Pisces IV research submersible finds oil on Baffin Shelf

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Abstract

Evidence of natural seepage of petroleum from the seabed off the coast of Baffin Island was first reported in 1976. Chemical analyses of samples from the oil slick on the sea surface, and geological and geophysical studies of the Baffin Shelf supported this interpretation. Liquid oil recovered from the sea floor off Scott Inlet in October, 1985, by the research submersible **Pisces IV**, confirms the existence of natural oil seeps, and indicates that source rocks for petroleum are present in the Baffin Bay region.

Résumé

Des traces de suintement naturel de pétrole provenant du fond de la mer au large de la côte de l'île Baffin ont été signalées pour la première fois en 1976. L'analyse chimique des échantillons de la nappe d'hydrocarbures trouvée à la surface de la mer ainsi que l'étude géologique et géophysique de la plate-forme continentale de Baffin ont appuyé cette interprétation. La récupération du pétrole liquide du fond de la mer au large de l'Inlet Scott en octobre 1985 par le submersible PISCES IV confirme l'existance de suintements naturels de pétrole et indique la présence, aux alentours de la baie de Baffin, de roches mères pétrolifères.

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Introduction

Evidence of natural seepage of petroleum from the seafloor off the northeast coast of Baffin Island was first recognized in 1976 (Loncarevic and Falconer, 1977; Levy, 1977). The evidence consisted of an oil slick on the sea surface and eruption of gas bubbles and oil droplets within the area of the slick. Several detailed studies were subsequently undertaken of the background levels of petroleum residues in the surface slick, water column, and surficial bottom sediments, and of the geology of the area (Levy, 1978, 1979a, b; MacLean, 1978; MacLean and Falconer, 1979; Levy and MacLean, 1981). A comprehensive review of all previous investigations was published by MacLean et al. (1981).

In 1981 the research submersible **Pisces IV**, operating from the support vessel **Pandora II**, was used to investigate the sea bottom northeast of Scott Inlet in the area where seepage appears to be most active. No seepage of oil or gas from the seafloor was found at that time, but a number of patches of white "fuzzy slime", which were interpreted as evidence of bacterial growth associated with emission of hydrocarbons, were observed. With the return of **Pandora** and

