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### Abstract

A preliminary analysis of the 1978 data concerning dissolved and dispersed petroleum residues in the water column and surface microlayer of the Baffin Island shelf provided further evidence for natural seepage of petroleum from the seabed at Scott Inlet, Buchan Gulf, and possibly northeast of Bylot Island. A model was proposed to account for the observed distributions.

### Introduction

In a previous publication, visual and chemical evidence, which suggested natural seepage of petroleum from the seabed off Scott Inlet, Baffin Island, was reported (Levy, 1978). Visible slicks and gas bubbles erupting at the sea surface as well as anomalously high concentrations of petroleum residues in the surface microlayer and in the water column seemed to be associated with the submarine trough which extends seaward across the continental shelf from the fjord at Scott Inlet. Geological and geophysical data for this area demonstrated that a structural high containing two basement ridges underlies the south wall and trends northwesterly across the floor of the trough and that a sedimentary basin is present between the structural high and the coast (MacLean and Falconer, 1979). Seismic records showed that the strata forming the walls of the Scott Inlet trough are flat-lying for the most part and that strata which have been folded and faulted occur in the floor of the trough and in places form the lower part of the walls where they are separated from the overlying strata by an angular unconformity (MacLean, 1978). The geological environment, therefore, provides conditions which are favourable for the migration of hydrocarbons present in the rock formation and their subsequent escape to the water column and appearance at the sea surface.

In view of the southward surface currents in this area, the presence of slicks to the north of Scott Inlet in 1977 led to the postulation that there might also be seepage at Buchan Gulf, where there is a similar bathymetric feature, and at other locations on the Baffin Island continental shelf (Levy, 1978). To investigate these possibilities and to learn more about the seep at Scott Inlet, a multidisciplinary chemical-biological-geological study was carried out by the Bedford Institute of Oceanography during the summer of 1978. This report summarizes some of the preliminary results pertaining to the chemical portion of this study.

### Sampling and Analytical Procedures

During the 1978 cruise (78-026) samples of seawater were collected at standard oceanographic depths throughout the water column at Scott Inlet, Buchan Gulf, the entrance to Lancaster Sound and in the northern portion of Baffin Bay (Fig. 42.1). At Scott Inlet and Buchan Gulf, sampling was carried out on grids

