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A revised Triassic and Jurassic lithostratigraphic nomenclature for the Norwegian North Sea

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INTRODUCTION

History of project

In early 1980 an initiative was taken by the exploration committee of NIFO (Norwegian Industry Association for Operating Companies) to organize a working party to consider the revision of the existing lithostratigraphic nomenclature offshore Norway.

The Norwegian Petroleum Directorate (NPD) was invited to participate. Since the NPD was already working on updating nomenclature, and in view of their special position on data availability, they were asked to chair the meetings.

A preliminary meeting was called for in May 1980. The aim of the meeting was to establish a small working party of contributing geologists. The intention was that larger meetings should be held from time to time to allow contributions and comments from other companies. Initially eight companies replied on this invitation: BP, Conoco, Elf, Esso, Mobil, Norsk Hydro, Saga and Statoil. Immediately after the establishment of the working party Shell joined the party. After a few meetings it soon became clear that the amount of work to be done was much more extensive than at first anticipated. It was therefore decided that the Main Commitee and subcommitee system used by Deegan and Scull (1977) should be adopted. The Main Commitee should constitute the members of the working party. It was further agreed that the different subcommittees should report to the Main Committee on their proposals for revision and new formal naming. It was found convenient to establish subcommittes on a chronostratigraphic basis. In addition a regional subdivision was made.

The following four subcommitees were established: Triassic North (North Sea north of approx. 59°N), Triassic South (area south of approx. 59°N), Jurassic North (area north of approx. 59°) and Jurassic South (area south of approx. 59°N).

The intention was to establish subcommittees to cover all periods. Since, however, several of the members of the established subcommittees would also participate in subcommittees for other periods, it was decided to postpone the formal establishment of these subcommittees until the work of the Triassic and Jurassic subcommittees was concluded.

Compilation of the work in the established subcommittees was delayed due to a number of unavoidable factors. It was therefore decided to publish the proposed revision of the Triassic and Jurassic lithostratigraphic nomenclature separately.

Subcommittees for the other periods are at present about to be established and the results of their work will be published in the same manner as the present report.

Participation

Main Committee:

J. Vollset (NPD, chairman), D. L. Brehm (Esso), R. Færseth (Norsk Hydro), G. P. Hamar (Statoil), G. Indrevær (Elf), R. A. James (BP), R. H. Kirk (Mobil), R. Myrland (Saga), N.D. Shaw (Shell), J.W. Swann (Conoco).

In 1981, R. A. James (BP) and R. H. Kirk (Mobil) were transferred and they were replaced by I. Price (BP) and T. Christiansen (Mobil). G. Indrevær (Elf) resigned and he was replaced by G. Haarr (Elf). D. L. Brehm (Esso) assumed different duties in 1981 and P. Sandormirsky (Esso) took his place in the Committee. In 1982 J.W. Swann (Conoco) was transferred and replaced by A.G. Doré. In late 1982, R. Myrland (Saga) assumed different duties and O.F. Ekern (Saga) took his place in the Commitee.

In late 1983 N.D. Shaw was transferred.

Subcommittees:

The companies represented on each subcommittee were selected according to availability of important well information. Subcommittee members were nominated by their companies. Each subcommittee was chaired by the NPD representative.

1 Triassic North

V. W. Jacobsen (NPD, chairman), D. L. Brehm (Esso), O. F. Ekern (Saga), R. Færseth (Norsk Hydro), O. Skarpnes (Statoil).

In 1981 D. L. Brehm (Esso) and O. Skarpnes (Statoil) assumed different duties and were replaced by K. Kalgraff (Esso) and S. L. Røe (Statoil).

2 Triassic South

V. W. Jacobsen (NPD, chairman), T. Christiansen (Mobil), T. Hallberg (Norsk Hydro), K. Jakobson (Statoil), O. Skarpnes (Statoil).

3. Jurassic North

J. Vollset (NPD, chairman), R. Færseth (Norsk Hydro), W. Karlsson (Saga), O. Skarpnes (Statoil), J. W. Swann (Conoco), T. Williams (Mobil).

In early 1981 N. Shaw (Shell) joined the subcommittee. T. Williams (Mobil) and R. Færseth (Norsk Hydro) assumed different duties and were replaced by T. Christiansen (Mobil) and T. Lilleng (Norsk Hydro). J. W. Swann (Conoco) was transferred in 1982 and was replaced by A. G. Doré (Conoco).

4 Jurassic South

I. F. Strass (NPD, chairman), A. G. Doré (Conoco), O. F. Ekern (Saga), A. Glæserud (Norsk Hydro), R. C. Olsen (NPD), I. Price (BP), O. Skarpnes (Statoil). N. Shaw (Shell) joined the subcommittee in 1981.

In 1983 O. Skarpnes (Statoil) assumed different duties and was replaced by A. Hesjedal (Statoil).

Editorial statement

The standard lithostratigraphic nomenclature for the Central and Northern North Sea proposed by Deegan and Scull (1977) was published jointly by the Institute of Geological Sciences (U.K.) and the Norwegian Petroleum Directorate. It was the result of a broad collaboration between many companies and institutions in both the U.K. and Norway. The present report, which revises the Triassic-Jurassic lithostratigraphy of the Norwegian sector, is also the result of a major collaboration. Although the committee work and editing were in this case entirely carried out in Norway, we have endeavoured to maintain links with the Institute of Geological Sciences and the Danish Geological Survey in an attempt to arrive at a product which meets with their general approval.

Although major changes to the lithostratigraphic framework have been made in this report, some parts of the section are unaltered or only slightly modified from Deegan and Scull's publication. Where no change at all has occurred in a previous definition, we have referred the reader directly to Deegan and Scull. Where minor changes were thought necessary we have taken the liberty of quoting sections of the latter paper directly; this can be seen particularly in the definitions of the Statfjord Formation, Brent Group, Dunlin Group and Heather Formation. Although for sightliness we have chosen not to litter these sections with quotation marks, numerous citations throughout this report testify to the enormous debt which we owe to Deegan and Scull's original compilation.

Lithostratigraphy in general, and lithostratigraphic nomenclature in particular, are by their nature subjective. Disagreements inevitably arose during the course of the work at both subcommittee and main committee level. In general it can be said that all problems of correlation were resolved satisfactorily. On the more subjective level of unit organization and nomenclature, suitable compromises were generally found. Areas of doubt remain, however, and we have attempted to indicate these in the text.

The ideas expressed in this work are the result of extensive discussions within the committee framework, and credit for ideas is due to all participants. The introductory section of the report and all linking material was written by the editors. Authorship of the formal unit descriptions is indicated alphabetically at the beginning of each of the three main sections (Triassic North, Jurassic North and Jurassic South).

It should be stressed that the views and interpretations in this report are not necessarily those of the editors, although we concur with most of the broad framework.

NOTES ON LITHOSTRATIGRAPHIC PROCEDURES

General

The lithostratigraphy in this report in general follows the guidelines laid down by the International Subcommission on Stratigraphic Classification (Hedberg 1976). Any departures from internationally accepted procedures are made clear in the text.

Since this account is primarily concerned with establishing a usable system of nomenclature, a few remarks are appropriate on naming procedure. As in most offshore areas, there is a problem with finding enough nearby coastal or oceanographic features to provide names for all the newly designated units. We have approached this problem either by using coastal Norwegian names which have no particular connotation of proximity (e.g. Bryne Formation, Tau Formation) or by an arbitrary nomenclature system such as that of the Norwegian sea-birds used for some of the Triassic units (e.g. Hegre Group, Lomvi Formation). We have attempted to eliminate repetition of unit name in component parts of the same unit, even when this has necessitated abandonment of established nomenclature (see «Remarks» on Bryne Formation). We have not established a formal system of unit and boundary codes, as used for example by the Netherlands stratigraphic nomenclature group (Nederlands Aardolie Maatschappij B. V. and Rijks Geologische Dienst, 1980); it has been left to the individual institution or company to adapt our proposed nomenclature to its own data base.

We have limited ourself to three categories of lithostratigraphic unit, namely «group», «formation» and «member». A short definition of these terms is given below.

Group

This refers to an association of two or more contiguous formations, unified by significant common lithological features. For example, a sequence of claystone-siltstone units in the Norwegian-Danish basin (Egersund, Tau, Sauda and Flekkefjord Formation) together form a single group, the Boknfjord Group. Occasional exceptions have been made to this rule. For instance, where intertonguing marginal sandstone «formations» are found within an overall claystone «group» we have in some cases found it expedient to incorporate the sandstones into the group (see for example the Viking Group), a compromise which was also used by Deegan and Scull (1977). Another alternative, however, would be to separate out the sandstone formations as stand-alone units not belonging to any particular group.

Formation

«The formation is the primary formal unit of lithostratigraphic classification; it is a body of rock strata of intermediate rank in the hierarchy of lithostratigraphic units. Formations are the only formal lithostratigraphic units into which the stratigraphic column everywhere should be divided completely on the basis of lithology» (Hedberg 1976).

A prerequisite of a formation is its practical utility in mapping. For North Sea subsurface work we have in most cases taken this to mean that a formation should be correlatable over a fairly wide area; i.e. a basin or a significant part of a basin. It should be readily distinguishable from adjacent formations by its overall lithological character, determined from cores, cuttings and wireline logs.

Member

A member is defined as a component unit of a formation, lithologically distinct from adjacent parts of the formation.

In general this report does not concern itself with defining or naming units at the member level; its aim is to provide only a coarse lithostratigraphic framework. This does not mean, however, that such units do not exist or are impractical. Lithostratigraphic subdivision at this level is left to individual operators and institutions working with their own informal units in specific areas. Formalization of these units where necessary will be the business of future reports.

Boundaries

Boundaries between lithostratigraphic units have been placed where possible at positions of sharp lithological change. However, where gradational changes occur between units, boundaries have been placed arbitrarily but with some regard to practical application. Boundary characteristics are described under each lithostratigraphic unit, and boundary stratotypes are shown diagramatically for each type well.

Occoasionally we have erected a lithostratigraphic unit for which no base has been penetrated (e.g. Hegre Group, Teist Formation). We are aware that, without a lower boundary, such units cannot be formally defined; the names and descriptions provided in the text should therefore be regarded as convenience measures pending the establishment of lower boundary stratotypes.

Elevation of Lithostratigraphic Units

In a number of cases units defined as members in previous publications have been elevated to formation status (see for example Egersund Formation). In all cases this is because we considered that the units are now understood to be widespread, distinct and correlatable enough to rank as primary lithostratigraphic units.

Two important lithostratigraphic units, the «Dunlin» and «Brent», which were formerly defined only as «units» (Deegan and Scull, 1977) are assigned group status in this report. Their constituent «sub-units» are given formation rank.

Local nomenclature and the «persistence of facies»

It is generally recognised that at certain times in geological history similar or identical facies types were deposited over very wide areas (see for example Ager, 1981). This leads to the problem in lithostratigraphy of whether such broad facies developments should be unified under a single name or subjected to local nomenclature.

This problem was encountered in a number of cases by workers on the present project and provoked much discussion. The most prominent case was that of the Kimmeridge Clay Formation, a unit which has been extended into the Northern North Sea from its type area in Dorset, southern England (Rhys, 1975; Deegan and Scull, 1977). It was appreciated that organic-rich radioactive claystones of the «Kimmeridge» type are present in the late Jurassic section over vast areas of Europe. However, examination at the more local scale of the Norwegian North Sea indicated complex relationships, both within the late Jurassic claystone sequence and between adjacent basins (i.e. Central Graben, Viking Graben and Norwegian-Danish Basin). Here usage of the term «Kimmeridge Clay Formation», it was felt, would not throw light on the complexities, but on the contrary, would be detrimental to meaningful correlation (see remarks on the Draupne Formation). The Main Committee therefore opted for rejection of the old nomenclature in the Norwegian sector and for the erection of a local nomenclature for the various «hot shale» developments of the late Jurassic (Tau, Mandal and Draupne Formations). We feel that this procedure is defensible as a means to more precise correlation, and have applied it elsewhere in the section where appropriate. It in no way conflicts with the «persistence of facies» concept, but is a more palatable alternative to the recognition of continent-wide «formations» of dubious lithological continuity and limited lithostratigraphic value.

Presentation of type, reference and illustration wells

All well logs presented in this report are on a vertical scale of 1 : 2000. A lithological legend is given in Fig. 45. All units defined in this report are listed alphabetically in the appendix.

CHRONOSTRATIGRAPHIC FRAMEWORK

Age ranges for the lithostratigraphic units described in the text are indicated by reference to stage level. More precise (i.e. zonal) ranges have not been attemted. The Triassic and Jurassic stage names utilized are listed in Table 1 together with the two Lower Cretaceous stages referred to in this report.

The Triassic stages shown are the classic Tethyan stages in common usage throughout the North Sea. For the purposes of this account the Lower Triassic Scythian is treated as a stage, not a series as in North American chronostratigraphic terms. The continental nature of much of the Triassic sequence in the Norwegian offshore south of 62°N means that datings are frequently imprecise. Reference to the Tethyan stage system is often only tentative.

Boreal stage terminology is used for the con-

TRIASSIC

Upper	RHAETIAN
	NORIAN
	CARNIAN
Middle	LADINIAN
	ANISIAN
Lower	SCYTHIAN

CRETACEOUS

Lower	VALANGINIAN
	RYAZANIAN

JURASSIC

Upper	VOLGIAN
	KIMMERIDGIAN
	OXFORDIAN
Middle	CALLOVIAN
	BATHONIAN
	BAJOCIAN
Lower	TOARCIAN
	PLIENSBACHIAN
	SINEMURIAN
	HETTANGIAN

Stage nomenclature for the Triassic, Jurassic and earliest Cretaceous.

TABLE 1

troversial latest Jurassic-earliest Cretaceous stages. Although the claims of the Portlandian (e.g. Cope et al., 1980) and Berriasian (e.g. Saks and Shulgina 1973) are recognised, this report follows current Norwegian convention and the recommendations of Casey and Rawson (1973) and Riley (1977) in using the Volgian for the final Jurassic stage and the Ryazanian for the initial Cretaceous stage. The Volgian as used herein includes part of the Upper Kimmeridgian *sensu anglico* (see for example Riley, op.cit.).

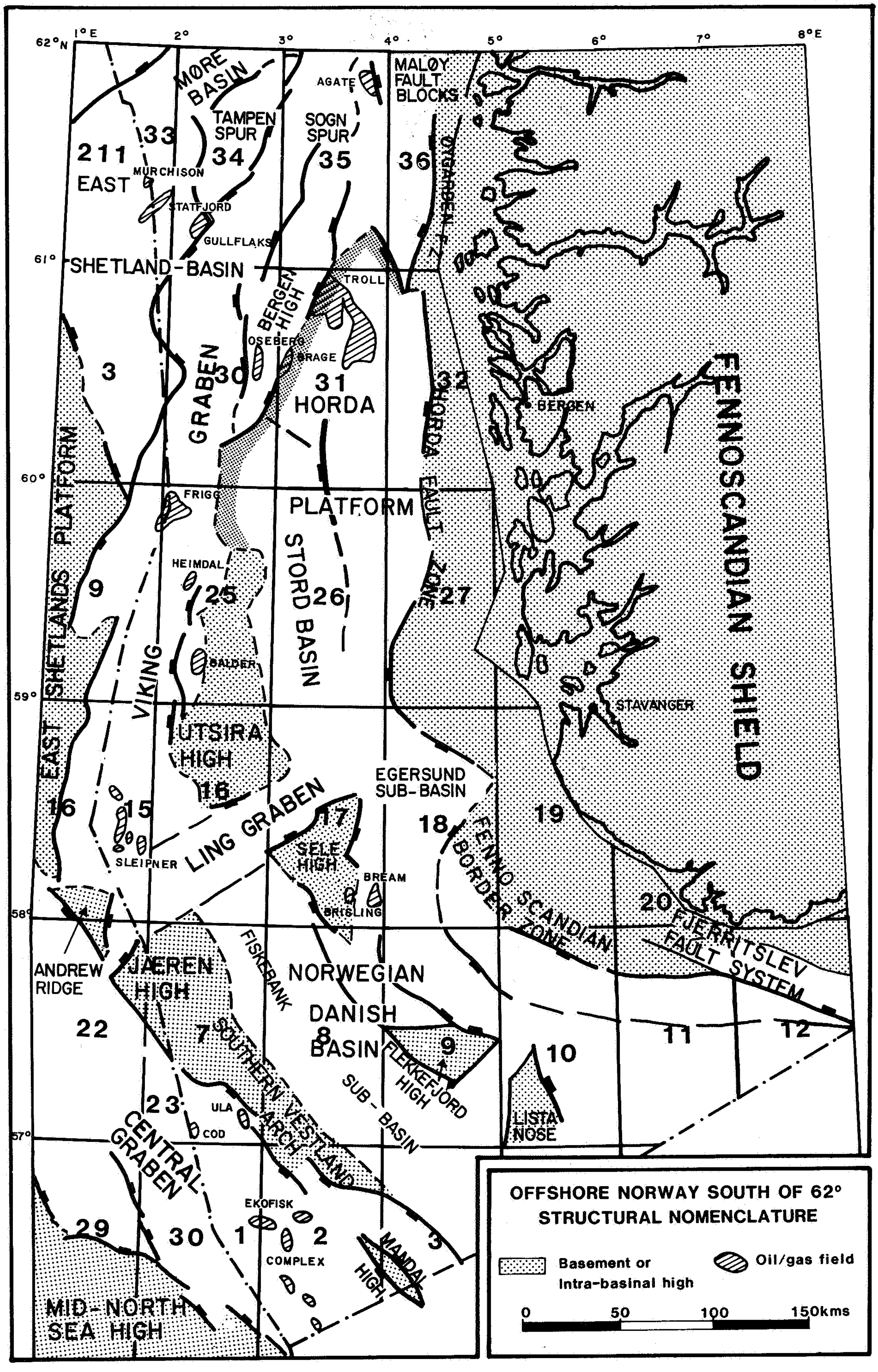
STRUCTURAL NOMENCLATURE

The names of structural features referred to in the text follow precedents set in the literature, principally by Rønnevik et al. (1975) and Hamar (1982). The main features are shown in outline form in Fig. 1. Note the following conventions:

— The East Shetland Basin as referred to herein encompasses everything between the East Shetland and Horda Platforms north of 60°N, including the northern part of the Viking Graben. It is bounded to the north by the Møre Basin.

— The term «Vestland Arch», which has largely fallen into disuse in the literature, is only applied here as the «Southern Vestland Arch» to define the intervening high region between the Norwegian-Danish Basin and the Central Graben.

FIG.1



OFFSHORE NORWAY SOUTH OF 62°
STRUCTURAL NOMENCLATURE
Basement or Intra-basinal high
Oil/gas field
0 50 100 150kms
MØRE BASIN
TAMPEN SPUR
SOGN SPUR
MALØY FAULT BLOCKS
AGATE
MURCHISON
STATFJORD
GULLFLAKS
EAST SHETLAND BASIN
TROLL
BERGEN HIGH
OSEBERG
BRAGE
VIKING GRABEN
HORDA PLATFORM
ØYGARDEN F.Z.
HORDA FAULT ZONE
BERGEN
FENNOSCANDIAN SHIELD
EAST SHETLANDS PLATFORM
FRIGG
HEIMDAL
BALDER
STORD BASIN
UTSIRA HIGH
STAVANGER
EGERSUND SUB-BASIN
LING GRABEN
SLEIPNER
SELE HIGH
BREAM
BRISLING
FENNO-SCANDIAN BORDER ZONE
FJERRITSLEV FAULT SYSTEM
ANDREW RIDGE
JÆREN HIGH
FISKEBANK
NORWEGIAN DANISH BASIN
FLEKKEFJORD HIGH
SOUTHERN VESTLAND ARCH
SUB-BASIN
LISTA NOSE
ULA
COD
CENTRAL GRABEN
EKOFISK
COMPLEX
MANDAL HIGH
MID-NORTH SEA HIGH

TRIASSIC

Basin evolution

For most of the Triassic period the Norwegian offshore region south of 62°N was an area of continental deposition. Thick sedimentary sequences accumulated in a rapidly subsiding intracratonic rift system bounded to the east and northeast by the Fennoscandian Shield, to the west by the East Shetland Platform and to the south by the Mid-North Sea and Ringkøbing—Fyn Highs. Movements on the bounding faults took place throughout Triassic time, with some associated tensional faulting within the basin. Accelerated phases of rifting are documented in the early Triassic (Hardegsen movements) and late Triassic (Early Kimmerian movements) (e.g. Ziegler 1982). Coarse-grained fluvial deposits accumulated close to the rift margins, giving way to a predominance of finer-grained alluvial, flood plain or lacustrine deposits towards the basin centres (Clemmensen et al., 1980).

Periods of high eustatic sea level allowed marine influences from the Boreal and Tethyan oceans to penetrate the northern and southern extremities of the rift system. The Middle Triassic Muschelkalk transgression was particularly important in the south, emanating from Tethys and proceeding northwards via the Norwegian-Danish Basin (Bertelsen 1980). Marine influences of this age have been detected as far north as the Egersund Sub-Basin, where limestones and evaporites are recorded (Jakobson et al., 1980). A more widespread transgression from both north and south beginning in latest Norian-Rhaetian times (Clemmensen et al., 1980) brought an end to continental deposition and heralded the dominantly marine environment of the ensuing Jurassic.

General lithostratigraphical notes

No revision of Triassic lithostratigraphy has been carried out for the southern part of the Norwegian North Sea. The Triassic South subcommittee considered that no new important information had become available since Deegan and Scull's (1977) classification. A number of 6th Round wells (on concessions awarded in 1981 in the Southern Vestland Arch — Central Graben region) have penetrated Triassic rocks, but these are not available for incorporation into this study. The broad twofold subdivision of the Triassic rocks into the proximal, arenaceous Skagerak Formation and the more argillaceous Smith Bank Formation should therefore be allowed to stand; the reader is referred to Deegan and Scull's paper for formal definitions of these units. However, it is worthy of note that Jakobson. et al. (1980) recognise the potential for future subdivision in the Egersund Sub-Basin, where the Middle Triassic sequence displays a mixed lithology with marine influences (carbonates and evaporites), possibly equating to the Germanic Mushelkalk transgression. The «type well» for this development is 17/12-1 (Phillips).

The predominantly continental deposits of the northern area (East Shetland Basin and Horda Platform) have been completely reclassified, based on new studies of deep wells in the Statfjord Field-Tampen Spur region. The new Hegre Group and its subdivisions (Teist, Lomvi and Lunde Formations) is essentially based on areas west of the Viking Graben, although preliminary data suggest that the same scheme, or a similar scheme, can be used for the Horda Platform. The chronostratigraphic framework of these units is, however, only poorly understood. The relationship between the lithostratigraphic units of the Triassic period in the Northern North Sea is shown in Table 2.

A more restricted usage of the name Cormorant Formation (from Deegan and Scull, 1977) is suggested herein (see description of Hegre Group).

NOTE: Units which span the Triassic—Jurassic boundary (Statfjord and Gassum Formations) are detailed in the Jurassic section of this report.

REVISED TRIASSIC LITHOSTRATIGRAPHY OF THE NORWEGIAN NORTH SEA; NORTHERN AREA

by O. F. Ekern, R. Færseth, V. W. Jacobsen and S. L. Røe

Hegre Group (new)

Name:
From the bird (English: heron) of the same name. The pre-Rhaetian Triassic rocks of the Northern North Sea were earlier designated the Cormorant Formation by Deegan and Scull (1977), having UK well 211/21-1A (Shell) as a type well section. In this report this Triassic unit is given group status, while the Cormorant Formation is only applied to certain areas where a subdivision of the Triassic is impossible. We suggest that the Cormorant Formation should refer to attenuated sequences confined to structural highs in the UK sector.

Type area:
The type area is the East Shetland Basin, west of the Viking Graben. The group is illustrated by UK well 211/29-5 (Shell), and Norwegian wells 33/5-1 (Norsk Hydro), 33/12-2 and 5 (Mobil).

Thickness:
No well has penetrated a complete Triassic succession. The maximum drilled sequence is 1839 m in well 33/12-5.

Lithology:
The Hegre Group consists of intervals of interbedded sandstones, claystones and shales associated with sequences of dominantly sand or shale/claystone. Shales and claystones usually have reddish colours whereas the sandstones show a range in colour from white, light grey, orange to brick red. The grain size varies from very fine to very coarse and the sediments are in parts of a pebbly nature. The Hegre Group also

has subordinate white limestone, anhydrite and brownish-red marl.

Boundaries:
The Hegre Group is directly overlain by Cretaceous strata on some of the structural highs. Where Jurassic is present, the top of the Hegre Group is normally placed at the change from interbedded sandstones and shales of the Hegre Group to the relatively massive clean sandstones of the Statfjord Formation. This is normally represented by a change from an irregular sonic log response in the Hegre Group to a more regular or blocky one in the Statfjord Formation. In addition the upper boundary of the Hegre Group is often close to the top of abundant red beds in the section. (See also the description of the Statfjord Formation). The base of the Triassic rocks is only penetrated on structural highs and close to the margins of the sedimentary basin. In these sections only late Triassic seems to be present, and hence the nature of the lower boundary of the Hegre Group is not yet established. It is realized that the Hegre Group cannot be given full formal definition until its base has been adequately defined, but we nevertheless offer the term for interim use.

Distribution
The Hegre Group is apparently present in the whole Northern North Sea area. Its relationship to the Triassic units defined further south by Deegan and Scull (1977) is unclear. We therefore recommend that the term Hegre Group should only be used in the area north of 60°N. It is terminated to the west by major faults along the east flank of the East Shetland Platform and to the east by the Øygarden Fault Zone (Hamar et al., 1980). In the northeastern part of the North Sea area, where Precambrian/Caledonian basement dips gently to the west, progressively younger Triassic sediments onlap basement in an easterly direction. In the east, on the Måløy Fault Blocks, Triassic strata are probably missing, but may have been preserved from erosion in N-S elongated basins to the east of the structural highs. Alternatively Triassic sediments might not have been deposited in this area. The thickness of the Hegre Group within the East Shetland Basin shows a general increase from the western flank toward the central part of the depositional basin. On the eastern flank thick Triassic deposits are found just west of the Øygarden Fault Zone, which may indicate that the Triassic sediments were deposited in an asymmetric basin.

Age:
The Triassic sections penetrated in the Northern North Sea show ages from Late Triassic (early Rhaetian) to possibly Early Triassic (? Scythian).

Subdivision:
The Hegre Group is divided into three formations: the (basal) Teist Formation, the Lomvi Formation and the Lunde Formation (top). The subdivision suggested here for the Triassic of the Northern North Sea is based on information from areas to the west of the Viking Graben. However, available data from the Horda Platform indicate that a subdivision is also possible in that area.

Teist Formation (new)

Name:
From the bird (English: black guillemot) of the same name.

Well type section:
Norwegian well 33/12-5 (Mobil) from 3867 m to TD, 4573 m, coord N 61° 11′05.53″, E 01°51′53.34″ (Fig. 2).

Well reference section:
Norwegian well 33/5-1 (Norsk Hydro) from 3298 m to TD, 3829 m, coord N 61°44′46.10″, E 01° 34′47.40″ (Fig. 3).

Thickness:
The base of the formation has not been reached. Minimum thickness is 706 m in the type well and 531 m in the reference well.

Lithology:
The Teist Formation consists of interbedded sandstone, claystone and marl. The sandstones are dominantly very fine to fine-grained, dark red brown and calcareous. In addition white and pink, medium to coarse sandstone is present in the upper levels of the succession. Red marl forms the main argillaceous lithology with green and dark grey claystone as subordinate constituents. In the type well (33/12-5) the formation is a gradual coarsening upward succession with an upward increase in sandstone/shale ratio.

To the north, in the reference well (33/5-1), fine-grained sandstone is the dominant lithology throughout most of the formation except for the lowermost 24 m which consist of a red marl.

Boundaries:
The lower boundary has not been penetrated. The authors accept that the Teist Formation must remain as an informal unit until a satisfactory base is defined. The upper boundary marks the base of the coarser-grained, cleaner and more massive sandstones of the Lomvi Formation. The Teist Formation is characterized by a more irregular gamma ray response with higher readings than the overlying Lomvi Formation. In the northern area, the boundary is also marked with a sonic log break.

Distribution:
The Teist Formation has been recognized in all deep wells between the Brent Field and the southern edge of the Møre Basin.

Age:
Probably early Triassic (? Scythian, 33/5-1), to, late Triassic (Carnian, 33/12-5).

Depositional environment:
The formation is probably of continental origin, and the sandstones may include both fluvial and eolian deposits. The finer-grained lithologies are assigned to overbank and lacustrine environments.

Lomvi Formation (new)

Name:
From the bird (English: guillemot) of the same name.

Well type section:
Norwegian well 33/12-5 (Mobil) from 3747 m to 3867 m, coord N 61°11'05.53'', E 01°51'53.34'', (Fig. 2).

