Jorsalfare Formation (new)
(Jorsalfareformasjonen)

Name:
Named after Sigurd "Jorsalfare" Magnusson, a Norwegian king (A.D. 1103-1130).

Well type section:
Norwegian well 25/1-1 from 2997 to 2711 m, coordinates N 59°53'17.40", E 02°04'42.70" (Fig. 33). One core (17 m) in the middle of the formation and another (4 m) at the base.

Well reference sections:
Norwegian well 35/3-2 from 1665 to 1520 m, coordinates N 61°51'05.98", E 03°46'28.22" (Fig. 34). No cores.

Norwegian well 24/9-1 from 3117 to 2752 m, coordinates N 59°16'09.48", E 01°47'31.18" (Fig. 35). No cores.

Thickness:
The formation is 286 m thick in the type well (25/1-1), 145 m in well 35/3-2 and 365 m in well 24/9-1.

Lithology:
The formation generally consists of mudstones interbedded with thin limestone beds. The mudstones are light to medium grey, often calcareous. The limestones are white to light grey, fine grained, occasionally sandy and dolomitic.

Basal stratotype:
The lower boundary is defined by a decrease in gamma-ray intensity and an increase in velocity, reflecting an increase in calcareous content from the Kyrre Formation into the Jorsalfare Formation (Figs. 33 and 34). In the Tampen Spur area, however, the boundary may be difficult to identify due to small differences in calcareous content. The lower boundary may be unconformable above the Jurassic sequences (e.g. in the Gullfaks area).

Characteristics of the upper boundary:
The upper boundary may be towards the Våle, Lista or Ty Formations of the Rogaland Group. When the upper boundary is towards the shale of the Lista Formation it is usually characterised by an upward increase in gamma-ray intensity and a distinct drop in velocity (Fig. 34). When it is towards the Våle Formation it does not show the same distinct drop in velocity and increase in gamma-ray intensity, because the overlying lithology consists of limestones or calcareous mudstones (Fig. 35). Where the upper boundary is towards the Ty Formation it is identified as a change to sandstone (Fig. 33).

Distribution:
The formation is present in the Viking Graben and on the Tampen Spur. Its boundaries towards the Jorsalfare Formation in the Viking Graben, the Hardråde Formation on the Horda Platform and the Tor Formation on the Utsira High are illustrated in Fig. 32b.

The main characteristics that can be used to distinguish the three formations are:
a. The Jorsalfare Formation contains shales with thin limestone beds which are usually no thicker than 5 m.
b. The Tor Formation is dominated by limestones, and has a negligible shale content.
c. The Hardråde Formation contains thick limestone beds (10-60 m), as well as shales, except in the Troll area where it is thin and may consist of only a single bed of limestone or marly limestone.

Separation of these three formations may be difficult in transitional areas.

Age:
Late Campanian to Maastrichtian.

Depositional environment:
Open marine.

Remarks:
Hardråde and Tor Formations of the Shetland Group, and also with the informal "formation E" of Deegan & Scull (1977) (Fig. 6).

Hardråde Formation (new)
(Hardrådeformasjonen)

Name:
Named after Harald "Hardråde" Sigurdsson, a Norwegian king (A.D. 1046-1066).

Well type section:
Norwegian well 30/11-3 from 2892 to 2601 m, coordinates N 60°02'38.59", E 02°32'15.47" (Fig. 36). No cores.

Well reference section:
Norwegian well 31/6-2 from 968 to 978 m, coordinates N 60°34'58.24", E 03°54'55.76" (Fig. 37). No cores.

Thickness:
The formation is 291 m thick in the type well (30/11-3) and 10 m in well 31/6-2. It is absent on tilted fault blocks in the Troll area (e.g. well 31/2-9).

Lithology:
The formation consists generally of interbedded limestones and mudstones, except in the Troll area where it is thin and consists of a single limestone bed. The limestones are white or pale, moderately hard to very hard. The mudstones are medium to light grey, often silty and calcareous.

Basal stratotype:
The lower boundary is towards the Kyrre Formation or an unconformity above older rocks. The boundary towards the Kyrre Formation is identified by the absence of relatively thick limestone beds in this formation and a lower content of calcareous material in the mudstone. This results in a decrease in gamma-ray intensity and an increase in velocity from the Kyrre Formation into the Hardråde Formation (Fig. 36). The formation has an unconformable lower boundary in the Troll area.

Characteristics of the upper boundary:
The upper boundary is towards the Rogaland Group. When it is towards the Lista Formation it is characterised by an upward increase in gamma-ray intensity and a distinct drop in velocity due to a transition from limestones to mudstones (Fig. 36). An upper boundary

CRETACEOUS

WELL 30/11-3

TYPE WELL: HARDRÅDE FORMATION

REFERENCE WELL: SVARTE FORMATION
TRYGGVASON FORMATION
KYRRE FORMATION

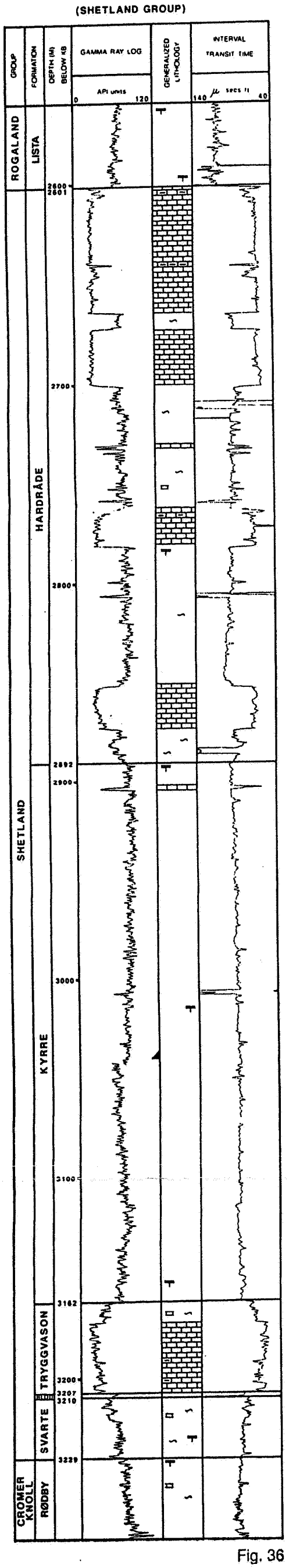


Fig. 36

CRETACEOUS

WELL 31/6-2

REFERENCE WELL: HARDRÅDE FORMATION
UNDIFF.SHETLAND GROUP
IN THE TROLL AREA

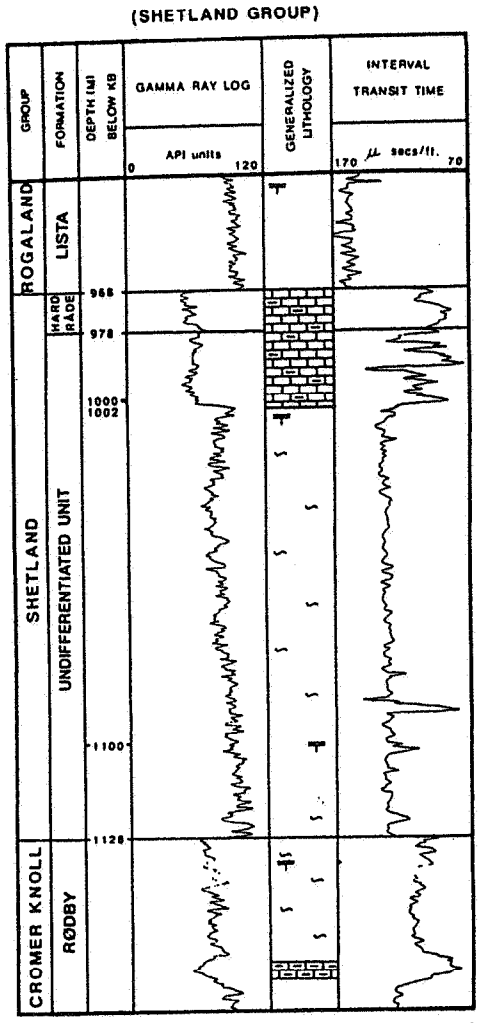


Fig. 37

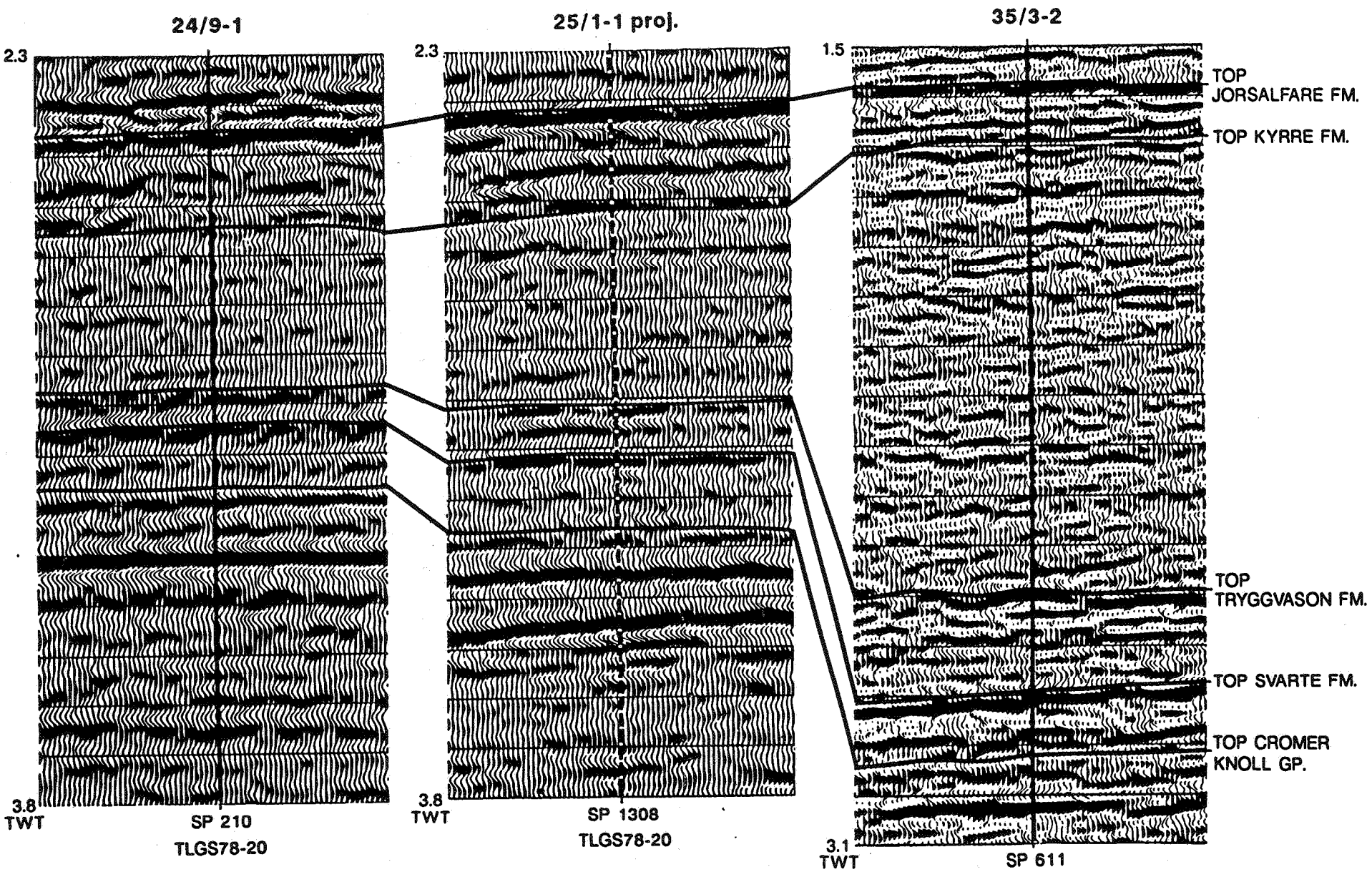


Fig. 38 Seismic character of the Shetland Group.

towards the Våle Formation lacks the distinct drop in velocity. This is due to the presence of limestones and a more marly facies in the Våle Formation. An upper boundary towards the Ty Formation is shown by a change to sandstone.

Distribution:
The formation is present on the Horda Platform (Fig. 32b).

Age:
Late Campanian to Maastrichtian.

Depositional environment:
Open marine.

Remarks:
The Hardråde Formation is time-equivalent with the Jorsalfare and Tor Formations of the Shetland Group (Fig. 6).

Undifferentiated Shetland Group in the Troll area (Udifferensiert Shetlandsgruppe i Troll-området).
General:
In the Troll area a part (probably the lower part) of the Shetland Group shows a different lithological development from that found in the type and reference wells. Hence, the subdivision based on the Viking Graben is not used there. Furthermore, because the proven lateral extent appears to be limited there is not defined any new stratigraphic unit. A description of the unit is, however, given below.

Reference well section:
Norwegian well 31/6-2 from 1128 to 978 m, coordinates N 60°43' 58.24", E 03° 54' 55.76" (Fig. 37). No cores.

Thickness:
In well 31/6-2 the thickness is 50 m, but the unit is absent from several wells in the area.

Lithology:
The unit generally consists of marly mudstones containing occasional limestone beds. In some wells, such as the type well, there is a relatively thick marly limestone bed uppermost. The mudstones are calcareous, medium to light grey, and the limestones are argillaceous, mainly white to medium grey.

Basal stratotype:
The lower boundary of the unit is towards the more carbonate rich Cromer Knoll Group. There is an increase in gamma-ray intensity and a distinct decrease in velocity across the boundary from the Cromer Knoll Group (Fig. 37).

Characteristics of the upper boundary:
The upper boundary is unconformable towards the limestones of the Hardråde Formation. This boundary can be difficult to detect on logs if the thick upper limestone bed is present (Fig. 37), but it is then defined by datings.

Distribution:
The unit is present in the Troll area.

Age:
Turonian to Cenomanian.

Depositional environment:
Open marine.

Remarks:
This unspecified unit is time-equivalent with the Svarte, Blodøks and Tryggvason Formations (Fig. 6).

TERTIARY

BASIN EVOLUTION

Early Tertiary time saw the culmination of a significant episode of rifting in the North Atlantic region. Oceanic crust was emplaced between Greenland and the Hebridean-Norwegian Margin during the Mid Paleocene (Gage & Dore 1986). In the context of this active rifting there was a late Early Paleocene tectonic event which was accompanied by a global drop in sea level.

This tectonic activity resulted in downwarping of the North Sea Basin, generally centred above the main Mesozoic rift system, complicated by intrabasinal uplift. The rapid subsidence of the Viking Graben and the Central Trough was accompanied by tilting of their flanks, in particular the East Shetland Platform and the Utsira High.

On the topographical highs, the Ekofisk Formation and sometimes the Tor Formation were eroded and redeposited in basinal areas by mass gravity flows (e.g. well 2/1-4, Fig. 51). This reworking is commonly observed along graben margins and intrabasinal highs, and close to rising salt diapirs.

The tectonic activity led to the production of coarse clastics derived from the faulted basin margins in the west. Associated tilting produced an easterly drainage pattern. The Shetland Platform was covered by a deltaic prism prograding towards the continental slope. The deep zones were gradually filled in by submarine fans (Maureen, Ty, Andrew, Heimdal, Forties and Hermod Formations) interbedded with hemipelagic sediments (Våle, Lista and Sele Formations).

Simultaneously, the uplifted intrabasinal areas were gradually submerged by the deepening sea, and covered by marine muds.

During the late Paleocene and early Eocene, progressive infill of the basin, combined with a drop in sea level in the early Eocene, the relatively shallow marine area changed to a non-marine shelf and deltaic environment. Sediments prograded eastwards. Sediments from the Shetland Platform were eroded to form a second depositional sequence - the Frigg Formation (Conort 1986).

At the end of the Paleocene, the general pattern of sedimentation was interrupted by ash-fall deposits (Balder Formation). These represent explosive volcanism, probably linked to an active rifting phase. The main eruption centres were probably the Møre Basin and the Faeroe-Shetland region (Malm et al. 1984), with an additional centre in the Skagerrak.

Further subsidence resulted in a major Early Eocene transgression. Marine muds (Hordaland Group) covered the Late Paleocene ash beds, except in marginal

