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VISUAL AND CHEMICAL EVIDENCE FOR A NATURAL SEEP AT SCOTT INLET, BAFFIN ISLAND, DISTRICT OF FRANKLIN

E.M. Levy[1]

Abstract

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A visual reconnaissance of the sea surface off Scott Inlet in 1977 demonstrated the presence of slicks in an area where they were observed in 1976, although their extent was very much greater than previously thought. An extensive hydrochemical investigation was carried out, and elevated concentrations of dissolved and/or dispersed petroleum residues both at the surface and in the water column provided strong evidence for natural seepage of petroleum from the seabed.

Introduction

On two occasions during the 1976 **CSS Hudson** cruise to the Arctic, what appeared to be oil slicks were observed in the vicinity of Hecla and Griper Bank off Scott Inlet, Baffin Island (Loncarevic and Falconer, 1977) (Fig. 4.1). Water samples were taken from the surface and at depths of 50 and 300 m, and a sample of the slick was collected by swabbing the sea surface with cheesecloth. Direct high temperature gas chromatographic analysis of a scraping of the material on the cheesecloth revealed a broad spectrum (140 to 350°C) of aliphatic hydrocarbon peaks protruding from an unresolved envelope. This is typical of the chromatograms obtained by this procedure for partially weathered crude oils. Although more volatile compounds might have been present in the sample, they would not have been detected under these analytical conditions. In addition, the ultraviolet absorbance ratio (2.72) was in the range of those found for a variety of crude oils and the lighter residual fuel oils (Levy, 1972a). The water samples contained fluorescing substances (primarily aromatic hydrocarbons) as measured by fluorescence spectrophotometry (Levy, 1977a) in concentrations equivalent to 33 to 890 $\mu g\ L^{-1}$ of Bunker C fuel oil from the **Arrow** at the surface and 2 to 7.6 $\mu g\ L^{-1}$ in the water column. On the basis of the background levels previously observed on the Scotian Shelf and in the Gulf of St. Lawrence (Levy, 1971, 1972b; Levy and Walton, 1973), the concentrations in the water column and particularly those at the surface at Scott Inlet were very much higher than would have been anticipated for such a remote area and suggested that the elevated concentrations were the consequence of a local source on the seabed.

In addition to the information obtained from the 1976 cruise, floating petroleum residues were collected near Scott Inlet in 1971 during a study of the distribution of tar in the North Atlantic (Levy and Walton, 1976). This was one of only four areas throughout the Eastern Arctic where floating residues were encountered, but the possible significance of these observations was not appreciated at the time. Subsequently, these other areas — the entrance to Lancaster Sound north of Bylot Island, the northern Labrador Sea, and the Labrador Shelf — have attracted the attention of the oil industry for their potential as petroleum resource regions. In any event, the slick observed off Scott Island in 1976 and the floating residues collected in 1971 suggested that the source in this area had been active for a number of years. Because of the possibility that this source might be submarine seepage of petroleum from the seabed, and not merely the consequence of some anthropogenic input, a more detailed visual reconnaissance of the area and a more extensive hydrochemical survey was carried out in 1977.

Field Observations (September 5-6, 1977)

Because of ice conditions, **Hudson** approached the Scott Inlet area from the northeast (Fig. 4.2) under conditions that were ideal for visual observation of the sea surface. With excellent lighting and only a very light breeze, damping of capillary waves by surface-active substances was readily detected. An extensive slick was sighted at 1537 GMT and photographs were taken before crossing the boundary (Fig. 4.3). The slick was virtually continuous for 9 km along the ship's track and extended in a northwest-southeast direction as far as it was possible to see. Water samples were collected for the determination of salinity, oxygen, dissolved 'petroleum residues', volatile hydrocarbons, alkalinity, nutrients, and stable isotopes of carbon and oxygen. The surface microlayer was sampled with a stainless steel screen sampler (Garrett, 1965) while bottom sediments were collected with a Shipek grab and floating particulate matter was collected with a neuston net. While these operations were underway, two short excursions were made in the ship's launch for a closer inspection of the slick. At one location it had the appearance of an oily film with iridescent interference colours and a small patch of "chocolate mousse" was observed. Samples were collected. At a nearby location gas