Well reference section:
Norwegian well 33/5-1 (Norsk Hydro) from 3220 m to 3298 m, coord N 61°44'46.10'', E 01°34'47.40'' (Fig. 3).

Thickness:
120 m in the type well, 78 m in the reference well.

Lithology:
The Lomvi Formation consists of fine to coarse-grained kaolinitic sandstone with subordinate and thin red marls and claystones. The sandstones, which are light brown, grey or white, are generally more coarse-grained in the reference well than in the type well.

Boundaries:
The lower boundary represents the transition from interbedded sandstones and marls to the coarse-grained sandstones of the Lomvi Formation. The upper boundary, in the Statfjord Field area, is chosen at the base of the first thick argillaceous unit belonging to the Lunde Formation. Gamma ray log patterns are more regular in the Lomvi Formation than in the overlying and underlying formations.

Distribution:
The Lomvi Formation is present in all deep wells between the Brent Field and the southern edge of the Møre Basin.

Age:
Triassic; no more precise dating available.

Depositional environment:
The Lomvi Formation most probably consists of fluvial deposits.

Lunde Formation (new)

Name:
From the bird (English: puffin) of the same name:

Well type section:
Norwegian well 33/12-2 (Mobil) from 2951 m to 4048 m, coord N 61°13'31.38'', E 01°51'25.97'', (Fig. 4).

Well reference section:
UK well 211/29-5 (Shell) from 3003 m to 4055 m. coord N 61°04'43.0'', E 01°45'46.5'', (Fig. 5).

Thickness:
1079 m in the type well, 1052 m in the reference well.

Lithology:
The formation is an interbedded sequence of very fine to very coarse-grained sandstones (2 to 10 m thick), claystones, marls and shales.

The sandstones are mainly white, pink or grey and cemented to a variable degree with kaolinite, anhydrite and carbonate. Fine-grained sandstones from the upper portion of the formation (core data from UK well 211/13-1) display small scale ripple cross stratification, bioturbation and incorporated mud clasts and mud balls. This part of the formation may also have small fining upward sequences.

The interbedded argillaceous units are dominantly red-brown claystones, siltstones and shales with thin limestones (possibly caliche). Tuff horizons are present in the lower half of the formation in the Statfjord Field area. The lowermost part of the Lunde Formation consists in the Statfjord Field area (and westward into UK waters), of a sequence which is very uniform both in lithology and thickness. It is around 300 thick and consists mainly of brick red to red brown calcareous claystones grading to marls which are normally soft, silty and micaceous. This lower sequence is easily recognisable and may eventually be separated out and assigned formation status.

Boundaries:
The base of the formation is picked at the base of the first thick claystone unit. This boundary is marked by sonic and gamma ray log breaks. The alternating lithologies of the Lunde Formation result in an irregular gamma ray response. On structural highs the top of the formation is represented by a hiatus, with Jurassic or younger strata resting on the Triassic sequence. Where the Statfjord Formation is present, the upper boundary of the Lunde Formation is placed at the change to the relatively massive clean standstone of the overlying Statfjord Formation. In the Statfjord Field area, this transition often occurs via a coarsening upward unit, clearly defined on gamma ray and sonic logs. The base of this unit is the top of the Lunde Formation. (See also the description of the Statfjord Formation).

FIGURE 2

TRIASSIC
WELL 33/12-5

TYPE WELL:
TEIST,LOMVI FORMATIONS
(HEGRE GROUP)

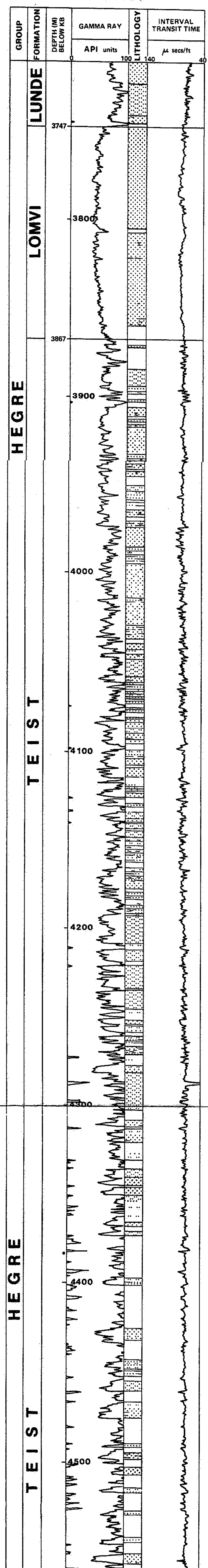


FIGURE 3

TRIASSIC
WELL 33/5-1

REFERENCE WELL:
TEIST,LOMVI FORMATIONS
(HEGRE GROUP)

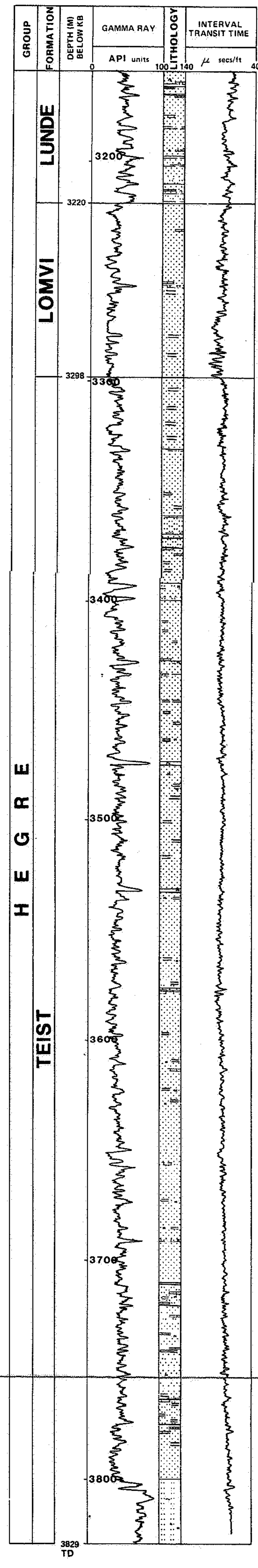


FIGURE 4

TRIASSIC
WELL 33/12-2

TYPE WELL:
LUNDE FORMATION
(HEGRE GROUP)

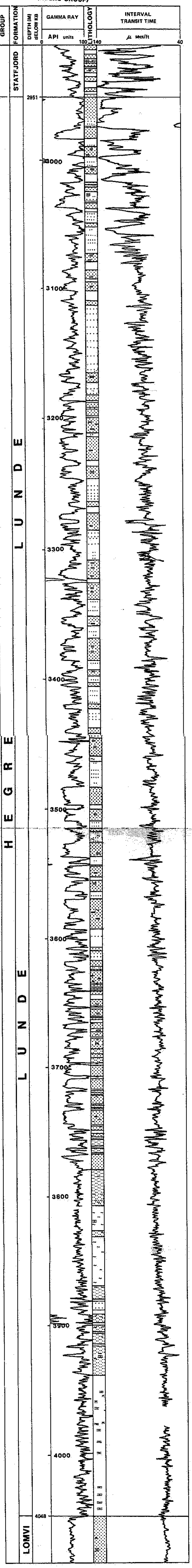
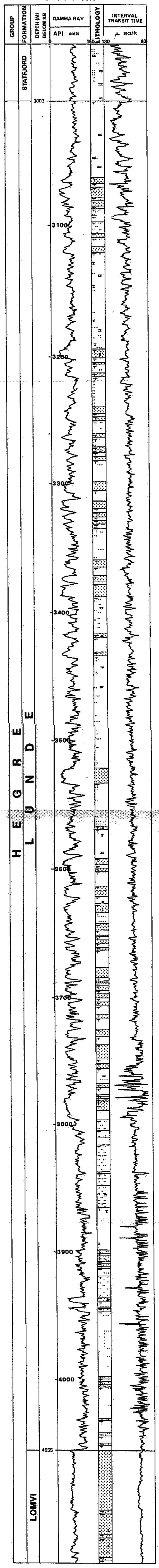


FIGURE 5

TRIASSIC
WELL UK 211/29-5

REFERENCE WELL:
LUNDE FORMATION
(HEGRE GROUP)



Distribution:
The formation is assumed to be present throughout the northern North Sea Area, although major parts may be missing on structural highs owing to erosion or non-deposition.

Age:
Late Triassic, possibly Norian to early Rhaetian age.

Depositional environment:
The Lunde Formation is dominantly of continental origin, deposited in lacustrine and fluvial environments.

JURASSIC

Basin evolution

In the Jurassic the southern Norwegian province was affected by the series of earth movements broadly grouped together as the Kimmerian tectonic episode. Rifting, with associated block faulting and erosion of the basin sediments, took place throughout Jurassic times within the general rift framework inherited from the Triassic (e.g. Ziegler 1982). Phases of more intense activity occured at the beginning and end of the Middle Jurassic, and during the Late Jurassic.

The steady rise of sea level which commenced in latest Triassic times in all probability established marine conditions throughout the study area in the early Jurassic. At the beginning of the Middle Jurassic volcanic updoming took place, centred in the region of the Forties and Piper Fields in the U.K sector (Howitt et al., 1975) with a smaller related volcanic occurrence in the Egersund Sub-Basin (Dixon et al., 1981). Associated erosion removed much of the presumed pre-existing Lower Jurassic marine cover, with the result that these sediments have only a patchy distribution south of the Egersund Sub-Basin and Ling Graben (e.g. Hamar et al., 1982). Deltaic systems built outwards radially from the volcanically updomed area during the Middle Jurassic, depositing the sands which comprise the Brent Group in the northern area (East Shetlands Basin, North Viking Graben, Horda Platform) and the basal Vestland Group in the southern area (South Viking Graben, Central Graben, Norwegian-Danish Basin).

Collapse of the updomed areas in Callovian times and rising sea levels brought the return of marine conditions to most of the study area. Shales accumulated in the basin centres while local marine sands formed on the basin flanks and around intra-basinal highs. Late Jurassic block faulting and tilting were responsible for periods of erosion and non-deposition, particularly in marginal areas. This sequence of movements continued into the early Cretaceous. The resulting unconformities and non-sequences vary in intensity and timing from area to area (Rawson and Riley 1982).

General lithostratigraphic notes

The wealth of new data which has become available since Deegan and Scull's (1977) publication has necessitated extensive revision of the Jurassic lithostratigraphic scheme in the Norwegian North Sea. The relationships between the different lithostratigraphic units are illustrated schematically in three diagrams (Table 2, 3 and 4), The changes which have been made are documented in the formal unit definitions which follow, but short notifications of the principal revisions and their accompanying problems are given below.

The Statfjord and Gassum Formation

We have not found it necessary to elevate the Statfjord Formation to group status, as has been done in the case of the later Dunlin and Brent units. The constitutent units of the Statfjord Formation (Raude, Eiriksson and Nansen Members) can only be recognised with any certainly in the "type area" west of the Viking Graben, and in fact the subdivision is often difficult to apply in that area. The sub-units therefore retain their member status. The definitions of these members are essentially unchanged from Deegan and Scull (1977) and have not been repeated here.

The Gassum Formation has been extended into the southern Norwegian offshore from onshore Denmark, where it was defined by Larsen (1966). It is acknowledged that the Gassum and Statfjord Formations are part of the same suite of late Triassic to early Jurassic continental/paralic deposits. Unification of the two units under the same name is, however, impractical. It is recognised that there may have been depositional continuity between the two units, although this continuity is at present difficult to prove. The connection, if it existed, may have been via the Stord Basin or, more probably, via the southern Viking Graben. In the part of the Viking Graben lying approximately between the Frigg and Sleipner Fields there are sparse penetrations of this lithological suite, and nomenclature is problematical. Each operator has its own preference regarding referral to the Statfjord or Gassum Formation. There is obviously no perfect solution to this problem, but we recommend for convenience that the term Gassum Formation should at present be restricted to the area south of the Ling Graben.

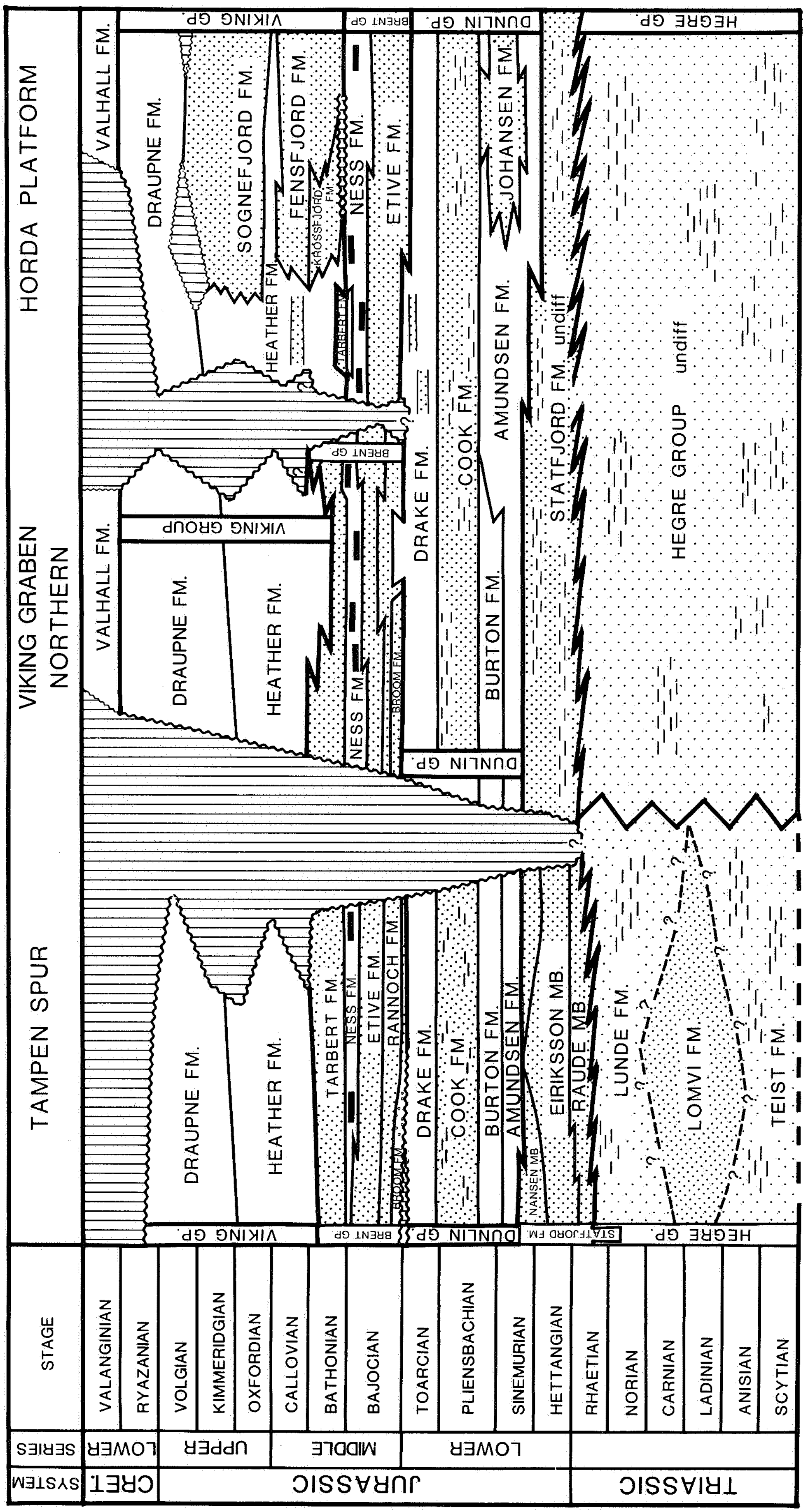


TABLE 2 TRIASSIC AND JURASSIC LITHOSTRATIGRAPHIC NOMENCLATURE NORTHERN NORTH SEA (NORTH OF APPROX. 60°N)

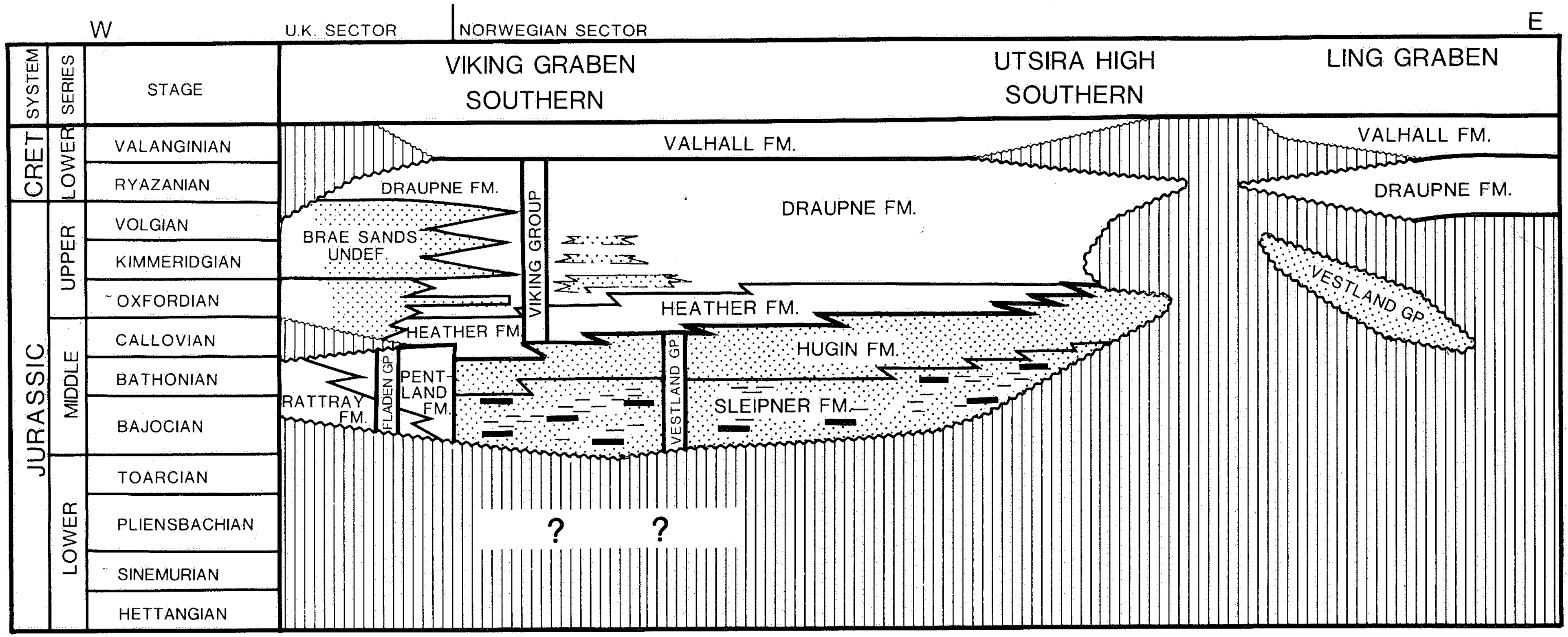


TABLE 3 JURASSIC LITHOSTRATIGRAPHIC NOMENCLATURE
SOUTHERN VIKING GRABEN – UTSIRA HIGH – LING GRABEN

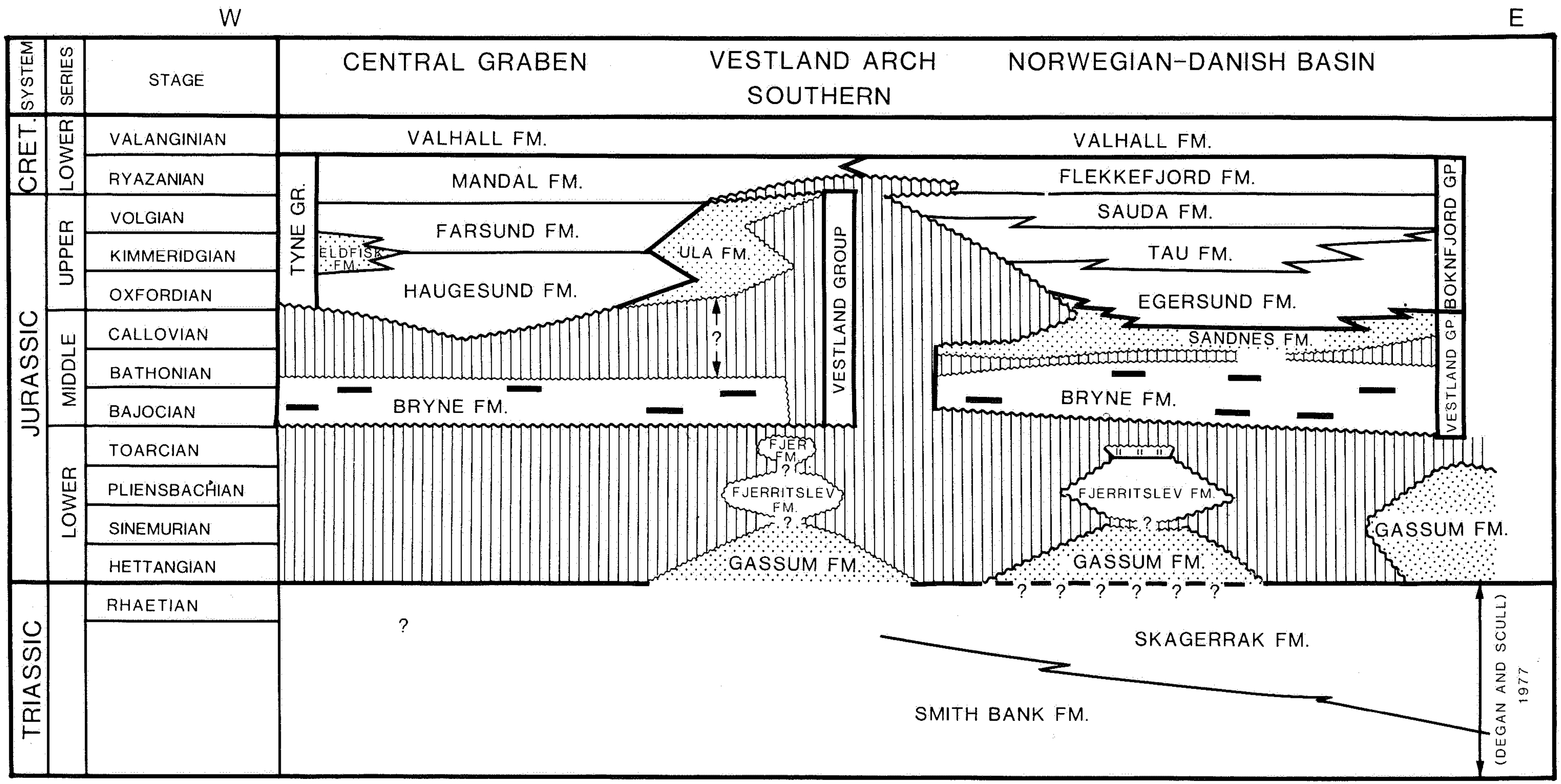


TABLE 4 JURASSIC LITHOSTRATIGRAPHIC NOMENCLATURE
CENTRAL NORTH SEA — NORWEGIAN DANISH BASIN

The Dunlin Group and Fjerritslev Formation

The Lower Jurassic Dunlin sequence is recognised as an important and widely developed unit in the northern Norwegian North Sea, and is herein reclassified from the «unit» status of Deegan and Scull (1977) to group rank. The new group includes the Amundsen, Burton, Cook and Drake Formation (fomerly "subunits") and incorporates a new unit, the Johansen Formation.

In comparing the Dunlin Group with the southern Fjerritslev Formation (also a predominantly shaly lower Jurassic sequence) we once again encounter the problem of demarcating the boundary between a unit which has been well established in the northern area (Dunlin) and one which has been extended northward from the Danish sector (Fjerritslev). In this case it seems almost certain that there was original continuity between the two units (e.g. Ziegler, 1982, Encl. 18). However, the Fjerritslev Formation of the Norwegian-Danish Basin/Southern Vestland Arch area is patchily distributed as a result of the mid-Jurassic erosional episode. It is doubtful whether physical continuity now exists with the Dunlin Group. For this reason we find it convenient to remain the bipartite nomenclature. Again the Ling Graben appears to be a practical dividing line between the two units.

The Brent and Vestland Groups

The Brent was also assigned temporary «unit» status by Deegan and Scull, and is here elevated to a group. The deltaic and marine sands of the Brent Group pass southwards, from their type area in the East Shetland Basin, into the Vestland Group. The latter group, as developed in the South Viking Graben, consists of a lower deltaic sequence (Sleipner Formation) and an upper marine sand (Hugin Formation). The absence of the basal marine sand which typifies the Brent Group serves as a means of distinguishing the Vestland Group. Although the Sleipner-Hugin sequence is genetically assignable to the Vestland Group, it is undoubtedly true that these sands form part of the same depositional "fairway" as the Brent, and we recognise that there may be a case for future incorporation of the Sleipner and Hugin Formations into the Brent Group.

The new Vestland Group is a sandy sequence of middle-late Jurassic age flanking the emergent mid-Jurassic highs of the southern Norwegian North Sea. The Bryne and Sleipner Formation comprise the lowermost deltaic developments of the group. They represent a reclassification of the Haldager Formation, extended by Deegan and Scull from the Danish sector into the Norwegian sector (see remarks on Bryne Formation). The uppermost marine sands of the group are subdivided by areal distribution into the Hugin, Sandnes and Ula Formations. Attention is drawn to the fact that "flanking" marine sands of this type are also present in the northern Norwegian sector, particularly on the Horda Platform, (e.g. Fensfjord, Krossfjord and Sognefjord Formations). The areal distribution of these sands appears, however, to be comparatively limited, and they frequently interdigitate with shales of the Heather Formation. For these reasons it is not considered suitable to separate out the sands as a group. They are therefore included, together with the late Jurassic shale units, in the Viking Group (see below). Although the Vestland Group sands also interdigitate with late Jurassic shales in places, the general sequence from deltaic sands to marine sands to marine shales is consistent in most wells.

Viking, Tyne and Boknfjord Groups

These groups refer to predominantly shale sequences of middle Jurassic to earliest Cretaceous age, and represent a complete revision of the earlier nomenclature. The Viking Group replaces the Humber Group of the Northern North Sea (Deegan and Scull 1977), while the Tyne Group encompasses the shale units of the Central North Sea (Central Graben area) a region which was not covered in detail by Deegan and Scull. Replacement of the Humber Group in the area north of the Mid-North Sea High is recognised as an important and potentially controversial modification. For the rationale behind this change, the reader is referred to the "remarks" section of the Viking Group.

The Boknfjord Group is confined to the Norwegian—Danish Basin and was erected as a result of new studies and newly available well data in the area. It includes intervals formerly assigned to the Bream and Valhall Formation (Deegan and Scull, 1977). A full discussion of this revision can be found in the formal definition of the Boknfjord Group (and its constituent formations) given in this volume.

Another significant modification which we propose is the abandonment of the "Kimmeridge Clay Formation" as an overall term for radioactive shale of late Jurassic to earliest Cretaceous age found north of the Mid-North Sea High. The "hot" shale developments of the Norwegian sector are herein referred to the Draupne, Mandal and Tau Formations, units which are more restricted areally but also more useful stratigraphically (see "Notes on lithostratigraphic procedure" and "remarks" on the Draupne Formation).

REVISED JURASSIC LITHOSTRATIGRAPHY OF THE NORWEGIAN NORTH SEA, NORTHERN AREA.

by A.G. Doré, G.P. Hamar, T. Lilleng, N.D. Shaw, O. Skarpnes and J. Vollset.