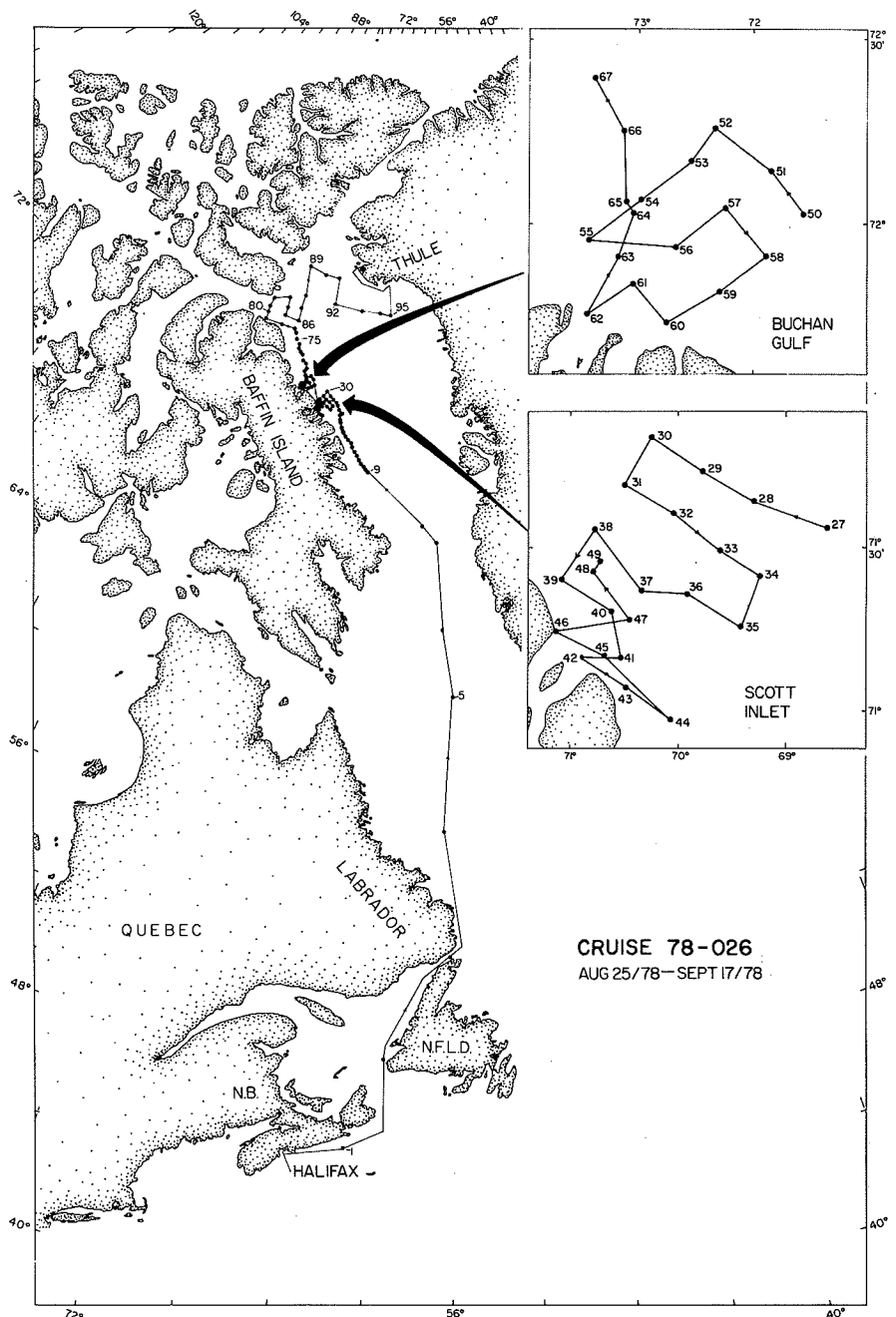
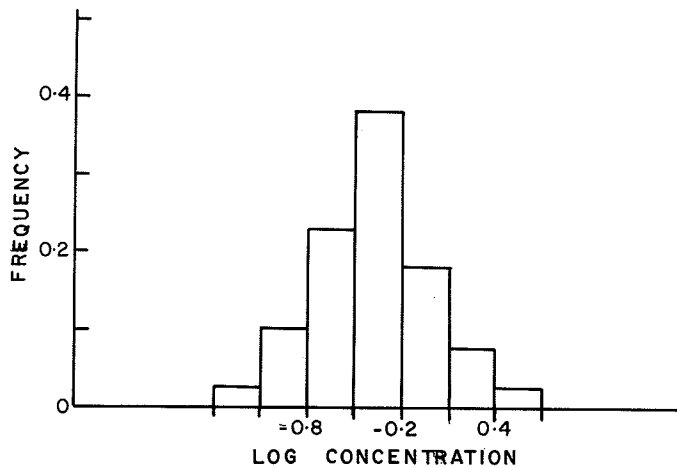


Figure 42.1. 1978 cruise track and location of stations.

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**Figure 42.2.** Lognormal distribution of 1977 data for dissolved and dispersed petroleum residues in the water column of Baffin Bay.

centred over the submarine troughs that extend seawards across the Baffin Island continental shelf in these areas. Separation between stations was about 19 km. Twenty-three stations were occupied at Scott Inlet (259 samples) and 18 at Buchan Gulf (140 samples). An expanded grid of 17 stations (166 samples) was sampled at the entrance to Lancaster Sound and extended into northern Baffin Bay (75 samples). In addition, stations were occupied en route from Halifax to Baffin Island.

