DANMARKS OG GRØNLANDS GEOLOGISKE UNDERSØGELSE RAPPORT 1997/97

Lower and Upper Cretaceous stratigraphy in the Central Trough: executive summary

- a contribution to the EFP-93 project: Lower and Upper Cretaceous stratigraphy in the Central Trough

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Contents

1. Introduction

The EFP 93 project on the stratigraphy of the Cretaceous strata in the northern Contiguous Area of the Danish Central Trough is presented in this completion report by means of 12 individual reports covering various aspects of the investigation. In this introductory report, the main results and conclusions are drawn together to provide an overview of the project.

2. Aims

Central to the aims of the project was the detailed biostratigraphic analysis of borehole material (core in preference) from the northern part of the Contiguous Area in order to refine the understanding of the Cretaceous stratigraphy of the area. Previous investigations on the basis largely of seismic, sedimentological and log data had illustrated the inadequacies of the existing biostratigraphic data to constrain these studies and demonstrated the necessity for increased biostratigraphic resolution to guide correlation, both on regional and field scales.

The central aim, therefore, was to study in detail the biostratigraphy of certain key (cored) wells and to integrate the new data and zonation with the results of previous log correlation/sequence stratigraphic studies (e.g. EFP 87 Intra-Chalk, EFP 91 Lower Cretaceous) and with new seismic analysis of 3D data.

The project thus became resolved into four major subject areas:

(1) Biostratigraphic zonation

(2) Regional stratigraphy of the Cromer Knoll Group in the northern Contiguous Area

(3) High-resolution stratigraphy of the mid-Cretaceous of the northern Contiguous Area, with particular focus on the Valdemar Field area

(4) Regional stratigraphy of the Chalk Group in the northern Contiguous Area.

The main results of these sub-projects are summarised below; due to the confidential status of the 3D seismic dataset, the results of the seismic work are necessarily generalised in this summary.

3. Database

3.1 Biostratigraphy

Core material was utilised as far as possible in this study; previous industrial and research work (e.g. EFP 87 Intra-Chalk) has been based largely on cuttings samples, with all the associated potential errors, and the aim here was to date and correlate the critical stratigraphic surfaces as accurately as possible. However, in certain intervals, particularly in the Valhall Formation of the Cromer Knoll Group, core material is lacking and it was necessary to include cuttings samples.

The following wells were included in the study (Fig. 1):

Lower Cretaceous

Iris-1 (cuttings)
Adda-3 (core)
Deep Adda-1 (core, cuttings)
North Jens-1 (core)
Valdemar-1 (core)

Upper Cretaceous - Danian

Bo-1 (core)
Adda-3 (core)
TWC-3 (cuttings)

In the case of the Iris-1 and TWC-3 wells, the analysis included both new biostratigraphical data and review of previous biostratigraphic studies.

3.2 Seismic

The 3D seismic study was based on a continuous 3D dataset produced by Mærsk Olie og Gas that incorporates a series of earlier, more localised 3D surveys. This merged 3D seismic net remains confidential.

The seismic data are tied by 13 wells, including the key wells in the biostratigraphic study e.g. Adda-3, Deep Adda-1, North Jens-1, Bo-1, Adda-3.

3.3 Petrophysical data

It was not the aim of this project to duplicate previous log correlation studies of the Cretaceous in the Danish Central Trough. The log-stratigraphy of the Lower Cretaceous was studied in some detail as part of EFP 91 Lower Cretaceous (see also Kühnau & Michelsen, 1993) and the relevant correlation panels from this study were utilised in tieing the new

biostratigraphic and seismic data.; important wells in this context were Jens-1, Bo-1, North Jens-1 (and the Valdemar wells), Boje-1 and selected wells from the Tyra, Adda and Roar fields. Although outside the immediate study area, the Iris-1 well was also included in order to constrain the stratigraphy of the Valhall Formation.

Similarly, previous log correlation studies of the Upper Cretaceous arising from the EFP 97 Intra-Chalk project and subsequent in-house consultant studies were utilised in tieing the Upper Cretaceous seismic and biostratigraphic data. The key wells in this context were Bo-1 and Adda-3.

4. Results

4.1 Biostratigraphic zonation

The micropalaeontological and palynological studies undertaken in the present project have resulted in the establishment of an improved biozonation scheme for the Cretaceous interval in the northern Contiguous Area (Fig. 2). The scheme is based on calcareous and siliceous microfossils as well as nannofossils, as these groups proved most useful for the construction of a high-resolution biostratigraphy in the area. Palynomorphs (mostly dinoflagellate cysts) from the Upper Cretaceous Chalk Group were studied in the Adda-3 and Bo-1 wells, and were recovered from most samples. However, relatively thick barren intervals were encountered and many of the dinoflagellate assemblages from the Chalk Group were highly impoverished. As a consequence, no dinoflagellate zonation scheme has been established for the Upper Cretaceous in this study. However, a number of key dinoflagellate events were noted in the succession, and have been used to support the zonation shown in Fig. 2. Palynomorphs from the Lower Cretaceous were studied in the Iris-1 well; the succession could be readily referred to the zonation scheme of Davey (1982), but further improvements of that scheme were not possible on the basis of the results from the Iris-1 well.