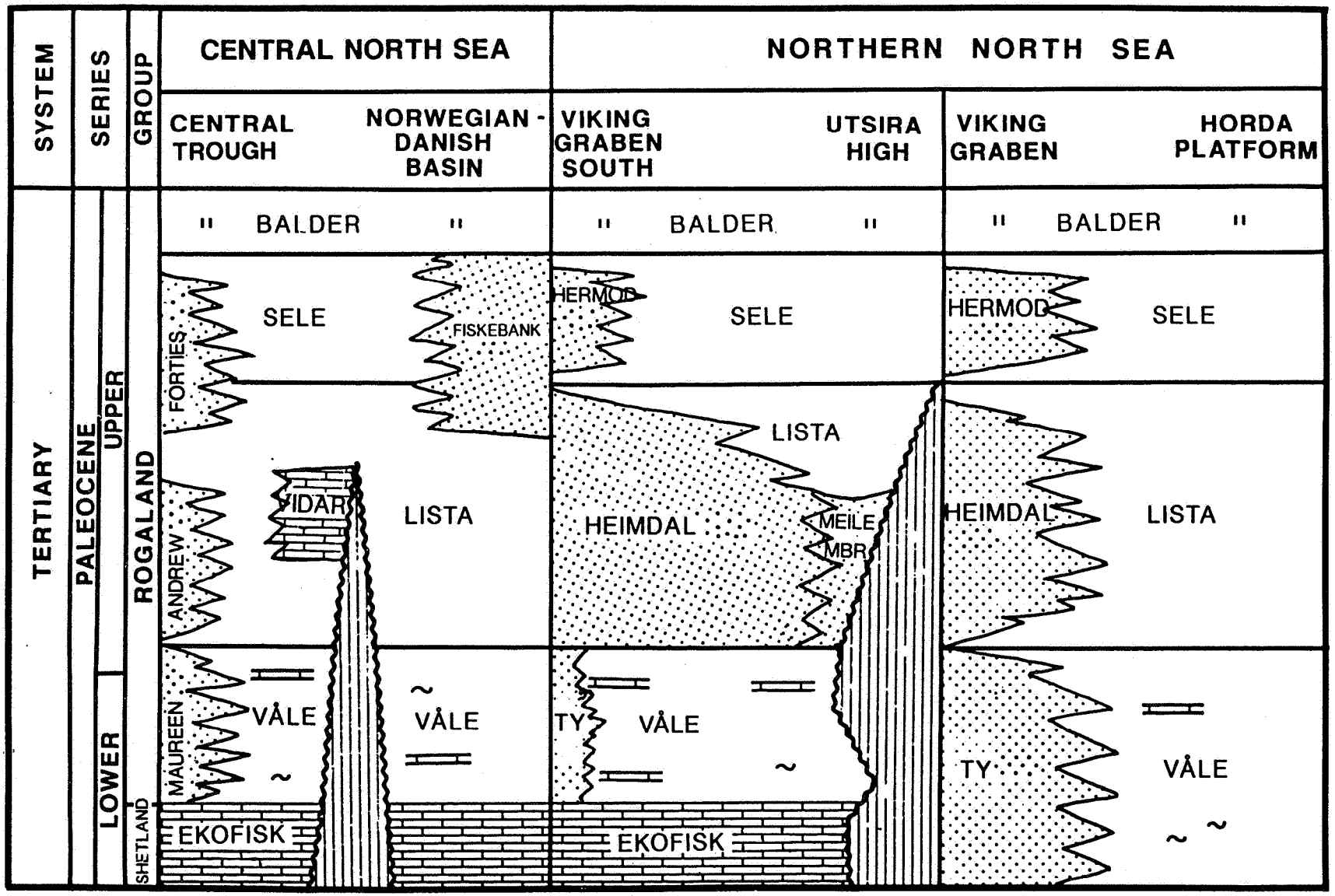


Fig. 39 **PALEOCENE LITHOSTRATIGRAPHIC NOMENCLATURE, NORWEGIAN NORTH SEA.**

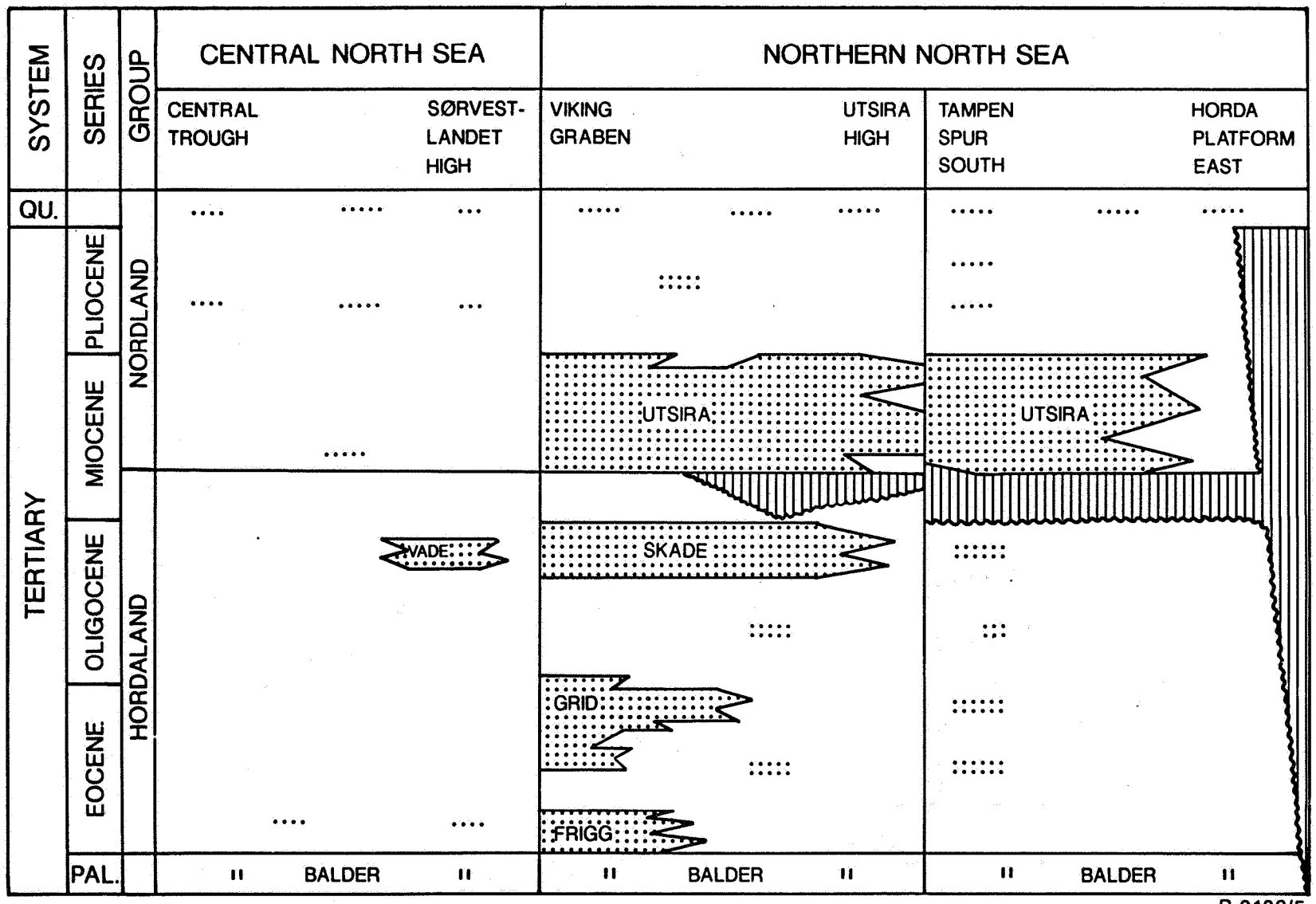


Fig. 40 LITHOSTRATIGRAPHIC NOMENCLATURE IN THE HORDALAND AND NORDLAND GROUPS (TERTIARY)
NORWEGIAN NORTH SEA

TERTIARY

WELL 1/3-1

TYPE WELL: VÅLE FORMATION
REFERENCE WELL: VIDAR FORMATION

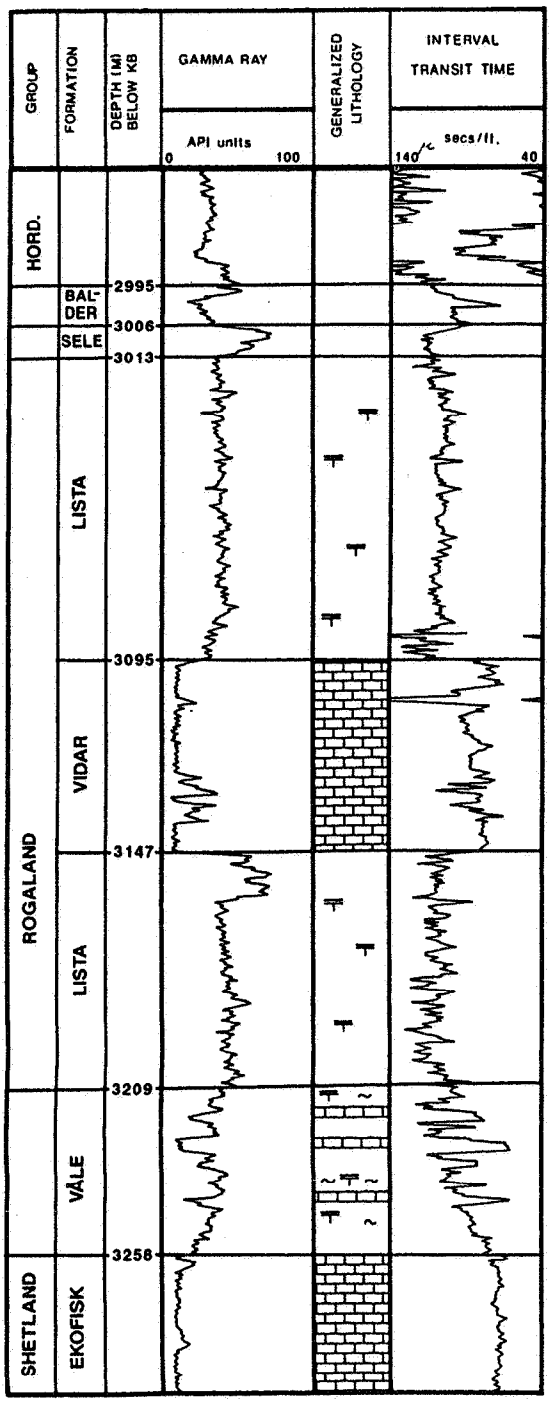


Fig. 41

TERTIARY

WELL 15/9–5

REFERENCE WELL: HEIMDAL FORMATION, VÅLE FORMATION

(ROGALAND GROUP)

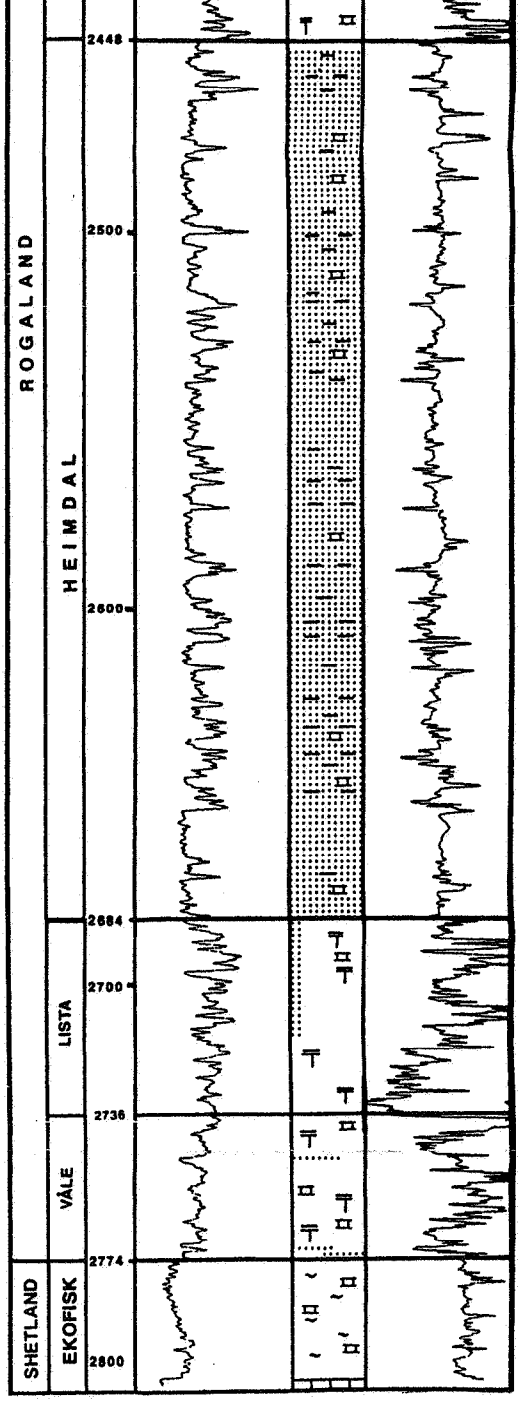


Fig. 42

areas around the East Shetland Platform where sands were locally deposited. Towards the end of the Eocene, the sea level dropped resulting in local erosion on highs and a hiatus. Sedimentation was continuous (Grid Formation) in basins.

Oligocene sediment was dominated by shales. Late in the period, however, the general pattern of sedimentation became dominated by deposition of sandstones (Skade Formation). The change in the sedimentation pattern was probably connected with a general lowering of the sea level.

From the Late Miocene, sedimentation was dominated by fine- grained marine clastics (Nordland Group). Local uplifts produced marginal, marine sands. In general, the period from Late Miocene to Recent is a regressive period. Sedimentation was affected by glacio-eustatic fluctuations of sea level.

During the Quaternary (Pleistocene), ice sheets advanced and retreated several times across the North Sea spreading a sheet of boulder clay, moraines and outwash sands across large areas of the North Sea Basin. Glaciomarine clays (Nordland Group) were deposited in front of the ice.

The Quaternary deposits vary in thickness, being up to 500 m in some areas and thin or absent elsewhere. The Pleistocene glacial deposits are often overlain by sheets of unconsolidated sand and gravel generated by the reworking action of present-day currents (Nordland Group).

General lithostratigraphic notes

Some changes to the nomenclature proposed for the Tertiary by Deegan & Scull (1977) have been made at group level, but all the formations are retained. Some new formations are defined for sections that were undifferentiated or unnamed by Deegan & Scull (1977).

Rogaland Group:
The strata deposited from the end of the Upper Cretaceous to the Balder Formation represent a genetical rock sequence deposited by gravitational forces as submarine fans interbedded with hemipelagic sediments. The sandstones grade into shales which are the distal representatives of the same sequence. When Deegan & Scull (1977) erected one group (the Montrose Group) containing the sandstone sequences and another group (the Rogaland Group) containing the shaly sequences they created a number of nomenclatorial problems. This division has therefore been abandoned, and the Rogaland Group now comprises all the formations from the earlier Montrose and Rogaland Groups.

Two new sandstone formations have been defined in the Rogaland Group. These were not identified or differentiated by Deegan & Scull (1977). They have previously been given informal names, the Ty Formation being called the '10/1-1 sand' and the Hermod Formation the 'Cod sand'. In addition, a new member, the Meile member, is informally named; it has previously been referred to as the 'Gamma sand on Sleipner'.

The distal equivalent of the Maureen Formation is formally named as the Våle Formation. The Lista and Sele Formations are distal representatives of those formations, and are unaltered from Deegan & Scull (1977).

Hordaland Group:
In the previously undifferentiated part of the Hordaland Group, three new, formally defined, formations (the Grid, Skade and Vade Formations) have been identified.

Nordland Group:
No changes from the existing nomenclature.

REVISED TERTIARY LITHOSTRATIGRAPHIC NOMENCLATURE FOR THE NORWEGIAN NORTH SEA

by T. Hardt, E. Holtar, D. Isaksen, G. Kyllingstad, K. S. Lervik, A. S. Lycke and K. Tonstad.

Rogaland Group (Rogalandsgruppen)

Name:
The Rogaland Group was named by Deegan & Scull (1977) after the county of Rogaland in southwest Norway.

Type area:
The group is developed in the northern and central North Sea. In this paper the Rogaland Group comprises all the formations allotted to the Montrose and Rogaland Groups by Deegan & Scull (1977). The division into the Montrose Group and the Rogaland Group is not retained. It was based on differences in proximal and distal parts of the same sedimentary system, and therefore caused numerous practical problems.

The Rogaland Group in the Norwegian sector consists generally of proximal sediments in the west which interfinger with more distal equivalents in the east. The proximal part is illustrated in UK wells 10/1-1A and 21/10-1 from the northern and central North Sea, respectively. The corresponding distal part of the sedimentary system is illustrated in Norwegian wells 31/2-6 and 2/7-1.

Thickness:
The group is 684 m thick in UK well 10/1-1A and 459 m in UK well 21/10-1. It thins eastwards and is 345 m and 112 m thick in Norwegian wells 31/2-6 and 2/7-1, respectively.

Lithology:
Dominant lithologies in the west are sandstones interbedded with shales. These sandstones form lobes which passes laterally into shales eastwards, and in most of the Norwegian sector the Rogaland Group consists of argillaceous marine sediments. The basal deposits frequently contain reworked limestones and marls. Towards the top of the group the shales become increasingly tuffaceous.

Basal stratotype:
The base of the Rogaland Group is placed at the contact with the underlying chalk or marl sequences of the Shetland Group. This boundary is defined by increasing gamma-ray response and reduced velocity, reflecting a reduction in carbonate content.

In the central North Sea, the lithology changes from the chalk facies of the Shetland Group to shales or marls of the Rogaland Group. In the western part of the area, calcareous sandstones may overlie the Shetland Group. In the northern North Sea, the boundary is reflected by a change from the calcareous sha-

les of the Shetland Group to shales with a variable carbonate content. In the southwest, sandstones frequently overlie the Shetland Group.

Characteristics of the upper boundary:
The upper boundary of the Rogaland Group is marked by a change from laminated tuffaceous shales to more irregularly bedded sediments which are much less tuffaceous.

Distribution:
The Rogaland Group is widely distributed in the central and northern North Sea.

Age:
Paleocene - Early Eocene

Depositional environment:
The sediments of the Rogaland Group were deposited in a relatively deep marine environment characterised by submarine fans which built out from the west, and possibly from the southeast.

Subdivision:
The Rogaland Group is subdivided into twelve formations. The Våle (new), Lista, Sele and Balder Formations all represent a distal marine depositional environment. Arenaceous fans splaying from the East Shetland Platform are to varying extents interdigitated with the first three of these formations. These clastic sediments are defined as separate formations developed south and east of the Fladen Ground Spur, and other formations are developed east of the East Shetland Platform in the Viking Graben area. South and east of the Fladen Ground Spur, the Rogaland Group is subdivided into the Maureen, Andrew, Forties and Balder Formations, the first three having their approximate argillaceous equivalents in the Våle, Lista and Sele Formations.

In the southern Viking Graben, the Rogaland Group is subdivided into the Ty (new), Heimdal, Hermod (new) and Balder Formations, the first three having their argillaceous equivalents in the Våle, Lista and Sele Formations.

In the Norwegian-Danish Basin, the Fiskebank Formation replaces the Sele Formation and probably part of the Lista Formation.

Fig. 39 illustrates the relationship between these Paleocene formations.

Våle Formation (new) **(Våleformasjonen)**

Name:
Våle was a son of the Norse god Odin and his wife Rind. He was one of the twelve principal gods of Norse mythology.

Well type section:
Norwegian well 1/3-1 from 3258 to 3209 m, coordinates N 56°51'21.00", E 02°51'05.00" (Fig. 41). No cores.

Well reference sections:
Norwegian well 15/9-5 from 2774 to 2736 m, coordinates N 58°24'12.47", E 01°42'29.20" (Fig. 42). No cores.

Norwegian well 2/7-1 from 2934 to 2918 m, coordinates N 56°25'44.68", E 03°12'14.21" (Fig. 43). No cores.

TERTIARY

WELL 2/7-1

TYPE WELL: LISTA FORMATION
REFERENCE WELL: VÅLE FORMATION
(ROGALAND GROUP)

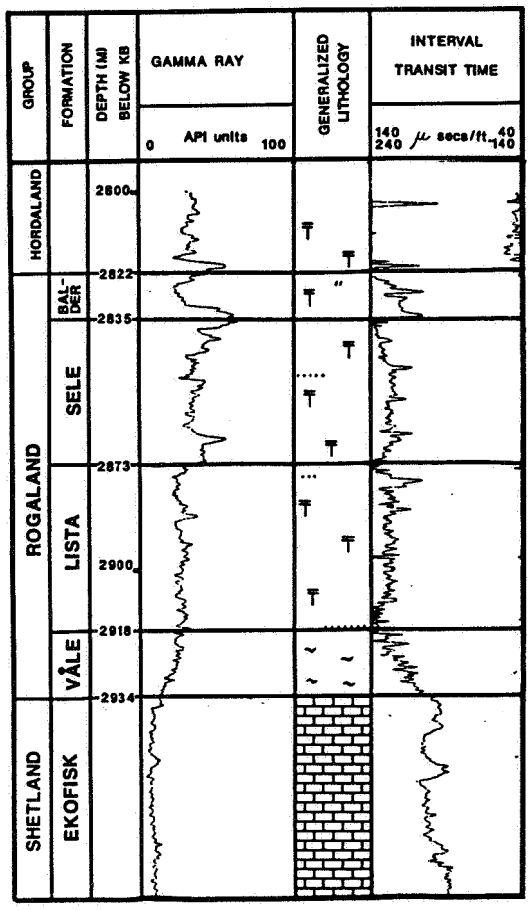


Fig. 43

Thickness:
In the type well, the Våle Formation is 49 m thick. The formation is generally of moderate thickness, normally less than 100 m. Its thickness decreases in central parts of the Central Trough and northwards in the Viking Graben.

Lithology:
The Våle Formation typically consists of marls and claystones interbedded with limestone beds and stringers of sandstone and siltstone. In the Central Trough, the formation is developed as a light grey marl, but locally has chalk and limestone interbeds probably eroded from rising diapirs. It also contains carbonate layers in the southern Viking Graben area.

Basal stratotype:
The Våle Formation rests on the Shetland Group, and the lower boundary is defined where the calcareous sediments grade into marl or shale. The boundary is placed at the upward increase in gamma-ray readings and decrease in velocity (Figs. 41 and 43). These trends may be interrupted by carbonate layers.