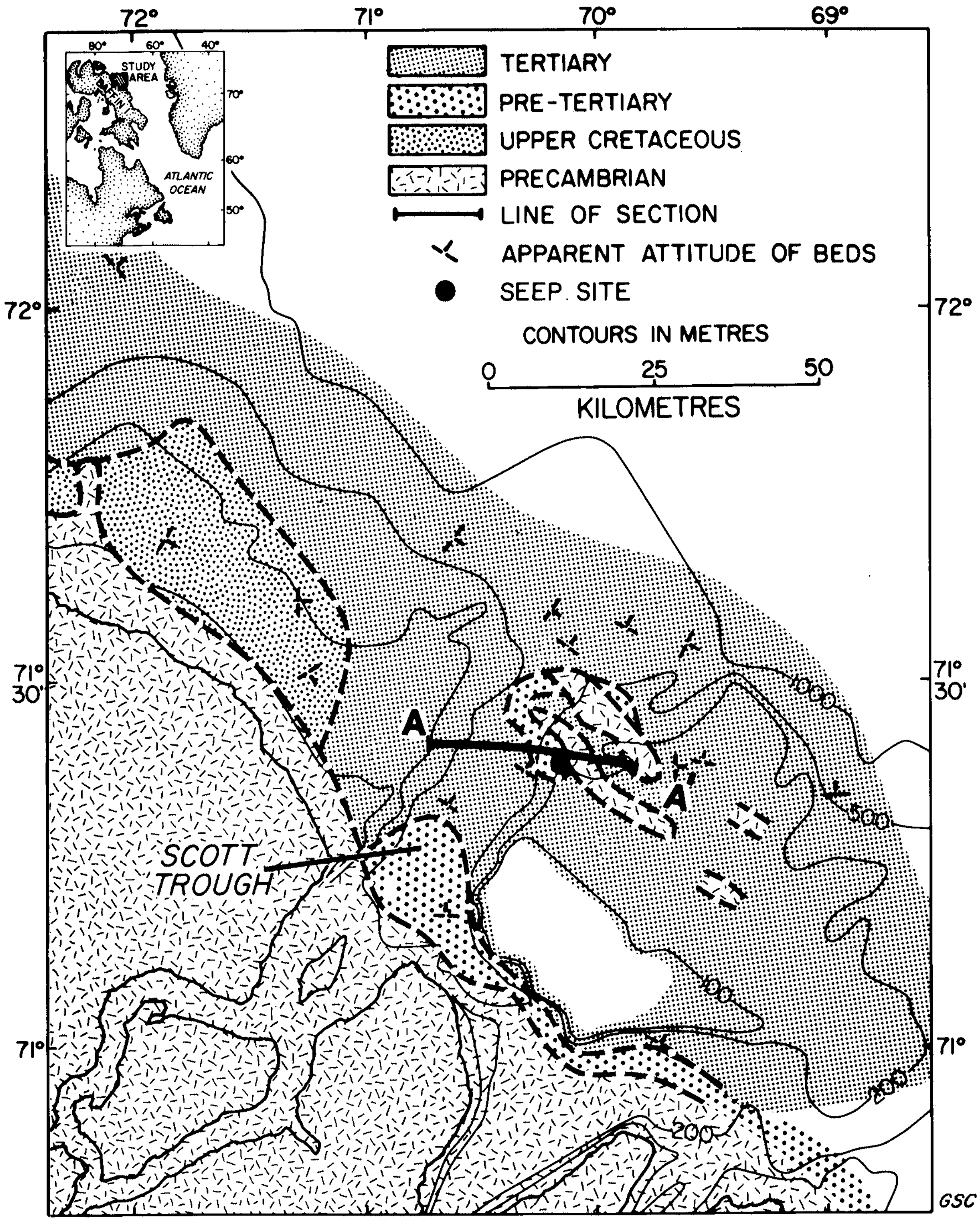

Figure 8.1. Geological map of Baffin Shelf off Scott Inlet (modified after MacLean et al., 1981). Line A-A[1] is location of cross section in Figure 8.2.

Pisces to the east coast of Canada for the 1985 field season, a joint cruise (BIO cruise 85-063) to the seep area was organized by the Chemical Oceanographic Division of the Atlantic Oceanographic Laboratory and the Atlantic Geoscience Centre of the Geological Survey of Canada. This work (September 23 to October 5) was the final phase of the **Pisces** program in Arctic waters for 1985. This paper is a preliminary report of the results from this cruise, with emphasis on geological observations.

Regional geology and morphology of the seep area

The principal features of the submarine geology and morphology of the continental shelf off Scott Inlet, Baffin Island, are indicated in Figure 8.1. Scott Trough is a deep, erosional depression trending northeast across the shelf, with depths as great as 800 m. Oil slicks have been observed on many occasions on the sea surface over Scott Trough and the bank area to the southeast. The most persistent slick is near a basement high on the southeast flank of the outer part of Scott Trough (Fig. 8.1), and seepage in that area appears to originate within sedimentary strata flanking the northwest-southeast trending basement high (Fig. 8.2).

Cruise program

The objectives of the 1985 cruise to the seep area were to obtain samples of the white slime observed previously; to collect samples of the gas emanating from the seafloor in the areas of the slime; to collect samples of dissolved or dispersed seep material from the overlying water column; to measure the rate and direction of ascent of oil released from the seabed; and to carry out additional geological reconnaissance of the area.

