Plutonium in the environment at Thule, Greenland, from sampling in 2003

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INTRODUCTION

On January 21, 1968, an American B52 bomber carrying four nuclear weapons crashed on the sea ice 15 km west of the American air base at Pituffik, Thule Air Base. Both the aircraft and the weapons disintegrated on impact. The wreckage and the remains of the weapons were cleaned up after the accident. About 6 kg plutonium was dispersed at the accident according to American information. The plutonium distributed on the sea ice, about 3 kg, was removed. After the clean up operation and the melting of the ice the following summer, finely dispersed plutonium remained in the marine environment, primarily on the seabed under the point of impact. Since 1968 several sampling campaigns have been carried out resulting in estimates of the seabed inventory of plutonium (^{239}Pu and ^{240}Pu) of about 1.4 TBq corresponding to about 0.5 kg (Dahlgaard, 2001). However, a re-evaluation focusing on hot particles in the sediments indicates that the inventory could be significantly underestimated (Eriksson, 2002). The present investigation of the plutonium contamination at Thule is based on a sampling campaign carried out in August 2003. The scope of this investigation includes an estimate of the inventory of plutonium in marine sediments with special focus on radioactive particles, a mapping of bottom sediments in the most contaminated area based on acoustic sonar, an investigation of the transfer of plutonium to marine biota, and an investigation of plutonium in the terrestrial environment. Bylot Sound and surrounding areas are shown in Fig. 1. This work is supported by the Danish Environmental Protection Agency.

SAMPLING

The sampling was carried out during 14-27 August 2003 from the research vessel FS Adolf Jensen. The expedition was headed by research specialist Henning Dahlgaard; additional participants were laboratory technician Svend K. Olsen from Risø National Laboratory, scientist Mats Eriksson from Institute for Transuranium Elements in Karlsruhe, senior geologist Jørn Bo Jensen and senior engineer Peter Trøst Jørgensen both from the Geological Survey of Denmark and Greenland (GEUS), and the crew of Adolf Jensen headed by skipper Flemming Heinrich.

Sediment mapping

The sediment mapping was carried out by GEUS from FS Adolf Jensen and included recording of bathymetri and characterisation of the seabed. Bathymetri, sediment profiles and surface seabed mosaic were mapped by chirp and side-scan sonar. Classification of sediments included identification of soft and hard bottoms and surface irregularities due to large objects and iceberg scour. The bathymetri of Bylot Sound is characterised by a north-south going ridge with water depths less than 100 m and a southern channel partitioned in a northern and southern basin with water depths of up to 250 m. The seismic grid used for the sediment mapping is shown in Fig. 2.