The new integrated zonation (Fig. 2) allows a break-down of the Cretaceous System into 44 microfossil zones and 51 nannofossil zones. Ten of the zones can be further subdivided, resulting in a total of 59 nannofossil zonal units. For practical reasons, the microfossil and nannofossil zones have been combined into 50 zones and 20 subzones.

4.2 Regional stratigraphy of the Cromer Knoll Group

It was appreciated under EFP 91 that the sequence stratigraphic scheme for the Cromer Knoll Group erected during this project (see Fig. 3) required testing by means of integration of seismic and detailed biostratigraphic data. Seismic analysis of the Cromer Knoll Group in the northern Contiguous Area has confirmed the validity of the main sequence stratigraphic subdivision erected by Ineson (1994). The sequence boundaries intra-Valhall, base-Tuxen and top-Tuxen (Fig. 3) can be shown on seismic to show truncation - onlap relationships, thus confirming their status as significant sequence boundaries in this area. The intra-Valhall and base-Tuxen surfaces had been recognised on earlier 2D seismic data (see Vejbæk, 1986), but the top-Tuxen surface had been beyond the resolution of previous datasets. Mapping of the extent of the truncation at base-Tuxen clearly demarcates the zone and trend of Early Cretaceous (Hauterivian) inversion uplift. The biostratigraphic significance of the surfaces bounding the Tuxen Formation has been substantiated by biostratigraphic work undertaken as part of the project (e.g. in the North Jens-1, Valdemar-2 and Deep Adda-1 wells).

The mid-Cretaceous sequences identified from log, biostratigraphic and core data (see below) are largely beyond the resolution of the 3D seismic data; no reliable seismic mark-

ers were identified between top-Tuxen and top-Rødby (i.e. base-Chalk) although a top-Sola reflector can be traced locally. An additional reflector, base Munk Marl Bed (i.e. intra-Tuxen Formation) can be traced in expanded sections but the seismic data cannot be utilised to confirm this surface as a sequence boundary (see below).

The Iris-1 well was included in this study, although outside the strict confines of the study area, in order to re-evaluate the biostratigraphy of the Valhall Formation. Core from the Valhall Formation is scarce in the Danish Central Trough so that it was necessary to select a well that penetrated a thick, well-developed Valhall Formation thus reducing to a minimum the potential errors associated with biostratigraphic analysis of cuttings samples; the Iris-1 well fulfilled these criteria. Integrated palynological, nannofossil and microfossil data have refined the Valhall Formation stratigraphy and dated the intra-Valhall sequence boundary to be of mid-Valanginian age; strata beneath the boundary are of Early Valanginian age whereas Late Valanginian-Early Hauterivian ages were obtained from the succeeding strata. This intra-Valanginian hiatus is an important feature in the North Sea basin (Rawson & Riley, 1982) and in certain settings is marked by significant lowstand sand deposits (e.g. Riley *et al.*, 1992). On the basis of these new data, the stratigraphic location of this sequence boundary in "basinal" wells (e.g. Iris-1, I-1, Elin-1, Sten-1) in the Danish sector, as originally interpreted by Ineson (1994), has been modified.

4.3 High-resolution sequence stratigraphy of the mid-Cretacous

The Tuxen and Sola Formations together form an important stratigraphic interval in the Danish Central Trough with respect to the Lower Cretaceous chalk play (Ineson, 1993). In particular, an understanding of the detailed stratigraphy of the succession in the northern part of the Contiguous Area is critical to the future production profile of the Valdemar Field and the development of the Adda Field. The interval has thus been the focus of an integrated study on the extensively cored North Jens-1 well to test the preliminary sequence stratigraphy of Ineson (1993). The aim was to produce a robust genetic stratigraphy from this well that, in ongoing and future studies, can be expanded to the remainder of the Valdemar Field and further afield (i.e. the Adda Field, in the first instance).

Integration of palynological and nannofossil data has largely confirmed the position of the major sequence boundaries within the Upper Hauteriviuan - Upper Aptian section but has also identified a new "cryptic" sequence boundary within the upper Tuxen Formation (Fig. 4). This boundary defines the base of one of the best reservoir chalk intervals in the succession and as such is an important stratigraphic surface for regional and intra-field correlation. The new data have also resulted in significant modification of the sequence subdivision into systems tracts and in a greater understanding of basin evolution in the Early Cretaceous. In particular, palynofacies analysis has proved to be an essential tool for the recognition of the regional sea-level signal in such chalk successions and thus for the subdivision into systems tracts.

4.4 Stratigraphic breakdown of the Upper Cretaceous - Danian chalks

On the basis of the 3D seismic dataset, the Chalk Group in the northern Contiguous Area is subdivided into four seismic sequences, based on the recognition of seven intra-Chalk markers, in addition to the base- and top-Chalk markers. These sequences are largely in accordance with previous integrated seismic-log studies (e.g. EFP 87 Intra-Chalk), although additional intra-sequence reflectors can be resolved on the new 3D dataset. Although the broad seismic framework had been established in previous studies, the aim of this work was firstly to accurately locate and date biostratigraphically the major sequence boundaries and secondly to perform seismic facies analysis and investigate the morphology of the surfaces themselves via the 3D dataset.

