UPPER JURASSIC DINOCYST STRATIGRAPHY IN THE DANISH CENTRAL TROUGH

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Abstract

The English dinocyst zonations established by Woollam and Riding (1983) and Riding and Thomas (1988), and the Danish – English zonations of Davey (1979, 1982), are unified for the Danish North Sea area and the subzones of the *Endoscrinium luridum* Zone are redefined.

Two standard sections for the Upper Jurassic are described and correlations to five other wells in the Danish North Sea area are demonstrated.

Zonations

Many Jurassic dinoflagellate cyst zonations for NW Europe have been published during the last twenty years. Several are figured by Woollam and Riding (1983, fig. 9a, b). Additional data published simultaneously with or subsequent to the latter work include Davey (1982), Riley and Fenton (1982), Nøhr-Hansen (1986), Riding and Thomas (1988), Prauss (1989), Courtinat (1989).

An Upper Jurassic zonation (figs 1 and 2) is presented here for the Danish Central Trough. It is based on the work of Davey (1979; 1982), Woollam and Riding (1983), Nøhr-Hansen (1986), and Riding and Thomas (1988). Data on the stratigraphical distributions of dinoflagellate cysts from Riding (1987) and Cox *et al.* (1987) have also been incorporated. Some of the zones and subzones are discussed, and two subzones are revised. If correlation establishes the identity of two units, the first published name is preferred in the interest of simplicity (Hedberg, 1976 p. 20).

The standard ammonite zones are here treated as chronostratigraphic units (see Callomon, 1984; Wimbledon and Cope, 1978). The ammonite zones are referred to by the species name alone, e.g. Giganteses Zone.

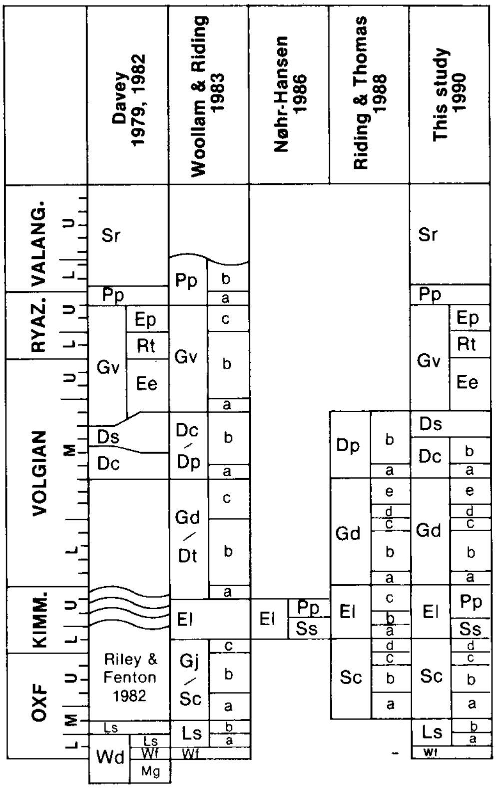

Fig. 1. Diagrammatic comparison of the proposed zonation scheme with others, published 1979–1988.

