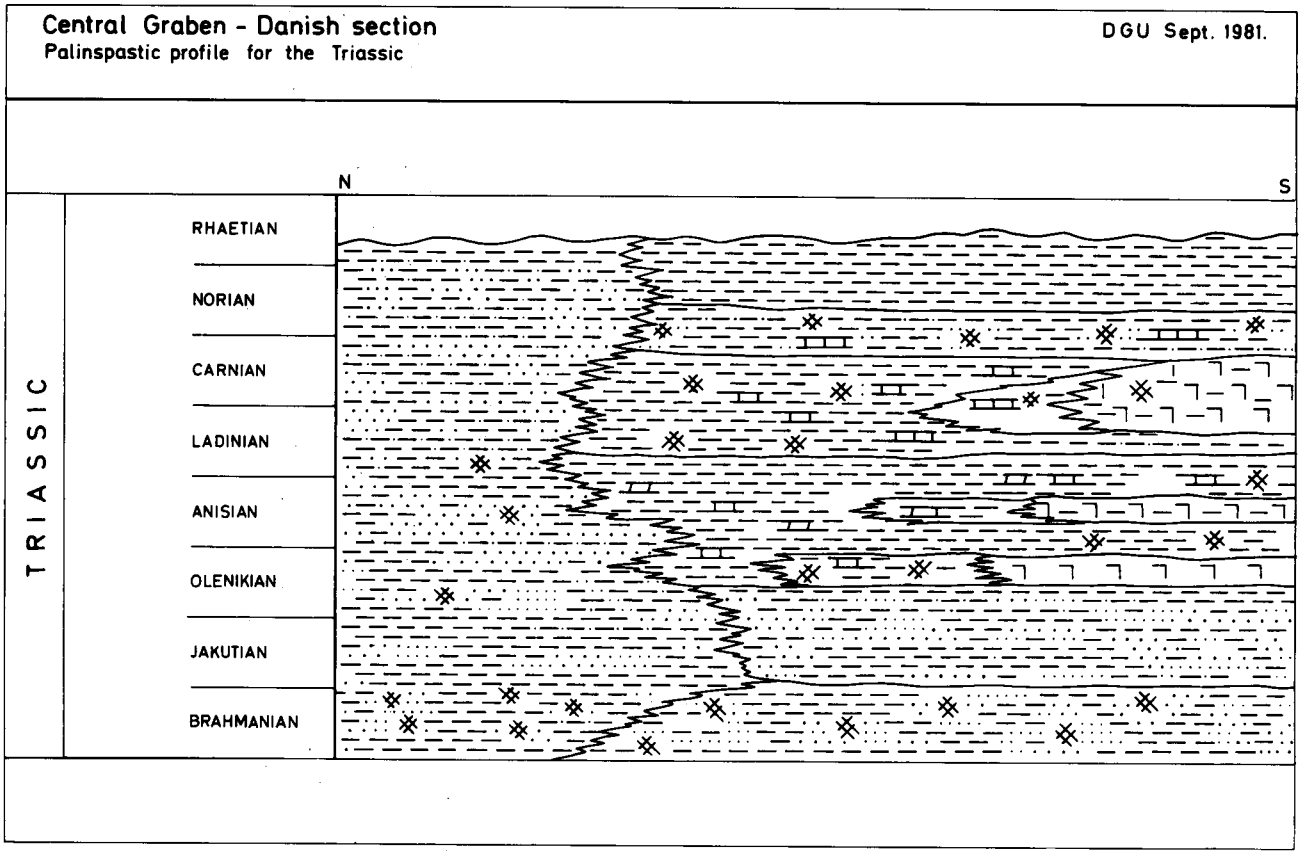

Fig. 20: Palinspastic profile of the Triassic deposits. For legend, see fig. 3.

i.e. with a pronounced, more coarse-grained clastic infill in the northern basin (fig. 20). The Triassic represents a regressive period in the North Sea area, with dominant continental sedimentation of sandstone, shale, and evaporites in red bed facies. Strong subsidence is recorded in the center of the Danish Subbasin with more than 5000 m Triassic sediments, and in the Horn Graben with approximately 3000 m. In the Danish Central Graben the Triassic has not yet been mapped, but thicknesses of about 2000 m or more are expected locally.

Bacton Group Rhys 1974

The Bacton Group was defined by Rhys (1974) as the sequence of red beds, with a relatively low content of anhydrite and carbonate, forming the lowermost unit of the Triassic series in the Southern North Sea Basin.

The Group consists of a lower pelitic formation, the Bunter Shale, and an upper arenaceous formation, the Bunter Sandstone. A tentative subdivision based on the wire line logs is proposed for the Danish Central Graben area.

