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Proceedings of the Fifth Annual NEA-Seabed Working Group Meeting Bristol, England March 3 - 5, 1980

MASTER

D. Richard Anderson, Editor

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BRISTOL, ENGLAND
MARCH 3-5, 1980

D. Richard Anderson, Editor
Sandia National Laboratories
Albuquerque, NM 87185

NOTICE

This report is an account of work sponsored by the Governments of the United States, the United Kingdom, France, Canada, Japan, and the Netherlands in the framework of the OECD/NEA Seabed Working Group. Neither OECD/NEA nor the Governments of the United Kingdom, France, Canada, Japan, or the Netherlands, nor any of their employees, nor any of their contractors, subcontractors, or their employees, assume any legal liability for the contents hereof.

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PROCEEDINGS OF THE FIFTH ANNUAL
NEA-SEABED WORKING GROUP MEETING
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PART I: SUMMARY OF NATIONAL POLICIES AND POSITIONS

Introductory Remarks

D. Glenn Boyer, Chairman
Seabed Working Group Meeting
Bristol, England, March 3, 1980

To Dr. Frank Feates and Dr. Keith Johnson:

On behalf of the participants I wish to express our thanks to our United Kingdom hosts; to Dr. Frank Feates; and to the Department of the Environment staff, Dr. Allan Duncan, Mr. C. M. Basford, and the others, who have spent so much time and effort to make the detailed arrangements for this, the Fifth Annual Seabed Working Group Meeting, thank you.

My welcome to those of you who are participating in the seabed workshops for the first time, either as designated representatives or as observers. I trust you will take the opportunity to participate fully and contribute to the informality of the discussions. And, of course, welcome to those of you who have added measurably to the results of these workshops over the years.

We welcome the Netherlands representatives who have officially joined the NEA/Seabed Working Group since our last meeting, and we are looking forward to their full participation.

It is nice to have Dr. F. Gera, of the NEA/OECD, and Dr. Rip Anderson of Sandia Labs, who act as secretariat and task group coordinator to the group, respectively, to provide the coordination and exchange of information with other members of the group and with the NEA Radioactive Waste Management Committee.

I wish to acknowledge for the record the letter to me dated April 17, 1979, from Dr. Wallauscheck, Head, Radiation Protection and Waste Management Division, confirming the recommendations of the NEA Radioactive Waste Management Committee (RWMC) that the Seabed Working Group be part of the NEA program as a "restricted group," formed by a limited number of countries having an active program of research and development in the field of seabed disposal of radioactive waste and coordinating work at a national level in the frame of the group. One of the consequences of the NEA restricted group status is that the Seabed Working Group programs are to be agreed to among the participants as a whole, rather than by the NEA-RWMC, recognizing the needs of the Group to sponsor task groups and specialists' meetings organized on an ad hoc basis to deal with specific technical problems and to select a scientific secretary from the Group.

It is a pleasure to continue the Seabed Working Group affiliation under the auspices of the NEA/OECD and I am looking forward to a long period of continued cooperation.

The role and objectives of the group as outlined at the Second Annual Seabed Working Group Meeting at Washington, DC, in March 1977, are being met. They are:

- To provide a forum for discussion, assessment of progress and planning of future efforts
- To coordinate cooperative research vessel cruises and experiments
- To share facilities and test equipment
- To exchange information
- To maintain cognizance of international policy issues.

Based on previous Seabed Working Group and task group meetings, this year's meetings have these major objectives:

- To coordinate a total system approach to assure data are being acquired that can be used as parameters in predictive models of seabed disposal concepts
- To continue the multinational coordination of research and development in the specific task group areas
- To review the status and significant changes in national seabed disposal programs.

By the end of the workshop it is anticipated we will have a basis for:

- A summary report to NEA-RWMC on the SWG activities
- Identification of specific areas of continued task group coordination.
- An update of specific task group members.
- Identification of continued methods for multinational participation.

Thank you. We will now proceed to the national reports on our agenda.

CANADA

Participation in marine geological programs related to the environmental feasibility of disposing of wastes in the deep sea began in 1978. Initial activities were limited to information exchange and participation in a US cruise to monitor the effect of test mining of manganese nodules in the Pacific Ocean. In 1979 a more direct involvement in research was initiated by geoscientists located at the Atlantic Geoscience Centre, Bedford Institute of Oceanography, by proposing a research project to be funded by the Department of Energy, Mines, and Resources through the Geological Survey of Canada. This project has now been approved with field and laboratory investigations already in progress and with related or associated projects due to begin in 1980.

In this report, a detailed outline of the deep-sea geological program is presented as well as preliminary progress reports on a site investigation in the northern Nares Abyssal Plain conducted in January 1980. Plans for further deep-sea site investigations are also presented.

Program Outline

Environmental Geology of the Deep Ocean

The specific project designed to study the environmental geology of the deep-ocean basins was initiated through the Atlantic Geoscience Centre, a division of the Geological Survey of Canada. The general objectives of this project are:

- To investigate the capacity of the deep-ocean sediments to maintain normal processes and environmental quality under conditions of stress imposed by waste disposal practices and resource exploration and exploitation

- To participate in the Seabed Working Group of NEA in order to maintain awareness of progress in feasibility studies for disposal of high-level nuclear waste in the seabed.

Under these general objectives, four specific research tasks were identified for investigation.

<u>Task I - Seabed Characteristics and Surficial Geology in Deep Ocean Plains</u> -- Investigations of potential waste disposal areas will be conducted in selected abyssal deeps with relatively smooth flat surfaces and with accumulated sediments being deposited in consistent layers having an accumulated thickness of at least 200 m. Selected sites for detailed investigation will be over areas of 10^2 to 10^3 km^2 in water depths ranging from 3 to 6 km. The resolution of the survey should be sufficient to recognize slopes of 1° and anomalous relief features as small as 100 m horizontal distance. Surficial and near-surface geological surveys will identify sedimentary facies and shallow stratigraphy and will be based mainly on acoustic methods. Ultimately, technological developments may allow vertical resolution of layered sediments as thin as 2 m, with subsurface penetration depths of 200 m. Geochronology and paleoecology of the uppermost (~20 m) stratigraphic layers of sediment will be used to accurately date sediments and to identify any changes in the oceanic environment of deposition. Over a 5-yr period, scientific and technological developments will be required to meet the objectives of this task. Bathymetric surveys will require refinements in narrow beam sounding systems presently available. Shallow seismic systems will be modified initially using a hydrophone array and tuned air gun system to give optimum stratigraphic resolution of 2 m, with depth penetration to 200 m using a frequency envelope of 100 to 500 Hz and an air gun short pulse of 20 ms. Future development of a deep-towed high-precision shallow seismic and side scan system is under consideration. Accurate dating of marine sediments will be attempted using ^{210}Pb for most recent sediments and thorium/protactinium methods for older sediments. Stratigraphic and paleoceanographic conditions will be interpreted by analyses of fish skeletal remains and microfossils.

Task II - Physical Properties of Deep-Sea Sediments -- From a combination of remote sensing surveys, in-situ measurements and bottom sampling of deep-sea sediment geotechnical properties, permeability, and cohesive nature will be evaluated. Geotechnical properties will, at first, be approximated by using conventional methods of box coring and piston coring, with subsequent engineering testing being carried out on board ship or in land-based laboratories. Subsequently, certain measures such as shear strength, compressibility, and pore pressure may be carried out using in-situ probes, possibly in combination with heat flow probes and pore water sampling probes. Conventional heat flow probes will be used for direct measurement of thermal gradient and thermal conductivity with adaptation for determining fluid migration within the uppermost unconsolidated sediments. Acoustic signal processing from shallow seismic systems or deep tow systems offer some potential for indirectly determining some physical properties of surficial and near-surface sediments. Developments in this technological field are presently underway for shelf-depth systems by Huntec Canada Limited.