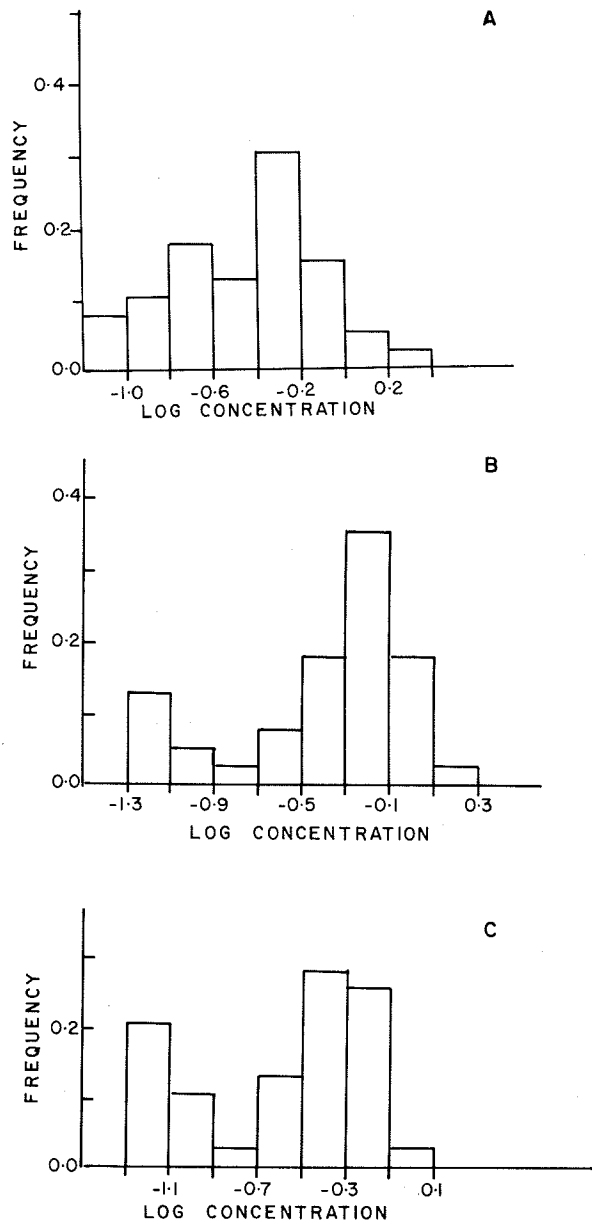
Water samples were collected in 5 L Niskin samplers in a Rosette assembly which was lowered to within a few metres of the bottom and the samples were collected during retrieval. Immediately on recovery, 1 L subsamples were drawn for extraction and subsequent analyses for dissolved and dispersed petroleum residues (Levy, 1977). In addition, duplicate samples were drawn into 250 mL amber glass bottles and capped for the determination of volatile low molecular weight hydrocarbons. One of these was immediately extracted by equilibration with helium (McAuliffe, 1974) and analyzed by gas chromatography while the other was returned to the Institute for more detailed analyses. Processing of these data has not yet been completed. Samples from the surface microlayer were collected with a stainless steel screen (Garrett, 1965).

## Results and Discussion

### Water Column

It has been demonstrated (Levy, 1978, 1979) that the background level of dissolved and dispersed petroleum residues in the waters of Baffin Bay and adjoining Sounds during 1977 was  $0.46 \mu\text{gL}^{-1}$  with subsequently higher concentrations in a few regions, notably the area off Scott Inlet. Although the concentration data for Baffin Bay were lognormally distributed (Fig. 42.2), those for the Scott Inlet area were not. This led to postulation that there were two distinct populations; namely, those samples in which only the general background level was observed and those which contained an additional input of oil from the seepage. However, sufficient data were not available from the 1977 cruise to establish the distributions.

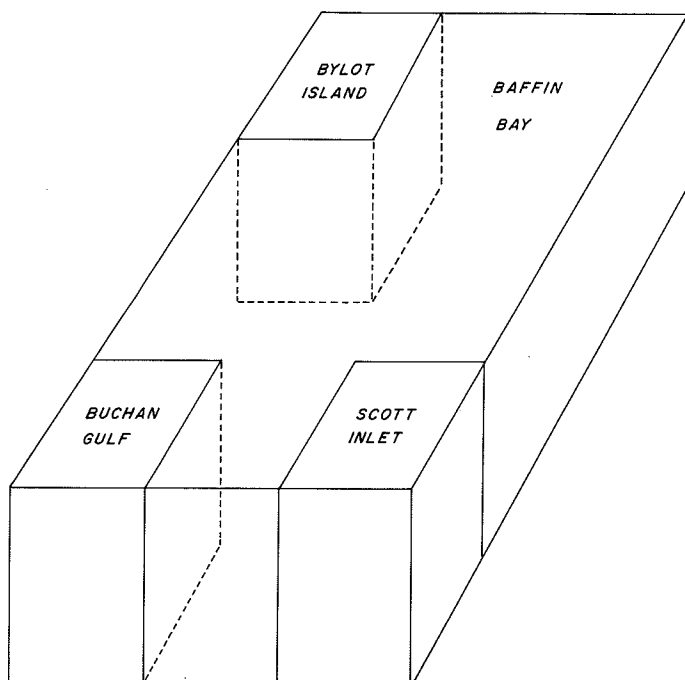
Whereas the 1977 data pertaining to the background levels in Baffin Bay were lognormally distributed, those collected during 1978 at Scott Inlet, Buchan Gulf and Bylot Island failed to meet the stringent criteria imposed on