Type section: Conoco Group 49/21-2 well, British North Sea sector (see Bertelsen 1980). Here the thickness is 571 m.

Reference sections: The Formation is found only incompletely developed in the B-1 (9990-10190' b.KB) and U-1 (14651-16045' b.KB) wells.

In the Q-1 well the section from 13921' to 14385' may represent the Bacton Group, but it seems more reasonable to refer the section to the Smith Bank Formation, described by Deegan & Scull (1977). This Formation is not treated in the present publication.

Thickness: The contact with the underlying Zechstein is only found in the B-1 well. The thickness here is 51 m, but the Formation seems to be incomplete due to erosion of the uppermost part.

The uppermost part of the Formation is reached in the U-1 well. The thickness here is more than 425 m. Seismic evaluation in the southern part of Central Graben indicates greater thicknesses near the highs.

Lithology: The Formation is dominated by red brown to brown, occasionally silty, anhydritic, and calcareous claystone with minor silt- and sandstone beds.

Due to the general lack of sandstone, it has not been feasible to divide the Group, based on lithology.

Log characteristics: The Formation is characterized by very uniform log motifs indicating laminated clay/siltstone. The sandstone beds show distinct log readings.

A tentative subdivision of the Group in the U-1 well is attempted from the log motifs. The very uniform log motif below the base of a sandstone bed at 4672.6 m may correspond to the Bunter Shale Formation. This log motif is similar to the log motifs in Danish onshore wells.

The more irregular log motif in the section from 4437 m to 4672.6 m is more or less similar to the Bunter Sandstone Formation in the type section and may therefore represent this formation.

Boundaries: The upper boundary is placed at the base of the overlying evaporites. The lower boundary is placed at the top of the uppermost massive Zechstein anhydrite bed. Both boundaries are distinctive on the log pattern.

Distribution: The Group is known only from two wells (B-1 and U-1) in the southern part of the Danish Central Graben. As seen from the seismic evaluation, the Group is present in this part. In the middle and northern part of Danish Central Graben, the Triassic cannot be deliniated on the seismic profiles and the occurrence of the Triassic is therefore undeterminable. To the north the Group may pass into the Smith Bank Formation in the Q-1 well (fig. 20).

Geological age: No biostratigraphical data are available but the sequence can probably be referred to the Scythian Series (Bertelsen 1980).

Depositional environment: The Group is considered to have been deposited in supratidal and continental (alluvial) environments that are placed on a supposed extensive and flat continental plain fringing the northern margin of the southern mega-basin.

The low sand content recorded is explained by the distal position of the area in relation to the main source area, which is believed to have been situated to the north. Some material may have originated in the suggested positive area, which has been exposed to erosion during the Late Carboniferous and Permian periods.

Source rock potential: Probably poor, but this has not yet been studied.

Reservoir potential: Poor due to the thin deposits of the sand beds. In areas around highs, sand beds may be thicker.

Sealing potential: The Formation itself may have a fair sealing potential, while the overlying evaporites may even have a better one.

Dowsing Dolomitic Formation Rhys (1974)

The Formation was established by Rhys (1974) on the basis of the relative importance of dolomite. The Central Graben area is slightly influenced only by the Muschelkalk transgression. Therefore the lithostratigraphy proposed may not fit the northern part of the Central Graben.

Type section: Conoco Group 49/21-2 well, British North Sea sector (Bertelsen 1980). The thickness here is 92 m.

Reference well: Danish U-1 well (13074-14651' b.KB).

Thickness: The total Formation is represented in the U-1 well only, where the thickness is 480 m. In areas with halokinetic movements (the A-2 well), the top of the Triassic, including the uppermost Dowsing Dolomitic Formation, is eroded. The thicknesses in A-2 and V-1 are 333 m and 175 m respectively.

Lithology: The Formation consists of variegated, dark reddish-brown, grey and grey green calcareous (dolomitic) claystone with two members of halite surrounded by, and with interbeds of, light grey to greenish grey marlstone/claystone and anhydrite. Subordinate siltstone beds may occur. The halite members grade laterally into marlstone and calcareous grey claystone (the V-1 well).

