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Yngve KRISTOFFERSEN

Geophysical and Geological Exploration of the Eurasia Basin, Arctic Ocean from Ice Drift Stations "Fram-I–IV"

Kurzfassung

Die Umwelt des Arktischen Meeres stellt eine logistische Herausforderung für die wissenschaftliche Erforschung dar. Ein Jahrhundert lang war das Ausnutzen von Treibeis als Plattform ein Eckpfeiler für Forschungsvorhaben im polaren Meer. Es erforderte Engagement und ein Langzeitdenken seitens der Geldgeber. Als wissenschaftlicher Leiter war Leonard Johnson wesentlich daran beteiligt, dass dies über einen Zeitraum von fast zwei Jahrzehnten der Fall war. Als Teil dieses Forschungsvorhaben arbeiteten die Treibeisstationen „Fram I–IV" im Frühjahrs-Wetterfenster 1979–1982 und trugen zur substanziellen Erforschung des Nördlichen Polarmeeres bei.

Abstract

The Arctic Ocean environment presents a logistical challenge for scientific exploration. For a century the use of drifting sea ice as a platform was a corner stone for endeavours in the polar basin. It required committment and a long term perspective on the part of the funding agencies. As a science administrator, Leonard Johnson was instrumental in making this happen over a period of almost two decades. As a part of this, the "Fram I–IV" ice drift stations operated in the spring weather window of 1979–1982 and made a substantial contribution to exploration of the Eurasia Basin.

Résumé

L'environnement de l'océan glacial lance un défi logistique à l'exploration scientifique. Pendant un siècle l'utilisation des glaces flottantes en tant que plate-forme était un pilier d'angle pour des travaux de recherche dans l'océan polaire. Les bailleurs de fonds devaient s'engager et penser à long terme. Leonard Johnson comme directeur scientifique était essentiellement intéressé au fait que c'était le cas sur une durée de presque deux décénies. Les stations des glaces flottantes „Fram I–IV" faisaient partie de ces projets de recherche pendant le temps printanier des années 1979–1982, entrant ainsi pour beaucoup dans l'exploration substantielle de l'océan glacial arctique.

Keywords

Arctic, Drifting Ice Stations, Geophysics

1. Introduction

Nansen's successful drift with "Fram" from the New Siberian Islands to Svalbard (1893–96) and Papanin's operation of a camp "Northpole I" on drifting sea ice from the North Pole to Iceland (1936–37) set an operational strategy for exploration of the Arctic Ocean seafloor during the twentieth century. After World War II, Russian scientists operated altogether about 30 icestations, most of them occupied more than a year. The most well known American ice drift camp "T-3", was established in 1952 on a fragment of glacier ice (8 x 14 km, thickness about 50 m) and operated almost continuously for 22 years. It completed two orbits in the Beaufort Gyre in the Canada Basin.The contemporary station "Arlis II" (1961–1965) drifted from north of Alaska to the Denmark Strait and was the only U.S ice station to traverse the Eurasia Basin (WEBER & ROOTS 1990).

In 1976, the U.S. Polar Research Board presented a plan for a science program which required an icebreaker to be frozen in the pack ice north of the Laptev Sea to duplicate Nansen's drift with "Fram". Insufficient support was received and it was subsequently decided on an alternative programme using temporary ice drift stations to be named after "Fram" (JOHNSON 1983). The logistics of these U.S. stations were organized by Polar Science Center, University of Washington, under contract to U.S. Navy, Office of Naval Research (ONR). The "Fram" stations (1979–1982) were platforms (Fig. 1) for a multidisiplinary effort involving scientists from United States, Canada, Denmark and Norway through their respective home institutions. The driving force behind this effort was L. Johnson, manager of Arctic Programs at ONR.

Ice drift station "Fram-IV" in March–May 1982 was the last in the series and also part of a coordinated programme celebrating the centennial of the First International Polar Year (ROBIN 1982)

2. Logistics

Operation of a temporary camp on drifting sea ice is determined by the time window for safe landing and take-off on the ice by small aircrafts. It starts with return of the daylight by mid-March and come to a close with frequent fog and white-out conditions in early-mid May.

