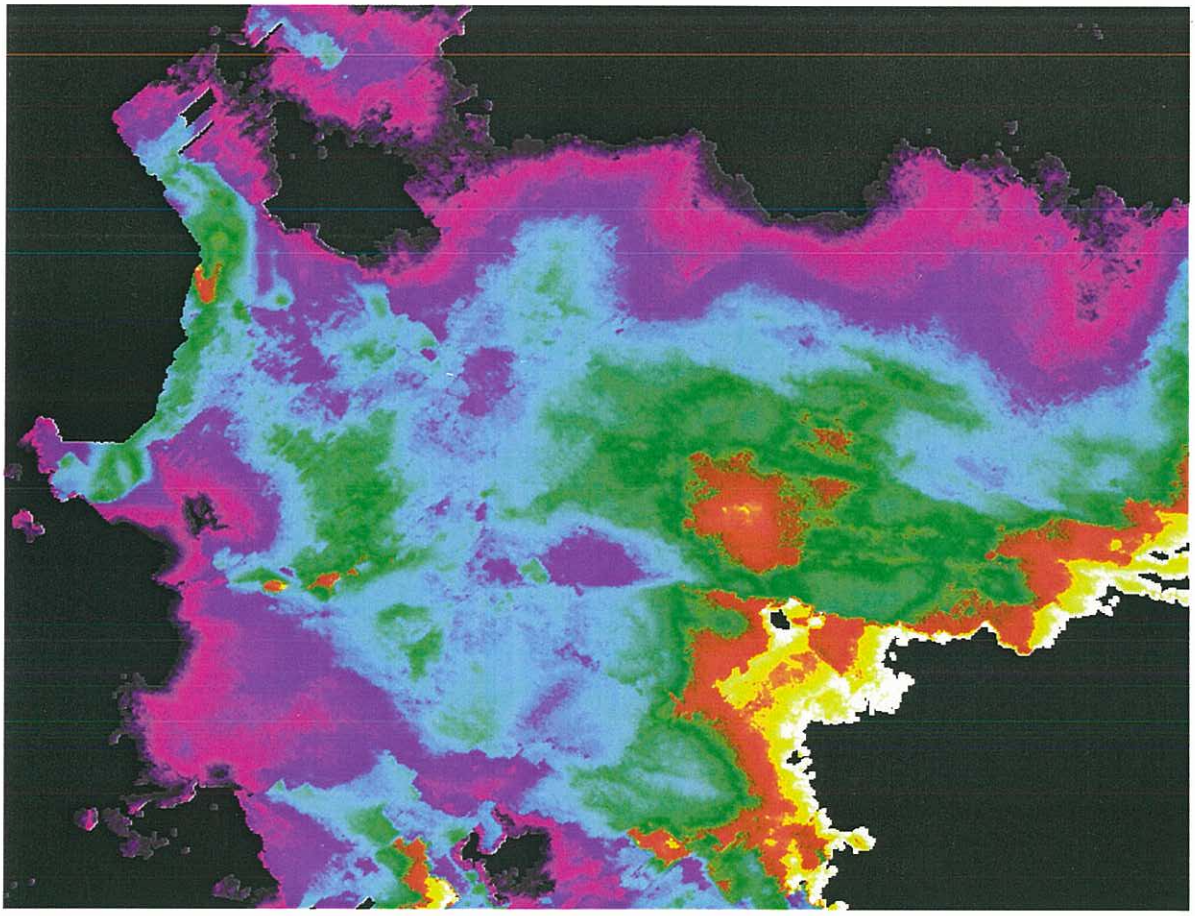
Faroe Islands Exploration Conference 2004



Abstracts

Tuesday May 4
09:00

THREE GOOD THINGS – ALL WHAT'S NEEDED FOR A MAJOR DISCOVERY

Geir Lunde, Man. dir. GeysirPetroleum hf

In fairytales the number "three" frequently occurs. A major hydrocarbon discovery in Faroese waters may to some sound like a fairytale, but all what is needed is three good things – a good reservoir, a large trap and lots of hydrocarbons.

The first four exploration wells have together proven all these elements. The thick Paleocene sands proven in the southern part of Faroese waters may reduce the potential for stratigraphic traps but are excellent for structural traps. The regional sand distribution is still not known and therefore presence and quality of reservoir represents a major uncertainty in prospect evaluation. Both the likelihood of a western sand source and the thick proven sands are positive factors.

Large structural closures have been mapped both in licensed and open areas, especially below the basalt. The Amerada oil and gas discovery proves a working petroleum system. The challenge now is to find all the three good things at the same spot.

The oil industry has a lot of tools at hand to reduce the risk before drilling, but at the moment we may not have enough experience with these tools in an environment where sediments, basalt layers, volcano-clastics and sills intermingle. Most of the tools have been used prior to drilling without impressive results. In addition to improved understanding of the Faroese geology some of the brand new technologies may prove to be useful. Sea bed logging may be such a new technology worth considering.

Even if technology should not be capable of significant risk reduction we are confident that the industry will find that a number of the large structural closures below the basalt are attractive drilling targets.

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Tuesday May 4
09:25

Faroese Area: Structural Interpretation of Seismic Data in a Basalt Environment

Judith Keser Neish
Geophysical Consultant
Faroese Geological Survey

Abstract

The Faroe Islands and associated offshore shelf area are located on the North Atlantic Margin of Europe, and form one of the principal components of the North Atlantic Large Igneous Province. A significant amount of volcanic material was laid down over this area in the Paleocene, consequently blanketing the geological structure. This presents a substantial challenge for geophysical exploration in the region, where precise geological information is sparse, as well control is confined to a small, restricted corner of the area.

However, over the last ten years, advances in seismic data acquisition and processing technology have resulted in specific data sets which allow imaging of intra and sub-basalt units in the more basinal areas, where basalt is not present at outcrop. This data was analyzed to determine the geophysical characteristics of the geological units present, and a system was developed for the differentiation, categorization, and correlation of geological units and structures based upon these geophysical characteristics. The corresponding areal mapping of these units can assist in documenting the definition and evolution of structural relationships of the basalt and sub-basalt units throughout the region.

In areas adjacent to the Faroese Platform, Paleocene flow basalts are overlain by a post-basalt sedimentary section which is thick and well-developed towards basin centres. The flow basalt units are underlain by older interpreted sedimentary units which may be considered to be of interest to hydrocarbon exploration. These units are in turn underlain by a block-faulted basement whose fault and structural trends define the pre-existing features of the area.

Although structure throughout the area has been strongly influenced by Paleocene volcanism and subsidence, the main controls upon formation and orientation of structural features have been exerted by the basement faults. The predominant trend direction in the area is SW-NE (Caledonian), and a younger, NNW-SSE trend is also seen and constrains, for example, Munkagrunnur Ridge. Later Eocene-Miocene compressional events are also evident within the area. Another key to the structural genesis is given by the presence of NW-SE trending transfer zones, which serve to offset and terminate structures as well as providing sediment entry points into the basinal features which they may influence or control.

These factors indicate that the evolution of margin features as a result of changing stress regimes has played a major role in defining the Faroese area in its current form.

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Tuesday May 4
09:50

Transfer Zones : Their Influence on the Onshore and Offshore Geological Development in the Faroes Underground

D.Ellis[1], Ragnar Poulsen[1], Peter Dromgoole[2] and Joseph W Gallagher[1]

[1] *Statoil Færøyene as*
[2] *APPRO Consultants Ltd*

Abstract

Transfer Zones are large, linear features interpreted to be geologically very old (600 Ma or older) and linked to deep crustal fractures. Transfer Zones in the North Atlantic around the Faroe-Shetland area have a strong NW-SE orientation and subparallel spacing of 20-25km. Seismic images over transfer zones give poor definition, possibly due to oblique slip movement of rock units across complex fracture systems. Better evidence for the existence and role of transfer zones comes from gravity, magnetic, outcrop and well penetration data.

In the Faroes area, onshore evidence is presented to show the influence of the Judd and Westray Fracture Zones on the development of the lava sequences and interbedded coals and other sediments. Well data offshore is coupled with gravity-magnetic interpretations to show the influence of transfer zones on sediment distribution through geological time and their influence on the area structural history. Critical linking of transfer zones from the Faroe-Shetland margin across to Greenland during the geological past will have had great influence on the volumes, location and type of sediments made available for reservoir development especially during the Cretaceous and Early Tertiary times.