Task III - Geochemical Properties of Deep-Sea Sediments -- Evaluation of the chemical capacity of deep-sea sediments to form an effective barrier to the migration of fission products and transuranic nuclides will depend on the phase equilibrium between sediment pore water and the particulate solids, and on the advective and diffusive mechanisms of migration within the sedimentary column. The essential research in this area will be focused on determining the chemical nature of pore waters, the chemical state of the contained elements, and the crystal chemical characteristics of the marine clays. Models of chemical diffusion based on natural environmental analyses will be tested by experimentation with laboratory test materials under conditions which simulate deep sea environments.

Initially pore water extractions and analyses will be carried out under controlled temperature and nitrogen atmospheres from samples obtained by conventional box and piston coring. In the latter stages of the project, it is hoped that satisfactory in-situ harpoon samplers will be available for collecting pore water samples. Similarly, in-situ electrochemical probes for the measurement of pH, pS, and pE are planned for use in the latter stages of the project. Modifications of existing multiprobe and water sampling systems will be used for measurement of near-bottom water qualities such as conductivity, temperature, turbidity, and sampling for laboratory analyses of trace metals, nutrients, and suspended particulate matter.

Task IV - Sediment Dynamics of the Deep Ocean -- Movement of surficial sediments under the influence of strong bottom currents will be evaluated in selected sites by both short- and long-term measurements of bottom currents and sediment dynamics. Initially, seabed sediment stability will be evaluated by using conventional bottom photography in combination with sampling devices or alone as a bottom survey system. Extended development of an existing shelf sediment dynamics monitoring system is planned which will measure bottom conditions, including time-lapse photography, current metering, and turbidity. Conventional near-bottom current meter arrays will also be deployed for long-term monitoring in selected areas.

Project Participants

D. E. Buckley, Geochemistry and Sedimentology--Project Leader
R. E. Cranston, Geochemistry
G. Vilks, Paleoecology, Paleoceanography
M. A. Rashid, Organic Geochemistry
G. Winters, Geochemistry
S. Blasco, Geophysics, Seismics
D. Heffler, Engineering, Geophysics
A. Judge, Geophysics, Heat Flow
J. Smith, Geochronology

Project Schedule and Estimated Resources*

1979-80	Item	$ K Cost
Field (Jul-Aug 1979)	Hudson cruise to shelf and slope East Newfoundland and Labrador to test sampling and shipboard analyses system	40.0
Field	Dawson cruise to northern Nares Abyssal Plain, January 1980 (in conjunction with LADLE experiment)	35.0
Task I (geology)	Bathymetry - conventional sounding and air gun survey, using 10 to 40 in.^{3} air gun	
Task II (geo-chemistry)	Geochemical sampling - box coring. Collection and analysis of pore water and sediments for major and trace constituents; evaluation of sediment (near surface) redox conditions	71.0
	Total	146.0

1980-81	Item	$ K Cost
Field	Hudson cruise to Sohm Abyssal Plain, June 1980	178.0
Task I (geology)	Bathymetry - conventional 12 kHz sounder	
	Stratigraphy - air gun model 600B, tuned array	
	- ^{210}Pb dating of surficial sediments from box core	
	- paleoecology study of box core samples	2.0
Task II (physical)	Heat flow probe - on loan from Earth Physics Branch	1.0
	Geotechnical properties measured on box core samples on board ship and in lab	10.0
Task III (geo-chemistry)	Box coring and piston coring. Collection and analysis of pore water and sediments for major and trace constituents; multiprobe (CTD, turbidity, water sampling)	162.0
Task IV (dynamics)	Bottom photography of survey area, using existing BIO cameras	1.0
	Total	354.0

*Financial estimates exist only for 1981-82 and beyond. For 1979-80 and 1980-81, the costs are actual or approved budgets.

1981 82	Item	$ K Cost
	This period used to complete analyses of existing samples and to develop methods and technology for last 2 yr of project	130.0
Task I (geology)	Stratigraphy-development/rental of tuned air gun array and deep tow system	100.0
Task II	Development of heat flow/thermal conductivity system for the deep ocean (Earth Physics Branch)	12.0
	Development of geotechnical equipment for in-situ analyses	20.0
Task III (geo-chemistry)	Development of in-situ pore water sampler with electrochemical probes	50.0
Task IV (dynamics)	Development of deep ocean sediment dynamics monitoring. Development of deep side scan	100.0
	Total	442.0

1982-83		
Field	Cruise to North Atlantic	200.0
Task I (geology)	Bathymetry - narrow beam transducer	10.0
	Stratigraphy - tuned air gun array	10.0
	- deep tow seismic survey	110.0
	- Th/Pa dating	10.0
	- paleoecology and paleontology	5.0
Task II (physics)	In-situ heat flow/thermal conductivity measurements	3.0
	In-situ and laboratory geotechnical measurements	10.0
	Acoustic analyses of sediments	13.0
Task III (geo-chemistry)	Giant piston coring (loan from Woods Hole/URI). Collection and analysis of pore water and sediments for major and trace constituents	50.0
	In-situ pore water collection with electro-chemical analyses (pH, pS, pE probes)	90.0
	Diffusion experiments by injecting sediment core subsamples with tracers	110.0

1982-83 (cont)	Item		$ K Cost
Task IV	Deep sediment dynamics survey (photography, dynamics) of currents, turbidity		15.0
	Deep side scan survey		15.0
	Current meter array		5.0
		Total	656.0
1983-84			
Field	Cruise to North Atlantic		250.0
Task I (geology)	Bathymetry - narrow beam transducer		50.0
	Stratigraphy - multichannel seismic system or deep tow seismic system		250.0
	- dating		40.0
	- paleontology		10.0
Task II (physics)	In-situ heat flow multiprobe system to measure thermal properties and retrieve pore waters		50.0
	In-situ geotechnical probe		50.0
Task III chemistry)	Giant piston coring		105.0
	Collection and analysis of pore water and sediment		100.0
	In-situ pore water collection with electro-chemical analyses		160.0
	Diffusion experiments by injecting sediment core subsamples with radioactive tracers		30.0
Task IV (dynamics)	Long-term sediment dynamics monitoring development		10.0
	Deep side scan		40.0
	Current meter array (long-term)		70.0
		Total	$1 215.0
		Project Total	$2 813.0

Associated Projects

Feasibility Studies of Disposal of High-Level Nuclear Waste in the Deep Sea -- As part of the Canadian Geological Disposal of Radioactive Waste Program, Atomic Energy of Canada Limited provides funds to certain agencies to carry out research on various aspects of the problems of containment of waste. This corporation also assists in the coordination of research and dissemination of information. In association with the Geological Survey of Canada project described above, a proposed research task has been submitted which places particular emphasis on the chemical, geochemical and mineralogical aspects of the problem of determining the effectiveness of natural marine sediments as a barrier to movement of radioactive wastes. The objectives of this research would be:

- To quantitatively estimate the distribution constants for several trace elements between natural pore waters and deep sea sediments
- To estimate diffusion rates for several cations and anions which can be attributed to chemical potential and thermal fluxes
- To evaluate crystal chemical characteristics of clay minerals found at selected deep sea sites, with special emphasis on their adsorption and chemical exchange properties and thermal stability
- To evaluate changes in sediment properties with age and depositional environment.

Project Participants

D. E. Buckley	Geochemistry, Sedimentology (Principal Investigator)
R. E. Cranston	Geochemistry
G. Vilks	Paleoecology, Paleoceanography

Funding

1980-81: $29 500 (estimated). Confirmation of funding expected by April 1, 1980.