Statfjord Formation

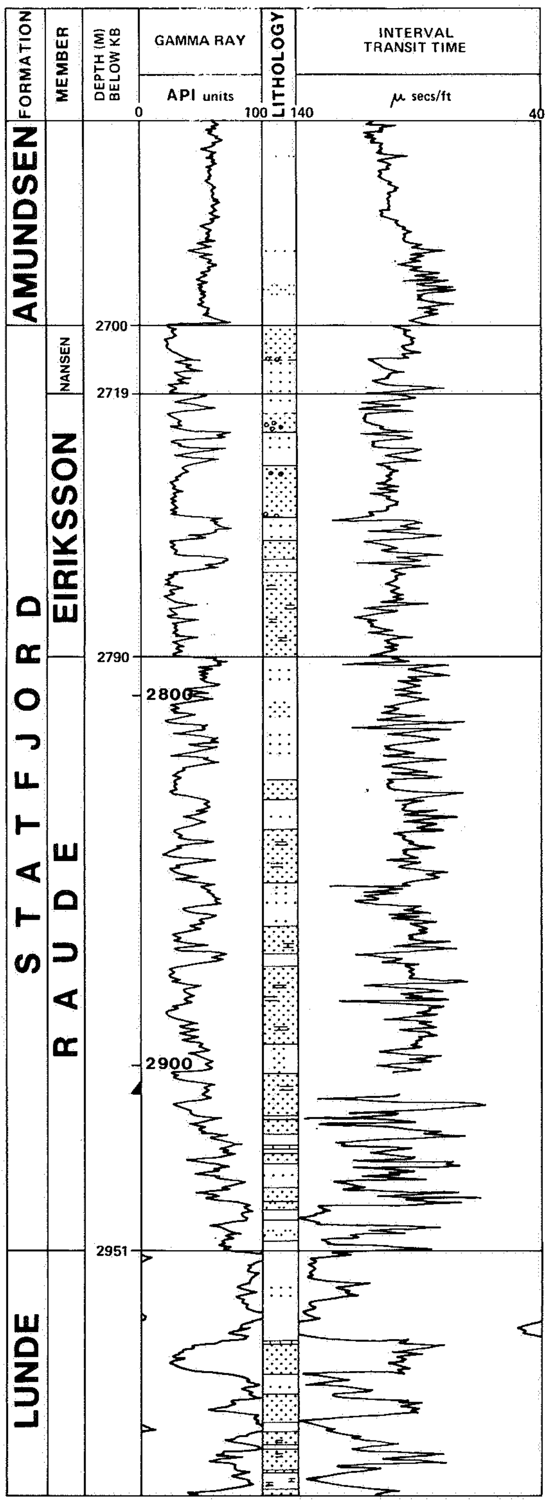
Name:
Named by Deegan and Scull (1977)

FIGURE 6

TRIASSIC/JURASSIC
WELL 33/12-2

TYPE WELL
STATFJORD FORMATION,
RAUDE AND EIRIKSSON MEMBERS
(STATFJORD FORMATION)

REFERENCE WELL:
NANSEN MEMBER
(STATFJORD FORMATION)



Well type section:
Norwegian well 33/12-2 (Mobil), from 2700 m to 2951 m, coord N 61° 13′31.18″, E 01°51′25.97″, (Fig. 6).

Well reference sections:
UK well 211/24-1 (Conoco) from 3112 m to 3434 m, coord N 61°11′46.2″, E 01°46′26.3″, (Fig. 7), and Norwegian wells 30/6-1 (Statoil), from 2712 m to 3003 m, coord N 60°33′15.10″ E 02°46′38.36″, (Fig. 8), and 25/2-5(Elf)from 3652 m to 3847 m, coord N 59°48′01.40″, E 02°28′18.30″, (Fig. 9).

Thickness:
251 m in the type well, 322 m in UK well 211/24-1, 291 m and 195 m in Norwegian wells 30/6-1 and 25/2-5 respectively. The formation is thinner on the crest of fault blocks and thicker on the downthrown side. It attains its fullest development in the central part of the Viking Graben. To the west, e.g. in the area of the Cormorant Field, only the upper member is present and this is reduced to a sandstone only a few metres in thickness. To the east, toward the bounding fault zone of the Fennoscandian Shield, the formation is reduced to tens of meters in thickness.

Lithology:
The formation exhibits a transition from continental to shallow marine sediments. In the type well area it is a transitional "coarsening upward" sequence in the basal parts consisting of grey, green and sometimes red shale interbedded with thin siltstones, sandstones and dolomitic limestones. Above are massive white to grey sandstone bodies interbedded with greenish-grey to red-brown shales. The top part of the formation consists of thick, white to grey, fossiliferous and glauconitic sandstones. On the Horda Platform, east of the Viking Graben, the formation consists of massive, white, fine to coarse grained sandstones interbedded with light grey, and sometimes red, silty micaceous, lignitic shales. Towards the east the frequency of black, coaly shales and coal layers increases.

Boundaries:
The base of the Statfjord Formation is very difficult to define, and different operators have established different boundaries. In the type well area the proposed boundary marks the base of the thin transitional unit (coarsening upward sequence), which marks the passage from the more shaly Lunde Formation of the Hegre Group to the massive sandstones of the Statfjord Formation. It should be emphasized that this transition can only be clearly recognized in some wells in the area of the Brent and Statfjord Fields. Towards the east, e.g. in the Viking Graben and the Horda Platform, the lower boundary is chosen at the base of the lowest massive sandstone unit before passing downwards into dominantly red brown shales. This

FIGURE 7

TRIASSIC/JURASSIC

UK WELL 211/24-1

TYPE WELL:
NANSEN MEMBER (STATFJORD FORMATION)

REFERENCE WELL:
RAUDE AND EIRIKSSON MEMBERS (STATFJORD FORMATION)

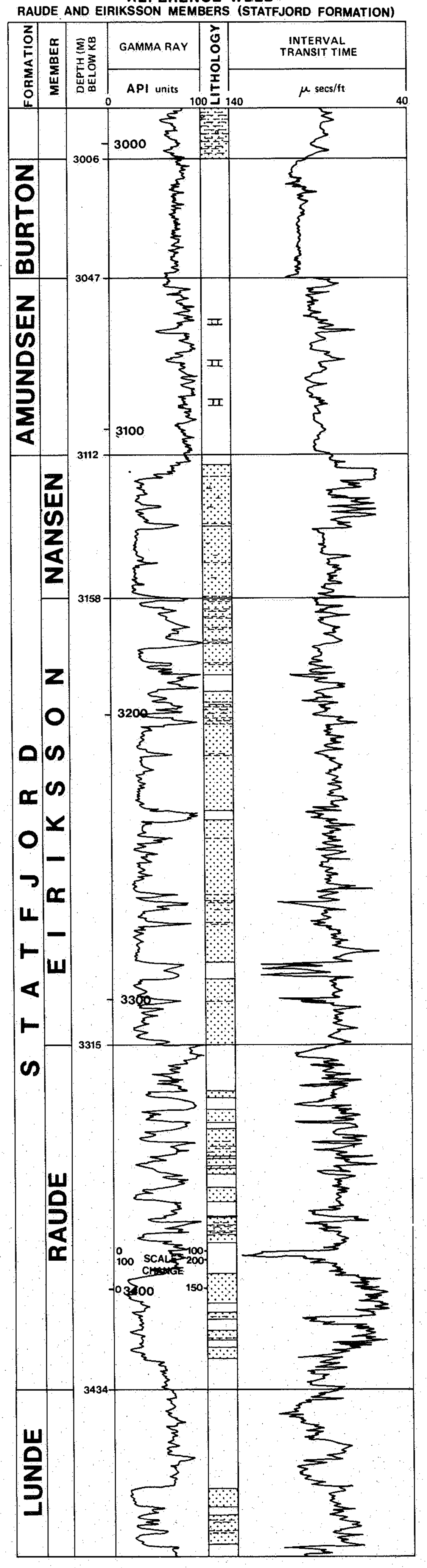
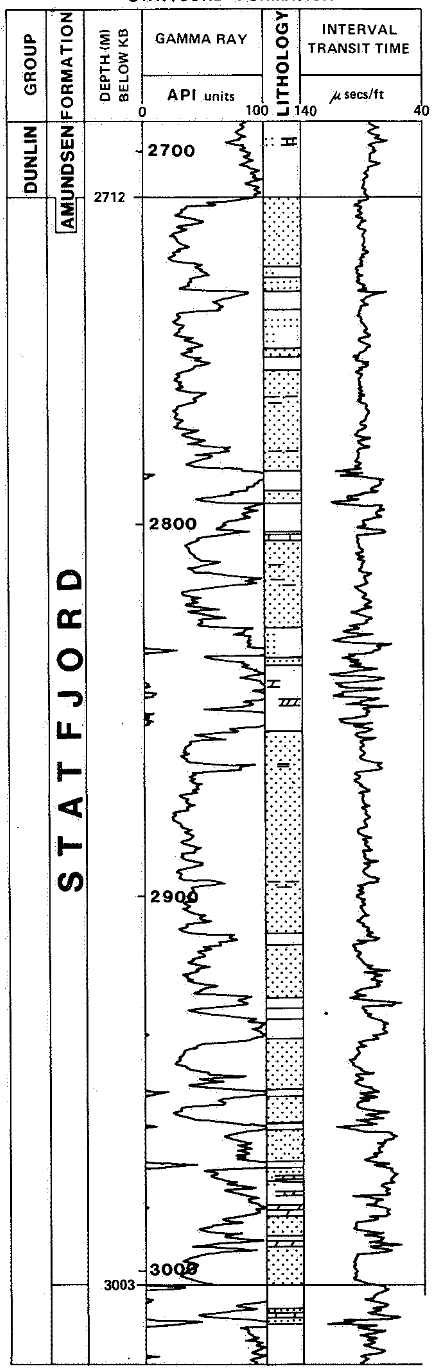


FIGURE 8

TRIASSIC/JURASSIC
WELL 30/6-1

REFERENCE WELL:
STATFJORD FORMATION



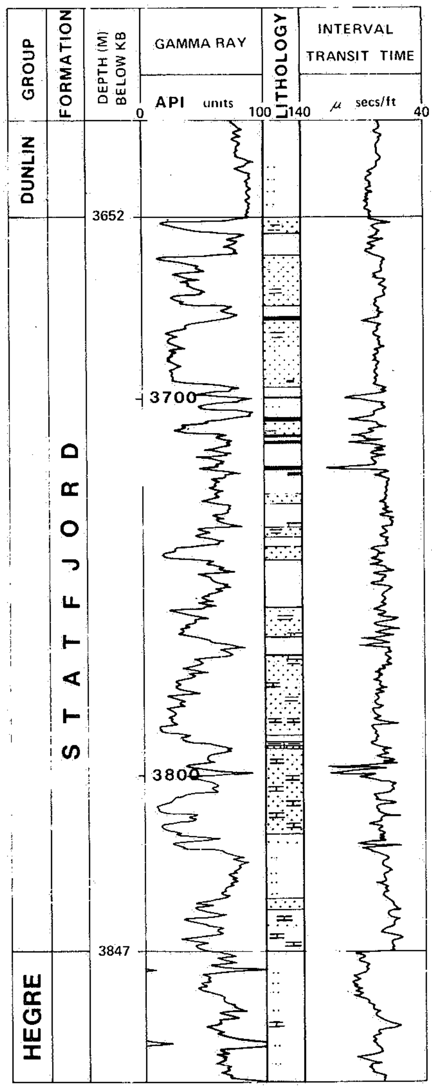
boundary is often associated with a sonic log break.

The top of the formation is at the contact between the uppermost medium to coarse-grained calcareous sandstones and the dark shales and siltstones of the overlying Dunlin Group. It should be noted that the top part of the calcareous sandstones in the UK sector (e.g. in the Brent Field and in UK part of the Statfjord Field). passes laterally into calcareous shales and siltstones in the Norwegian sector. The formation boundary, being a lithological one, however, is placed at the top of the sandstones, regardless of age.

FIGURE 9

TRIASSIC/JURASSIC
WELL 25/2-5

REFERENCE WELL:
STATFJORD FORMATION



Distribution:
The Statfjord Formation can be recognized in the entire area between East Shetland Platform to the west and the bounding fault zone of the Fennoscandian Shield to the east. The formation is identified in the Viking Graben as far south as Norwegian blocks 25/8 and 11 (e.g. in wells 25/8-1 and 2 (Esso)).

Age:
The formation ranges in age from Rhaetian to Sinemurian.

Depositional environment:
The lower transitional unit in the type well area appears to represent an upward passage from

the dominantly continental deposits of the Lunde Formation of the Hegre Group to lower alluvial plain and braided stream deposits which make up most of the Statfjord Formation (Kirk, 1979, Chauvin and Valachi, 1980). Towards the top of the formation coarse sandstones with pebble beds, crossbedding and channel structures appear to have been deposited in a coastal environment. The uppermost sandstones are relatively structureless but the presence of marine fossils and glauconite suggests a shallow marine environment (Deegan and Scull, 1977).

Subdivision:
The Statfjord Formation is divided in the type well area (Statfjord Field) into three members, the Raude Member (base) the Eiriksson Member and the Nansen Member (top). (Deegan and Scull, 1977). It should be emphasized that this subdivision can only be applied west of the Viking Graben. Even within this area application of the subdivision is often difficult. No workable subdivision has been established in the few well penetrations of the Statfjord Formation east of the Viking Graben. The currently limited scope for subdivision of the Statfjord Formation indicates that it would serve no purpose to elevate the unit to group status (c.f. the underlying Hegre and overlying Dunlin Group). For definition and detailed description of the members of the Statfjord Formation, see Deegan and Scull (op. cit).

Dunlin Group (elevated)

Name:
Named by Deegan and Scull (1977). According to earlier Norwegian usage the unit had formation status, and the type well was UK well 211/29-3. In this report the unit is given group status in Norwegian as well as UK usage.

Type area:
The type area is the East Shetland Basin, in particular the region of Brent Field. The group is illustrated in the following wells: UK well 211/29-3 (Shell), Norwegian wells 33/9-1 (Mobil), 30/6-7 (Norsk Hydro), 31/2-1 (Shell) and 25/2-4 (Elf).

Thickness:
222 m in the UK well 211/29-3, 255 m, 365.5 m, 308 m and 204 m in Norwegian wells 33/9-1. 30/6-7, 31/2-1 and 25/2-4 respectively. The group is thickest in the northern Viking Graben area.

Lithology:
The group consists mainly of dark to black argillaceous marine sediments, but in the marginal areas of the basin marine sandstones are well developed at several stratigraphic levels and can extend a considerable distance into the basin. The sandstones are white to light grey, very fine to medium grained and generally well sorted. The group tends to be more calcareous in the Norwegian sector, and in places limestone beds, some of which contain chamosite and siderite ooliths, are found.

Boundaries:
The lower boundary with the Statfjord Formation and the upper boundary with the Brent Group are clearly marked by gamma ray log breaks. The Dunlin Group generally has a more regular log caracter than the underlying and overlying sediments. In the northernmost area where the Brent Group is not recognised, the Dunlin Group is often unconformably overlain by the Viking Group.

Distribution:
The group is more widespread than the underlying Statfjord Formation and is thickest in the Viking Graben area, east of the Statfjord and Brent Fields. It is recognizable over most of the East Shetland Basin and northern part of the Horda Platform. In places the Dunlin Group rests with an apparent unconformity on the Statfjord Formation. In the western part of the basin higher formations within the group are thought to be transgressive onto pre-Statfjord Formation sediments. Variation in thickness on tilted fault blocks probably reflects syndepositional movement.

Age:
The group ranges from Hettangian to Bajocian in age.

Subdivisions:
The Dunlin Group is divided into five formations. These are named the Amundsen (base), Johansen, Burton, Cook and Drake (top) Formations and can be clearly differentiated on sonic and gamma ray logs. The Amundsen, Cook and Drake Formations are found throughout the East Shetland Basin. The Burton Formation is found over most of the area but is not present on the Horda Platform. The Johansen Formation, on the other hand, has so far only been found on the Horda Platform. It should be stressed that the upper part of the calcareous sands in the Statfjord Formation passes laterally into the lower part of the calcareous silts and shales of the Amundsen Formation in the central parts of the basin.

Amundsen Formation (elevated)

Name:
Named by Deegan & Scull (1977) who gave it "sub-unit" status.

Well type section:
UK well 211/29-3 (Shell), from 2993 m to 3051 m, coord N 61°08'06'', E 01°43'36.5 (Fig. 10).

Well reference sections:
Norwegian wells 33/9-1 (Mobil) from 2838 m to 2923 m, coord N 61°15'07.5'', E 01°50'25.8'',

FIGURE 10

JURASSIC
U.K. WELL 211/29-3

TYPE WELL:
AMUNDSEN,BURTON,COOK, DRAKE FORMATIONS
AND BROOM,RANNOCH,ETIVE,NESS, TARBERT FORMATIONS
(DUNLIN AND BRENT GROUPS)

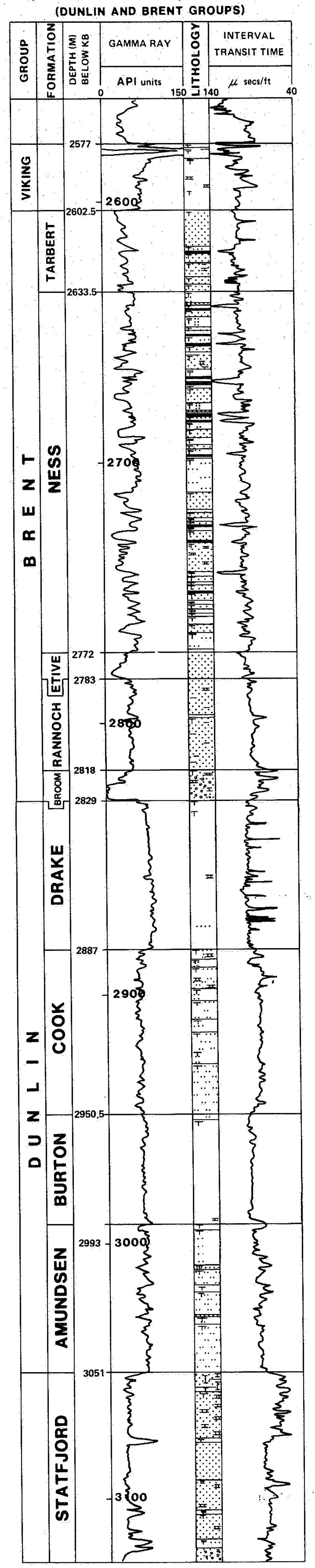


FIGURE 11

JURASSIC
WELL 33/9-1

REFERENCE WELL:
AMUNDSEN,BURTON,COOK
DRAKE FORMATIONS
(DUNLIN GROUP)
BROOM,RANNOCH,ETIVE,NESS,
TARBERT FORMATIONS
(BRENT GROUP)
HEATHER, DRAUPNE FORMATIONS
(VIKING GROUP)

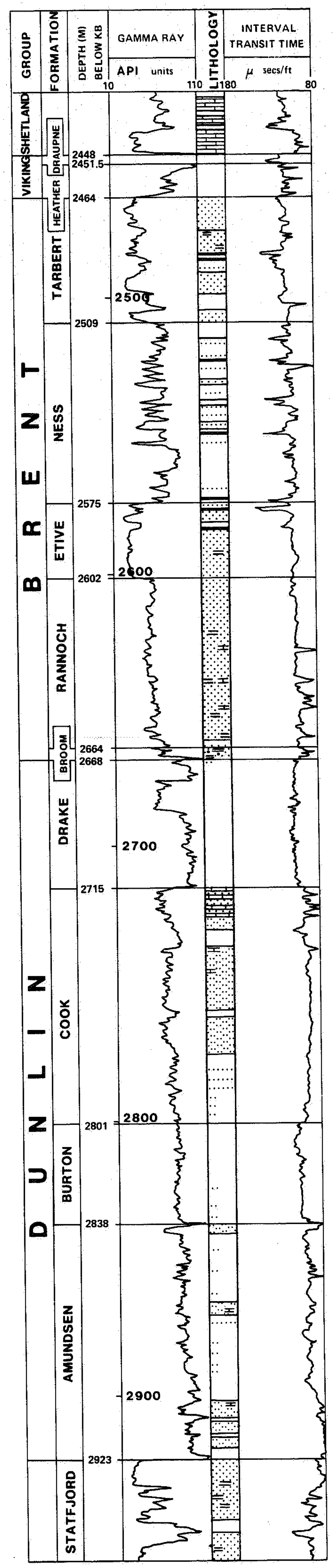
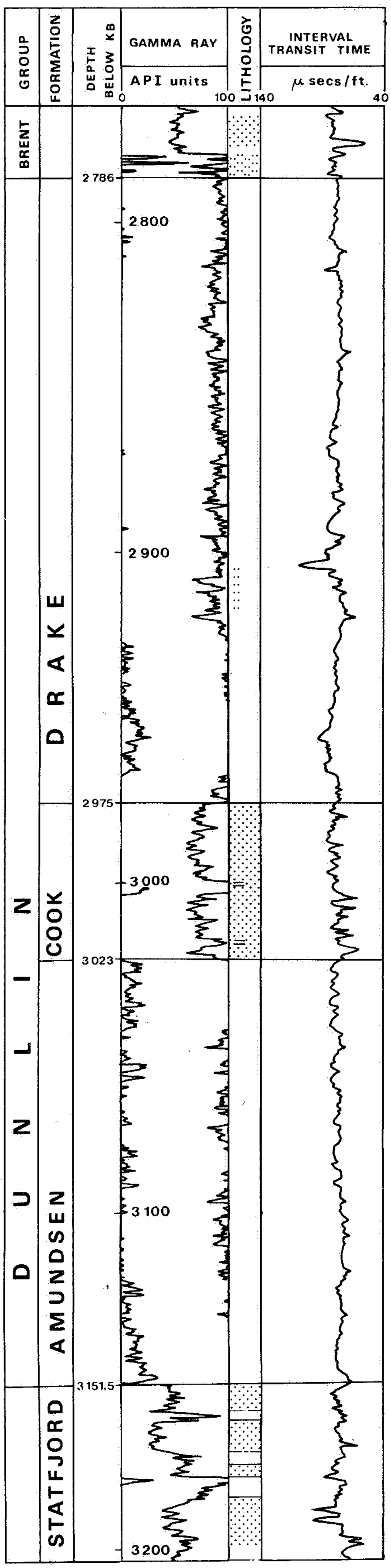


FIGURE 12

JURASSIC
WELL 30/6-7

REFERENCE WELL:
AMUNDSEN, COOK, DRAKE FORMATIONS
(DUNLIN GROUP)



(Fig. 11), 31/2-1 (Shell), from 2272.5 m to 2292.5 m and from 2134 m to 2176 m, (Fig. 13) coord N 60°46′19,16′′, E 03°33′15.87′′, and 30/6-7 (Norsk Hydro) from 3023 m to 3151,5 m, coord N 60°38′39.49′′, E 02°45′21.74′′, Fig. 12).

Thickness:
58 m in the type well, 85 m in well 33/9-1 128.5 m in well 30/6-7 and 62 m in well 31/2-1, where the formation is split by the Johansen Formation, forming an upper (42 m) and å lower (20 m) unit.

Lithology:
In the well type section the formation consists of light to dark grey, firm, non-calcareous siltstones and shales, in part carbonaceous and pyritic. Thin, fine to coarse grained, grey calcareous and glauconitic sandstone beds are present in the marginal areas of the basin. In the Norwegian sector the formation is more calcareous, especially in the lower part.

Boundaries:
The base of the formation is the base of the Dunlin Group (defined above). The top is marked by the change to the more regular gamma ray and sonic log response of the overlying Burton Formation. Where the Burton Formation is missing (on the Horda Platform), the upper boundary is the base of the Cook Formation.

Distribution:
The formation is widely distributed in the East Shetland Basin and Viking Graben north of 59°N. Towards the northwest the formation appears to overstep the Statfjord Formation and rests on the Hegre Group.

Age:
Probably Hettangian to Sinemurian or Early Pliensbachian.

Depositional environment:
The formation contains exclusively marine sediments, representing deposition on a shallow marine shelf.

Johansen Formation (new)

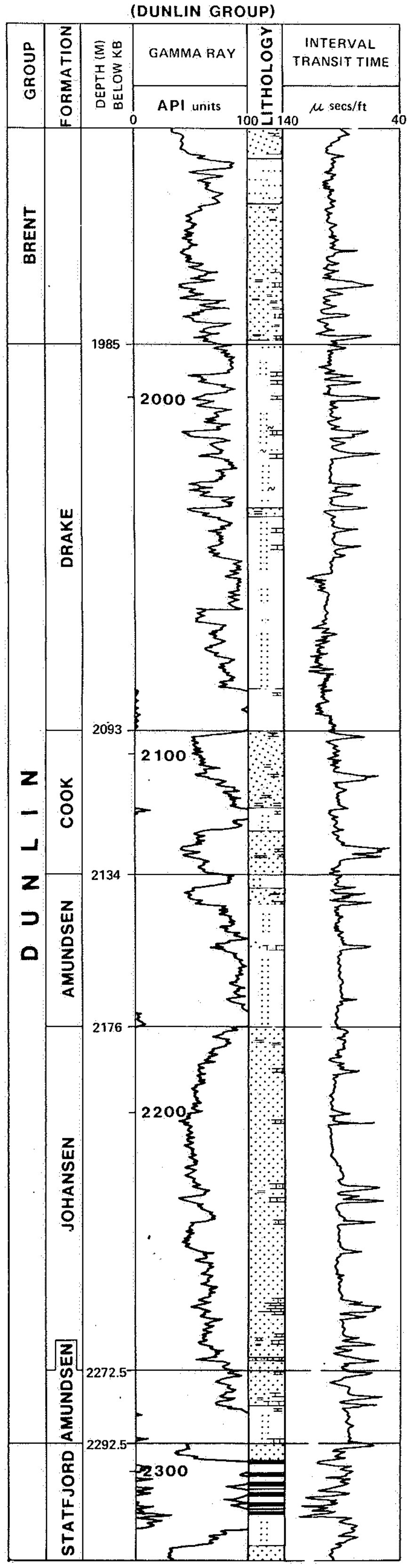
Name:
Named after Hjalmar Johansen, member of the Amundsen South Pole expedition.

Well type section:
Norwegian well 31/2-1 (Shell), from 2176 m to 2272.5 m, coord N 60°46′19.16′′, E 03°33′15.87′′, (Fig. 13).

Well reference section:
None at present.

Thickness:
95.5 m in the type well.

FIGURE 13
JURASSIC
WELL 31/2-1
TYPE WELL:
JOHANSEN FORMATION
REFERENCE WELL:
AMUNDSEN,COOK,DRAKE FORMATIONS
(DUNLIN GROUP)



Lithology:
In the type well the formation consist of a sequence of sandstones with thin calcite cemented streaks throughout. The lower part is medium to fine-grained, micaceous, well sorted sandstone which grades downwards into light grey silty micaceous claystone. The main section of the formation is composed of medium grained, friable sandstones, with well sorted quartz grains which are angular to subrounded. The uppermost part is composed of medium to fine grained, micaceous sandstones, which are moderately sorted, silty and argillaceous.

Boundaries:
In the type well area the Johansen Formation splits the Amundsen Formation. It is distinguished by a low response, crescentic gamma ray profile.

Distribution:
The formation is restricted to an area extending from the eastern part of the Horda Platform northwards to the Måløy Fault Blocks.

Age:
Sinemurian to Pliensbachian.

Depositional environment:
The formation was probably deposited on a high energy, shallow marine shelf.

Burton Formation (elevated)

Name:
Named by Deegan and Scull (1977) who gave it "sub-unit" status.

Well type section:
UK well 211/29-3 (Shell), from 2950.5 m to 2993 m, coord N 61°08'06'', E 01°43'36.5'', (Fig. 10).

Well reference section:
Norwegian wells 33/9-1 (Mobil), from 2801 m to 2838 m, coord N 61°15'07.5''
E 01°50'25.8'' (Fig. 11).

Thickness:
42.5 m in the type well and 37 m in the reference well.

Lithology:
In the type well it consists of a uniform development of dark grey to reddish-grey, soft non-calcareous claystone and shale, which may be in part slightly carbonaceous.

Boundaries:
The formation is normally represented on both gamma ray and sonic logs by smooth linear almost constant readings, reflecting the lithological uniformity. The upper and lower contacts are identified where this log character changes.

Distribution:
Although the log character changes slightly away

from the type section, the formation can be recognised over a wide area of the northern North Sea. The formation has not been identified on the Horda Platform. It represents essentially a basinal facies and passes laterally into the Amundsen Formation in marginal areas.

Age:
Sinemurian — Pliensbachian

Depositional environment:
The formation is believed to represent open marine basinal deposits.

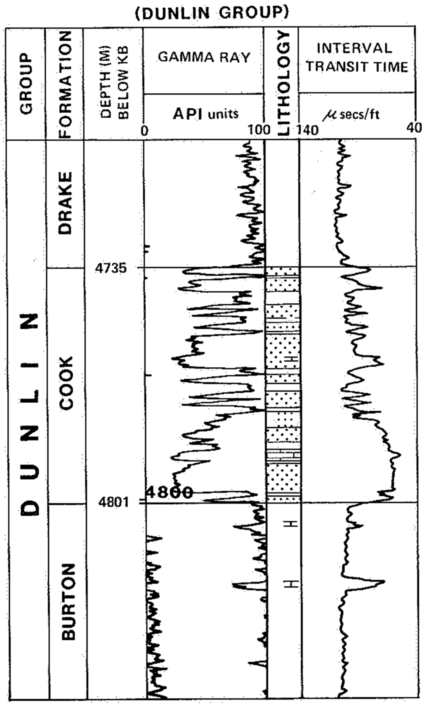
Cook Formation (elevated)

Name:
Named by Deegan and Scull (1977) who gave it "sub-unit" status.

Well type section:
UK well 211/29-3 (Shell), from 2887 m to 2950.5 m, coord N 61°08′06′′, E 01°43′36.5′′, (Fig. 10).

Well reference sections:
Norwegian wells 33/9-1 (Mobil), from 2715 m to 2801 m, coord N 61°15′07.5′′, E 01°50′25.8′′ (Fig. 11), 30/6-7 (Norsk Hydro), from 2975 m to 3023 m, coord N 60°38′39.49′′ E 02°45′21.74′′ (Fig. 12), 31/2-1 (Shell) from 2093 m to 2134 m, coord N 60°46′19.16′′ E 03°33′15.87′′ (Fig. 13), and 30/7-7 (Norsk Hydro) from 4735 m to 4801 m, coord N 60°16′19.30′′, E 02°16′07.30′′, (Fig. 14).