TERTIARY

WELL UK 21/10-1

TYPE WELL: SELE FORMATION
FORTIES FORMATION
MAUREEN FORMATION

REFERENCE WELL: ANDREW FORMATION

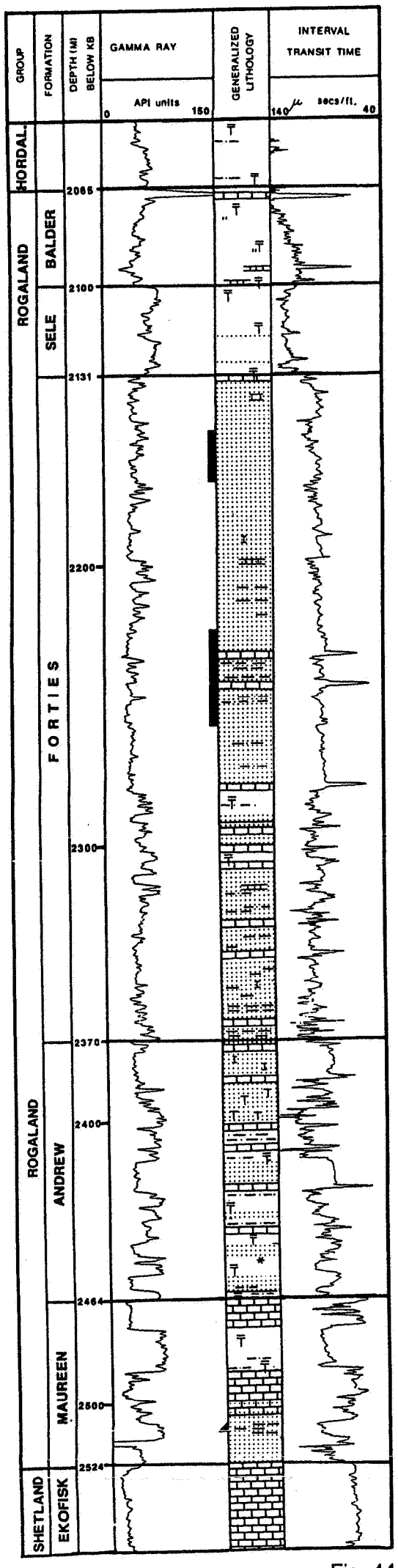


Fig. 44

TERTIARY

WELL UK 16/29-4

REFERENCE WELL : MAUREEN FORMATION

(ROGALAND GROUP)

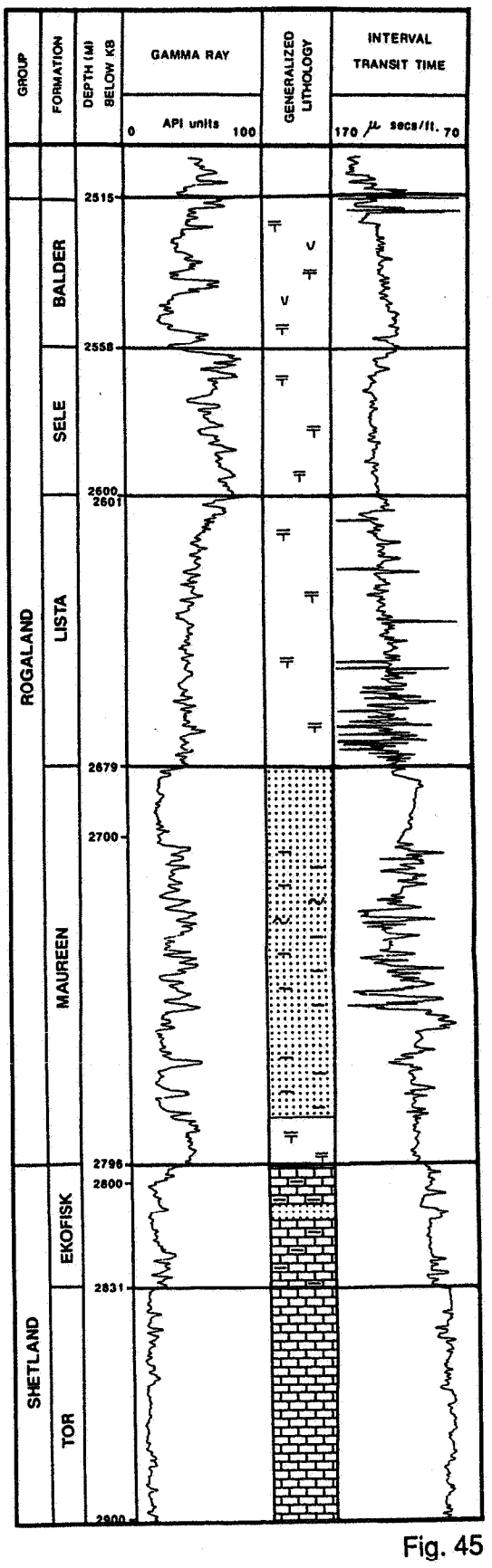


Fig. 45

Characteristics of the upper boundary:
The upper boundary is placed where the shales or marls of the Våle Formation give way to the shales of the Lista Formation. This boundary is defined by decreasing gamma-ray response and increasing velocity (Fig. 41). When the Våle Formation is overlain by sandstone-dominated formations, the upper boundary is marked by decreasing gamma-ray readings and higher velocity.

Distribution:
The Våle Formation is recognised in the central and northern North Sea, except for intrabasinal highs. In the northern part of the northern North Sea, the Lower Paleocene is very thin. The formation generally becomes coarser towards the west where it interfingers with the time-equivalent Maureen Formation in the Central Trough and Ty Formation in the Viking Graben.

Age:
Early Paleocene

Depositional environment:
The Våle Formation was deposited in a marine environment.

Maureen Formation (Maureenformasjonen)

Name:
Named by Deegan & Scull (1977) from the Maureen Field in UK block 16/29.

Well type section:
UK well 21/10-1 from 2524 to 2464 m, coordinates N 57°43'50.37", E 00°58'29.19" (Fig. 44). No cores.

Well reference sections:
UK well 16/29-4 from 2796 to 2679 m, coordinates N 58°05'20.90", E 01°39'15.10" (Fig. 45). No cores.

Norwegian well 7/11-1 from 3173 to 3069 m, coordinates N 57°04'15.60", E 02°26'24.40" (Fig. 46). No cores.

Thickness:
The Maureen Formation is thickest in the Witch Ground Graben in the UK sector of the central North Sea where it consists of as much as 400 m of mainly sandstones. It thins westwards and southwards, and is poorly developed in Norwegian waters, the maximum thickness in a well is found 7/11-1 where there are 104 m of sandstones and carbonates.

Lithology:
The Maureen Formation consists of sandstones that are slightly to very calcareous and often contain reworked limestones. The sandstones are interbedded with brown and dark grey shales, and are fine to medium grained, locally very coarse.

The type well established by Deegan & Scull (1977) represents a distal and somewhat atypical section. A more representative well from the Maureen Formation sandstones is UK well 16/29-4 (Fig. 45).

The formation pinches out distally and is replaced by the light grey marls and shales of the Våle Formation.

Basal stratotype:
The Maureen Formation rests on the Shetland Group.

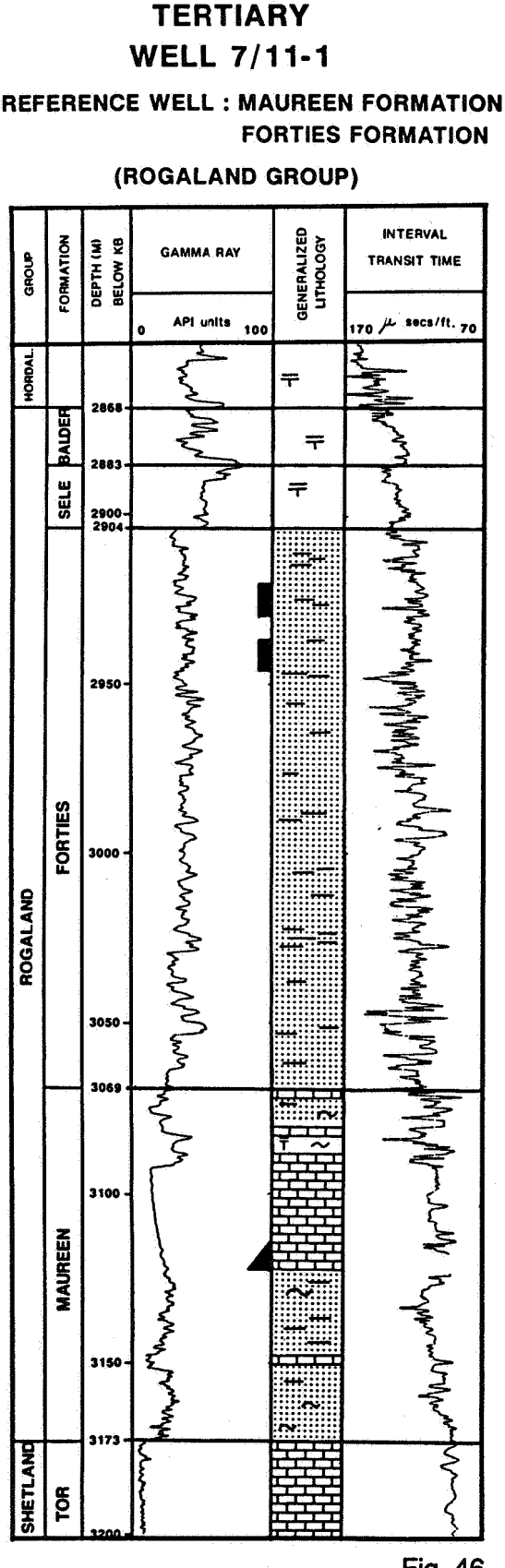
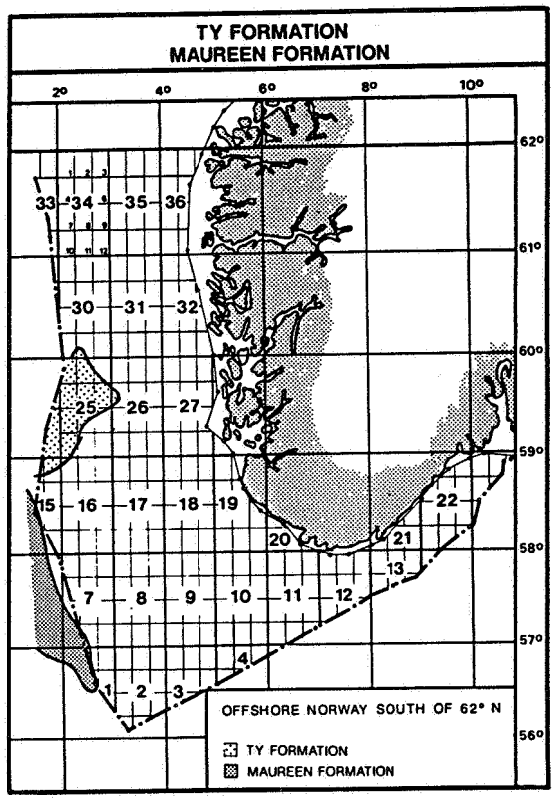
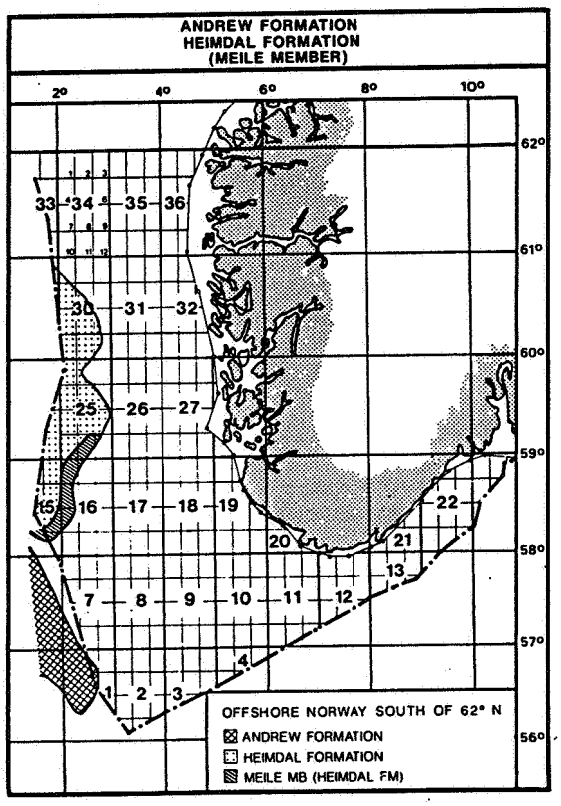


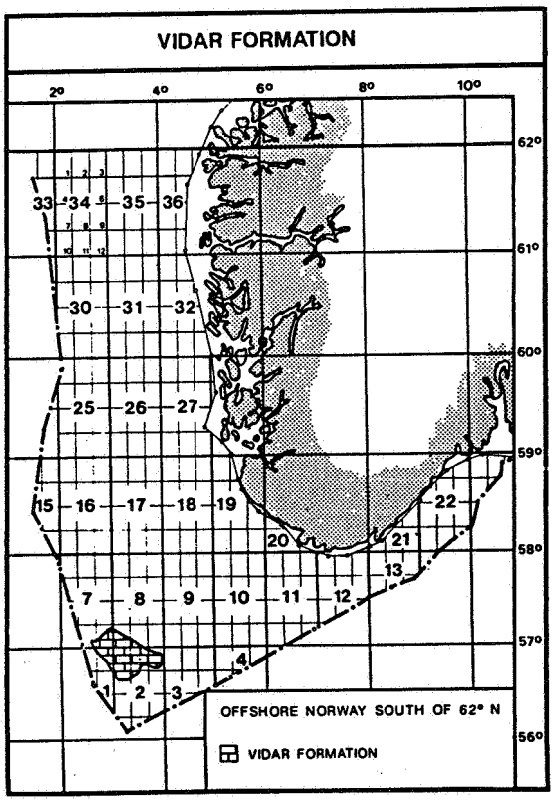
Fig. 46

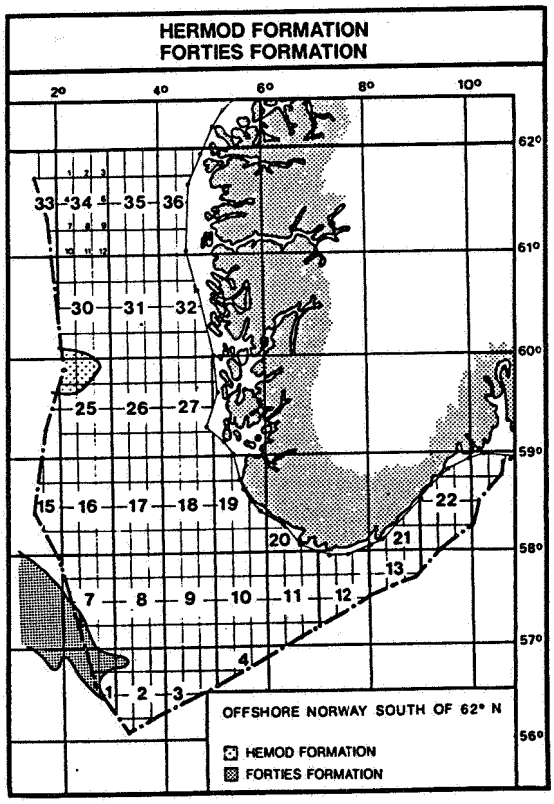
The change from the primarily calcareous deposits of the chalk facies, or the calcareous mudstones of the siliciclastic facies, to the heterogeneous sandstones of the Maureen Formation is generally shown as an increasing and more irregular gamma-ray response (Fig. 45) and a decreasing velocity (Figs. 44 and 46).

APPROXIMATE DISTRIBUTION OF PALEOCENE FORMATIONS









RS-0061

Fig. 47

TERTIARY

WELL UK 10/1-1A

TYPE WELL: TY FORMATION
REFERENCE WELL: HERMOD FORMATION

(ROGALAND GROUP)

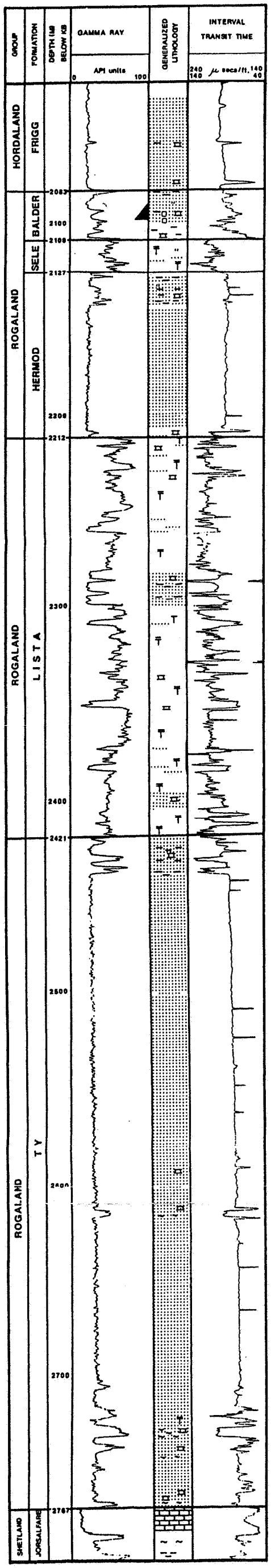


Fig. 48

TERTIARY

WELL 15/3-1

REFERENCE WELL: TY FORMATION

(ROGALAND GROUP)

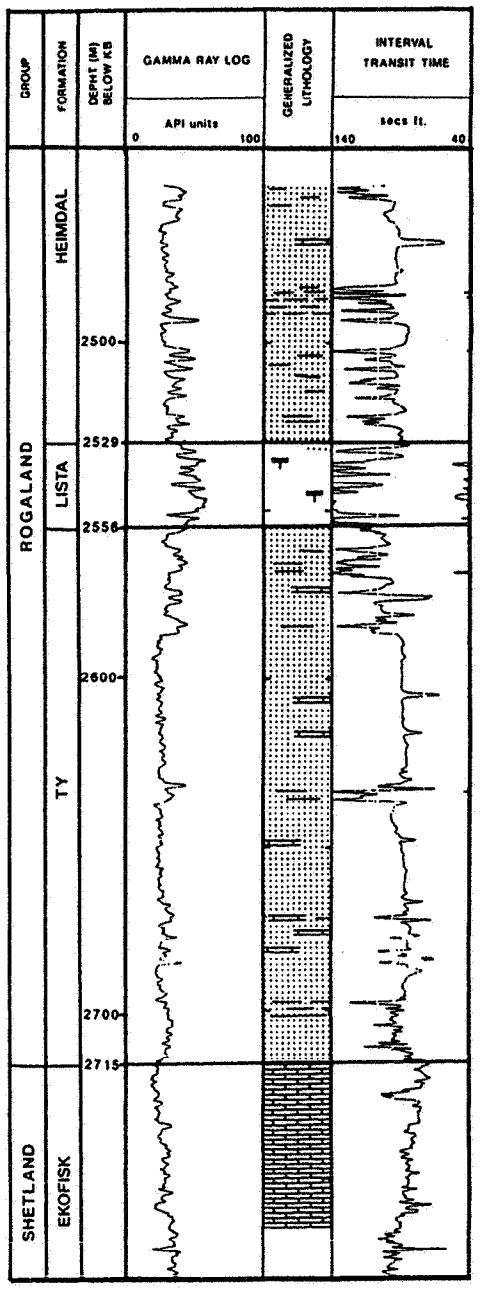


Fig. 49

Characteristics of the upper boundary:
The upper boundary is defined by the change from sandstones containing reworked limestone fragments and limestone beds, to the shales of the Lista Formation. The boundary is characterised by an upward increasing gamma-ray response (Fig. 45) and an overall decreasing velocity. Where the Andrew Formation rests on the Maureen Formation the transition is seen as an increase in gamma-ray readings and decrease in velocity (Fig. 44).

Distribution:
The coarse detrital facies of the Maureen Formation is developed in the central North Sea, in what is in general a lobe-shaped deposit trending from the East Shetland Platform southeast along the Central Trough. The formation thins towards the east and west, and grades into the Våle Formation. The Maureen Formation is not well developed in the Norwegian sector. Its approximate distribution on the Norwegian continental shelf is shown in Fig. 47.

Age:
Early Paleocene.

Depositional environment:
The Maureen Formation was deposited in an open marine environment dominated by sand influx from the northwest, together with local erosion of Danian and Cretaceous rocks.

Ty Formation (new) **(Tyformasjonen)**

Name:
Ty was a son of the Norse god Odin and was one of the 12 principal gods in Norse mythology.

Well type section:
UK well 10/1-1A from 2767 to 2421 m, coordinates N 59°50'10.50", E 02°00'33.60" (Fig. 48). No cores.

Well reference section:
Norwegian well 15/3-1 from 2715 to 2556 m, coordinates N 58°50'57.00", E 01°43'13.25" (Fig. 49). No cores.

Thickness:
The Ty Formation is 346 m thick in the type well. The formation has its depocenter west of the type well, and thins towards the east. It is 159 m thick in the reference well.

Lithology:
The Ty Formation consists of clean sandstones, generally massive and clear to light grey in colour. Distally the sandstones are interbedded with dark grey shales, but the sandstone bodies tend to be clean.

Basal stratotype:
The Ty Formation rests on the Shetland Group. The lower boundary represents a distinct change from calcareous sediments into clean sandstones with regular gamma-ray and velocity patterns. The log response changes from low gamma- ray readings and high velocity in the Shetland Group, to higher gamma-ray readings and lower velocity in the Ty Formation sandstones (Fig. 48). The boundary may be confused by interbedded shales in the Ty Formation, but the distinct drop in carbonate content distinguishes the formation from the underlying sediments.

Characteristics of the upper boundary:
The upper boundary is characterised by the transition into the shales of the Lista Formation with higher gamma-ray readings and lower velocity (Figs. 48 and 49). Where the Heimdal Formation overlies the Ty Formation, the boundary is recognised by the change to slightly more erratic log patterns. This boundary may be difficult to identify, but the two formations are normally separated by the Lista Formation.