The Fundamental Chemical Dynamics Implicit in the Seabed Disposal Program -- This program is to determine the effect of high temperatures and pressures on the mobility of anions and cations normally associated with clay minerals in deep marine sediments.

This project, to be undertaken at Dalhousie University, Halifax, Nova Scotia, is supported by a research agreement with the Federal Department of Energy, Mines, and Resources. The intended research will study the effects of high temperature and pressure on the reactions between sea water and marine red clays, over the temperature range 25° to 500°C and at pressures to 500 atm. Both oxidizing and reducing environments will be examined. At the higher temperatures, sea water acts as an acid, and its composition changes radically as a result of precipitation of magnesium oxysulfate and of anhydrite. These precipitations should affect the physical state as well as the ion exchange properties of the clays.

Project Participants

R. C. Cooks	Chemical Oceanography (Principal Investigator)
P. J. Wangerskey	Chemical Oceanography
D. J. Plasse	Chemical Oceanography

Funding

1980-81	\$16 000 (confirmed)
1981-82	\$26 000 (estimated)

Progress in 1979

Only preliminary investigations were undertaken during the past year to establish methods of sampling the sea bottom, processing these samples on board ship for immediate geochemical measurements, and establishing laboratory methods for detecting and quantitatively measuring trace elements in the pore water samples and associated sediments. Taking advantage of a cruise by the CSS Hudson to the shelf and slope off eastern Newfoundland and Labrador, the following list summarizes the activities and results which are discussed in more detail in the Rock and Sediments Task Group report:

- Box and piston core samples were recovered from shelf and slope depths, to the 3.2 km depth.
- Electrochemical measures under cold N_2 atmospheres clearly identified oxidizing and reducing conditions in several different environments of deposition.
- Pore water extractions with squeezers yielded sufficient samples to allow analytical determination of eight trace elements and six major elements.
- (a) Offshore slope sediments (upper 40 cm) contain less organic carbon as compared with shelf sediments, and slope sediments appear to be more oxidized as compared with shelf or restricted bay sediments.

  (b) Pore water from the slope sediments contained significantly more dissolved Cr as compared with shelf sediment pore water.

  (c) The trace elements Fe, Mn, Zn, and Co were more concentrated in pore water from shelf sediments compared with the more oxidized slope sediments.

Deep-Sea Site Investigations 1980

Northern Nares Abyssal Plain -- During January and February 1980, the CSS *Dawson* participated in a geophysical experiment along with the *Discovery* in the Nares Abyssal Plain region. This experiment, called the Lesser Antilles Deep Lithospheric Experiment (LADLE), was designed to obtain seismic reflection and refraction data along a 1500 km line extending from 20°11'N to 30°24'N latitude along 61°30'W longitude (see track plot, Figure I-1). At various times during this geophysical experiment, bottom sediment samples were obtained using a box corer, some shallow seismic reflection data, and a small air gun as a sound source. Bathymetric data were obtained with a conventional 12-KHz hull-mounted sounder.

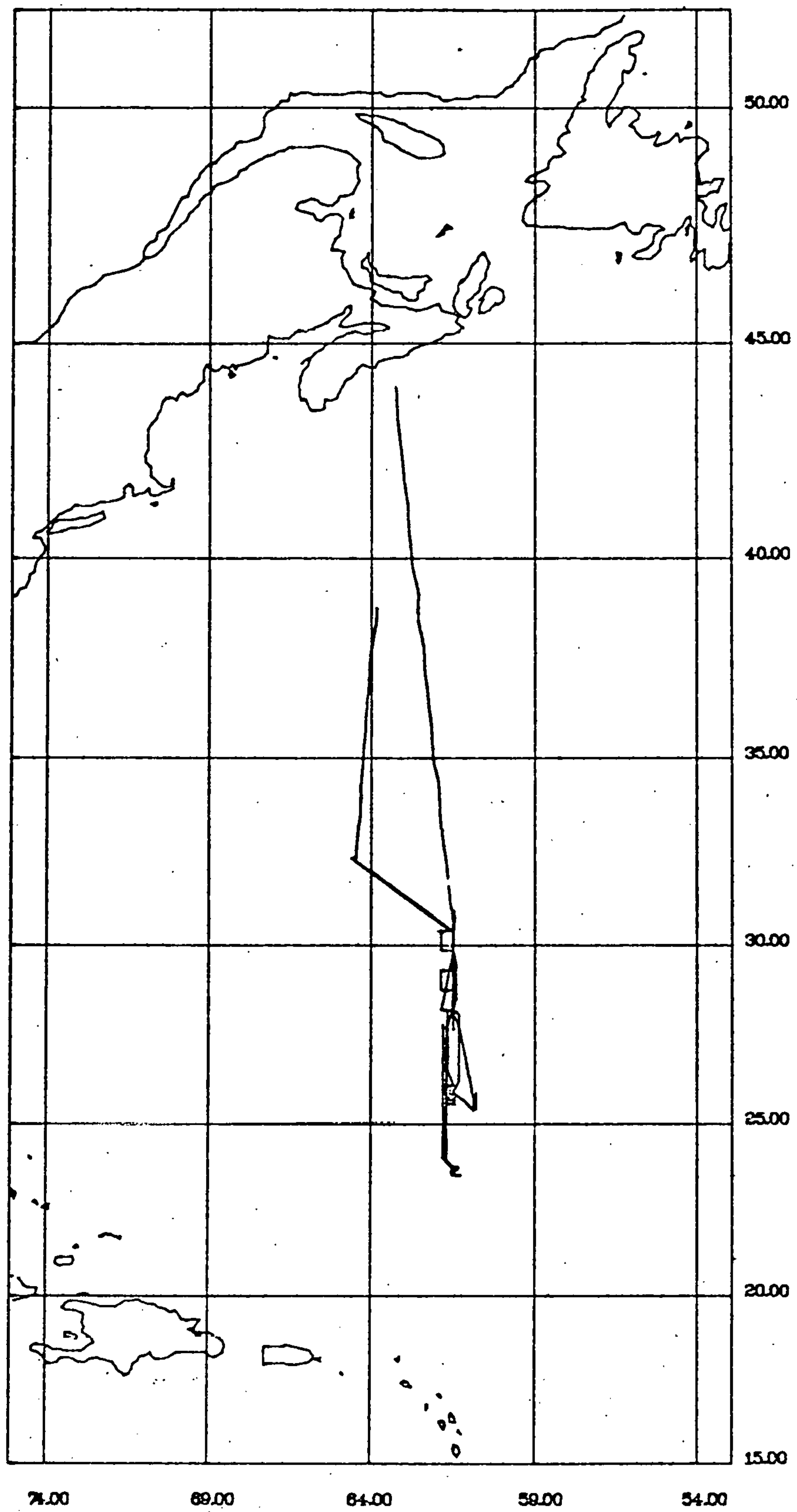

Figure I-1 Dawson 80-001 Cruise Track

Because of the deep-sea core failure after only two box cores had been obtained, the bottom sampling program had to be abandoned. Some shallow seismic reflection data were obtained from the vicinity of the two box core stations and are reproduced with this report.

The two box cores were obtained at:

1. 25° 39.00' N 61° 33.40' W
2. 23° 41.75' N 61° 26.40' W

Both samples were of very fine-grained red clays. There appeared to be little or no evidence of macrobenthic organisms inhabiting this area. Both box core samples were subsampled for immediate extraction of pore waters and for measurement of pH, pE, and pS. There was no evidence of reducing conditions within the sediments nor of a discontinuity in electrochemical measures to a depth of 40 cm. At the time of writing of this report, most of these samples were just reaching the laboratories for detailed geochronological, geochemical, and paleoecological analyses.