FIGURE 14
JURASSIC
WELL 30/7-7
REFERENCE WELL:
COOK FORMATION
(DUNLIN GROUP)



Thickness
63.5 m in the type well, 86 m in 33/9-1, 66 m in 30/7-7, 48 m in 30/6-7 and 41 m in 31/2-1.

Lithology:
In the type well section the formation is dominantly a marine siltstone with minor grey, silty claystone intercalations. The siltstones and claystones may contain sandy streaks, becoming more prominent away from the type well, especially in Norwegian waters. On the Horda Platform and along its western margin, sandstones are the dominant lithology in the formation. The sands are white to greyish brown, very fine to fine grained, subangular to subrounded and well sorted. Occasionally thin layers of medium to coarse grained sandstones are found. The sandstones are hard to friable. Silica is the most common cement. Mica, glauconite, carbonaceous material and calcareous cement may be present.

Boundaries:
The formation can be distinguished from the more uniform and more argillaceous sediments above and below by a decrease in gamma ray response and an increase in velocity.

Distribution:
The formation appears to be present throughout the East Shetland Basin and on the northern part of the Horda Platform.

Age:
Pliensbachian — Toarcian.

Depositional environment:
The sandstones can be divided into three types, related to depositional environment and basin geometry. In the Statfjord Field area the sandstones are believed to represent marine shoal sands (e.g. ref. well 33/9-1). On the Horda Platform and along its western margin the sandstones represent prograding shelf sands and several cycles can be identified within the formation (ref. 31/2-1 and 30/6-1). In the graben area the sands are thinner bedded, and the shale intercalations show no gradations into the sands (ref 30/7-7). These sandstones are believed to represent redeposited sands from the edge of the shelf (the Horda Platform and East Shetland Basin west of the graben area).

Drake Formation (elevated)

Name:
Named by Deegan and Scull (1977) who gave it "sub-unit" status.

Well type section:
UK well 211/29-3 (Shell), from 2829 m to 2887 m, coord N 61°08′06′′, E 01°43′36.5′′, (Fig. 10).

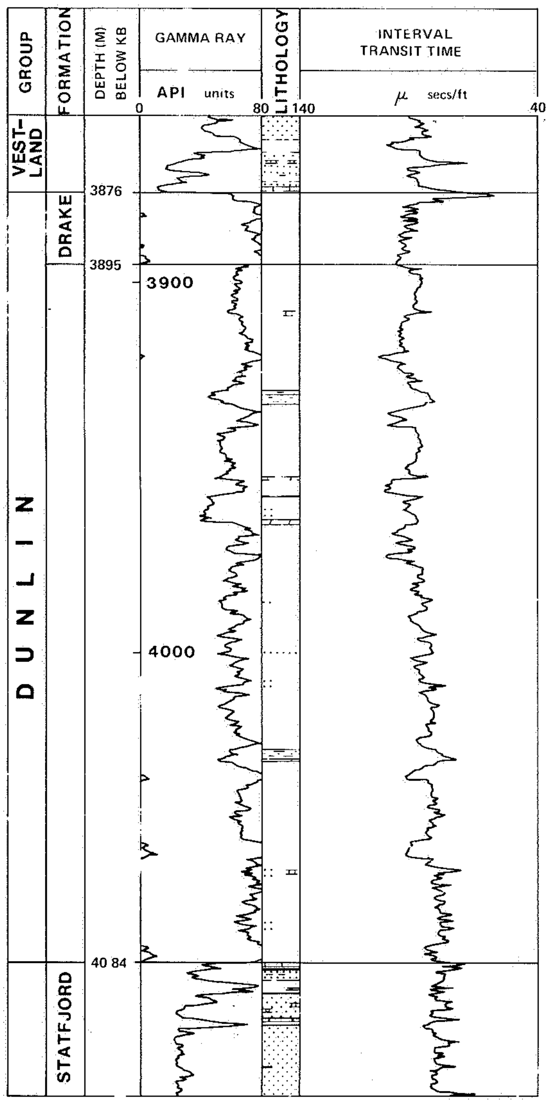
Well reference sections:
Norwegian wells 33/9-1 (Mobil) from 2668 m to 2715 m, coord N 61°15′07.5′′ E 01°50′25.8′′

(Fig. 11), 30/6-7 (Norsk Hydro) from 2786 m to 2975 m, coord N 60°38′39.49′′ E 02°45′21.74′′
(fig. 12), 31/2-1 (Shell) from 1985 m to 2093 m, coord N 60°46′19.16′′ E 03°33′15.87′′ (Fig. 13), 25/2-4 (Elf) from 3876 m to 3895 m N 59°58′44.09′′, E 02°22′58.88′′ (Fig. 15).

FIGURE 15

JURASSIC
WELL 25/2-4

REFERENCE WELL:
DRAKE FORMATION
(DUNLIN GROUP)



Thickness:
58 m in the type well, 47 m in 33/9-1, 189 m in 30/6-7, 108 m in 31/2-1 and 19 m in 25/2-4.

Lithology:
In the type well the lower part of the formation consists of medium grey, slightly sandy, calcareous claystone. The upper part is dark grey to black, fissile, micaceous shale containing calcareous nodules. On the Horda Platform and along its western margin white to grey, fine to coarse sandstones are found within the formation. The sandstones are often hard and calcite cemented. They also show and "upward coarsening" on the gamma ray log. The claystone is often silty.

Boundaries:
In the basinal areas, where the sandstones are not present, the formation has more regular gamma ray and sonic log responses than that of the underlying formation, the gamma ray response being uniformly higher and the velocity lower. The lower velocity is also apparent where sandstone beds are present. The upper boundary is marked by the presence of arenaceous sediments of the overlying Brent Group, and the upper boundary is placed at the base of the upward coarsening sequence of the Rannoch Formation of the Brent Group. The Brent Group shows a more erratic sonic log pattern than the Drake Formation. In the south the top of the formation is marked by an unconformity (e.g. well 25/2-4, Fig. 15). In the northernmost area where the Brent Group is not recognised, the Dunlin Group is often unconformably overlain by the Viking Group.

Distribution:
The formation is widely distributed throughout the East Shetland Basin and northern Horda Platform. It thins towards the west and south, where it may be absent due to erosion. The sand developments within the formation seem to be a function of marginal position within of the basin.

Age:
Toarcian - Bajocian

Depositional environment:
The Drake Formation is generally considered to have been deposited in prodelta and delta front environments.

Brent Group (elevated)

Name:
Named by Deegan and Scull (1977). According to Norwegian usage the unit earlier had formation status and the type well was UK well 211/29-3 (Shell). In this report the unit is given group status, also, in the Norwegian sector.

Type area:
The type area is the East Shetland Basin. In this report the following wells are used to illustrate the Brent Group: UK well 211/29-3 (Shell), Norwegian wells 33/9-1 (Mobil), 30/6-7 (Norsk Hydro) and 31/4-4 (Norsk Hydro).

Thickness:
The thickness of the group varies considerably. In UK well 211/29-3 (Brent Field) it is 226.5 m, while the Norwegian well 33/9-1 in the Statfjord Field has 204 m of Brent Group sedi-

ments. Wells used to illustrate the group on and around the Horda Platform have thicknesses between 159 m (30/6-7) and 78 m (31/4-4). Thicknesses of 200 m or more are present to the north in quadrant 35.

Lithology:
The group consists of grey to brown sandstones, siltstones and shales with subordinate coal beds and conglomerates.

Boundaries:
In the Brent-Statfjord area the group normally rests with a minor disconformity on the predominantly argillaceous Dunlin Group. To the west and in the southern Viking Graben it cuts down onto lower levels within the Dunlin Group. On the Horda Platform the lower boundary is either picked at the base of a "coarsening upward" log motif, with underlying marine shales, or at the base of a homogenous sandstone with a "blocky" log appearance. The upper boundary of the Brent Group may vary in nature due to post-middle Jurassic tectonism and erosion. Variable amounts of the group may be missing, particulary, towards the crests of tilted fault blocks, but the contact is nevertheless easy to pick where the sandy Brent Group is overlain by Heather Formation shales.

Distribution:
The Brent Group is recognizable over most of the East Shetland Basin and the northern part of the Horda Platform. It passes southwards into the Vestland Group south of the Frigg Field area. The absence of the basal marine sandstones is considered to be the distinguishing feature of the Vestland Group. Northwards, the Brent Group shales out within the East Shetland Basin between 61°30′ N and 62°N.

Age:
Mainly Bajocian to Early Bathonian but including Late Toarcian to the east.

Subdivision:
The group is divided into five formations. These are: the Broom (base), Rannoch, Etive, Ness and Tarbert (top) Formations. According to Norwegian usage, the units earlier had a member status (Deegan and Scull, 1977). In this report it is proposed to give the units formation status also in the Norwegian sector. All formations are recognizable in the Brent-Statfjord area. However, difficulties are met when moving away from the type area. On the Horda Platform the Broom Formation appears to be absent, and the presence of the Rannoch Formation is under debate.

Broom Formation (elevated)

Name:
Named by Deegan and Scull (1977) who gave it "sub-unit" status.

Well type section:
UK well 211/29-3 (Shell), from 2818 m to 2829 m, coord N 61°08′06′′, E 01′43′36.5′′, (Fig. 10).

Well reference section:
Norwegian well 33/9-1 (Mobil), from 2664 m to 2668 m, coord N 61°15′07.5′′, E 01°50′25.8′′ (Fig. 11).

Thickness:
11 m in the type well and 4 m in 33/9-1. In the Brent-Statfjord area it varies from a few meters to about fifteen meters in thickness.

Lithology:
In the type well it is a pale grey to brown, coarse-grained poorly sorted conglomeratic sandstone containing shale clasts.

Boundaries:
The Broom Formation is distinguished from the underlying Dunlin Group and the overlying Rannoch Formation by its irregular, but generally lower, gamma ray readings.

Distribution:
The Broom Formation is easily identified in the Brent—Statfjord area. In parts of the East Shetland Basin a thin distal equivalent of the Broom Formation is present within the shales of the Drake Formation.

Age:
Late Toarcian to Bajocian.

Depositional environment:
The Broom Formation is a shallow marine deposit, and is a precursor of the regression which characterizes the overlying Rannoch Formation.

Rannoch Formation (elevated)

Name:
Named by Deegan and Scull (1977) who gave it "sub-unit" status.

Well type section:
UK well 211/29-3 (Shell), from 2783 m to 2818 m, coord N 61°08′06′′, E 01°43′36.5′′, (Fig. 11).

Well reference section:
Norwegian well 33/9-1 (Mobil), from 2602 m to 2664 m, coord N 61°15′07.5′′, E 01°50′25.8′′, (Fig. 11).

Thickness:
35 m in the type well and 62 m in 33/9-1.

Lithology:
In the type well the formation is a light brown, fine grained, well sorted, friable, very micaceous sandstone. In the Brent Field area the lower part is more argillaceous with siltstones and thin shales.

Towards the top the formation tends to be coarser grained and less micaceous, often resulting in a distinctive gamma ray pattern suggesting a "coarsening upward" sequence. Some workers consider that the Rannoch Formation is occasionally represented on the Horda Platform by one or more such coarsening upward cycles. However, in the majority of cases these cannot be observed and the presence of the Rannoch Formation must be considered debatable.

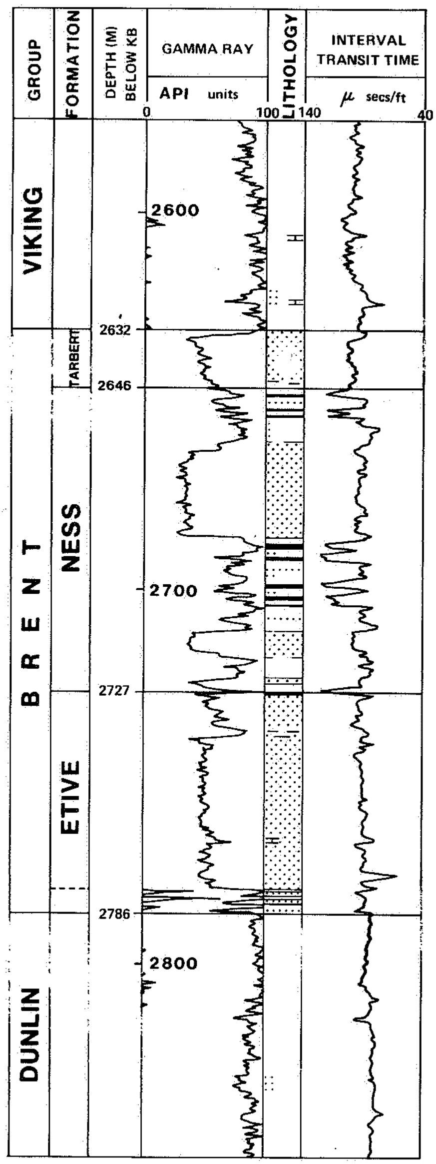
Boundaries:
The high mica content of the sandstone produces an anomalously high gamma ray log response and generally distinguishes the Rannoch Formation from the overlying and underlying sandstones. Where the Broom Formation is missing the lower boundary is gradational into the dark, silty shales of the Dunlin Group. The upper boundary is normally defined by the "blocky" gamma ray log of the overlying Etive Formation.

Distribution:
The distribution of the Rannoch Formation is essentially the same as that of the Brent Group, except on the Horda Platform where the presence of the formation is under debate (see "lithology").

Age:
Late Toarcian to Bajocian.

Depositional environment:
The formation is generally interpreted as delta front sheet sands and/or prograding shoreface sands.

FIGURE 16
JURASSIC
WELL 30/6-7
REFERENCE WELL:
ETIVE, NESS AND TARBERT FORMATIONS
(BRENT GROUP)



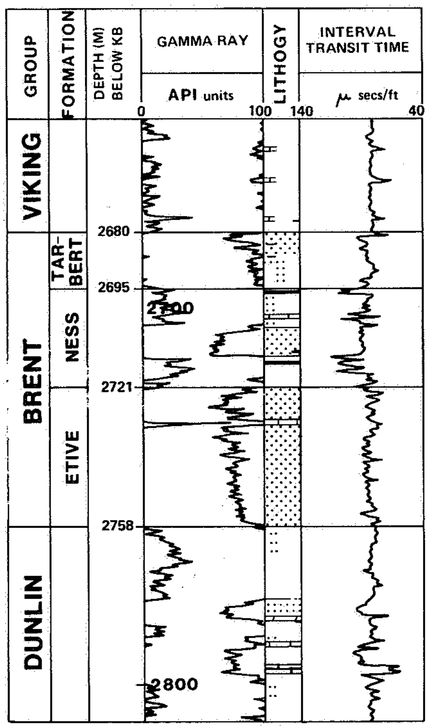
Etive Formation (elevated)

Name:
Named by Deegan and Scull (1977) who gave it «sub-unit» status.

Well type formation:
UK well 211/29-3 (Shell), from 2772 m to 2783 m, coord N 61°08′06′′, E 01°43′36.5′′ (Fig. 10).

Well reference sections:
Norwegian wells 33/9-1 (Mobil), from 2575 m to 2602 m, coord N 61°15′07.5′′

FIGURE 17
JURASSIC
WELL 31/4-4
REFERENCE WELL:
ETIVE, NESS, TARBERT FORMATIONS
(BRENT GROUP)



E 01°50'25.8'' (Fig. 11) 30/6-7 (Norsk Hydro), from 2727 m to 2786 m, coord N 60°38'39.49'' E 02°45'21.74'' (Fig. 16), and 31/4-4 (Norsk Hydro) from 2721 m to 2758 m, coord N 60°40'01.12'', E 03°06'54.12'', (Fig. 17).

Thickness:
11 m in the type well, 27 m in 33/9-1, 59 m in 30/6-7 and 37 m in 31/4-4.

Lithology:
The formation consists of massive grey-brown to clear, fine to coarse, occasionally pebbly and cross-bedded sandstones. The mica-content is generally low. Calcite cemented stringers are also present, especially on the Horda Platform.

Boundaries:
The formation is characterised by low gamma ray readings. This characteristic and the low mica content distinguish it from the underlying Rannoch Formation. The lower boundary may, however, be transitional in places. The formation is often found to cut into and occasionally through the underlying formations, thus giving a «blocky» gamma ray log character either above a truncated Rannoch Formation, or directly above marine shales of the Dunlin Group (ref. well 31/4-4). The upper boundary is taken at the first significant shale or coal in the overlying Ness Formation.

Distribution:
The distribution of the Etive Formation is essentially the same as that of the Brent Group.

Age:
Bajocian

Depositional environment:
The formation has been interpretated as upper shoreface, barrier bar, mouth bar and distributary channel deposits.

Ness Formation (elevated)

Name:
Named by Deegan and Scull (1977) who gave it "sub-unit" status.

Well type section:
UK well 211/29-3 (Shell), from 2633.5 m to 2772 m, coord N 61°08'06'', E 01°43'36.5'', (Fig. 10).

Well reference sections:
Norwegian wells 33/9-1 (Mobil), from 2509 m to 2575 m, coord N 61°15'07.5'' E 01°50'25.8'', (Fig. 11), 30/6-7 (Norsk Hydro) from 2646 m to 2727 m, coord N 60°38'39.49'' E 02°45'21.74'', (Fig. 16), and 31/4/4 (Norsk Hydro) from 2695 m to 2721 m, coord N 60°40'01.12'', E 03°06'54.12'', (Fig. 17).

Thickness:
138.5 m in the type well, 66 m in 33/9-1, 81 m in 30/6-7 and 26 m in 31/4-4.

Lithology:
The formation consists of an association of coals, shales, siltstones and very fine to medium grained sandstones. The formation is carbonaceous throughout and contains numerous rootlet horizons. Small scale cross-bedding and horizontal bedding are common. Synsedimentary deformation is frequently observed. The shales are silty, fissile and frequently pyritic. The formation occasionally shows some marine influence. Coarsening and fining upward sequences are common features. The varied lithology produces an irregular but distinctive gamma ray and sonic response.

Boundaries:
The lower boundary defines the top of the Etive Formation (see above). The upper contact is marked by the change to the more massive cleaner sandstone of the overlying Tarbert Formation. This upper contact may be a minor disconformity.

Distribution:
The distribution of the Ness Formation is essentially the same as that of the Brent Group.

Age:
Bajocian.

Depositional environment:
The formation is thought to represent delta plain or coastal plain deposition.

Tarbert Formation (elevated)

Name:
Named by Deegan and Scull (1977) who gave it "sub-unit" status.

Well type section:
UK well 211/29-3 (Shell), from 2602.5 m to 2633.5 m, coord N 61°08'06'', E 01'36.5'', (Fig. 10).

Well reference sections:
Norwegian wells 33/9-1 (Mobil), from 2464 m to 2509 m, coord N 61°15'07.05'' E 01°50'25.8'' (Fig. 11), 31/4-4 (Norsk Hydro) from 2680 m to 2695 m, coord N 60°40'01.12'' E 03°06'54.12'' (Fig. 17) and 30/6-7 (Norsk Hydro) from 2632 m to 2646 m, coord N 60°38'39.49'', E 02°45'21.74'', (Fig. 16).

Thickness:
31 m in the type well, 45 m in 33/9-1, 15 m in 31/4-4 and 14 m in 30/6-7.

Lithology:
In the type well section it consists of grey to brown relatively massive fine to medium grained sandstone with subordinate thin siltstone, shale and coal beds and some calcareous bands. On the Horda Platform the formation usually constitutes one or more "coarsening upward" sequences of fine to medium, occasionally coarse, micaceous

and carbonaceous sandstones, which become increasingly silty and argillaceous downward. Stringers of calcite cemented sandstone and coal beds occur in this area.

Boundaries:
The base of the formation is taken at the top of the last "fining upward unit of the Ness Formation, i.e. at the top of an argillaceous bed or coal-bed. The upper boundary coincides with the top of the Brent Group (see above).

Distribution:
The distribution of the formation is not known in detail, but is usually well developed within the western part of the East Shetland Basin, including the central and western part of the Viking Graben. The formation has a sporadic distribution on the Horda Platform.

Age:
Bajocian to Bathonian

Depositional environment:
The environment of deposition of the formation was marginal marine. In places it may rest with minor disconformity on the coaly Ness Formation (Hodson, 1975), and possibly in part represents reworked delta plain deposits at the onset of the marine transgression which deposited the overlying Upper Jurassic argillaceous sediments. sediments.

Viking Group (new)

Name:
Taken from the Viking Graben where the group attains maximum development. It replaces the Humber Group, extended into the Northern North Sea by Deegan and Scull (1977).

Type area:
The type area is the Northern North Sea north of 58° N and east of the East Shetland Platform boundary faults. In this report the following wells are used to illustrate the Viking Group: UK well 211/21-1A (Shell) and Norwegian wells 33/9-1 (Mobil), 31/2-1 (Shell) and 15/3-1 (Elf).

Thickness:
The thickness of the group may vary considerably since the sediments were deposited on a series of tilted fault blocks produced by predepositional and syndepositional tectonic activy. The measured thicknesses vary from a few metres up to 1039 metres. The thicknesses of the above selected wells are 110.5 m (21/21-1A), 21 m (33/9-1), 210 m (31/2-1) and 1039 m (15/3-1).

Lithology:
In the type area the group consists of dark, grey to black, marine mudstones, claystones and shales. Locally these argillaceous sediments are replaced by sandstones and occasionally conglomerates.

Boundaries:
In the type area, the lower boundary is marked by the distinct contrast between the fine grained sediments and the sands of the Brent and Vestland Groups. In the northernmost area (between approximately 61°30' N and 62°N) where the Brent Group is not recognized, the Viking Group is often unconformable on the Dunlin Group.

The upper boundary of the group in most wells in the Northern North Sea is an unconformity, normally overlain by higher velocity and lower radioactivity Cretaceous to Paleocene sediments.

Distribution:
The group is distributed as defined under the type area.

Age:
The group ranges from Bathonian to Ryazanian in age. The group is approximately time equivalent to the new Boknfjord Group of the Norwegian-Danish Basin (Norwegian sector), and the new Tyne Group of the Central Graben (Norwegian sector).

Subdivision:
Five formations are defined within the group in the Norwegian sector. The Heather and Draupne Formations are widely distributed. However, the Krossfjord, Fensfjord and the Sognefjord Formations, which represent marginal sandy developments, are more restricted.

Elsewhere within the group thick local sandstones and conglomerates occur (Brennand and Siri, 1975), which are not given any formal status in this report. They are described from the Magnus area by De' Ath and Schuyleman (1981) and from the Brae area by Harms et al. (1980, 1981).

Remarks:
The Norwegian Lithostratigraphic Nomenclature Commitee formally proposes substitution of the names "Tyne Group" in the Northern ben area and «Viking Group» in the Northern North Sea for intervals formerly termed the "Humber Group".

The name "Humber Group" was first proposed by Rhys (1974) for the Middle-Late Jurassic claystones in the Southern North Sea. Deegan and Scull (1977) extended the usage to the Northern North Sea where three formations were recognised, namely the Heather, Kimmeridge Clay and Piper Formations. The Piper Formation is restricted to the area around the Piper Field, while the two other formations are widely distributed.

Recognition of three Middle Jurassic to earliest Cretaceous «claystone» formations in the Central Graben area, none of which can alone be referred to the Heather Formation has led us to restrict the Heather Formation to the part of the North Sea north of 58°N (e.g. Ofstad 1983, and this report). We have further recommended restriction of the term «Kimmeridge Clay Formation» to the area south of the Mid-North Sea

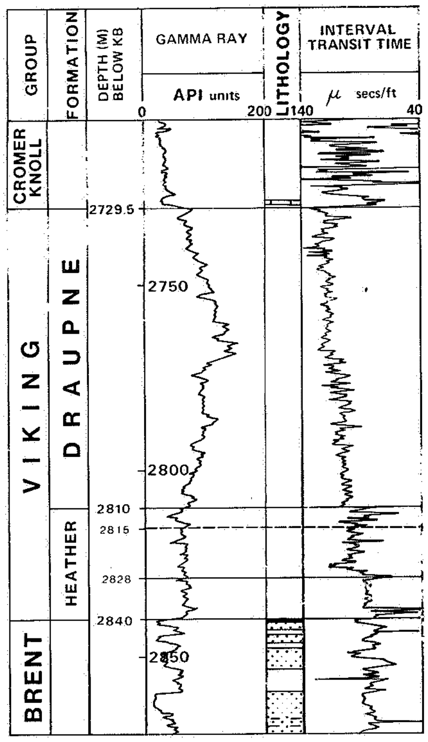
High and its replacement by local nomenclature in both the Central Graben and the Northern North Sea (see "Remarks" on the Draupne Formation).

The differences in mode of subdivision which exist between the Northern North Sea, the Central Graben and the type area of the Southern North Sea would, perhaps, not alone constitute grounds for replacement of the Humber Group with more localized group names. However, there is a major conceptual difference between the northern and southern Norwegian North Sea in the way the «group» is defined. In the north, the practise of Deegan and Scull of including the marginal sands (e.g. Piper Formation) in the group has been continued with units such as the Sognefjord Formation. In the south it was found to be practical and convenient to separate out the marginal sands as the Vestland Group. This suggested to the subcommittees the desirability of erecting locally defined units (Viking and Tyne Groups) to replace the Humber Group, a term which was in any case becoming unwieldy and virtually a synonym for the Upper Jurassic. We nevertheless recognise the unifying concept of an «Upper Jurassic claystone» suite throughout the North Sea, reflecting the general transgressive nature of the epoch. This overall character could perhaps be expressed as a "Humber Supergroup", although we have not for the present made this a formal proposal.

FIGURE 18

JURASSIC
UK WELL 211/21-1A

TYPE WELL:
HEATHER FORMATION (VIKING GROUP)
REFERENCE WELL:
DRAUPNE FORMATION (VIKING GROUP)



Heather Formation

Name:
Named by Deegan and Scull (1977).

Well type section:
UK well 211/21-1A (Shell), from 2810 m to 2840 m, coord N 61°11'9.6'', E 01°06'5.7'', (Fig. 18).

Well reference sections:
Norwegian wells 33/9-1 (Mobil), from 2450 m to 2464 m, coord N 61°15°07.5'' E 01°50'25.8'' (Fig. 11), 31/2-1 (Shell) from 1531.5 m to 1594.5 m, coord N 60°46'19.16'°.
E 03°33'15.87'' (Fig. 21), and 15/3-1 (Elf) from 4754 m to 4986 m, coord N 58°50'57.0'', E 01°43'13.25'', (Fig. 19).

Thickness:
30 m in the type well, but attains thicknesses in the order of a thousand metres in graben areas. In the reference wells the thicknesses are 14 m (33/9-1), 63 m (31/2-1) and 232 m (15/3-1).

Lithology:
The formation consists of mainly of grey silty claystone with thin streaks of limestone. A further subdivision of the formation is possible (Fig. 18), although no formal status is proposed for this subdivision. Two divisions are commonly recognized. The lower division is light to dark grey, hard, silty claystone, often micaceous and calcareous. The upper division is separated into two further units by an unconformity detected by dipmeter data or biostratigraphical gaps, but no distinct lithological difference is noted. The lithology is dark grey silty claystone, carbonaceous in part with limestone streaks. (For further discussion see Deegan and Scull (1977) p. 18). On the Horda Platform where the Heather Formation interdigitates with sandstones of the Krossfjord, Fensfjord and Sognefjord Formations, it becomes in places highly micaceous and may grade into a sandy siltstone.

Boundaries:
The lower boundary is the contact with the arenaceous Brent Group. The upper boundary is the contact with the Draupne Formation, which has an anomalously high gamma ray response and low velocity. Both boundaries are therefore marked by log breaks.

Distribution:
The formation can be recognized over most of the northern North Sea north of 58°N and east of the East Shetland Platform boundary faults.

Age:
Bathonian to Kimmeridgian.

Depositional environment:
The silty claystones of the Heather Formation were deposited in an open marine environment, brought about by the marine transgression which initially deposited the youngest formation of the Brent group.

Remarks:
Use of the Heather Formation is here restricted to the part of the North Sea north of approximately 58°N. Deegan and Scull (1977) indicated the presence of the formation in the Central Graben, but did not describe the area in any detail. Recent work (e.g. Ofstad 1983, and this report) suggests a subdivision of the Middle Jurassic-earliest Cretaceous claystones of this region into three new formations. None of these can alone be referred to the northern Heather Formation, and the name has therefore not been used in the southern area.

Krossfjord Formation (new)

Name:
After a fjord on the west coast of Norway, adjacent to the type area in Quadrant 31.

Well type section:
Norwegian well 31/2-1 (Shell) from 1741.5 m to 1880 m, coord N 60°46′19.16′′, E 03°33′15.87′′, (Fig. 21).

Well reference section:
None at present.

Lithology:
The formation consists of sandstones, light grey-brown in colour, medium to coarse grained, well sorted, and loose to very friable. Occasionally calcite cemented streaks occur. The lower portion of the Krossfjord Formation is slightly argillaceous and carbonaceous with minor shale intercalations.

