GEOLOGICAL AND ENVIRONMENTAL SUMMARY

Geophysical Data Availability

Considerable amount of seismic data has been acquired through the years on the Jan Mayen Ridge, including the northern Dreki Area by academic and government institutions. In addition, speculative seismic surveys from the area are available from two sources: Wavefield Inseis has for sale data from speculative seismic surveys of the northern Dreki Area from 2001 and 2008; TGS-NOPEC shot a speculative seismic survey in 2002 south of the northern Dreki Area. The academic data is very heterogenous, ranging from single-channel seismic profiles to crustal-scale seismic reflection/refraction experiments. A list of existing industry and government seismic datasets is given below. Further information on available seismic data can be found on the web-site of the National Energy Authority. The joint Norwegian-Icelandic surveys from 1985 and 1988 are being reprocessed by Spectrum and they will have the reprocessed data available for sale by the end of 1st quarter of 2009.

1) Norwegian Petroleum Directorate, 1979: Jan Mayen Ridge within Jan Mayen agreement area, joint ownership, may be purchased through the Norwegian Petroleum Directorate, 600 km, shot and processed by GECO.
2) Norwegian Petroleum Directorate and National Energy Authority of Iceland, 1985. Jan Mayen Ridge, mainly within Jan Mayen agreement area, joint ownership, 4000 km, shot and processed by GECO. Available as raw-stack and raw-mig at copy-cost upon request to the NEA. The seismic data is being reprocessed by Spectrum, and reprocessed lines are estimated to be available for sale by Spectrum by end of 1st quarter of 2009.
3) Norwegian Petroleum Directorate and National Energy Authority of Iceland, 1988: Jan Mayen Ridge, Jan Mayen agreement area and southern Jan Mayen Ridge, joint ownership, 950 km, shot by the University of Bergen and processed by the National Energy Authority of Iceland. Available as raw stack, raw mig, final stack and final mig upon request to the NEA. The seismic data is being reprocessed by Spectrum, and reprocessed lines are estimated to be available for sale by Spectrum by end of 1st quarter of 2009.
4) InSeis Terra, 2001: Southern Jan Mayen Ridge, non-exclusive speculative survey, 2800 km, owned and shot by InSeis Terra, now Wavefield InSeis, and processed by Ensign Geophysics.
5) TGS-NOPEC, 2002: Southern Jan Mayen Ridge and eastern Icelandic shelf, non-exclusive speculative survey, 800 km, owned, shot and processed by TGS-NOPEC.
6) Wavefield InSeis, 2008: Southern Jan Mayen Ridge, non-exclusive survey, 900 km, owned and shot by Wavefield InSeis, processed by Geotrace.

No deep wells have been drilled on the Icelandic continental shelf for the purpose of exploring for petroleum. Some shallow boreholes were drilled in the area during Leg 38 of the Deep Sea Drilling Programme and the data is available at the web-site of the U.S. National Geophysical Data Center.

Geology and Hydrocarbon Potential

A joint Icelandic-Norwegian interpretation report on the geology of the Jan Mayen Ridge, based on the 1985 seismic survey, has now been released and is available on the NEA web-site. Furthermore, a large number of scientific papers have been published on the geology of the area; alist of those can be found on the NEA website.

The Jan Mayen Ridge, including the part covered by the northern Dreki area, is thought to have potential for hydrocarbon accumulations because of its geological similarity to hydrocarbon basins which were its next door neighbours prior to the opening of the northeast Atlantic ocean basin. The basins in question are the Jameson Land Basin onshore East Greenland, where oil is known to have been generated and preserved in sandstone bodies, and basins offshore western Norway, Shetland and in the North Sea, where oil and gas has been discovered in commercial quantities.

Prior to the onset of seafloor spreading in the northeast Atlantic 55 million years ago, the hydrocarbon basins mentioned above were located in close proximity to one another. Since that time they have gradually moved apart as a result of the plate tectonic movements that created Iceland and the surrounding ocean basins. A part of this development was that the Jan Mayen Ridge was gradually separated from the continental shelf of Norway and Greenland and became isolated far from shore and surrounded by newly created ocean floor. This occured in parallel with the gradual emergence of Iceland and its surrounding insular shelf.

Thus, the Jan Mayen Ridge is a sliver of continental crust – a microcontinent – bounded by rifted continental margins on both sides. The eastern margin developed as the outermost part of the continental shelf of Greenland during the initial breakup of the continent and the opening of the Norway Basin. It is characterized by an eastward thickening pile of basaltic lava flows which was erupted over the pre-existing continent during the events leading to the creation of the ocean basin east of the ridge (Norway Basin). The western margin developed as a result of rifting within the Greenland continental shelf and seafloor spreading on the Iceland Plateau. It is characterized by tilted extensional fault blocks and an extensive complex of sills or lava flows which covers the deep basins west of the ridge.