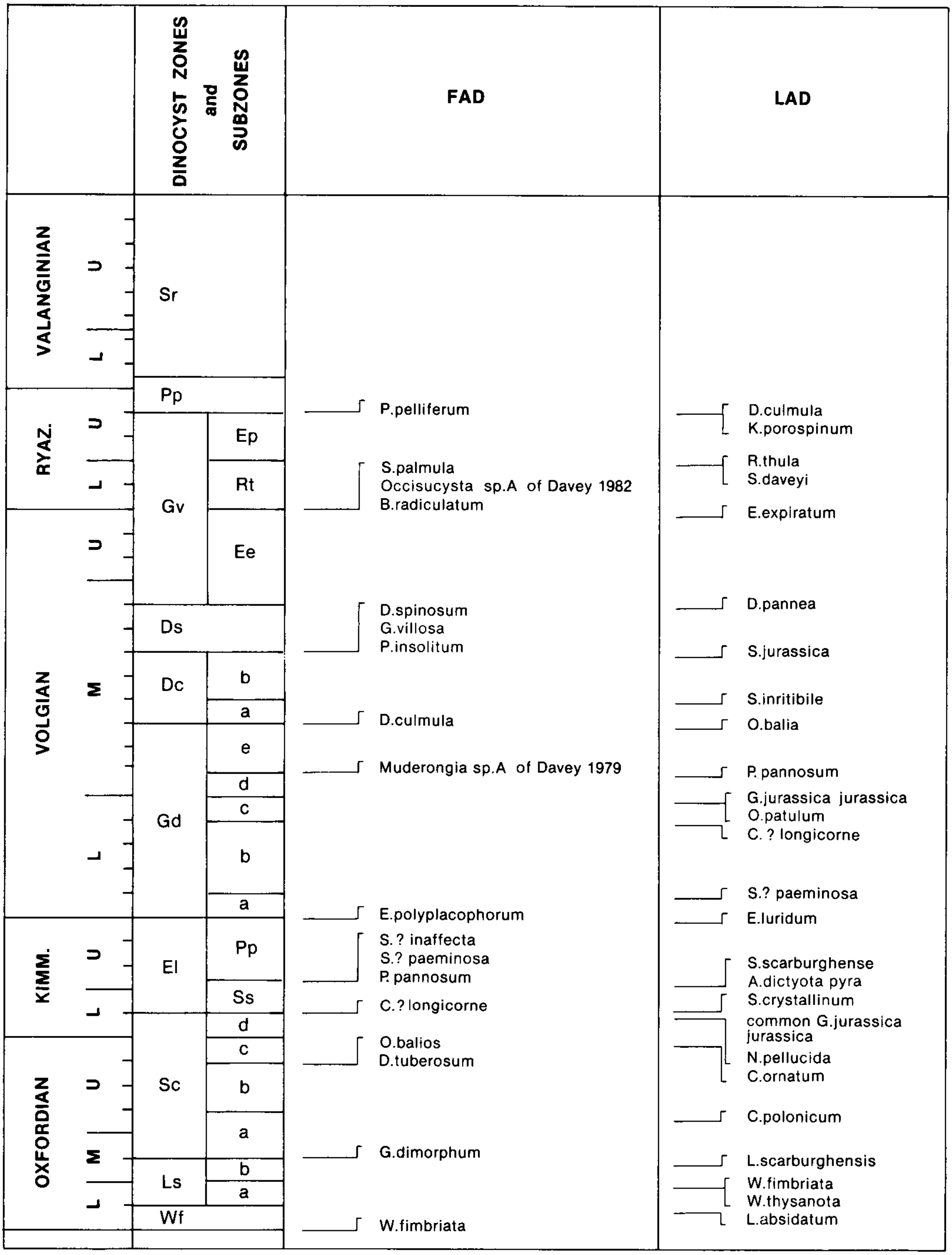

Fig. 2. Zonation scheme with first appearance datums (FAD) and last appearance datums (LAD).

Zone Dc and Zone Ds

The *Dichadogonyaulax culmula* Zone and the *Dingodinium spinosum* Zone were erected by Davey (1979). These two zones are based on the Portland Sand and the

Portland Stone of the Dorset coastal sections (Davey, 1979). Wimbledon and Cope (1978) revised the ammonite Zones corresponding to the *D. culmula* and *D. spinosum* Zones.

Davey (1979) correlated his *D. culmula* Zone with the Albani and Gorei Zones (Middle Volgian). The *D. culmula* Zone corresponds to the Portland Sand on Davey's (1979) Dorset section. Davey (1982) subsequently correlated the *D. culmula* Zone with the Albani to mid Okusensis Zone.