Faroe Islands Exploration Conference 2004

Tuesday May 4
10:35

An Updated View of the Faroes-Shetland Basin Petroleum System:

Steve Cawley (BP), Hamish Matheson (BP) and Gordon Stalker (RML)

Abstract

After disappointing results in the Svinoy (6004/12-1) and other wells in the Faroes-Shetland Basin in 2001-2002, BP (on behalf of BP-Shell in Faroes License 004) reviewed the methodology it had used to risk the individual elements of the Petroleum System of the Faroes-Shetland Basin. These were:-

- Reservoir Presence
- Reservoir Effectiveness
- Top Seal Effectiveness
- Access to Charge

The new well data were incorporated into BP's existing wells and seismic database which allowed the integration of the risked elements into a single model from the Base Tertiary to the top of the Paleocene T36 Sequence. This risk model had three specific aims:-

1) Identify areas of regional prospectivity and provide a tool for prospect scale de-risking.
2) Provide a vehicle to quantify and visualize charge risk, building in both lateral and vertical migration via coherent fetch-area mapping from Base Tertiary.
3) Clearly communicate predicted modes of failure in high risk areas.

Key conclusions:-

Basin general:

1. Reservoir presence is generally low risk but effectiveness is highly spatially variable, primarily controlled by sediment provenance.
2. Seal effectiveness is equally variable and a key control on charge migration out of the first Tertiary carrier (T10-T20 sequences) into the shallower Palaeocene reservoirs (T31-T36).
3. Charge is generally low-medium risk but migration/access is a complex plumbing issue governed by 3D seal distribution.

License specific:

1. T36 is the most prospective sequence; low geological model risk and medium charge risk.
2. T34 Kunoy has medium risk on reservoir effectiveness, seal presence and access to charge.
3. T31 Kunoy has medium/high risk on reservoir presence and high risk on seal effectiveness.

Faroe Islands Exploration Conference 2004

Tuesday May 4
11:00

The Lower Cretaceous play in the Faroes – A comparative study from the North Atlantic western margin (Kangerlussuaq, southern East Greenland)

Michael Larsen[1] and Snorre Olaussen[2]

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[2]ENI, Norsk Agip A/S, Travbaneveien 3, P.O. Box 101, Forus, NO-4064 Stavanger, Norway

Abstract

Following the first Faroes Licensing Round and the somewhat discouraging results of recent drilling campaigns with focus on the Paleocene deep water sandstones, other play concepts may receive renewed interest. Lower Cretaceous sandstones are thus proven an excellent reservoir in the Victory Gas Field (west of the Shetland Islands), and Lower Cretaceous units forming potential reservoirs are also known from the southern part of the Faroe Shetland Channel, .

The use of analogues from the West Shetland area, however, depends on the assumption, that sedimentary basins of the Faroes continental shelf have gone through the same geological evolution. This is probably true for the southern and eastern areas, whereas areas to the north and west may be linked closer to the development of the East Greenland margin. Alternative sediment source areas need also to be considered for these areas, which in periods may have received significant amounts of sediment from East Greenland (Larsen et al. 1999a).

In the Kangerlussuaq Basin, southern East Greenland, Lower Cretaceous (Upper Aptian–Albian) fluvial-estuarine and shallow marine sandstones form an outcrop analogue for the Lower Cretaceous Play of the Faroes. The coarse-grained succession is up to 100 m thick and characterised by stacked lenticular sandstone-bodies up to 20 m thick which may be divided into two types characterised by their geometry and internal facies. *Massive, channelised sandstones* dominate the lower part of the succession. They are amalgamated, showing erosional lower boundaries with a relief of up to several metres and are interpreted as channel-fills deposited in the inner part of an estuary. *Large-scale cross-bedded sandstones* occur in the upper part of the succession. They show conformable lower boundaries and form isolated bodies encased in marine mudstones. The sandstones show simple avalanche foresets, up to 12 m thick, and were formed by migration of tidally influenced sandbars.

The excellent, almost vertical outcrop allows detailed analysis of sandstone-body geometry and vertical-stacking patterns based on stereographic photographs and vertical sections. An upward-change from amalgamated channel-fills to isolated large-scale cross-bedded sandstones towards the top of the succession suggests creation of increasing accommodation space through time reflecting an overall rise in relative sea-level. The Lower Cretaceous succession was affected by a mid-Cretaceous? tectonic phase leading to block rotation and the formation of local unconformities. The sandstones are thus unconformably overlain by a thick succession of Cretaceous and Paleocene marine mudstones.

Based on the East Greenland succession, the reservoir of the Lower Cretaceous Play may be predicted as eustarine and shallow marine systems deposited along structurally controlled basin margins. Reservoir quality is expected to be good, but may be dependent on the precipitation of chlorite coatings preserving porosity at depths. A combination of lateral and vertical migration pathways may have focused hydrocarbons towards structural highs, where potential trap configuration was established by mid-Cretaceous? rifting. The main concerns for a

prolific Lower Cretaceous Play are the deep burial in the central Faroe-Shetland Basin and the basaltic cover hindering seismic imaging of leads in the northern and western Faroes area.

Larsen, M., Hamberg, L., Olaussen, S., Nørgaard-Pedersen, N. & Stemmerik, L. (1999) Basin evolution in
southern East Greenland: An outcrop analog for Cretaceous-Paleogene basins on the North Atlantic volcanic
margins. Bulletin American Association of Petroleum Geologists, **83**(8),1236-1261.

Faroe Islands Exploration Conference 2004

Tuesday May 4
11:25

The Deepwater Cretaceous Frontier – Geology and Exploration of the Vøring and Møre Basins.

Elisabeth Berg Kristensen, Harald Brekke, Christian Magnus, Tore Høy & Robert Williams.
Norwegian Petroleum Directorate

Abstract

Exploration in the deep water areas in the Norwegian Sea offshore Norway has, since its beginning in 1995, been focussed on the Cretaceous and Palaeocene sequences of the Vøring and Møre basins. These basins were established by the main rifting episode in the Late Jurassic to earliest Cretaceous and the subsequent Early Cretaceous thermal subsidence. Starting in latest Turonian to earliest Coniacian times, the Vøring Basin was subject to Late Cretaceous block faulting, flank uplift and increased subsidence. Towards the end of the Cretaceous the tectonic activity increased and culminated in Mid-Palaeocene accompanied by basin uplift and widespread erosion of basin highs. The Møre Basin, situated to the south of the Jan Mayen Lineament, show little evidence of this tectonic activity. Minor discoveries were made in reservoir sands of the Lower and Upper Cretaceous in the eastern flanks of the basins before the deep-water drilling campaign started. In the basins themselves, no well have so far penetrated rocks below the Turonian. However, sandy intervals have been confirmed in the Conaician, Santonian, Campanian and Maastrichtian, as well as in the Lower Palaeocene. Provenance studies show that a major part of the Cretaceous western and central basin fill is derived from East Greenland, whereas minor contributions from the Norwegian mainland are seen in deposits along the eastern basin flanks. The distribution in time and space of these sand deposits is complex and further exploration calls for improved sedimentological models. To date three gas discoveries and one oil discovery are made within the deep basin areas. The hydrocarbons are probably generated from both Jurassic (gas) and Cretaceous (oil) source rocks. Well data indicate possible source rock intervals in the both Lower and Upper Cretaceous of the basins and their eastern flanks but a good quality source rock of Cretaceous age is still to be confirmed. In-house analyses of the state of oxidation of Cretaceous shales indicate local favourable environment for the development of Cretaceous source rock within the basin setting. The NPD play models of the Cretaceous and Lower Palaeocene of the Vøring and Møre Basins are updated according to the latest well information of the area.