The geological development of the ridge may be divided into four main phases:

1. The eastern margin was formed as the continent broke up on the Greenland side of the regional sedimentary rift basin between Greenland and Norway. Basaltic lava flows were erupted subaerially over the continent. On the outer margin, which now constitutes the eastern flank of the ridge, they form a wedge-shaped pile thickening eastwards into the line of breakup. There the pile merges with the oldest oceanic crust in the Norway Basin. Elsewhere on the ridge the lavas are thought to form a relatively thin layer. Pre-rift sediments are imaged locally beneath the lavas. They are probably analogs to sediments preserved onshore East Greenland but their distribution is not well known. There is little evidence for rift-related faulting beneath the lava cover, the rifting was apparently concentrated on a few widely-spaced faults.
2. Breakup was followed by seafloor spreading in the Norway Basin and gradual cooling and subsidence of the eastern margin. Sediments derived from Greenland began to accumulate at the margin on top of the lavas.

3a. The western blockfaulted margin was formed when a new rift opened on the East Greenland margin and began to separate its outermost part from the rest of the continent in a 25 million year long process that operated contemporaneously with seafloor spreading in the Norway Basin. The rifting process broke the earlier continental margin into a series of tilted fault blocks which subsided to form a rift graben bounded on the east by the emerging ridge. As the incipient rift subsided, sediment input from Greenland to the ridge, was shut off. Parts of the ridge were uplifted above sea level and eroded extensively. Shortlived submarine fans developed on both flanks of the ridge in response to sediment supply from its exposed top.

3b. As the local provenance areas were submerged some time prior to breakup west of the ridge, the ridge complex became sediment starved. At breakup, the plains west of the ridge, which lay several hundred meters below sea level, were covered with flatlying basalts. These were either empaced as voluminous submarine lava flows or as an extensive complex of sills just beneath the seafloor.

4. After breakup the ridge continued to subside, driven by cooling and thermal contraction. Sedimentation became increasingly pelagic, but due to the steep slopes created in the second rift phase, some gravity flow of sediments continued onto the basin plains from both the eastern and the western slopes.

The main geological units for the Jan Mayen Ridge in order of decreasing age:

1. Continental basement rocks.
2. Sedimentary rocks pre-dating the opening of the Norwegian-Greenland Sea.
3. Subaerial basaltic lavas extruded during initial breakup of the continent.
4. Oceanic crust in the Norway Basin (eastern end).
5. Sedimentary rocks derived from Greenland and deposited prior to the onset of rifting within the Greenland shelf.
6. Sedimentary rocks deposited during rifting within the Greenland shelf.
7. Lava flows or a complex of flat-lying intrusives emplaced just prior to breakup within the Greenland shelf.
8. Oceanic crust on the Iceland Plateau (western end).
9. Sediments deposited after breakup west of the ridge during seafloor spreading on the Iceland Plateau.

Several factors indicate that the northern Dreki area may have significant hydrocarbon potential:

- The Jan Mayen Ridge is a sliver of continental crust
- Sedimentary rocks of sufficient thickness and age are present.
- There are indications of the presence of sedimentary strata pre-dating the initial opening of the Norwegian-Greenland sea. Such sediments are likely to be analogous to those preserved in the Jameson Land Basin onshore East Greenland where source rocks are present and oil is known to have been generated.
- Reservoir rocks are also likely to be present. Among the candidates are submarine fans derived from East Greenland.
- Structures and stratigraphic configurations with potential to act as hydrocarbon traps are clearly present.
- Seismic reflection anomalies are observed which may indicate the presence of hydrocarbons.

The area is, however, in the initial stage of exploration. Sufficient seismic reflection data is available to do in-depth studies, but no exploration wells have been drilled in the area to date. Calibration of lithology, physical properties and age is therefore still lacking.

Environmental Conditions

Strategic Environmental Assessment

The Strategic Enviromental Assessment of the area has been finished, and no major obstacles have been identified. A draft report published in March 2007 is available on website of the Licensing Round, as well as comments on the report and the responses to those. A research program has been implemented as a result of the SEA on natural conditions of the area. Most of this data is available upon request to the NEA. The research includes:

- A weather buoy that has recorded meterological, wave and surface current data since November 2007
- A mooring with ADCP current meters recorded data between November 2007 and December 2008.
- Shipboard ADCP current measurements on two transects in the area. The transects were measured three times, in February, June and December of 2008.
- A multibeam bathymetric survey in June 2008 of 10,500 sq. km of the area. The data is available upon request to the National Energy Authority.
- A survey of benthic organisms was conducted in August 2008. Samples were collected and preserved and pictures were taken of the sea floor. A summary of the sampling as well as some further information on the survey are available upon request to the NEA.

