

7. Geology of the Jan Mayen area (extended abstract)*

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Introduction

The Jan Mayen ridge is a complex system that reaches southwards from the Jan Mayen Transform. This ridge system is believed to be mostly of continental origin, but shows transitional and oceanic crust characteristics at the margins. The Jan Mayen ridge is believed to be a part of the continental shelf of Greenland, but it has, due to a complicated rifting history of the northeast Atlantic, ended up in the middle of the ocean floor between Norway and Greenland.

The ridge can be divided into two main components, the main ridge in the north and the southern ridge complex. The main ridge reaches from the transform in the north to the Jan Mayen trough, which separates the two main features. The northern main ridge is well defined, continuous and stands higher than the southern part. The southern part is composed of several smaller ridges which become indistinct to the south and disappear beneath sediments and lavas closer to Iceland.

7.1. The opening of the North Atlantic and Stratigraphy of the Jan Mayen ridge

In the beginning of the opening of the northeastern Atlantic, in early Eocene, the continental crust splitted from south to north. About 54 million years ago, a spreading ridge was formed east of the Jan Mayen area. Greenland and Norway began to drift apart and the Jan Mayen area was still attached to the continent of Greenland. This spreading ridge is now called the Aegir ridge. The rift continued in this way until about 44 million years ago, when a new spreading ridge began to form to the west of Aegir ridge. This ridge gradually protruded northwards. Before that happened, a considerable amount of stretching had occurred west of the Jan Mayen ridge. The new spreading ridge split the Jan Mayen ridge away from the continent of Greenland and it is called the Kolbeinsey ridge today. Both these spreading ridges were active in parallel for about 18 million years. The Kolbeinsey ridge was most active in the south to begin with but gradually protruded northwards but at the same time the activity at Aegir ridge diminished gradually from south to north. That caused the Jan Mayen ridge to rotate counter clockwise. Finally about 26-30 million years ago the activity at Aegir ridge ceased and the seafloor-spreading is only active at Kolbeinsey ridge. From that time onward, the Jan Mayen ridge gradually moves away from Greenland.

Era	Period	Epoch	Million years
Ceno-zoic	Quaternary	Holocene	- 0,1
		Pleistocene	0,1-1,65
	Tertiary	Pliocene	1,65-5
		Miocene	5-24
		Oligocene	24-37
		Eocene	37-58
		Paleocene	58-65
Meso-zoic	Cretaceous		65-146
	Jurassic		144-208
	triassic		208-245
Paleo-zoic	Permian		245-286
	Carboniferous		286-360
	Devonian		360-408
	Silurian		408-438
	Ordovician		438-505
	Cambrium		505-570
Proterozoic			540-2500
Archean			2500-4600

Before the opening of the northeast Atlantic the area had gone through extensive rifting back to Permian times. When the continental crust broke, stretched and subsided, a shallow ocean formed where thick sediments accumulated. Large continental blocks tilted and halfgrabens formed where sediments settled at the same time. In middle and upper Jurassic a claystone was formed with high organic content. This clay formation (Kimmeridge clay) is the main source rock all around the northeast Atlantic today. When the rifting ended in late Jurassic the subsidence continued throughout the Cretaceous period and more sediments accumulated. In late Cretaceous/beginning of Tertiary the rifting resumed and ended in the breakup of the continent. Oceanic crust formed in early Eocene (app. 54 million years ago). Lava flows and intrusions covered the sediments on the eastern slopes of the Jan Mayen ridge, which at this stage was still attached to the continent of Greenland. This formed dipping reflectors as the oceanic crust thickened. At 45-50 million years ago the lavas no longer managed to flow over the Jan Mayen ridge and the older lavas were covered with sediments. These sediments are mostly derived from the old basement rocks of Greenland. At this time, rifting started to the west of the Jan Mayen ridge and the continental crust began to break up. The seafloor-spreading at Aegir ridge diminished as the spreading protruded northwards on the Kolbeinsey ridge. The Jan Mayen ridge rose above sea-level about 30 million years ago and was heavily eroded. Up to 1000 - 1500 metres were eroded away and settled on both flanks of the ridge. Finally at about 20 million years ago the ridge had subsided again below sea-level. The sedimentary accumulation was now much slower in calm, deep waters. Until today the Jan Mayen ridge has cooled and subsided even further as it drifted out into the middle of the northeast Atlantic.