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Tuesday May 4
13:30

Palaeogene magmatism within the Faroe-Shetland and Rockall-Hatton areas

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[3] Faroese Geological Survey, Brekkutún 1, P.O. Box 3169, FO-110 Tórshavn
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Abstract

The structure, nature, facies, age, geochemistry and distribution of approximately 0.75×10^6 square km of Palaeogene igneous rocks within the Faroe-Shetland and Rockall-Hatton areas are summarised. A review of models regarding the offshore continuation of the Faroe Plateau Upper, Middle and Lower Basalt formations suggests that the Upper Basalt Formation probably progrades the furthest to the SE within the Faroe-Shetland Basin and to the SW towards Hatton Bank. The majority of sills of mid-ocean ridge basalt composition forming the NE-trending Faroe-Shetland Intrusive Complex are considered to have been emplaced synchronously with geochemically similar lavas, dykes or sills from the younger part of the Faroes succession though later than the development of the Erlend Igneous Centre. In the Wyville-Thomson Ridge area, the initial results of seismic mapping have indicated that the Palaeogene lavas have been extensively deformed and that volcanic rocks derived from the Sigmundur Seamount, Darwin Igneous Centre, Drekaeyga Volcanic Centre, Faroe Channel Knoll and Regin Smiður Volcanic Centre appear younger than those from Munkagrunnur Ridge. The Regin Smiður and Drekaeyga Volcanic centres form significant caldera-like features, though unusually, the latter feature is not associated with a positive gravity anomaly. Within the Rockall Basin, examples of post-Balder Formation (c. 55 Ma) submarine lavas are considered to have been derived from the Rockall Basin Intrusive Complex. Within the Rockall - Hatton area, nine igneous complexes in various states of preservation have been identified from seismic and potential field data, although igneous rocks have only been recovered from the Rockall and Sandastre Igneous centres. Seismic mapping of lavas derived from igneous complexes within the Hatton Bank and Basin areas suggests that these are younger than those that comprise the SDRs identified on the NW margin of Hatton Bank.

The age correlations of igneous features and events within the study area are derived within the context of a new compilation of radiometric ages for the North Atlantic Igneous Province as a whole. Two main phases of magmatism have been identified between approximately 62-57 Ma and 57-54 Ma. The older phase is associated with the development of the Iceland Plume and includes nearly all the British Onshore Tertiary Volcanic Province, the Faroe Plateau Lower Basalt Formation and extrusive activity within Greenland. The younger phase is mainly associated with the development of extrusive and intrusive rocks within East Greenland, the Vøring Margin, the Faroe Plateau Upper and Middle Basalt formations, the Faroe-Shetland and Rockall Intrusive complexes and possibly the vast majority of the numerous igneous centres (e.g. Rockall and Darwin) within the Wyville-Thomson and Hatton-Rockall areas. From the results of biostratigraphical analysis, the Rosemary Bank and Anton Dohrn seamounts within the Rockall Basin are of latest Cretaceous age, although both appear to have undergone subsequent phases of activity.

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Tuesday, May 4
13:55

New understanding of the environments of eruption of the lava flows and their relationship with interbedded sedimentary rocks of the Faroe Plateau Lava Group, Faroe Islands, NE Atlantic

Simon R. Passey

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Abstract

The exposed Faroe Plateau Lava Group (FPLG) on the Faroe Islands can be separated into three subaerial lava-dominated formations: the Lower Basalt Formation (LBF), the Middle Basalt Formation (MBF), and the Upper Basalt Formation (UBF). The LBF and UBF have a tabular-classic facies architecture, in contrast with the MBF, which has a compound-braided facies architecture. LBF and UBF lavas, averaging *ca.* 25 & 8 m thick, respectively, are characterised by massive sheet flows with rubbly tops that were erupted at high effusion rates, travelled significant distances, and each flow was emplaced in a matter of weeks to a few months. Prismatically jointed flows, which are dominant throughout the LBF and UBF, were erupted into relatively dry environments. Conversely, columnar jointed flows, dominant within the uppermost *ca.* 100 m of the LBF, were emplaced into wet environments. These flows are commonly associated with fluviatile/lacustrine/swamp strata and preserve morphological evidence for damming of river channels. The MBF lava flows are *ca.* 20 m thick and are made up of thinner flow units, <0.5 to 2 m in thickness. These flow units exhibit characteristic pahoehoe flow features, including ropy surfaces, pipe vesicles and lobes, and were passively emplaced through inflation and via very efficient lava tube networks. The MBF lava flows were erupted from low shields at lower effusion rates than the lavas of the LBF and UBF and were emplaced over months to years. The interlava fluviatile/lacustrine lithologies of the LBF are composed of reworked palagonitised basaltic tephra and basalt lava clasts, whereas the terrestrial lithologies of the MBF and UBF are composed predominantly of reworked palagonitised basaltic tephra.

Faroe Islands Exploration Conference 2004

Tuesday, May 4
14:20

Affects of Tertiary Volcanism and later Events upon the Faroese Hydrocarbon System

Stephen Linnard, Rob Nelson

Abstract

The Faroes-Shetland continental margin has long been a tectonically active area. We believe that only with a regional geological understanding can the hydrocarbon potential of the region be properly assessed. Information has been gathered from numerous sources in order to build a picture of the evolution of the area. This is a massive undertaking and must consider analyses, observations and conclusions of co-workers from both industry and research. We offer ideas on how just one part of the geological jigsaw, the early Tertiary volcanic phase, may have fundamentally affected the development of the hydrocarbon system of the Faroese continental area. The impact of volcanic events at this time on trapping, source, reservoir seal and charge should be ignored at our peril. Post volcanic events have also significantly affected the Faroese hydrocarbon system and should be given due consideration.

This paper is intended primarily to provoke a thought process amongst explorers, and it is in this spirit that it is offered.

Faroe Islands Exploration Conference 2004

Tuesday, May 4
15:05

Tectonic and Palaeorelief Control on Slope Channels and Submarine Canyons: Implications for the Palaeogene Play of the North Atlantic

Gregers Dam[1], Michael Larsen[2] and Andrew G. Whitham[3]

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Abstract

The Palaeogene play is one of the key plays of the North Atlantic containing large accumulations of both oil and gas in basins along the margin. The play is closely related to processes controlling Late Cretaceous – Early Paleocene rifting and Paleocene–Early Eocene volcanism. The rifting episode and magmatic underplating was thus associated with substantial uplift and repeated erosion along the basin margins leading to increased sediment input into offshore basins. Studies of three Late Cretaceous – Palaeogene sedimentary successions in the North Atlantic, including the West Greenland Nuussuaq Basin, the East Greenland Kangerlussuaq Basin, and the Faroe-Shetland Basin demonstrate that the major controls on the position of sediment input points are the presence of northwest–southeast trending lineaments and the palaeorelief of the basement.

In the Nuussuaq Basin in West Greenland, large subaerial valleys and submarine canyons, up to 200 m deep and 2 km wide, were incised along Early Paleocene northwest–southeast trending faults. These faults are parallel to the major lineaments of the basins, clearly showing that major sediments transfer paths were structurally controlled. The canyons and valleys acted as sediment path for a major basin-floor-fan system situated in the offshore areas of West Greenland.

In southern East Greenland a major sediment input point existed in the Kangerlussuaq region. The presence of a structurally-controlled sediment input point in this region is supported thick Palaeogene sediments along the axis of a structurally controlled sub-basin lying west of a major northwest–southeast oriented fault. The sandstone dominated succession consists of turbidite channel, deltaic and fluvial deposits showing palaeocurrents parallel to the lineament and probably feeding offshore basins to the southeast. Pre-drift reconstructions indicate that the present-day Faroe Islands were situated less than 100 km southeast of the Kangerlussuaq, suggesting that the East Greenland entry point may have had a major impact on reservoir distribution in the Faroes area.

In the Faroe-Shetland Basin detailed structural mapping and studies of the sedimentary successions indicate that the primary control on sediment input points are the presence of northwest-southeast trending lineaments related to major transfer elements.

Additional sediment entry points may occur along old topographic lows in the basement surface. At the margin of the Nuussuaq Basin the pre-basalt basement surface is an undulating surface rising from 100 m above sea level to 900 m in the east, with local palaeomountains rising 700 m above this surface. Locally, in topographic lows in the basement surface Paleocene turbidite sandstones and marine mudstones lie between the basement and the overlying basalt indicating that these topographic depressions are very old features formed by fluvial incision and acted as major sediment pathways for turbidite slope channels during the Palaeogene. These spectacular old incised valley systems are up to 650 m deep. Similar old incised valley systems have been mapped in the Faroe-Shetland Basin and locally also had a major importance as sediment pathways in this basin.