Distribution:
The Ty Formation has been identified in the southern Viking Graben, especially in the northwestern part of quadrant 25 and the northernmost part of quadrant 15. Its approximate distribution on the Norwegian continental shelf is outlined in Fig. 47.

Age:
Early Paleocene.

Depositional environment:
The Ty Formation was deposited in a deep marine fan system which built out from the west.

Vidar Formation (Vidarformasjonen)

Name:
Vidar was a son of the Norse god Odin.

Well type section:
Norwegian well 2/1-4 from 3138 to 3075 m, coordinates N 56°54'39.82", E 03°04'02.25" (Fig. 50). No cores.

Well reference section:
Norwegian well 1/3-1 from 3147 to 3095 m, coordinates N 56° 51'21.00", E 02°51'05.00" (Fig. 41). No cores.

Thickness:
The Vidar Formation is 63 m thick in the type well and 52m thick in the reference well.

Lithology:
Homogenous limestone is the dominant lithology, but streaks of skeletal detritus and clasts of sandstone occur.

Basal stratotype:
The lower boundary represents a sharp transition from the claystones of the Lista Formation or the marl of the Våle Formation to the overlying limestones of the Vidar Formation. This is marked by a distinct decrease in gamma-ray readings and an increase in velocity (Figs. 41 and 50).

Characteristics of the upper boundary:
The upper boundary represents a transition to the claystones of the Lista Formation, characterised by a dramatic increase in gamma-ray readings and a decrease in velocity (Figs. 41 and 50).

Distribution:
The Vidar Formation is present in the Central Trough (Fig. 47). A similar limestone is found in well 16/1-1. This might be an equivalent to the Vidar Formation.

TERTIARY

WELL 2/1-4

REFERENCE WELL: VIDAR FORMATION

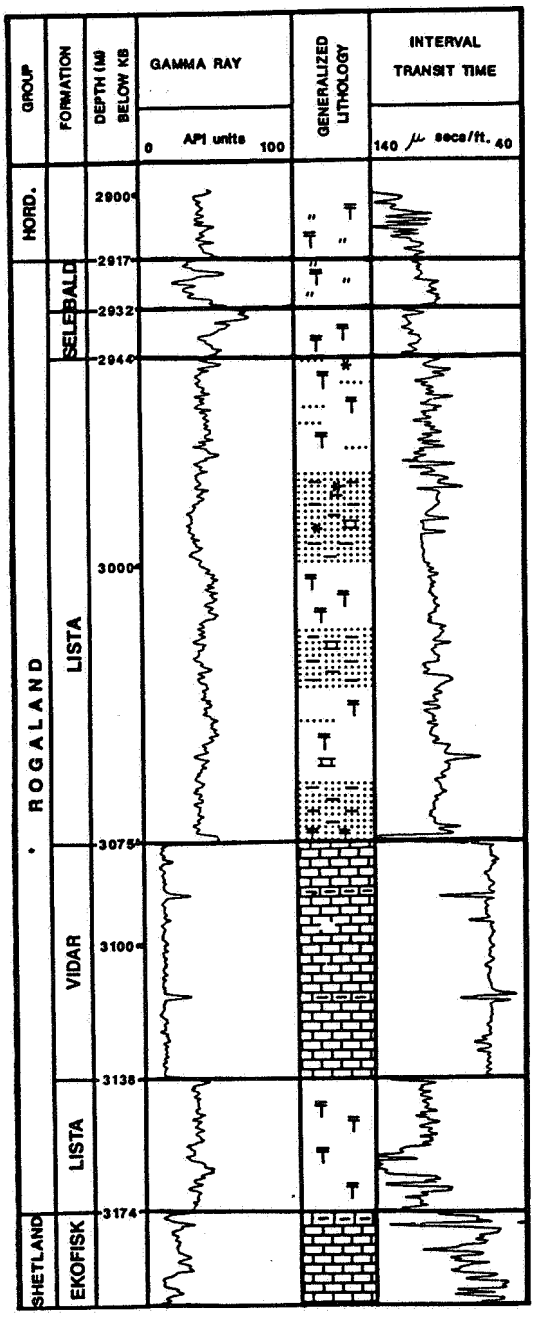


Fig. 50

Age:
Early Paleocene.

Depositional environment:
Presence of reworked Upper and Lower Cretaceous material indicates that the Vidar Formation represents reworked chalk from the Shetland Group chalk facies as well as reworked marls and claystones from the Cromer Knoll Group. Mass flows from each side of the Central Trough are the most probable transport mechanism for this reworked material.

Lista Formation (Listaformasjonen)

Name:
Named by Deegan & Scull (1977) after the Lista Spur structure (Lista Fault Block Complex on Fig. 3) in the Norwegian-Danish Basin.

Well type section:
Norwegian well 2/7-1 from 2918 to 2873 m, coordinates N 56°25'44.68", E 03°12'14.21" (Fig. 43). No cores.

Well reference sections:
Norwegian well 15/9-11 from 2386 to 2308 m, coordinates N 58°24'02.53", E 01°53'41.79" (Fig. 51). 10 m of cores from the lowermost part of the formation.

Norwegian well 16/8-1 from 1749 to 1708 m, coordinates N 58°27'24.80", E 02°25'56.80". No cores.

Thickness:
The Lista Formation is 45 m thick in the type well. In the Viking Graben its thickness varies between 100 and 200 m. There are two major depocentres, a northern one around the Beryl Field where thicknesses are up to 550 m, and a southern one at the northwestern edge of the Jæren High with a maximum thickness of approximately 350 m. Between these two depocentres the formation is thin (less than 50 m). The formation generally thins towards the highs where thicknesses are less than 50 m.

Lithology:
The Lista Formation consists of brown to grey-brown shales, which are generally non-tuffaceous and poorly laminated. Occasionally it contains stringers of limestone, dolomite and pyrite. Thin sandstone layers are locally developed. They are less than 5 m thick, and are most common in the lower part of the formation.

Basal stratotype:
In general, the lower boundary is marked by a transition into a lithology with higher gamma-ray and lower velocity readings than the underlying formations (Figs. 41, 48 and 50).

Characteristics of the upper boundary:
In areas where the Lista Formation is overlain by sandy Paleocene formations, the logs show the incoming of coarser clastics with a characteristic, blocky, gamma-ray and sonic log pattern (Figs. 48 and 52). Where the Sele Formation overlies the Lista Formation, the boundary is well defined on logs, without any distinct changes in lithology. The Sele Formation shows higher, and often smoother, gamma-ray readings and a very smooth, lower velocity pattern (Fig. 51). In some areas, both the Lista and Sele Formations contain sandstone beds, resulting in a poorly defined boundary based on log character. Where the Lista Formation is overlain by the Balder Formation, the boundary is defined by lower gamma-ray readings and higher velocity in the Balder Formation.

It is difficult to distinguish the Lista and Sele Formations in the Frigg area.

Distribution:
The Lista Formation is widespread in the Norwegian North Sea.

Age:
Late Paleocene.

Depositional environment:
The deposition of the Lista Formation shales took place in relatively deep water under low-energy conditions. Sandstone layers represent distal parts of sandy formations within the Rogaland Group.

Andrew Formation (Andrewformasjonen)

Name:
Named by Deegan & Scull (1977) after the Andrew Field in UK blocks 18/27 and 16/28.

Well type section:
UK well 14/25-1 from 2199 to 1897 m, coordinates N 58°01'11.40", E 00°00'56.40". No cores.

Well reference section:
UK well 21/10-1 from 2464 to 2370 m, coordinates N 57°43'50.37", E 00°58'29.19" (Fig. 44). No cores.

Thickness:
The Andrew Formation is 302 m thick in the type well and 94 m in the reference well, which represents the general thinning southwards from the East Shetland Platform. Close to the Fladen Ground Spur, the formation reaches thicknesses of approximately 1200 m.

Lithology:
The Andrew Formation consists of sandstones with claystone interbeds. The sandstones are generally very fine to medium grained and are composed of subangular to subrounded, clear to orange-stained quartz and feldspar grains. The sandstones are poorly sorted and often have a calcareous cement. Thin stringers of limestone occur.

Basal stratotype:
The Andrew Formation overlies the shales, marls and limestone interbeds of the Våle Formation, reflected by a higher gamma-ray level in the Andrew Formation. It may also rest on the Maureen Formation, and in that case the boundary is still seen as an increase in gamma-ray readings upwards into the less calcareous Andrew Formation (Fig. 44).

Characteristics of the upper boundary:
The Lista Formation usually overlies the Andrew Formation, and the boundary is characterised by higher gamma-ray readings and lower velocity upwards into the Lista Formation. Where the Forties Formation directly overlies the Andrew Formation, the boundary may be difficult to define, but the Forties Formation generally has a lower velocity than the Andrew Formation (Fig. 44). This boundary is very difficult to determine in the Norwegian sector.

Distribution:
The Andrew Formation was deposited as an elongated lobe trending southeastwards from the western part of the Fladen Ground Spur into the Central Trough. The formation is not well developed in the Norwegian sector, even though the distal parts of the lobe may be expected to occur. Its approximate distribution is shown in Fig. 47.

Age:
Paleocene.

Depositional environment:
The Andrew Formation was deposited as submarine fans.

Heimdal Formation (Heimdalformasjonen)

Name:
Named by Deegan & Scull (1977) after the Heimdal Field on the Norwegian continental shelf. Heimdal was a son of the Norse god Odin, and one of the principal gods in Norse mythology.

Well type section:
Norwegian well 25/4-1 from 2423 to 2067 m, coordinates N 59°34'27.30", E 02°13'22.60" (Fig. 52). 36 m of cores from the upper part of the formation, and 6.5 m from the lower part.

Well reference section:
Norwegian well 15/9-5 from 2684 to 2448 m, coordinates N 58°24'12.47", E 01°42'29.20" (Fig. 42). No cores.

Thickness:
The Heimdal Formation is 356 m thick in the type well and 236 m thick in the reference well. It thins rapidly east of these wells and south of well 15/9-5.

Lithology:
The formation is dominated by thick units of poorly sorted, fine to coarse grained, poorly cemented sandstones with variable amounts of mica, glauconite and detrital lignite. The sandstone units are interbedded with grey and black shales, limestones and sandy limestones. There is a wide range in number and thickness of interbedded lithologies. In general, the amount of carbonate increases towards the base of the formation.

Basal stratotype:
The lower boundary of the Heimdal Formation is usually marked by a transition from the Lista Formation into the interbedded sandstones of the Heimdal Formation. The log response is characterised by lower gamma-ray readings and higher velocities when entering the overlying Heimdal Formation (Fig. 52). The Heimdal Formation locally overlies the cleaner sandstones of the Ty Formation. In that case, the lower boundary is placed where clean sandstones give way to the interbedded sandstones of the Heimdal Formation. These formations are normally separated by the Lista Formation.

Characteristics of the upper boundary:
The upper boundary is usually defined by a transition into the Lista Formation shales and is then characterised by higher radioactivity and lower velocity (Fig. 52). Locally, the Heimdal Formation is overlain by the Hermod Formation, the upper boundary therefore being defined by a change into clean, "blocky" sand.

Distribution:
The sandstones of the Heimdal Formation are distributed in a broadly lobate pattern eastwards from the western margin of the Viking Graben. Their approximate distribution on the Norwegian continental shelf is shown in Fig. 47.

Age:
Paleocene.

Depositional environment:
In the westernmost areas (East Shetland Platform/Fladen Ground Spur), the Heimdal Formation was deposited on a shallow-marine shelf under high-energy conditions. In the Viking Graben, the formation was deposited as submarine fans derived from sand accumulations on the shallow shelf to the west. The shale layers consist partly of the fine fraction of the turbidity currents and of hemipelagic mud.

Remarks:
In a narrow belt extending from the eastern part of quadrant 15 (Fig. 47), the Heimdal Formation is developed as a clean sandstone without interbedded shales. This is described as the Meile member.

Meile member (new) (Meileleddet)

Name:
Meile was a son of the Norse god Odin. Little is told about him except that he was one of 3 messengers from the gods to save Balder from Hel (hell in Norse mythology).

Well reference section:
Norwegian well 15/9-11 from 2526 to 2386 m, coordinates N 58°24'02.53", E 01°53'41.79" (Fig. 51).

Thickness:
The Meile member is 140 m thick in the reference well. It has a relatively constant thickness.

Lithology:
The Meile member consists of clean, well-sorted sandstones, which are very fine to fine grained, friable to hard, and clear to white.

Basal stratotype:
The lower boundary of the Meile member is defined by the transition from the marly claystones of the Våle Formation. The gamma and sonic logs change from an erratic pattern in the Våle Formation to a smooth pattern with low gamma-ray readings when passing into the Meile member (Fig. 57). Where the Våle Formation is absent the Meile member rests directly on the calcareous deposits of the chalk facies of the Shetland Group. This boundary is characterised by upward increasing gamma-ray readings and decreasing velocity (Fig. 51).

Characteristics of the upper boundary:
The upper boundary is identified by a transition from clean sandstones into the shales of the Lista Formation. On the logs the upper boundary is seen as an increase in gamma-ray values and a change to a more erratic log pattern on both gamma and sonic logs (Fig. 51).

Distribution:
The Meile member is found in a narrow belt extending northnortheastwards from the eastern part of quadrant 15. Its approximate distribution on the Norwegian continental shelf is shown in Fig. 47.

Age:
Paleocene.

Depositional environment:
The clean sandstones of the Meile member may have been derived by winnowing of the Heimdal Formation sands by submarine currents acting along highs. The formation can also be interpreted in terms of high-density turbidites which source from well-sorted shelf sand.

Remarks:
The Meile member has earlier informally been referred to as the "Gamma sand on Sleipner". The Meile member is defined informally.

Sele Formation (Seleformasjonen)

Name:
Named by Deegan & Scull (1977) after the Sele High off the coast of southwest Norway.

Well type section:
UK well 21/10-1 from 2131 to 2100 m, coordinates N 57°43'50.37", E 00°58'29.19" (Fig. 44). No cores.

Well reference section:
Norwegian well 31/2-6 from 1225 to 1167 m, coordinates N 60°54'13.57", E 03°38'49.43" (Fig. 53). No cores.

Thickness:
The Sele Formation is 31 m thick in the type well and 58 m thick in the reference well. The thickness is variable, with a maximum of 80-90 m.

Lithology:
The Sele Formation consists of tuffaceous montmorillonite- rich shales and siltstones which are medium to dark grey or greenish-grey. They are finely laminated and carbonaceous, with minor interbeds of laminated sandstone which is frequently glauconitic.

Basal stratotype:
Where the Sele Formation directly overlies the Lista Formation, the boundary is defined by an upward increase in gamma-ray readings and a decrease in velocity (Figs. 44 and 58). Where the Sele Formation is situated directly above sandy formations, the boundary is defined by an upward increase in gamma-ray readings and a decrease in velocity (Figs. 46 and 48).

Characteristics of the upper boundary:
The upper boundary towards the Balder Formation is expressed by a reduced gamma-ray response and an increase in velocity (Fig. 44). It is difficult to distinguish the Lista and Sele Formations in the Frigg area.

Distribution:
The Sele Formation is widely distributed throughout the North Sea. It probably has several local depo-

TERTIARY

WELL 15/9-11

REFERENCE WELL: LISTA FORMATION
MEILE MEMBER, HEIMDAL FORMATION

(ROGALAND GROUP)

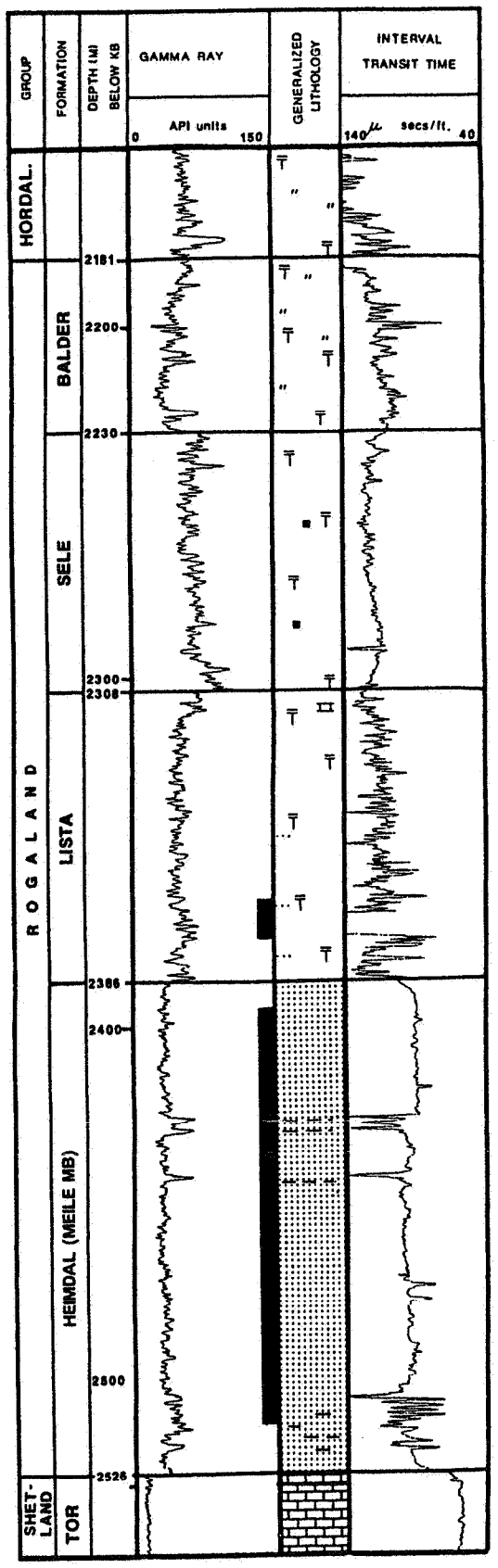


Fig. 51

TERTIARY

WELL 25/4-1

TYPE WELL : HEIMDAL FORMATION

(ROGALAND GROUP)

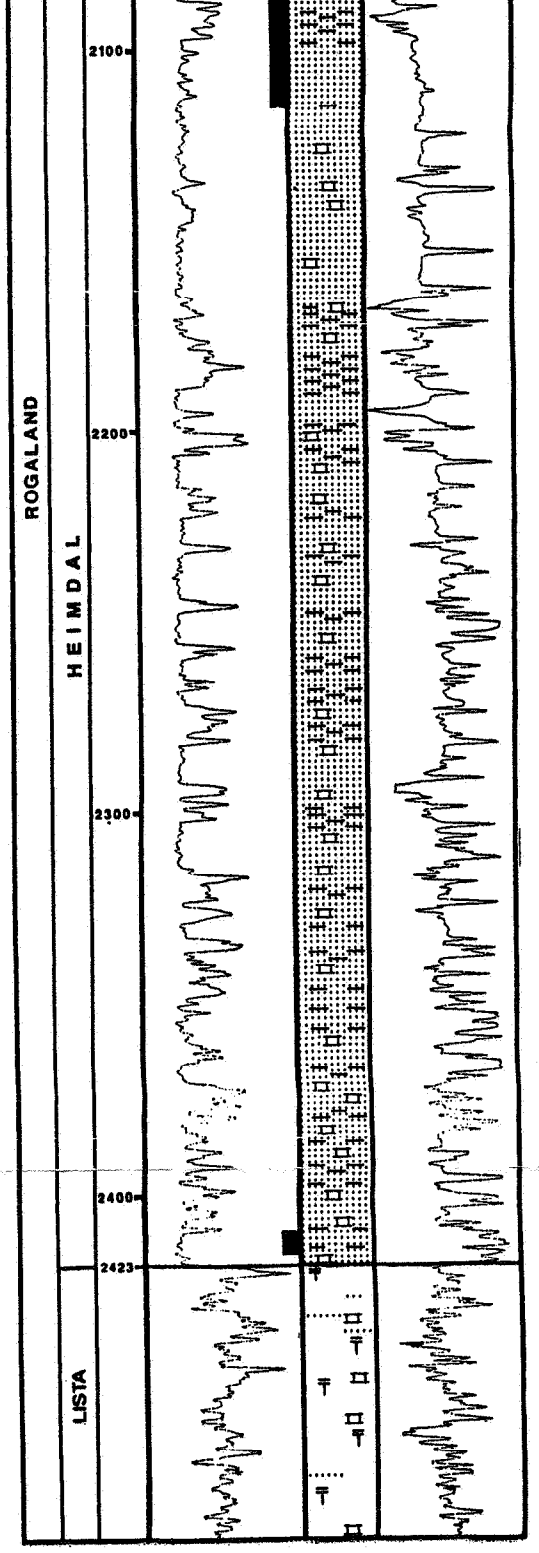


Fig. 52

TERTIARY
WELL 31/2-6

REFERENCE WELL: SELE FORMATION

(ROGALAND GROUP)