Two important intra-Chalk seismic sequence boundaries in the study area are the informally named "Chalk Unconformity" and the Campanian Marker (Fig. 5). These surfaces show significant erosion/truncation/onlap features and although recognised by most workers, their stratigraphic age and significance have been the subject of some dispute. In particular, the "Chalk Unconformity" has been referred informally to both the Coniacian and the mid-Santonian by different workers. On the basis of this study, the two intra-Chalk unconformity surfaces are referred to the mid-Santonian and the late (uppermost?) Campanian (Fig.5). The former surface, although locally eroding deep into the Coniacian - Turonian section (hence alternative age assignments of this surface), is developed within the Santonian section in the most complete sections.

Seismic facies mapping of certain key surfaces, e.g. the "Chalk Unconformity" and the Campanian marker, has revealed a number of spectacular erosional features that resemble channels and/or slump scars.

5. Conclusions

The EFP 93 Cretaceous Stratigraphy Project has resulted in:

(1) A refined biostratigraphic zonation of the Cretaceous in the northern Contiguous Area, particularly of the mid-Cretaceous (Upper Hauterivian - Upper Aptian) and Upper Cretaceous-Danian.

(2) A high-resolution sequence stratigraphy of the mid-Cretaceous (Upper Hauterivian - Upper Aptian), of particular benefit to ongoing reservoir studies in the Valdemar and Adda fields.

(3) A more precise chronostratigraphic understanding of the seismic subdivision of the Upper Cretaceous - Danian chalks and an illustration of the complex nature of erosional processes in the Danish Central Trough during the Late Cretaceous.

6. References

Davey, R.J., 1982: Dinocyst stratigraphy of the latest Jurassic to Early Cretaceous of the Haldager No. 1 borehole, Denmark. *Geological Survey of Denmark, Series B* 6, 57 pp.

Ineson, J.R., 1993: The Lower Cretaceous chalk play in the Danish Central Trough. *In*: Parker, J.R. (ed.): Petroleum Geology of Northwest Europe, *Proceedings of the 4th Conference, Geological Society* (London), 175-183.

Ineson, J.R. 1994: Sequence stratigraphy of the Cromer Knoll Group (Lower Cretaceous) in the Danish Central Trough. *Danmarks Geologiske Undersøgelse, Service report* 14, 40 pp.

Kühnau, L. & Michelsen, O., 1993: Detailed log-stratigraphic study of the Lower Cretaceous in the Danish Central Trough, North Sea. *Marine and Petroleum Geology* 11, 467-477.

Rawson, P.F. & Riley, L.A., 1982: Latest Jurassic - Early Cretaceous events and the "late Cimmerian unconformity" in North Sea area. *American Association of Petroleum Geologists Bulletin* 66, 2628-2648.

Riley, L.A., Harker, S.D. & Green, S.C.H., 1992: Lower Cretaceous palynology and sandstone distribution in the Scapa Field, UK North Sea. *Journal of Petroleum Geology* 15, 97-100.

Vejbæk, O.V., 1986: Seismic stratgraphy and tectonic evolution of the Lower Cretaceous in the Danish Central Trough. *Danmarks Geologiske Undersøgelse, Series A* 11, 46 pp.

