Callovian-Volgian dinocyst stratigraphy of the Central Trough in the Danish North Sea Area

NIELS E. POULSEN


The Danish North Sea wells U-1 and E-1 have been dated on the basis of dinocysts and correlated with the established ammonite stratigraphy of Western Europe. The palynostratigraphy of the U-1 well shows that the age of the Jurassic lithostratigraphic units is of Callovian to Kimmeridgian age. In the E-1 well, only the upper part of the Farsund Formation (of Jensen et al., 1986) has been penetrated. The age of this part is of Ryazanian to Volgian age. The four new formations (Lower Graben Sand Formation, Middle Graben Shale Formation, Lola Formation and Farsund Formation (of Jensen et al., 1986) show a marked difference in organic facies. It seems possible to relate these differences in organic facies to sea-level changes.


This report presents the result of palynological studies of two wells (U-1 and E-1) from the Central Trough area. The first part of the report gives the biostratigraphic dating of the samples. In the second part accumulation rates are estimated. They document great variation in the sedimentation history. Finally, a comparison of the palynofacies of the samples with the accumulation rate and eustatic sea-level changes is presented.

Geographic scope, lithostratigraphy and subsidence

The E-1 and U-1 wells are situated in the Danish part of the Central Trough area in the North Sea (fig. 1). The E-1 well is situated in the Tail End Graben and the U-1 well in the Southern Salt-dome Province.

The Middle and Upper Jurassic sequences in the Central Trough area are divided into 6 new formations (Jensen et al., in prep.) (fig. 2). The equivalent lithostratigraphic units from the Norwegian North Sea and from England are also shown and correlated with these units in fig. 2.

The lithostratigraphic nomenclature and description used in the text and in the figures are based on Jensen et al. (1986).

The Middle Jurassic sequence (the Lower Graben Sand and the Middle Graben Shale Formations) consists of deltaic or fluviatile coal-bearing sandstones, claystones and heteroliths. The Upper Jurassic sequence (the Lola Formations and the Farsund Formations) is a marine claystone. The Lola Formation unit is a grey, often silty, and slightly calcareous claystone. The Farsund Formations unit is a dark grey to brownish or olive black laminated, shaly, slightly silty claystone with dolomite stringers.

Near the marginal structural highs of the Central Trough are minor sand bodies. The sandy Upper Jurassic – Lower Cretaceous formation Poul Sand is located on the down faulted SW margin of the Ringkøbing-Fyn High. These units consist of grey sandstones with interbedded claystones and heteroliths. The sandy Upper Oxfordian – Lower Kimmeridgian formation Heno Sand is situated along the northeastern margin of the Dogger High. This formation consists of grey to white sandstones with minor conglomerates, siltstones, claystones and heteroliths.

The subsidence history of the Jurassic sequences is described in Hansen & Mikkelsen (1982) and in Holm (1983). Both reports conclude that strong subsidence took place in Late Jurassic time.
Biostratigraphy

Methods

The dinocysts occurring in the Danish North Sea wells in most cases are correlated to the English dinocyst stratigraphy (Raynaud, 1978; Riley & Fenton, 1982; Sarjeant, 1979; Woollam & Riding, 1983) which again has been correlated to the classic subboreal ammonite stratigraphy.

In this work, cutting samples as well as sidewall cores have been dated. Each cutting sample (C.S.) has been dated to the oldest range top of the species found in the sample. The age of a cutting sample is therefore a minimum age.