At each of the coring sites, the short seismic surveys show some of the general characteristics of the sea floor (see Table I-1). Although the table clarity of the graphic records is hampered by side echoes, it is possible to determine major characteristics about the bottom topography and subsurface sediments down to about 300 m.

Both the topography and sediment thickness are slightly different at the two localities. Along the ship's track of Area 2 (Figure I-2), 78% of the bottom is flat with a few small hills (Figure I-3). The hills protrude to a maximum height of 70 m over the surrounding area over a distance of 0.6 km (close to a gradient of 11%). Area 1 is far more uneven, with only 26% of flat sea floor along the ship's track (Figures I-4 and I-5). Here the depth difference between the hills and the flat areas is at maximum 320 m with slopes that grade at least 18%.

Table I-1

Activities and Committed Funds Toward Deep Sea Research
To Investigate Radioactive Waste Disposal in the Seabed

Year	Area	Activity	Funds ($ K)
1978	Pacific Ocean Latitude 10°N, longitude 150°W *Domes* Cruise	Box coring with bottom navigation, geotechnical, and paleontological clay analysis	8
1979	East Newfoundland Continental Slope, Labrador Continental Shelf, Lake Melville	Box coring, piston coring to test sampling, and shipboard analyses system	40
1980	CSS *Dawson* 1 - latitude 20°N, longitude 61°W 2 - latitude 23°N, longitude 61°W	Box coring and 40 $in.^3$ seismic survey. Pore water analysis for trace and major elements; Foraminifera	106
1980	CSS *Hudson* Latitude 33°N, longitude 56°W Distal Sohm Abyssal Plain	Box coring and piston coring, 10-40 $in.^3$ air gun survey, heat probe, bottom photography, suspended sediment, and CTD profiles; Foraminifera	354