**Figure 42.3.** Frequency distribution plots of 1978 data for dissolved and dispersed petroleum residues in the water column at Scott Inlet (A), Buchan Gulf (B), and Bylot Island (C).

the  $\chi^2$  test by the large number of observations. The frequency distribution plots for these areas (Fig. 42.3) exhibit an almost bimodal character which indicates that two different populations are, indeed, present in the water column.

On the basis of this hypothesis, the observed distribution of dissolved and dispersed petroleum residues in Baffin Bay can be described in terms of a simple box model (Fig. 42.4) throughout which there is a general concentration level of  $0.46 \mu\text{gL}^{-1}$  but which receives additional inputs from natural seepage from the seabed in several localities. Potential inputs such as leakage from a sunken wreck or spills occurring at the surface are not consistent with the chemical nature of the material or its distribution in the water column and are not included in the model. Since the seepage at Scott Inlet is believed to consist of small discrete releases from the



**Figure 42.4.** Box model describing concentrations of dissolved and dispersed petroleum residues in Baffin Bay.

walls and bottom of the submarine trough, the seep "site" is not localized but consists of many sites which are spread over a considerable area of the seafloor and which are probably not continuously active. Immediately upon escaping from the seabed, the oil droplets begin to rise under the force of their own buoyancy and are swept along by water currents. The result of this is the presence of "swarms" of oil droplets which are non-homogeneously distributed with respect to both space and time in the water body. Within a swarm, there are particles of various sizes that are separated by various distances which are large in relation to the size of sampler. As a result, the probability of catching one or more of them in a sampler at a given time and place in the water column accounts for the variability in the concentration data and the fact that not all samples from a given station, even in the seep areas, have higher than background concentrations. Qualitatively, then, this model can account for the lognormal distribution of the data and the general background level in Baffin Bay as a whole, as well as the elevated and highly variable concentrations observed in those areas where there is a second population of concentration levels arising from dispersed clouds of seep particles superimposed on the general background level.

From the properties of the Gaussian distribution of the log transformed concentration data for Baffin Bay, it can be shown that 99.9 per cent of the samples can be expected to have concentrations of dissolved and dispersed petroleum residues within the range of  $0.41\text{--}0.52\ \mu\text{gL}^{-1}$ . Accordingly, there should be less than one chance in a thousand of encountering a concentration in excess of  $0.52\ \mu\text{gL}^{-1}$  in this population. Concentrations greater than this can therefore be considered as belonging to a different population. (This includes artifacts arising from analytical and sampling errors as well as true concentration anomalies.)

Since a total of 628 samples were collected from Baffin Bay waters during the 1977 cruise it would be predicted that only one observation would fall outside the 99.9 per cent range. In fact, however, 218 samples contained more than  $0.52\ \mu\text{gL}^{-1}$  while 94 had concentrations greater than  $1\ \mu\text{gL}^{-1}$

Table 42.1  
Dissolved/dispersed petroleum residue concentration anomalies – Baffin Island Shelf, 1978

Area	No. Samples	No. Anomalies		Greater than $1\ \mu\text{gL}^{-1}$	
		No.	%	%	%
Scott Inlet	259	65	25.1	17	6.6
Buchan Gulf	140	43	30.7	15	10.7
Bylot Island	166	16	9.6	1	0.6

and 6 greater than  $5\ \mu\text{gL}^{-1}$ . During the 1978 cruise, 565 samples were collected from the waters over the Baffin Island shelf at Scott Inlet, Buchan Gulf and northeast of Bylot Island and 124 anomalies were observed (Table 42.1). In all cases, the statistics support the presence of two (or more) populations of concentration levels.