Climate and condition of the sea

The average temperature in the northern part of the Dreki area is below 10°C year-round, but the period January through March is usually coldest (average temperature 2°C to 0°C). The month of August is usually warmest (average temperature 7°C to 8°C). There is frequent precipitation, especially in the fall and winter. The average annual precipitation is near 700 mm, which is less than in Reykjavík. The distribution throughout the year is similar to the closest coastal areas of Jan Mayen and in Iceland's East Fjords. Precipitation, in the form of rain, sleet and snow, is quite heavy in the winter low pressure systems. If the temperature is close to freezing, the snow can form icing on the windward side of structures. Observations from weather stations in Iceland and Jan Mayen indicate that fog is the most common impairment to visibility in the northern part of the Dreki area, and it is most frequent in the summer. Precipitation, especially snow, can cause poor visibility in the winter. From December to March the average wind speed is about 10 m/s and about 6 m/s in the summer.

Sea temperature in the Dreki area is about 0°C to 1°C during the winter, but up to 7°C in late summer. Most of the time the sea surface temperature is higher than air temperature, because of the advection of cool air from the north. This difference in temperature between the air and the sea is, however, negligible during the summer.

It seems that the wave height in the Dreki area is generally significantly lower than in the area south and west of Iceland or at the west coast of Norway. In the Dreki area the wave height reached once in 100 years is about 12 m, while the corresponding wave height off the west coast of Norway is 14 to 16 m. The mean of the highest wave height reached in the Dreki Area once a year, as well as the waveheight reached in 98% of cases, is around 5-6 m.

Little pack ice has drifted into the area in recent decades although the pack-ice period 1965 to 1971 is an exception. The southwest corner of the area has nevertheless been free of ice during this time. Icing creates temporary problems during the winter, but its frequency varies greatly from year to year, and increased frequency is related to the periods characterised as pack-ice years. Increased probability of heavy icing is associated with spindrift in sharp northerly winds. The main weather related difficulties for oil production in the northern part of the Dreki area are considered to be the risk of icing in the winter and lack of good visibility (more likely in the summer). A buoy has collected meterological and wave data in the Dreki area since November 2007.

Biota

No islands or skerries rise out of the sea in the Dreki area, and the biota in the northern part of the area is therefore primarily in the ocean, but birds also go through looking for food or passing over on their way to other areas. Commercial fisheries are related solely to fish stocks, especially pelagic species.

Large changes have occurred in the biota of the ocean area between Iceland and Jan Mayen in recent decades. The changes are associated with the shifting equilibrium between cold currents to the north and the flow of the Atlantic sea north of Iceland around the West Fjords. These changes have then been reflected in changes occurring, for example, in the distribution and migration pattern of herring in the 1960s and changes in 10 the migration pattern of capelin in recent years. Further information on the hydrography and currents in the Dreki area have been acquired, with current measurements collected on a mooring for one year and shipboard measurements of currents collected along transects that were measured at three different times during that period.

The biomass of zooplankton is greater near the Dreki area than in most places around Iceland. The area is an important feeding ground for organisms nourished by zooplankton, like pelagic fish, especially herring and probably capelin, but it is also important for whales. There are several samples of benthic species in the Dreki area that show great variability in the type of bottom and benthic communities. There are many sensitive benthic species in the north seas that are confined to specific features on the sea bottom. Any disturbance of the bottom can have a serious effect on the species' communities. Various different types of benthic habitats in the Dreki area have been mapped, with special attention given to the potential presence of sensitive or rare habitats and species.

There is no information available about the demersal fish in the area. Part of the explanation can be that the area is not near any known fishing area and is rather deep. On the other hand, there is a possibility that delimited stocks of deep-sea fish are there. Such stocks have been found under similar conditions off the continental shelf south and west of Iceland.

The whale counts that have been done do not detect possible changes in the distribution of whales caused by activities in so small an area as that of the oil exploration area. For this purpose much tighter search lines and more frequent counts would be required. It is most efficient to make such counts from an airplane, but ships and other surveillance trips in the area could also be utilised. During such trips, skin samples could also be collected for genetic analysis to cast light on the whale stocks' types, which is important in evaluating the potential impact on stocks.

The number and distribution of seals in the Dreki area depends primarily on the presence of pack ice there, but the edge of the pack ice in recent decades has been at a considerable distance to the west of the Dreki area.

The Dreki area is probably traversed by dozens of species of sea birds over the entire year. It can also be assumed that each species shows great variability in distribution and number depending on the season, how long they remain in the area, the feeding conditions, and where suitable food is each time, depending on the ice conditions, etc. Based on the available knowledge, it can be assumed that the most common species in the contemplated oil area are fulmar, black-legged kittiwake, Brünnich's guillemot, common guillemot, puffin, razorbill and little auk. These species are among the most common ones in the North Atlantic.