The present study indicates that Palaeogene depositional systems were focussed along tectonic lineaments and palaeotopographic lows, which acted as a conduit for sediments being transported from both the Greenland and UK basin margins towards the Faroe-Shetland Basin. Understanding of these systems has an extremely important impact on our understanding of reservoir distribution in the sub-basaltic areas of the Faroes and future development of the Palaeogene play the North Atlantic region.

Tuesday, May 4
15:30

Paleocene development of the Faroes area

Ragnar Poulsen[1], Dave Ellis[1], Joseph W Gallagher[1], Rune Lundstrøm[2] and Peter Dromgoole[3]

[1] *Statoil Færøyene as*
[2] *Statoil UPN LET*
[3] *APPRO Consultants Ltd*

Abstract

Drilling of exploration wells in the last two years in the Faroes area has yielded new and exciting information about the geological development of the Palaeocene within the western portion of the Faroe-Shetland Basin.

During the deposition of the early Paleocene Sullom and Vaila formations, copious amounts of sand were shed into the basin and were deposited in a deep marine environment. As the basin filled, deltas built out from the eastern side of the basin during Upper Lamba and Flett Formation times and the far-reaching basaltic lava flows of the Faroes Lower Formation were deposited in a subaerial delta-top environment.

Provenance studies indicate that during the early Paleocene, sediments were sourced from both the Shetland Platform to the east and East Greenland margin to the west. During late Paleocene times the Shetland Platform was the dominant source region supplying sediment into the Faroes area.

Significant challenges lie ahead in understanding the stratigraphical and sedimentological evolution of the Faroes margin, especially where the thick development of basaltic lavas hampers seismic imaging over much of the Paleocene interval.

Faroe Islands Exploration Conference 2004

Tuesday, May 4
15:55

Paleocene sandstones in the Faroes area, from erosion to deposition

John R. Smallwood

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Abstract

The former "White Zone" or undesignated area, the previously unlicensed acreage between the UK and Faroe Islands, was opened through the Faroes 1st and the UK 19th Licensing Rounds in 2000 and 2001. In 2001 and 2002, the first 6 of 15 commitment exploration wells were drilled in these licenses, on a variety of play types. An assessment of the risks of stratigraphic traps in the area, and analysis of the petroleum system, led to the siting of the 6004/16-1z well, drilled in 2001 by Amerada Hess and its partners, on the structural high of a Tertiary inversion anticline. The resulting "Marjun" discovery, the first in the Faroes, consisted of 170m of hydrocarbon-bearing sands in the T10 Early Paleocene interval.

The 6004/16-1Z Marjun well, along with several of the other recent exploration wells drilled in the Faroe-Shetland Channel area, encountered significant thicknesses of Paleocene sandstones. 6004/16-1Z penetrated T36 to T28 sediments totalling *c.* 1500 m in thickness, with an overall average sand net to gross ratio of 0.6-0.7. Although oil shows were encountered at several levels within the T30s and T20s intervals in 6004/16-1Z, the absence of a significant hydrocarbon accumulation at these levels can be attributed to the lack of an integral top seal between T28 and T36 in this part of the basin. A similar high sand proportion and corresponding lack of shale seal development appears to have been a factor in the lack of an oil accumulation in the location tested by Svinoy well 6004/12-1.

The presence of such high sand:shale ratios poses some questions for those seeking to understand the development of the basin during the Paleocene. Does the large quantity of sand encountered in the basinal wells explain the apparent mass balance mismatch between hinterland erosion and sediment quantities in the basin? Where did all this sand originate and what controlled the development of accommodation space? Drilling has established the presence of large quantities of sandstones, but deep seismic methods and gravity methods have historically struggled to identify igneous underplating in the Faroe-Shetland area that could be associated with Paleocene hinterland and shelfal uplift. Igneous sills in the basin that have been Ar/Ar dated generally have ages corresponding to the Early Eocene, too late to be part of an intrusion event causing sands to be shed from shelfal area in the Lower Paleocene.

Evidence and lack of evidence for igneous underplating therefore has sustained a debate on the base level variations attributed to intrusion and solidification of igneous material within the crust. Can gravity gradiometry find high density material in mid and lower crust in the hinterland? I present new analysis of an old gravity gradiometry survey in Scotland – can the underplating now be found?

Faroe Islands Exploration Conference 2004

Wednesday, May 5
09:00

Imaging sub-basalt with deep towed streamer: A case study from the Faroe Islands

Rupert Hoare, Phil Schearer, Andrew Langridge and Emmanuel Saragoussi, WesternGeco *, Philip Christie, Schlumberger* [†] *, and the iSIMM team* [1]

Abstract

The integrated Seismic Imaging and Modelling of Margins (iSIMM) project is a joint industry-university research project seeking to characterize magmatic ocean margins and develop new models for their evolution. The iSIMM project aims to tackle two of the biggest problems facing hydrocarbon explorationists on the NW European Atlantic margin, and on all other volcanically dominated margins. These are the inability of conventional seismic reflection methods to image through basalt layers overlying sediments, and the failure of current methods and software to model properly the stretching, subsidence, and thermal history of rifted continental margins.

The seismic components of iSIMM seek to address the seismic imaging problem by developing techniques using very long-offset, low-frequency, streamer acquisition, together with wide-angle imaging using ocean-bottom seismometers (OBS) to penetrate through the basalts. It will then be possible to develop a structural model from seabed to Moho to image the stretched crust and the extruded, intruded, and under-plated igneous material, and to use these constraints in magmatic margin basin modeling.

In summer 2002, seismic data were acquired successfully over two such margins: the Hatton-Rockall margin and the margin to the northeast of the Faroe Islands, using a combination of towed streamers and ocean-bottom seismometers (OBS). This paper describes the towed-streamer survey over the Faroes margin, where a 385-km profile was acquired by WesternGeco using three single-sensor streamers.

The acquisition used a source array tuned for low frequencies, building upon reported experiences of imaging below shallow basalts west of Ireland, and seismic characterisation of Lower Series basalts in the Lopra borehole. The time and depth processing of the towed-streamer data has been completed and, in this paper, we describe key features of the acquisition and the processing, and we present examples of the data.

Wednesday, May 5
09:25

Imaging Through Igneous Rock on the Faroese Shelf

Robert S White & iSIMM Scientific Team
University of Cambridge
Email: rwhite@esc.cam.ac.uk

Abstract

Massive magmatism occurred on the North Atlantic margins when the continents broke apart in the presence of the Iceland mantle plume. The magmatism resulted primarily from interaction between the Iceland mantle plume and the rifting continents. The igneous rocks were emplaced as extrusive lava flows, as sills and as intrusions in the lower crust. I discuss the challenges they pose to seismic imaging, and the advances we have made in imaging through the basalts and into the underplated lower crust. I show results from two recent seismic experiments undertaken across the Faroes Shelf and continental margin: The Faroes Large Aperture Research Experiment (FLARE), which used two ship techniques to record data to maximum offsets of 38,000 metres; and the integrated Seismic Imaging and Modelling of Margins (iSIMM) profiles shot in 2002 which recorded spectacular data using a 12,000 metre, 4000 channel Q-streamer with a 48-gun array, together with long-range data to beyond 140 kilometres using 85 four-component ocean bottom seismometers deployed along the same profile.
Combination of normal incidence and wide-angle seismic data, together with use of sources tuned to the low frequencies required for intra- and sub-basalt penetration enable us to see structure both within and below the basalts. I discuss the processing and imaging strategies we have developed, show examples from two contrasting environments with extrusive igneous rocks, one on the rifted Atlantic continental margin and the other on the flank of the Faroe-Shetland Trough, and discuss their geological interpretation.

The FLARE profiles were shot by Amerada Hess Limited and its partners LASMO (ULX) Limited, Norsk Hydro a.s., DOPAS and Atlantic Petroleum. The iSIMM project is supported by Liverpool and Cambridge Universities, Schlumberger Cambridge Research, Badley Technology Limited, WesternGeco, Agip, Amerada Hess, Anardarko, BP, Conoco-Phillips, Statoil, Shell, the Natural Environment Research Council and the Department of Trade and Industry. The iSIMM Scientific Team comprises NJ Kusznir, RS White, AM Roberts, PAF Christie, R Spitzer, N Hurst, ZC Lunnon, CJ Parkin, AW Roberts, LK Smith & V Tymms.