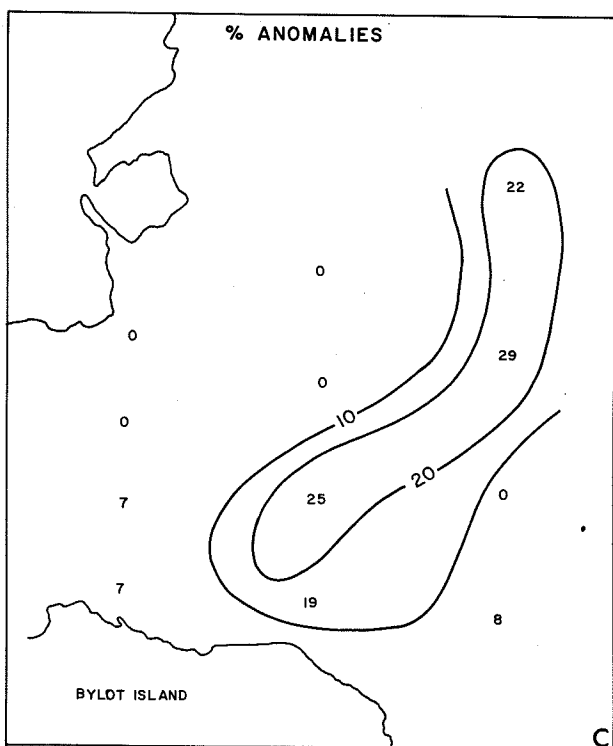
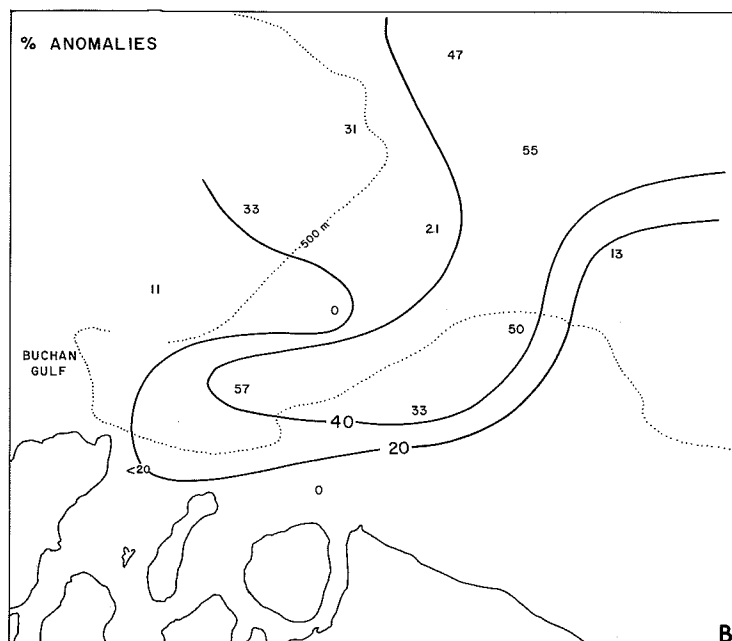
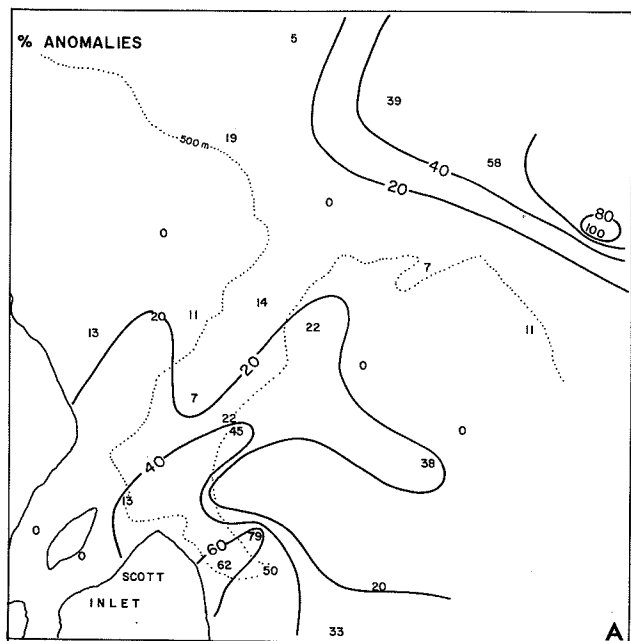
In the Scott Inlet area, concentration anomalies in 1978 were clustered along the south wall of the trough (Fig. 42.5A) and the trough extension which lies between Hecla and Griper Bank and Baffin Island. In addition, there were high percentages of anomalies at the seaward portion of the Scott Inlet grid. It is pertinent to note also that the anomalies observed during the 1977 cruise are compatible with this contour map. At Buchan Gulf (Fig. 42.5B) although the anomalies tended to congregate over the trough, there was a pronounced offshore component and at the entrance to Lancaster Sound (Fig. 42.5C) anomalies trended in a northeasterly direction from Bylot Island. Notable in this area was the absence of anomalies in the northern portion of Lancaster Sound and the region southeast of Devon Island.

