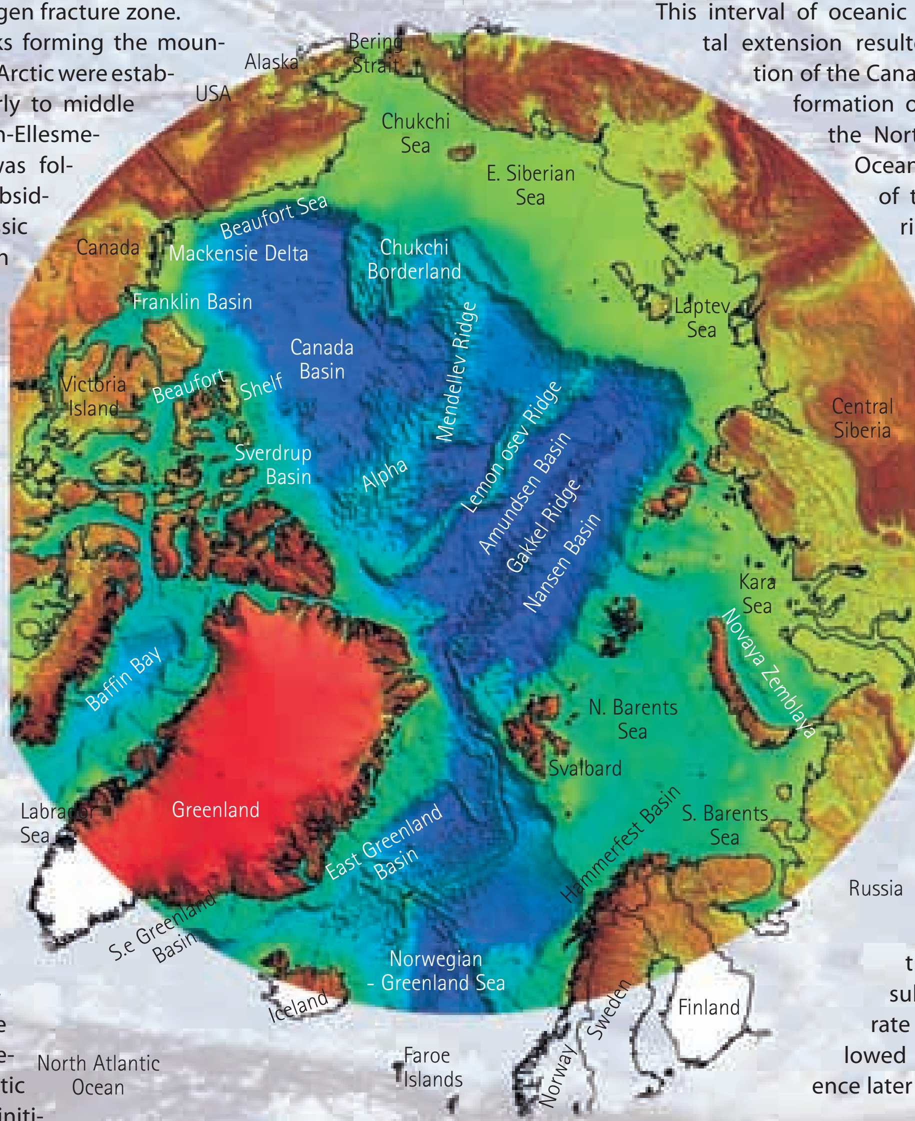
Geological History of the Arctic Ocean

As global interest in the hydrocarbon potenital of the Circum-Arctic increases, it is becoming vital to unravel the complex geological history of the region.

The Arctic Ocean consists essentially of two large basins separated by the Lomonosov Ridge. The Amerasia Basin covers the Canada Basin, and the Beaufort and Chukchi Seas and Eurasia Basin includes the Amundsen and Nansen Basins and the Barents and Laptev Sea. Most of the oceanic crust was generated during the Cenozoic to Present from the active Gakkel spreading ridge, which forms a continuation of the mid-Atlantic ridge, offset by the Spitzbergen fracture zone.

The basement rocks forming the mountains surrounding the Arctic were established during the early to middle Palaeozoic Caledonian-Ellesmerian Orogeny. This was followed by regional subsidence during the Triassic and Jurassic which resulted in the deposition of key sources and reservoirs. The Late Jurassic – Cretaceous opening of the Canada Basin and creation of associated mountains in Alaska resulted in maturation and migration of hydrocarbon towards Prudhoe Bay. The MacKenzie Delta was formed at the same time from sediments derived from the early Canadian Rockies.

Since the Late Cretaceous the history of the Arctic Ocean Basin has been dominated by the northward migration of the North Atlantic mid-oceanic ridge into the Arctic Ocean region, which initiated rifting between Greenland and Canada, and then between Greenland and Spitsbergen. The latest model opens the Amerasia Basin by progressive spreading sub-parallel to the Canada Arctic Margin, with the Chukchi Borderland being transported north-eastwards to Siberia by transform faults. With further spreading a triple junction developed in the centre of the basin forming the Alpha-Mendeleev Ridge in the Late Cretaceous.



