

## GREENLAND - SUMMARY OF HYDROCARBON GEOLOGY AND STRUCTURAL ELEMENTS

Exploration Hot Spots

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### **Introduction**

The sedimentary basins in the Baffin Sea, Davies Strait and Labrador Sea are surrounded by old continents consisting of 2.4 to 3.6 billion year Proterozoic and Archean rocks. The old continents may have been connected or been very close. Coastal exposures and geophysical data demonstrate marine deposition during Archean and Proterozoic and from Cambrian and onwards in the basins and grabens between the continents.

The basins and grabens were not formed simultaneously in the entire region but as a consequence of slow progressive continent drift. Triassic rifting opened deep narrow grabens and parallel linear extensional fault zones in the Labrador Sea as part of the opening of the south Atlantic. Greenland drifted slowly northwards creating a superregional dog leg pattern known as the combined Baffin Bay Graben, Ungava rift and Labrador Sea Graben. The drift created compression to the north, and forced listric faulting along the main grabens and additional sub parallel faults. The listric faults helped stretching the continent allowing up to 200 km continent drift in the Labrador Sea. Drift are diminishing northwards in the Baffin Sea as a consequence of strike slip movements in the Ungava Fault Zone between the Labrador Sea Graben and the Baffin Sea Graben.

It may be demonstrated that Greenland has drifted north-north-eastwards compared to Canada, while at the same time rotating slightly anticlockwise. Major strike slip movements caused both divergent subsidence and convergent uplifting. The main periods of Triassic, Jurassic and Tertiary extension are supported by dyke swarms in onshore basement, and rifting has locally happened so fast that volcanic rocks was extruded along fracture zones in the deep oceanic basins.



Fig 1: Oil seeps onshore Nussuaq.

The dominant part of the region is underlain by continental crust that only locally is stretched so much that intrusive rocks create local areas resembling oceanic crust. Many of the sediment basins are very deep. This is also the case for the grabens that connect from the Labrador Sea to the Baffin and act as narrow seaways possibly from Triassic time. Both grabens and basins contain organic material that generates oil and gas. This is documented in wells along Canadian Labrador coast, in scientific wells and from oil seeps onshore west-central Greenland. And also two out of six old offshore wells have shows of hydrocarbons.

Until recently, interest in the petroleum prospectivity offshore West Greenland has been limited. When TGS-NOPEC Geophysical Company (TGS) came to Greenland in 1999, only two areas offshore West Greenland were covered by Expl. & Prod. Licences, and the few and shallow offshore exploratory wells had been unsuccessful. The total seismic coverage amounted to 60,000 line km of generally poor to extremely poor quality 2D data, including the 37,000 line km of data acquired in the 1970s. A small database considering that the region is the size of NW Europe.

TGS started data acquisition in 1999. The 1999 survey that was the first modern survey in the region was tying the five unsuccessful wildcat wells from the 1970s. The survey demonstrated hitherto unknown deep basins and was the backbone for additional seismic acquisition. TGS have in the period from 1999 to now acquired close to 90,000 km's seismic and ship track data, 175,000 km's airborne gravity profiles and close to 300,000 km's of airborne magnetic profiles. Surveys have been followed up with seafloor sediment sampling and EM. The data demonstrate the presence of deep basins and rifted graben system and old sediments that has been sampled at seismic reflectors outcropping at sea bottom.



Fig 2: 600 km long seismic line acquired from the Canadian coast to the Greenland coast. The line shows deep basins and rift systems in Paleozoic, Mesozoic and younger sediments.

The seismic data acquired have revealed the existence of very large sedimentary basins offshore West-Greenland. An integrated evaluation of seismic, gravity, magnetic and satellite data confirms the existence of a very large interconnected Mesozoic graben systems with petroleum deposits along the so-called Ungava Fault Zone with the Central Ungava Horst consisting of Pre-Cambrian granites. The basin systems links the petroleum deposits in the Labrador-sea south of 60 °N along the Canadian, with oil seeps onshore Disko-Nuussuaq, all the way up to 71 °N. Numerous and widespread oil seeps next to the Disko West Expl. & Prod. Licenses, in combination with amplitude anomalies and shallow gas related features observed in the seismic data, clearly indicate the presence of working petroleum systems. There are so far documented 7 different distinct types of oils ranging in age from Paleocene through the Cretaceous, Jurassic and all the way down to the Paleozoic, thus giving the possibility of several different play concepts. Reservoir rocks do also exist in several stratigraphic intervals. There are many good analogues onshore, and throughout Cretaceous and Paleocene huge quantities of sand were poured into the basins. The seismic data demonstrate that the deep Basins and rift correlate far into the Baffin Bay, and all the way south through the Labrador Sea to the Atlantic margin.



Fig 3: Seismic line in the Baffin Bay demonstrate large traps and deep basins.

The Oil Companies have followed TGS into this new exploration area. 9 Oil Companies have signed up 134,000 km<sup>2</sup> of Expl. & Prod. Licenses, and additional areas have been applied for in the ongoing Baffin Bay Round comprising additional 150,000 km<sup>2</sup>. The Oil Companies have acquired substantial additional databases including 2D and 3D seismic, gravity, magnetic, EM surveys and seep surveys, and Cairn Energy together with Nunaoil and Petronas are presently drilling 3 wells. Two of the wells have so far found hydrocarbons, and 2 hydrocarbon systems have been documented. More info may be available at the Petex 2010 conference:

## **Conclusions**

It seems very likely that marine areas between Greenland and Canada hides large hydrocarbon resources.

## **References**

From Cairns Press release

### The Alpha-1S1 well

The multiple-objective Alpha-1S1 well has reached an intermediate depth of 4,358 metres (m) in volcanic sections. Following the conducting of extensive logging operations the well is now being deepened. The well has encountered gas shows in silty and volcanic sections over several hundreds of metres. Oil has also been observed intermittently over a 400m section in the volcanic and volcano-clastic intervals of the well which requires further evaluation.

Initial geochemical analysis of various hydrocarbon samples recovered from the well, undertaken by independent UK laboratories, confirms the presence of two oil types which have different origins and levels of maturity and are the first oils encountered in the current exploration campaign. Further geochemical analyses are ongoing on a number of oil samples.

### The T8-1 well

The T8-1 well, which, as announced on 24th August 2010, encountered gas in thin sands, reached a TD of 3,250m. The well has been plugged and abandoned. The T8-1 well did not result in a commercial discovery, consequently the well costs of US \$84.2 million excluding demobilisation costs, the majority of which were incurred after 30 June 2010, have been written off in accordance with Cairn's accounting policies.

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