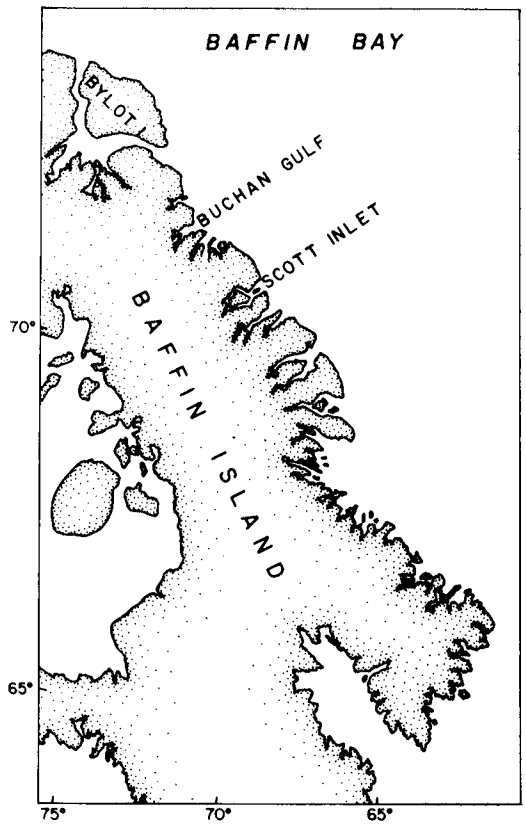

Figure 4.1. Map of Eastern Arctic.

[1]Atlantic Oceanographic Laboratory, Bedford Institute of Oceanography, Dartmouth, N.S., Canada B2Y 4A2.

