During the entire Cenozoic, characterized by a gradual and rapid subsidence pattern in the Central North Sea area except for mild Laramide inversions in the former Graben areas, more than 3000 m of sediments accumulated in the northern part of the Central Graben. Only the Early Tertiary lithological units vary significantly in thickness, and these deposits become thicker in the northern part.

The central part of Dogger High showed a separate subsidence pattern during the Early Tertiary. Fig. 11 shows that sediments prograded eastwards from this high into the basin to the east. The base of the Upper Miocene is locally developed as a weak angular unconformity and marks the shift from an Early Tertiary, predominant-shale sedimentation into a more sandy, Late Tertiary sedimentation. This indicates that sedimentation rates probably started to exceed subsidence rates.

The Late Tertiary sedimentary sequence shows uniform progradation from the east. The fairly monotonous and uniform Tertiary evolution is interrupted only locally by continued salt diapirism.

The thickness of the Quaternary cover is up to 600 m in the Central Graben area.

3.0 Description of the formations

All formations recorded by drilling in the Danish Central Graben area are listed and described in the present chapter. The descriptions are based on a compilation of information available in the DGU files. This basic material is of a heterogeneous character as it comprises analyses and reports worked out by various companies and by DGU. The descriptions given below are, therefore, to be regarded as preliminary, and further investigations must be carried out to elucidate certain stratigraphic and depositional aspects. Thus, the majority of the lithostratigraphic units are treated and named here informally. Only for the Triassic, Lower Jurassic, and Lower Cretaceous units sufficient knowledge has been established to refer these to formal lithostratigraphic units. All lithostratigraphic units are defined on wire-line log characteristics.

A review of the present standard stratigraphic subdivision is given in fig. 2. The bio- and chronostratigraphic correlation is generally at the same level of documentation. This stratigraphic concept will probably be revised through supplementary biostratigraphic studies.

As a rule, the lithology of each unit or formation is described, as interpreted from various sample descriptions and from wire line logs. The diagnostic log motifs and formation boundaries are treated. Furthermore, the thickness, distribution, geological age, depositional environment, source rock potential, reservoir potential, and sealing potential are described. The evaluation of thickness and distribution is partly based on seismic data. The formation descriptions are accompanied by palinspastic profiles and generalised formation maps comprising thickness and distribution. Tables on such primary data as depth, thickness, porosities etc. are presented in chapters 8 and 9.

Well locations are given on a map (fig. 1). Legends for signature on maps, palinspastic profiles, and well sections are given in fig. 3.

3.1 Pre-Permian

By Jørgen Gutzon Larsen & Olaf Michelsen

Data on Pre-Permian rocks are reported only from the P-1 well, which was bottomed in Caledonian basement. The geology of this formation in the western part of the Danish sector is, therefore, poorly known. According to the age determinations performed and reviewed by Frost et al. (1981), the North German-Polish Caledonides extend under most of the North Sea and join the Scottish-Norwegian Caledonides, whereas most of the Ringkøbing-Fyn High is underlain by Precambrian basement.

Caledonian basement

The P-1 well, situated on the western extension of the Dogger High, was bottomed in a sequence of greenschists, believed to be meta-tuffs between 11259-11464' b.KB. In some of these beds, phenocrystal relics of clinopyroxene, titanite and apatite may be abundant, whereas green biotite (?primary), zircon and brown amphibole are scarce. The amphibole is surrounded by a clinopyroxene reaction zone - a relation, which is believed to be of igneous origin, e.g. caused by resorption of amphibole phenocrysts or xenocrysts by lowering of the water pressure or increase in temperature in a crystallizing magma. Light grey to reddish, thin beds are intercalated with the meta-tuff. They are rich in albite-oligoclase, forming fragmental to more or less rounded relics, together with scattered grains of the