Boundaries:
In the type well the formation overlies the lower part of the Heather Formation. It has a "blocky" log character and is the first continuous thick sandstone unit above the Brent Group. The base of the formation is shown by the underlying reduction in gamma-ray intensity and FDC-CNL separation. The top is characterized by the change to the serrate gamma ray log motif of the overlying Fensfjord Formation and an overall upward increase in gamma ray intensity.

Distribution:
The formation has only been clearly recognized in the Troll Field area.

Age:
Bathonian.

Depositonal environment:
The formation was deposited in a coastal shallow marine environment.

Fensfjord Formation (new)

Name:
After a fjord on the west coast of Norway, adjacent to the type area in Quadrant 31.

Well type section:
Norwegian well 31/2-1 (Shell) from 1594.5 m to 1741.5 m, coord N 60°46′19.16′′, E 03°33′15.87′′, (Fig. 21).

Well reference section:
None at present.

Lithology:
The formation consists of sandstones, grey-brown in colour, fine to medium grained, well sorted and moderately friable to consolidated. Calcite cemented sandstones occur in bands containing common bioclastic material. In the type well it is often carbonaceous and occasionally micaceous. Minor shale intercalations occur throughout. The formation has a "serrate" log character, composed of 3-5 m thick units arranged in several cycles.

Boundaries:
The formation has an overall higher gamma-ray intensity and larger FDC-CNL separation than the underlying Krossfjord Formation. The top of the Fensfjord Formation is characterized by a transition in the gamma-ray log from a high intensity, serrate log shape to a high intensity but smooth outline in the overlying Heather Formation.

Distribution:
The formation has only been clearly recognized in the Troll Field area.

Age:
Callovian.

Depositional environment:
The formation was deposited in a coastal shallow marine environment.

Sognefjord Formation (new)

Name:
After a fjord on the west coast of Norway, adjacent to the type area in Quadrant 31.

Well type section:
Norwegian well 31/2-1 (Shell), from 1440 m to 1531.5 m, coord N 60°46′19.16′′, E 03°33′15.87′′, (Fig. 21).

Well reference section:
None at present.

Lithology:
The formation consists of sandstones and sands, grey-brown in colour, medium to coarse grained, well sorted and friable to unconsolidated. Locally the formation is weakly micaceous with minor argillaceous and carbonaceous beds.

FIGURE 19

JURASSIC
WELL 15/3-1
REFERENCE WELL:
HEATHER,DRAUPNE FORMATIONS
(VIKING GROUP)

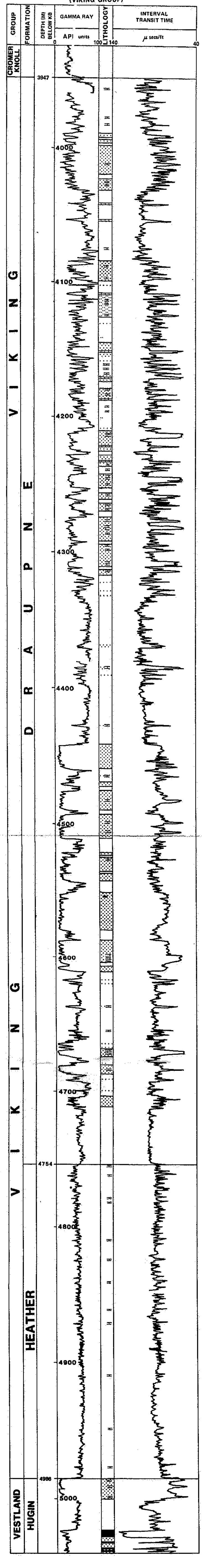


FIGURE 20

JURASSIC
WELL U.K. 210/30-1
REFERENCE WELL:
DRAUPNE FORMATION
(VIKING GROUP)

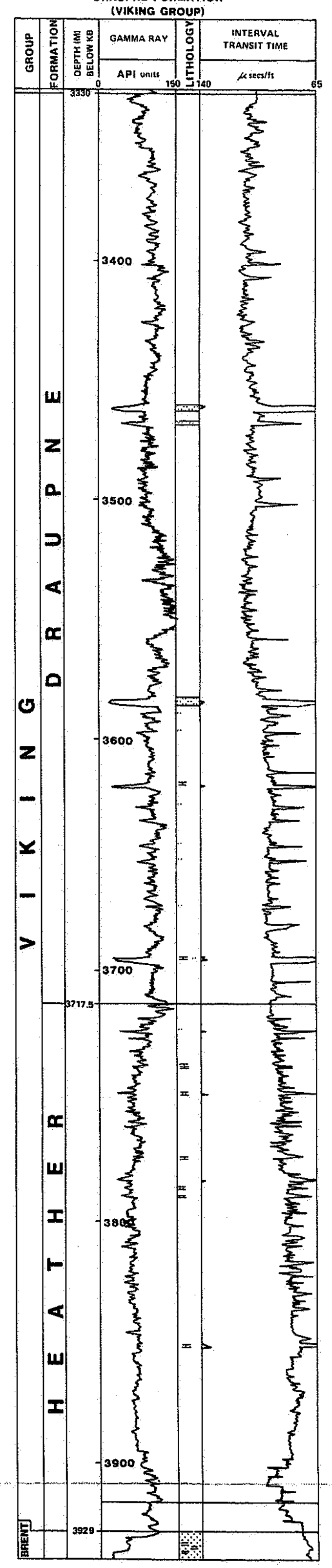
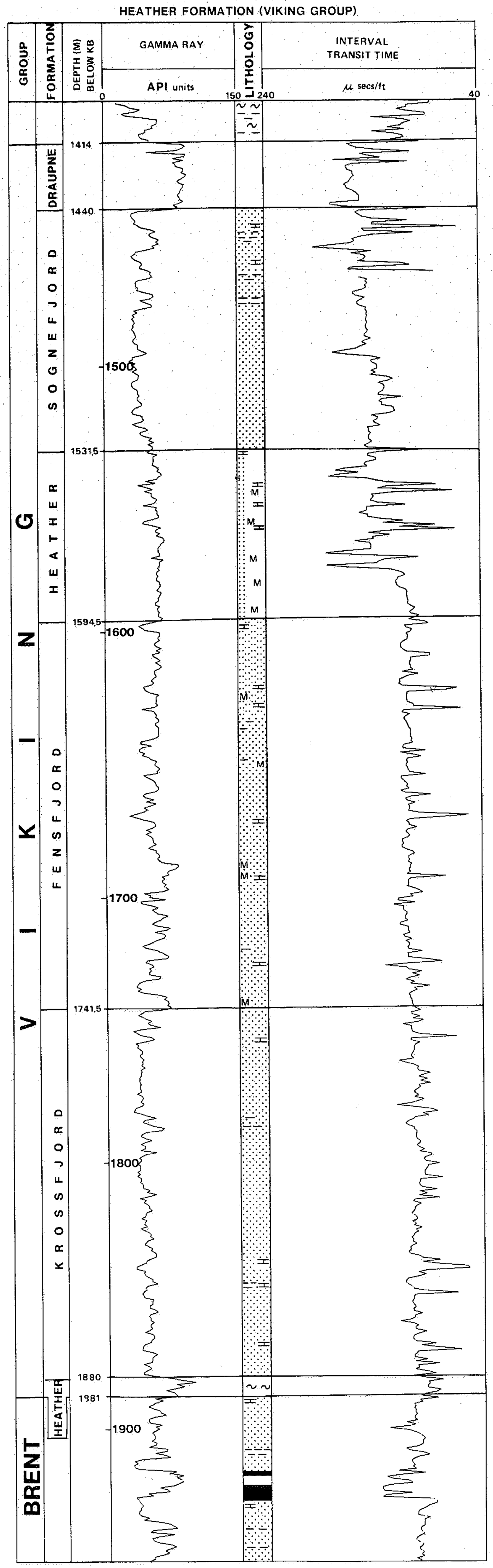


FIGURE 21

JURASSIC
WELL 31/2-1

TYPE WELL:
KROSSFJORD, FENSFJORD, SOGNEFJORD FORMATIONS (VIKING GROUP)

REFERENCE WELL:
HEATHER FORMATION (VIKING GROUP)



Bioclastic material and occasional calcite cemented bands occur locally.

Boundaries:
The Sognefjord Formation has a gradational lower boundary, due to the interdigitation of sandstones with the siltstones which form the upper part of the Heather Formation. The base is chosen immediately below the first continuous sandstone, often shown by reduction in gamma ray intensity. The formation has a homogenous "blocky" log motif in the lower half. The upper half comprises several cycles displaying "funnel-shaped" gamma ray log motifs coincident with coarsening upward sequences. The top of the formation is marked by the distinct lithological break into claystones or shales, which in the type well are the overlying Draupne Formation.

Distribution:
The formation has only been clearly recognized in the Troll Field area, where it is the major reservoir interval.

Age:
Oxfordian to Kimmeridgian/Volgian.

Depositional environment:
The formation was deposited in a coastal-shallow marine environment.

Draupne Formation (new)

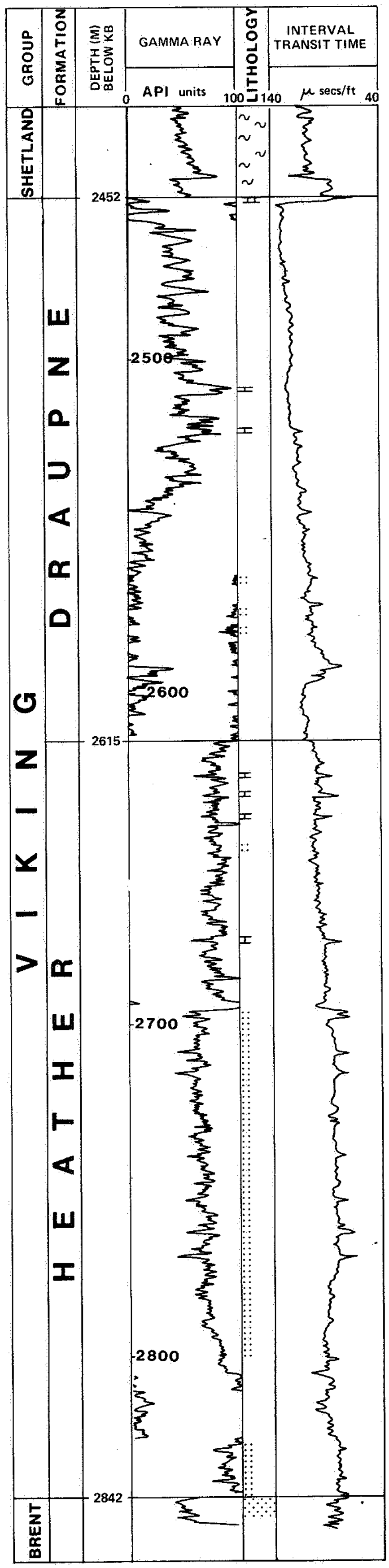
Name:
From a gold ring owned by Odin (the mythologic Viking God) which "dripped" 7 new rings, of the same weight as the original, every 9th day. The name is considered particularly appropriate in view of the Draupne Formation's role as a prolific hydrocarbon source in the Northern North Sea. It replaces the name "Kimmeridge Clay Formation" as used by Deegan and Scull (1977) in the Northern North Sea (see remarks).

Well type section:
Norwegian well 30/6-5 (Norsk Hydro), from 2452 m to 2615 m, coord N 60°41'20.6'', E 02°57'11.09'', (Fig. 22).

Well reference sections:
UK wells 211/21-1A (Shell), from 2729.5 m to 2810 m, coord N 61°11'09.6'' E 01°06'45'', (Fig. 18), and 210/30-1 (Arpet), from 3330 m to 3717.5 m, coord N 61°04'05.4'', E 00°54'14.4'', (Fig. 20), and Norwegian wells 33/9-1 (Mobil) from 2443 m to 2450 m, coord N 61°15'07.5'' E 01°50'25.8'', (Fig. 11), 15/9-2 (Statoil) from 3397 m to 3478 m, coord. N 58°25'34.06'' E 01°42'28.2'', (fig. 26), and 15/3-1 (Elf) from 3947 m to 4754 m, coord N 58°50'57.00'', E 01°43'13.25'', (Fig. 19).

Thickness:
163 m in the type well, 80,5 m in 211/21-1A, 387,5 m in 210/30-1, 7 m in 33/9-1, 81 m in 15/9-2, and 807 m in 15/3-1.

FIGURE 22
JURASSIC
WELL 30/6-5
TYPE WELL:
DRAUPNE FORMATION
(VIKING GROUP)



Lithology:
The formation consists of dark grey-brown to black, usually non-calcareous, carbonaceous, occasionally fissile claystone. It is characterized by very high radioactivity (often above 100 API units) which is a function of organic carbon content. It has anomalously low velocity, density and high resistivity. Minor limestone streaks and concretions occur throughout the formation. In addition interbedded sandstones and siltstones can cause a reduction in gamma ray response. The reference well 15/3-1 is an atypical example of the Draupne Formation which has been chosen to illustrate these arenaceous intercalations.

An informal three-fold subdivision has been identified, and is best recognizable along the basin rim areas where a middle high gamma ray zone separates two zones of lower gamma ray response (e.g. 210/30-1).

Boundaries:
These are marked by distinct log breaks due to the very high gamma ray response and low velocity shown by the Draupne Formation.

In basinal areas the formation generally has a diachronous contact with the Heather Formation. On marginal highs the formation onlaps pre-Upper Jurassic rocks. On the northern Horda Platform, Upper Jurassic sandstones of the Sognefjord Formation mark the base of the Draupne Formation.

The upper boundary is often an unconformity or discontinuity, usually overlain by Cretaceous sediments which have a higher velocity and lower gamma ray response than the Draupne Formation. The importance and regional validity of this unconformity is currently under debate; see for example Rawson and Riley (1982).

Distribution:
The formation is found in the East Shetland Basin, the Viking Graben and over the Horda Platform.

Age:
The formation ranges from Oxfordian to Ryazanian in age.

Depositional environment:
The Draupne Formation was deposited in a marine environment with restricted bottom circulation and often with anaerobic conditions. In places the formation may contain sandstones which are generally considered to be of turbiditic origin (De' Ath and Schuyleman, 1981; Harms et al, 1981).

Remarks:
The Norwegian Lithostratigraphic Nomenclature Committee formally proposes abandonment of the name "Kimmeridge Clay Formation" for Upper Jurassic claystones encountered north of the Mid-North Sea High. The committee further recommends substitution of the names "Mandal Formation" (in the Central Graben area) and "Draupne Formation" (in the Northern North Sea) for intervals formerly termed Kimmeridge Clay Formation in those areas. The principal reasons for this revision are: (i) distance from type area, and (ii) change in meaning of the term "Kimmeridge Clay Formation" from area to area.

The type area for the Kimmeridge Clay Formation is Kimmeridge Bay in Dorset, southern England (e.g. Arkell 1947). There the unit consists of dark, organic-rich claystones of Kimmeridgian to Volgian age (using Boreal stage terminology). The term was extended by Rhys (1974 and 1975) into the Southern North Sea to describe a unit of comparable age overlying Oxfordian limestones (Corallian Formation) in type well 47/15-1. Deegan and Scull (1977) further extended the Kimmeridge Clay into the Northern North Sea to denote a generally highly radioactive, generally low velocity claystone sequence. The age range of the formation was broadened to include part of the Oxfordian and Ryazanian. It was remarked that the sediments in the Southern North Sea were less radioactive (less than 60 A.P.I. units compared with 100-200 A.P.I. units in the north). However, the low seismic velocities shown by both units were considered sufficient grounds to justify a correlation.

Deegan and Scull did not specifically discuss the application of the term "Kimmeridge Clay" to the Central Graben region of the Central North Sea. Nevertheless, the name is in common usage there (e.g. Ofstad, 1983). It has, among other meanings, been taken to denote: (i) all claystones of Upper Jurassic age regardless of log character, or more usually, (ii) only the upper, most highly radioactive claystone unit of Volgian-Ryazanian age. To the northwest, in the Norwegian-Danish Basin, a similar deposit is present (the Tau Formation, described in this publication). This unit has never been referred to the Kimmeridge Clay Formation but is nevertheless a typical Upper Jurassic organic shale. It is of Kimmeridgian — Volgian age and occupies a lower relative position in the overall Upper Jurassic shale sequence than the Central Graben "hot shales". (Table 4). A connection between the two deposits across the Southern Vestland Arch is most unlikely.

In extending the Kimmeridge Clay Formation from the type area to the Northern North Sea (a distance of approximately 1300 km) the stratigraphic meaning of the name has varied considerably (Table 5). It is recognised that deposits of this type were laid down over a very wide area in intervals of the late Jurassic, the widespread deoxygenated bottom conditions reflecting the combined effect of paleogeography with general sea level rise (e.g. Tyson et al., 1979; Ziegler 1982). However, acceptance of this overall régime should not alone be taken as a basis for lithostratigraphic classification. The nature and timing of the organic shales appears to have varied according to the evolution of individual basins. Use of the generic term Kimmeridge Clay Formation is a potential cause of mistaken correlation and does not further

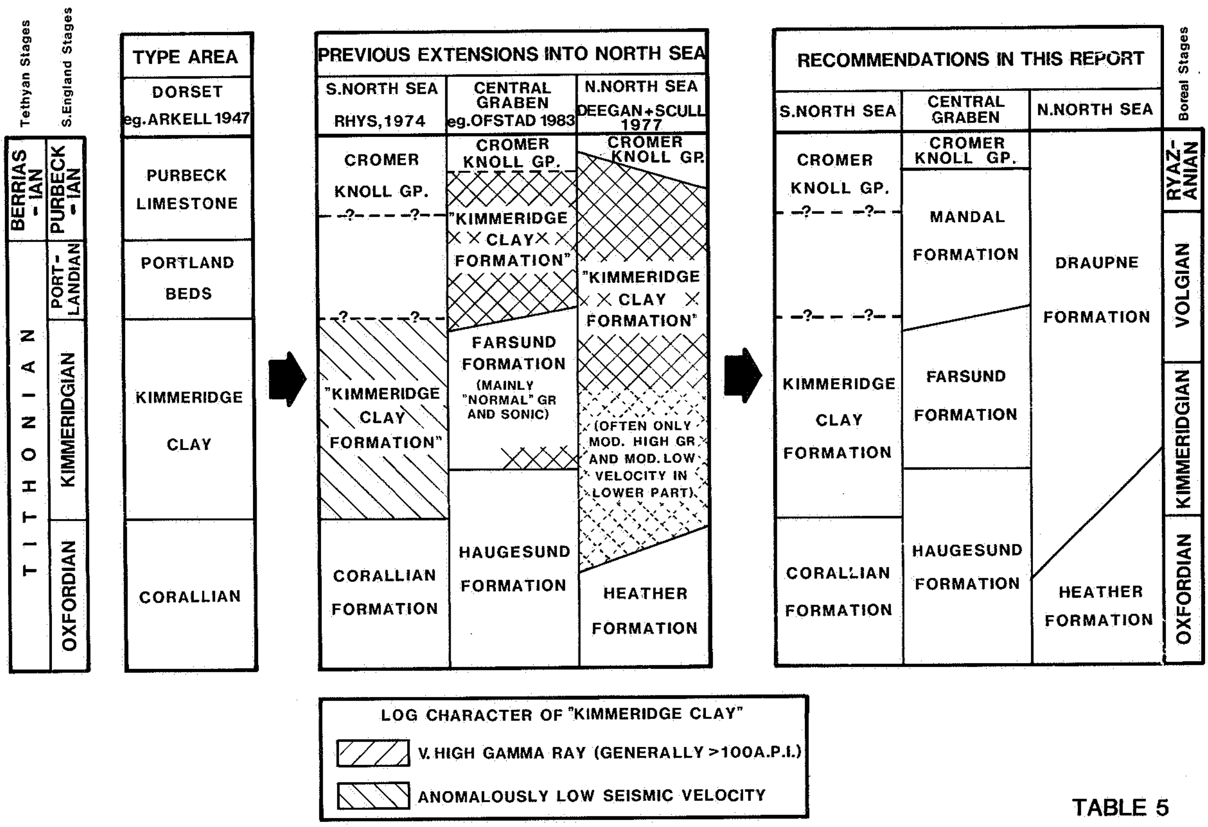


TABLE 5

understanding of inter-basin relationships. Replacement of the name is a more palatable alternative to its continued extension northwards to the Arctic and Russia, where alternative nomenclature already exists.

It therefore seems appropriate to limit the "Kimmeridge Clay Formation" of the North Sea to to the area south of the Mid-North Sea High, as described by Rhys (1974). The Norwegian Lithostratigraphic Nomenclature Committee proposes substitution of the name "Draupne Formation" for the "Kimmeridge Clay Formation" of the Northern North Sea as defined by Deegan and Schull (1977). It is suggested that the name "Mandal Formation" should be applied specifically to the "hot" shales of Volgian — Ryazanian age in the Central Graben region (Table 4), following the precedent set by Hamar et al., (1982).

REVISED JURASSIC LITHOSTRATIGRAPHY OF THE NORWEGIAN NORTH SEA; SOUTHERN AREA

by A. G. Doré, A. Hesjedal, R. C. Olsen, I. Price, O. Skarpnes and I. F. Strass.

Gassum Formation

Name:
After the village of Gassum, Jutland, Denmark, (Larsen, 1966).

Well type section:
Danish well Gassum No. 1 from 1613 m to 1643 m below ground (Ground evelation 53.3 m) (Bertelsen, 1978).

Well reference sections:
In Norwegian waters wells 17/10-1 (Shell) from 2682 m to 2825 m, coord N 58°01′54″, E 03°09′58″, (Fig. 23), and 7/9-1 (Conoco) from 2601 m to 2609 m, coord N 57°20′37.1″, E 02°51′21.4″, (Fig. 24). The section in well 17/10-1 was included by Deegan and Scull (1977) in the Skagerak Formation.

Thickness:
In the Norwegian reference wells the thickness of the Gassum Formation is 143 m (17/10-1) and 8 m (7/9-1).

Lithology:
In the type well the formation consists of predominantly light grey to whitish, in places rather coarse-grained sandstones, with subordinate dark-coloured clay bands and coal lenses (Larsen, 1966). In Norwegian waters the formation is predominantly a white to light grey, mainly fine to medium grained sandstone, but frequently contains coarse sand and gravel. It is often calcite cemented and in some instances contains glauconite.

Boundaries:
In the Norwegian sector the lower boundary may be characterized by a general lowering of the velocity when entering the underlying Skagerak Formation. Often this boundary coincides with a distinct horizon with high gamma ray response (e.g. well 17/4-1 (Elf) and well 9/12-1 (Shell)).

The upper boundary of the Gassum Formation is easily picked where it is overlain by

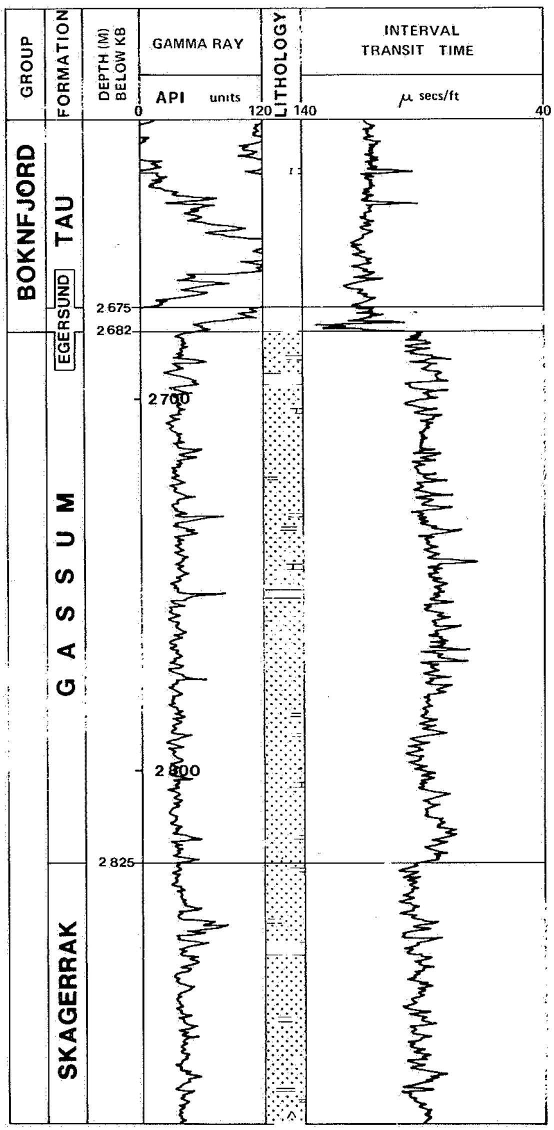
FIGURE 23

TRIASSIC/JURASSIC

WELL 17/10-1

REFERENCE WELL:

GASSUM FORMATION



Lower Jurassic shales of the Fjerritslev Formation or Upper Jurassic shales of the Boknfjord or Tyne Groups. Where the Gassum Formation is overlain by the Middle Jurassic Bryne Formation (Norwegian sector), the boundary may only show a slight decrease in the gamma-ray response and an overall decrease in velocity marking the appearance of the Bryne Formation.

In the reference well 17/10-1, where the Fjerritslev and Bryne Formations are missing, the Gassum Formation is overlain by the shales of the Boknfjord Group.

Distribution:
In the Norwegian sector the Gassum Formation occurs throughout the Norwegian-Danish Basin, on the Southern Vestland Arch and along the northeastern margin of the Central

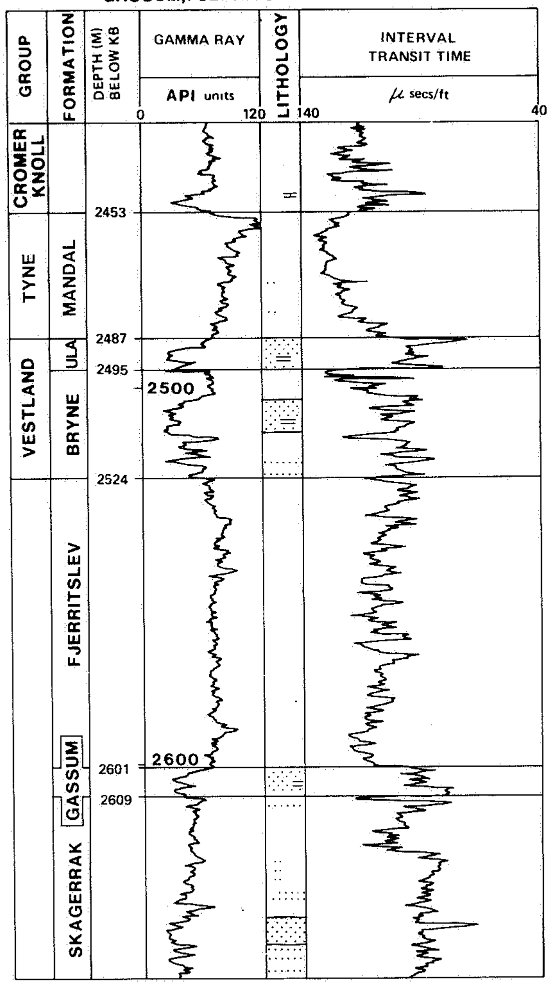
FIGURE 24

TRIASSIC/JURASSIC

WELL 7/9-1

REFERENCE WELL:

GASSUM,FJERRITSLEV FORMATIONS



Graben. Its distribution towards the axial part of the Central Graben is unknown. It is often completely or partially eroded as a result of mid-Jurassic earth movements.

Age:
Rhaetian in the type well, but seems to become younger northwards (Bertelsen, 1978). Sparse dating in the Norwegian sector gives Rhaetian to Sinemurian ages.

Depositional environment:
The sedimentology of the Gassum Formation in the Norwegian sector has not been much studied, but is assumed to represent fluvial to marginal marine deposits laid down during a transgressive phase at the Triassic/Jurassic transition.

Fjerritslev Formation

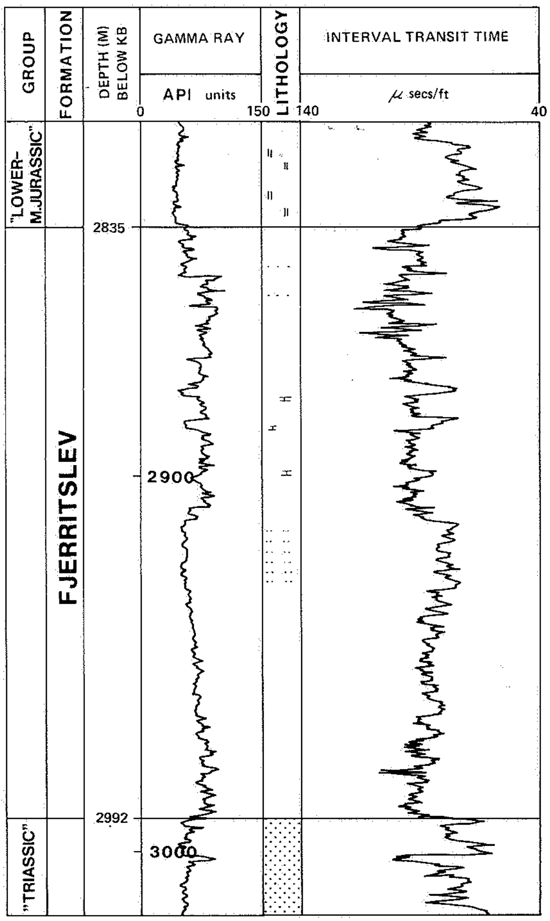
Name:
After the village of Fjerritslev, Jutland, Denmark, (Larsen, 1966).