7.2. Hydrocarbon potential of the Jan Mayen area

As stated earlier the geological history of the Jan Mayen ridge is much older than the opening of the northeast Atlantic. The older strata of the ridge are analogous to those of the continental shelves of Norway and Greenland. On both these shelf's hydrocarbon occurrences have been proven and on the continental shelf of Norway a massive production of oil and gas is a fact. The following criteria must though be present so that any occurrence can be considered a resource.

1. *Source rock*: Organic material must be present, be buried and mature suitably. The main source rock around the northeast Atlantic is a clay formation, formed in middle and upper Jurassic. Since this source rock is all around the northeast Atlantic, it is likely that it also occurs at the Jan Mayen ridge. It is also possible that anoxic conditions formed source rocks in the beginning of Eocene
2. *Reservoir rocks (reservoir sand)*: Sandstone is mostly the reservoir rocks in all the area around the northeast Atlantic. In the older sediments it is sandstone from the Jurassic and late Cretaceous periods. In sediments younger than the Cretaceous, it's expected that sandstones from Eocene and Oligocene could be good reservoir rocks.
3. *Cap rock (seal rock)*: In the area around the northeast Atlantic it is mostly claystone from the Cretaceous and Eocene periods that covers the reservoir rocks and seals the traps.
4. *Traps (prospect)*: There are three types of traps that could be present.
 - a. *Structure traps*, but they are blocks containing sand layers which rotated and subsided with the blocks. Clay later seals it off.

- b. *Stratigraphic traps* are sand lenses or layers with limited distribution, such as fans, cones and wedges, that transport into the basins, while clay is still accumulating, and seals off the lenses/layers.
- c. *Domes* form when later tectonics form a dome or vault, bending the sedimentary layers, making them convex.

Figure 1 shows the essential elements needed for a petroleum system to generate, migrate and accumulate hydrocarbons in the subsurface.

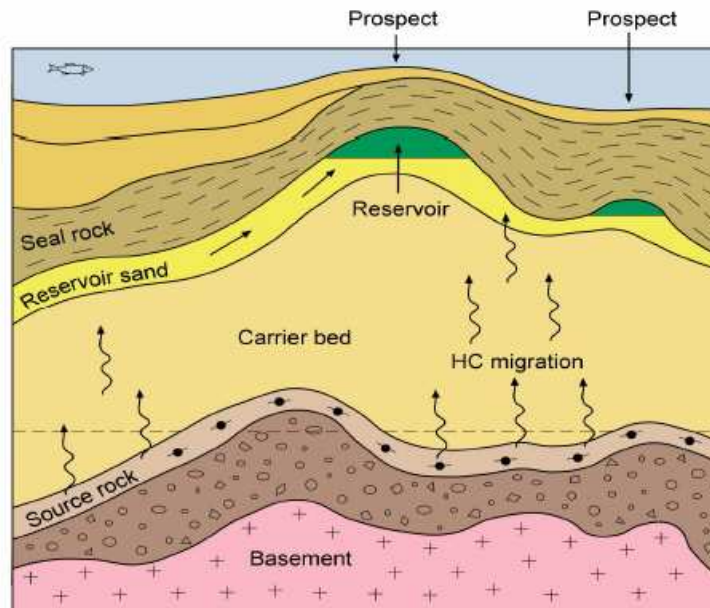


Figure 1. Petroleum system illustration, showing the essential elements needed for a petroleum system to generate, migrate and accumulate hydrocarbons in the subsurface. Sagex (2006)¹

Following these criteria there could be three different hydrocarbon plays regarding the Jan Mayen area.