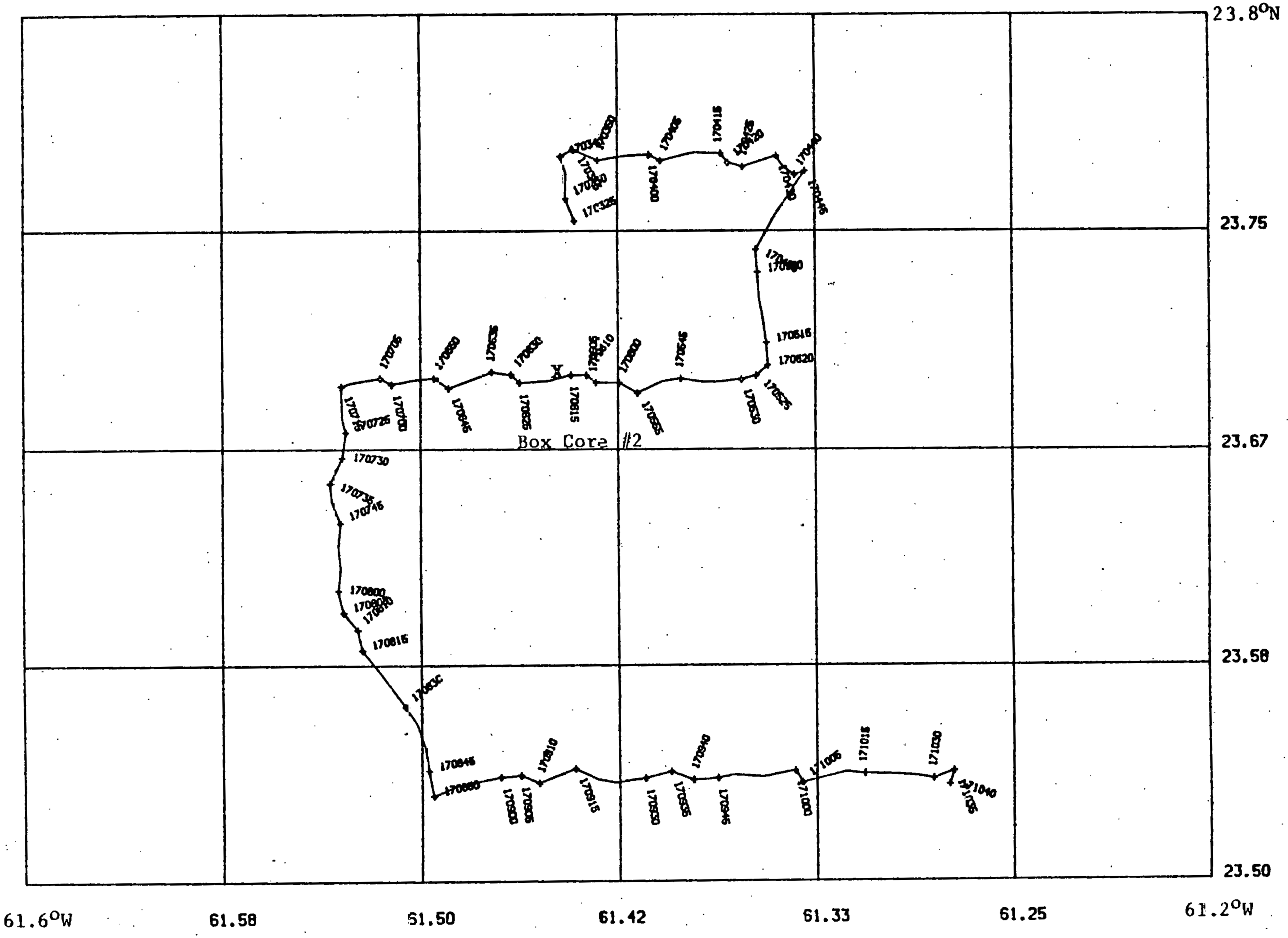

Figure I-2 Cruise Track of Area 2

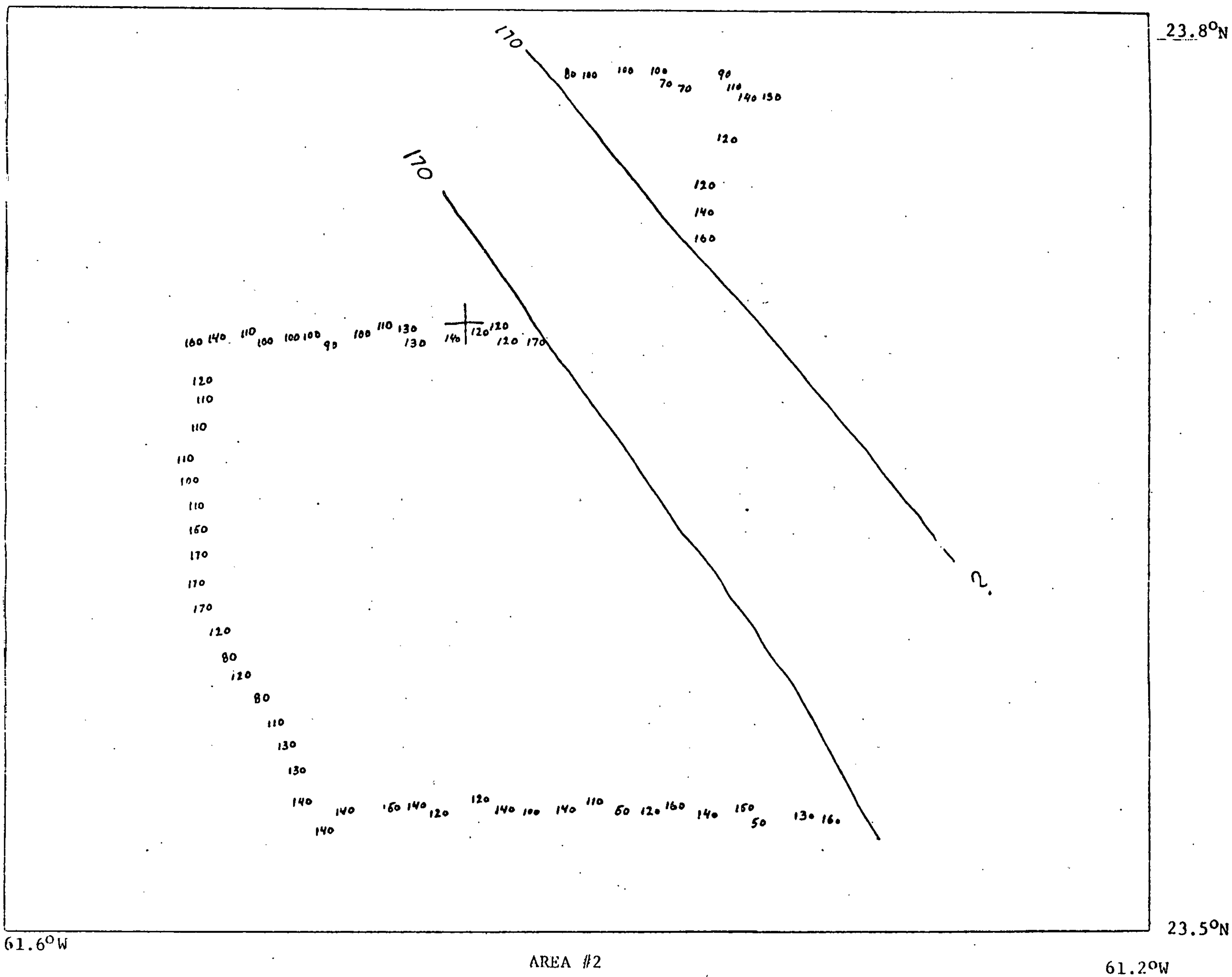

Figure 2-3 Estimated Thickness of Sediment (m) in Area 2

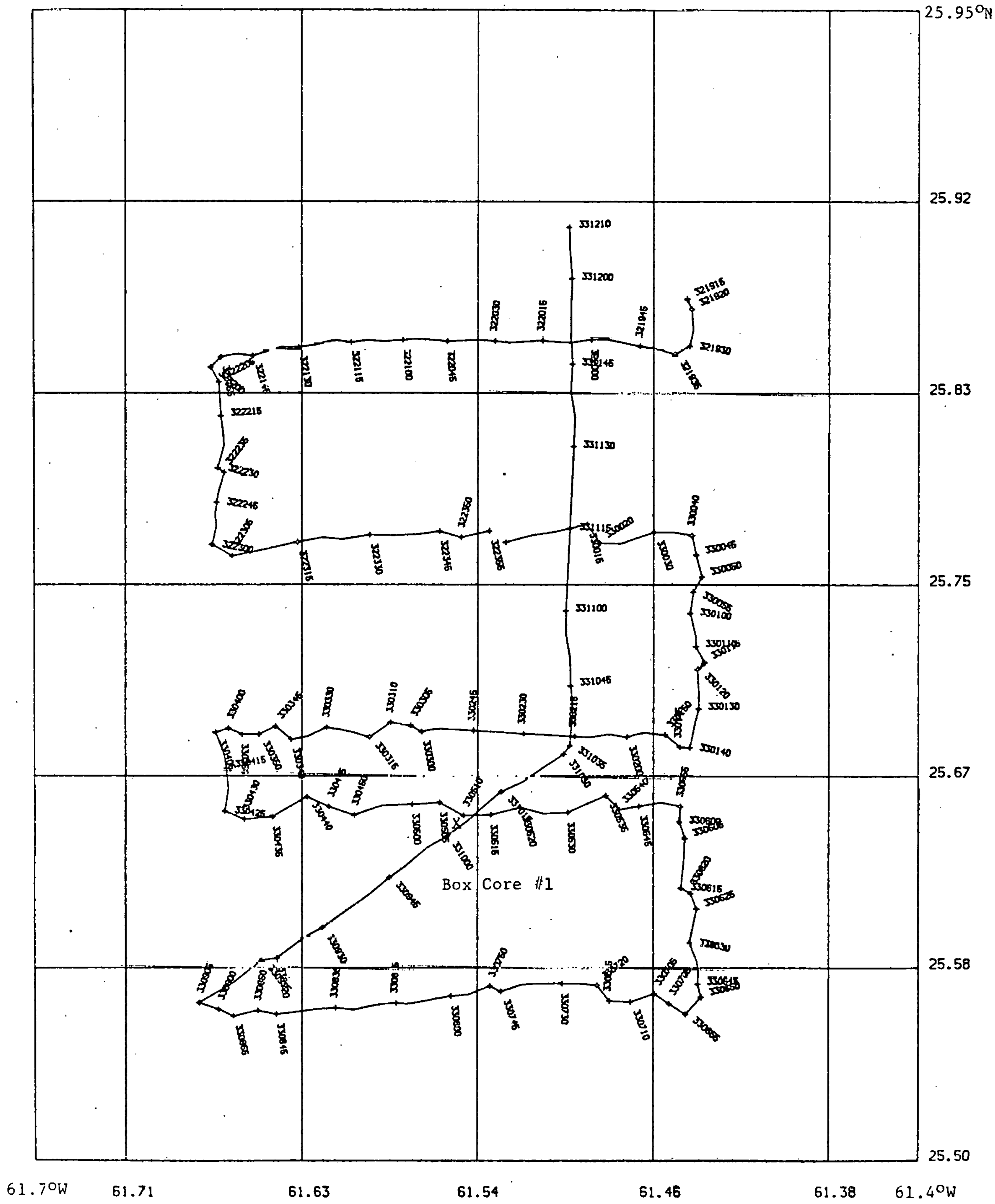

Figure I-4 Cruise Track of Area 1

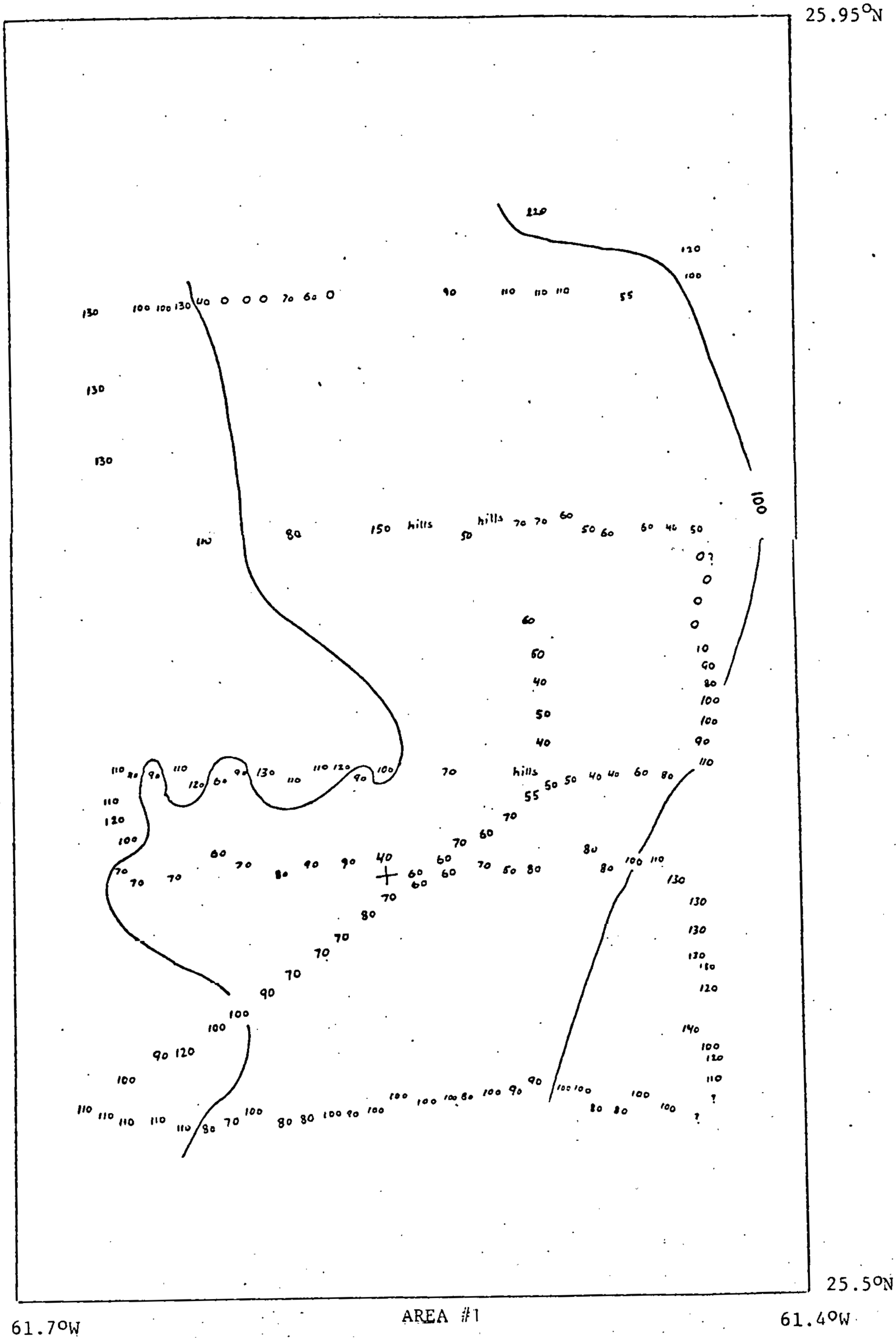

Figure I-5 Estimated Thickness of Sediment (m) in Area 1

So far, only two seismically distinct units are recognized in both areas: the unconsolidated muds and the uneven basement surface below. The unconsolidated sediment that forms the flat areas contains several internal reflectors that are lost where the sea floor is uneven. In both areas the records show sediments on top of the hills, with a few questionable exceptions in Area 2 where the bedrock may crop out.

In Area 2 the sediment is at least 130 m thick on the average, but the few hilltops are covered with only 50 m of sediment. An elongated one where the sediment is at least 170 m thick can be traced along a northwest-trending depression in the bedrock.

In Area 1 the average sediment thickness is 83 m with a recorded maximum of at least 20 m. Here also, most of the hilltops are covered with 50- to 60-m-thick sediment (Figure I-5). The records suggest that the zone of thinner sediment may have a north-south trending linearity.

Sohm Abyssal Plain -- In May-June 1980, a second deep sea cruise will take place in the CSS Hudson to investigate the area around 33.00° N 56.0° W. The cruise will include a detailed bathymetric and shallow seismic survey over a selected site of approximately 12 x 15 km. The shallow seismic reflection system will consist of a tuned air gun array to provide optimum resolution for this type of system in an expected average water depth of more than 5 km. A network of bottom transponders will be used to position the sampling devices as well as the survey data.

Sampling will include box core (0.5 m^2), gravity, and piston cores (6-cm and 10-cm diameter), as well as bottom water column samples for suspended particulate matter and trace elements. In-situ measurements of heat flow and thermal conductivity are also planned.

Core samples will be subsampled on board the ship under cold nitrogen atmospheres and analyzed for pH, pS, and pE. Pore waters will also be squeezed from the sediment samples under high pressure-cold nitrogen; and chemical subsamples will be obtained for trace metal analyses, nutrients, and some major elements.

COMMISSION OF THE EUROPEAN COMMUNITIES

For the past two years, the Commission of the European Communities (CEC) has been represented as an observer at the NEA International Seabed Working Group and has taken an active part in the task group developing an overall systems analysis model of the option. It is expected that this participation will continue; participation within the Sediment and Rock Task Group has also started this year.

Within the new 1980-1984 "indirect action" Nuclear Waste Management and Radiation Protection program, there are projects considering certain aspects of the seabed. In the "direct action" Nuclear Regulatory Commission (NRC) program, which is awaiting official approval, is a proposal for the study and development of consequence analysis for the seabed. An experimental program at present studying the migration of transuranics through subsoils has shown the importance of understanding thermodynamic, kinetic, and oxidation state properties and their interaction with environmental factors. These aspects are also of prime importance for the seabed option.