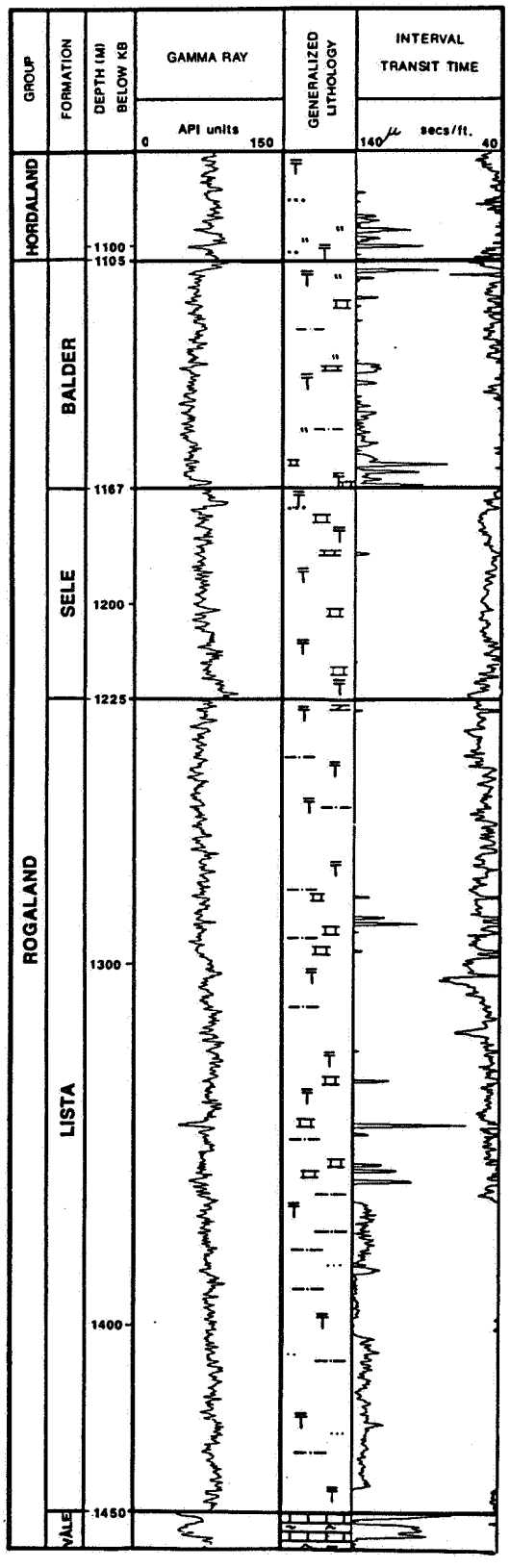


Fig. 53

TERTIARY
WELL 9/11-1

TYPE WELL: FISKEBANK FORMATION

(ROGALAND GROUP)

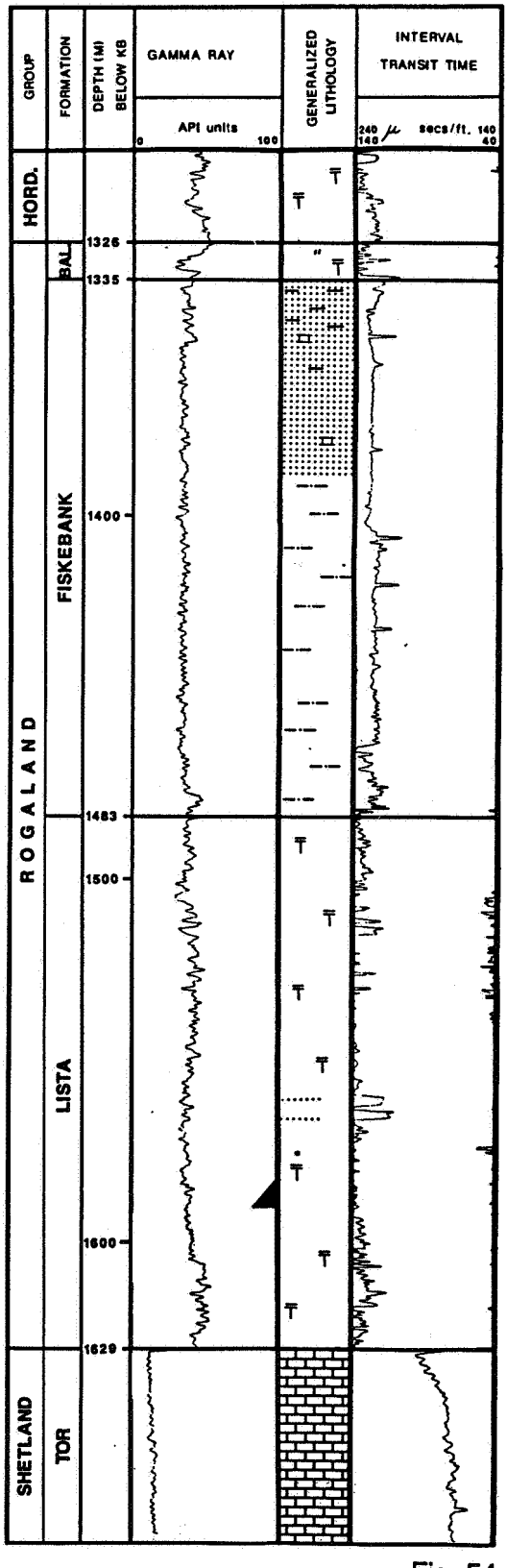


Fig. 54

centres on and near the flanks of the Viking Graben and the Central Trough. North of 60° N, the Sele Formation has only been penetrated in an area off Sognefjord. It is not found west of there, into the Viking Graben, where the Lista Formation alone is present. It does not occur on the Tampen Spur.

Age:
Late Paleocene.

Depositional environment:
The Sele Formation was deposited in a deep marine setting similar to that of the Lista Formation.

Fiskebank Formation (Fiskebankformasjonen)
Name:
From the Fiskebank (Fisher Bank), off the shore of southern Norway. Named by Deegan & Scull (1977).

Well type section:
Norwegian well 9/11-1 from 1483 to 1335 m, coordinates N 57°00'41.40", E 04°00'33.52" (Fig. 54). No cores.

Well reference section:
Norwegian well 8/9-1 from 1399 to 1307 m, coordinates N 57°26'27.28", E 03°51'03.48" (Fig. 55). No cores.

Thickness:
The formation is 148 m thick in the type well and 92 m thick in the reference well.

Lithology:
In the type section the major lithology is very fine grained, well sorted, slightly silty sandstone, which occasionally has calcareous cement.

Basal stratotype:
The basal contact of the Fiskebank Formation is defined by the boundary between the shales of the Lista Formation and the coarser sediments of the Fiskebank Formation. The difference between the two formations is not well defined on the logs. The boundary is placed where the gamma-ray readings decrease and the velocity increases somewhat upwards into the Fiskebank Formation (Figs. 54 and 55).

Characteristics of the upper boundary:
The Fiskebank Formation is overlain by the shales of the Balder Formation. The boundary is generally seen as an upward decrease in gamma-ray response and an increase in velocity (Fig. 55).

Distribution:
The formation is encountered in the Norwegian-Danish Basin.

Age:
Late Paleocene.

Depositional environment:
The formation is probably a basin-margin deposit, and appears to be mostly time-equivalent with the Sele Formation.

TERTIARY

WELL 8/9-1

REFERENCE WELL:
FISKEBANK FORMATION

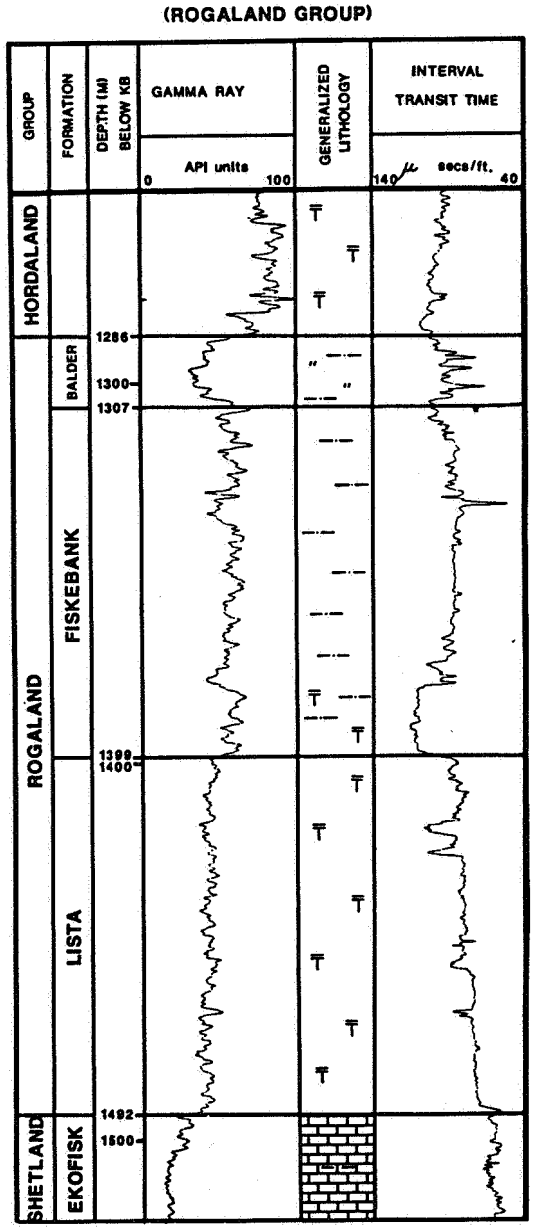


Fig. 55

Forties Formation (Fortiesformasjonen)
Name:
Named by Deegan & Scull (1977) from the Forties Field in UK block 21/10.

Well type section:
UK well 21/10-1 from 2370 to 2131 m, coordinates N 57°43'50.37", E 00°58'29.19" (Fig. 44). Cores.

Well reference section:
Norwegian well 7/11-1 from 3069 to 2904 m, coordinates N 57°04'15.60", E 02°26'24.40" (Fig. 46). No cores.

Thickness:
The Forties Formation is 239 m thick in the type well and 165 m thick in the reference well. The thickness decreases eastwards and southwards into the Norwegian sector.

Lithology:
The formation typically consists of interbedded sandstones, siltstones and claystones, becoming predominantly sandy higher in the section. The sand is fine to coarse grained, poorly to moderately sorted and contains minor amounts of lignite, pyrite, glauconite and mica. The sands encountered in the Norwegian sector were deposited distally in a lobe, and consist of very fine to fine, angular to subangular grains often with mica and a calcareous cement.

Basal stratotype:
Where the Forties Formation rests on the Andrew Formation Deegan & Scull 1977) its lower boundary is defined by a ecrease in velocity into the sandstones of the Forties ormation (Fig. 44). This boundary may be difficult to define on logs. Eastwards the Forties Formation overlies the argillaceous Lista Formation, and the boundary is haracterised by decreasing gamma-ray and increasing elocity readings into the Forties Formation.

Characteristics of the upper boundary:
The upper boundary is defined as the break between the Forties sandstones and the shales of the more or less time- equivalent Sele Formation. The log response changes from low gamma-ray readings and high velocity to higher gammaray readings and lower velocity in the Sele Formation (Fig. 44). As the Forties Formation passes into shales eastwards it may be enveloped by the Sele Formation.

Distribution:
The Forties Formation extends as a large lobe from the area south of the Halibut Horst to the northwestern part of the Central Trough. Its approximate distribution on the Norwegian continental shelf is shown in Fig. 47.

Age:
Late Paleocene.

Depositional environment:
The Forties Formation was deposited as submarine fans.

Hermod Formation (new) **(Hermodformasjonen)**
Name:
Hermod was a son of Odin, and was known as "the quick one".

Well type section:
Norwegian well 25/2-6 from 2361 to 2221 m, coordinates N 59°45'33.55", E 02°33'05.96" (Fig. 56). No cores.

Well reference section:
UK well 10/1-1A from 2212 to 2127 m, coordinates N 59°50'10.50", E 02°00'33.60" (Fig. 48). No cores.

TERTIARY

WELL 25/2-6

TYPE WELL: HERMOD FORMATION

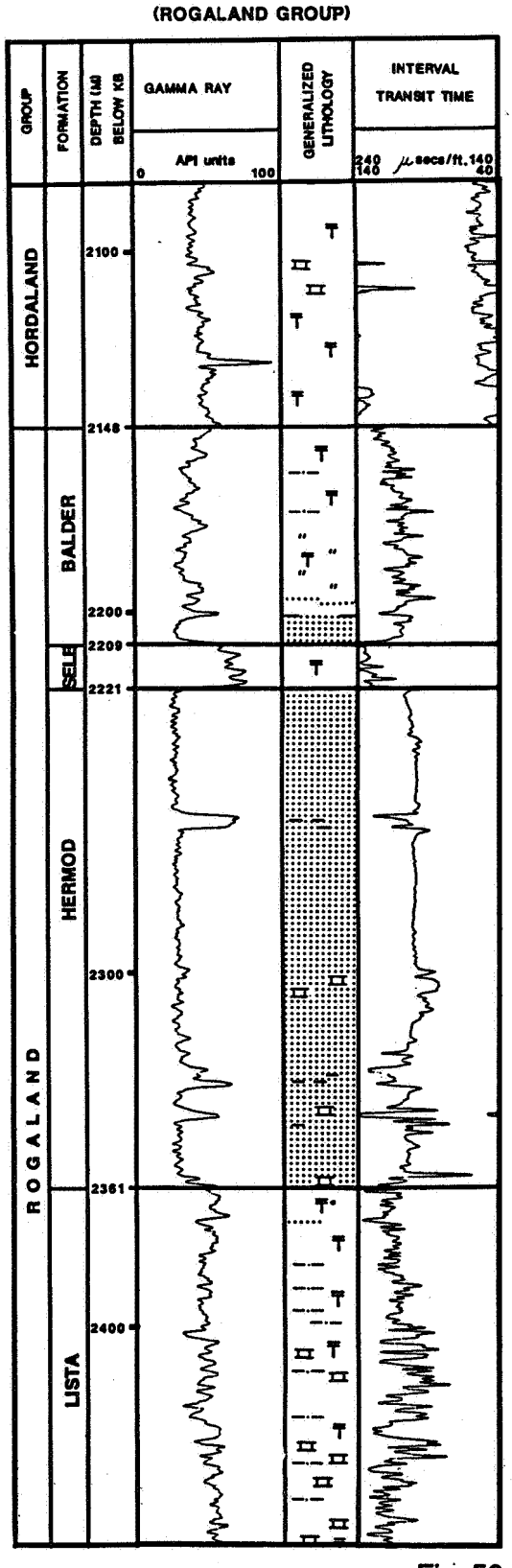


Fig. 56

Thickness:
The Hermod Formation is 140 m thick in the type well and 85 m thick in the reference well. It thickens towards the centre of its distribution area (Fig. 47).

Lithology:
The Hermod Formation consists of clean sandstones which are very fine to fine grained and clear to grey. The formation is to a limited extent interbedded with dark shales.

Basal stratotype:
The lower boundary of the Hermod Formation is identified by a transition from the shales of the Lista Formation. This boundary essentially represents the boundary between the Lista and Sele Formations, and the Hermod Formation may rest on shales of the Sele Formation. The log response in both cases is a sharp transition from the high gamma-ray readings and low velocity of the shales to the low and regular gammaray readings and higher velocity of the Hermod Formation sandstones (Fig 56). Where the Hermod Formation rests directly on the Heimdal Formation the boundary may be indistinct, but the log response changes from an erratic pattern in the Heimdal Formation to a smoother one, reflecting the more homogeneous sandstones of the Hermod Formation.

Characteristics of the upper boundary:
The Hermod Formation is overlain by the time-equivalent Sele Formation, and the boundary is an abrupt change from sandstones to dark shales. The gamma-ray response changes from low readings in the sandstones to significantly higher ones in the Sele Formation, and the velocity is lower in the Sele Formation (Fig. 56).

Distribution:
The Hermod Formation is found in the South Viking Graben, in the northwestern part of quadrant 25. It may also be found in other parts of the South Viking Graben. The main distribution area is outlined in Fig. 47.

Age:
Late Paleocene.

Depositional environment:
The Hermod Formation was deposited in submarine fan systems connected with the deltaic Moray Group in the west.

Balder Formation (Balderformasjonen)

Name:
Named by Deegan & Scull (1977) from the Balder Field in Norwegian blocks 25/10 and 25/11. Balder was a son of Odin, and one of the most famous gods in Norse mythology.

Well type section:
Norwegian well 25/11-1 from 1780 to 1705 m, coordinates N 59°10'57.39", E 02°24'28.18" (Fig. 57). Cores.

Well reference sections:
Norwegian well 30/2-1 from 1993 to 1917 m, coordinates N 60°52'05.42", E 02°38'49.16". Cores.

TERTIARY

WELL: 25/11-1

TYPE WELL: BALDER FORMATION

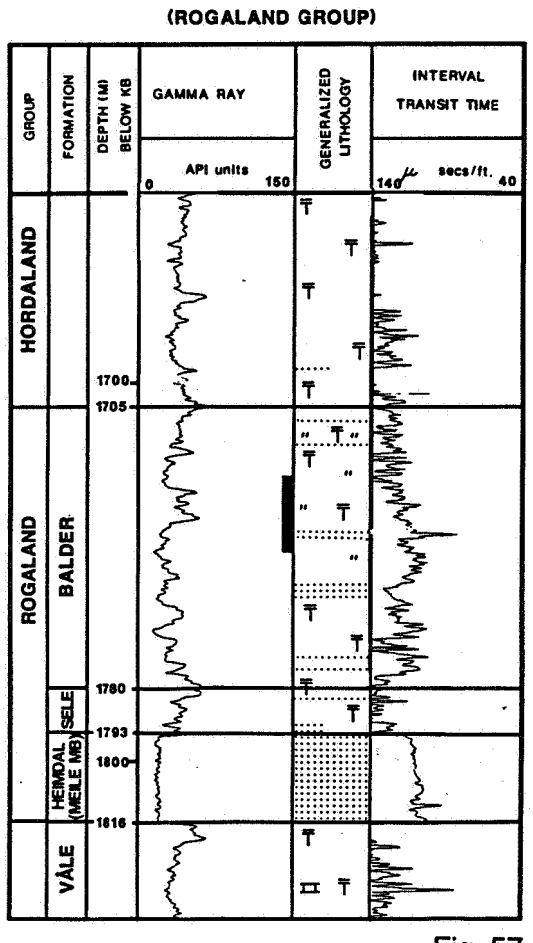


Fig. 57

Norwegian well 15/9-17 from 2253 to 2204 m, coordinates N 58°26'44.19", E 01°56'53.58" (Fig. 58). No cores.

Thickness:
The Balder Formation is 75 m thick in the type well. Generally its thickness varies from less than 20 m to more than 100 m. Normally it is between 40 and 60 m.

Lithology:
The Balder Formation is composed of laminated varicoloured, fissile shales with interbedded grey, green and buff, often pyritic, sandy tuffs and occasional stringers of limestone, dolomite and siderite. Sandstones are locally present, as shown in the type well (Fig. 57).

Basal stratotype:
The lower boundary to the Sele or Lista Formations is generally identified on logs as an upward decrease in gamma-ray response and an increase in velocity (Figs. 56 - 58). This probably reflects the increase in the tuffaceous component of the Balder Formation.