Well type section:
Fjerritslev No 2 well, Jutland, (Larsen 1966).

Well reference sections:
In Norwegian waters wells 17/9-1 (Esso) from 2835 m to 2992 m, coord N 58°28'27.26'', E 03°50'16.18'' (Fig. 25), and 7/9-1 (Conoco) from 2524 m to 2601 m, coord N 57°20'37.10'', E 02°51'21.4'' (Fig. 24).

FIGURE 25
JURASSIC
WELL 17/9-1

REFERENCE WELL:
FJERRITSLEV FORMATION



Thickness:
In the Norwegian reference wells the thickness of the Fjerritslev Formation is 157 m (17/9-1) and 77 m (7/9-1).

Lithology:
The formation consists predominantly of grey to dark grey or greyish brown marine claystone. It is variably calcareous and pyritic. Silty intervals occur frequently, grading into grey or buff micaceous siltstone.

In the Danish area the Fjerritslev Formation is divided into four members according to degree of siltiness (Michelsen, 1978). However, such a subdivision is not merited in the Norwegian sector.

Boundaries:
The formation is distinguished from the underlying sandy deposits of the Gassum and Skagerak Formation, and from the overlying sands of the Vestland Group, by its higher gamma ray and lower sonic log velocity readings.

In reference well 17/9-1 the Fjerritslev Formation is overlain by a sequence of interbedded lavas and sediments over 500 m thick. They are belived to be of Lower-Middle Jurassic age (Dixon et al., 1980). This sequence has only been identified in one well, and is not named in this report. The boundary between the Fjerritslev Formation and the volcanics is again made by an upward change to lower gamma ray readings and higher sonic log velocities, (Fig. 25).

Distribution:
The Fjerritslev Formation is only patchily developed in the Norwegian sector. The developments which are present probably represent those remnants of a once more widely distributed deposit which survived the mid-Jurassic erosional episode. The formation has been penetrated in two distinct and separate areas; around the Southern Vestland Arch (e.g., blocks 7/9 and 7/12) and in the Egersund Sub-Basin (e.g. block 17/9).

Age:
The formation ranges in age from Hettangian to Pliensbachian. It is approximately equivalent to the Lower Jurassic Dunlin Group of the Northern North Sea, although no direct connection between the two sequences is thought likely.

In reference well 17/9-1 a dyke immediately below the Fjerritslev Formation has been dated as Pliensbachian (Furnes et al., 1982).

Depositional environment:
The claystones of the Fjerritslev Formation are shallow marine sediments deposited during a widespread marine transgression.

Remarks:
In block 17/12 (Bream area) a sequence of continental clastics has been dated as Pliensbachian to Toarcian (Olsen and Strass, 1982). They are therefore partially age-equivalent to the Fjerritslev Formation, but cannot on lithological grounds be referred to the latter, (Table 4). These deposits have not been named by the present nomenclature group.

Vestland Group (new)

Name:
Derived from the name used to denote the western part of Norway.

Type area:
The group is widespread in the southern parts of Norwegian waters. It occurs in the southern Viking Graben, the Central Graben and the Norwegian-Danish Basin, but it is thin or absent over structural highs. The group is illustrated in Norwegian wells 9/4-3 (Conoco) and 15/9-2 (Statoil).

Thickness:
The thickness of the group varies considerably. Thick sections with more than 450 m of Vestland Group are penetrated in the southern Viking Graben. The thicknesses in the above selected wells are 123 m (9/4-3) and 216 m (15/9-2).

Lithology:
The lower part of the group consists of a predominantly sandy deltaic sequence with shaly and silty layers and coal horizons. In the deeper parts of the basins the sequence seems to be influenced by marine conditions with thicker and more homogeneous sands.

The upper portion of the group generally consists of fairly clean, marine sands with minor shale interbeds.

Boundaries:
The lower boundary of the Vestland Group is easily picked where it overlies Lower Jurassic shales of the Dunlin Group or Fjerritslev Formation. Where these shales are absent, the boundary may only show a slight increase in the gamma ray response and an overall increase in velocity marking the appearance of Triassic sediments. At this point the lower velocity peaks of the coal layers disappear suddenly and high velocity peaks from anhydrite, dolomite and limestone in the Triassic are often seen below the boundary.

The upper boundary is easily picked where the sandy sections pass into overlying shales giving clear log breaks on both sonic and gamma ray logs.

Distribution:
The Vestland Group is widely distributed in the southern part of the Norwegian North Sea. It passes northwards into the Brent Group, north of the Frigg Area. The presence of a basal marine sandstone is considered to be the distinguishing feature of the Brent Group. The Vestland Group includes sediments formerly assigned to the Haldager Formation by Deegan and Scull (1977).

Age:
The group ranges from Bajocian to Volgian, or possibly Ryazanian.

Subdivision:
Five formations are recognized within the group, namely the Sleipner, Hugin, Bryne, Sandnes, and Ula Formations.

Sleipner Formation (new)

Name:
From the Sleipner Field. Sleipner was Odin's eight-legged horse in Norse mythology. (Larsen and Jaarvik, 1981).

Well type section:
Norwegian well 15/9-2 (Statoil) from 3657 m to 3699 m, coord N 58°25'34.06'', E 01°42'28.2'' (Fig. 26).

Well reference section:
Norwegian well 15/12-1 (Statoil) from 3152 m to 3204 m, coord N 58°10'32.6'', E 01°44'23.6'' (Fig. 27).

Thickness:
42 m in the type well and 52 m in the reference well.

Lithology:
The formation consists of a mixed sandstone and silty claystone lithology with coal measures. The sandstones are non-calcareous, light to medium brown, fine to medium grained, with occasional coarse and pebbly layers. The sandstones show a moderate to poor sorting with sub-angular to sub-rounded grains. The silty claystones are medium to dark grey or greyish brown, micromicaceous, hard and slightly fissile. Coal fragments, fossil leaves and root hairs are commonly found. The coals are mature, black and massive, often with thin laminations of silty claystone.

Boundaries:
The formation lies unconformably on erosional relics of lower Jurassic or older rocks, and a break on dipmeter logs can frequently be observed. Sandstones within the formation in general show lower interval velocites than sandstones in the underlying formations. The upper boundary marks the transition into the shales of the Viking Group or the sandstones of the Hugin Formation. Where the formation is overlain by the shales, clear breaks can be observed both on sonic and gamma ray logs. Where the formation is overlain by the Hugin Formation, the erratic sonic log pattern of the Sleipner Formation becomes smoother when entering the overlying sandstones. On gamma ray logs the sandstones of the Hugin Formation in general appear cleaner, more massive and often thicker than in the Sleipner Formation.

Distribution:
The formation is found in the southern Viking Graben between approximately 58° and 60°N. The Ness Formation in the East Shetland Basin is broadly equivalent to the Sleipner Formation. The name Sleipner Formation should be applied when the marine sandstones underlying the coaly sequence are absent. Non-marine sands, and associated strata, in the Central Graben and Norwegian-Danish Basin are referred to the Bryne Formation.

Depositional environment:
The Sleipner Formation represents a continental fluviodeltaic coaly sequence.

Age:
Usually Bajocian to Bathonian, but can locally be as young as Callovian (e.g. 15/12-1).

FIGURE 26

JURASSIC
WELL 15/9-2

TYPE WELL:
SLEIPNER,HUGIN FORMATIONS
(VESTLAND GROUP)
REFERENCE WELL:
DRAUPNE FORMATION
(VIKING GROUP)

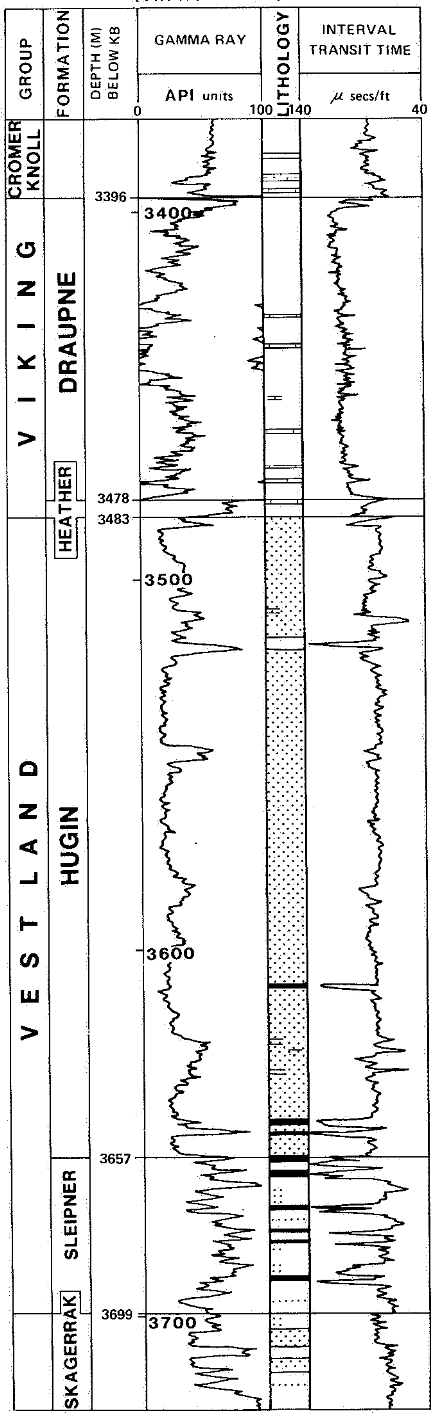
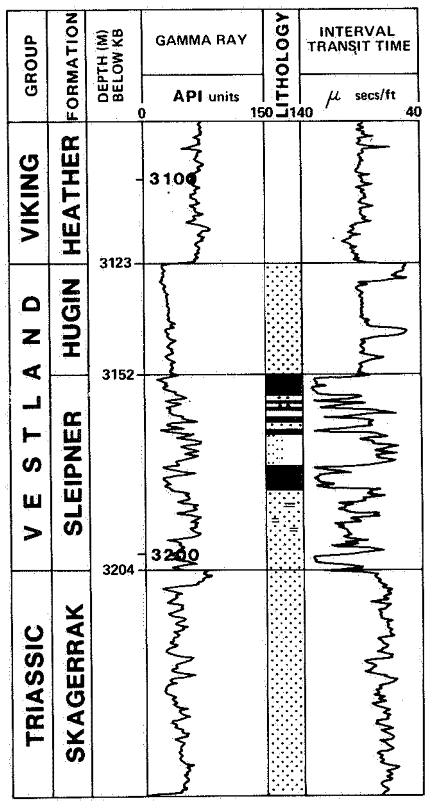


FIGURE 27

JURASSIC
WELL 15/12-1

REFERENCE WELL:
SLEIPNER FORMATION
(VESTLAND GROUP)



Hugin Formation (new)

Name:
One of Odin's two ravens in Norse mythology.

Well type section:
Norwegian well 15/9-2 (Statoil) from 3483 m to 3657 m, coord N 58°25'34.06'', E 01°42'28.2'' (Fig. 26).

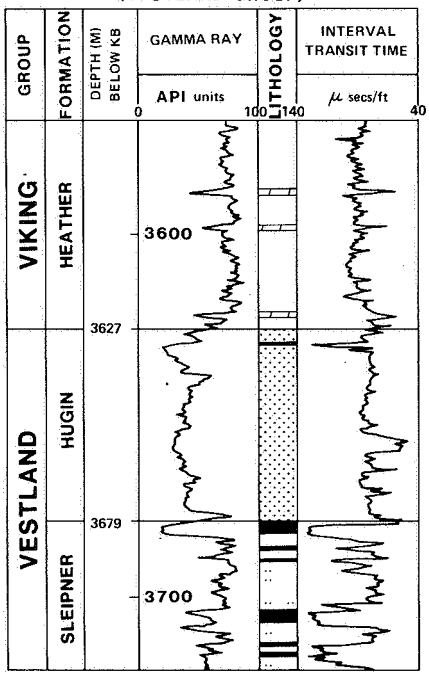
Well reference section:
Norwegian well 15/6-5 (Esso) from 3627 m to 3679 m, coord N 58°30'29.67'', E 01°45'50.4'' (Fig. 28).

Thickness:
The formation is 174 m thick in the type well and 52 m thick in the reference well.

Lithology:
The formation consists of light brown to yellow, very fine to medium grained sandstones. Occasional coarse grained layers are found. The sandstones have fair sorting, and the grains are subangular to subrounded. Shale and siltstone partings are common. Carbonaceous material and coal fragments are abundant. Occasional thin coal beds can be observed. The

FIGURE 28

JURASSIC
WELL 15/6-5
REFERENCE WELL:
HUGIN FORMATION
(VESTLAND GROUP)



sandstones are often bioturbated, but cross bedding can sometimes be observed. The sandstones are often calcareous and glauconitic.

Boundaries:
The lower boundary represents the transition from the coaly Sleipner Formation (described above). The upper boundary represents the transition into the shales of the Viking Group, giving clear breaks both on sonic and gamma ray logs.

Distribution:
The formation is found in the southern Viking Graben, north of the Jæren High.

Age:
Early Bathonian to Early Oxfordian.

Depositional environment:
The formation represents near shore, shallow marine sandstones with the occasional influence of continental fluviodeltaic conditions.

Bryne Formation (new)

Name:
From a town in the south-western part of Norway. This new formation represents the lower part of the Haldager Formation as decribed by Deegan and Scull (1977).

Well type section:
Norwegian well 9/4-3 (Conoco) from 2507.5 m to 2613 m, coord N 57°36′54.5′′, E 04°18′57.7′′ (Fig. 29).

Well reference section:
Norwegian well 8/12-1 (Conoco) from 2710.5 m to 2813 m, coord N 57°13′18.6′′, E 03°46′45.13′′ (Fig. 30).

Thickness:
The formation is 105.5 m thick in the type well and 102.5 m in the reference well. It shows local variations in thickness which probably reflect both Middle Jurassic syndepositional structuring and later erosion.

Lithology:
The Bryne Formation comprises interbedded sandstones, siltstones, shales and coals. The sandstones are white to grey, very fine to coarse grained, poorly sorted, friable to hard and occasionally kaolinitic. The shales are generally grey to brown, micaceous, occasionally silty, non-calcareous and often carbonaceous.

FIGURE 29

JURASSIC
WELL 9/4-3
TYPE WELL:
BRYNE, SANDNES FORMATION (VESTLAND GROUP)

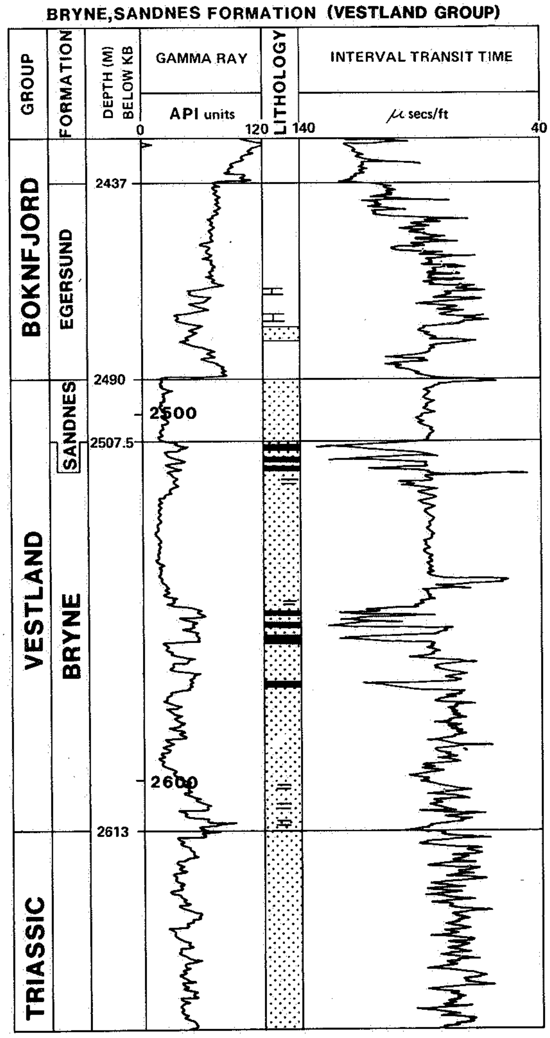
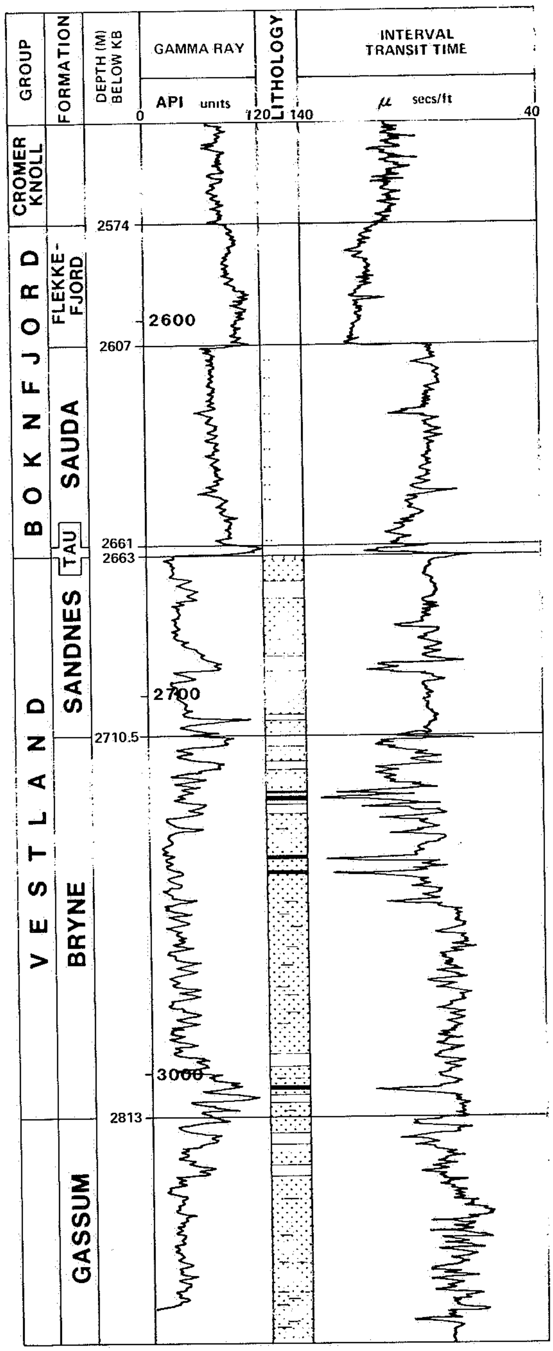


FIGURE 30

JURASSIC
WELL 8/12-1

REFERENCE WELL:

BRYNE FORMATION
(VESTLAND GROUP)



Boundaries:
The base of the Bryne Formation is unconformable and represents the contact with the partly eroded shales of the Fjerritslev Formation or with arenaceous Triassic rocks. The boundary with the Fjerritslev Formation is usually clearly defined on both gamma ray and sonic logs, whereas the boundary with the Lower Jurassic/Triassic sandy sequences (Gassum and Skagerak Formation) often gives no appreciable log breaks. However, on most logs the appearance of these sediments is marked by an overall sonic log shift to higher interval velocities. Where the formation is overlain by the shales of the Boknfjord or Tyne Groups, clear breaks can be observed both on gamma ray and sonic logs. However, where the formation is overlain by the Sandnes or Ula Formation the boundary is not so easily defined due to internal facies changes within these two formations (see description of the Sandnes and Ula Formation).

Distribution:
The Bryne Formation is present in the Norwegian-Danish Basin and in the Central Graben. Two main Middle Jurassic depocentres are recognized; one in the Danish Sub-Basin and another in the Fiskebank Sub-Basin (Hamar et al., 1982).

The Bryne Formation is equivalent to the Haldager Sand Member of the Haldager Formation as described in Denmark (Larsen, 1966; Michelsen, 1978).

Age:
Mainly Bajocian to Bathonian, but may locally be older in the Norwegian-Danish Basin.

Depositional environment:
The Bryne Formation represents deposition in a fluvial/deltaic environment.

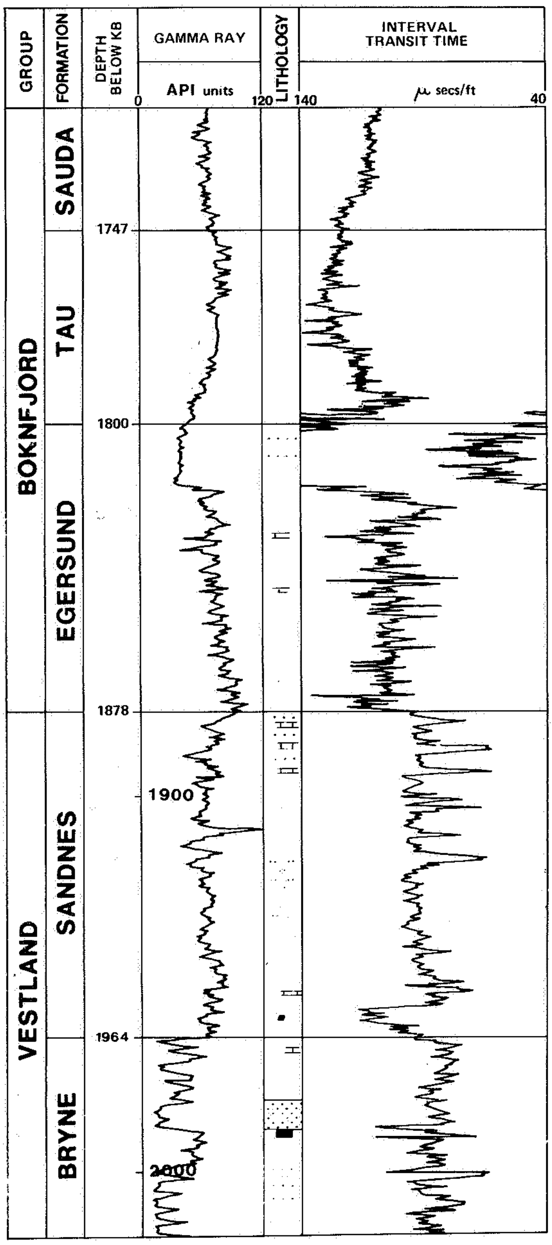
Remarks:
The Bryne Formation as described above is approximately equivalent in age and lithofacies to the Sleipner Formation of the Southern Viking Graben. So far it is not possible to demonstrate a connection between the two deposits, and this constitutes the reason for use of separate nomenclature.

The Bryne Formation represents the lower part of the Haldager Formation, extended into the Norwegian sector from the Danish sector by Deegan and Scull (1977). Having defined extensive marine sands worthy of formation status (Ula, Sandnes Formation) comprising the upper part of Deegan and Scull's Haldager Formation, workers on this project saw the need for a separate formation, defining the lower non-marine sands. The term "Haldager Formation" could not be used since it essentially equates to the Haldager Sand Member, the lower part of the Haldager Formation in the Danish sector (Michelsen, 1978). (The upper part of the Danish Haldager Formation is the Flyvberg Member, a marine sandstone/siltstone unit approximately time-equivalent to the Sandnes Formation of the Norwegian-Danish Basin). When a previously established formation is subdivided into new units which are formally given formation status, the original formation with its original name should be either raised to group rank or abandoned; the old name should not be retained for any of the divisions of the original unit (Hedberg, 1976). It was therefore thought expedient to abandon the name "Haldager Formation" in the Norwegian sector. It is recognised, however, that there is probably complete lithological continuity between the new Bryne Formation of the Norwegian sector and the Haldager Sand Member of the Danish Haldager Formation.

Sandnes Formation (new)

Name:
From a town on the south-west coast of Norway. This formation was formerly included in the Haldager Formation (Deegan and Scull, 1977).

FIGURE 31
JURASSIC
WELL 18/11-1
REFERENCE WELL:
SANDNES FORMATION
(VESTLAND GROUP)



Well type section:
Norwegian well 9/4-3 (Conoco) from 2490 m to 2507.5 m, coord N 57°36′54.5″, E 04°18′57.7″, (Fig. 29).

Well reference section:
Norwegian well 18/11-1 (Elf) from 1878 m to 1964 m, coord N 58°04′21.3″, E 04°32′00.1″ (Fig. 31).

Thickness:
17.5 m in the type well and 86 m in the reference well.

Lithology:
In the type well the Sandnes Formation consists of a massive white, very fine to coarse grained glauconitic sandstone. It is firm to friable, poorly sorted and slightly silty. In other wells (e.g. 18/11-1) the formation comprises interbedded sandstones and shales. The shales are generally dark grey to brown, micaceous and occasionally carbonaceous.

Boundaries:
The base of the Sandnes Formation is usually an unconformable contact with the non-marine Bryne Formation or older Jurassic or Triassic rocks. Generally it is defined at the base of the massive and clean sand, usually well marked on both gamma ray and sonic logs. In the type well the lower boundary is picked at the top of the first coal bed of the underlying Bryne Formation. In wells where the Sandnes Formation is more argillaceous it can be harder to distinguish between the Sandnes and Bryne Formation on log characteristics alone. In such cases the occurrence of deltaic/non-marine palynofloras would serve to define this boundary (e.g. 18/11-1). The upper contact with the overlying silts and shales of the Boknfjord Group is marked by good gamma ray and sonic log breaks.

Distribution:
The Sandnes Formation is developed in the Fiskebank Sub-Basin and in the Egersund Sub-Basin. It is broadly homotaxial with the Hugin Formation in the southern Viking Graben and the Flyvbjerg Member of the Haldager Formation in the Danish Sub-basin.

In the transition between the Southern Vestland Arch and the Fiskebank Sub-Basin it can be difficult to distinguish between the Ula Formation and the Sandnes Formation, (see Table 4); In such cases detailed paleontology is required to decide the ages of the sands, and hence their lithostratigraphic relationships.

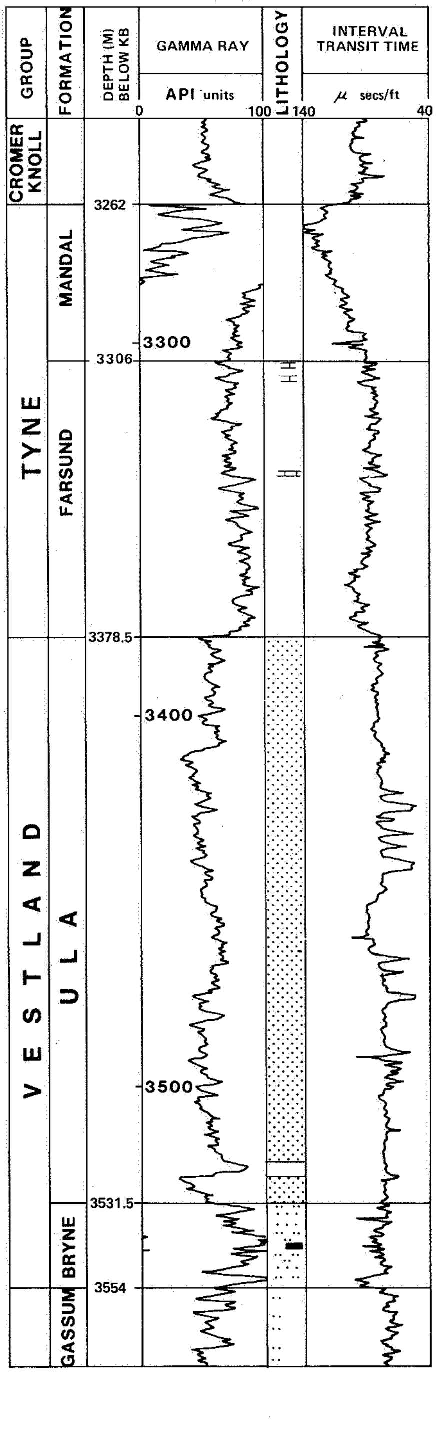
Age:
Callovian.

Depositional environment:
The Sandnes Formation was deposited in a coastal/shallow marine environment.

Ula Formation (new)

Name:
From the Ula Field in Norwegian Block 7/12. The name was first proposed by Bailey et al., (1981) to describe a sequence of Oxfordian-Kimmeridgian marine sands overlying the non-marine Bryne Formation (then termed the Haldager Formation) in the Ula Field, but is extended here to a wider geographic area and stratigraphic range.