Thus, methods are being developed to study and characterize physico-chemical species of transuranics. The importance of such methods has been recognized and has resulted in a jointly sponsored CEC/IAEA technical meeting on behavior of transuranics in the aquatic environment, sediment-water exchanges, and techniques for speciation. The meeting is specifically aimed at giving a state-of-the-art view for basic methods in transuranics. These may be summarized as:

- Chemical methods for characterization of species, thermodynamic and complex behavior;
- Techniques for distinguishing metal fractions on bottom and suspended sediments; and
- Methods for studying bioavailability.

It is believed that the development of these methods within these areas of research are basic to studies on the long-term behavior of transuranics in the environment, both for fresh water and seawater, and may also be of use for the experimental study of the seabed disposal options.

Details of the direct-indirect action programs of the CEC have not as yet been defined. The final details will take into account input from national programs through the consultative management committees within the European community.

FEDERAL REPUBLIC OF GERMANY

The aim of the waste management program of the Federal Republic of Germany is still to store high-level active waste in the salt formations of that country. The storage of low- and medium-level active waste into old salt mines has been stopped for political and legal reasons, but the government hopes that it can be continued in the future.

Because of restraining political conditions, the attitude of the responsible administrators in relation to the seabed disposal program as well as to the NEA/Dumping Program has changed. Positive, though informal, signals from these authorities gave rise at the end of last year to the submission of a research proposal to the appropriate Ministry. A part of this program will probably be funded in 1980.

Two institutes intend to work together in implementing this proposal: the Isotope Laboratory of the Federal Center for Fisheries Research (Werner Feldt, Principal Investigator), and the Institute for Hydrobiology and Fisheries Science of the University of Hamburg (Hjalmar Theil and Dietrich Schnack, Principal Investigators). Apart from this, the government's Isotope Laboratory of the Federal Center for Fisheries Research, on its own responsibility, has continued its investigation of the NEA/Dumping sites. The first research program, which started in 1966, will be continued through 1980.

It is the aim of this investigatory program to obtain information about the vertical biological transport. In the course of this investigation the Laboratory has measured

- Primary production
- Radionuclide distribution in the biomass
- Stable element distribution in the biomass
- Concentrations of radionuclides and stable isotopes in the sediment.

On the next cruise these investigations will be extended to include an understanding of the dependence of radionuclide concentrations in benthic organisms as a function of geographical position. The ^{228}Ra and ^{137}Cs concentrations in seawater will be measured for different depths, in order to get an idea about the physical oceanographic transport of radionuclides.

At this time the funding for this program is nearly 1 million DM per year.