Subdivision: In the U-1 well it is possible to subdivide the Formation into five members:
Unnamed member: 13074-13443' b.KB (3956-4069 m b.MSL): Claystone, dark reddish-brown, occ. grey to green and grey, calcareous (dolomitic). Some anhydrite. Marlstone increasing downward.
Unnamed member: 13443-13528' b.KB (4069-4095 m b.MSL): Marlstone or claystone, very calcareous (dolomitic), light grey to grey to greenish interbedded with anhydrite.
Muschelkalk Halite Member: 13528-13728' b.KB (4095-4156 m b.MSL): Rock salt, clear, colourless interbedded with marl- and claystone, light grey.
Unnamed member: 13728-14478' b.KB (4156-4385 m b.MSL): Claystone, silty, dark reddish-brown and variegated greyish, calcareous, interbedded with thin greyish to reddish silt beds and marlstone. At the base, claystone and marlstone, light grey, anhydrite and some dolomite.
Röt Halite Member: 14478-14651' b.KB (4385-4436 m b.MSL): Rock salt, clear, colourless to orange with small content of limestone and marlstone. A potash-rich bed is found in this member.

Log characteristics: The evaporite sections are characterized by rather uniform straight sonic velocity and gamma ray readings, occasionally with distinct peaks reflecting dolomitic and potash-rich beds.

The variable lithology of claystone, siltstone, marlstone, and anhydrite in the other members is seen as rather irregular serrate log motifs.

Boundaries: The lower boundary of the Formation is placed at the base of the Röt Halite Member. The upper boundary of the formation is indistinct and is based mainly on changes in the carbonate content.

Distribution: Hitherto the Formation has been drilled only in the southern part of the Danish Central Graben area, so the northern limit is unknown. Northwards the formation probably grades (laterally) into parts of the Smith Bank Formation. Facies changes in the halite members towards marly/anhydritic equivalent beds suggest limitation of the northern outlines of Röt and Muschelkalk salt (fig. 20).

Geological age: The upper halite member has been dated to Anisian by means of palynology in the A-2 and V-1 well (Bertelsen 1975). The lower halite member is considered more or less contemporaneous with the Röt deposits of Poland and Germany, Late Olenikian-Early Anisian (Bertelsen 1975).

Depositional environment: The deposits were formed under conditions which were highly controlled by the connection to the Tethys Sea. The southern megabasin most probably had the character of one large lagoonal area. The lowermost deposits represent a transgressive period in the Triassic. Due to a high degree of evaporation and a low influx of fresh water, salinity was high. In the centres of the basin, halites were precipitated in playa-like conditions, while large-scale coastal sabkhas seem to have fringed the basin in which anhydrite claystone was deposited.

Continental plain deposits of fluvial lacustrine origin replaced the salt lake. A new transgression resulted in the Muschelkalk Halite Member. In the Central Graben area, brackish conditions with deposition of dolomitic mudstone have prevailed.

As seen from the fossils and sediment characteris-

tics, the climatic conditions during the deposition of the Formation seem to have been arid to semi-arid and rather hot.

Source rock potential: Probably poor, but this has not yet been studied.

Reservoir potential: Poor.

Sealing potential: Fair.

Dudgeon Saliferous Formation Rhys 1974

The Formation was defined by Rhys (1974) in the Southern North Sea Basin to comprise the halite-bearing claystone sequence found between the dolomitic claystone of the Dowsing Dolomitic Formation (below) and the mainly anhydritic claystone of the Triton Anhydritic Formation (above). The lithological development in the Danish area during the Middle and Late Triassic is comparable to that of the southern North Sea, and therefore the formation name of Rhys (1974) has been adopted for this sequence.

Type section: Conoco Group 49/21-2 well, British North Sea sector. The thickness is 276 m.

Reference section: Danish U-1 well, 12159-12074' b.KB.

Thickness: The Formation has been drilled only in the southern area. It is penetrated in the U-1 well (279 m) and drilled in the O-1 (166 m) and M-8 (131 m) wells.

Lithology: The Formation consists of silty, dark reddish-brown, brick-red and grey-green calcareous, and sporadically anhydritic claystone.

A prominent halite member is present in the O-1 and M-8 wells, whereas equivalent deposits of mainly grey coloured marlstone, dolomite, and anhydrite are encountered in the more marginally situated U-1 well.

Subdivision: In the U-1 well the Formation can be subdivided into four members:
Unnamed member: 12159-12428' b.KB (3678-3760 m b.MSL): Claystone, brick-red to dark reddish-brown, calcareous and anhydritic. In the lower part, reddish marlstone.
Unnamed member: 12428-12550' b.KB (3760-3797 m b.MSL): Claystone, silty, dark reddish-brown to violet. Varying content of calcareous material, but commonly anhydritic.
Unnamed member: 12550-12674' b.KB (3797-3825 m b.MSL): Marlstone, light grey to greenish-grey, rare reddish/violet dolomitic and anhydritic. (This evaporite-dominated member is proposed to be the marginal equivalent to the Keuper Halite Member described by Rhys (1974)).
Unnamed member: 12674-13074' b.KB (3835-3957 m b.MSL): Claystone, occasionally siltstone, reddish-brown, grey or greenish-grey, micaceous and generally calcareous. Minor beds of limestone may occur.