The *D. spinosum* Zone was correlated with the Giganteus Zone (Davey, 1979) which is equivalent to the Portland Stone on Davey's (1979) Dorset section. The *D. spinosum* Zone was correlated with the mid Okusensis to Kerberus Zone by Davey (1982).

The Dorset section of Davey (1979, fig. 2) refers to the Purbeck section of Arkell (1933 p. 495) and Wimbledon and Cope (1978) (Fig. 3). The Portland Sand of this section was assigned to the Albani and Glaucolithus Zones (Fig. 3) by Wimbledon and Cope (1978). For this reason, the *D. culmula* Zone is correlated with these two ammonite zones. The Portland Stone of the Purbeck section is equivalent to the Okusensis, Kerberus and Anguiformis Zones (Fig. 3) (Wimbledon and Cope, 1978) and the *D. spinosum* Zone is correlated to these zones. Hence, Davey's (1979) correlations between his dinoflagellate zones and the ammonite stratigraphy are believed to be correct.

The proposed *Dichadogonyaulax pannea* Zone (Dp) of Riding and Thomas (1988) correlates with the Dc and Ds Zones of Davey (1979). The latter zones have publication priority and are preferred to the more recently defined Dp Zone. However, the Subzone a and the Subzone b proposed by Woollam and Riding (1983), can be considered as subzones of the Dc Zone.

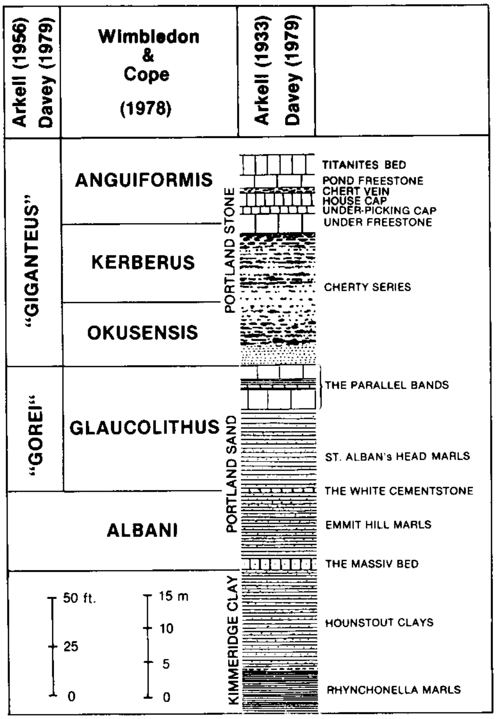

Fig. 3. Ammonite zonation of the Purbeck section, Dorset coast. After Arkell (1933, 1956), Wimbledon & Cope (1978) and Davey (1979).

The Subzone b of the Gd Zone

The *Glossodinium dimorphum* (Gd) Zone, Subzone b (Lower Volgian), was defined by Riding and Thomas (1988) as the interval from the top of their Subzone a to the last appearance of *Cribroperidinium longicorne*. The age of the top of this subzone is the top of the Hudlestoni Zone (Riding and Thomas, 1988). However, Raynaud (1978) reported the last appearance of *C. longicorne* as within the Pallasioides Zone; *C. longicorne* is, however, never found above the Hudlestoni Zone within England (Riding, oral commun., 1990). Therefore, based on the present knowledge,the top of the proposed subzone of Riding and Thomas (1988) should be maintained at the range top of *C. longicorne*.