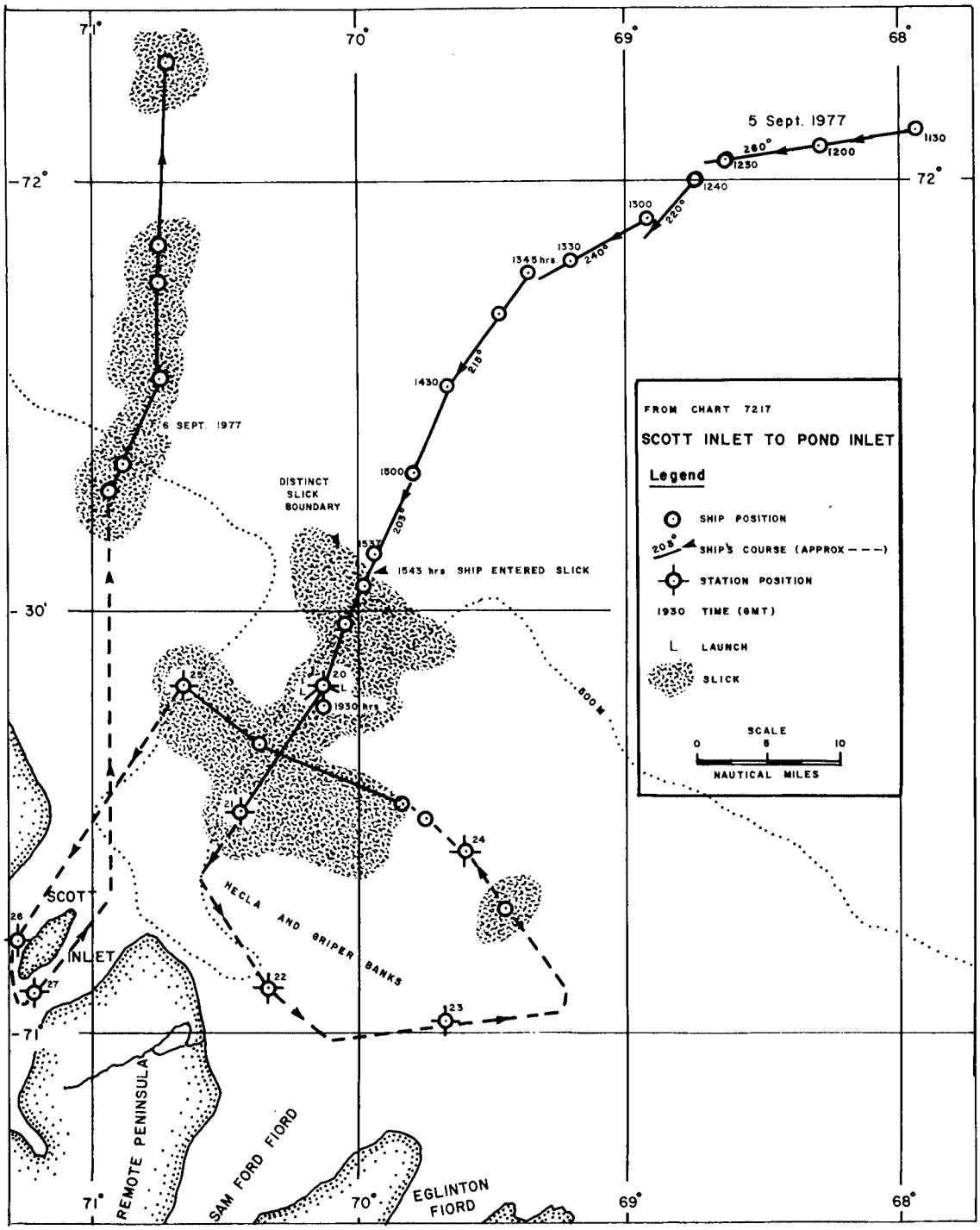

Figure 4.2. Map of Scott Inlet region ship's track and location of slick observed in September 1977.

bubbles were observed to be erupting through the sea surface, and samples of surface water were collected. Shortly afterwards a light wind arose, and light conditions changed slightly so that it was difficult to observe the slick from the launch. However, it was still plainly visible from **Hudson.** An almost continuous slick extended between Stations 20 and 21 in an undetermined distance to the northwest and southeast. Careful watch was maintained until nightfall, although conditions for observing the slicks deteriorated and finally ice was encountered. The ship did not get out of the ice until 1041 GMT on September 6. An almost continuous slick to the northeast of Hecla and Griper Banks extended between the edge of the ice field and Station 25, a distance of about 40 km. Its width, or its extension beyond the ice and north of Station 25, was not determined.

In order to establish whether the slick-forming material was entering the coastal waters via Scott Inlet from a source on land, Scott Island was circumnavigated. However, no slicks were observed in Scott Inlet, nor was there any other evidence of a terrestrial source for the slick-forming material (Levy, 1977b).

The **Hudson** left the area in late afternoon of September 6 and proceeded in a northerly direction. At that time there was sufficient ripple on the water that slicks were not observed. Towards evening, however, the breeze abated and the ship passed through an area of continuous slick which was at least 40 km long.

Unfortunately, time was not available to map out in more detail the extent of the slick or to locate the source (or sources?) of the slick-forming material. Nevertheless, this reconnaissance not only confirmed the presence of slicks in the Scott Inlet area as observed during 1976 but also demonstrated that the slick area is much more extensive than previously believed. In view of the southward currents in this region, the slick observed on the northward passage from Scott Inlet suggests that there might be a number of other sources on the Baffin Shelf.