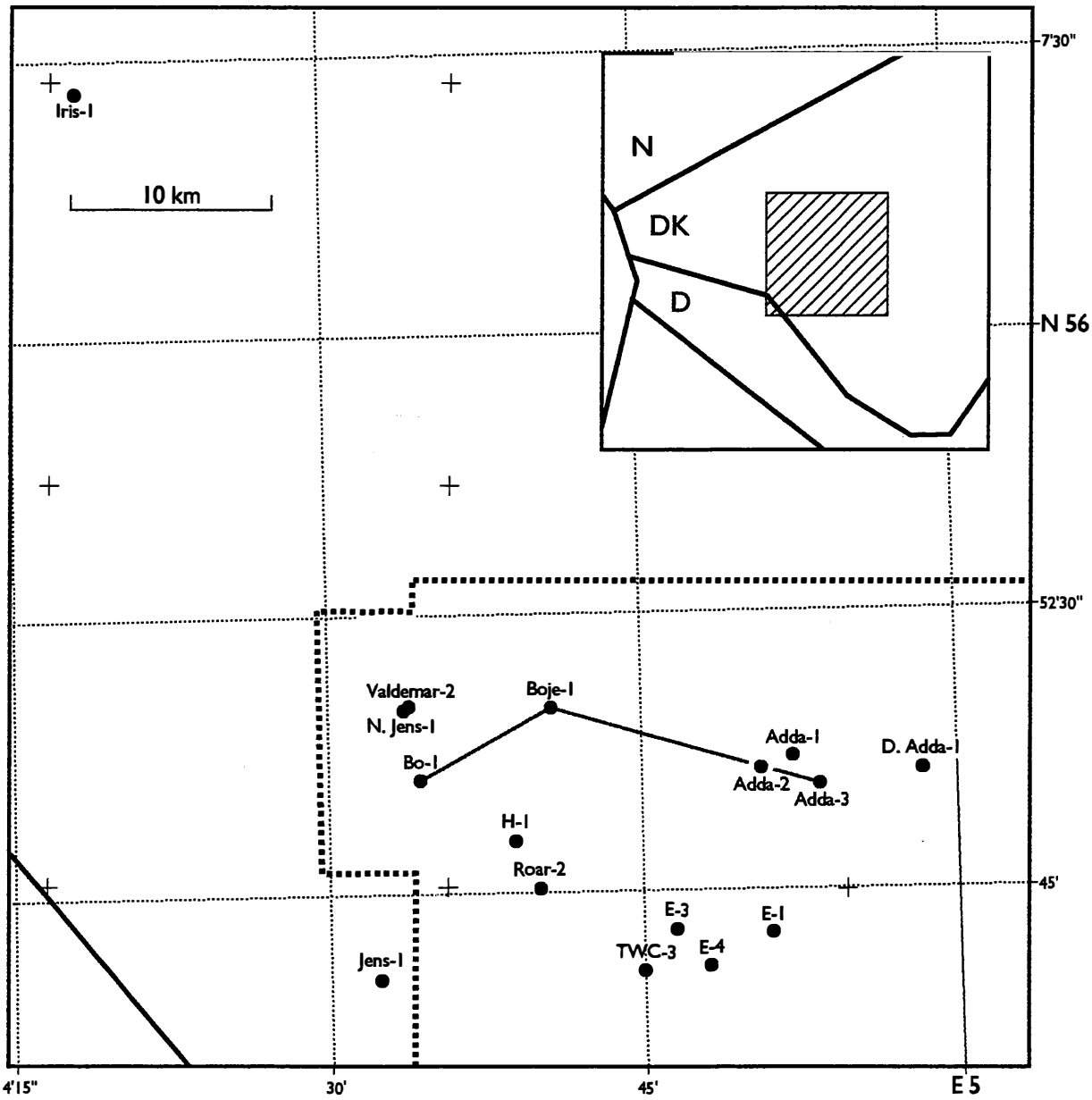

Fig. 1. Map showing the location of the studied wells and the well correlation panel in Fig. 5; the outlined area is that covered by 3D seismic data utilized in this study. Inset map shows the location of the study area in the Danish sector. N=Norway, DK=Denmark, D=Germany.