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Wednesday, May 5
09:50

Towards Imaging Beneath Thick Basalt - Multiple Suppression

Riaz Alai, Simon Robinson
Anadarko Petroleum Corporation
London, December, 2003-12-03

Abstract

The 2D seismic data in the study area offshore the Faroes contains a series of strong multiples which would mask any primaries beneath the very thick basalts. Anadarko obtained and implemented the SRMA software through participation in the Delphi consortium (Verschuur et al., 1992, Berkhout and Verschuur, 1997). The SRMA procedure uses the data itself as the multiple prediction operator. Since the quality of the signal above the basalt layer is relatively good, the estimation of the surface related multiples using this technique was expected to be relatively successful.

The data were first prepared using linear noise suppression and near offset interpolation (in the parabolic Radon domain proposed by Kabir and Verschuur, 1995). After near offset interpolation, reciprocity was used to create split-spread data, reducing artefacts at the near offsets. As expected, the SRMA techniques provided a stable estimate of multiples at near offsets. These appeared to be the strongest multiples, as predicted from the velocity profile. The application of the multiple estimation procedure and adaptive least squares subtraction of the multiples proved very effective.

The problem that faces us now is what to do next?

Faroe Islands Exploration Conference 2004

Wednesday, May 5
10:35

Applications of seafloor compliance measurements to petroleum exploration

Wayne C. Crawford, Satish C. Singh, and Thomas Hulme

Laboratoire de Géosciences Marines

Abstract

Seafloor compliance is a geophysical prospecting method that uses the seafloor motion under ocean waves to determine the shear modulus structure of the subsurface. This method, introduced nearly 20 years ago for sediment studies and subsequently developed for the study of magma chambers at mid-ocean ridges and of gas hydrates, is of general interest to petroleum exploration, because of its sensitivity to fluid-filled regions and the continuous nature of its source. We will present an overview of the method: how compliance is measured, what it is sensitivity to, what kinds of studies have already been performed and how it can be used for petroleum exploration and monitoring of oil reservoirs. We will show specific examples of the compliance sensitivity to buried fluid (or fluid-saturated) bodies, and we will compare the compliance sensitivity to P and S-wave velocities, anisotropy and attenuation to that of seismic wave propagation methods. We will how the joint inversion of seismic and seafloor compliance data can improve the quantification of sub-surface geology. Finally, as an illustrative example, we will show the compliance sensitivity to sub-basalt sediments and to deep unconsolidated sediments.

Faroe Islands Exploration Conference 2004

Wednesday, May 5
11:00

Elastic Impedance Inversion to aid lithology prediction in the Palaeocene of the Judd sub-basin

Mark Woodfin[1], Jon Seedhouse[1], Giacomo Spadini[2], and Maurizio Cardamone[2].

(1) ENI UK, Wellington Circle, Redmoss, Aberdeen, AB12 3JG, United Kingdom.
(2) ENI - E&P Division, Via Emilia 1, San Donato Milanese, 20097, Italy.

Abstract

Prior to drilling in Faroes Licence 002, the presence of seals and trapping geometries were highlighted as the most risky elements of the petroleum system. This paper outlines how Elastic Impedance Inversion was used to aid the identification of sealing lithology and trapping geometries in the sand-prone Palaeocene sediments of Licence 002.
Two discrete stratigraphic traps were identified using inversion volumes generated with calibration to a single offset well. The data also proved valuable during the design of the casing scheme for the well. A second well was made available prior to drilling and an interim inversion exercise, using the data from two offset wells, was undertaken prior to the drilling of the 6004/17-1 well.
Good lithology prediction was achieved in the 6004/17-1 well with the limited pre-drill well control. Knowledge of P-impedance, S-impedance and Poisson Ratio sheds light on the subtle lithological variations responsible for the possible stratigraphic closures and the related reservoir presence. The integration of those diagnostics from well data analysis and fluid-replacement modeling appears to be the key ingredient for a correct interpretation and use of the EI results.
Key issues arising from the well results involve the prediction of tuffaceous sandstones and the resolution of the inversion volumes – the seal intervals are at the very limit of resolution of this technique.

Faroe Islands Exploration Conference 2004

Wednesday, May 5
11:25

A scorecard to assess the quality of 3D seismic amplitudes - a case study from the Atlantic Margin.

Richard Hinkley

ChevronTexaco

Abstract

"ChevronTexaco drilled well 204/17-1 in the UK Atlantic Margin during Q2 2003, to test a stacked Late Paleocene amplitude play in the Judd Basin. This paper describes a technical "look-back" on the results, using a proprietary intranet-based scorecard that was developed during 2002. The scorecard, through a series of technical questions and associated weights, enables the quantification and calibration of amplitude anomalies in terms of (1) technical maturity and (2) the ability to predict lithology and fluid-fill. Using this tool, it's been possible to re-benchmark amplitude expectations in the region, in anticipation of the 2nd Round of Offshore Licensing".

Faroe Islands Exploration Conference 2004

Wednesday, May 5
13:30

The use of AVO in lithology determination, NW Atlantic margin

Richard Morgan and Dave Went, Veritas DGC Ltd.

Abstract

Previous success of AVO to support prospects in the Faroe-Shetland Basin has not continued in recent exploration drilling and outcomes have been disappointing. This must inevitably raise doubts in many explorationist's minds as to whether AVO can be used as a prospect finding technique in this area.

To better understand the fundamentals underpinning the seismic response in this area a multiple well log-based rock property study has been performed, incorporating all released exploration wells in the Judd Basin. Analysis of this database including, generation of forward models of the AVO signature, indicates that AVO can be used to characterise aspects of lithology and pore fluid. But, there are important mitigating factors that can result in ambiguity and misinterpretation when this approach is applied.
Key amongst these are:

1. the non-uniqueness of the near offset reflection co-efficient associated with a shale over sandstone interface
2. the strong AVO effect associated with brine filled lithologies, that can commonly overpower other oil bearing responses
3. the effects of noise in the AVO inversion procedure which limits the practical usefulness of traditional pre-stack AVO attributes and which results in mismatches between rock property models and inversion results.

The first two factors limit the usefulness of the stack, partial stacks and elastic impedance inversions (generated from partial stacks) as anomaly indicators. The third limits the usefulness of pre-stack attributes that purport to invert for rock properties such as Poissons ratio etc, but which in reality are less powerful.

An appreciation of these key factors can significantly reduce risk in itself. It also allows for the design of seismic attributes that are less susceptible to misinterpretation. Building upon the results of the rock property work, an AVO based inversion, here termed Facies Finder, has been produced that, when used with appropriate controls, can discriminate lithology and fluid differences. Advantages of this particular AVO procedure are independence from well log-derived models and an output that allows representation of lithology differences basin-wide. Because well logs are not an input to the inversion, the validity of the technique can be demonstrated through blind tests using discovery well and dry hole locations. Furthermore, favourable indicators can be placed in context within the basin and validated geologically, linking the seismic anomaly to the prospect. Examples of drilled and undrilled prospects are shown from the Judd Basin.

Faroe Islands Exploration Conference 2004

Wednesday, May 5
13:55

Interpretation of the FSB Mega Survey (Phase I)

*Nick Terrell,** *PGS Reservoir Consultants*
Perry Scoffield, *PGS Geophysical*
Huw Edwards, *PGS Reservoir Consultants*
Alex Ball, *PGS Reservoir Consultants*

* *denotes speaker*

Abstract

The first phase of the Faroe-Shetland Basin (FSB) Mega Survey has been created from the merging of both oil company and service company 3D seismic data in and around the former "White Zone" of the Faroe-Shetland Basin. This Mega Survey provides a continuous dataset over an area of 10,000 sq km of which some 1,650 sq.km covers Faroese acreage to the north and west of the Westray Ridge.

The paper will focus on the initial results from the interpretation which has been focused on key regional horizons in order to create a consistent structural and stratigraphic framework. The Mega Survey dataset allows visualisation and analysis of the subsurface on a scale and resolution that has not previously been fully recognised in this frontier province, providing detailed depositional and structural information over much of the basin. This new regional scale interpretation has included integration with potential field modelling and attribute analysis to provide answers to localised as well as regional questions, with dramatic visualisations of the subsurface to allow a step change in our understanding of the hydrocarbon potential of the Faroe-Shetland Basin.