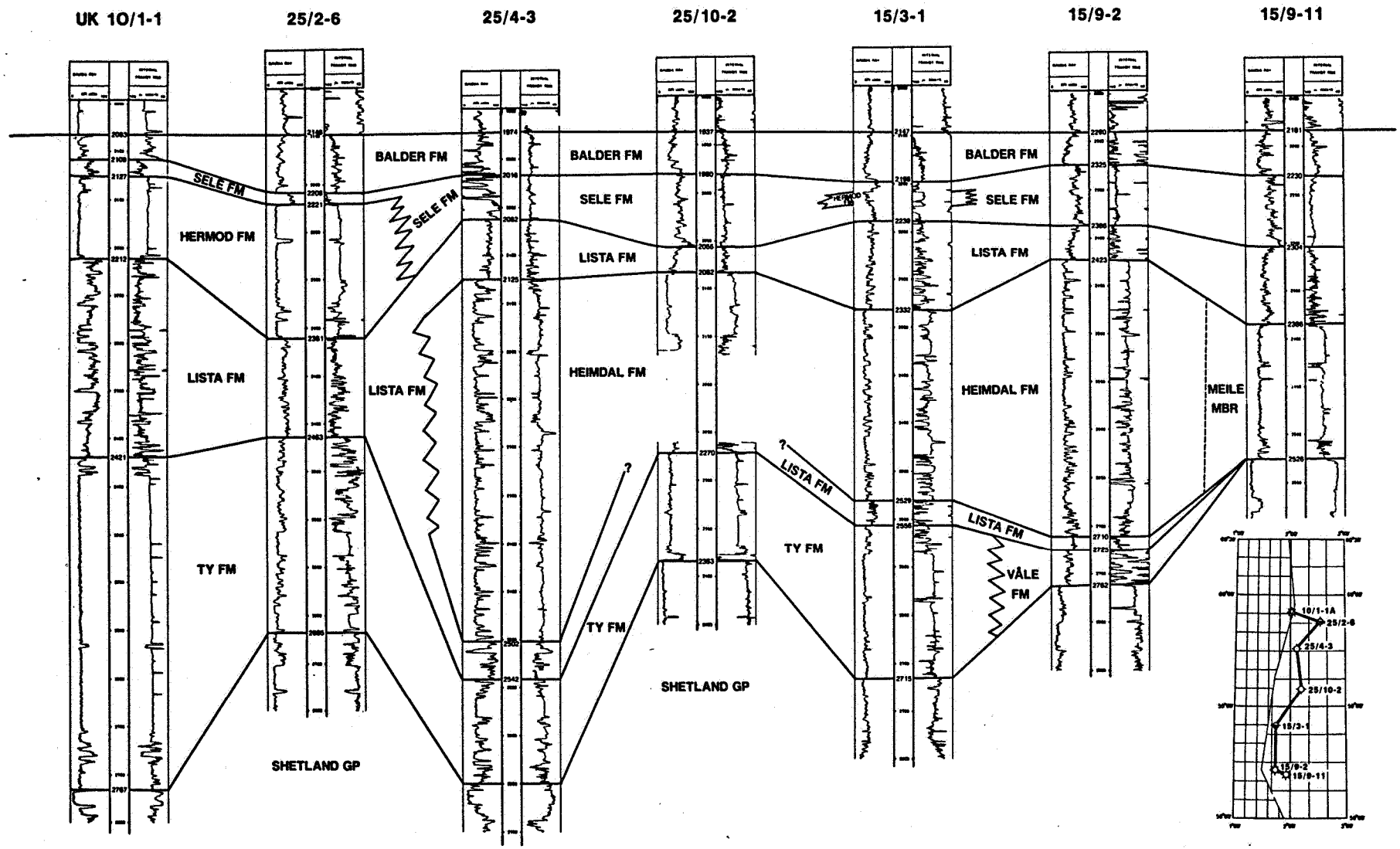


Fig. 59 **Well correlation for some Paleocene wells.**

TERTIARY

WELL 15/9-17

REFERENCE WELL: BALDER FORMATION

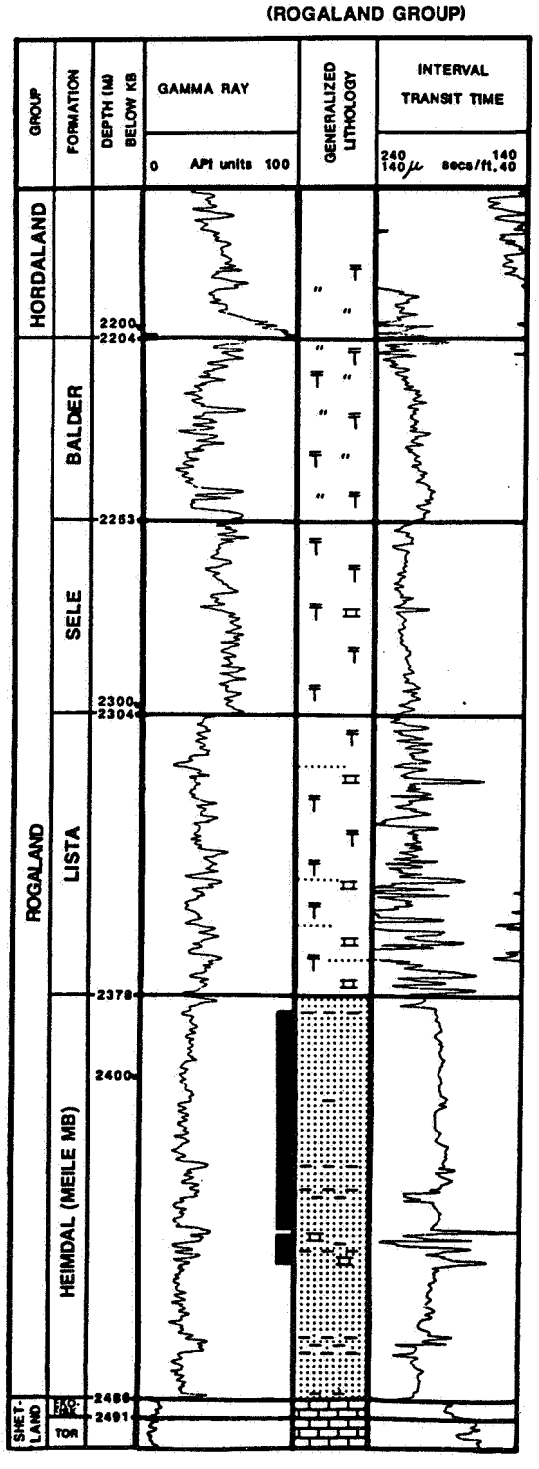


Fig. 58

Characteristics of the upper boundary:
The upper boundary is defined at the transition from the laminated shales of the Balder Formation to the nonlaminated, often glauconitic, occasionally reddish, overlying sediments. On logs this can normally be seen as an upward reduction in gamma-ray response and a decrease in velocity Fig. 56). When the Balder Formation is overlain by the Frigg Formation the boundary is seen as a decrease in gamma-ray response and an increase in velocity into the Frigg Formation (Fig. 62). The log response of the Balder Formation is often described as bell-shaped (Fig. 58).

Distribution:
The Balder Formation is distributed over most of the North Sea, and may correspond in part to the Mo Clay Formation in Denmark.

Age:
Paleocene - Early Eocene

Depositional environment:
The Balder Formation was deposited in a deep marine setting, mainly as hemipelagic sediments. Some turbiditic sands occur locally. There was probably more than one volcanic source.

Hordaland Group (Hordalandsgruppen)

Name:
The group was named by Deegan and Scull (1977) after the county of Hordaland in Norway.

Type area:
The type area is the North Sea Tertiary Basin. Typical sections through the group are shown in Norwegian wells 2/2-1 (Fig. 60) and 24/12-1 (Fig. 61). Fig. 69 shows a seismic section through the group in the Central Trough area. The lithostratigraphy is shown in Fig. 40.

Thickness:
The group has a thickness of 1060 m in well 2/2-1 and 1365 m in well 24/12-1. Its average thickness is around 1100-1200 m in the central and southern part of the Viking Grabens, but in the northern Viking Graben the group only reaches a thickness of a few hundred metres. Maximum thicknesses in the central and southern part of the Viking Graben are approximately 1300 m and 1400 m, respectively. The thickness decreases towards the basin margins.

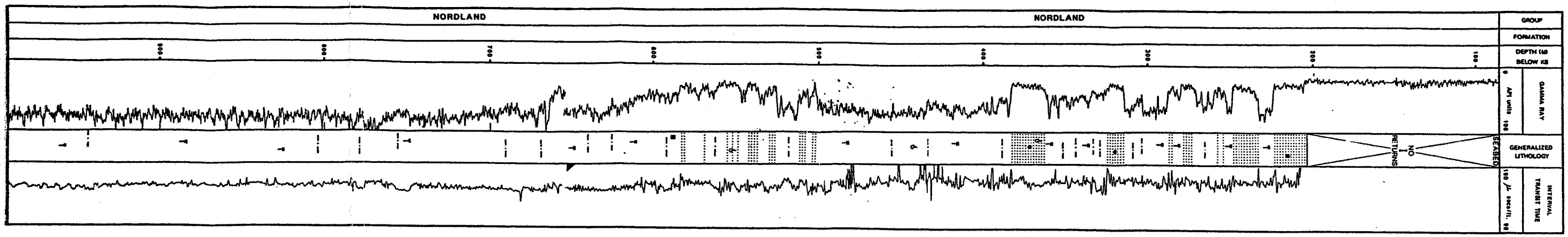
Lithology:
The group consists of marine claystones with minor sandstones. The claystones are normally light grey to brown, fissile and fossiliferous. Red and green claystones sometimes occur at the base. Thin limestones and streaks of dolomite are present. Sandstones are developed at various levels in the group. These are generally very fine to medium grained, and are often interbedded with claystones.

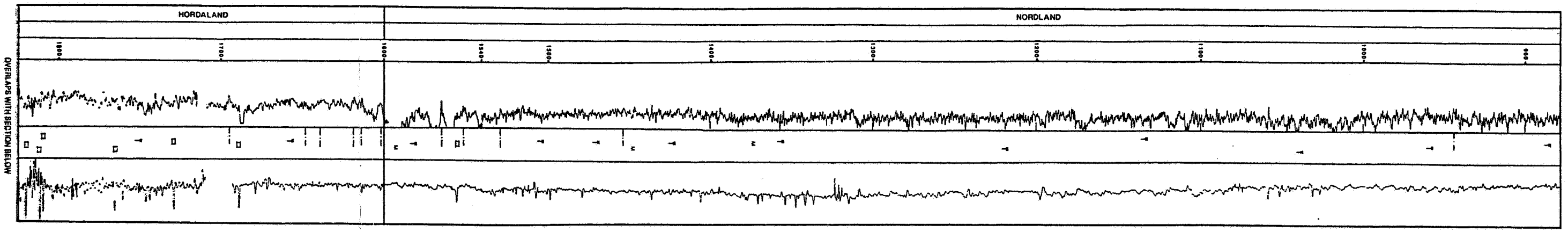
Basal stratotype:
The lower boundary shows an increase in gamma-ray intensity and a decrease in velocity from the laminated tuffs of the Balder Formation into the claystones of the Hordaland Group (Fig. 56). Where the Frigg Formation is present at the base of the Hordaland Group the lower boundary normally shows a decrease in gamma-ray response and an increase in velocity from the Balder Formation into the Frigg Formation (Fig. 62).

WELL 2/2-1

TYPE WELL: VADE FORMATION

(NORDLAND GROUP)
(HORDALAND GROUP)





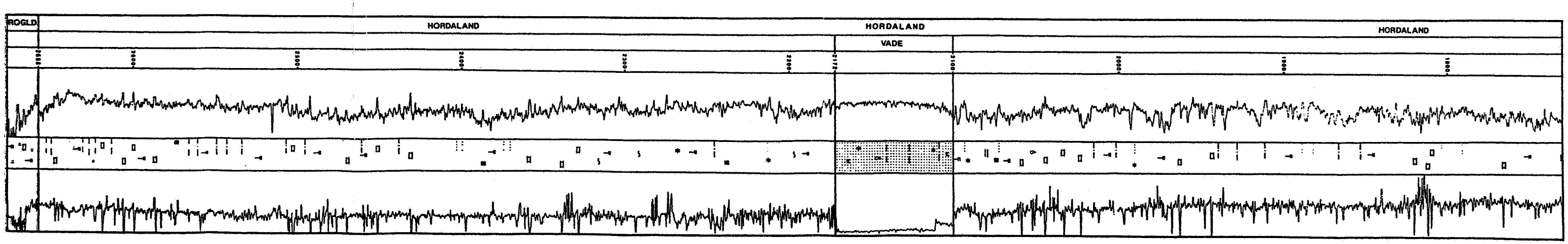


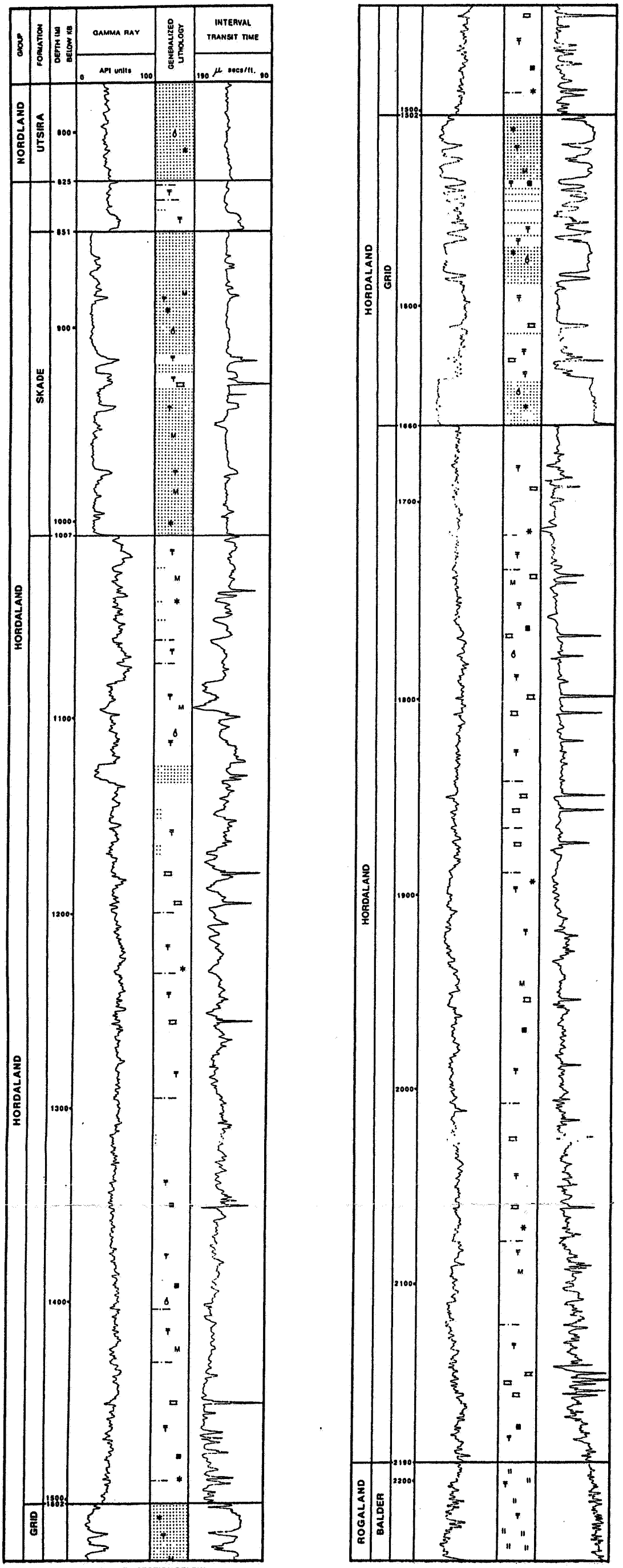
Fig. 60

TERTIARY

WELL 24/12-1

TYPE WELL: SKADE FORMATION
REFERENCE WELL: GRID FORMATION

(HORDALAND GROUP)



OVERLAPS WITH SECTION BELOW

Fig. 61

Characteristics of the upper boundary:
The upper boundary is placed at the contact with undifferentiated grey to grey-brown claystones of the Nordland Group or sandstones of the Utsira Formation. It represents an unconformity of Early to Middle Miocene age, which may be difficult to identify in some wells.

In the Central Trough, a zone occurs which has high gamma-ray readings and usually a slightly lower velocity than the underlying and overlying claystones. The upper boundary of the Hordaland Group is placed at the base of this zone (Fig. 60). On seismic sections, the sediments below this horizon normally have a distorted signature whilst those above it have a smoother one. The boundary shows a very small angular unconformity; it is not clear whether a small hiatus is present. In the Viking Graben, the upper boundary is normally the base of the sandy Utsira Formation. The contact is then marked by an upward decrease in gamma-ray intensity (Fig. 70). Where the basal part of the Nordland Group is developed as claystone the boundary is placed at log breaks associated with a change in claystone colour.

Distribution:
The group is distributed over most of the North Sea Tertiary Basin. It is incomplete at the basin margins, owing to erosion or non-deposition. The Hordaland Group is also present on the Mid Norwegian Shelf (Dalland et al. 1988).

Age:
The group is of Eocene to Early Miocene age. Datings in wells 2/2-1, 2/2-2 and 2/2-3 indicate that the uppermost part of the group may be of Middle Miocene age in the Central Trough.

Depositional environment:
Open marine.

Subdivision:
The Frigg Formation was formally erected by Deegan & Scull (1977). Three additional sandstone formations are now recognised in the Hordaland Group, and are described here. Claystone intervals between the sandstones are not defined as formations and remain as unnamed units of the Hordaland Group. The Grid and Skade Formations are widely distributed in the Viking Graben area, whereas the Vade Formation, which is found in the Central Trough, has a limited distribution. Other sandstones, which cannot be assigned to the formations described here, are found in the Norwegian part of the North Sea Basin. Subregional work and further information from wells may enable more units to be formally erected in the future.

Remarks:
The boundary between the Hordaland and Nordland Groups in the Central Trough area may be slightly different from the position selected in well 2/7-1 by Deegan & Scull (1977). The boundary is difficult to identify in that well, owing to the borehole being damaged directly below the casing which is placed at 1591 m (5221 ft).

Frigg Formation (Friggformasjonen)

Name:
Named by Deegan & Scull (1977) after a Norse goddess, the wife of Odin.

Well type section:
Norwegian well 25/1-1 from 2115 to 1836 m, coordinates N 59°53'17.40", E 02°04'42.70" (Fig. 62). 42 m of cores (1868-1910 m).

Well reference section:
Norwegian well 30/7-6 from 1923 to 1783 m, coordinates N 60°29'29.82", E 02°03'26.14" (Fig. 63). No cores.

Thickness:
The formation has a thickness of 279 m in the type well and 140 m in the reference well. A depocentre with a maximum thickness of approximately 300 m lies in Norwegian block 25/1.

Lithology:
The formation consists of sandstones with some lenses and streaks of silty claystone. The sandstones are poorly consolidated, light brown to buff, micaceous and carbonaceous, and very fine to medium, occasionally coarse grained. Some layers have a calcareous cement. Traces of glauconite are present. The silty claystones are green to grey and carbonaceous.

Basal stratotype:
The lower boundary normally shows a decrease in gamma-ray intensity and an increase in velocity from the Balder Formation into the Frigg Formation (Fig. 62).

Characteristics of the upper boundary:
The top of the formation is placed where the sandstones give way to light grey to brown, occasionally green claystone of the Hordaland Group. The boundary is seen on logs as an increase in gamma-ray response and a decrease in velocity (Fig. 62).

Distribution:
The Frigg Formation is found in the southwestern part of quadrant 30, the northwestern part of quadrant 25, and in adjacent areas in the UK sector. The Frigg sands of the Beryl and Bruce Fields just extend into the Norwegian sector at about 59°30'N.

Age:
Early Eocene.

Depositional environment:
The Frigg Formation was deposited as submarine fans, by gravity flows. The mode of deposition led to the formation varying in thickness over short distances. The source was the East Shetland Platform to the west.

Grid Formation (new) (Gridformasjonen)

Name:
Named after a female giant in Norse mythology, who was one of the wives of Odin.