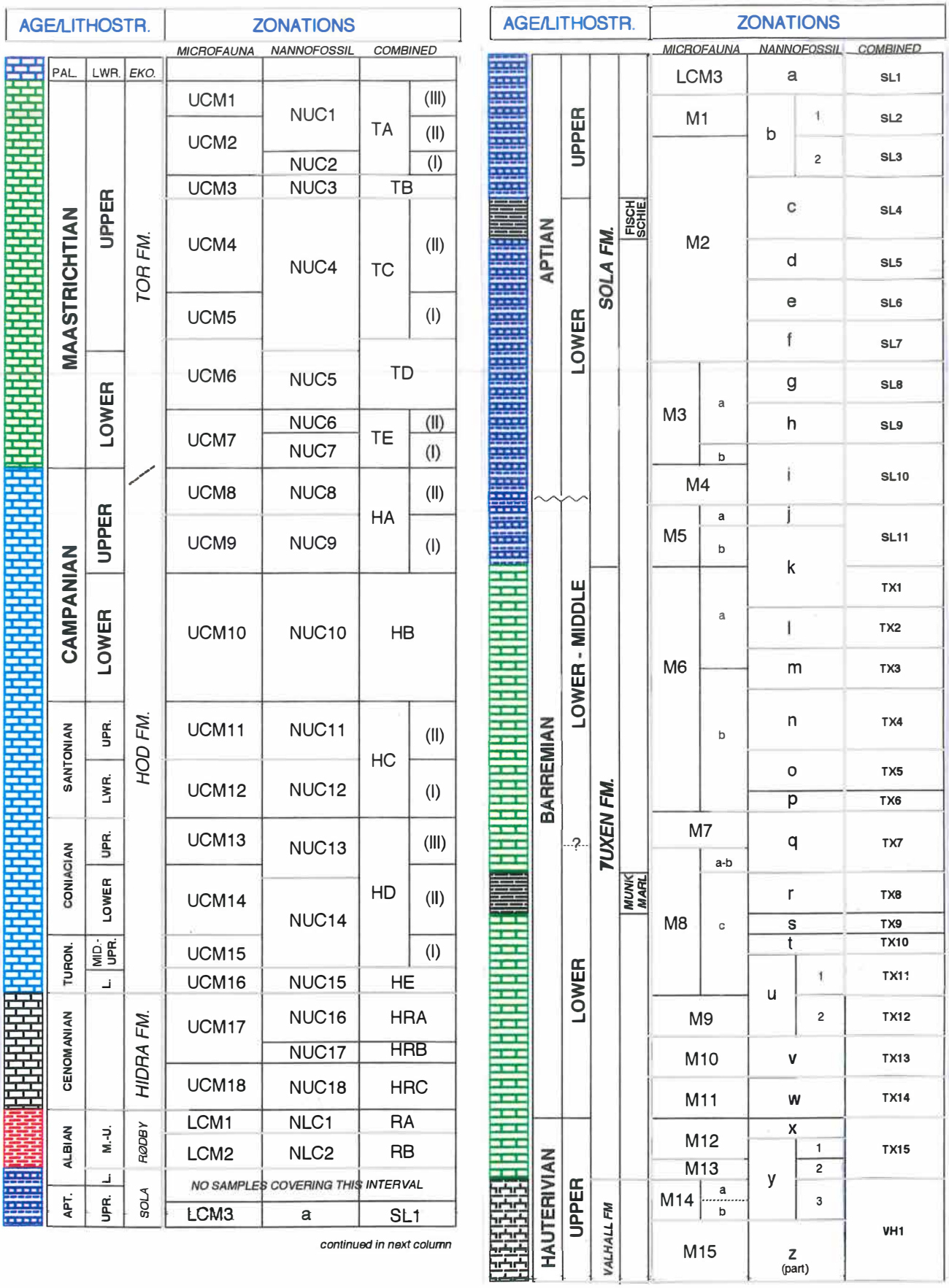

Fig. 2 Biostratigraphic zonation scheme for the Cretaceous interval in the northern Contiguous Area based on micro- and nannofossils. Key dinoflagellate events in the Upper Cretaceous are indicated.

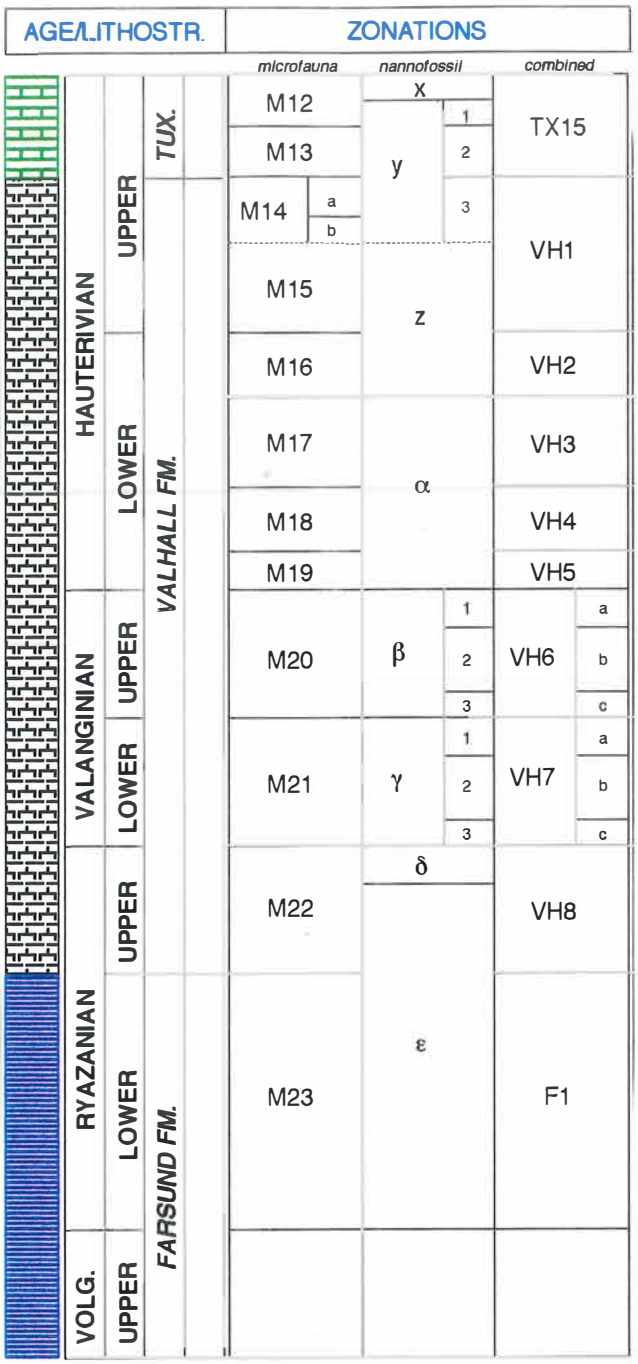
AGE/LITHOSTR.
ZONATIONS
microfauna
nannofossil
combined
HAUTERIVIAN
UPPER
LOWER
VALANGINIAN
UPPER
LOWER
RYAZANIAN
UPPER
LOWER
VOLG.
UPPER
TUX.
VALHALL FM.
FARSUND FM.
M12
M13
M14
a
b
M15
M16
M17
M18
M19
M20
M21
M22
M23
x
y
z
α
β
γ
δ
ε
1
2
3
TX15
VH1
VH2
VH3
VH4
VH5
VH6
VH7
VH8
F1
a
b
c