In the first feet of the drilled section below a
<table>
<thead>
<tr>
<th>SYSTEMS</th>
<th>AREAS</th>
<th>DANISH CENTRAL TROUGH</th>
<th>NORWEGIAN CENTRAL TROUGH</th>
<th>SOUTH ENGLAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cretaceous</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Valanginian</td>
<td></td>
<td>VALHALL FM.</td>
<td>VALHALL FM.</td>
<td>PURBECK FM.</td>
</tr>
<tr>
<td>Ryazanian</td>
<td></td>
<td>FARSUND FM.</td>
<td>MANDAL FM.</td>
<td>PORTLAND BEDS</td>
</tr>
<tr>
<td>Volgian</td>
<td></td>
<td></td>
<td>FARSUND FM.</td>
<td>KIMMERIDGE CLAY</td>
</tr>
<tr>
<td>Kimmeridgian</td>
<td></td>
<td></td>
<td></td>
<td>CORALLIAN</td>
</tr>
<tr>
<td>Oxfordian</td>
<td></td>
<td>LOLA FM.</td>
<td>HAUGESUND FM.</td>
<td>OXFORD CLAY</td>
</tr>
<tr>
<td>Callovian</td>
<td></td>
<td></td>
<td></td>
<td>KELLAWAYS ROCK</td>
</tr>
<tr>
<td>Bathonian</td>
<td></td>
<td>LOWER GRABEN SAND</td>
<td></td>
<td>CORNBRAsh</td>
</tr>
<tr>
<td>Bajocian</td>
<td></td>
<td></td>
<td></td>
<td>FULLERS EARTH</td>
</tr>
<tr>
<td>Aalenian</td>
<td></td>
<td></td>
<td></td>
<td>INFERIOR OOLITE</td>
</tr>
</tbody>
</table>

Fig. 2. Lithostratigraphic subdivision of the Central Trough: Danish Sector (after Jensen et al., 1986 (see this paper for further revisions)) and Norwegian Sector (after Vollset & Dore, 1984), and a generalized South English composite section (after Sarjeant, 1979). (M. G. Shale = Middle Graben Shale Formation).
casing shoe, species originating from cavings cannot be expected. The age of the first cutting sample below a casing is regarded as exact age.

Each side wall core sample (S.W.C.) has been dated to the period in which all the species have a concurrent range (contemporary occurrence). The age of a side wall core is therefore also regarded as exact age.

Using this method, the age of cutting samples from the U-1 well is in agreement with the age found from the side wall core samples from the Late Callovian to Middle Oxfordian. On the other hand, the minimum age of the cutting samples from the Farsund Formation in the U-1 well is less than the ages based on the side wall core samples. The cause of this discrepancy seems to be due to the low diversity and density in these cutting samples. (These cutting samples are omitted in fig. 7).

Results

Well E-1

Fig. 3 shows the previously reported top occurrence of the species used for the stratigraphic interpretation of the well. In all samples, diverse dinocyst assemblages are found to indicate a Middle to Early Volgian age. (See fig. 7 concerning the dating of the samples).

Well U-1

Fig. 4 shows the previously reported ranges of the stratigraphic marker species from the uppermost side wall core of the Farsund Formation in the well. The age of this sample is Upper Kimmeridgian, equivalent to the Eudoxus ammonite Zone.

Occisucysta monohuriskos is found in the cutting sample at 9280'. This species is reported only from the Cymodoce ammonite Zone, indicating a minimum age of Early Kimmeridgian. At 9550'
Early Oxfordian or younger age, equivalent to the Cordatum ammonite Zone.

In the cutting sample 10570' + 10670' and in the side wall core sample 10654', Mendicodinium groenlandicum is very common. This species is common in Lower Oxfordian strata and very common in Upper Callovian strata. According to this, the age is assumed to be Late Callovian.

Below this level, only few dinocysts were found. At 10800' some badly preserved Ctenidiodinium specimens were found. Pareodinia prolongata occurs at 10970', indicating a Callovian or older age. The contemporary occurrence (concurrent range) of Pareodinia prolongata and Rigaudella filamentosa, (Hoelstad, 1986) in the side wall core samples from 10940' to 10990', indicates a Callovian age for this level (fig. 6). This is supported by the presence of Gonyaulacysta jurassica, which is uncommon below the Callovian (Raynaud, 1978; Sarjeant, 1979; Woollam & Riding, 1983). (See fig. 7 concerning the dating of the samples).