Play 1:

- **Area:** Western and eastern slopes of the main ridge, as well as the southern ridge complex.
- **Source rock:** Eocene or older source rock.
- **Reservoir rock:** Eocene/Oligocene sandstone.
- **Cap rock:** Eocene or younger clays.
- **Traps:** Stratigraphically isolated traps made of sandstone lenses, cones and wedges in halfgrabens around rotated blocks.
- **Remark.** It is probable that source rock older than Eocene is over-matured in the western flanks of the main Jan Mayen ridge. It is not known if that also applies to the southern ridge complex.

¹ Evaluation of the petroleum potential of the Jan Mayen Ridge is in an early stage, based on limited amounts of seismic data and geological analogues with other better know areas. However, the interpretation of the seismic data has identified basins with sediment thickness up to 8km and structural highs capable of acting as hydrocarbon traps. The crucial elements such as source rock, reservoir rock and seal rock as well as generation, migration and accumulation of hydrocarbons, see figure 1, are likely to be present. See Sagex (2006), *Preparations for awarding licenses for exploration and production of hydrocarbons. Basic premises, possible development paths and scenarios*, p. 7. The report can be found at the homepage of the Ministry of Industry in Iceland: http://www.ivr.is/media/Acrobat/SAGEX_Project_G-1_Report.pdf

Play 2.

- ***Area:*** The whole Jan Mayen ridge.
- ***Source rock:*** Eocene or older source rock.
- ***Reservoir rocks:*** Eocene or older sandstones.
- ***Cap rock:*** Mesozoic clays or younger.
- ***Traps:*** Structure traps in rotated blocks which contain sandstone. The blocks have rotated and covered with younger clay layers.
- ***Remark:*** It is probable that this type of trap may leak at the top of the main ridge as well as locally at the southern ridge complex where the blocks are insufficiently buried. The source rocks older than Eocene may be over-matured in the western slopes of the main ridge. It is not known if that also applies to the southern ridge complex.

Play 3.

- ***Area:*** Western and eastern slopes of the main ridge, as well as the southern ridge complex.
- ***Source rock:*** Eocene or older source rock.
- ***Reservoir rock:*** Eocene/Oligocene sandstone.
- ***Cap rock:*** Eocene or younger clays.
- ***Traps:*** Sandstones formed in depressions, that due to later tectonic events, fold and become convex.

Indications of oil and gas

A few indications of oil and/or gas have been seen in data from Jan Mayen ridge. The main indications are:

- ***Amplitude anomalies.*** These are various types of anomalies in seismic sections, indicating possible hydrocarbons in the sediments.
- ***Pockmarks.*** These features are well known and have been seen on the Jan Mayen ridge. They are usually connected to migration of gas in the sediments.
- ***Gas in top sediments and water column.*** Direct indications of gas have been found. Further studies showed that the results were not decisive enough to prove the presence of thermogenic hydrocarbons.

Resource estimate

Even though there are indications of hydrocarbons in the Jan Mayen area, it must be kept in mind that they are not conclusive. Absolute outcome is not to be expected until one or more drillings have taken place.

Loose estimate indicates that the northern Dreki-area (which is the area where the Jan Mayen ridge enters the Icelandic Exclusive Economic Zone – see figure 1) can be divided into three subareas, regarding resource estimate.

1. The main ridge area (both northern ridge and southern ridge complex) where lavas and intrusions do not limit seismic research.
2. Areas where lavas and intrusions limit seismic research, but odds are that older sediments are to be found underneath the volcanic.
3. The outer margins (to the east and west) which lie close to or on oceanic crust.

Area 1 is the most accessible, within the northern Dreki-area, for further research. This area is about 10000 km² in size and covers the southern ridge complex as well as the southernmost part of the main ridge. The consulting company Sagex has estimated that up to 3600 km² within area 1 could be possible prospect areas (see figure 2).