This interval of oceanic and continental crustal extension resulted in further separation of the Canadian Arctic Islands, the formation of a passway between the North Atlantic and Arctic Oceans and the separation of the Alaskan and Siberian Peninsulas across the Bering Straight during the Miocene. Tertiary intra-plate deformation related to Pacific subduction, the India-Eurasia collision, and the opening of the North Atlantic played an important role in creating traps throughout the Arctic.

Initiation of seafloor spreading from the Gakkel Ridge commenced at the Palaeocene – Eocene boundary. As rifting progressed, the Lomonosov Ridge moved away from the continent towards the pole and began to subside, initially at a slow rate in the Palaeogene, followed by more rapid subsidence later in the Neogene.

Jane Whaley

Unravelling Plate Tectonics in the Arctic

The history of the Arctic Basin is irrevocably tied up with plate tectonics. A new study by the consultancy GETECH seeks to redefine a plate tectonic model of the area in order to help reassess the hydrocarbon potential of the Arctic.

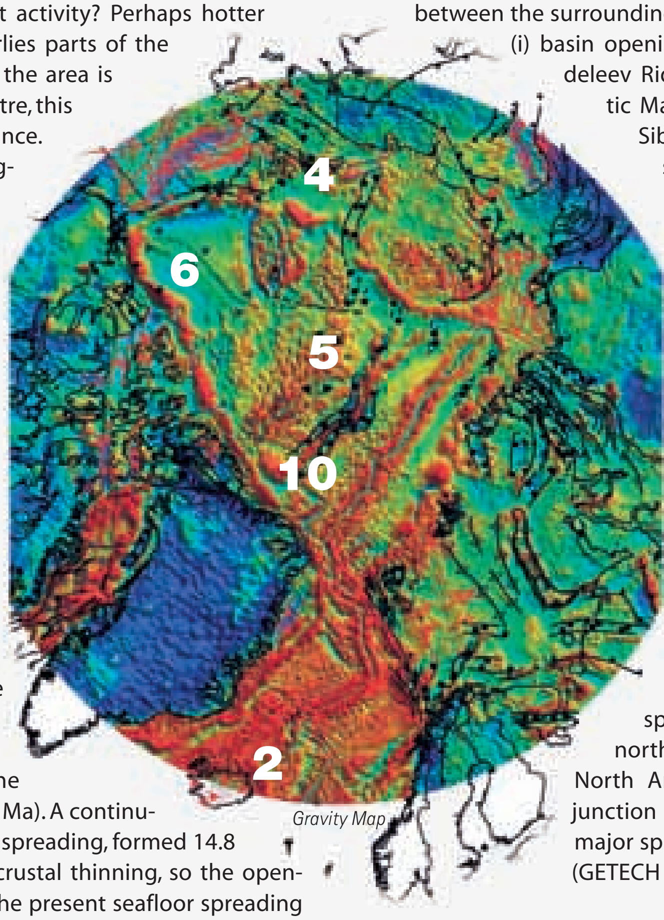
"At GETECH we hold the world's most extensive commercial library of gravity and magnetic data, which we are using this build up our knowledge of the history of the circum-Arctic," says Simon Campbell, senior geophysicist at GETECH. "There are still fundamental questions about the movement of plates in this area, as outlined on these gravity and magnetic maps. We hope to define the opening history of the Canada Basin and investigate the isolation of the Arctic, the nature of the Chukchi Borderlands and the composition of the crust underlying the ridges. We also seek to quantify the amount of extension/compression exerted on the interior of moving plates. " Further interesting challenges are related to hydrocarbon potential, including research into the nature of the structural continuation of the Gakkel Ridge into Siberia and the manner in which an evolving stress field influences trap development and expulsion in the Laptev Sea.

1 Central Arctic zone

What is this zone of incoherent magnetic anomalies - are they related to similar volcanics on the Barents/Kara Shelf? The seafloor is apparently populated by numerous seamounts, so is this a zone of intense hot-spot activity? Perhaps hotter than normal upper mantle underlies parts of the Alpha and Lomonosov Ridges? If the area is at present an active magmatic centre, this might explain the diffuse appearance. Although largely chaotic in magnetic character, the zone shows some pervasive features which careful processing of data may highlight, like a slightly arcuate lineament through the central part of the area perpendicular to the Lomonosov Ridge.

2 North Atlantic opening

What is the history of the isolation of the Arctic and the nature and timing of tectonically mediated seaways resulting from the Oligocene opening of the northern North Atlantic? Gateway opening requires the change from strike-slip to oblique extension between Svalbard and North-east Greenland at the Eocene-Oligocene transition (33.3 Ma). A continuous corridor of immature seafloor spreading, formed 14.8 Ma, indicates extensive pre-drift crustal thinning, so the opening may not have occurred until the present seafloor spreading regime was established 9.8 Ma.