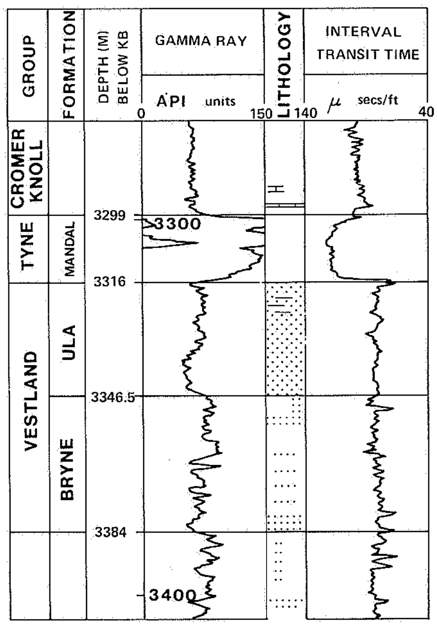
FIGURE 32
JURASSIC
WELL 7/12-2
TYPE WELL:
ULA FORMATION
(VESTLAND GROUP)
REFERENCE WELL:
FARSUND FORMATION
TYNE GROUP



Well type section:
Norwegian well 7/12-2 (BP) in the Ula Field, from 3378.5 to 3531.5 m,
coord N 57°06'41.34'', E 02°50'50.73'' (Fig. 32).

Well reference sections:
Norwegian well 2/1-2 (BP) from 3316 m to 3346.5 m, coord N 56°57'30.76'',
E 03°12'23.07'' (Fig. 33).

FIGURE 33
JURASSIC
WELL 2/1-2
REFERENCE WELL:
ULA FORMATION
(VESTLAND GROUP)
MANDAL FORMATION
TYNE GROUP



Thickness:
152 m in the type well and 30.5 m in the reference well.

Lithology:
In the type well the Ula Formation is a generally massive, fine to medium grained, grey sandstone. A thin, dark grey siltstone is present in the basal part of the formation. The sandstones are arkosic to subarkosic, glauconitic and micaceous. Sorting and angularity vary between individual units of the formation. Bivalve shells and belemnite debris occur, often concentrated in thin lag deposits. Thin, nodular calcite-cemented bands are common.

Within the Ula Field the Ula Formation can be subdivided into a number of units on the basis of large scale coarsening upward and fining upward cycles (Bailey et al., op. cit.). The sandstones are extensively bioturbated throughout, and this usually obliterates smaller scale sedimentary features. However, in rare zones, parallel or low angle inclined lamination and planar cross bedding are preserved.

Boundaries:
The base of the Ula Formation usually occurs where the marine sandstones pass downwards into the non-marine sandstones/shale/coal sequence of the Bryne Formation. This boundary is often difficult to establish on log characteristics alone. In the region of the Ula Field there is a gamma ray break between the low values of the Ula Formation and the higher values of the more argillaceous Bryne Formation (e.g. in the type well 7/12-2). Elsewhere, where the Bryne Formation contains cleaner, more massive sands, the base of the Ula Formation is picked at the top of the highest penetrated coal band. The top of the Ula Formation is easily recognized where the sands give way to the shales of the Tyne Group.

Distribution:
The Ula Formation is developed around the eastern flanking "highs" of the Central Graben, in particular on the south-western flank of the Southern Vestland Arch. It passes basinwards into marine shales but is often recognizable as a very thin sandstone. It becomes thin or absent over the "highs". Tongues of similar sands occur locally in the Tyne Group mudstones (e.g. 3/5-2 from 3175 m to 3182.5 m). Comparable formations in lithofacies and partly in age occur both in the Sleipner Area (the Hugin Formation) and in the Fiskebank and Egersund Sub-Basins (the Sandnes Formation).

Age:
Oxfordian to Ryazanian. In the region of the Ula Field the sands are Oxfordian to Early Volgian in age. Around the fringes of the Jæren and Mandal Highs and locally on the Southern Vestland Arch, developments of the formation may be as young as Middle/Late Volgian or possibly Ryazanian.

Depositional environment:
The sands of the Ula Formation are generally shallow marine in origin although the type of marine environment probably varies from area to area. In the Ula Field the depositional environment of the sands is particularly difficult to establish due to the unusual thickness of the formation and the scarcity of sedimentary structures; the sands have at this location variously been called shoreface, offshore bar and tidal sand wave deposits (Bailey et al., 1981).

Boknfjord Group (new)

Name:
From the main fjord in Rogaland, Norway.

Type area:
The Fiskebank and Egersund Sub-Basins comprise the type area. The group is illustrated in the Norwegian well 9/4-3 (Conoco), (Fig. 36).

Thickness:
In the type area wells show thicknesses of up to 500 m. In well 9/4-3 the thickness of the group is 290 m. Towards the basin margins the section thins considerably.

Lithology:
The sediments of the group are dominated by shales. Varying amounts of siltstone, sandstone, limestone stringers and differences in organic content make it possible, however, to subdivide the group into formations (Olsen and Strass, 1982).

Boundaries:
The lower boundary is characterized by a distinct log break with the underlying sandstones of the Vestland Group. The upper boundary is usually characterized by abrupt changes in log response to lower gamma ray and interval transit times in the overlaying Valhall Formation. In the Egersund Sub-Basin this boundary may be difficult to identify due to a large supply of clastic material.

Distribution:
The group is confined to the Fiskebank and Egersund Sub-Basins although the upper two formations extend further westwards than those lying below.

Age:
The group ranges in age from Callovian to Ryazanian.

Subdivisions:
The group can be subdivided into four formations, the Egersund (base), Tau, Sauda and Flekkefjord Formation (top).

Remarks:
The term "Bream Formation" was first used by Deegan and Scull (1977) to describe a Callovian-Portlandian (Volgian) sequence, mainly claystones and siltstones, distributed throughout the Norwegian-Danish Basin. The formation comprised the Egersund Member, Børglum Member and Fredrikshavn Member. The Bream Formation was adopted with some modification by Michelsen (1978) for the Danish Sub-Basin where it comprises the Børglum and Fredrikshavn Members. Recent correlation work in the Egersund and Fiskebank Sub-Basin (e.g. Olsen and Strass, 1982) shows the existence of four argillaceous units, ranging in age from Callovian-Ryazanian, which are considered stratigraphically useful. They are widespread enough to deserve formation status and different enough from the Danish deposits to merit separate nomenclature. These units are the Egersund, Tau, Sauda and Flekkefjord Formations. The formal definitions of the unit in this volume outline

their relationship to the Egersund/Børlum/ Fredrikshavn Members of Deegan and Scull (1977). Note that the Flekkefjord Formation was formerly part of the early Cretaceous Valhall Formation, also defined by Deegan and Scull.

The four formations fall naturally into a single "claystone" group. It is not however considered proper to elevate the former Bream Formation to a "Bream Group" which would encompass these units, since it may still desirable to retain the formation status of the Bream Formation and the member status of the Børglum/Fredrikshavn Members in the Danish sector.

It is therefore proposed that the term "Bream Formation" should be abandoned for the Fiskebank and Egersund Sub-Basins, and replaced by the Boknfjord Group, which is defined above.

Egersund Formation (elevated)

Name:
Named by Deegan and Scull (1977) who gave the unit member status.

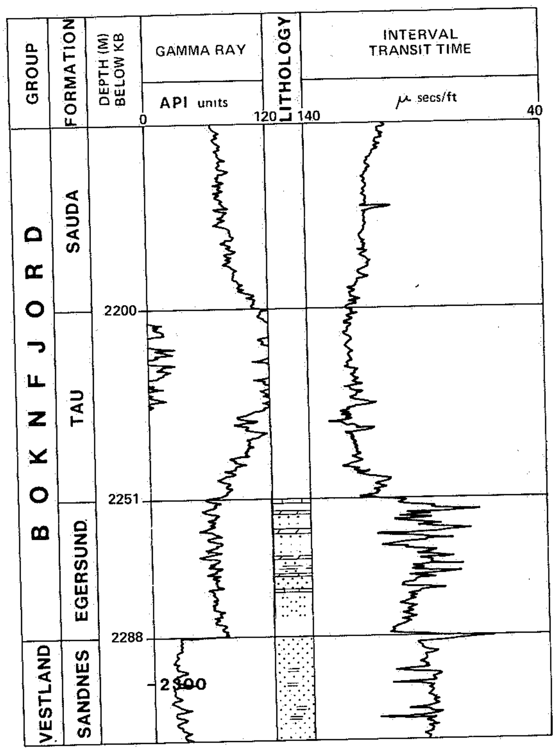
Well type section:
Norwegian well 9/4-1 (Amoseas) from 2251 m to 2288 m, coord N 57°35'02'', E 04°01'13'' (Fig. 34).

FIGURE 34

JURASSIC
WELL 9/4-1

TYPE WELL:

EGERSUND FORMATION
(BOKNFJORD GROUP)



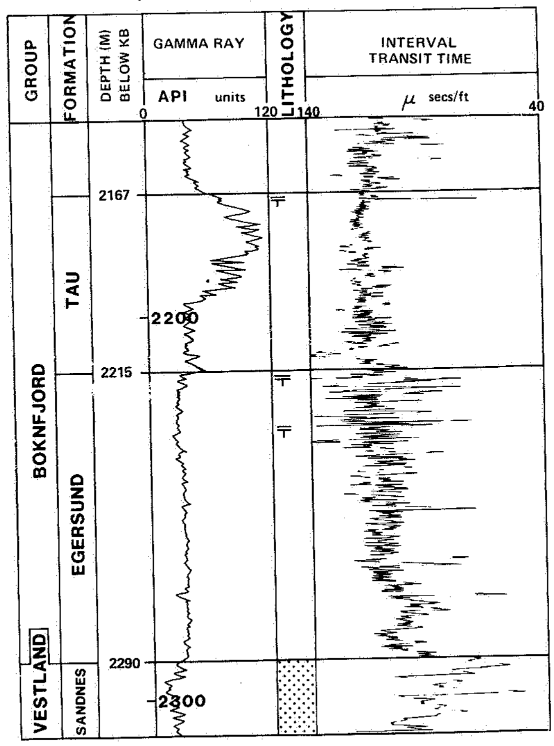
Well reference section:
17/12-1 (Phillips) from 2215 m to 2290 m, coord N 58°11'15.4'', E 03°56'22.2'' (Fig. 35).

FIGURE 35

JURASSIC
WELL 17/12-1

REFERENCE WELL:

EGERSUND FORMATION
(BOKNFJORD GROUP)



Thickness:
37 m in the type well and 75 m in the reference well.

Lithology:
In the type well the formation consists of dark grey micromicaceous shales and siltstones with brownish, locally oolitic, microcrystalline carbonate beds and occasionally sandstone streaks. The latter become more important east and north-east of the type well.

Boundaries:
The lower boundary is also the junction of the Boknfjord Group with the Vestland Group and is described above. At the base of the formation a more radioactive part is recognizable in several wells. The upper boundary is marked by the appearance of the dark grey to black organic-rich shales of the overlying Tau Formation. The shales of the Tau Formation have a high radioactivity and a low velocity, and therefore the upper boundary is marked by strong log breaks.

Distribution:
The formation is distributed throughout the Fiskebank and Egersund Sub-Basins.

FIGURE 36

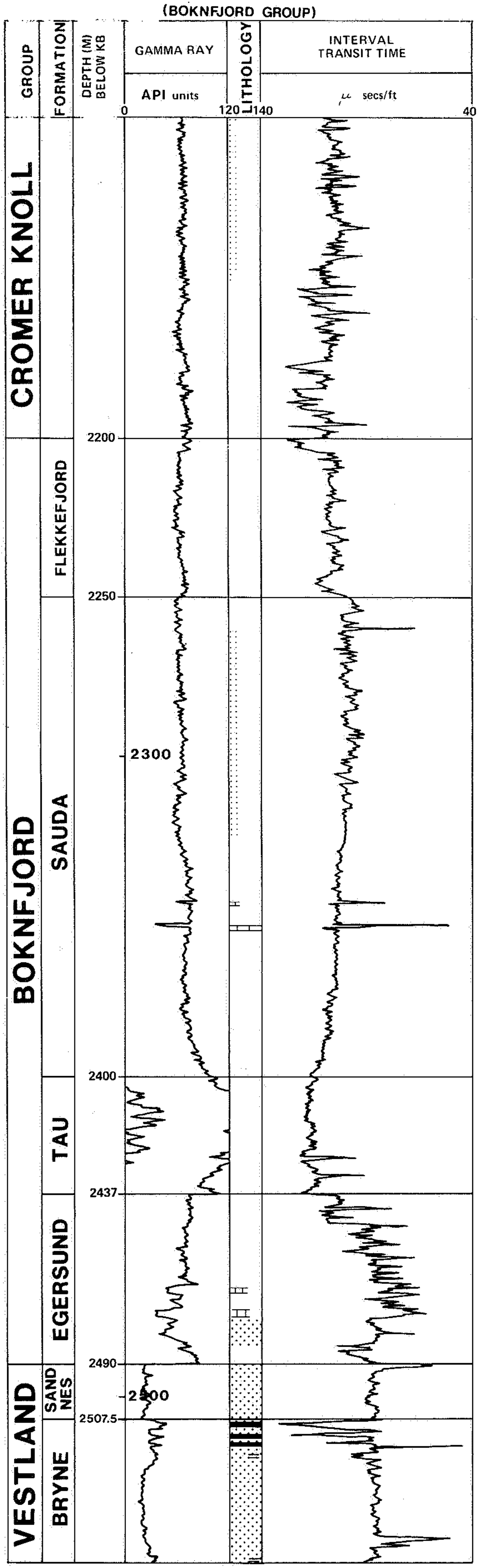
JURASSIC

WELL 9/4-3

TYPE WELL:

TAU,SAUDA FORMATIONS

(BOKNFJORD GROUP)



Age:
Callovian to Kimmeridgian.

Depositional environment:
The Egersund Formation was deposited in an open marine, generally low energy basinal environment.

Tau Formation (new)

Name:
From a village within the Boknfjord area in Rogaland. The formation represents only the lowermost, radioactive part of the Børglum Member as defined by Deegan and Scull (1977).

FIGURE 37

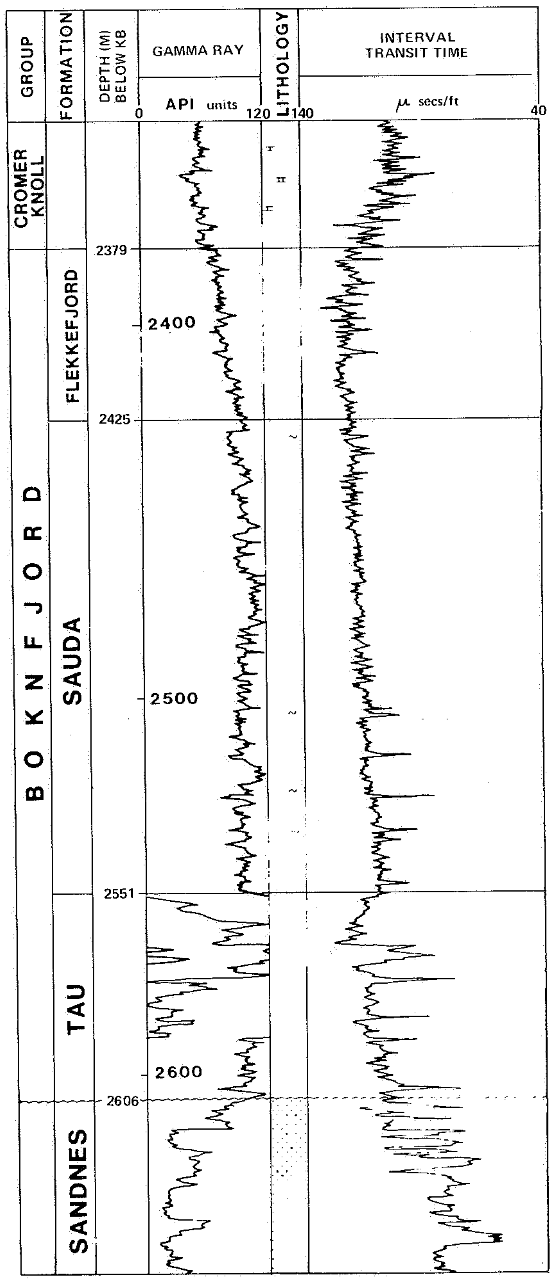
JURASSIC

WELL 8/1-1

REFERENCE WELL:

TAU,SAUDA,FLEKKEFJORD FORMATIONS

(BOKNFJORD GROUP)



Well type section:
Norwegian well 9/4-3 (Conoco) from 2400 m to 2437 m, coord N 57°36′54.5′′, E 04°18′57.7′′ (Fig. 36).

Well reference section:
Norwegian well 8/1-1 (Phillips) from 2551 m to 2606 m, coord N 57°51′43.53′′, E 03°12′27.64′′ (Fig. 37).

Thickness:
37 m in the type well and 55 m in the reference well.

Lithology:
The Tau Formation consists of dark grey to black, pyritic, fissile, organic rich slightly to non-calcareous shales.

Boundaries:
This formation is highly radioactive and the boundaries are characterized by prominent log breaks. The underlying Egersund Formation is less radioactive and has a lower interval transit time than the Tau Formation. The upper boundary may be more gradational but shows a marked increase in radioactivity compared to the overlying unit.

Distribution:
The formation is confined to the central part of the type area of the Boknfjord Group, and grades laterally into the Børglum unit southwards and eastwards.

Age:
Kimmeridgian to Early Volgian.

Depositional environment:
The Tau Formation was deposited in an anaerobic marine environment with high organic productivity and restricted bottom circulation.

Sauda Formation (new)

Name:
From an industrial town in Rogaland. The formation comprises the upper part of the Børglum Member and the Fredrikshavn Member as defined by Deegan and Scull (1977).

Well type section:
Norwegian well 9/4-3 (Conoco) from 2250 m to 2400 m, coord N 57°26′54.5′′, E 04°18′57.7′′ (Fig. 36).

Well reference section:
Norwegian well 8/1-1 (Phillips) from 2425 m to 2551 m, coord N 57°51′43.53′′, E 03°12′27.64′′ (Fig. 37).

Thickness:
150 m in the type well and 126 m in the reference well.

Lithology:
The lower part is mainly a dark grey claystone with some siltstone and pyrite. The upper part is more silty, commonly developed as a siltstone. Shell fragments and pyrite are common.

Boundaries:
The upper boundary is marked by the contrast between the predominantly silty upper part of the Sauda Formation and the overlying finer grained shales of the Flekkefjord Formation. This is usually accompanied by marked breaks both on gamma and sonic logs. The lower boundary is with the very radioactive Tau Formation.

Distribution:
The formation is present in the Fiskebank and Egersund Sub-Basins. The thickest and most complete sequence is found in the Egersund Sub-Basin. In the western part of the Fiskebank Sub-Basin only the upper silty part is present.

Age:
Middle to Late Volgian.

Depositional environment:
The Sauda Formation was deposited in a open marine, generally low energy basinal environment. The energy level became slightly higher in the later stages of deposition of the formation.

Flekkefjord Formation (elevated)

Name:
From a town on the south-west coast of Norway. This formation was formerly included in the Valhall Formation of the Cromer Knoll Group (Deegan and Scull, 1977). The same unit was defined as the Flekkefjord Member by Rawson and Riley (1982), and is here elevated to formation status.

Well type section:
Norwegian well 9/4-2 (Texaco) from 2155 m to 2208 m, coord N 57°41′11.05′′, E 04°02′34.85′′, (Fig. 38).

Well reference section:
Norwegian well 8/1-1 (Phillips) from 2379 m to 2425 m, coord N 57°51′43.53′′, E 03°12′27.64′′, (Fig. 37).

Thickness:
In the type well it is 53 m, and in the reference well it is 46 m. This is also the approximate thickness in most wells within the Egersund Sub-Basin.

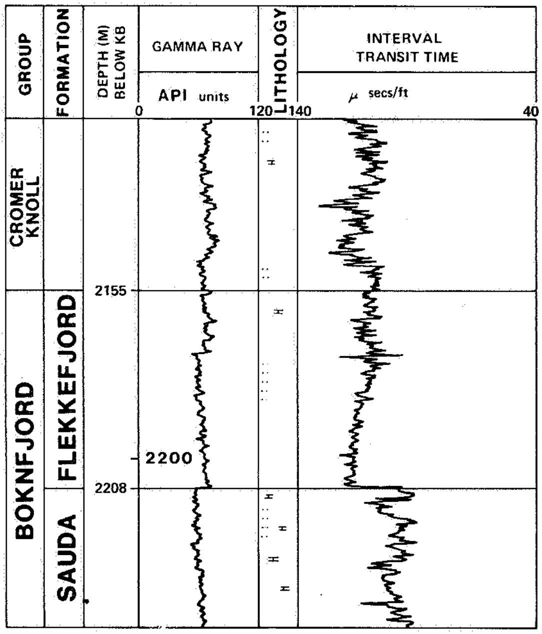
Lithology:
The formation consists of dark grey shales which are variably carbonaceous, pyritic and may contain thin limestone stringers.

Boundaries:
The lower boundary of the formation is clearly defined both on gamma and sonic logs by the contact with the more silty Sauda Formation.

FIGURE 38

JURASSIC
WELL 9/4-2

TYPE WELL:
FLEKKEFJORD FORMATION
(BOKNFJORD GROUP)



The upper boundary usually appears as a distinct log break, with higher radioactivity and higher interval transit times in the Flekkefjord Formation. In the Egersund Sub-Basin, which is situated closer to the source area, the boundary may be difficult to identify on logs.

Distribution:
The formation is present in the Norwegian-Danish Basin. It is time-equivalent to the upper part of the Mandal Formation in the graben areas to the west and to the Fredrikshavn Unit C in the Danish sector to the east (Michelsen, 1978)

Age:
Ryazanian.

Depositional environment:
The Flekkefjord Formation was deposited in a marine, low-energy, basinal environment.

Børglum unit

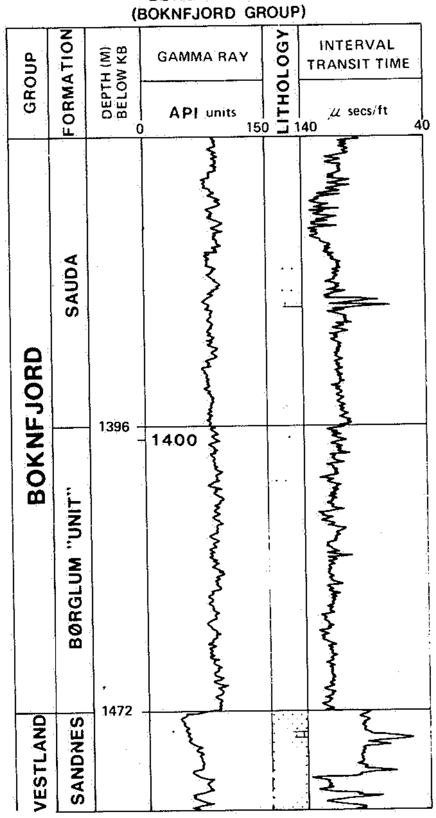
This unit was first described by Larsen (1966) as the Børglum Formation. Later it was amended several times, the latest being by Michelsen (1978) who redefined it and reduced it to member status. It has been informally redesignated a formation by Hamar et al. (1982).

In the type area in Jutland, Denmark, the formation is of Kimmeridgian-Volgian age and consists of homogeneous shaly claystones, olive grey to blackish grey, slightly calcareous to non-calcareous, with mica, pyrite, shell fragments and lignite. This description is generally valid also in the eastern and southern parts of the Fiskebank Sub-Basin, as illustrated by the Norwegian well 10/5-1 (Conoco) from 1396 m to 1472.5 m, (Fig. 39). Further to the west a gra-

FIGURE 39

JURASSIC
WELL 10/5-1

ILLUSTRATION WELL:
BØRGLUM "UNIT"
(BOKNFJORD GROUP)



dual change in lithology can be observed. The amount of carbonaceous material in the upper claystones increases (Norwegian well 9/12-1 (Shell) from 2011 m to 2038 m (Olsen, 1980) resulting in the transition to the Tau Formation in the Fiskebank Sub-Basin and in the Egersund Sub-Basin (see above). The lower part of the Børglum unit as observed in the eastern areas is probably equivalent to the silty Egersund Formation in the north-west (see above).

It is therefore recommended that the Danish nomenclature (the Børglum Member) should be applied in the south-eastern Norwegian Danish Basin and that the revised Norwegian nomenclature as described in this volume should be applied in the north-western area.

Tyne Group (new)

Name:
From the River Tyne in north-eastern England. It includes sediments formerly assigned to the

FIGURE 40

JURASSIC

WELL 2/7-3

TYPE WELL:

HAUGESUND,ELDFISK,FARSUND FORMATION

TYNE GROUP

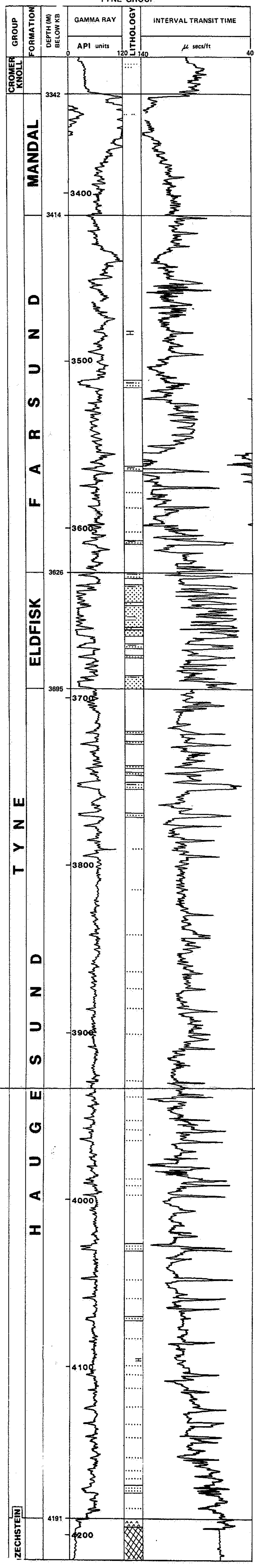


FIGURE 41

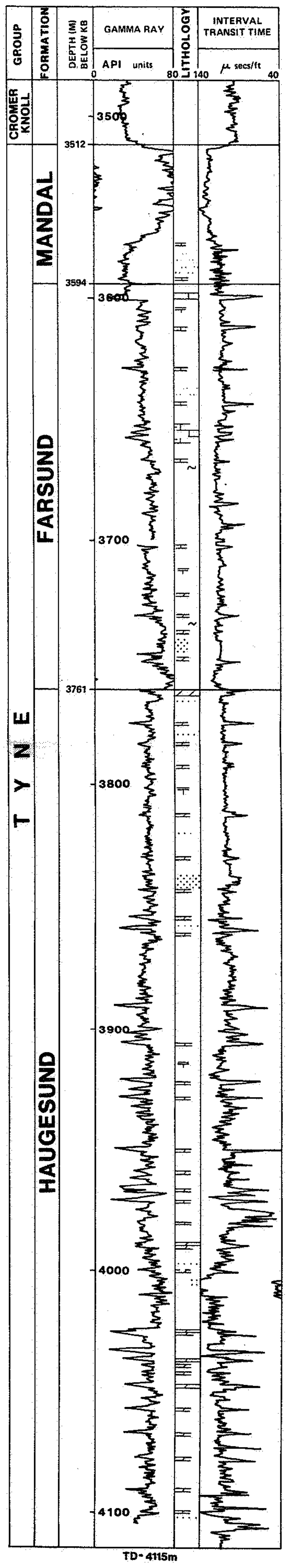
JURASSIC

WELL 2/8-3

REFERENCE WELL:

HAUGESUND,FARSUND FORMATION

TYNE GROUP



Humber Group by Deegan and Scull (1977). For further discussion, see "remarks" under the Viking Group.

Type area:
The group is found in the Central Graben and the Southern Vestland Arch. Its northern limit is defined approximately by 58° N. The Tyne Group is illustrated in the Norwegian sector by wells 2/7-3 (Phillips) and 7/12-2 (BP).

Thickness:
The Tyne Group is thickest in the axial regions of the Central Graben, where more than 800 m of the group have been penetrated. The group thins, locally to only a few metres, over intrabasinal highs and the Southern Vestland Arch.
The thicknesses in the above selected wells are 839 m (2/7-3) and 116.5 m (7/12-2).

Lithology:
Claystone is the dominant lithology of the Tyne Group sediments. These range in colour from grey to brownish black and contain frequent silty, sandy and calcareous horizons. The Tyne Group also includes a thicker, discrete sand unit occuring locally in the Central Graben which is named the Eldfisk Formation.