#### Surface Microlayer

Under suitable meteorological and oceanographic conditions, petroleum-derived components in seawater tend to accumulate at the surface of the sea. As a result, capillary waves are damped and the light reflecting properties of the sea surface are thereby modified. This results in the formation of a surface slick which, under favourable light conditions, is readily discernable. If this surface film is compressed; for example, by encountering a physical barrier or by the convergence of surface circulation cells, iridescence may be observed and in more extreme cases a mousse-like material may be formed. This phenomenon results in a marked enrichment of the surface-active substances in the sea surface microlayer relative to the water immediately below.

During the 1977 cruise weather and sea conditions in the Scott Inlet region were ideal for the formation and observation of surface slicks and extensive areas of the sea surface were covered with slicks (Levy, 1978). Unfortunately, during the chemical phase of the 1978 cruise conditions varied from unsuitable to barely marginal for the formation and observation of surface slicks. As a result, visual observations could not be made and interpreted with a high degree of reliability in 1978.

Surface microlayer concentrations at Scott Inlet were highest over the south wall of the trough (Fig. 42.6A) and over its southern extension. Since this was also the case for the concentration anomalies in the water column, it would seem that two of the most active seep sites during 1978 were in the vicinity of stations 40, 47, 43, and 45. During the 1977 cruise, extensive surface slicks were observed in the former area (Station 21) and extremely high concentrations of petroleum residues in the water column were encountered at the latter (Levy, 1978). Accordingly, these sites have been active for some time and might very well be the major seep



**Figure 42.5.** Concentration anomalies during 1978 at Scott Inlet (A), Buchan Gulf (B), and Bylot Island (C).

area at Scott Inlet. Regrettably, the 1978 sampling grid did not resample the exact site (Station 20) where the highest surface microlayer concentrations were measured in 1977 and where extensive slicks were present and gas bubbles observed. Slicks in this area were again observed during the geology cruise (MacLean, pers. comm.). Although the 1978 grid failed to locate a more active region, it is possible that they exist and, therefore, the area should be resampled on a more closely spaced grid and over a sufficient period of time to ensure favourable weather and sea conditions so that the sampling program can be complemented and guided by visual observations as was done in 1977.

At Buchan Gulf (Fig. 42.6B) an exceedingly high concentration of petroleum residues ( $1200 \mu\text{g L}^{-1}$ ) in the surface microlayer was observed (Station 61). While this might have been the result of contamination from the ship or other source, a high surface concentration was also observed at Station 60. As it is unlikely that there would be contamination at both stations, it would seem reasonable to conclude that there was active seepage somewhere in this region. In the Bylot Island area (Fig. 42.6C), the surface microlayer concentrations were lowest at those stations which had the highest percentages of concentration anomalies. This is contrary to the trend at Scott Inlet and Buchan Gulf and is probably a consequence of surface currents in this area.

#### Concluding Remarks

A preliminary analysis of the data collected during 1978 concerning the concentration of dissolved and dispersed petroleum residues in the water column and surface microlayer in several regions of the Baffin Island shelf provided additional evidence for the natural seepage of petroleum from the seabed. The seepage at Scott Inlet was again detected and two of the seep sites were more closely located. In addition, some evidence was gained for seepage at Buchan Gulf and northeast of Bylot Island. Since conditions were not favourable for the formation of well-defined surface slicks at the time the sampling program was carried out, the surface data and observations were not as informative as they might otherwise have been — such are the realities of oceanographic research in the Arctic.