Log characteristics: The variable lithology of claystone, siltstone, anhydrite, and limestone is reflected as irregular serrate log motifs, but in the different wells with a variable evaporite and carbonate content.

Boundaries: The lower boundary is indistinct but defined by the higher gamma ray and lower sonic velocity in this formation, probably due to the lower carbonate content than in the formation below.

The upper boundary in the type well and the O-1 well is defined as the top of the Keuper Halite Member, which is easily recognizable on the gamma ray and sonic velocity. In wells with imperfectly developed or missing halite beds (e.g. U-1), the upper boundary is set at the shift from high sonic velocities below to lower above.

Distribution: The Formation is drilled only in the southern area. Here the Keuper Halite is more restricted in the lateral extension than the above-mentioned Röt and Muschelkalk halites (fig. 20).

In the middle and northern part of the Central Graben, neither well nor seismic data are available.

Geological age: The occurrence of the miospores *Ovalipollis ovalis* and *Porcellispora longdonensis* indicates a Carnian age of the Formation (Bertelsen 1975).

Depositional environment: The lithology indicates continental sabkha deposits. Soluble salts are precipitated in the basin center, whereas the less soluble sulphates and carbonates are found in fringing facies belts.

Source rock potential: Probably poor, but this has not yet been studied.

Reservoir potential: Poor.

Sealing potential: Fair.

Triton Anhydritic Formation Rhys 1974

The Triton Anhydritic Formation was proposed by Rhys (1974) for the uppermost, anhydrite bearing part of the Triassic red bed sequence of the Southern North Sea Basin. The Formation is recognizable without any difficulties in the Danish sector.

Type section: Conoco Group 49/21-2 well, British North Sea sector. The thickness is here 214 m.

Reference section: The Danish O-1 well, 10401-11193' b.KB (Bertelsen 1980). The formation is also fully drilled in the U-1 and M-8 wells (see chapter 8).

Thickness: The recorded thicknesses of the Formation vary from approximately 230-280 m to zero - due to erosion on halokinetic structures.

Lithology: A threefold division of the Formation can be made with :

A lower section of dark reddish-brown and grey-green, slightly calcareous to non-calcareous, micaceous claystone with some anhydrite.

A middle section (Keuper Anhydritic Member) of grey to reddish-brown variegated or brick-red, calcareous, and anhydrite-bearing claystone with some silt- and marlstone intercalations.

An upper section of calcareous, light grey, greenish-grey, or reddish marlstone and claystone.

Log characteristics: The log motif shows a separate configuration. The Middle Keuper Anhydritic Member is characterized by many distinct peaks on the sonic velocity, density and resistivity responses corresponding to the individual anhydrite layers.

Boundaries: The lower boundary is described above (see Dudgeon Saliferous Formation). The upper boundary is placed at the basal claystone of the Winterton Formation and it is very distinct in the gamma ray and sonic velocity readings.

Distribution: Unknown, only drilled in the southern part of the area. Seismic evaluation is not yet possible in the northern and middle parts.

Geological age: No palynomorphs or other microfossils have been recovered from the Formation in the Danish sector. It is, however, thought to correspond to the upper part of the Oddesund Formation (Bertelsen 1980), which means a Carnian to Early Norian age.

Depositional environment: The predominant environment seems to have changed from distal flood plains through continental coastal sabkha to distal flood plains.

Source rock potential: Investigations of one well section (M-8) indicate no source rock potential for oil.

Reservoir potential: Poor.

Sealing potential: Fair-good because of the anhydrite content.

Winterton Formation Rhys 1974

The Formation is proposed by Rhys (1974) to replace the North Sea 'Rhaetic' because this sequence is not compatible with the British onshore Rhaetic, where the grey to green shales are missing from its lower part.

Contrary to the definition by Bertelsen (1980) of the Winterton Formation in the Central Graben, the Formation includes only the pure claystone in the present report. This revision was made because of the lithological similarity between the upper part of the former Winterton Formation and the overlying Early Jurassic section.

The Rhaetic Sandstone Member recognized in the Southern North Sea Basin is not present in the Danish wells. Seismic events, however, seem to indicate sandy layers in connection with erosional areas.

Type section: Conoco Group 49/21-2 well, British North Sea sector. The thickness here is 76 m.