Boundaries:
In wells situated in the axial portion of the Central Graben the base of the Tyne Group is not penetrated except where the group is underlain by diapiric Zechstein salt (e.g. 2/7-3). On the south-western flank of the Southern Vestland Arch the Tyne Group overlies sands of the the Vestland Group or may locally rest with unconformity on Triassic or Lower Jurassic sediments. In most cases the lower boundary is marked by a downward break to lower gamma ray and generally higher sonic log velocities.
The upper boundary is picked where the exceptionally high gamma ray response and low sonic velocity of the Mandal Formation (the uppermost formation of the group) gives way to the lower gamma ray, and higher sonic velocity values of the Lower Cretaceous Cromer Knoll Group.

Distribution:
The Tyne Group is distributed throughout the Central Graben and over the Southern Vestland Arch. It passes northwards (in the Viking Graben) into the Viking Group. Due to the overall transgressive nature of the unit the higher formations of the group are more widely distributed.

Age:
The group ranges in age from Callovian to Ryazanian.

Subdivision:
Four formations are recognised within the Tyne Group, namely the Haugesund, Eldfisk, Farsund and Mandal Formations. The lowermost is the Haugesund Formation, which is generally overlain by the Farsund Formation. Locally in the Central Graben the two formations are separated by the Eldfisk Formation. The uppermost and most widespread unit is the Mandal Formation.

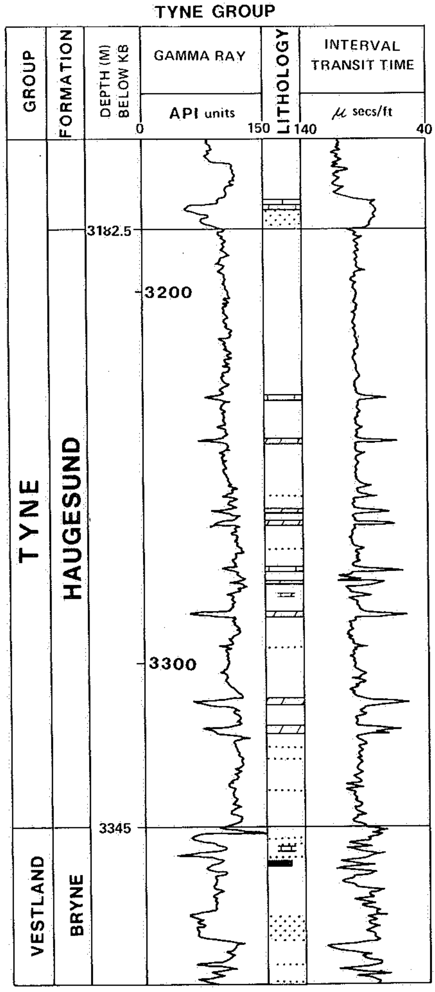
Haugesund Formation (new)

Name:
After the town of Haugesund on the west coast of Norway.

Well type section:
Norwegian well 2/7-3 (Phillips) from 3695 to 4191 m, coord N 56°23'02.9'', E 03°15'45.9'7 (Fig. 40). See "remarks" for qualification of this well type section.

Well reference sections:
Norwegian well 3/5-2 (Gulf) from 3182.5 to 3345 m, coord N 56°32', 56°32'34.46'', E 04°23'11.1'', (Fig. 42) and 2/8-3 (Amoco) from

FIGURE 42
JURASSIC
WELL 3/5-2
REFERENCE WELL:
HAUGESUND FORMATION
TYNE GROUP



3761 m to 4115 m (T.D.), coord N 56°18′31″, E 03°26′54.1″ (Fig. 41).

Thickness:
496 m in the type well, 162.5 m in 3/5-2, and 354 m in 2/8-3. The formation is thickest in the axis of the Central Graben and thins towards the flanking highs, where it passes partially or entirely into the sandy lithology of the Ula Formation.

Lithology:
The Haugesund Formation consists predominantly of shale ranging in colour from light grey to brownish black. The shale is often carbonaceous and calcareous, and contains frequent thin sandstone interbeds. In general the upper part of the formation represents an overall "coarsening-upward cycle", becoming sandier and siltier upwards.

Boundaries:
In the type well, 2/7-3, the Haugesund Formation overlies Zechstein salt and the base of the formation is therefore obvious from both logs and cuttings. However, the Zechstein salt is almost certainly penetrative at this location and does not therefore provide a true stratigraphic base for Haugesund Formation (see "remarks". In the reference well 2/8-3 and elsewhere in the Central Graben the base of the Haugesund Formation is often found overlying the Vestland Group. This is shown in the reference well 3/5-2 where the upward change from the sandy Bryne Formation to the shales of the Haugesund Formation produces the expected gamma ray/sonic log break (see Fig. 42).

The top of the Haugesund Formation in the type well is the contact with the sandy Eldfisk Formation. In areas of the Central Graben where the Eldfisk formation is absent, the top of the Haugesund Formation is picked at a clearly correlatable gamma ray minimum, above which the gamma ray increases to the higher values of the basal Farsund Formation (e.g. well 2/8-3).

Distribution:
The formation is ubiquitous in the Central Graben and widely distributed around the flanks of the basin and intra-basinal highs. It is absent in the Ula Field where it is entirely replaced by time-equivalent sands of the Ula Formation, and is also absent on the crest of the Southern Vestland Arch and intra-basinal highs.

Age:
Callovian to Early Kimmeridgian. In neither the type nor the reference wells have pre-late Oxfordian ages been proven but Callovian mudstones assignable to the Haugesund Formation occur in the vicinity of the reference well, 3/5-2.

Depositional environment:
The bulk of the shales of the Haugesund Formation were deposited in a marine, low energy, basinal environment. The common thin sand interbeds may represent sporadic turbidite influxes emanating from the adjacent shelf where coarser clastics (i.e. the Ula Formation) were being deposited. The "coarsening-upward" nature of the sequence represents an overall regression which was terminated by a further transgression and the deposition of the Farsund Formation shales.

Remarks:
The type well 2/7-3 penetrated a thick development of the Haugesund Formation, considered to be typical of the formation as it is commonly encountered in the Central Graben. However, the inadequately defined base of the formation makes 2/7-3 ultimately unsatisfactory as a type well. None of the other Central Graben wells available to this study establish a base for this formation, and penetrations on the flanks of the basin (such as the reference well 3/5-2) are fewer, atypical and potentially controversial stratigraphically. Penetration of a well-defined base for the Haugesund Formation by a future well in the Central Graben would perhaps provide a rare instance in which replacement of a type well might be justified.

Eldfisk Formation (new)

Name:
From the Eldfisk Field in Norwegian block 2/7.

Well type section:
Norwegian well 2/7-3 (Phillips) from 3626 m to 3695 m, coord N 56°23′02.9″ E 03°14′45.9″ (Fig. 40).

Well reference section:
Norwegian well 1/9-3 (Statoil) from 4359.5 m to 4386.5 m, coord N 56°24′56.2″, E 02°54′15.15″ (Fig. 43).

Thickness:
69 m in the type well 2/7-3 and 27 m in the reference well.

Lithology:
The Eldfisk Formation consists predominantly of sandstone but contains substantial interbeds of shale. In the type well the sandstone is dark yellowish brown, fine to coarse grained, poorly sorted and generally angular, while the shale is medium light grey to dark grey. Both the sandstone and the shale contain calcareous streaks which produce high amplitude peaks on the sonic log.

Boundaries:
The sands of the Eldfisk Formation are entirely enclosed within the thick upper Jurassic shale sequence of the Central Graben. The Eldfisk Formation is therefore easily distinguished from the underlying Haugesund Formation and the overlying Farsund Formation by its lower gamma ray readings.

Distribution:
As defined at present, the main development of the Eldfisk Formation is confied to the region of the Eldfisk Field, although thin time equivalent sands are present in other parts of the Central Graben.

Age:
Kimmeridgian

Depositional environment:
The Eldfisk Formation represents an influx of sand into the axial portions of the Central Graben at a time of regression, and for this reason it is postuilated that the formation is turbiditic in origin. However, no conventional cores have been taken in the sands and there is no definitive sedimentological evidence.

Farsund Formation (new)

Name:
After the town of Farsund on the south-west coast of Norway.

Well type section:
Norwegian well 2/7-3 (Phillips) from 3414 m to 3626 m, coord B 56°23'02.9'', E 03°14'45.9'' Fig. 40).

Well reference sections:
Norwegian well 7/12-2 (BP) from 3306 m to 3378.5 m, coord N 57°06'41.34'', E 02°50'50.73'', (Fig. 32) and 2/8-3 (Amoco) from 3594 m to 3761 m, coord N 56°18'31'', E 03°26'54.1'', (Fig. 41).

Thickness:
200 m in the type well and 72.5 m (7/12-2) and 167 m (2/8-3) in the reference wells. The formation attains its maximum thickness in the axial part of the Central Graben and thins towards the flanking highs.

Lithology:
The Farsund Formation consists predominantly of medium to dark grey shale. The shale is often well laminated and contains frequent calcareous streaks. Sandstone stringers are common in the type well 2/7-3, particularly in the lowermost part of the sequence. In the reference well 7/12-2, closer to the flank of the Southern Vestland Arch, a thinner Farsund Formation is present as a clear "coarsening upward cycle", becoming consistently less radioactive towards the top of the unit.

Boundaries:
In the type well the base of the Farsund Formation occurs at the top of the sandy Eldfisk Formation and as a consequence is a pronounced gamma ray marker. Similarly, in the reference well the Farsund Formation overlies the sandy Ula Formation and is easily distinguished on logs. In several wells within the Central Graben, the Farsund Formation overlies the shaly Haugesund Formation with no intervening sand (e.g. reference well 2/8-3). Here the base of the Farsund Formation is picked directly above the gamma ray minimum which forms the top of the Haugesund Formation.

The top of the Farsund Formation is marked by a further gamma ray minimum. Above this occurs the distinct log motif of the Mandal Formation, with its high gamma ray and interval transit time readings.

Distribution:
The formation is present throughout the Central Graben but thin or absent over the Southern Vestland Arch and intra-basinal highs.

Age:
Kimmeridgian to Volgian.

Depositional environment:
The Farsund Formation shales were mainly deposited in a low energy marine environment. The gamma ray log profile suggests that the formation represents an initial period of deepening followed by gradual shallowing. In parts of the Central Graben the occurence of thin sand stringers in the lower part of the formation probably represent minor turbidite influxes from the adjacent shelf, where time equivalent sands of the Ula Formation were being deposited.

Mandal Formation (new)

From a town on the south coast of Norway. It replaces the Kimmeridge Clay Formation as used by authors in the Central Graben area (e.g. Ofstad, 1983). The name was informally proposed by Hamar et.al., (1982).

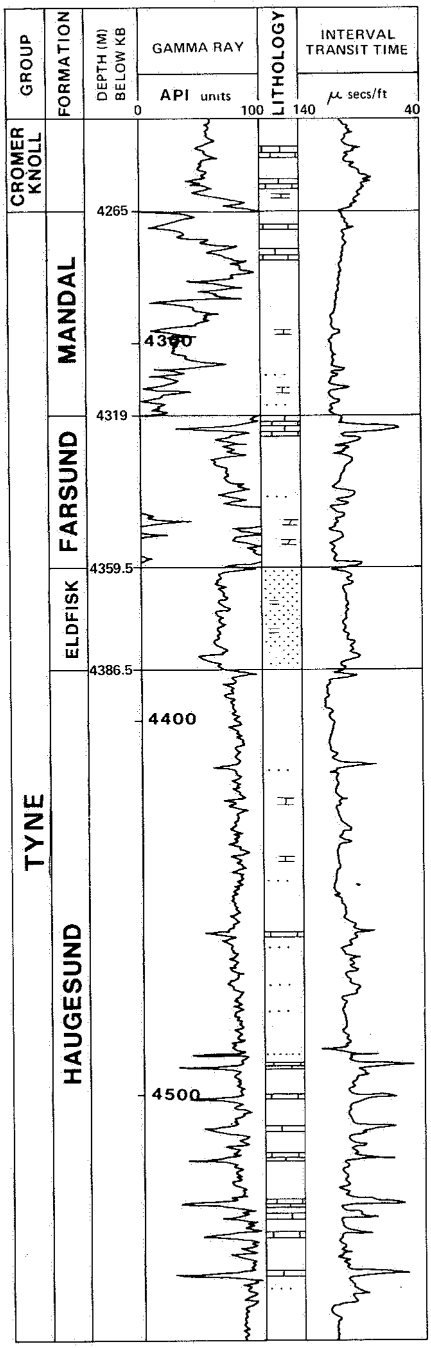
Well type section:
Norwegian well 7/12-3A (BP) from 3514 m to 3552 m, coord N 57°06'24.54'', E 02°48'41.56'', (Fig. 44).

Well reference sections:
Norwegian wells 2/1-2 (BP) from 3300 m to 3316 m, coord N 56°57'30.76'', E 03°12'32.07'', (Fig. 33) and 1/9-3 (Statoil) from 4265 m to 4319 coord N 56°24'56.2'', E 02°54'15.15'', (Fig. 43).

Thickness:
In the type well 38 m and in the reference wells 16 m and 54 m. The thickness usually varies between 10 m and 70 m and generally thins over structural highs.

Lithology:
The formation consists of a dark grey-brown to black, slightly to non-calcareous, carbonaceous claystone becoming fissile in places. It is characterized by a very high level of radioactivity which is a function of organic carbon content. In addition it has an anomalously low velocity, a high resistivity and a low density. It may con-

FIGURE 43
JURASSIC
WELL 1/9-3
REFERENCE WELL:
ELDFISK, MANDAL, FORMATIONS
TYNE GROUP



tain thin stringers of limestone/dolomite and, in some areas, sandstone (e.g. 1/9-3).

Boundaries:
The contacts of the Mandal Formation with underlying and overlying sediments are easily recognized on logs due to its high gamma ray and resistivity readings and its low velocity and density.

Distribution:
The Mandal Formation is found in the Central Graben, and on the margins of the Southern Vestland Arch. The northern limit is the Jæren High.

Age:
Volgian to Ryazanian.

Depositional environment:
The formation was deposited in an anaerobic marine environment with high organic productivity and restricted bottom circulation.

Remarks:
See Draupne Formation.

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REFERENCES

Ager, D. V. 1981: The nature of the stratigraphical record. 2nd Edn, Macmillan Press Ltd.

Arkell, W. J. 1947: The geology of the country around Weymouth, Swanage, Corfe and Lulworth. Mem. geol. Surv. G. B.

Bailey, C. C, Price, I. and Spencer, A. M, 1981: The Ula Field, block 7/12, Norway. In, Norwegian Symposium on Exploration (NSE -81), Norsk Petroleumsforening, Bergen.

Bertelsen, F. 1980: Lithostratigraphy and depositional history of the Danish Triassic. Danm. Geol. Unders. Ser. B. No. 4.

Casey, R. and Rawson, P. F. 1973: A review of the Boreal Lower Cretaceours. In, The Boreal lower Cretaceous. Geol. J. Spec. Iss. 5, 415—430.

Chauvin, A. L. and Valachi, L. Z. 1980: Sedimentology of the Brent and Statfjord Formation of Statfjord Field. In, The Sedimentation of the North Sea Reservoir Rocks. Norsk Petroleumsforening, Geilo.

Clemmensen, L. B, Steel, R. J. and Jacobsen, V.W., 1980: Some aspects of Triassic sedimentation and basin development: East Greenland, North Scotland and North Sea. In, The Sedimentation of North Sea Reservoir Rocks. Norsk Petroleumsforening, Geilo.

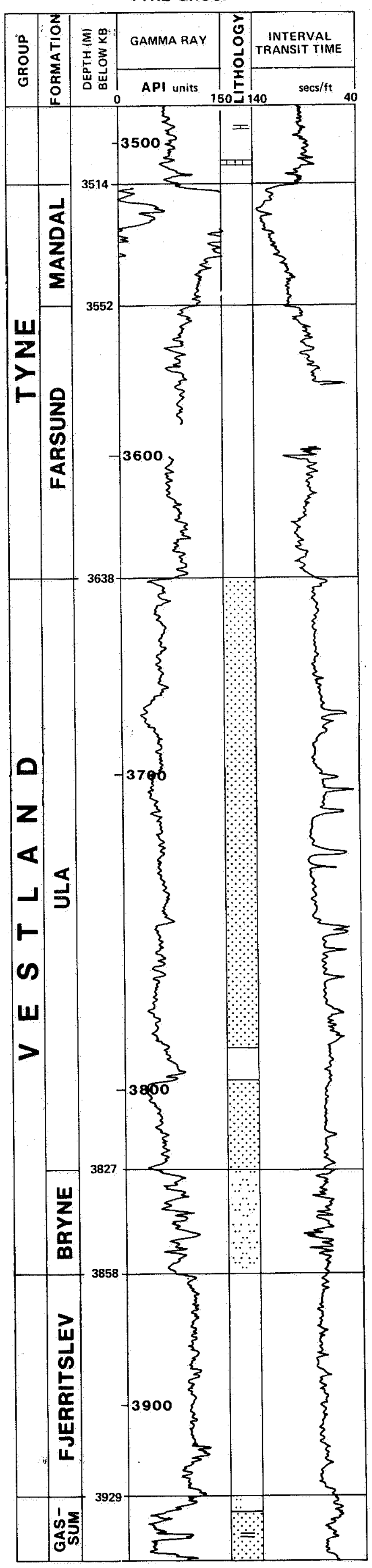
Cope, J. C. W., Duff, K. L., Parsons, C. F., Torrens, H.S., Wimbledon, W.A. and

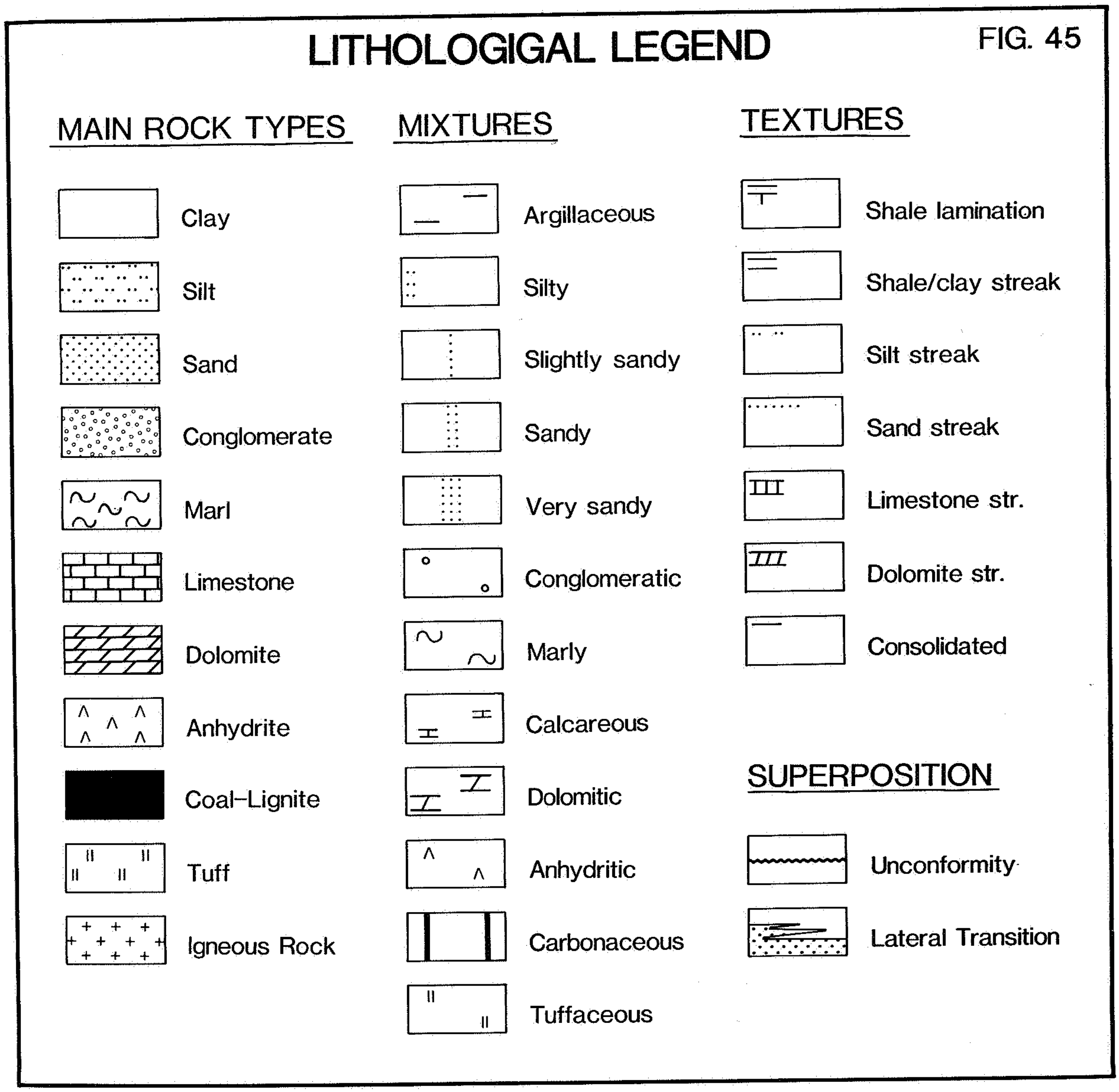
FIGURE 44

JURASSIC
WELL 7/12-3A

TYPE WELL:

MANDAL FORMATION
TYNE GROUP





Wright, J. K. 1980: A correlation of Jurassic rocks in the British Isles. Part 2. Middle and Upper Jurassic. Geol. Soc. Lond. Spec. Rep. No. 15.

De 'Ath, N. G. and Schuylman, S. F. 1980: The Geology of the Magnus oil field. In, Illing and Hobson (Eds.), Petroleum Geology of the continental shelf of North-West Europe. Institute of Petroleum, London, 342 — 351.

Deegan, C. E and Scull, B. J, (compilers), 1977: A proposed standard lithostratigraphic nomenclature for the Central and Northern North Sea. Rep. Inst. Geol. Sci.,No. 77/25: Bull. Norw. Petrol. Direct., No. 1, HMSO, London.

Dixon, J. E., Fitton, J. G. and Frost R. T. C. 1981: The tectonic signifiance of post-Carboniferous igneous activity in the North Sea Basin. In, Illing and Hobson (Eds.), Petroleum geology of the continental shelf of North-West Europe. Institute of Petroleum, London.

Furnes, H., Elvsborg, A. and Malm, O. A. 1982: Lower and Middle Jurassic alkaline. magnetism in the Egersund Sub-Basin, North Sea. Marin. Geol. vol. 46, nos. 1—2. 53—69.

Hamar, G. P., 1982: Tektonisk historie av Nordsjøen. Dansk geologisk Foren. Årsskrift for 1981. 161—164.

Hamar, G. P., Fjæran, T. and Hesjedal, A. 1982: Jurassic stratigraphy and tectonics of the south-eastern Norwegian offshore. In, Petroleum geology of the south-eastern North Sea and adjacent onshore areas. Geol. en Mijnb. The Hague.

Harms: J. C., Tackenberg, P. and Pickles, E. 1980: The Brae Field area. In, The Sedimentation of the North Sea Reservoir Rocks. Norsk Petroleumsforening, Geilo.

Harms, J.C., Tackenberg, P., Pickles, E. and Polloch, R. E. 1981: The Brae oilfield area. In, Illing and Hobson (Eds.), Petroleum geology of the continental shelf of

North-West Europe. Institute of Petroleum, London. 352—357.

Hedberg, H. D. (Ed.), 1976: International Stratigraphic Guide: a guide to stratigraphic classification, terminology and procedure. International Subcommission on Stratigraphic Classification of IUGS Commission on Stratigraphy. Wiley — Interscience, New York.

Hodson, G. M. 1975: Some aspects of the geology of the Middle Jurassic in the northern North Sea, with particular reference to electro-physical logs. In, Jurassic northern North Sea Symposium. Norsk Petroleumsforening, Stavanger.

Howitt, F., Aston, E. R. and Jacque, M. 1975: The occurrence of Jurassic volcanics in the North Sea. In, Woodland, Ed., Petroleum and the Continental Shelf of North-West Europe, vol. 1. Applied Science Publishers. 379—386.

Jakobson, K. H., Hamar G. P., Ormaasen, D. E. and Skarpnes, O. 1980: Triassic facies in the North Sea north of the Central Highs. In, The Sedimentation of the North Sea Reservoir Rocks. Norsk Petroleumsforening, Geilo.

Kirk, R. H. 1980: Statfjord Field — North Sea Giant. In, Giant Oil and Gas Fields of the last decade. Am. Ass. Petrol. Geol. Mem. 30.

Larsen, G. 1966: Rhaetic — Jurassic — Lower Cretaceous sediments in the Danish Embayment (A heavy mineral study). Danm. geol. Unders., Ser II, 91.

Larsen, R. M. and Jaarvik, L. J. 1981: The geology of the Sleipner Field Complex, In, Norwegian Symposium on Exploration (NSE -81), Norsk Petroleumsforening, Bergen.

Michelsen, O. 1978: Stratigraphy and distribution of Jurassic deposits of the Norwegian—Danish Basin. Dan., geol. Unders. ser. B No. 2.

Nederlandse Aardolie Maatschappij B. V. and Rijks Geol. Dienst. 1980: Stratigraphic nomenclature of the Netherlands. Verl. K. Ned. geol. Mijnb. Genoot.

Ofstad, K. 1983: Geology of the southernmost part of the Norwegian section of the Central Trough. NPD Paper No. 32.

Olsen, R. C. 1980: Lithology, Well 9/12-1. NPD Paper No. 27.

Olsen, R. C. and Strass, I. F. 1982: The Norwegian-Danish Basin. NPD Paper No 31.

Rawson, P. F. and Riley, L. A. 1982: Latest Jurassic — Early Cretaceous events and the "Late Cimmerian Unconformity" in North Sea area. Bull. Am. Assoc. Petrol. Geol. 66, 12, 2628—2648.

Rhys, G. H. (compiler), 1974: A proposed standard lithostratigraphic nomenclature for the Southern North Sea and an outline structural nomenclature for the whole of the (UK) North Sea. Rep. Inst. Geol. Sci., No. 74/8.

Rhys, G. H. 1975: A proposed standard lithostratigraphic nomenclature for the Southern North Sea. In, Woodland (ed.) Petroleum and the continental shelf of North-West Europe. Vol. I. Applied Science Publishers. 151—163.

Riley, L. A. 1977: Stage nomenclature at the Jurassic-Cretaceous Boundary, North Sea Basin. In, Mesozoic northern North Sea Symposium, Norsk Petroleumsforening, Oslo.

Rønnevik, H. C., van den Bosch, W. and Bandlien, E. H. 1975: A proposed nomenclature for the main structural features in the Norwegian North Sea. Jurassic North Sea Symposium. Norsk Petroleumsforening, Stavanger.

Saks, V. N. and Shulgina, N. L. 1973: Correlation of the Jurassic-Cretaceous boundary beds in the Boreal Realm. In, The Boreal Lower Cretaceous. Geol. J. Spec. Iss. 5. 387—392.

Tyson, R. V., Wilson, R. C. L. and Downie, C. 1979: A stratified water column environment model for the type Kimmeridge Clay. Nature. 277, 5695, 377—380.

Ziegler, P. A. 1982: Geological Atlas of Western and Central Europe. Shell Internasjonale Petroleum Maatschappij B. V. The Hague.

APPENDIX 1

Lithostratigraphic unit	Type well	Fig	Page
Amundsen Formation	UK 211/29-3	10	20 a
Boknfjord Group			42
Brent Group			24
Broom Formation	UK 211/29-3	10	20 a
Bryne Formation	9/4-3	29	38
Burton Formation	UK 211/29-3	10	20 a
Cook Formation	UK 211/29-3	10	20 a
Drake Formation	UK 211/29-3	10	20 a
Draupne Formation	30/6-5	22	31
Dunlin Group			20
Egersund Formation	9/4-1	34	43
Eldfisk Formation	2/7-3	40	46 a
Etive Formation	UK 211/29-3	10	20 a
Farsund Formation	2/7-3	40	46 a
Fensfjord Formation	31/2-1	21	30 b
Fjerritslev Formation	DK Fjerritslev no 2		
Flekkefjord Formation	9/4-2	38	46
Gassum Formation	DK Gassum no. 1		
Haugesund Formation	2/7-3	40	46 a
Heather Formation	UK 211/21-1A	18	29
Hegre Group			10
Hugin Formation	15/9-2	26	37
Johansen Formation	31/2-1	13	22
Krossfjord Formation	31/2-1	21	30 b
Lomvi Formation	33/12-5	2	12 a
Lunde Formation	33/12-2	4	12 b
Mandal Formation	7/12-3A	44	50 a
Rannoch Formation	UK 211/29-3	10	20 a
Sandnes Formation	9/4-3	29	38
Sauda Formation	9/4-3	36	44
Sleipner Formation	15/9-2	26	37
Sognefjord Formation	31/2-1	21	30 b
Statfjord Formation	33/12-2	6	18
Tarbert Formation	UK 211/29-3	10	20 a
Tau Formation	9/4-3	36	44
Teist Formation	33/12-5	2	12 a
Tyne Group			46
Ula Formation	17/12-2	32	41
Vestland Group			35
Viking Group			28