FRANCE

In the French radioactive waste disposal program, the first priority has been to assess continental geological formations. For this reason the financial effort for the seabed program in 1979 was modest--about 2 500 000 F. Current policy is to proceed with a constant effort in the seabed program in order to have some alternate solution to continental disposal. In 1980, the Commissariat A L'Energie Atomique (CEA) contribution will be supplemented by an equivalent contribution through Centre National Pour L'Exploitation Des Océans (CNEXO). The total budget of the French radioactive waste seabed disposal program in 1980 will therefore be about 7 000 000 F. This is a very significant increase in comparison to last year.

In France, the disposal of nuclear waste into the seabed sediments is considered geological disposal; therefore, the French are mainly interested in sedimentary layers with a thickness of several hundred meters.

In 1979, the French work was focussed mainly on the following areas:

1. The Resolution Cruise (IFP). In the Cape Verde region, two areas, CV1 and CV2, were investigated; very good results were obtained by microflexichoc seismic reflection techniques identifying subseabed geologic structures. About 1200 km of seismic profile records were obtained; these records show in detail the complexity of some regions. The sediment thickness was found to be 600 to 2000 m. This study also confirms the capability of the microflexichoc technique to provide a quick and cheap method of investigating subseabed geologic structures.

2. The CNEXO Studies. The CNEXO group has completed both theoretical and field studies on certain large areas of the North Atlantic. From these studies several interesting areas have been selected for further study. CV1 and CV2 are two of the areas where studies will continue. In addition, physical oceanography

literature studies have been completed on the characteristics of the bottom boundary layer for CV1 and CV2. Another study, developed in a manner similar to the framework of the TOURBILLON program, is addressing the benthic boundary layer. A mooring containing 5 current meters spaced between 10 and 800 m from the bottom has been deployed and will be recovered in 1980. The deep benthic ecological research is underway in the following areas:

- Assessment of the quantities of benthic biomass at certain sites
- Assessment of the importance of bioturbation in the transport of nuclear waste
- Completion of preliminary development of a free vehicle for measuring the oxygen consumption of the sediment-fauna
- Completion of the construction of a particle trap for measuring the downward flux of organics.

A biological transfer model is under development at the Laboratorie de Radioecologie of the CEA and with the System Analysis Task Group. The Laboratorie de Radioecologie Marine de la Hague (CEA) has focussed its activity on the behavior of radionuclides in the benthic boundary layer. Studies include chemical speciations, sorption onto the sediments, and biological availability for ^{99}Tc, ^{239}Pu, and ^{241}Am, which seem the more significant isotopes for long term disposal. Sediments and organisms are taken from the coastal waters of France. Experiments are planned to compare results for deep and surface sediments and organisms.

A more complete review of the studies is presented in the Task Group reports. No significant work was performed in France in 1979 on canisters and waste forms.

For 1980, France will investigate sites CV1 and CV2, using the CNEXO ships Charcot amd Suroit (September to December). This program will include bathimetry and sediment sampling (Kullenberg coring and large surface coring), a study of the characteristics of the water below 3 km, an examination of Antarctic bottom waters and the thickness of the mixed deep layer, and studies of the gradients in the benthic boundary layer.

Other studies include current meter moorings near the bottom (up to 500 m from the bottom), nephelometric profiles, and temperature profiles. Two stations will be setup in each of the CV1 and CV2 areas.

JAPAN

In 1978, Japan's Nuclear Safety Research Association established a Seabed Working Group under the Expert Committee on Disposal of High-Level Radioactive Waste, and the Group started to collect the fundamental information concerning the feasibility of future high-level radioactive waste disposal. In fiscal year 1978, information on the following items was collected and compiled:

- Research articles for ocean bed geology: topography, sediments, geological structures, etc, in the northwestern Pacific Ocean
- Research articles for oceanographical structure: physical and chemical characteristics of marine water, movement of marine water, and seabed boundary layers
- Research articles for marine biology: fishery and other marine resources, and radioactivity in the marine organics.

The actual work included the collection and regulation of existing knowledge, data, and information available in Japan and other countries.

The organizational chart of the Expert Committee on Disposal of High-Level Radioactive Wastes of NSRA and the membership of the Seabed Working Group of the Committee is shown below.

MEMBERSHIP

Ocean Geology Group

Hiroshi Hotta, Chief Scientist, Marine Technology Department, Japan Marine Science and Technology Center

Kazuo Kobayashi, Professor, Ocean Research Institute, University of Tokyo

Hideo Kagami, Assistant Professor, Ocean Research Institute, University of Tokyo

Saburo Aoki, Assistant Professor, Natural Science Laboratory, Tokyo University

Toshiro Tamano, Managing Director, Japan Petroleum Co., Ltd.

Ocean Physics Group

Hideo Sudo, Chief, the Second Research Laboratory (Physical Oceanography Laboratory), Marine Radioactivity Division, Tokai Regional Fisheries Research Laboratory, Fishery Agency

Hideo Nitani, Director, Japan Oceanographic Data Center, Hydrographic Department, Maritime Safety Agency

Hideaki Kunishi, Professor, Laboratory of Physical Oceanography, Geophysical Institute, Faculty of Science, Kyoto University
Sumio Horibe, Professor, Ocean Research Institute, University of Tokyo

Ocean Biology Group

Ryushi Ichikawa, Dean, Division of Environmental Health, National Institute of Radiological Sciences

Yukio Nose, Professor, Department of Fisheries, Faculty of Agriculture, University of Tokyo

Masuoki Horikoshi, Professor, Ocean Research Institute, University of Tokyo

Takahisa Nemoto, Assistant Professor, Ocean Research Institute, University of Tokyo

Keiji Nasu, Chief Scientist, Far Seas Fisheries Research Laboratory, Research Planning and Liaison Office

Ryonosuke Kitamori, Acting Director, Second Technical Laboratory, Shin-Nihonkishokaiyo Co., Ltd.

ORGANIZATIONAL CHART

Nuclear Safety Research Association

Expert Committee on Disposal of High Level Radioactive Wastes
Chairman: Fumio Yamazaki
Managing Director, Japan Radioisotope Association

Seabed Working Group
Chairman: Ryushi Ichikawa
Head, Division of Environmental Health
National Institute of Radiological Sciences

Task Group on Ocean Geology
Leader: Hiroshi Hotta
Japan Marine Science and Technology Center

Task Group on Ocean Physics
Leader: Hideo Sudo
Tokai Regional Fisheries Laboratory, Fishery Agency

Task Group on Ocean Biology
Leader: Ryushi Ichikawa
National Institute of Radiological Sciences

Investigation of the Ocean Bed Geological Data in the Northern Pacific Ocean

The General Bathymetric Chart of Oceans (GEBCO) is the accepted submarine topographic map all over the world. Since the first map was issued at the seventh meeting of the International Geographic Society in 1877, four editions have been made. The Hydrographic Department of Japan produced the bathymetric chart of the western regions of the Northern Pacific Ocean and the United States produced the bathymetric chart of the eastern regions. The GEBCO sheets are printed in color in Mercator projection on a scale of 1:10 000 000. In the fourth printing, the original data of bathymetric values on each track are also reported on the plotting sheets in a scale of 1:10 000 000. On the plotting sheets produced by the Hydrographic Department of Japan, the bathymetric values are shown in black with an accuracy of 1 m on each track, and the contour lines are drawn in blue every 500 m. Near the Japanese Islands the tracks are numerous, but they decrease with distance from Japan; near the Aleutian Islands there are only a few. Although the data are not so numerous in some areas, the plotting sheets are fundamentally very valuable for the investigation of submarine topography. In addition to the plotting sheets, the Hydrographic Department of Japan produced the submarine topographic maps for the seas around Japan. These multicolored maps are drawn with Mercator projection, and have multiple printings. Although the maps are very nice, in many areas updates should be made by using the data from new bathymetric surveys.