Well type section:
Norwegian well 15/3-3 from 1840 to 1470 m, coord-

TERTIARY

WELL 25/1-1

TYPE WELL: FRIGG FORMATION

(HORDALAND GROUP)

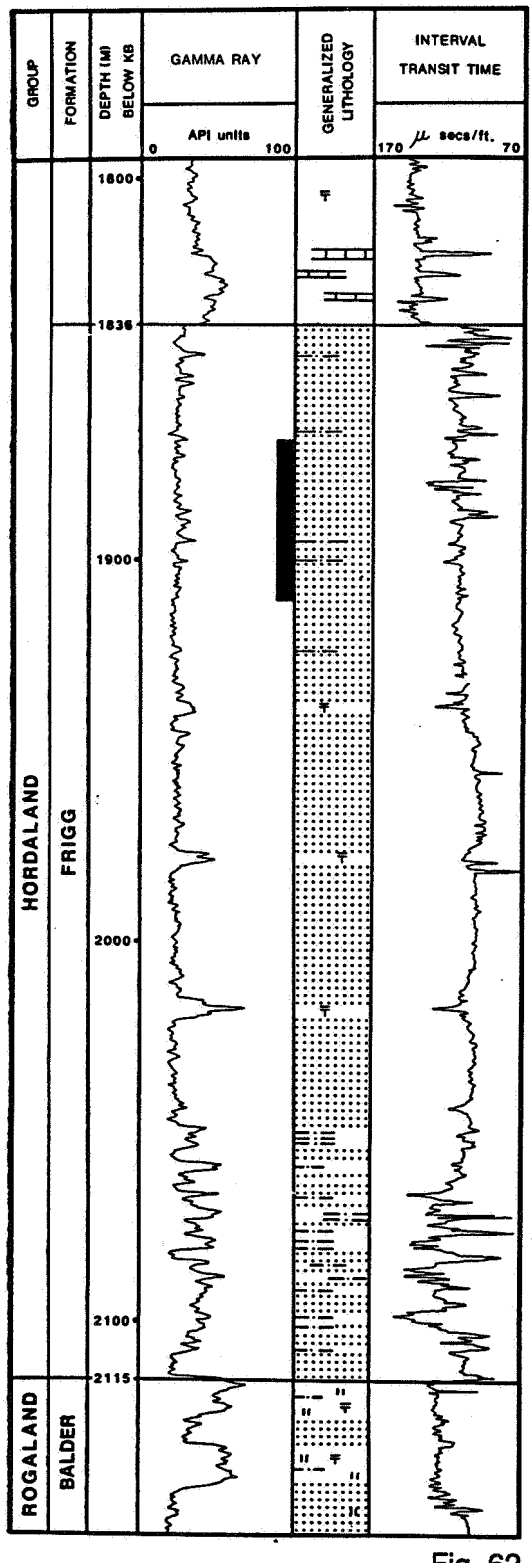


Fig. 62

TERTIARY

WELL 30/7-6

REFERENCE WELL: FRIGG FORMATION

(HORDALAND GROUP)

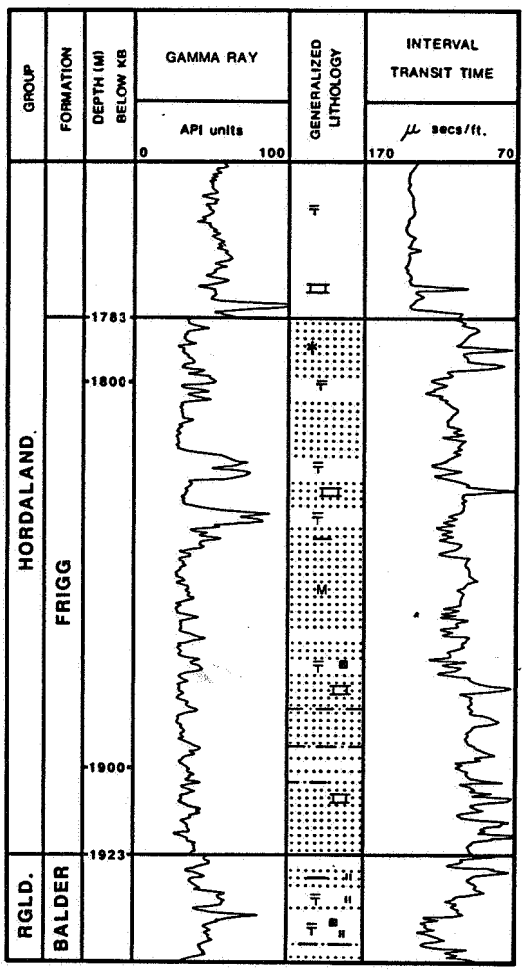


Fig. 63

inates N 58°52'31.25", E 01°46'46.24" (Fig. 64). No cores.

Well reference sections:
Norwegian well 24/12-1 from 1660 to 1502 m, coordinates N 59°02'29.80", E 01°52'57.93" (Fig. 61). No cores.

Norwegian well 24/12-2 from 1397 to 1282 m, coordinates N 59°12'00.75", E 01°52'53.34" (Fig. 65). No cores.

Thickness:
wells 24/12-1 and 24/12-2 it is 158 m and 115 m, respectively.

Lithology:
The formation consists of sandstones with interbeds of claystone and siltstone. The sandstones often have a massive, "blocky", appearance as illustrated by type well 15/3-3 (Fig. 64). Individual sandstone beds show little or no evidence of fining-upwards or coarsening-

TERTIARY
WELL 15/3-3

TYPE WELL: GRID FORMATION

(HORDALAND GROUP)

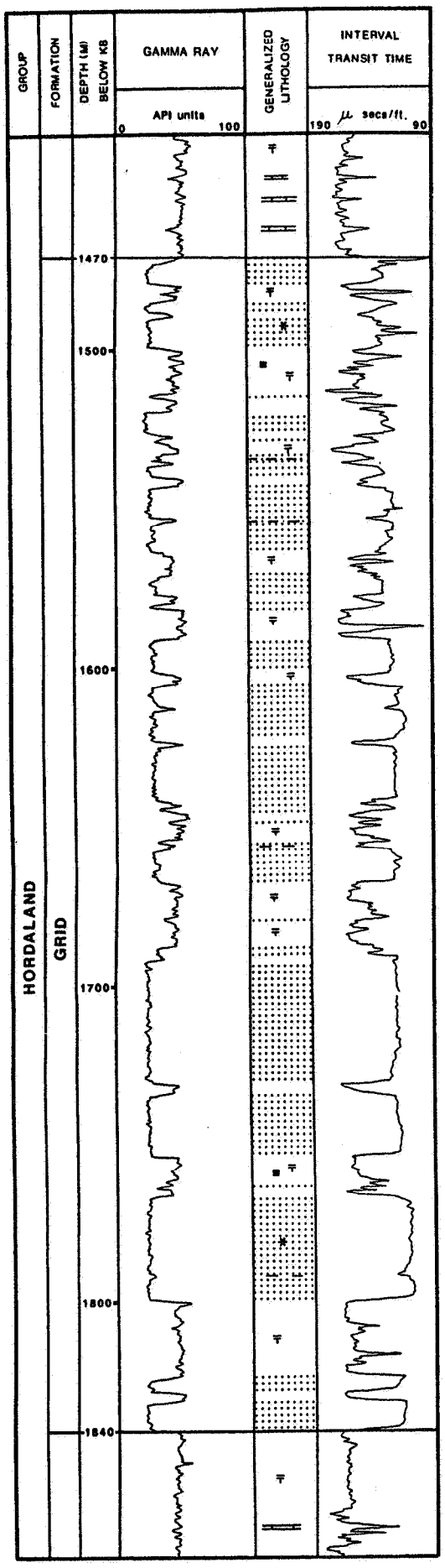


Fig. 64

TERTIARY
WELL 24/12-2

REFERENCE WELL: GRID FORMATION

(HORDALAND GROUP)

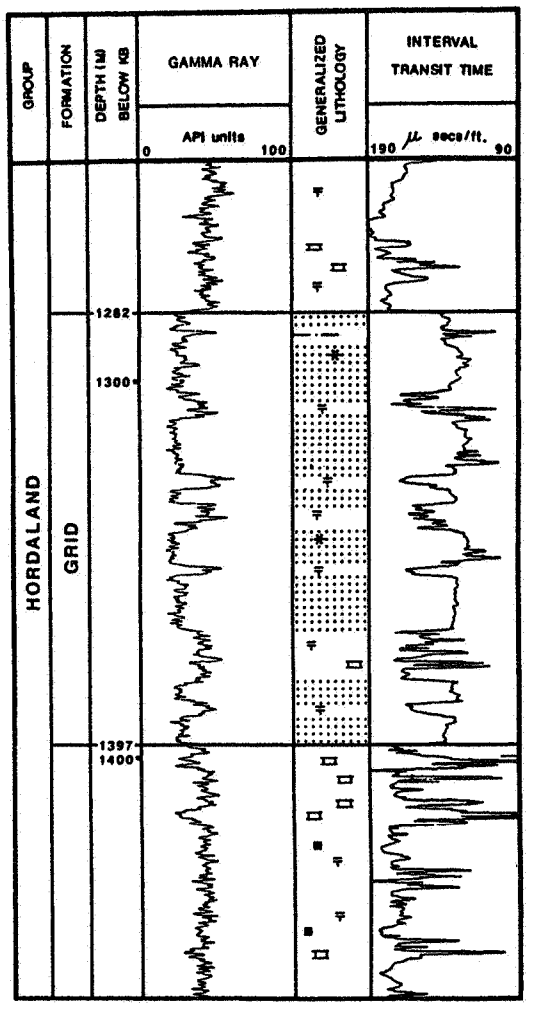


Fig. 65

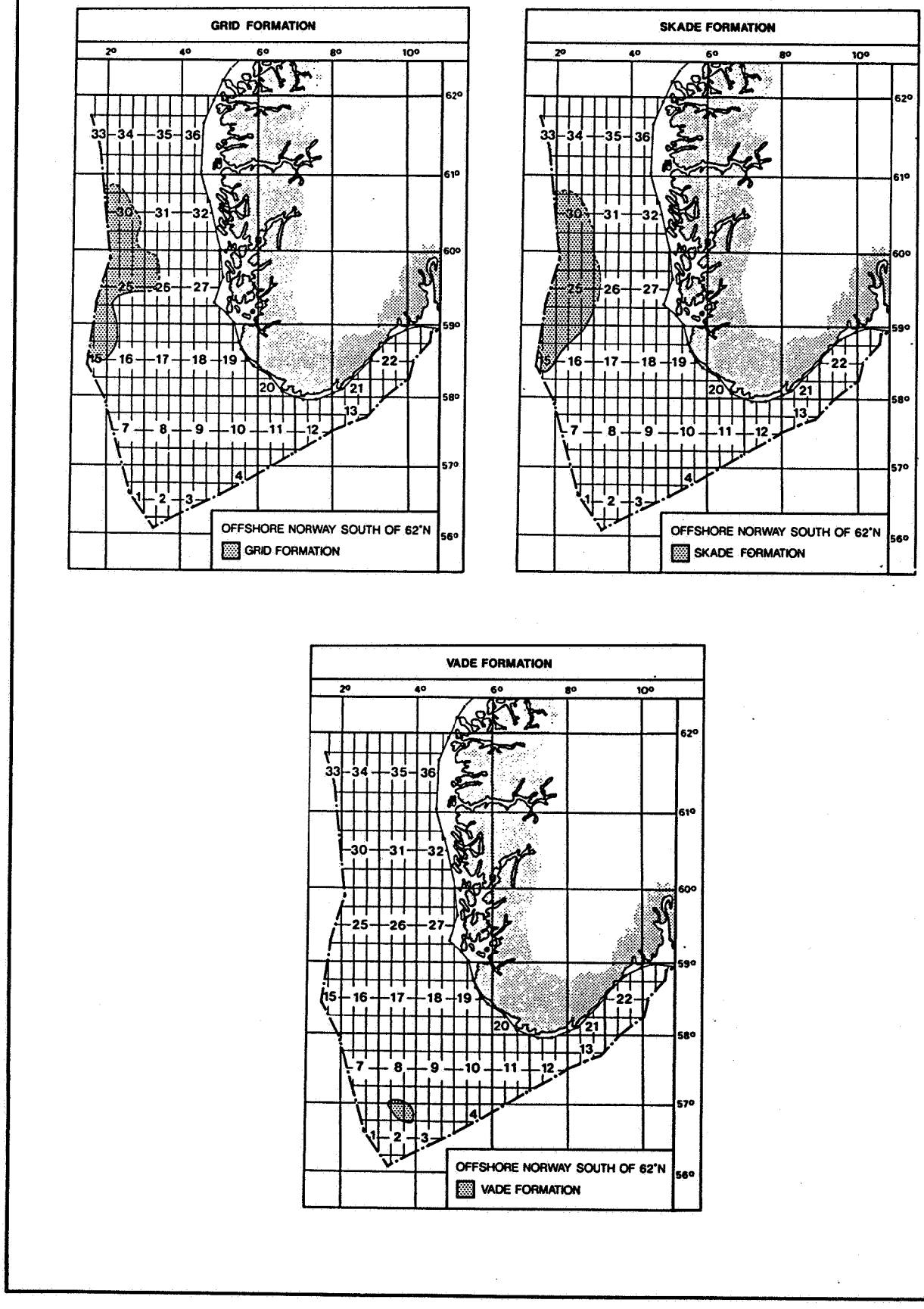


Fig. 66 Approx. distribution of the Grid, Skade and Vade Formations

upwards. The sandstones are very fine to fine, sometimes medium to coarse. Sorting is generally moderate to good. Traces of mica, pyrite, glauconite and fossil fragments are common. A higher argillaceous content is found in distal areas. Well 24/12-1 illustrates the interfingering of thicker claystone units of the Hordaland Group with the Grid Formation (Fig. 61) Further subdivision may be possible in the future (see Remarks).

Basal stratotype:
The lower boundary shows a decrease in gamma-ray response and an increase in velocity from the Hordaland Group into the sandstones of the Grid Formation (Fig. 64).

Characteristics of the upper boundary:
The upper boundary is characterised by an increase in gamma-ray readings and a decrease in velocity from the sandstones of the Grid Formation into the claystones of the Hordaland Group (Fig. 64).

Distribution:
The sandstones were probably derived from the East Shetland Platform and the formation is recognised in the Viking Graben area between 58°30'N and approximately 60°30'N (Fig. 66). A depocentre lies in Norwegian block 15/3 where the formation reaches a thickness of nearly 400 m. It thins eastwards and is not penetrated by wells on the Utsira High. It has been identified in some wells in the Oseberg area. In the Viking Graben north of 61° N, several sandstone bodies occur in the Hordaland Group at the same level, but it is uncertain whether they belong to the Grid Formation.

Age:
Middle to Late Eocene, but wells 25/6-1 and 24/12-2 have given an Early Oligocene age.

Depositional environment:
The formation is thought to have been deposited in an open marine environment during a regressive period. An eustatic fall in sea level in the Late Eocene is indicated by Haq et al. (1987).

Remarks:
The formation comprises a series of sand bodies which interfinger with claystones. There is a considerable increase in thickness from less than 200 m north of 59° N (e.g. wells 24/12-1 and 24/12-2) to nearly 400 m south of 59° N (e.g. well 15/3-3). This is not due to a general increase in thickness, but rather to sand deposition having started earlier in the south. This could give grounds for erecting two formal units, a lower one confined to the area south of 59° N and probably of Middle Eocene age, and an upper one. In some areas the lower unit is separated from the upper one by a sequence of claystones which is referred to informally as the Belton member in the UK sector. However, lithological uniformity renders such subdivision impractical at present.

Skade Formation (new) (Skadeformasjonen)

Name:
Named after a female giant in Norse mythology, the wife of the god Njord.

Well type section:

Norwegian well 24/12-1 from 1007 to 851 m, coordinates N 59°02'29.80", E 01°52'57.93" (Fig. 61). No cores.

Well reference section:
Norwegian well 15/9-13 from 1224 to 1143 m, coordinates N 58°22'25.96", E 01°56'02.86" (Fig. 67). No cores.

Thickness:
The Thickness is 156 m in the type welland 81 m in the reference well. It reaches nearly 200 m in Norwegian block 15/3, but is usually around 50-100 m. The formation shows a general eastward thinning.

Lithology:
The formation consists of marine sandstones with thin claystone interbeds. The sandstones are clear to light grey, usually fine to medium, occasionally coarse grained, with subrounded to rounded grains which are moderately to well sorted. Traces of fossils, shell fragments, mica and abundant glauconite occur. In some wells the sandstones are interbedded with silty claystones as illustrated by reference well 15/9-13 (Fig. 67). The formation often interfingers with the unnamed claystones of the Hordaland Group.

Basal stratotype:
The lower boundary shows a decreasing gamma-ray response from the underlying claystones into the sandstones of the Skade Formation. The velocity log usually records no distinct break (Fig. 61).

Characteristics of the upper boundary:
The gamma-ray response increases from the sandstones of the Skade Formation into the overlying claystones of the Hordaland Group. The velocity log usually records no distinct break (Fig. 61). Where the Skade Formation is directly overlain by the Utsira Formation the boundary is normally a break on the velocity log.

Distribution:
The formation has been identified in the Viking Graben area between 58° N and approximately 60°30' N (Fig. 66). Several sandstones occur in the upper part of the Hordaland Group in wells to the north and northeast of the known distribution area of the formation, and it may be present in these areas, but identification is difficult.

Age:
Late Oligocene.

Depositional environment:
The formation is thought to have been deposited in an open marine environment as a response to a fall in sea level. A globally low sea level during the late Oligocene is indicated by Haq et al. (1987).