The FSB Mega Survey is currently being expanded with the merging and interpretation of a further 10,000 sq.km of proprietary and non-exclusive 3D surveys in the basin.

Mega Surveys are an exciting new concept that push current technology to the limit and are already providing a basis for a new era of hydrocarbon exploration, not only reducing risk in mature provinces such as the North Sea but also in frontier provinces such as the Faroe-Shetland Basin.

Acknowledgements
PGS would like to acknowledge the support of the FSB Mega Survey project by the Faeroese Petroleum Administration, the UK DTI and both Oil and Service Companies who have contributed their data to the Mega Surveys.

Faroe Islands Exploration Conference 2004

Wednesday, May 5
14:20

Interpreting Aeromagnetic Data in a Basalt Province: Case study from the Faroe Islands

Heri Ziska[1] and Richard Morgan[2]

[1] *Faroese Geological Survey*
[2] *Veritas DGC plc*

Abstract

Magnetic data are in many areas, along with gravity data and seismic data, the backbone of any exploration effort, and it is in this context that several magnetic surveys have been acquired in the Faroese area, both onshore, offshore either in conjunction with seismic surveys or as dedicated airborne surveys. There is however a Palaeogene volcanic section of varying thickness which covers most of the Faroese area. The succession is divided into three separate volcanic successions called the lower, middle and upper series basalts. An onshore well was drilled in 1981 and deepened in 1996 in order to find the base of the volcanic section, but failed to do so despite a TD at 3565 m, and thus bringing the total stratigraphic thickness of the known volcanic pile to in excess of 6 km. This volcanic succession does have a very high magnetic susceptibility, and does in addition contain very high remanence. The latter does poses an additional problem with part of the lower series basalts being normally polarised, while the remainder of the section is reversely polarised.

Profile modelling demonstrates that there are so many factors that can affect the model when working with magnetic data that the end result is too ambiguous to be of any value as stand alone or even as an aid to conventional work. The high level of remanent magnetisation of the basalts does therefore make conventional methods of less value, but it can be used as a tool when trying to define the extent of the different series of basalt. Integrating those results with other methods, can reveal new information about the subsoil.

This article demonstrates that it is possible to correlate onshore measurement of paleomagnetic data with remotely measured magnetic response. This relationship can then be extrapolated offshore and does thereby provide a good tool for mapping certain features within the basalt offshore, and by consequence also give some evidence about the extent of the different basalt sections and the nature of the underlying section.

The basement structure under the Faroe Islands is poorly constrained. It has been possible to integrate the magnetic data with other data, and this has resulted in some indications on the basement structure under the Faroe Islands.

Another important point is that the suggested approach demonstrates that there might be ways of extracting useful information out of data, which can not be used the conventional way.

Wednesday, May 5
15:05

The SINDRI project - Linking the Faroese area and Greenland: New methods and techniques used in an innovative, integrated provenance study.

Knudsen, C., Frei, D., Rasmussen, T.V., Morton, A. & Whitham, A.:

Abstract

Three main analytical techniques are being used in the SINDRI project of which two are new in sediment provenance analysis, namely Laser Ablation - Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS) and Computer Controlled Scanning Electron Microscopy (CCSEM). The LA-ICP-MS method is a much faster and cheaper method of dating zircons compared to conventional SHRIMP dating. Furthermore, the method can be used to obtain trace element analytical data from other heavy minerals in the sediment. The CCSEM method is an automated analytical technique which, as well as yielding quantitative modal abundances of the heavy minerals present, also yields chemical analyses of the heavy minerals together with grain-size and grain-shape information. The application of these two techniques in provenance analysis has been developed at GEUS, and they are combined with information from detailed bulk rock geochemical analyses.
The new methods are compared with the more conventional methods such as point counting of heavy minerals and SHRIMP analysis, mainly using the SINDRI data. The three different techniques used at GEUS are self-supporting and the data from each of the techniques can be used independently. However, by combining and linking the methods they become a very powerful tool in provenance studies.

Faroe Islands Exploration Conference 2004

Wednesday, May 5
15:30

Joint Inversion of marine MT, Gravity and Seismic Data

(M. Jegen, University of Cambridge; R. Hobbs, University of Durham; P. Tarits, Universite de Bretagne Occ.)

Abstract

Exploration of sub-basalt targets is difficult because the basalt units reflect and scatter seismic energy, masking the characteristics of the underlying structure. Electromagnetic soundings are less sensitive to the highly resistive basalt units but are strongly influenced by the characteristics of the over and underlying sedimentary structures. So electromagnetic soundings are a valuable compliment to seismic surveys in such areas.

We have developed a joint interpretation scheme and inversion algorithm of seismic, MT (magneto-telluric) and gravity data that combines the information content in these data. While each method in itself is able to resolve only a part of the subsurface, we demonstrate that our joint inversion/interpretation technique allows us to identify the base of the basalt and yields information about the underlying sediment.

Using synthetic data we demonstrate how the various data types contribute to our inversion/interpretation technique, and show how we recover the sub-basalt structure. We then apply this combined scheme on marine MT, satellite gravity and long-offset seismic data acquired along FLARE-10 profile.

This work has been conducted under the EU funded SIMBA project and the FLARE-10 seismic data were made available to us by Amerada Hess.

Faroe Islands Exploration Conference 2004

Wednesday, May 5
15:55

Holistic Assessment of the Atlantic Margin Exploration Potential

Torgeir Stordal, Shell Exploration and Production

Abstract

The Atlantic Margin has a proven petroleum system as demonstrated by fields and discoveries in all the major basins. Over the Margin area from Ireland to Northern Norway both pre-rift, syn-rift and post-rift plays exist. However, Exploration success is geographically restricted and disappointing drillings results show that the petroleum geology is not well understood in many areas.

At Shell, we believe the Atlantic Margin is only partially explored and has the potential to deliver material Exploration opportunities, which can compete globally. In recognition of the complex nature of the petroleum geology of the area and the fact that geology does not follow national boundaries (!), the Atlantic Margin Exploration effort was recently re-organised into one Theme, rather than four country teams. Focus on regional analysis in a theme-based organisation allows a holistic view, fosters rapid transfer of learning and provides a framework for consistent assessment of plays and prospects across the entire Margin area.

Moving to deeper water away from proven areas require focus on technology applications for de-risking of prospects. Sub-basalt plays may have significant potential, but significant improvement in the seismic imaging is key to unlocking this potential.

Faroe Islands Exploration Conference 2004

Wednesday, May 5
16:20

Exploration Opportunities on the Faroese Continental shelf

Heri Ziska[1] and Claus Andersen[12]

[1]Faroese Geological Survey, [2]now GEUS

Abstract

The interest for exploration in the Faroe Islands got a boost in 1992, when the Palaeocene Foinaven discovery was made on neighbouring UKCS west of the Shetlands. The subsequent years saw lots of exploration related activities within the Faroese area, but the first round was not opened until 2000. Interest level was high and resulted in award of 7 licences with a total of 8 commitment wells and substantial geophysical data acquisition as part of the work programmes. The first drilling campaign in 2001 saw 3 wells focussed on Foinaven analogies. The results were disappointing, and a further test two years later confirmed that seismic amplitude driven prospects with a high stratigraphic component on the Upper Palaeocene play in the Judd Basin carry a high exploration risk.
On the positive side a hydrocarbon column was identified in the T10 Lower Palaeocene section on an anticlinal structure. It proved the existence of a working petroleum system and opened a possible new fairway. It is further emphasised that only a very small part of the Faroese area and a restricted stratigraphic section has been subject to exploratory drilling so far. The remaining part of the Faroese area is frontier with few 'hard' geological data to support evaluation of prospectivity.

Imaging below the cover of Paleogene basalts has proved to be a major challenge on the Faroes shelf. The available seismic data allows to a certain extent mapping of presumed sedimentary sub-basalt units E and SE of the islands along the slope of the Faroe-Shetland Channel. However, identification of nature and age of the pre-basaltic succession potentially spanning the interval Devonian – Palaeocene is conjectural. Structurally the area is composed of half-grabens divided by ridges and highs offering possibilities for formation of structural traps. The focus of this paper is to outline the exploration possibilities presented by the wide range of scenarios that are possible based on regional considerations and analogies to neighbouring area.