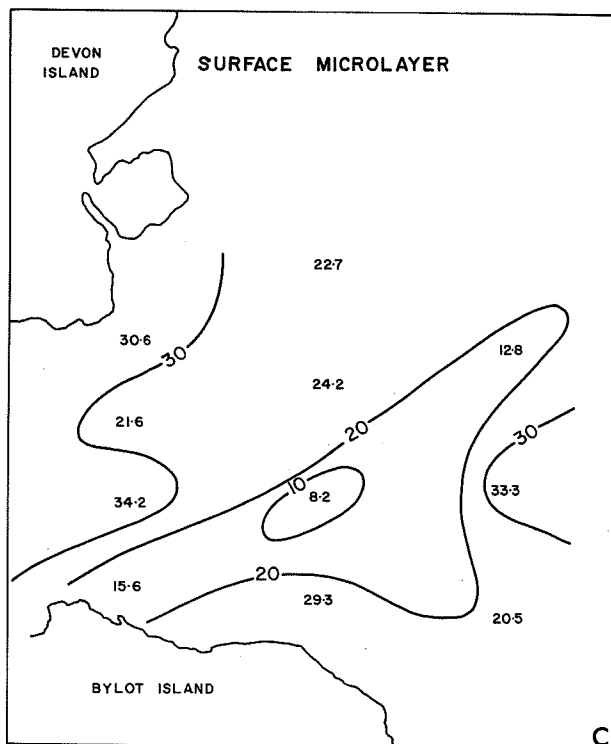
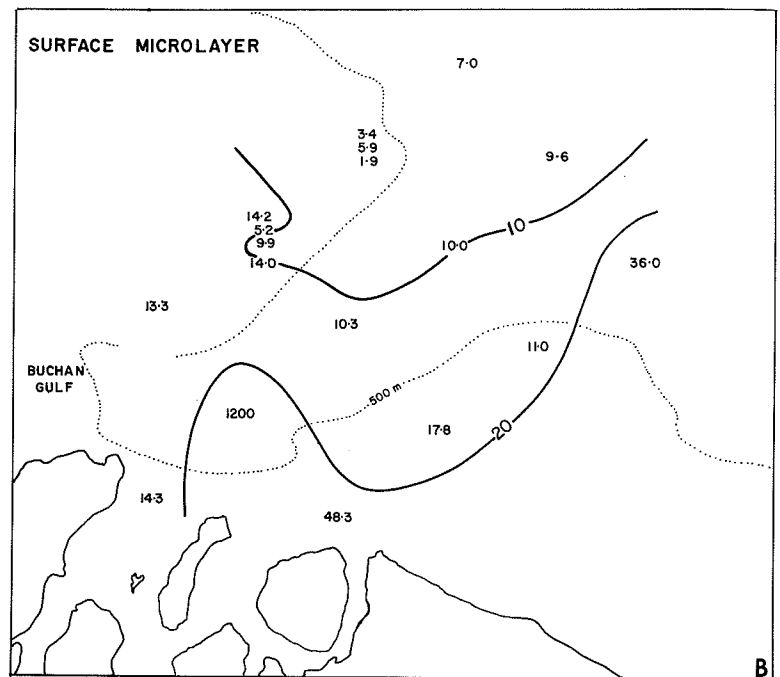
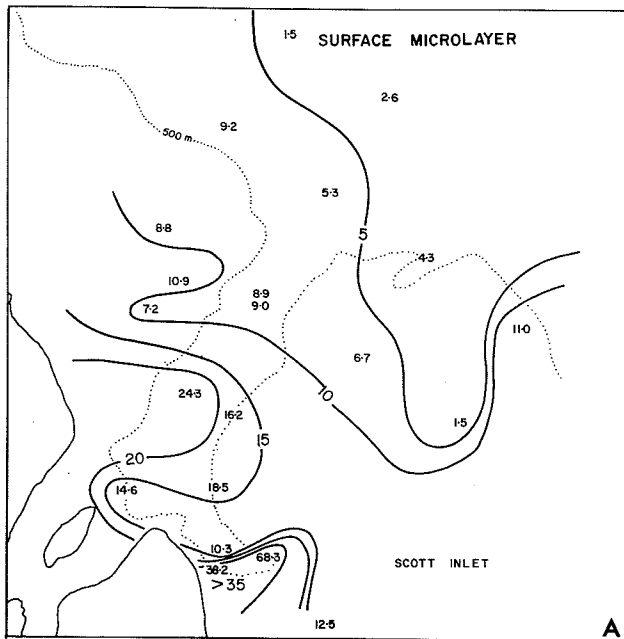


Figure 42.6. Surface microlayer concentrations during 1978 at Scott Inlet (A), Buchan Gulf (B), and Bylot Island (C).

#### Acknowledgments

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