The Subzones of the El Zone

Nøhr-Hansen (1986) proposed the *Stephanelytron scarburghense* and the *Perisseiasphaeridium pannosum* Subzones as a subdivision of the *Endoscrinium luridum* Zone. Riding and Thomas (1988) revised the subzones of this zone approximating the first and last appearance datums to the standard ammonite zonal boundaries. However, within the *E. luridum* Zone, this methodology led to an indefensible subdivision. The base of the zone is defined (Riding and Thomas, 1988) by the last appearances of *Scriniodinum crystallinum, Sirmiodiniopsis orbis*, and *Nannoceratopsis pellucida*, and the first appearances of *Cribroperidinium longicorne* and *Oligosphaeridium patulum*. The age is the base of the Cymodoce Zone (Kimmeridgian). However, Woollam and Riding (1983) reported the last appearance of *S. orbis* as the Autissiodorensis Zone (uppermost Kimmeridgian) although only indicated as rare or uncertain. Cox *et al.* (1987) reported the last appearance of *S. crystallinum* as Mutabilis Zone (Kimmeridgian), an occurrence which probably is related to reworking (Riding, oral commun., 1990). The species *N. pellucida* is rare in the Central Trough and is not useful for defining the zone boundary there.

Subzone a was defined by Riding and Thomas (1988) as the interval from the base of the zone to the range tops of *Tubotuberella dangeardii* and *Endoscrinium galeritum* and the range bases of *Subtilisphaera? inaffecta, Subtilisphaera? paeminosa* and *Perisseiasphaeridium pannosum*.

Age: Early Kimmeridgian, Cymodoce Chron (Riding and Thomas, 1988).

However, Woollam and Riding (1983) reported the last appearance of *E. galeritum* as Eudoxus Zone (Kimmeridgian), although they marked the last appearance as rare or uncertain. The last appearance of *T. dangeardii* was reported by Riding (1987) as Autissiodorensis Zone, but this occurrence is now believed to be related to reworking (Riding, oral commun., 1990).

The first appearances of *S?. paeminosa, S?. inaffecta*, and *P. pannosum* reported by Riding and Thomas (1988, text-fig. 4) as mid Mutabilis Zone were also reported by Nøhr-Hansen (1986).

Subzone b was defined by Riding and Thomas (1988) as the interval from the top of Subzone a to the range tops of *Aldorfia dictyota* subsp. *pyra* and *Stephanelytron scarburghense*.

Age: Early Kimmeridgian, Mutabilis Chron (Riding and Thomas, 1988).

However, the last appearance of *S. scarburghense* was reported by Riding and Thomas (1988, text-fig. 4) as mid Mutabilis Zone as it was reported by Nøhr-Hansen (1986). The last appearance of *A. dictyota pyra* is only indicated as the base of Mutabilis Zone (Riding and Thomas, 1988, text-fig. 4). In Riding (1987, text-fig. 5) the last appearance of *A. dictyota pyra* is indicated as mid Mutabilis Zone.

The boundary between Subzone a and b and the boundary between Subzone b and c are apparently the same, i.e. mid Mutabilis Zone. The division of the *E. luridum* Zone proposed by Nøhr-Hansen (1986) is preferred for the Riding and Thomas (1988) alternative. The zone and the two subzones are emended.

Endoscrinium luridum (El) Zone

Revised definition: The interval from the last appearance of *Nannoceratopsis pellucida* Deflandre 1938 emend. Evitt 1961, the last appearance of common *Gonyaulacysta jurassica* (Deflandre) Norris and Sarjeant 1965 emend. Sarjeant 1982 (see Raynaud (1978) concerning common *G. jurassica*) and the first appearance of *Cribroperidinium longicorne* (Downie) Lentin and Williams 1985, to the last appearance of *Endoscrinium luridum* (Deflandre) Gocht 1970 and the first appearance of *Egmontodinium*

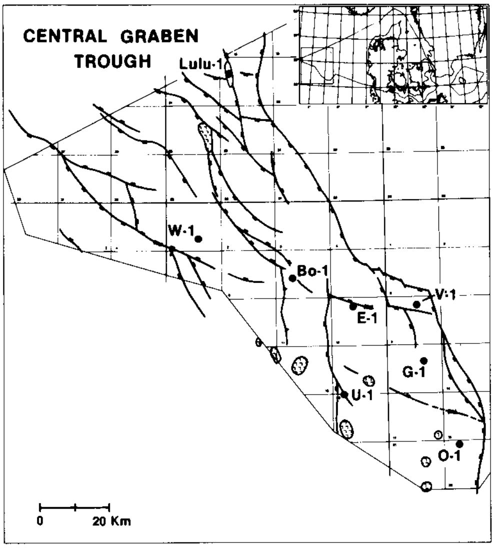

Fig. 4. Location map.

polyplacophorum Gitmez and Sarjeant 1972.