Analytical Results

Qualitative. The extracts from the surface microlayer samples collected in the Scott Inlet area were combined and analyzed by high-temperature gas chromatography using a procedure developed for the analysis of tar balls and other high-boiling petroleum residues (Column: 2 m x 3 mm stainless steel, 3% Dexsil-300 on 100-120 Chromosorb W; Temperature program: 6°C/min to 350°C; Levy et al., 1973). The chromatogram revealed the presence of a broad spectrum of saturated hydrocarbon peaks protruding from an unresolved envelope. Such chromatograms are typical of crude oils which have undergone weathering in the marine environment. Since there was no indication of either a narrow range of specific hydrocarbons or of an odd-carbon preference, the slick-forming material is not of recent biosynthetic origin. Although this analysis is not capable of unequivocally identifying the nature of the slick-forming material, it does provide strong evidence that the slick originates from petroleum which is seeping from the seabed. A submarine trough extends seaward from the fiord at Scott Inlet across the Baffin Island continental shelf and, as shown by the seismic records (MacLean, 1978), the strata exposed on the walls and floor of this trough provide geological conditions favourable for seepage to occur. Similar bathymetric conditions are present at Buchan Gulf and at some of the fiords farther south. These would seem also to be potential sites of seepage of petroleum from the seabed.

Quantitative. A total of 55 samples was collected from the water column at Stations 20 to 27 in the environs of Scott Inlet (Fig. 4.2). These samples were extracted with carbon tetrachloride on board **Hudson** and subsequently analyzed by fluorescence spectrophotometry (Levy, 1977a) at the Bedford Institute of Oceanography. The data (Table 4.1) demonstrate that, although the concentrations of dissolved and/or dispersed petroleum residues[1] at most of the locations and depths sampled in the Scott Inlet area were at the background level[2] measured for Eastern Arctic waters in 1977, concentrations at some sampling sites were very much higher. These 'anomalies' were well beyond the experimental variability and were not observed elsewhere in the region surveyed in 1977. Further, there was no correlation between the concentration anomalies in the Scott Inlet samples and depth, salinity, dissolved oxygen, or other chemical parameters measured on the same sample of water. This would be expected if seepage was occurring sporadically from the exposed strata on the walls of the submarine canyon with the sporadic injections of petroleum being swept along by the water movements at the same time as they were rising under the force of their own buoyancy. The variability in the concentration data, then, represents the statistical chance of capturing in a 5-litre sampler, at a certain depth and at a particular instant in time, one or more of these discrete and non-homogeneously distributed injections of oil.

Concentrations of oil in the surface microlayer (Table 4.2) as sampled by the screen technique and analyzed by fluorescence spectrophotometry in the Scott Inlet area were 22 to 42 $\mu g\ L^{-1}$ (arithmetic mean 30.2 $\mu g\ L^{-1}$) except in seven areas where deliberate attempts were made to sample the slick-forming material when concentrations ranging from 85.7 to 1726 $\mu g\ L^{-1}$ (arithmetic mean 424 $\mu g\ L^{-1}$) were encountered. The sample with the highest concentration of oil was taken from a small patch of thin "chocolate mousse" floating on the surface. The concentration in the surface microlayer at one location in Scott Inlet was 14.6 $\mu g\ L^{-1}$ and this provides further evidence that the slick which was present offshore was not derived from a source in the inlet itself. By way of comparison the surface microlayer concentrations throughout Baffin Bay, with the exception of values at the entrance to Lancaster Sound and in the slick off Scott Inlet, were 3.5 to 11.4 $\mu g\ L^{-1}$ (arithmetic mean 7.0 $\mu g\ L^{-1}$). It is notable also that the concentrations in the surface microlayer in Baffin Bay were about an order of magnitude higher than those in the water column below and that this is well within the range of enrichment factors reported for surface-active organic substances in the ocean (MacIntyre, 1974).

Although a large number of water samples were collected throughout the Eastern Arctic and analyzed shipboard for light hydrocarbons (C_1-C_6), the data have not yet been processed. In addition, grab samples of surficial bottom sediments were collected and frozen but the chemical analyses have not yet been completed.

Conclusions

On the basis of the field observations and the analytical data which resulted from the 1977 **Hudson** cruise to the Eastern Arctic, the following conclusions may be drawn:

- Slicks were present off Scott Inlet during early September 1977 in the same general area where they were observed in 1976. However, in 1977 the slick covered a much more extensive area.
- Existing observations and analytical data indicate that the source of the slick is seepage of petroleum from the seabed. However, a detailed compositional analysis of the slick-forming material remains to be done.
- The presence of extensive slicks to the north of Scott Inlet during 1977 suggests that there may be other locations where seepage occurs.