Gravity Map

3 The opening of the Canada Basin

The Canada Basin is considered to be predominantly of Cretaceous age, but an understanding of the interaction of strike-slip and rotation is crucial to our knowledge of the correlations between the surrounding areas. Suggested models include: (i) basin opening after spreading of Alpha-Mendeleev Ridge perpendicular to Canada Arctic Margin. Strike slip movements make Siberia an active and Alaska a passive margin as Alaska collides with Canada; (ii) Canada and Siberia both passive, spreading was rotational, displacement by major transform faults, which broke up and detached Chukchi Borderland; (iii) triangular orientation of strike-slips opened basin subparallel to Canadian Arctic Margin, (part of American plate), and Alaska and Siberia were diverted from American plate by dextral strike-slip, causing Alaska to move northward; (iv) multi-stage opening commencing late Jurassic - early Cretaceous, concluding when successive north-westward spreading made Chukchi collide with north-east Russia and North Alaska with North America in Aptian/Albian. A triple junction developed between two displaced major spreading centres in Late Cretaceous. (GETECH preferred model)

4 Chukchi Border land

Was this once part of Canada? If the most accepted theory of rotational opening of the Canada Basin is correct, the stratigraphy of Chukchi should be similar to that of Canada. Further research may verify this as well as possible links between Alaska and Arctic Canadian Islands.

5 Alpha-Mendeleev-Ridge

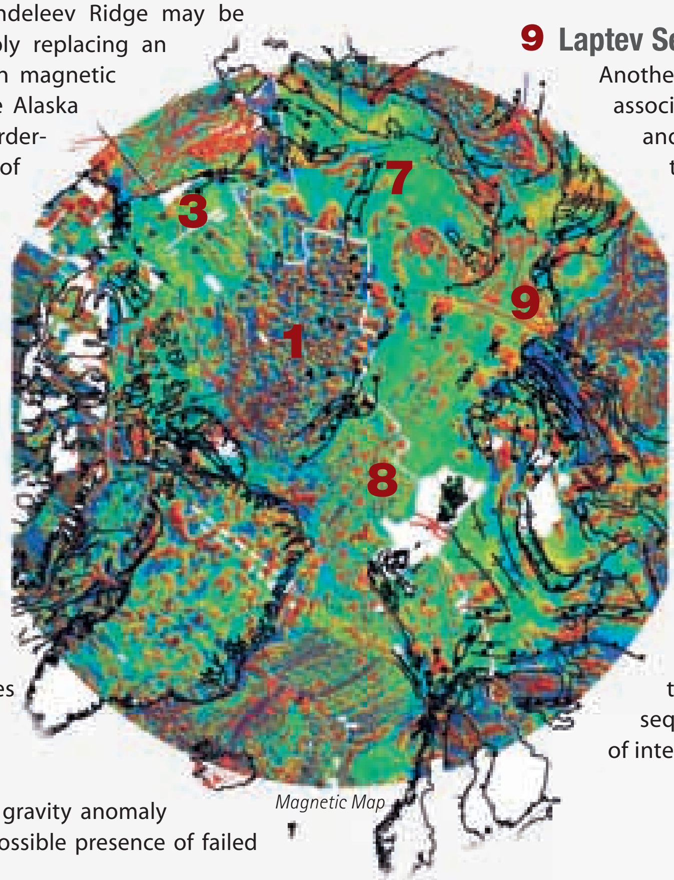
A 300 km wide bilaterally symmetrical pattern of magnetic lineations around the Alpha-Mendeleev Ridge may be an extinct spreading axis, possibly replacing an earlier western centre. Changes in magnetic and gravity patterns between the Alaska margin and southern Chukchi Borderlands imply at least three stages of opening of the Canadian Basin and it is possible that the Alpha-Mendeleev Ridge is continental fragment once adjacent to the Lomonosov Ridge. Modelling of gravity and magnetic data with plate tectonic reconstructions might verify this.

6 Spreading centre in the Canadian Basin

Identifying the Canada Basin spreading centre and its possible modern continuation from the potential field data will help in the definition of plate boundaries and plate tectonic reconstruction.

7 Chukchi Borderlands

Lineations in the magnetic and gravity anomaly maps of this region indicate the possible presence of failed rifts in this region.



Magnetic Map

8 Gakkel Ridge

The 1,800 km Gakkel Ridge has a uniquely slow spreading rate, an exceptionally deep rift valley, and a very thin crust, with small ridge offsets and orthogonal spreading. It appears the be responsible for the creation of 500 km of new ocean crust, but where and how can this extension be accommodated through geological time? Distinctive physical and chemical properties suggest that study of the Ridge should provide fundamental insights into global crustal accretion and mantle processes.

9 Laptev Sea

Another question centres on how the rift associated with the Gakkel Ridge ends and whether it propagates into continental crust in the Laptev Sea.

10 Lomonsov Ridge

The 1,800 km long Lomonsov Ridge crosses the Arctic Ocean from Canada to Siberia and detached from the Barents/Kara shelf in Palaeocene times. It appears to consist of a sediment starved continental margin with a variety of geological structures, but little is known of its true composition, although the recent ACEX drilling has shed some light on this. Estimates suggest that the ridge could contain up to 10 billion barrels of oil, and consequently it has become the subject of intense political interest recently.