In the cutting sample 10430', species of the “Meiourogonyaulax caytonensis group” indicates an Early Oxfordian age. In this sample, Gonyaulacysta jurassica "hlanc" was also found indicating a mid-Early Oxfordian minimum age. G. jurassica "hlanc" is a new subspecies of G. jurassica (Poulsen, 1986). Its stratigraphic range seems to be very short and equivalent to the Praecordatum ammonite Subzone (the upper subzone of the Mariae ammonite Zone) and the lowermost part of the Cordatum ammonite Zone (Poulsen, 1986).

In the side wall core sample 10474', Leptodiinium eumorphum is found, indicating a late
The upper boundary of the Farsund Formation

Dingodinium spinosum is present in the lowermost part of the Valhall Formation in the E-1 well, indicating that the base of this formation is of Ryazanian age (Heilmann-Clausen, pers. comm., 1984). This contrasts with the dating by Birkelund et al. (1983), who indicated a Valanginian age for the boundary between the Farsund Formation unit and the overlying Valhall Formation.

On the basis of ammonites and dinocysts, a core (9783'-9792') from near the top of the Farsund Formation unit in the E-1 well was correlated to the Cannospheropsis thula dinocyst Subzone and to the Kochi ammonite Zone (Lower Ryazanian) by Birkelund et al. (1983). These age determinations of the E-1 well does not support the theory of a “Late Cimmerian regional unconformity” between the new Farsund Formation and the Valhall Formation (See Birke-
lund et al. (1983 p. 67) for discussion of this event).

In the U–1 well in contrast, a major hiatus is present. This hiatus is however supposed to have been caused by salt.tectonic movements (See Michelsen (ed.), 1982).

Summary of stratigraphy

The Farsund Formation in the E–1 well is of Early Volgian to Ryazanian age. (Note, that the Farsund Formation has not been completely penetrated in this well). In the U–1 well the Farsund Formation is of latest Oxfordian to Kimmeridgian age. The Lola Formation is of Late Callovian or of Early Oxfordian age to Late Oxfordian age. The Lower Graben Sand Formation and the Middle Graben Shale Formation is of Callovian age in this well.

Sedimentary history

Most of the samples of the Farsund Formation in the E–1 well are of almost the same age. This indicates a very high accumulation rate as shown in fig. 8, where the sediment thickness per ammonite zone is illustrated.

The accumulation rates of the Farsund Formation in the U–1 well show much greater variation as compared to the Lola Formation. Owing to fewer and less accurate datings of the Middle Graben Shale and the Lower Graben Sand Formations, this level is illustrated with an apparently uniform accumulation rate.

The uppermost part of the Farsund Formation is informally known as the “hot shale”. It is a shale rich in organic matter with high gamma ray readings. The “hot shale” appears to have been deposited in the Ryazanian after a period of strong subsidence in the Volgian. The “hot shale” appears to be a condensed sequence with a very low accumulation rate approximately 7 mm/1000 years (uncorrected for compaction and based on the assumption that each ammonite zone is equivalent to approximately 500,000 years). In contrast, the accumulation rate of the Pallasioides ammonite Zone reached 1000 mm/1000 years.

The condensed sequence does not appear to represent pronounced periods of non-sedimentation, since caved specimens of Perrisseiasphaeridium insolitum occur in the investigated samples. The range of P. insolitum is restricted to the Kerberus to Lamplughi ammonite Zones. Consequently, the calculated accumulation rates may represent the actual sedimentation rates as well.

On the basis of seismic profiles through the E–1 well and the U–1 well it has been estimated that the sequence in other parts of the area which is not represented by the two wells comprises less than 200' (J. J. Møller, pers. comm., 1984). Consequently, this sequence, belonging in the uppermost Kimmeridgian and most of the Lower Volgian, appears to be another condensed sequence.

Organic facies in relation to sea-level changes

The accumulation rate of the Upper Jurassic seems to be dependent of local subsidence history and independent of the changes in sea level (fig. 8). In contrast to this, the organic facies reflect correlation to rising or falling sea level, as it will be explained below.