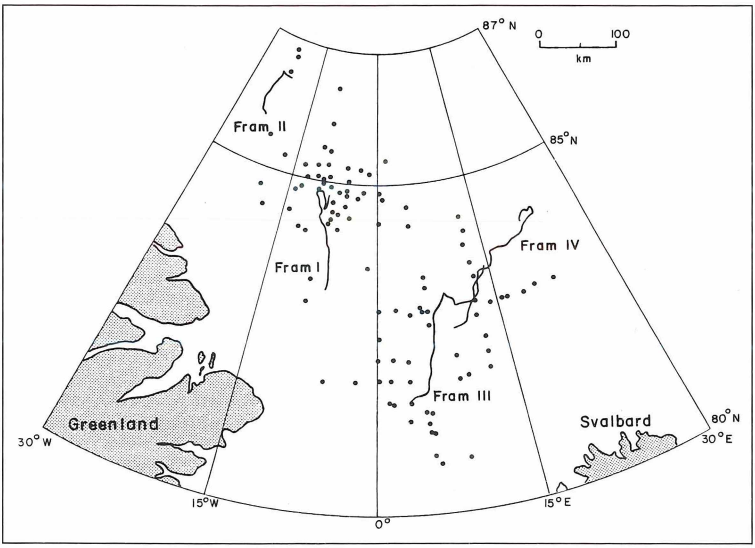

Fig. 1: Drift tracks of the "Fram I–IV" ice stations. Dots indicate helicopter stations for oceanographic and geophysical measurements (after JOHNSON 1983).

The personel, field- and scientific equipment were delivered to the ice by Twin Otter and Tri-Turbo 3 aircrafts from an advance base at Station Nord, northeast Greenland. The Tri-Turbo is a rebuilt DC-3 equipped with three turboprop engines to enhance short take-off and landing capabilities. Fuel drums and explosives were air-dropped from C-130 out of Thule Air Force Base, northwestern Greenland. A Bell 204 helicopter was stationed on the ice to support camp operations and the scientific programmes.

Once the experienced advance party had selected a suitable ice floe, a camp for about 20 persons was established. The buildings were mostly prefabricated box-shaped huts, 2.4 x 4.9 m, for living- and scientific quarter (Fig. 2). The mess hall was a larger 4.9 x 6.1 hut of semi-cylindrical shape.

3. Scientific Programmes

Each of the "Fram"-expeditions had a particular priority of scientific programmes:

- "Fram-I" (11 March – 5 May 1979): geophysics, hydroacoustics, oceanography, marine biology, geology
- "Fram-II" (19 March – 5 July 1980): hydroacoustics, oceanography, geophysics
- "Fram-III" (14 March – 13 May 1981): oceanography, geophysics, hydroacoustics, biology
- "Fram-IV" (15 March – 11 May 1982): hydroacoustics, geophysics, oceanography

We will highlight below some of the contributions of the geophysical and geological investigations to new understanding of the submarine geology of the Eurasia Basin. These include the first documentation of anomalously thin crust formed at slow spreading rate, recording of an active faulting within the axial valley of the Gakkel Ridge, sediment deposition in the Eurasia Basin and an investigation of the origin of Yermak Plateau. A more comprehensive review of exploration of the Eurasia Basin is also given by Kristoffersen (1990, 2000).

Fig. 2: Ice drift station "Fram I". Work on an ice station could be eventful when a lead opened through the camp.

4. Contributions from the Geophysics/Geology Programmes on "Fram-I–IV"

The oceanic crust in the Eurasia Basin was formed at the Gakkel Ridge spreading center (KARASIK 1968; VOGT et al. 1979). Seafloor spreading on Gakkel Ridge represents an end-member of the global mid-ocean ridge system as the rate of opening tends to zero as we approach the pole of rotation between Europe and North America located in Russia near the Lena River exit into the Laptev Sea. What is the crustal structure in an environment with slow spreading and low melt production? A morphological manifestation of a slow opening process appeared to be extreme axial valley depths (> 5 km) and relatively rough basement topography as observed at the western end of Gakkel Ridge (FEDEN et al. 1979).