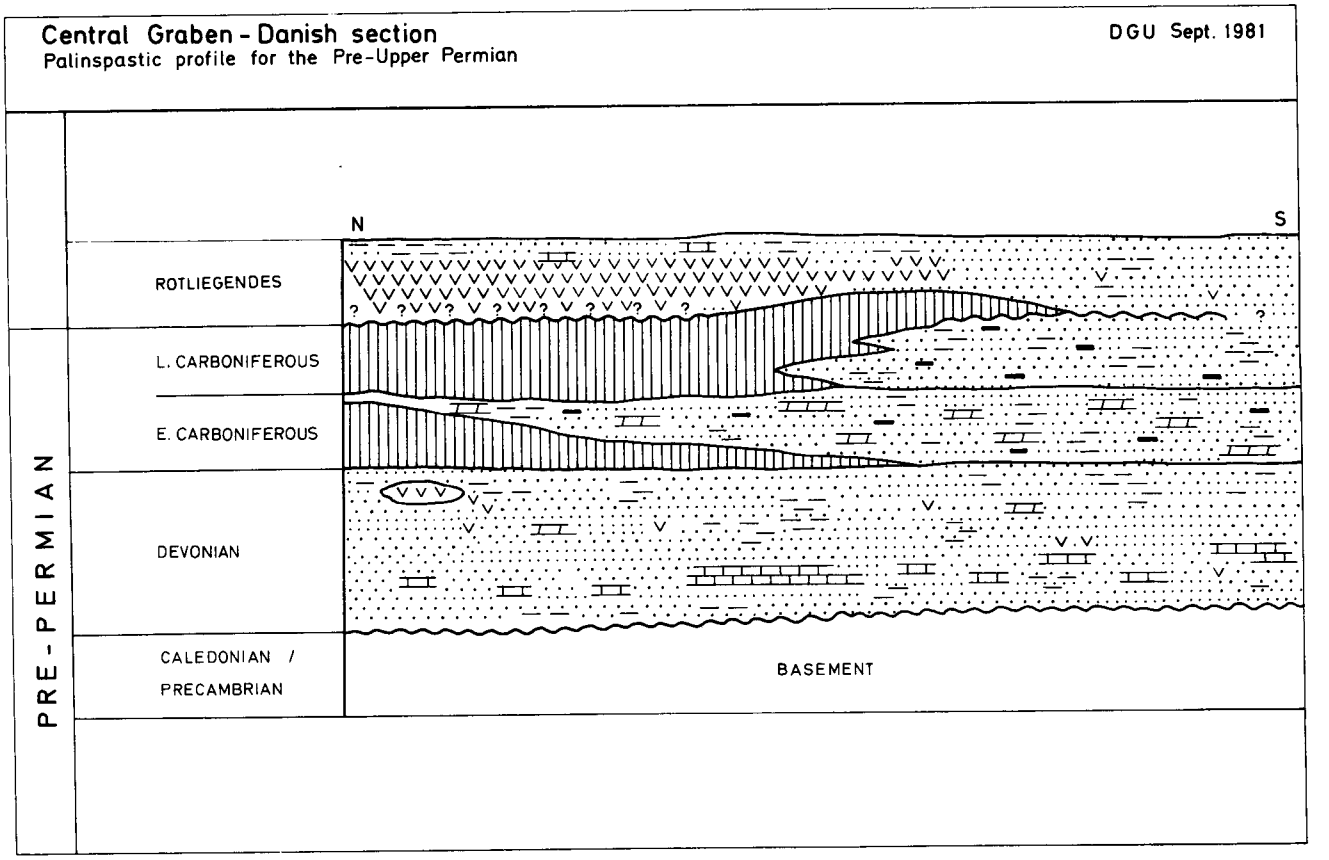

Fig. 17: Palinspastic profile of Pre-Upper-Permian deposits. For legend, see fig. 3.

minerals mentioned above in a cataclastic quartz-feldspar matrix. Settling texture in one of these light beds has been observed, but does not give certain evidence of their origin. They may be volcanogenic greywackes or salic crystalline tuffs. The phenocrystal assemblage described above suggests the presence of an alkaline, trachytic, volcanism (see Gaida et al. 1978). Argon 39/40 step heating ages of 436 +/- 4 Ma can be related to the Caledonian metamorphism with an Early Permian 271 +/- 6 Ma overprint (Frost et al. 1981). Combined results from K/Ar and Rb/Sr-age determinations agree with this conclusion (Ole Larsen, written com.).

Carboniferous

During the Carboniferous, the Danish Central Graben area was in a transitional position between a northern land mass and the shelf of the Variscian geosynclinal to the south. The substratum is supposed mainly to be the Caledonian basement or Devonian sediments (fig. 17). Only the Danish P-1 well has been drilled in the Carboniferous within the Central Graben. Just south of the Danish region, and further to the northwest pronounced Carboniferous series have been drilled.

CA-1 Unit *(informal name)*

The Lower Carboniferous series, the CA-1 Unit, drilled in the Danish P-1 well, indicates that more than one formation may be present, but the lack of usable reference wells makes it unreasonable to establish formal formational units.