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[1] All concentrations of dissolved and/or dispersed petroleum residues are expressed in terms of Bunker C fuel oil taken from the tanker, **Arrow**, which grounded off Nova Scotia in 1970. This oil has been used as the reference material throughout our studies of petroleum in the North Atlantic (Levy, 1971, 1972b; Levy and Walton, 1973) and ensures that our data remain internally consistent and intercomparable.

[2] This background level is taken as the geometric mean of the concentrations of dissolved and/or dispersed petroleum residues measured in 563 water samples collected at 46 stations and at all standard oceanographic depths throughout the northern Labrador Sea, Davis Strait, Baffin Bay, Lancaster Sound, Jones Sound and Smith Sound in 1977. Samples from Scott Inlet were not included. Because the distribution of the data very closely approximates a lognormal distribution, the geometric mean (0.46 $\mu g\ L^{-1}$) is a more appropriate measure of central tendency than the arithmetic mean (0.70 $\mu g\ L^{-1}$). The 95% confidence ranges are 0.43 to 0.49 $\mu g\ L^{-1}$ and 0.60 to 0.80 $\mu g\ L^{-1}$ for the geometric and arithmetic means respectively. Whichever approach is taken, the general background level in Eastern Arctic waters during 1977 was appreciably less than 1 $\mu g\ L^{-1}$.