The first dives in the seep area were used to emplace gas samplers in the area of white slime. The samplers were in the form of pyramids, constructed from aluminum, with and open bottom and a chamber for trapping gas at the apex. Two of these units were successfully deployed and subsequently recovered. Both traps contained small amounts of methane, ethane and hydrogen sulphide gas.

Samples of the white slime, generally observed as coatings on the surface of pebbles and cobbles on the seafloor, were obtained at several locations with a suction sampler and a robotic arm, operated from the submersible. The predominant slime material has been tentatively identified as filamentous bacteria of the genus **Beggiatoa.** Samples of the bacterial mat were incubated on board ship with radioisotopes to determine the rates of dark CO_2-fixation and heterotrophic potential. Bacterial standing stock will be determined by scanning electron and epifluorescence microscopy of fixed samples.

As the final procedure of two dives, samples of dyed diesel fuel were released from the seafloor to measure the rate and direction of ascent of oil droplets. From a release depth of 400 m, the oil reached the surface in slightly over one hour. One sample came to the surface about 400 m south of the point of release; the second came up almost directly over the release point. Although the properties of the diesel fuel no doubt differ from those of the natural oil, and recognizing that water currents in the area vary in direction and strength, this simple experiment nonetheless indicates that the slicks observed on the sea surface at Scott Trough lie fairly close to the location from which the material escapes from the seafloor.