Type section: The Danish P-1 well, 11038-11259' b.KB.

Thickness: 67 m in the P-1 well, but the regional thickness may well exceed this figure according to the thicknesses known from the area south of the Mid North Sea High (see Rhys 1974).

Lithology: The drilled sequence is an interbedded series of shale and sandstone. Minor coal seams occur in the sandstones, as do dolomitic limestone in the shale (Bertelsen 1978).

Log characteristics: The gamma ray changes between low and high readings reflect the mentioned layering of sandstone and shale. The sonic velocity is generally high and the log motif is nervous and undifferentiated.

Boundaries: The lower boundary is primarily marked by the sonic velocity which is high and uniform in the underlying metamorphic greenstone, and relatively lower and nervous in the present series. The upper boundary is between the present mainly greyish series and the overlying reddish series of assumed Rotliegendes age. The log motifs are not significant, but the change from high gamma ray readings above to relatively lower below is used for location of the boundary.

Distribution: The Early Carboniferous deposits are probably present in major parts of the Danish Central Graben, but due to lack of data (seismic mapping is critical), a delineation of the extension is not possible.

Geological age: Based on studies of the miospores, part of the series is dated to Early Carboniferous, Late Visean or Early Namurian (Bertelsen 1978). - The lower part of the series has not been dated, thus it may be of Carboniferous or Devonian age.

Depositional environment: It is a marginal fluvially dominated environment with minor coal swamps. The occurrence of thin limestone beds with foraminifera, ostracods, and crinoid fragments shows that short marine transgressions periodically flooded the area.

Source rock potential: Probably poor for oil since the Rotliegendes volcanism and/or depth of burial-temperature increase may have led to overcooking. No studies have been carried out in the Danish region.

Reservoir potential: Limited reservoirs in form of porous sandstones may be expected.

Sealing potential: The series is probably not sealed, being overlain by the Rotliegendes. The Carboniferous shale beds will possibly be able to act as seals.

3.2 Permian

By Fritz Lyngsie Jacobsen & Jørgen Gutzon Larsen

In North-West Europe two mega-basins began their development during Late Carboniferous to Early Permian: The South Permian Basin stretching from eastern England into Poland , and the North Permian Basin reaching from Scotland into Denmark. These two basins were separated by the Mid North Sea High and the Ringkøbing-Fyn High which came into existance early in Permian. The initial phase of subsidence was accompanied by extensive subaerial volcanism. This was followed by a period of oxidation and erosion under desert conditions and deposition of redbeds and sabkha sediments in the two Permian basins (fig. 19). These rocks are included in the Rotliegendes Group as originally established by Werner (1786). Continuous subsidence and transgression of the sea, but with a restricted connection to the ocean, lead to the formation of the evaporites of the Zechstein Group.

Rotliegendes Group

Autunian

Type section: For the present being the P-1 well, 10541-10865' b.KB may suffice as a reference for the Rotliegendes volcanics and underlying sediments belonging to the Autunian stage. However, it should be noted that this correlation is based purely on lithostratigraphical evidence.

Thickness: The volcanic rocks and interbedded sediments form a 99 m thick pile in the P-1 well, but in all other wells of the Danish off shore sector, the base of the volcanic rocks has not been penetrated. Therefore only minimum thicknesses of 44 m in B-1, 148 m in W-1, 71 m in Q-1 can be given. The underlying sediments in P-1 well comprises 33 m of redbrown sandstone, siltstone, claystone, and marlstone (Bertelsen 1978).

Lithology: The lithology is summarized in fig. 18. The volcanic sequences are classified as lava flows with interbedded agglomerates, tuffs and detrital sediments. The lava flows are generally a few metres in thickness or less, may be of the pahoehoe type, but flows up to 7 m in thickness occur. Presumably some of the 'agglomerates' noted in the mudlog may originate from scoriaceous or vesicular top zones. The cores and cuttings indicate, together with the log data, especially gamma ray, the predominance of basalts; but more differentiated rocks occur in the P-1 and W-1 wells. From the latter well these rocks are described as andesites and rhyolites (mudlog). They may occur as lava flows and pyroclastic beds. Most of the rocks look rather oxidized and they are often cut by secondary veins. The interbedded sediments are mostly (silty) claystone but a 28 m thick metamorphosed limestone occurs in W-1.

Log charactetistic: The volcanic rocks are characterized by cyclic variations in the sonic velocity, and