The organic facies are described in two ways: 1) The amount of structured organic material is estimated visually in relation to the amount of amorphous matter (fig. 8). 2) The organic material is classified according to Habib’s (1979) three organic facies: exinitic facies, characterized by numerous spores and pollen and structured palynodebris such as vascular plant cuticle and tracheids; micrinitic facies, characterized by abundant amorphous palynodebris in the form of small dark particles and a palynoflora dominated by bisaccates and dinocysts; and xenomorphic facies, characterized by a palynoflora similar to that of the micrinitic facies, but distinguished by abundance of amorphous palynodebris composed of optically translucent particles.

The Middle and Upper Jurassic Formations seem to be easily distinguished on the basis of organic facies. The Lower Graben Sand and the Middle Graben Shale Formations is dominated by structured material of the exinitic organic facies. The Lola Formation is still of the exinitic organic facies, the amount of amorphous matter is larger, although it is not dominating. The lower part of the Farsund Formation is characterized by
micrinitic organic facies and in the upper part of xenomorphic organic facies with dominance of optically translucent amorphous matter.

The regressive periods shown by the curves of Hallam (1978) and Vail et al. (1983) in fig. 8 correspond to higher content of structured material, whereas at least the longer transgressive periods correspond to a higher content of amorphous matter.

Hallam's data are based especially on interpretations the strata in England. On this interpretations he correlated the changes in sea level to the chronostratigraphy.

Besides Vail's et al.'s sea-level changes, which are based on global unconformities interpreted from seismic reflections, are shown in fig. 8. These sea-level changes are not as precisely correlated to the chronostratigraphy as Hallam's.

Each of the eustatic sea-level rise-fall cycles (fig. 8) has been numbered. The Middle Graben Shale Formation and the Lower Graben Sand Formation of the U-1 well has not been correlated to the ammonite stratigraphy, so this unit has not been compared to the curves of sea-level changes. As can be seen in fig. 8, the end of sea-level cycles 3 and 4 are marked by a relatively higher content of structured organic material in the samples. Apparently the strata corresponding to the end of cycle 2 and 5 do not have a higher content of stuctured material.

During cycle 5 there is a shift from exinitic organic facies to micrinitic organic facies. According to Habib (1979) the organic material from the exinitic organic facies is contributed from prograding deltas, whereas the material of the micrinitic organic facies represents diminished sedimentation of terrigenous material; organic material of this facies was deposited by marine currents which sorted the organic material. This changes indicates a diminished terrigenous supply which can be explained in several ways. There could have been a geographic shift in the position of the delta, but if the organic content of the Upper Oxfordian - Lower Kimmeridgian strata is compared with the sea-level curve of Vail et al. (fig. 8) the sea-level rise here called b could explain the higher content of amorphous matter, and the micrinitic organic facies could then be explained by a sea-level rise, which would cause diminished deltaic supply and more dominating marine currents.

Hallam (1978) writes that the sea-level probably began to fall during the Volgian. Vail et al. (1983) showed, that there is a maximum sea-level rise in late Jurassic times corresponding to the Kimmeridgian and Volgian stages. They have found several changes in sea-level (fig. 8) but these changes cannot be correlated to the chronostratigraphy as precisely as the changes presented by Hallam (1978). The maximum sea-level rise af Vail et al. (1983) seems to be equivalent to the deposition of strata with an organic content dominated by amorphous matter of Habib's (1979) xenomorphic organic facies. According to Habib the organic material of the xenomorphic organic facies is deposited from the sea without any influence of marine current activity.

Acknowledgments. This study is a part of an energy research project (EFP 1983). I. M. Jensen (Geological Survey of Denmark) typed the manuscript. T. Birkelund (University of Copenhagen), J. M. Hansen (Geological Survey of Denmark), S. Piascecki (Geological Survey of Greenland), L. B. Rasmussen (Geological Survey of Denmark) critically reviewed the manuscript.

Dansk sammendrag


De fire formationer viser en markant forskel i organisk facies (polynofacies). Det synes muligt at vise en sammenhæng mellem havniveau-svingninger og ændringer i organisk facies. Således markerer transgressionsperioder sig med dominans af ustrukturert (amorf) organiske stoffer, mens regressive perioder dominerer af struktureret organiske materiale.
References