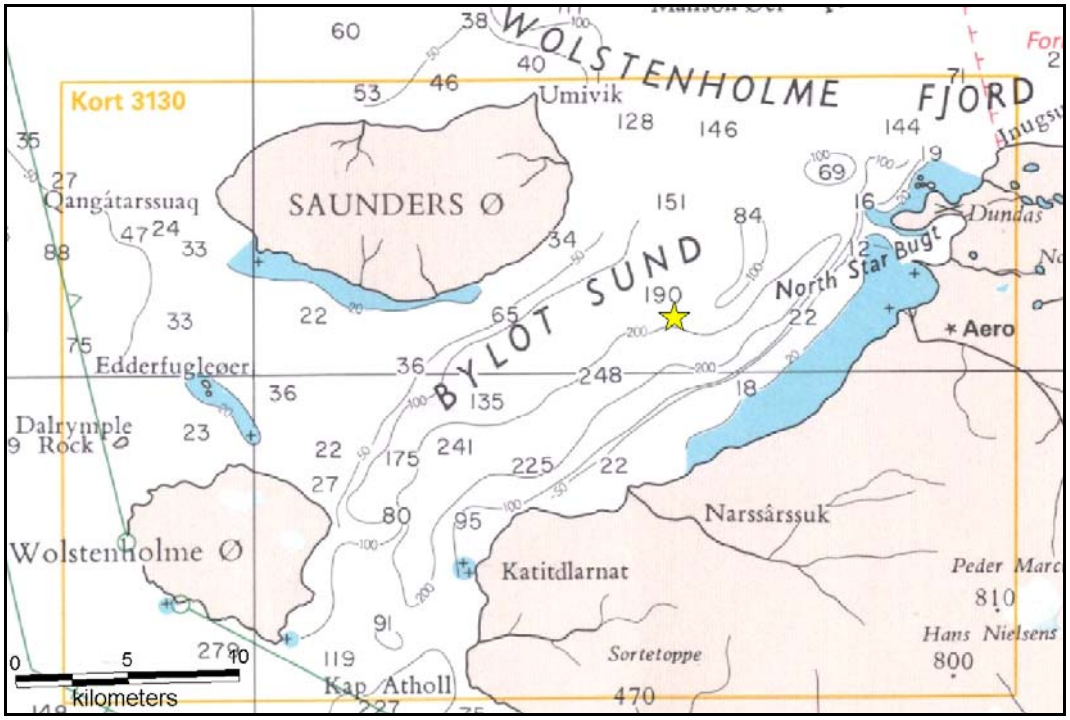

Figure 1. Map of Bylot Sound showing the site of the aircraft accident (star).

Sediments

Sediment samples were collected from 31 locations. Ten of these locations are stations from which sediment samples were obtained successfully at previous campaigns. The 21 new locations were selected based on the sediment mapping carried out by GEUS. The high success rate of this sampling demonstrates that the information obtained from the sediment mapping was extremely valuable considering the considerable problems from previous sampling campaigns to obtain useful sediment cores due to hard bottom conditions.

Biota

Benthic biota samples were collected by pulling a Sigsbee trawl along four 500 m transects. Three transects were in the contaminated area in Bylot Sound at 200-250 m depth, and the fourth transect north of Saunders Island in Wolstenholme Fjord at 135 m depth. Samples from a seal shot in Bylot Sound were collected of flesh and liver.

Seawater

Seawater samples were collected from the water column at three depths: 5 m under the surface, and 35 m and 15 m above the seabed. The samples were collected from four locations: one outside the contaminated area south of Wolstenholme Island serving as a background reference, one from north of Saunders Island as a low-level station, and two from near the accident site. The samples were filtered (Millipore 0.45 µm). Expectations were to find accident-related plutonium in the deep water near the accident site, but not in surface water or at the two other locations.