Age: Base of the Cymodoce Chron to the top of the Autissiodorensis Chron (Kimmeridgian).

Stephanelytron scarburghense (Ss) Subzone

Revised definition: The interval from the base of the zone to the last appearance of *Aldorfia dictyota* subsp. *pyra* (Gitmez) Davey 1982 and *Stephanelytron scarburghense* Sarjeant 1961 emend. Stover *et al.* 1977 and the first appearence of *Perisseiasphaeridium pannosum* Davey and Williams 1966, *Subtilisphaera inaffecta* (Drugg) Bujak and Davies 1983, *Subtilisphaera paeminosa* (Drugg) Bujak and Davies 1983.

Age: Cymodoce to mid Mutabilis Chron (Kimmeridgian).

Perisseiasphaeridium pannosum (Pp) Subzone

Revised definition: The interval from the top of the Ss Subzone to the top of the zone.

Age: Mid Mutabilis to Autissiodorensis Chron (Kimmeridgian).

Comments: There is no stratotype selected for the zone. However, the boundary between the two subzones was first described by Nøhr-Hansen (1986) at the clay-pit of Blue Circle Portland Cement, at Westbury, in Wiltshire, England.

Regional aspects: The zone and the two subzones are defined for, and found in the United Kingdom. The zone and at least the Pp Subzone are found in the Central Trough. The zone and the Pp Subzone are also present in the Danish Subbasin, both in several wells in Jutland and in wells in the Sound (between Denmark and Sweden). It is currently uncertain if the Ss Subzone is present in the Danish Subbasin. The zone is also present in East Greenland and again the Pp Subzone is recognized (Piasecki, 1980).

Standard sections and correlations

Two wells, U-1 and E-1 (figs 4 and 5), were chosen by the Geological Survey of Denmark in cooperation with the Geological Institute of the University of Copenhagen as standard section of the Upper Jurassic of the Danish Central Trough. The U-1 well represents the transition from the Middle Jurassic to the Upper Jurassic, and the lower part of the Upper Jurassic, i.e. the Lower Graben Sand, the Middle Graben Shale, the Lola Formations and the lower part of the Farsund Formation. The upper part of the Farsund Formation is missing, probably due to salt-tectonic movements. The well E-1 represents the uppermost Jurassic. More Jurassic strata are probably present, but are not penetrated in this well.

U-1

The Lower Graben Sand Formation was dated as Late Callovian by Hoelstad (1986). Common *Mendicodinium groenlandicum* at the base of the Lola Formation allow a possible correlation to the uppermost Callovian (Riley and Fenton, 1982). The last appearances of *Ctenidodinium continuum* at 10470 feet allow a correlation to the *Wanaea fimbriata* Zone (Piasecki, 1980). The last appearance of *Gonyaulacysta jurassica "hlanc"* (unpublished subspecies of Poulsen, in prep. (a)) at 10420 feet is referred to the *Liesbergia scarburghensis* Zone, Subzone a.

At 9990 feet *Scriniodinium crystallinum* Zone, Subzone a is marked by the last appearances of *Systematophora valensii* and *Compositosphaeridium polonicum*. The occurrence of *Atopodinium prostatum* in the sidewall core at 9806 feet allows its correlation with the *S. crystallinum* Zone, Subzone b. The last appearance of *Ctenidodinium ornatum* at 9740 feet indicates of correlation of this level to the *S. crystallinum* Zone, Subzone c. This subzone indicates the top of the Oxfordian. The occurrence of *Dingodinium tuberosum* together with common *Gonyaulacysta jurassica* in the sidewall core at 9690 feet permits a correlation to the *S. crystallinum* Zone, Subzone d. This subzone indicates the base of the Kimmeridgian. The Oxfordian – Kimmeridgian boundary is in this well found in the uppermost part of the Lola Formation.