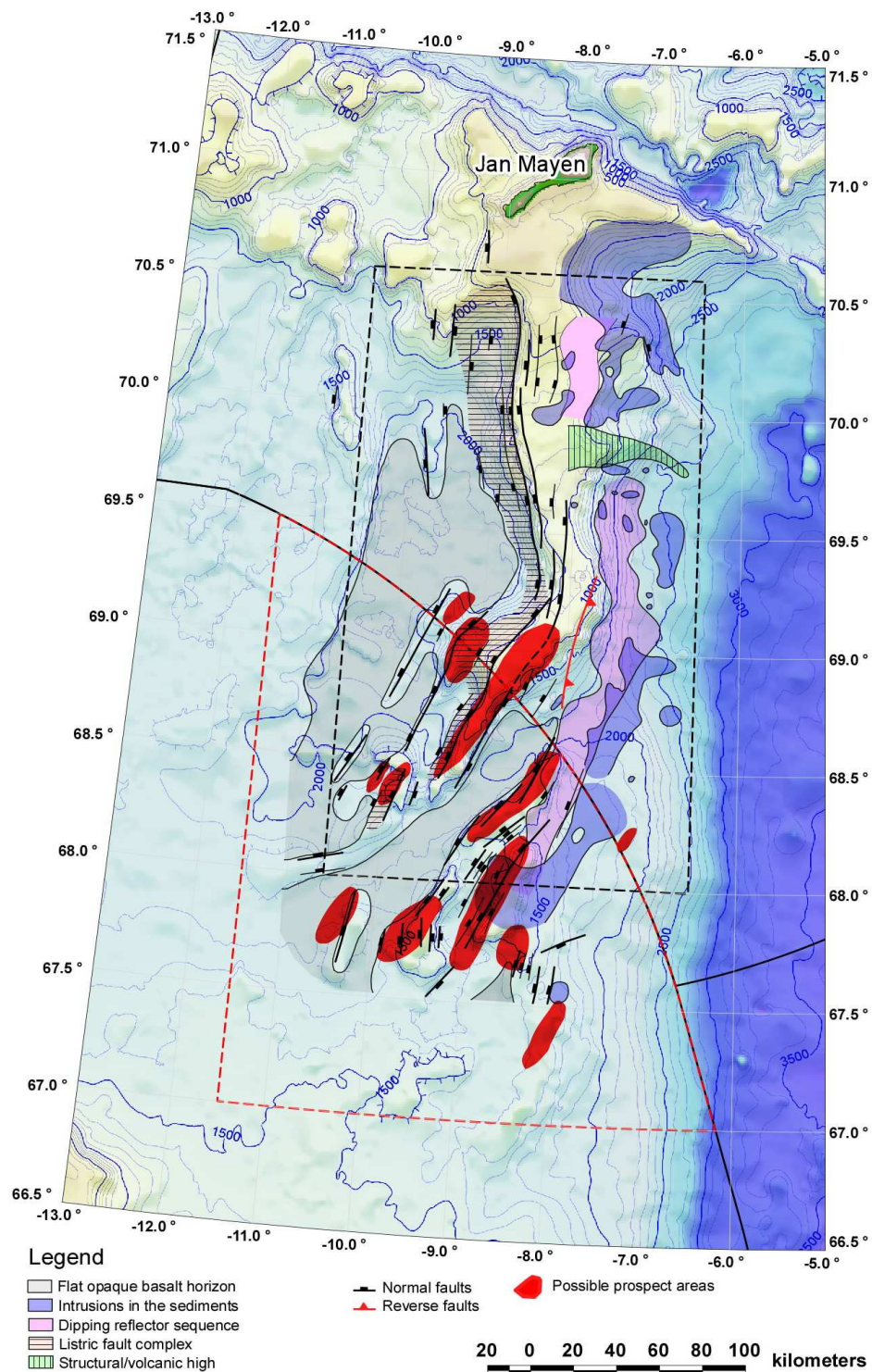


Figure 2. Structure map of the Jan Mayen ridge. Also indicated are possible prospect areas, according to Sagex, which covers approximately 4400 km², where 3600 km² are within the northern Dreki-area. Red, stippled line is the northern Dreki-area which covers about 43000 km². The black, stippled area is the contract area between Iceland and Norway, which covers about 46000 km².

*The full report in Icelandic can be found at the homepage of the Ministry of Industry:
http://www.ivr.is/media/Acrobat/Jardfr_Jan-Mayen-hryggur_ISOR-2007-004.pdf