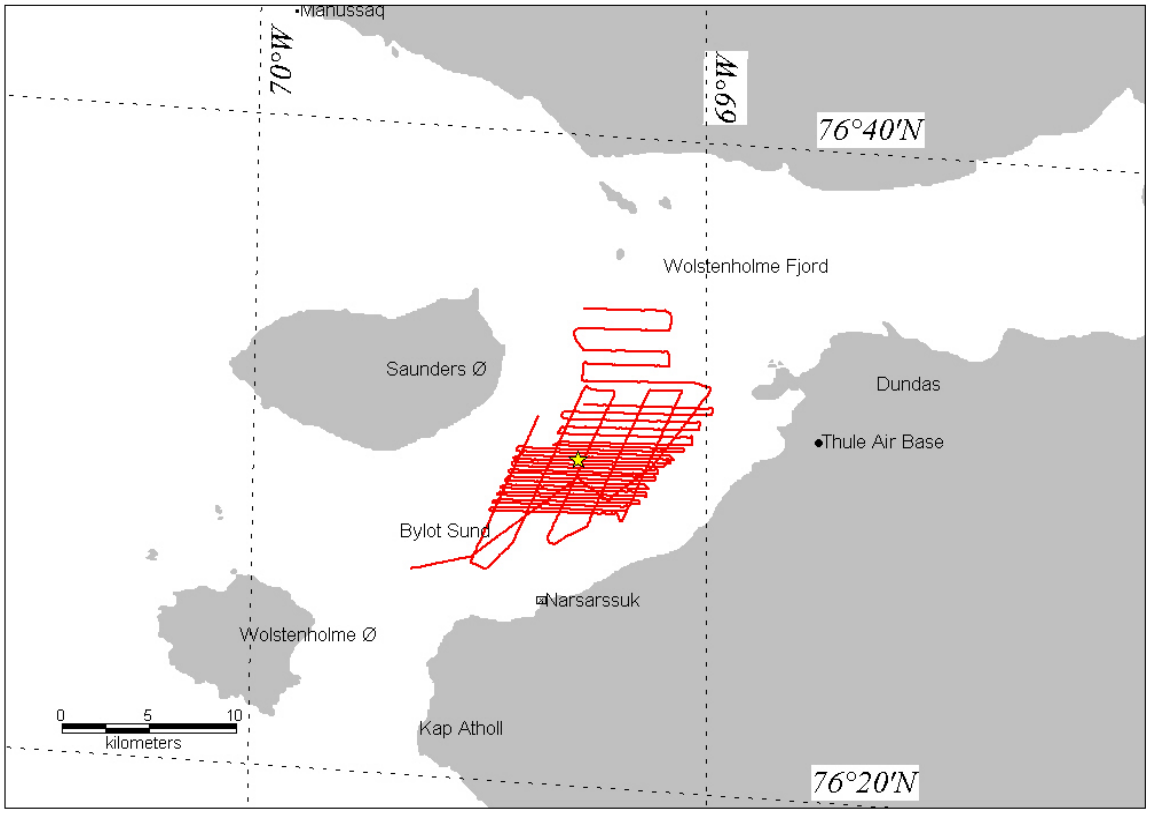

Figure 2. Seismic grid for the sediment mapping in the central part of Bylot Sound.

Seaweed: Twelve samples of seaweed were collected from coastlines at Narssarssuk south of the accident site, at Dundas Mountain, at the north coast of Wolstenholme Island and at the Eider Islands.

Soil: Soil samples were collected in the Narssarssuk area. Within small areas of one square metre 3 separate soil profiles were collected from eight locations, i.e. 24 profiles in total. Elevated levels of alpha radioactivity were found in the Narssarssuk area in spring 1968, but at that time it was not determined if this radioactivity was caused by local naturally occurring radioactivity, i.e. thorium or uranium isotopes, or due to uranium or plutonium from the aircraft accident.

RESULTS

Seawater: Results on plutonium in seawater are given in Fig. 3, which shows concentrations of 10 mBq ^{239,240}Pu m^{-3} and below at the reference site south west of Bylot Sound. Concentrations in Bylot Sound are significantly higher in near bottom waters, up to 40 mBq m^{-3} and mainly associated with particles. However, the samples of surface water in Bylot Sound show little or no influence from accident plutonium. Accident plutonium was identified by an isotopic ratio between ^{238}Pu and ^{239,240}Pu lower than that of fallout plutonium. The location in Wolstenholme Fjord north of Saunders Island is influenced by accident plutonium from Bylot Sound with concentrations higher throughout the water column than at the reference site and showing high fractions of plutonium on particles. The seawater data illustrate that plutonium is remobilised from the seabed in Bylot Sound on particles and transported to the north out of Wolstenholme Fjord into Baffin Bay.