Fig. 2

EFP 93

MICROFOSSIL ZONES AND KEY DINOFLAGELLATE EVENTS FROM THE UPPER CRETACEOUS OF THE CENTRAL NORTH SEA

Fig. 2

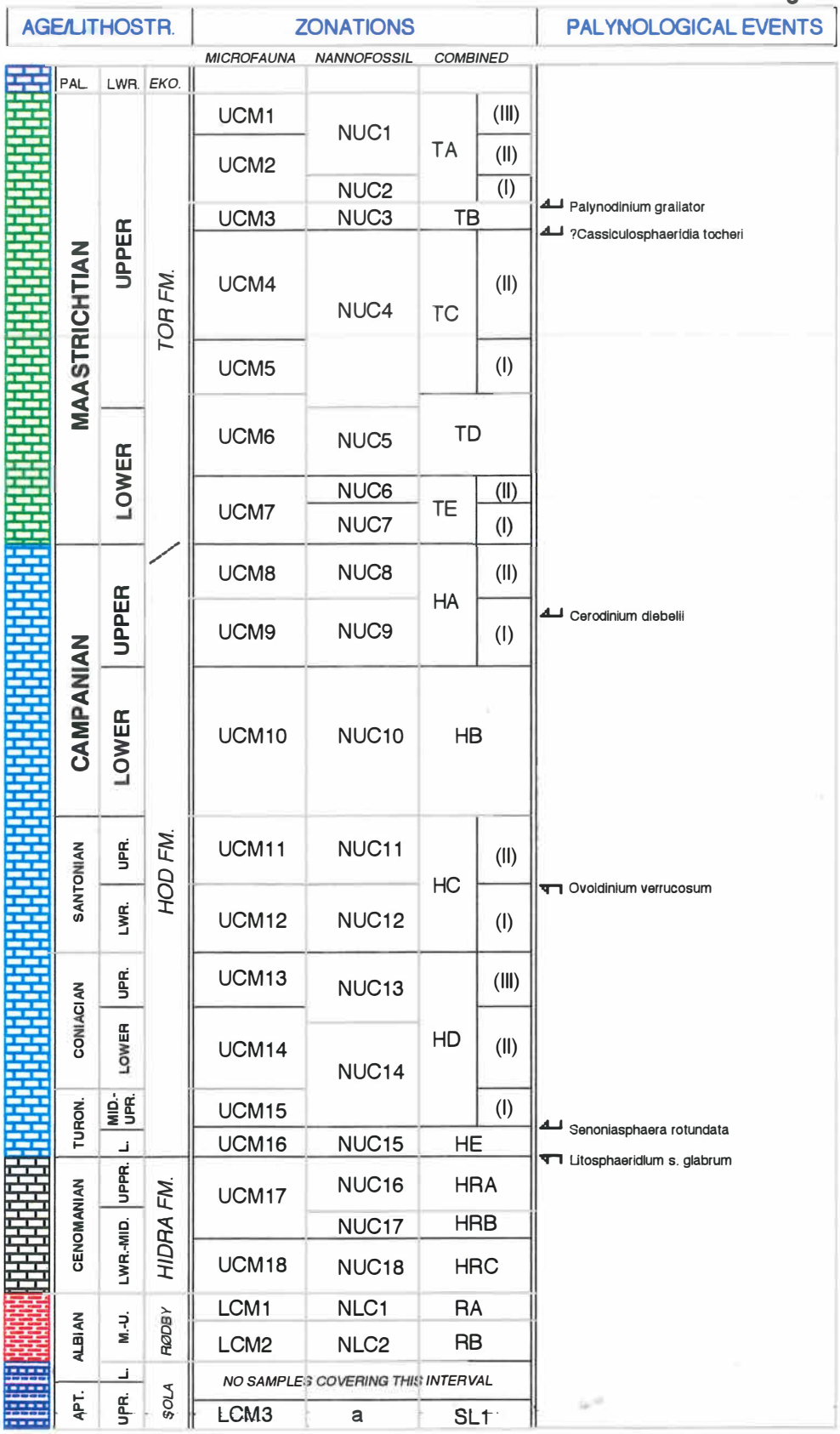

Fig. 2

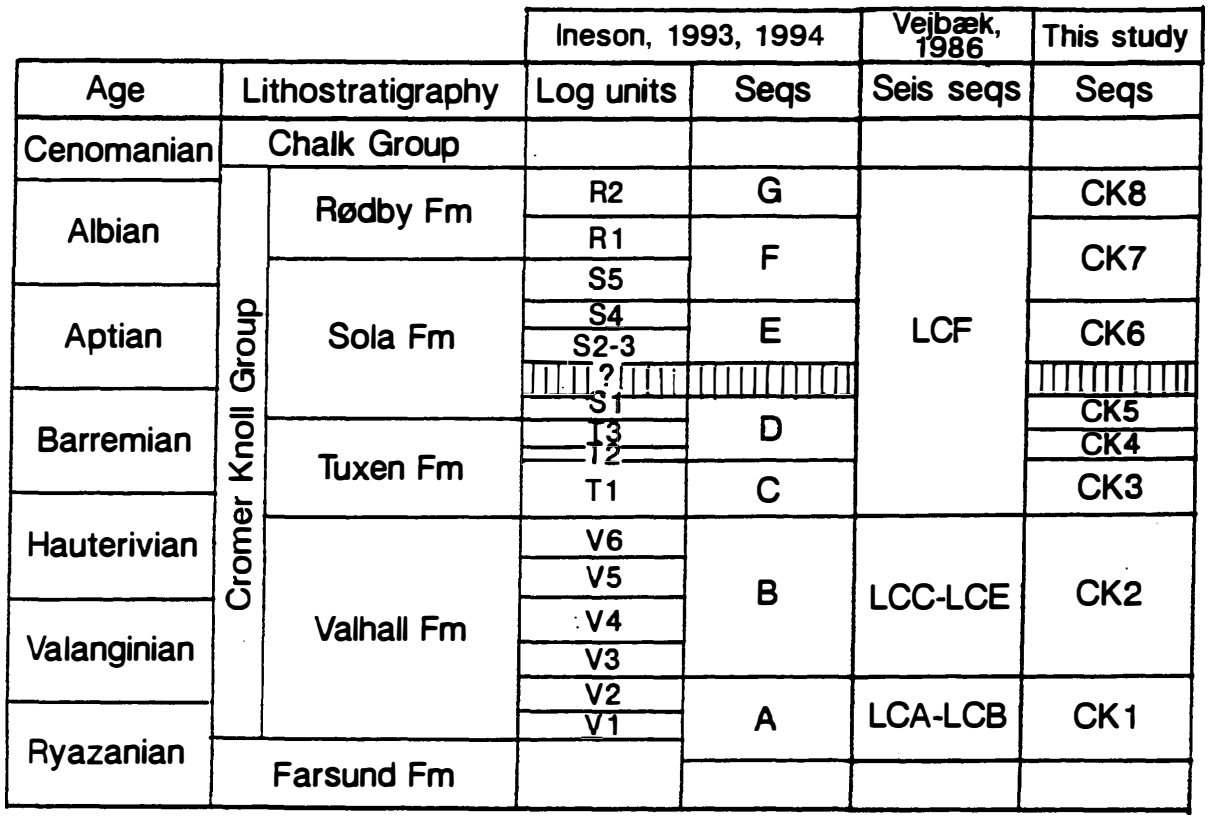

Fig. 3 Lower Cretaceous lithostratigraphy in relationship to log units and sequences described by Ineson (1993, 1994) and the sequence stratigraphic framework proposed here. Note that the seismic framework of Vejbæk (1986) has been modified by Britze (this report).