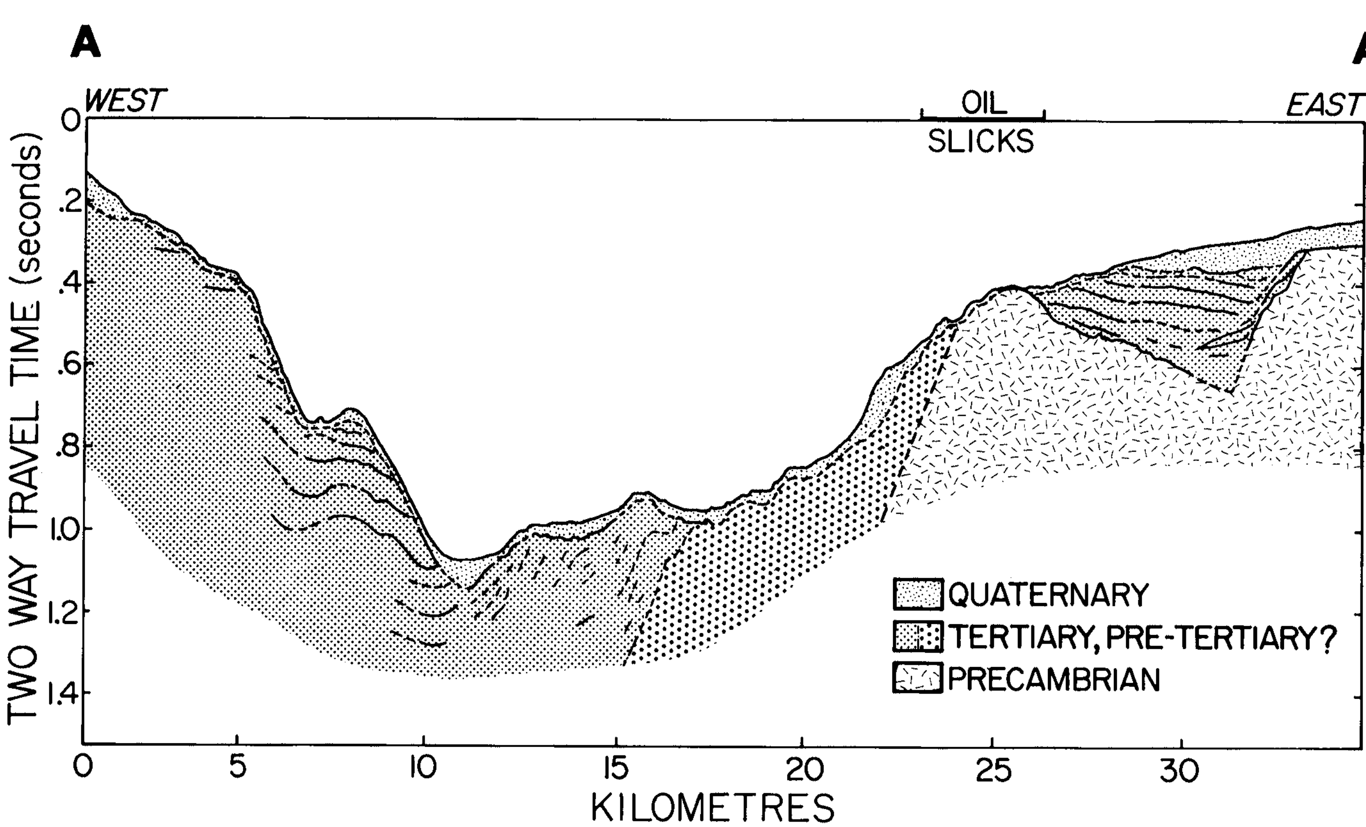

Figure 8.2. *Geological cross section across the outer part of Scott Trough showing the sedimentary sequences adjoining the basement high (modified after MacLean et al., 1981). Extent of oil slick along the line at the time of the survey (September 24, 1978) is indicated.*

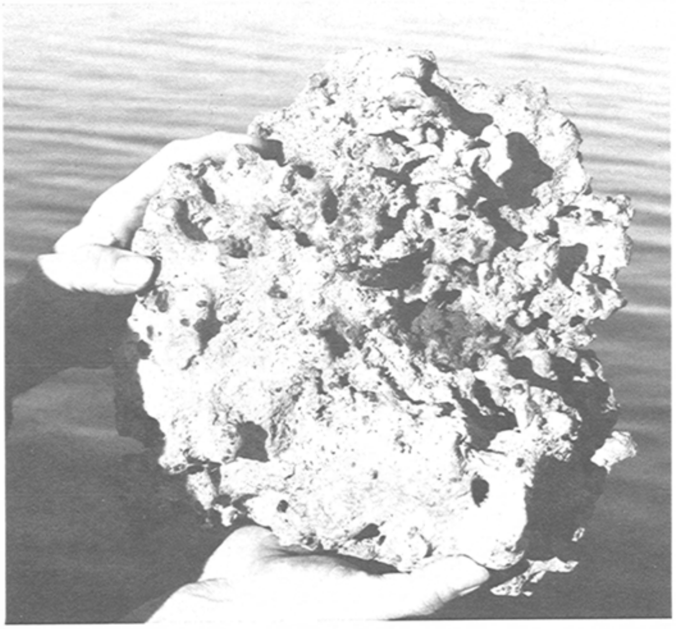

Figure 8.3. *Photograph of sample of crust formed around fissure in the seafloor (by R. Belanger).*

Sampling of the water column was carried out during periods when the **Pisces** was not deployed and the **Pandora** could remain on station for periods of several hours (usually overnight). The in situ sampler pumps seawater through a filter and a cartridge containing XAD-2 resin to extract particulate and dissolved organic compounds. The samples collected by this device are being analyzed.

Several dives were devoted primarily to geological reconnaissance of the seep area, with a principal objective of recovering samples of bedrock. Two dives were carried out on the southeast wall of Scott Trough, southwest of the seep area. An escarpment with outcropping bedrock was encountered approximately 20 km southwest of the seep site, at a depth of about 100 m. However, because of a strong current at the time of the dive it was not possible to obtain a sample from this location.