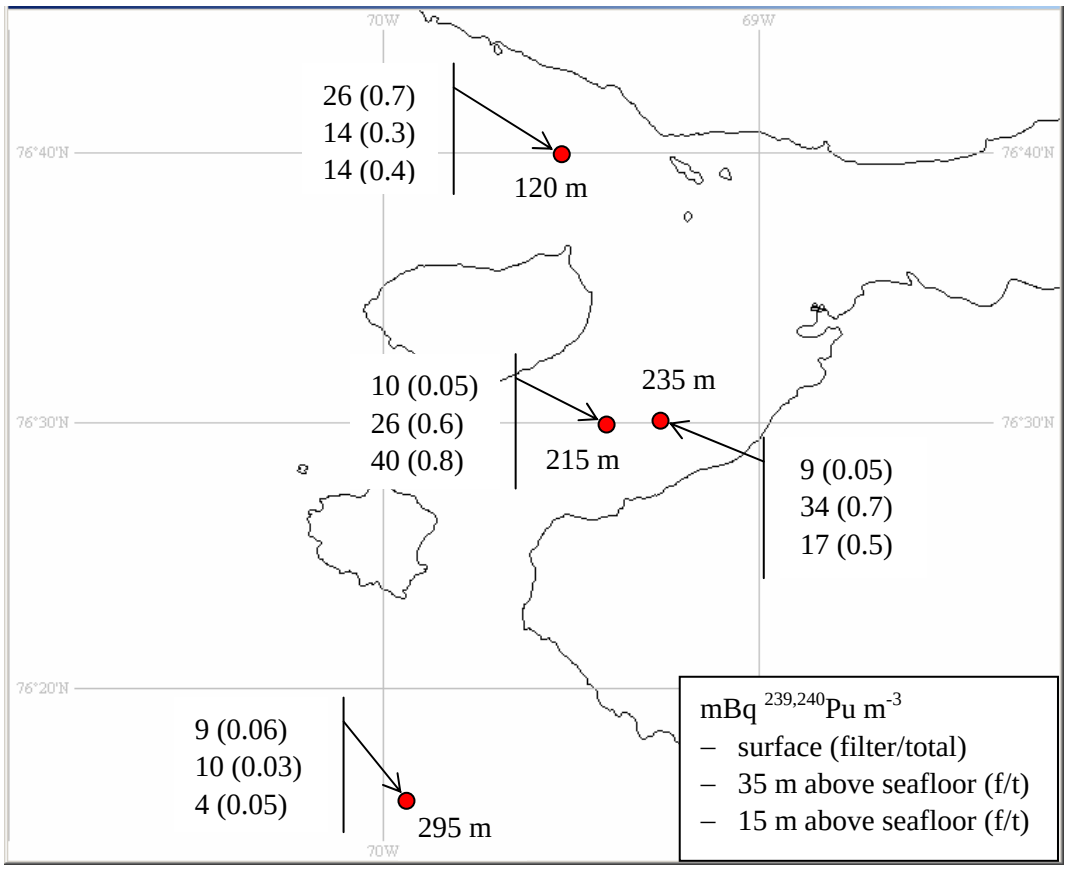

Figure 3. Plutonium in seawater at four locations sampled during 19-21 August 2003. Samples were taken at three depths for each location. Concentrations are given in mBq ^{239,240}Pu m^{-3}; ratios of Pu on particulate to total are given in brackets.

Seaweed: Plutonium concentrations in seaweed were found in the range 0.1-0.4 Bq ^{239,240}Pu kg^{-1} dw. The concentrations at Eider and Wolstenholme Islands and at Dundas were in the range 0.1-0.2 Bq kg^{-1} dw while concentrations at Narssarssuk were consistently higher, 0.2-0.4 Bq kg^{-1} dw. This shows that accident plutonium is transported to seaweed in surface waters of Bylot Sound.

Soil: Plutonium in soil at 8 locations around Narssarssuk showed depth-integrated concentrations from 20 to 900 Bq m^{-2}. The lower range of 20-50 Bq m^{-2} found at one location represents mainly fallout from atmospheric nuclear weapons tests, whereas the higher values are due to accident plutonium. Accident plutonium is inhomogeneously distributed in the soil samples and clearly associated with particles. Single particles were identified in the soil with activities up to about 30 Bq ^{239,240}Pu.

REFERENCES

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