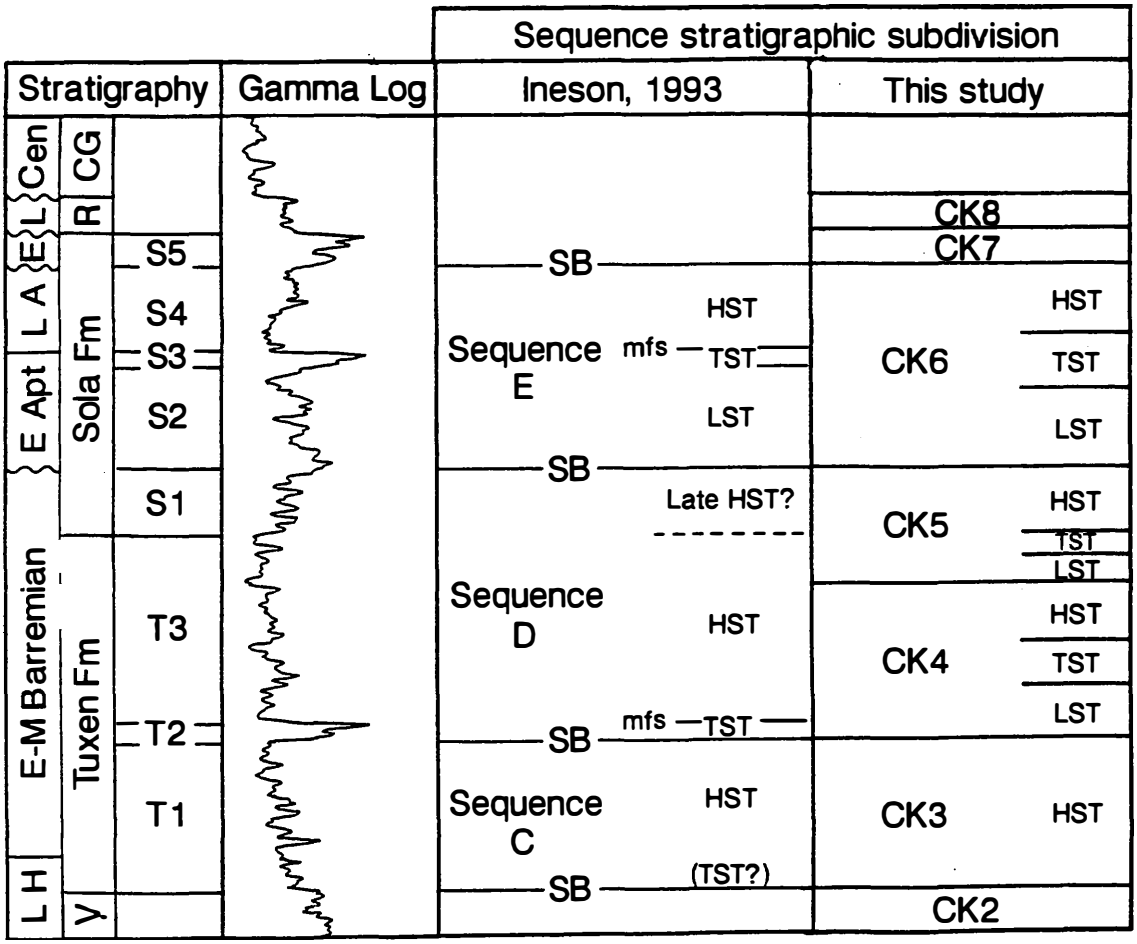

Fig. 4 The sequence stratigraphy of the mid-Cretaceous succession in relation to the previous scheme of Ineson (1993).

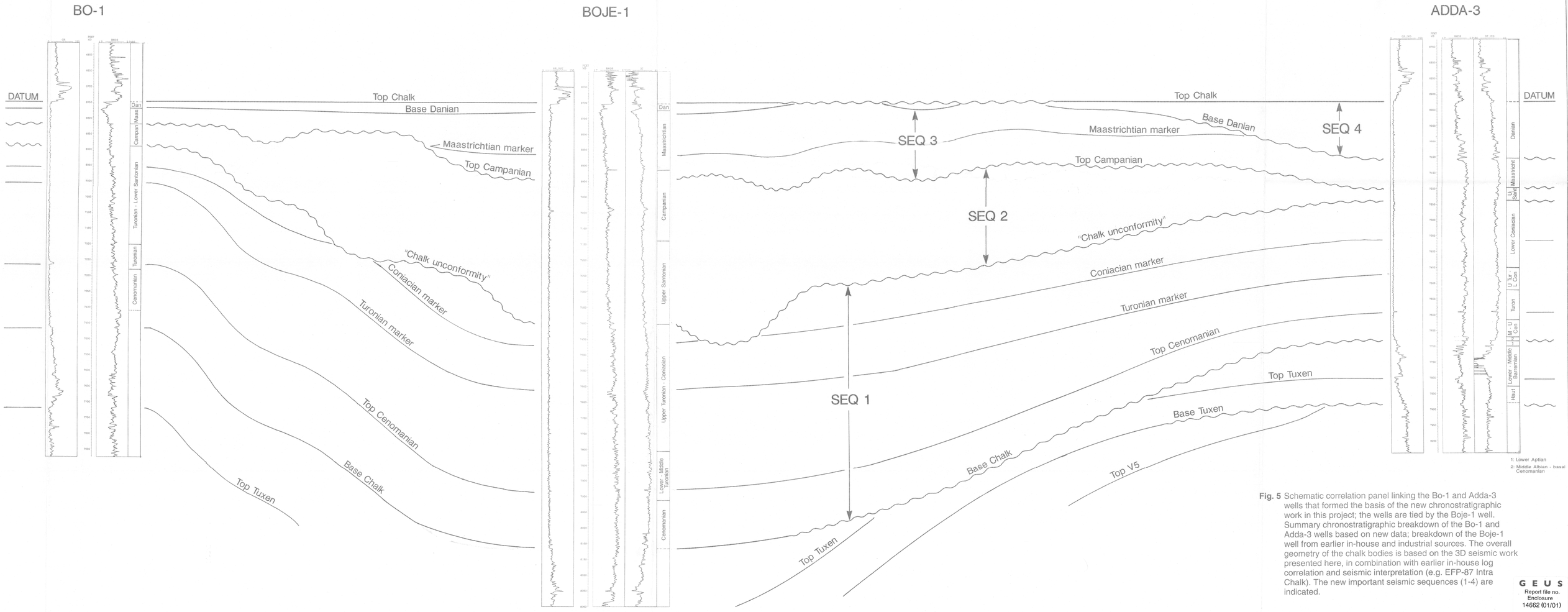

Fig. 5 Schematic correlation panel linking the Bo-1 and Adda-3 wells that formed the basis of the new chronostratigraphic work in this project; the wells are tied by the Boje-1 well. Summary chronostratigraphic breakdown of the Bo-1 and Adda-3 wells based on new data; breakdown of the Boje-1 well from earlier in-house and industrial sources. The overall geometry of the chalk bodies is based on the 3D seismic work presented here, in combination with earlier in-house log correlation and seismic interpretation (e.g. EFP-87 Intra Chalk). The new important seismic sequences (1-4) are indicated.

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