TERTIARY

WELL 15/9-13

REFERENCE WELL: UTSIRA FORMATION
SKADE FORMATION

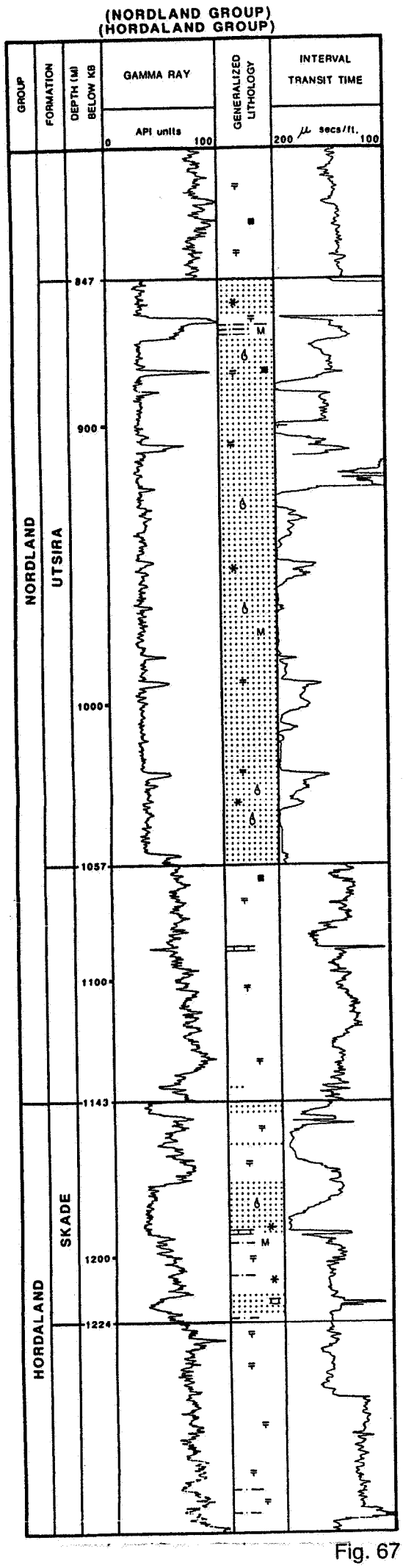


Fig. 67

TERTIARY

WELL 2/3-2

REFERENCE WELL: VADE FORMATION

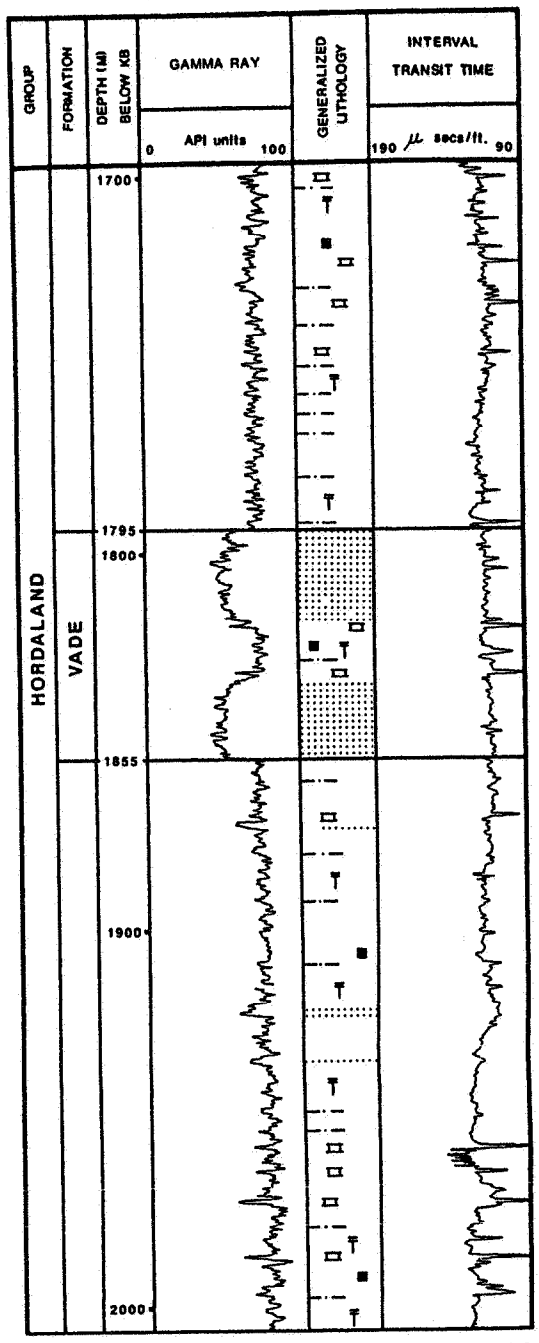


Fig. 68

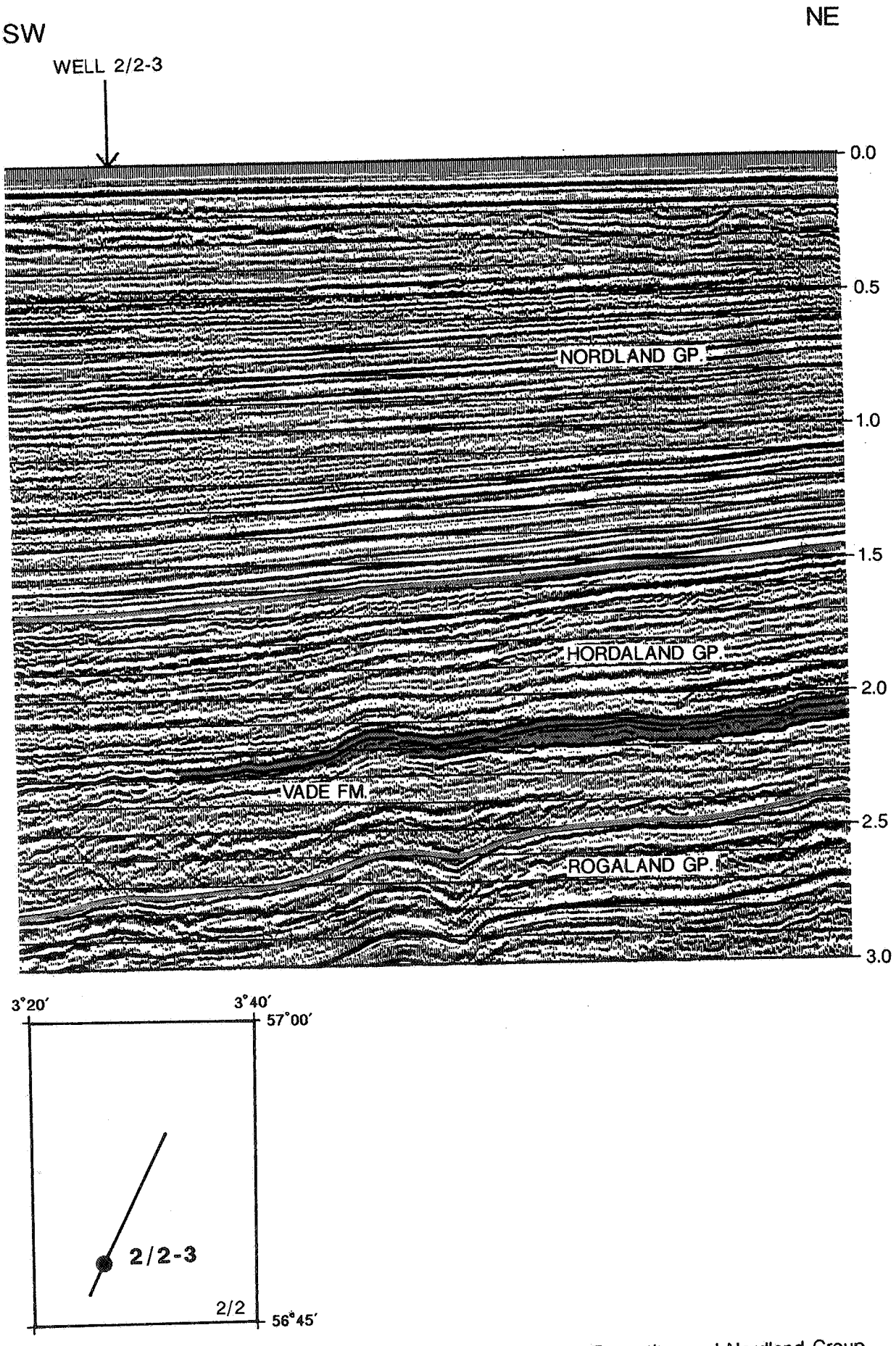


Fig. 69 Seismic section showing Hordaland Group with Vade Formation and Nordland Group.

Vade Formation (new) (Vadeformasjonen)

Name:
Vade is a giant from Norse mythology who wades across the fjords.

Well type section:
Norwegian well 2/2-1 from 2172 to 2100 m, coordinates N 56°47'15.69", E 03°38'15.62" (Fig. 60). No cores.

Well reference section:
Norwegian well 2/3-2 from 1855 to 1795 m, coordinates N 56°54'53.70", E 03°49'02.25" (Fig. 68). No cores.

Thickness:
The thickness is 72 m in the type well and 60 m in the reference well. Fig. 69 shows a seismic section through the Vade Formation which illustrates thinning to the southwest.

Lithology:
The formation consists of thinly interbedded, light green to grey, very fine grained sandstones and siltstones. These are glauconitic, slightly micaceous and well sorted. Fossils are present. Reference well 2/3-2 shows that the formation interfingers with the claystones of the Hordaland Group (Fig. 68).

Basal stratotype:
The lower boundary shows a decrease in gamma-ray intensity and an increase in velocity from the claystones of the Hordaland Group into the Vade Formation (Fig. 60).

Characteristics of the upper boundary:
The upper boundary is characterised by an increase in gamma-ray response and a decrease in velocity from the Vade Formation into the claystones of the Hordaland Group (Fig. 60).

Distribution:
The formation has only been penetrated in some wells in blocks 2/2 and 2/3. Its distribution is shown in Fig. 66.

Age:
Late Oligocene.

Depositional environment:
The sandstones were deposited in a shallow marine environment. Their deposition can be seen as a response to an eustatic fall in sea level or a tectonic uplift of the area. Regional considerations indicate a source area in the east or northeast.

Nordland Group (Nordlandsgruppen)

Name:
This group was named by Deegan & Scull (1977) after the county of Nordland in Norway.

Type area:
The type area is the North Sea Tertiary Basin. Typical sections through the group are seen in Norwegian well 2/2-1 (Fig. 60). Fig. 69 shows a seismic section through the group in the Central Trough area. The lithostratigraphy is shown in Fig. 40.

Thickness:
The group is 1514 m thick in well 2/2-1, but may exceed 1700 m in the Central Trough. It is approximately 1000 m thick in the Viking Graben area.

Lithology:
The Nordland Group is dominated by marine claystones. These are grey, sometimes greenish-grey and grey-brown, soft, locally silty and micaceous. The sandy Utsira Formation occurs in the lower part of the group in the Viking Graben area. The uppermost part of the group consists of unconsolidated clays and sands with glacial deposits uppermost.

Basal stratotype:
The base of the group occurs at the passage from the generally brown shales of the Hordaland Group into the more massive and blocky, generally grey, claystones of the Nordland Group. This contact is usually marked by a break on the logs which represents an unconformity of Early to Middle Miocene age. In the Central Trough the lower boundary is placed at the base of a claystone with high gamma-ray readings (Fig. 60). In the Viking Graben area the lower boundary is normally the base of the sandy Utsira Formation. In this case the contact is marked by a decrease in gamma-ray readings from the claystones of the Hordaland Group into the Utsira Formation. Where the basal part of the Nordland Group is developed as claystone the boundary is placed at log breaks associated with a change in claystone colour.

Characteristics of the upper boundary:
The upper boundary is the sea bed.

Distribution:
The group is distributed over most of the North Sea Tertiary Basin. It may be incomplete at the basin margins due to erosion or non-deposition. The Nordland Group is also present on the Mid Norwegian Shelf (Dalland et al. 1988).

Age:
Middle Miocene to Recent.

Depositional environment:
Open marine, with glacial deposits in the upper part in some areas.

Subdivision:
The Utsira Formation is the only formation defined in the Nordland Group at present. Additional units may be defined in the future from subregional work and further well information.

Utsira Formation (Utsiraformasjonen)

Name:
Named by Deegan & Scull (1977) after the Utsira High.

Well type section:
Norwegian well 16/1-1 from 1064 to 644.5 m, coord-

TERTIARY

WELL 16/1-1

TYPE WELL: UTSIRA FORMATION

(NORDLAND GROUP)

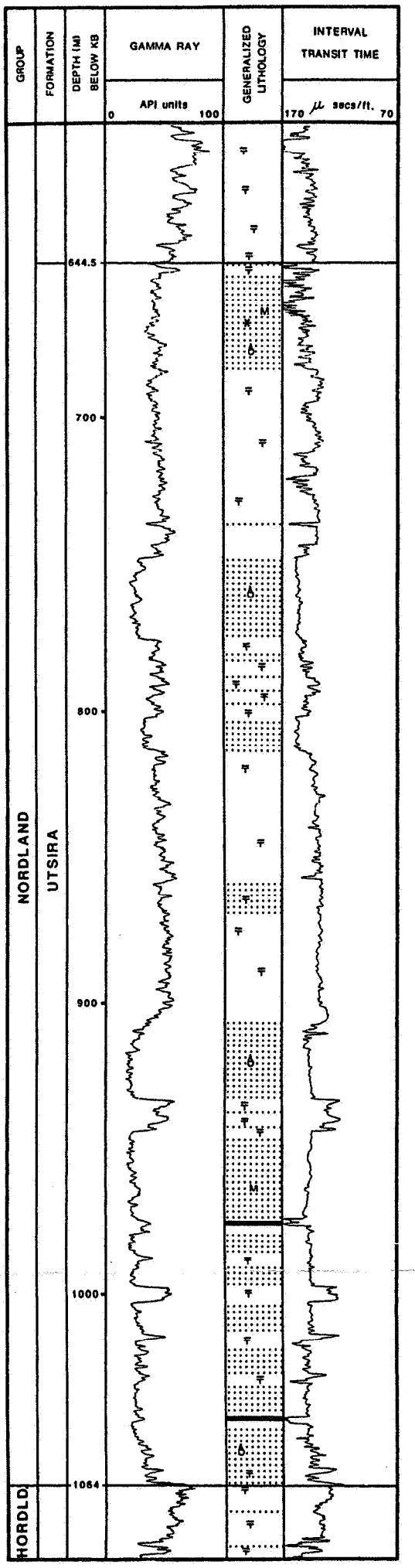


Fig. 70

inates N 58°59'18.38", E 02°02'02.97" (Fig. 70). No cores.

Well reference section:
Norwegian well 15/9-13 from 1057 to 847 m, coordinates N 58°22'25.96", E 01°56'02.86" (Fig. 67). No cores.

Thickness:
The thickness is 419.5 m in the type well and 210 m in the reference well.

Lithology:
The formation consists of marine sandstones and claystones. The sandstones are clear to white, often light greenish and normally very fine to fine grained, in places medium to very coarse grained. Occasionally rock fragments and lignite are found. The sandstones are separated by soft, plastic, light greenish claystones and minor siltstones. Glauconite and fossil fragments are common throughout.

Basal stratotype:
The lower boundary of the formation is normally well defined by a decrease in gamma-ray response from the underlying claystones into the sandstones of the Utsira Formation (Fig. 70). In wells where the formation directly overlies the Skade Formation the lower boundary may be more difficult to identify, but it is normally marked by a break on the velocity log.

Characteristics of the upper boundary:
The upper boundary is normally well defined by an increase in gamma-ray response into the overlying claystones (Fig. 70).

Distribution:
The formation is present in the Viking Graben area from about 580 N to the Tampen Spur. It pinches out in the northeast between the Oseberg and Troll Fields. General thinning and increase in clay content eastwards indicate that most of the sediment was derived from the west. However, local sources in the east are possible.

Age:
Middle to Late Miocene.

Depositional environment:
The formation probably represents shallow marine shelf sandstones.

LIST OF FIGURES

REFERENCES

Beaumont, C. & Sweeney, J.F. 1978:
Graben generation of major sedimentary basins. *Tectonophysics 5*, T19-T23.

Conort, A. 1986:
Habitat of Tertiary Hydrocarbons, South Viking Graben. *In*: Spencer, A.M. et al. (ed.): *Habitat of Hydrocarbons on the Norwegian Continental Shelf*, 159-170, Graham & Trotman, London.

Grittenden, S. 1982:
Lower Cretaceous lithostratigraphy NE of the Sole Pit Area in the UK southern North Sea. *Journal of Petroleum Geology 5 (2)*, 91-202.

d'Heur, M. 1984:
Porosity and hydrocarbon distibution in the North Sea chalk reservoirs. *Marine and Petroleum Geology 1*, 211-238.

d'Heur, M. 1986:
The Norwegian chalk fields. *In:* Spencer, A.M. et al. (ed.): *Habitat of Hydrocarbons on the Norwegian Continental Shelf*, 77-89. Graham & Trotman, London.

Dalland, A., Worsley, D. & Ofstad, K. (eds.) 1988:
A lithostratigraphic scheme for the Mesozoic

and Cenozoic succession offshore mid- and northern Norway. *NPD - Bulletin No. 6*, 65 pp.

Deegan, C.E. & Scull, B.J. (compilers) 1977: A standard lithostratigraphic nomenclature for the central and northern North Sea. *Institute of Geological Sciences Report 77/25, NPD - Bulletin No. 1*, 35 pp.

Doré, A.G., & Gage, M.S. 1986: Crustal alignments and sedimentary domains in the North sea, North-East Atlantic margin and Barents shelf. *Petroleum Geology of NW Europe, Conference, Proceedings, vol. 2*, 1131-1148.

Hancock, J.M. & Kauffmann, E.G. 1979: The great transgressions of the Late Cretaceous. *Journal Geological Society London 136*, 175-186.

Hancock, J.M. 1984: Cretaceous. *In:* Glennie, K.W. (ed.): *Introduction to the Petroleum Geology in the North Sea*, 133-150. Blackwell Sci. Publ.

Haq, B.U., Hardenbol, J. & Vail, P.R. 1987: Chronology of fluctuating sea levels since the Triassic, *Science 235*, 1156-1167.

Hart, M.B. & Leary, P.N., 1989: The stratigraphic and palaeogeographic setting of the late Cenomanian "anoxic" event, *Journal Geological Society London 146*, 305-310.

Hatton, I.R. 1986: Geometry of allochthonous Chalk Group members. Central Trough, North Sea, *Marine and Petroleum Geology 3*, 79-98.

Hedberg, H.D. 1976: *International stratigraphic guide: A guide to stratigraphic classification, t erminology and procedure.* International subcommision on Stratigraphical Classification of IUGS Commision of Stratigraphy. New York, Wiley & Jons.

Heilmann-Clausen, C. 1987: Lower Cretaceous dinoflagellate biostratigraphy in the Danish Central Trough. *Danmarks Geolologiske Undersøgelse, Serie A, 17*, 89 pp.

Hesjedal, A. & Hamar, G.P. 1983: Lower Cretaceous stratigraphy and tectonic of the south-southeastern Norwegian offshore. *In:* Kaasschieter, J. P.H. & Reijers, T.J.A. (eds.): Petroleum Geology of the southeastern North sea and the adjacent onshore areas. *Geologie en Mijnbouw 62*, 135-144.

Jeffries, R.P.S. 1963: The Stratigraphy of the Actinocamax plenus Subzone (Turonian) in the Anglo-Paris Basin. *Proceedings Geological Association 74*, 1-33.

Jensen, T.F., Holm, L., Frandsen, N. & Michelsen, O. 1986: Jurassic - Lower Cretaceous lithostratigraphic nomenclature for the Danish Central Trough. *Danmarks Geologiske Undersøgelse, Serie A. 12*, 65 pp.

Larsen, G. 1966: Rhaetic - Jurassic, Lower Cretaceous Sediments in the Danish Embayment (A Heavy - Mineral Study). *Danmarks Geologiske Undersøgelse, II Række 91*, 128 pp.

Malm, O.A., Christensen, O.B., Furnes, H., Løvli, R., Rueslåtten, H & Østby, K.L. 1984: The Lower Tertiary Balder Formation; an Organogenic and Tuffaceous Deposit in the North Sea Region. *In:* Spencer, A.M. et al. (ed.): *Petroleum Geology of the North European Margin*, 149-170.

McKenzie, D. 1978: Some remarks on the development of sedimentary basins. *Earth and Planetary Scientific Letters 40*, 25-32.

NAM & RGD (Nederlandse Ardolie Maatschappij B.V. & Rijks Geologische Dienst) 1980: Stratigraphic nomenclature for the Netherlands. Verk. van het KoniuklijkVed. *Geologish Mijnbouwkundig Genootschap 32*, 77 pp.

Nybakken, S. & Bäckström, S.A. in press: Shetland Group: Stratigraphic subdivision and regional correlation in the Norwegian North Sea. *In:* Hareshape, J. (ed.): *Correlation in hydrocarbon exploration.* Norwegian Petroleum Society, Bergen 1988, Graham & Trotman Limited.

Nystuen, J.P. 1986: Regler og råd for navnsetting av geologiske enheter i Norge av Norsk Strategrafisk komite. *Norsk Geologisk Tidsskrift Supplement 1*, 96 pp.

Rawsnn, P.F. & Riley, L.A. 1982: Latest Jurassic -Early Cretaceous events and the "Late Kimmerian Unconformity" in North Sea Area. *Bulletin of American Association of Petroleum Geologists 66 (12)*, 26282648.

Rhys, G.H. 1974: A Proposed standard lithostratigraphic nomenclature for the southern North Sea and an outline structural nomenclature for the whole of the (U.K.) North Sea. *Institute Geological Science, Report 74/8*, 14 pp.

Schmid, F. & Spaeth, C. 1980: Erster Nachweis von Schwarzschiefern in Under-Turon Helgolands (Nordsee, NW-

Deutschland). *Neues Jahrbuch Geologishe Paläontologische Mitteilungen 11*, 703-706.

Sclater, J.G. & Christie, P.A.E. 1980:
Continental stretching: An explanation of post-Mid-Cretaceous subsidence of the Central North Sea Basin. *Journal of Geophysical Research 85*, 3711-3739.

Skovbro, B., 1983:
Depositional conditions during Chalk sedimentation in the Ekofisk area Norwegian North sea. *In:* Kaasschieter, J-P.H. and Reijers, T.J.A. (eds.): Petroleum geology of the southeastern North sea and adjacent onshore areas. *Geologie en Mijnbouw 62*, 169-175.

Thomsen, E. 1987:
Lower Cretaceous nannofossil biostratigraphy in the Danish Central trough. *Danmarks Geolologiske Undersøgelse, Serie A, 20*, 89 pp..

Vollset, J. & Doré, A.G. (eds.) 1984:
A revised Triassic and Jurassic lithostratigraphic nomenclature for the Norwegian North sea. *NPD-Bulletin No. 3*, 53 pp..

Watts, N.L., Lapré, L.F., Schijndel-Goester, F.S. van & Ford, A. 1980: Upper Cretaceous and Lower Tertiary chalks of the Albuskjell area North Sea: Deposition in a slope and base-of-slope environment. *Geology 8*, 217-221.

Ziegler, W.H., Doery, R. & Scott, J. 1986:
Tectonic habitat of Norwegian oil and gas. *In*: Spencer, A.M. et al. (ed.): *Habitat of Hydrocarbons on the Norwegian continental shelf*, 3-19, Graham and Trotman, London.

Ziegler, P.A. 1982:
Geological Atlas of Western and Central Europe. Shell International Petroleum Maatachappij B.V., 130 pp.