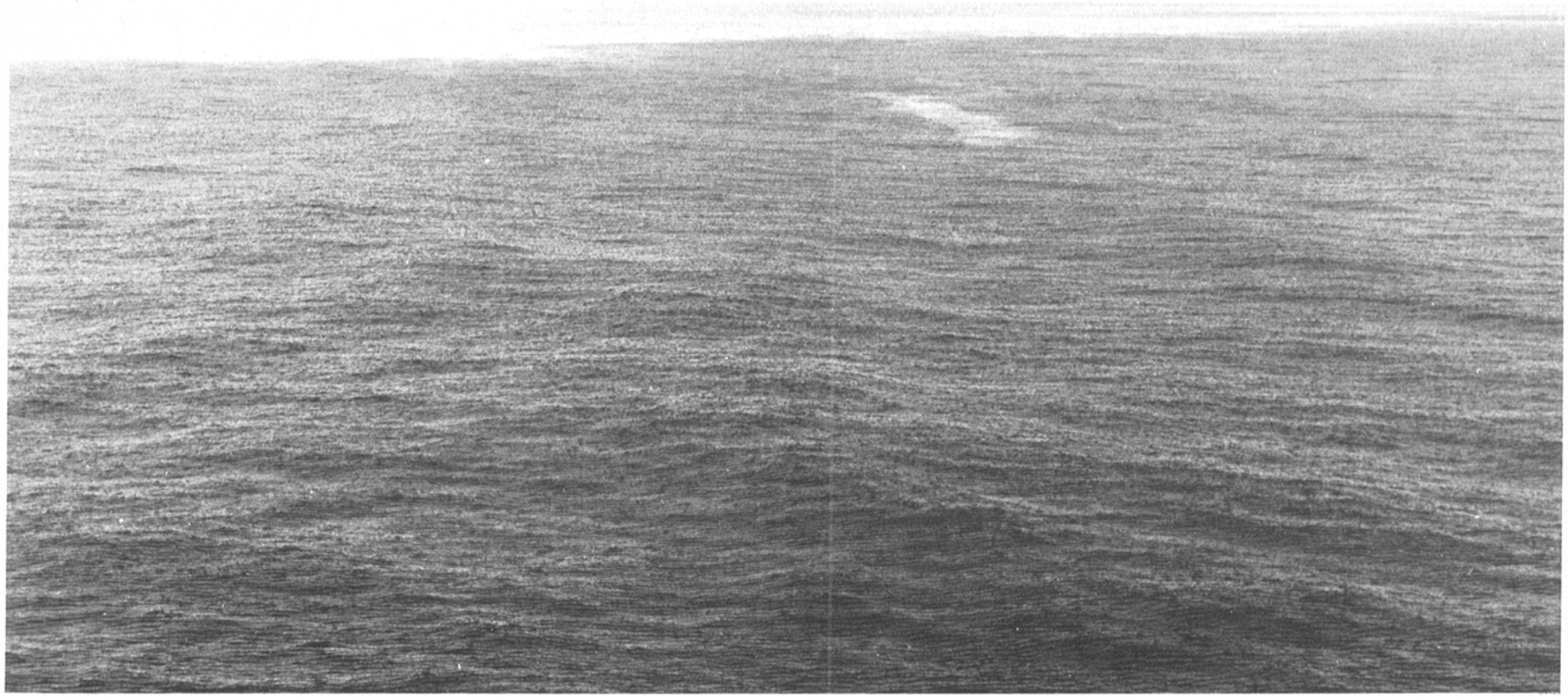

Figure 4.3. Photograph of slick off Scott Inlet.

Table 4.1

Concentrations of petroleum residues in the water column at Scott Inlet (September 1977)

Station	Depth (m)	Concentration ($\mu g\ L^{-1}$)
20	1	0.40
20	10	0.55
20	20	0.50
20	50	0.40
20	75	0.50
20	100	0.05
20	150	0.40
20	200	0.80
20	335	0.35
21	1	0.30
21	10	0.40
21	20	0.40
21	30	0.30
21	75	1.70
21	100	0.35
21	150	0.40
21	200	0.80
21	410	0.30
22	0	0.35
22	1	0.90
22	10	0.70
22	20	0.60
22	30	87.50
22	50	10.00
22	75	0.70
22	100	0.75
22	150	0.40
22	200	10.00
22	235	0.05
23	1	0.55
23	10	0.20
23	20	0.15
23	30	5.55
23	50	0.05
23	75	0.10
23	119	0.20
24	1	0.20
24	10	1.40
24	20	0.20
24	30	0.10
24	50	0.15
24	75	0.40
24	100	0.55
24	150	1.90
25	1	0.40
25	10	57.50
25	20	0.40
25	50	0.40
25	75	0.40
25	100	0.40
25	150	0.40
25	200	0.35
25	275	0.40
26	1	0.15
27	1	0.50

Table 4.2

Concentrations of petroleum residues in the surface microlayer at Scott Inlet (September 1977)

Station	Concentration ($\mu g\ L^{-1}$)
20*	85.7
	154.4
	1726.2
	212.0
	488.4
	202.0
21	22.8
24	26.3
25	41.6
26	14.6

*Samples collected from launch.

Future Work

Because of the potential economic and environmental importance of natural seepage of petroleum on the Baffin Island shelf and since the seep provides a natural laboratory for a study of the long term effects of chronic inputs of petroleum into an Arctic marine environment, a multidisciplinary chemical, biological and geological/geophysical investigation of the Scott Inlet seep and an exploratory survey of the Buchan Gulf region are being planned for the 1978 field season. Attempts will be made to map the slick areas more fully and to locate the source or sources of the slick-forming materials, to obtain a sufficient sample for detailed chemical analyses by modern analytical techniques including computerized gas chromatography-mass spectrometry, to collect and analyze the gases which are escaping from the sea surface in some areas, and to gather more extensive chemical data concerning the concentrations of petroleum-derived substances in the water column, on the sea surface and in the surficial bottom sediments. The biology program will focus on long term sublethal effects of petroleum on the physiology of Arctic phytoplankton and zooplankton and higher marine organisms and on the effects in carbon fluxes. Studies of primary production under Arctic conditions will also be carried out. The geology/geophysical program will be a continuation of the studies of the Baffin Island continental shelf already under way (MacLean, 1978). Together, these investigations should provide much more complete information concerning natural seepage on the Baffin Island shelf as well as an appreciation of the environmental consequences of exploration and production of oil in the Arctic.

Acknowledgments

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