All samples of the Farsund Formation in this well are correlated to the *Endoscrinium luridum* Zone. The occurrence of *E. luridum, Endoscrinium galeritum*, and *Perisseiasphaeridium pannosum* in the uppermost sidewall core of the Farsund Formation assigns this level to the *E. luridum* Zone, *P. pannosum* Subzone.

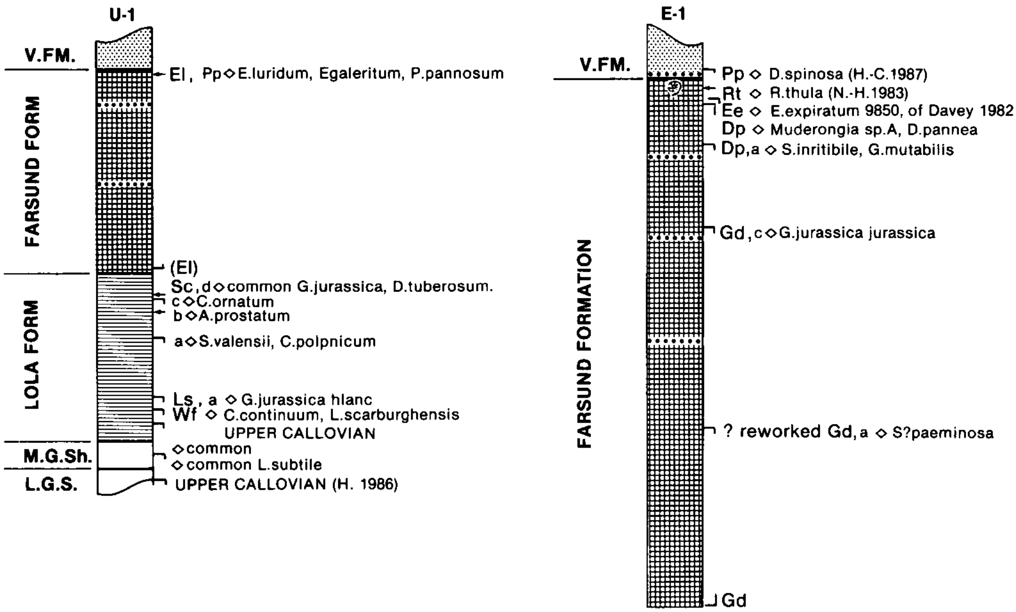

Fig. 5. Zonation of the wells U-1 and E-1. Zones and subzones are given in abbreviations, followed by index species. H. 1986 = Hoelstad, 1986; H-C, 1987 = Heilmann-Clausen, 1987; N-H, 1983 = Nøhr-Hansen, 1983.

E-1

The last appearance of *G. jurassica* at 10750 feet permits a correlation to the *Glossodinium dimorphum* Zone, Subzone c, Lower Volgian. The underlying subzones b and a or Zone El were not traceable. The occurrence of *Subtilisphaera? paeminosa* at 12050 feet is believed to be related to reworking. *Subtilisphaera? paeminosa* has its last appearance in the *G. dimorphum* Zone, Subzone a, lowermost Volgian, which apparently is not present in this well.

The last appearance of *Scriniodinium inritibile* and *Gochteodinia mutabilis* at 10190 feet is referred to the *Dichadogonyaulax panneum* Zone, Subzone a, Middle Volgian.

The last appearance of *Muderongia* sp. A of Davey 1982 and *D. pannea* at 9890 feet places this level at the top of the *D. panneum* Zone, Middle Volgian.