The final dive of the cruise was a traverse of about 3 km, south from Precambrian basement across the main seep area (Fig. 8.1). Extensive esposures of bedrock, strewn with numerous boulders, were observed in the area mapped as Precambrian by MacLean et al. (1981). The surfaces of the outcrops were smooth and rounded, presumably due to the action of glacial ice. The contact of the Precambrian with overlying "Pre-Tertiary" strata was covered with overburden and was not directly observed, but the transition to these younger rocks was expressed by a general decrease in the irregularity of the seafloor. The bottom deposits along the survey track consist of mud, gravel and boulders. Because the boulders are concentrated in low ridges, and linear areas of the seafloor are devoid of gravel, it is considered that the bottom morphology and sediment distribution have been modified by the effects of iceberg scouring. The water depth in this area ranges from 360 to 430 m.

Shortly after reaching the Pre-Tertiary zone (Fig. 8.1) occasional small patches of filamentous bacteria were observed. The area of earlier sampling dives on the seep site was recognized by the presence of **Pisces IV** skid marks in the bottom sediment. A short distance to the south of this area, it was noted that the surface layer of sediments in some of the white slime patches was hardened into a weakly cemented crust, and a sample was collected with the robotic arm of the **Pisces**. Continuing to the south, after passing over a low ridge on the seafloor, several prominent patches of bacteria were observed, with obvious crusts in two of the patches. A general impression of the setting of this concentration of bacterial mats was that they lie within a roughly circular, saucer-like depression, estimated to be about 30 m in diameter and 2 to 3 m deep. The two areas of crust appeared to be undermined and partially collapsed. Closer inspection revealed narrow fissures extending into the seafloor at these locations, and probing with the robotic arm indicated that the "crust" around the fissures was very hard. Two fragments of the crust were secured with the robotic arm and placed in the storage tray; one of these fragments (Fig. 8.3) exuded droplets of oil that floated upward. When this specimen was brought to the surface it was placed on a sheet of plastic, and several cubic centimeters of dark brown, medium viscosity oil dripped from it and were collected.

Further sampling and inspection of the fissures was precluded because the **Pisces** battery power was nearly exhausted and the dive was terminated. A follow-up dive was planned for the next day – the final day of the cruise, but it was cancelled because of bad weather.

Discussion of results

The discovery of oil in the indurated crust within an area of white, "fuzzy slime" confirms that these bacterial mats are related to the seepage of petroleum from the seafloor. As mentioned, laboratory analyses are in progress on the bacteria, gas, and oil samples recovered during this cruise.

The specimen of crust that has yielded oil appears to be composed of indurated bottom sediment, since it consists of pebbles of igneous rock cemented in a fine matrix. The matrix reacts readily with acid, and therefore has an appreciable carbonate content. A carbonate cement has been reported for crusty material collected at the site of a gas seep in the North Sea (Hovland et al., 1985). The surface of the specimen has a corroded aspect; the pits may express both dissolution of the matrix material and the imprints of igneous pebbles. The oil that drained from this rock was trapped in the downward concave pits on its under surface; the "crust" itself is not the source rock for the oil. The fissures in the seafloor within the patches of indurated sediment are assumed to be the routes of egress of the oil from a deeper source. No flow of oil from these fissures was noted during the brief time that they were under observation. It is anticipated that analyses of the oil may provide some indication of its geological age, and suggest whether it was derived from Tertiary or Mesozoic strata, or from older, Paleozoic rocks.

The dimensions of the saucer-like depression in which the crust, fissures and oil were found are within the size ranges reported for "pock marks", which are circular depressions on the seafloor believed to be due to flowage of gas from the underlying sediments (e.g. Josenhans et al., 1978; Hovland, 1981; Hovland et al., 1985; Nelson and Healy, 1984). The presence of pock marks on the seafloor could be documented by side-scan sonar surveys, and these should be included in future investigations of this area. Future studies should also include additional submersible work directed at locating the active fissure(s) in the seafloor. Active fissures may be the sites of enhanced biological activity, as reported from the Gulf of Mexico, the North Sea and Santa Barbara Channel (Kennicutt II et al., 1985; Hovland et al., 1985; Spies and DesMarais, 1983).

Acknowledgments

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