A series of seismic refraction experiments for investigation of the crustal structure were staged from all the "Fram"-stations. The ice covered ocean offer a number of advantages for seismic refraction experiments relative to operations in the open ocean such as low ambient noise levels and possibility to maintain constant receiver array geometry over time. The experiments were carried out by deploying explosive charges of up to 100 kilo at offsets up to 100 km from the camp. The receiving array in the vicinity of the camp was either hydrophones suspended at 60–90 m depth below the ice or a tethered ocean bottom seismometer on the ocean floor. During "Fram-I and -II" a total of 14 unreversed seismic refraction profiles were completed. They sampled oceanic crust ranging from zero age crust at the axis of the Gakkel Ridge to the oldest Eocene crust near the foot of the Lomonosov Ridge (DUCKWORTH et al. 1982; DUCKWORTH & BAGGEROER 1985; JACKSON et al. 1982; KRISTOFFERSEN et al. 1982). The evidence for anomalously thin oceanic crust outside the zone of elevated basement and high amplitude magnetic anomaly amplitudes of FEDEN et al. (1979) was quite convincing, but also thought provoking (JACKSON et al. 1982). A companion paper put these results into a global relation between oceanic spreading rate and crustal thickness (REID & JACKSON 1981). Here it was pointed out that the effect of slow spreading producing thin crust would be discernible at opening rates less than 20 mm/yr. Twenty years later, these results received new actuality when analysis of the first comprehensive gravity and bathymetric data set across the Gakkel spreading center also called for anomalously thin crust (COAKLEY & COCHRAN 1998).

Ice station "Fram-I" drifted over the crestal mountains of the Gakkel Ridge and enabled the first recording (69 events in 36 hours) of a microearthquake swarm in the rift valley (KRISTOFFERSEN et al. 1982). Event location was possible for 21 of these events. They grouped into two parallell trends separated by about 10 km probably related to block faulting along the northern rift valley wall.

The hemipelagic mud in eight sediment cores (7–95 cm) recovered by a small gravity corer from "Fram-I" represented the first seabottom samples from the floor of the deep Eurasia Basin since Nansen obtained mud on the sounding line during his transpolar drift 1893–96. Oxygen isotope analysis determined a sedimentation rate of about 1 cm/kyr over the last 10 kyr. (ZAHN et al. 1985). This rate was considerably larger than much debated estimates of sediment deposition over the Alpha Ridge in the Amerasia Basin (CLARK et al. 1980).

The first continuous multi-channel seismic reflection experiment conducted in the Arctic Ocean to study the sub-bottom sediments was carried out from "Fram-IV" and yielded 200 km of good quality seismic data from the Nansen Basin (KRISTOFFERSEN & HUSEBYE 1985). A line of 20 telemetering sonobuoys spaced 100 m apart along the average drift direction simulated a seismic cable and recorded the signal from an airgun fired at 50 m interval along the track. Sediment thickness below the Barents Abyssal Plain is up to 1.5 km and the conformable bedforms over gentle basement highs suggests a relatively stable bottom current regime since mid-Oligocene.

Yermak Plateau north of Svalbard and Morris Jesup Rise north of Greenland are two marginal plateaus which are conjugate features with respect to Gakkel Ridge. These features are considered to have a common origin as a single Iceland-like volcanic massif formed by excessive volcanism in middle Eocene-Olicocene (FEDEN et al. 1979).

However, Yermak Plateau display a conspicuous difference between high magnetic amplitudes over the northeastern part and a quiet magnetic field over the western and southern part.

Scientists on "Fram-III" were able to complete one seismic refraction line within each of the magnetic provinces and obtained a velocity structure in the northern part with similarities to oceanic crust, whereas velocities vs. depth in the western part are more akin to a thinned continental section (JACKSON et al. 1984).

5. Summary

A number of aspects of the submarine geology of the Arctic Ocean are unique in a global context. This includes the origin of Alpha-Mendeleyev Ridge and the issue of large igneous provinces, the origin of Lomonosov Ridge as an expression of rheological properties of the lithosphere during rifting, formation of thin oceanic crust at the Gakkel spreading center, as well as the record of high latitude palaeoclimate and palaeoceanographic history contained in the sub-bottom sediments.

Four decades of exploration by drifting platforms defined the first order framework, and in the Eurasia Basin, a major contribution was made by the "Fram" stations. We entered a new era in 1991 when icebreaking research vessels advanced to the North Pole (FÜTTERER 1992).

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Author's address:

Prof. Dr. Yngve Kristoffersen
University of Bergen, Norway – Institute of Solid Earth Physics
Allegate 41
N – 5000 Bergen
e-mail: yngve@ifjf.uib.no

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