The UK part of the Faroe-Shetland Basin is a proven hydrocarbon province, and it is likely that also the neighbouring areas on the Faroes Shelf outside the Judd Basin contain effective source kitchens. Satellite and airborne slick detection surveys and geochemistry on seabed cores support the presence of a petroleum system in Faroese basalt-covered areas.

The main exploration risk is associated the presence of effective reservoirs. Most stratigraphic levels since the Devonian have yielded discoveries on the UK side of the Faroe-Shetland Channel. Apart from burial depth, provenance area to supply coarse clastic sediments to sub-basalt structural plays is an important issue. A dominant western source from Greenland has been proposed for both the Cretaceous and Palaeocene. This requires long distance sediment transport, which can be either accommodated along NW-SE oriented transfer zones or as an analogy to the present day Ganges Delta and Fan, where sediments originating in the Himalayas are dumped after fluvial transport over 100s of km across low relief lowlands.

Sealing is considered a minor issue as regional seals are developed both in the Upper Cretaceous and Palaeocene by analogy to neighbouring UKCS. The sealing capacity of the Basalt is unknown, but intra-basaltic sediments are expected to be sealing.

Large-scale sub-basalt structural closures have been mapped. Even applying conservative input parameters, their trapping capacity is several billion barrels of oil in place. In-spite of basalt-cover reducing imaging possibilities, a wide range of plays is envisaged on the Faroes Shelf offering several attractive exploration opportunities.

Poster session

Sub-basalt imaging – new insight from investigations of petrophysical and seismic properties of Faroes basalts (SeiFaBa project)

Japsen, P.[1], Waagstein, R.[1], Andersen, C.[2], Andersen, M.S.[3], Djurhuus, J.[3], Mavko, G.[4], Boldreel, L.O.[5], Pedersen, J.M.[6], Petersen, U.K.[3], Rasmussen, R.[1], Shaw, F.[7], Springer, N.[1], White, R.S.[8] & Worthington, M.[7]

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[4] *Stanford University, Dept. of Geophysics, California 94305-2215, USA*
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[6] *Ødegaard A/S, Titangade 15, DK-2200 Copenhagen N*
[7] *University of Oxford, Department of Earth Sciences, Parks Road, Oxford OX1 3PR, UK*
[8] *University of Cambridge, Bullard Laboratories, Madingly Road, Cambridge CB3 0EZ, UK*

The development of methods of seismic imaging beneath basalts is still hindered by a lack of knowledge about the elastic properties of basaltic sequences and the degree of three-dimensional heterogeneity. The SeiFaBa project (2002-2005) is funded by the Sindri Group as part of the programmes for licensees within the Faroese area and will address these issues.
The Glyvursnes-1 well was drilled by SeiFaBa through the Upper basalt series outside Tórshavn during 2002. A full core and numerous logs were acquired from the 700 m deep well. During the same operations, the existing 660 m deep Vestmanna-1 well was reamed and logged. The two wells are central to a number of closely coordinated experiments, which all are targeted at creating firm data-derived models for seismic wave propagation through a succession of basalt by combining detailed analysis at core, log and seismic scales.
The seismic programme was initiated by a test during 2002 and the main part of the acquisition was carried out in 2003. The well site at Glyvursnes gives optimal conditions for combining VSP, offset-VSP and surface seismic experiments: the terrain is flat and the seismic effects of a nearby near-vertical shear zone can be studied in detail.
The investigations will provide a unique data set and new understanding of the petrophysical and seismic properties of Faroes basalt. Drilling of the new bore hole at Glyvursnes and re-logging of Vestmanna-1 in combination with the extensive data set for the Lopra-1 well will give valuable new stratigraphic control of the Lower, Middle and Upper Basalt formations on the Faroes.
The relations of sonic velocities of basalt to porosity, composition, stress and fluid content will be studied through detailed analysis of well logs and core material. This will allow for explanations of the sonic response of basalt in terms of physical and compositional properties and a better understanding of the seismic signatures of flood basalt successions.

Faroe Islands Exploration Conference 2004

Poster session:

A small reflection seismic experiment on Faroe Islands during summer 2003, preliminary results

Petersen, U.K.[1], Andersen, M.S.[1], Worthington, M.[2], White, R.S.[3], Mohammed, N.G.[3],Shaw, F.[2]
[1] University of the Faroe Islands, NoatÃºn 3, FO-100 TÃ³rshavn, Faroe Islands
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[3] University of Cambridge, Bullard Laboratories, Madingley Road, Cambridge CB30EZ, UK

The sub-basalt imaging is still hindered by a lack of knowledge about how the seismic waves are propagating through layered basalt flows. The SeiFaBa project (2002-2005), founded by the Sindri group, is investigating the seismic response of layered basalt flows.
As a part of the SeiFaBa project a comprehensive onshore-offshore seismic experiment was carried out around Glyvursnes, Faroe Islands, in the summer 2003. A 700 m deep borehole on Glyvursnes provides direct comparison between the seismic response and the basalt successions.
The onshore acquisition comprised five layouts of 120 vertical geophones using 250g dynamite charges at 3 m depth as source.
The onshore-offshore acquisitions comprised two layouts of a 96 channel moored streamer in combination with three layouts of 80 land stations using airguns as source offshore and dynamite as source onshore.
The streamer was 600 m with a group interval of 6.25 m. The land stations had 3-component geophones at every 4th position while the others were vertical geophones. Furthermore the signal was recorded in the borehole at 400 m depth by a 3-component geophone.
Preliminary seismic gathers and analysis of data will be presented.

Poster session

Studying sub-basalt sediments in the Faroes-Shetland Basin using seafloor compliance meaurements.

Wayne Crawford, Satish Singh and Thomas Hulme

In November 2004, we will study the existence and material properties of sub-basalt sediments in the Faeroes-Shetland basin, by measuring the seafloor compliance over sub-surface basalts. Seafloor compliance, the movement of the seafloor under pressure forcing from ocean waves, is sensitive to the subsurface shear modulus, and in particular to low shear modulus regions such as fluid-rich sediments. We measure seafloor compliance by deploying an autonomous long-period seismometer and pressure gauge to the seafloor for 1.5-2 days at a time. A 2D or 3D map of subsurface shear moduli can be made using repeated measurements and/or multiple instruments. Our measurements will be made in 900-1300 meters water depth, where compliance is sensitive to structure down to 5000-8000 meters beneath the seafloor. We will use the compliance measurements to determine the depth to the top and bottom of sub-basalt sediments, their shear modulus, and any lateral variations in shear modulus. The compliance measurements will lie along lines where seismic and electromagnetic data have previously been collected, to compare the sensitivity of these three methods to sub-basalt sediments and to investigate the advantages of joint inversion of seismic and seafloor compliance data.

Poster session

Seismic properties of Faroese basalts

Mohammed, N. G. [1], White, R. S. [1], Worthington, M. [2], Andersen, M.S. [3], Shaw, F. [2], Petersen, U.K. [3] & the SeiFaBa Group
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In order to fully understand and employ methods of seismic imaging beneath basalts a greater knowledge about the elastic properties of basaltic sequences and the degree of three-dimensional heterogeneity is required. The SeiFaBa project (2002-2005) is investigating the seismic response of the structure of layered basalt flows on the Faroe Islands and the link across scales from hand-specimens and core samples to those recorded by seismic techniques. We discuss the early results from an offshore-onshore (shooting offshore, recording onshore), seismic experiment designed to complement borehole sampling, VSP experiments and seismic reflection profiling of a region of layered flows from the Upper and Middle Series of the Faroes basalts.

A dense array of 45 autonomous Guralp (6TD) seismometers was deployed within the Glyvursnes region of Streymoy, Faroe Islands adjacent to the site of a 700 m borehole through the basalts (Glyvursnes-1). Deployment of the seismometers was in June-July 2003 and they were recovered in December 2003. During periods of controlled source seismic shooting, all sites maintained a sampling rate of 200 samples/sec. For intervening periods when they were recording earthquakes, a sampling rate of 100 samples/sec was used. In addition, three 400-m-long (120-channel) independent temporary land arrays were set up in September 2003 using a mixture of one- and three-component geophones.