Reference section: The Danish 0-1 well, 10347-10401' b.KB (Bertelsen 1980). The Formation is drilled also in the U-1 and M-8 wells (see chapter 8).

Thickness: Only small thicknesses are recorded. In the O-1 well the thickness is 16 m, in the U-1 well 12 m, and in the M-8 well 7 m. The above-mentioned wells are all placed on structures. It is therefore possible that greater thicknesses may be found in other parts of the area.

Lithology: Dark grey to black grey, non-calcareous, relatively pure, sticky claystone.

Log characteristics: The log motif is characterized by very low sonic velocity and high gamma ray readings, which separate the Formation from the ones above and below.

Boundaries: The lower and upper boundaries are defined at the base and top of the pure and soft claystone (see the log characteristics).

Distribution: The distribution may be as in the underlying formation (fig. 20). Due to the halokinetic movements the Formation may be absent locally.

Geological age: An ostracod assemblage of *Emphasia* ssp. (Michelsen 1978a) and the presence of *Ricciisporites tuberculatus* miospores indicate a Rhaetian age (Bertelsen 1978).

Depositional environment: The deposits are interpreted as being formed as the underlying sediments. A very characteristic kaoline content in the Formation seems to indicate weathering. This corresponds to the seismic information about the relatively elevated position of the drilled Formation and the probability of more sandy members along these areas.

Source rock potential: Data insufficient for an evaluation.

Reservoir potential: Poor in the claystone. May be fair to good in the sandy members.

Sealing potential: Probably poor due to the sandy sections.

3.4 Jurassic

By Jens Ole Koch, Lise Holm & Olaf Michelsen

During Early Jurassic time, deposition continued in the basinal areas occupied by Triassic sedimentation. The Danish Central Graben subsided strongly and more than 4000 m of sediments were deposited during Jurassic time (fig. 14). North of the area the thickness seems less than 2000 m and, in the Norwegian-Danish Basin, approximately 1200 m. The rythm of sedimentation corresponds closely to what is known from adjacent areas in the Northwest European sedimentary region.

During the Early Jurassic, relatively uniform marine claystone series, the Fjerritslev Formation, were deposited all over the North Sea region, including the main part of the highs. Large areas were uplifted and eroded during the Mid Cimmerian phase (fig. 23), accompanied by a general eustatic lowering of the sea level. During the Middle Jurassic period, deltaic or fluvial conditions prevailed in the main part of the North Sea, and coal-bearing sand bodies, the J-2 Unit, were deposited. During the Late Jurassic a general subsidence took place, but more restricted areas were transgressed by the sea than in the Early Jurassic. Thick marine claystone series (the J-3 and J-4 Units) were deposited in the main part of the basin. Near marginal highs, only minor sand bodies (the W-1 Unit) were laid down. The Late Jurassic is a period of main subsidence for the Central Graben. Figs. 21 and 23 show the distribution of Jurassic sediments.

Fjerritslev Formation Larsen 1966 and Michelsen 1978b

The Formation was established by Larsen (1966) and later revised and subdivided by Michelsen (1978b) into four members (F-I, F-II, F-III, and F-IV). The type well (Fjerritslev-2) is situated in northern Jylland in the northwestern part of the Danish Subbasin, in which the Formation is widely distributed.

On the basis of the assumption that the Lower Jurassic claystones present in the Central Graben and in the Danish Subbasin originally formed one coherent sediment body, which during the Mid Cimmerian tectonic episode was differentially eroded (see e.g. Michelsen 1978b, fig. 12), the name Fjerritslev Formation has also been assigned to the Lower Jurassic claystones in the Danish Central Graben.

The Fjerritslev Formation corresponds to the Dunlin Unit in the northern North Sea (Deegan & Scull 1977).

Type section: The Fjerritslev-2 well in northern Jylland from 1314 m to 2225 m b.MSL.

Reference sections: The O-1, U-1, and M-8 wells in the southern part of the Danish Central Graben (see chapter 8).

Thickness: The thickness of the Fjerritslev Formation is 155 m (O-1), 93 m (M-8), and 48 m (U-1).

In the Danish Central Graben, the Formation is rather thin in comparison to the type section. This is partly due to Mid Cimmerian erosion of the top of the Formation. The O-1 and M-8 wells are situated on domes induced by the flow of Triassic salt (or shale), but the thickness of the Fjerritslev Formation is probably unaffected by halokinesis. In the U-1 well the thickness might be slightly reduced due to Early Jurassic halokinesis in the underlying Zechstein salt pillow.

Lithology: The Fjerritslev Formation consists mainly