The last appearance of *Egmontodinium expiratum* at 9850 feet permits the correlation to the *Gochteodinia villosa* Zone, *E. expiratum* Subzone, uppermost Middle to Upper Volgian (Nøhr-Hansen, 1983).

The report of *Rotosphaeropsis thula* at 9783 feet close to the top of the Farsund Formation (Nøhr-Hansen, 1983) allows a correlation to the *G. villosa* Zone, *R. thula* Subzone, Lower Ryazanian.

The recorded last appearance of *Dingodinium spinosum* at the base of the Valhall Formation at 9690' (Heilmann-Clausen, 1987) permits a correlation to the *Pseudoceratium pelliferum* Zone, uppermost Ryazanian.

Correlations

Investigations of dinoflagellate cysts (Poulsen, in prep. (b)) have made biostratigraphical correlations between the O-1, U-1, G-1,

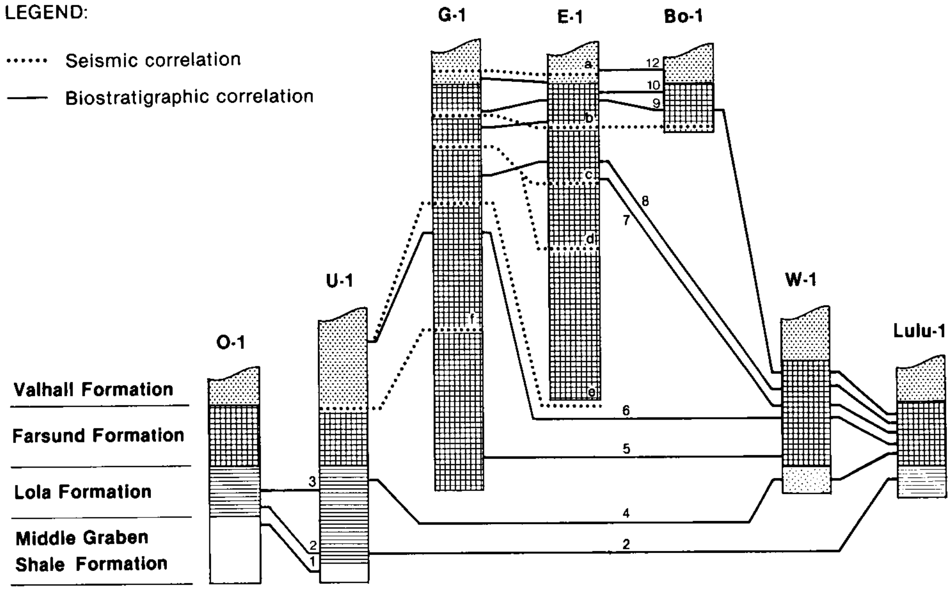

Fig. 6. Correlation between the wells O-1, U-1, G-1, E-1, Bo-1, W-1 and Lulu-1.
Biostratigraphic correlations
1. Late Callovian, 2. Early Oxfordian (Wf-Ls), 3. Middle Oxfordian Sc, a), 4. Late Oxfordian (Sc, c), 5. earliest Kimmeridgian (El/Sc), 6. Late Kimmeridgian (El, Pp), 7. early Middle Volgian (Gd, c), 8. early Middle Volgian (Gd, d), 9. mid Middle Volgian (Dc), 9a. mid Middle Volgian (Dc, a), 10. Late Volgian (Gv, Ee), 11. Early Ryazanian (Gv, Ep), 12. Late Ryazanian (Pp). (Abbreviations in parentheses = zone, subzone).
Seismic correlations
(Møller, 1986) a = LCU, b = UJ7, c = UJ6, d = UJ5, e = UJ3, f = UJ2.

E-1, Bo-1, W-1, and Lulu-1 wells possible (Fig. 4). On Fig. 6 the biostratigraphic correlations are shown in full lines. Seismic correlations after Møller (1986) are shown in dotted lines. As the figure demonstrates, seismic and biostratigraphic correlations are in many cases isochronous.

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