Throughout the shooting, a three-component borehole seismometer was held clamped at 400 m in Glyvursnes-1, in the Middle Series basalts. By combining the surface recordings of wide-angle arrivals, measured by both the temporary and autonomous arrays, with the three-component borehole seismometer, the characteristics of wave propagation through the medium, including P- and S-wave response, anisotropy, absorption and scattering may be investigated. Recording of teleseismic phases will make it possible to explore the response of the layered basalt flows to a wider spectrum of frequencies than that provided by the airgun sources alone and potentially to measure the crustal thickness and the evidence for underplating from receiver function analysis.

The SeiFaBa group comprise the authors mentioned explicitly above plus C. Andersen, L. O. Boldreel, J. Djurhuus, P. Japsen, G. Mavko, J. M. Pedersen, R. Rasmussen, N Springer & R. Waagstein. This project is funded primarily by the SINDRI group.

Poster session

Faroese Region: A Standard Structural Nomenclature System

Judith Keser Neish

At a relatively early phase of exploration, it was recognised that contradictions already existed in the naming of major features with the Faroese area and that in order to avoid further confusion, a reconciliation of and formalisation of structural feature names was necessary.

JFS, under the funding auspices of the Sindri Group, undertook to compile a standard structural nomenclature system for the Faroese area north of 60° in order to standardize the naming of structural features within the Faroese region. To this end, a formalized nomenclature system was developed, along with a map identifying the major structural elements and geoseismic profiles further detailing these features. Each feature is described as well as the major physiographic characteristics of the Faroese islands. New names are proposed for recently recognised features; some features have been re-named, when current names are contradictory, not held in common usage or inappropriate with the principles of nomenclature, while other older names commonly in usage and well-documented throughout the literature and wider society have been retained.

The first priority for use in the naming of a feature is given to geographical names in the immediate area of the feature; that is, previously named shelf bathymetric features, overlying associated local fishing ground terminology, and overlying oceanic areas, where applicable.

Where not already established, names derived from islands, towns, or coastal features will be used only for structural features within the immediate locality of the name location; use elsewhere is considered to be unsuitable.

Should appropriate unique geographical names be already in use, or otherwise unavailable, priority will be given to names with a suitable traditional or cultural affiliation – that is, derived from either the Faereyinga Saga or Faroese traditional folk epics, history, legend and mythology. These names are uniquely Faroese and do not conflict with the naming principles in adjacent areas. The use of bird, marine fauna, or oil prospect, discovery, or field names would be confusing and non-specific to the Faroese area and is therefore viewed as inappropriate.

Within this publication, these names have been used to name new or previously unnamed structural features, as well as for re-naming previously recognised features with conflicting, inappropriate, or informal names. Ridges or positive areas of elevation have been given male names, while basins or areas of depressed elevation have been given female names.

Poster session

Linking the Faroese area and Greenland: Innovative, integrated techniques in provenance studies.

Rasmussen, T.V., Frei, D., Knudsen, C., Larsen. M., Morton, A. & Whitham, A.:

Laser Ablation coupled with Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS) and Computer Controlled Scanning Electron Microscopy (CCSEM) are two new methods used in sediment provenance analysis within the SINDRI project. The LA-ICP-MS method is a much faster and cheaper method of dating zircons than conventional SHRIMP dating. The CCSEM method is an automated analytical technique which, as well as yielding modal analyses of the heavy mineral contents, also allows chemical analysis of the heavy minerals, grain-size and grain-shape information. The application of these two new techniques in provenance analysis has been developed at GEUS, and they are combined with information from detailed bulk rock geochemical analyses. The three different techniques are self-supporting and the data from each of the techniques can be used independently. However, by combining and linking the methods they become a very powerful tool in provenance studies. The new methods are compared with the more conventional methods such as point counting of heavy minerals and SHRIMP analysis, mainly using the SINDRI data.

Poster session

Stratigraphy of sub-volcanic basins of the North Atlantic – implications for basin evolution and petroleum assessment offshore the Faroe Islands

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The Cretaceous–Paleocene sub-volcanic basins of the North Atlantic have gained renewed interest with the licensing round in the Faroe Islands. Not only does the Faroes frontier area provide new opportunities, but it is also a high-risk area with poorly known plays and sedimentary basins in part covered by basalts. In order to minimise risk it is fundamental to achieve as much information on the sedimentary basins on the rifted volcanic margins as possible. In 2002, the Sindri Group therefore decided to support a study of the sedimentary succession of the Kangerlussuaq Basin in southern East Greenland. Plate reconstructions of the North Atlantic region indicate the former proximity of Greenland to the Faroe Island region and the Kangerlussuaq Basin probably constitutes the most important field analogue with regards to stratigraphy, major unconformities, basin evolution and the development of new play types in this frontier region. In this poster we present the preliminary results of this study and propose a new lithostratigraphy for the region.

The sedimentary succession is divided into two lithostratigraphic groups. The Kangerdlugssuaq Group comprises the main part of the non-volcanic succession and reaches up to 700 m in thickness. It is overlain by the volcanic dominated Blosseville Group, which also includes the several kilometres thick continental flood basalt succession. Larsen *et al.* (1999) recognised four major facies associations in the Kangerdlugssuaq Group: 1) alluvial plain and shallow marine (?Late Aptian); 2) fluvio-estuarine (Late Aptian–Early Albian); 3) offshore marine (Late Cretaceous–Early Paleocene); 4) submarine fan and channel-levee (Early Paleocene). In the overlying Vandfaldsdalen Formation of the Blosseville Group two associations were recognised: 5) fluvial (mid-Paleocene) and 6) volcanic (Late Paleocene). These associations and the biostratigraphic data collected by CASP and GEUS now form the basis for the new lithostratigraphic division. The study furthermore strengthens the evidence for sequence boundaries in the succession (Whitham and Morton, 2003) that may have important bearings on the supply of sandstone to the offshore basins.

Larsen, M., Hamberg, L., Olaussen, S., Nørgaard-Pedersen, N. & Stemmerik, L. 1999a. Basin evolution in southern East Greenland: an outcrop analog for the Cretaceous– Paleogene basins on the North Atlantic volcanic margin. *American Association of Petroleum Geologists, Bulletin* **83**, 1236–1261.

Whitham, A. G. & Morton, A. C. 2003. Insights into Cretaceous– Paleocene sediment transport paths and basin evolution in the North Atlantic from a heavy mineral study of sandstones from southern East Greenland. *Petroleum Geoscience*. **10**, 61–72.

Faroe Islands Exploration Conference 2004

Poster session

Inversion Method for In-Situ Stress Determination, based on Effective Stress Ratios.

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The paper presents a theory for determining the in-situ stress state from multiple fracturing data and induced fractures from image logs. A solution can be obtained with a minimum of three data sets. However, using an inversion technique, a solution can be obtained with any number of data sets, as the solution is over determined.

The magnitude of the stresses is mainly determined from the fracturing data. Fracture information from image logs is mainly used to determine the geographic direction of the principal in-situ stress
In the paper, plots of the Effective Fracture Pressure Ratio, the Fracture Angle and the Fracture Trace Angle give a good overview of how these three quantities behave, as functions of the borehole inclination and azimuth. This knowledge has advantages in planning new oil wells.

The mathematical technique is to describe the general fracture equations in terms of effective stress ratios and describe and solve the "Axial plane strain solution" of the Kirch equation for a cylindrical borehole. To solve the related numerical problem, the Gauss-Newton method for an over determined system of equations is chosen.
The data are leak-off data from oil wells. They are recorded in wells with different inclinations and azimuths, a requirement for a robust inversion. The method is not limited to any specific type of formations.

Faroe Islands Exploration Conference 2004

Poster session

Numerical simulation of tides and waves on the Faroe Shelf.

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For offshore activities around the Faroes waves may be a critical factor for operation. Waves arriving from the deep ocean around the Faroe Islands into the shelf in combination with relative strong tidal currents are known to generate extreme wave conditions. Relative detailed numerical simulations of the tides on the Faroe Plateau are conducted, and an ocean wave model is implemented for the Faroe Plateau. Here preliminary results of the simulated effect of tidal currents on waves at some locations on and outside the Faroe Shelf are presented.