On the submarine topographic map of the northern Pacific Ocean (Figure I-6), it can been seen that the most prominent features are the seamounts in the western regions (from 155° west longitude to the continent). These seamounts are fairly regular. Most of them are volcanic islands, and are arranged in three lines: from the Line Islands to the Gambie Islands via Gambie Islands and Tuamotu Island, from Tubuai Islands to the Marshall-Gilbert Islands via Cook and Samoa Island, and from the Hawaiian Islands to the Emperor Seamounts. All three volcanic lines trend WNW-ESE in the eastern parts and vary NNW-SSE near their middle points. These characteristic features can be explained by the Hot Spot Hypothesis, to be discussed later.

In the northern Pacific Ocean is a line of seamounts extending from the Hawaiian Islands to the Emperor Seamounts, and the northern parts of the Line Islands line and the Marshall-Gilbert Islands line.

The area between the Emperor Seamounts and the Kurile-Japan Trench in the Northwest Pacific Basin is relatively flat-bottomed, and is approximately 6 km deep. In the middle of the northwest Pacific Basin is the northwest Pacific Rise, also called Shatsky Rise. North of the Shatsky Rise, at a depth of 5 to 6 km, are many large and small fracture zones and deep sea channels.

West of the Shatsky Rise in the northwestern Pacific Ocean is a topographically flat area approximately 6 km deep. Although the northwestern Pacific Rise in the middle part of this basin has some topographical irregularities due to fault movements and other tectonic movements, the other parts have no topographical indication of large-scale tectonic movements except the Hokkaido Fracture Zone. The track charts of bathymetric surveys in these areas are sparse, however; thus it is possible that some smaller topographical irregularities were not identified.

Japanese studies of the sediments using data from the Deep Sea Drilling Project show that an important characteristic feature in wide areas of the northwestern Pacific Ocean is the lack of a sedimentary layer. This lack spans a time between 10 to 20 my and 80 my. It is postulated that the cause may be the absence of any depostional currents, such as turbidity currents. On the other hand, the lack could be explained by abyssal currents which could erode the sediments or limit deposition.

The results of acoustic seismic exploration show that the crustal structure in the northwestern Pacific Ocean has a thicker second layer and many regional irregularities compared to the eastern Pacific Ocean.

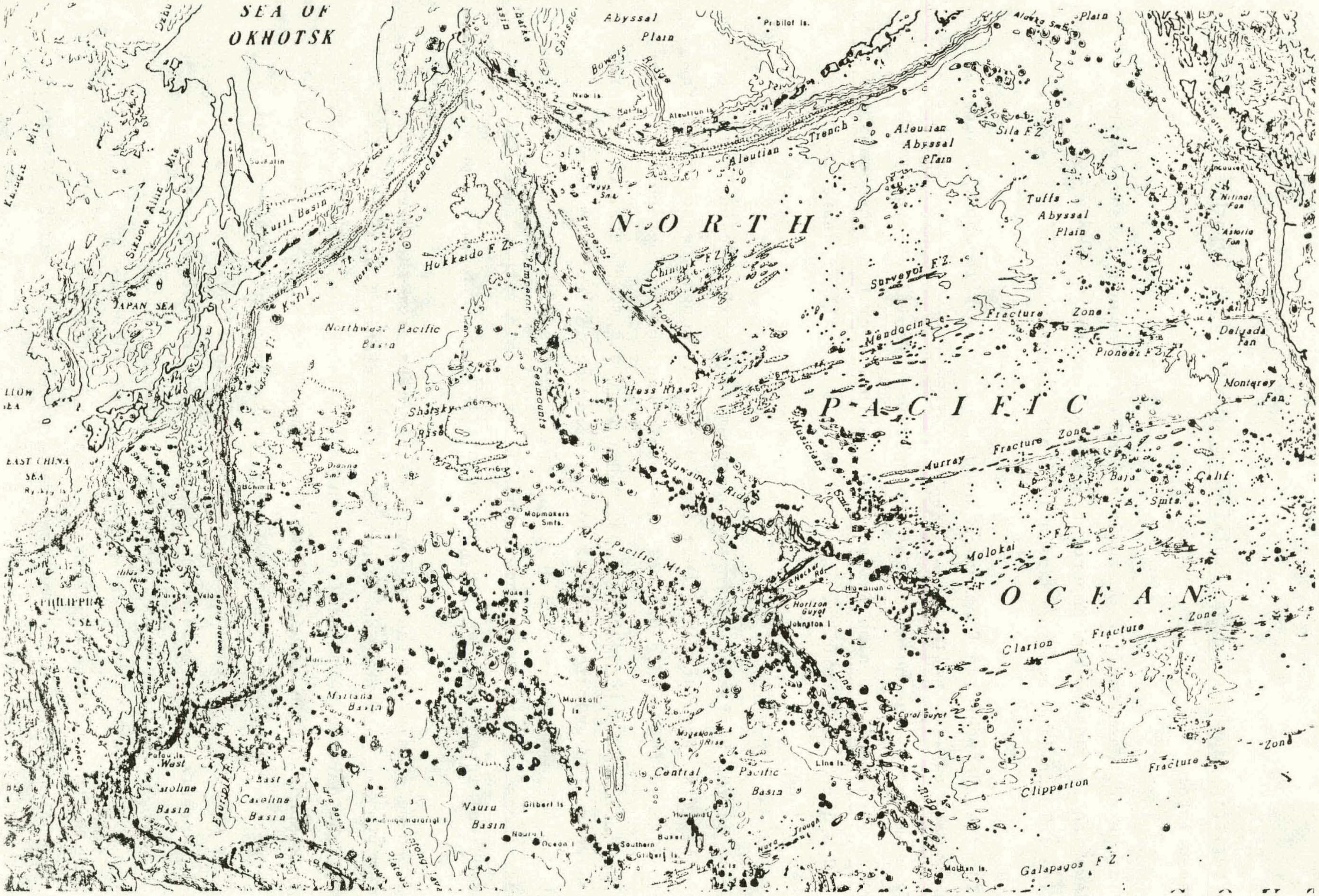

Figure I-6 Bathymetric Chart of Northern Pacific Ocean

The information on earthquake occurances in the northwestern Pacific Ocean is also insufficient, as seen from the fact that only a few midplate earthquakes have been reported. The known earthquakes in the northwestern Pacific Ocean are of magnitudes smaller than 5.5, and always occur in regions of great topographical variety. Thus sites for waste disposal in the seafloor of the Pacific should be selected from the regions of less topographical variety. Earthquakes in the more stable areas should also be measured over long periods of time, because the earthquakes of magnitudes smaller than 5 cannot always be detected or their epicenters determined by the existing seismographic observatory stations.

The gravity anomalies and the heat flow in the northwestern Pacific Basin have little variation and cannot be used to indicate any local tectonic movements. The geomagnetic anomalies give much better indications of the existence of fracture zones and other of submarine geologic features. The magnetic quiet zone discovered in the northwestern Pacific Ocean is due only to large slow changes in the earth's magnetic field. It will be explored in more detail during the coming years.

Investigation of the Structure of the North Pacific Ocean

The characteristics of the deep water in the northwestern Pacific Ocean are the simple vertical structure and the lack of horizontal variation. The vertical structure can be described as follows: Below the main thermocline layer, i.e., in depths greater than approximately 2 km, the water temperature decreases gradually with depth to a minimum temperature (about 1.5°C) at a depth of 4 to 4.5 km, then increases slowly with increasing depth thereafter. This slight rise of temperature in deeper waters is due to the adiabatic warming effect. The potential temperature obtained by subtracting this effect shows a decrease of temperature with depth. In the trenches and the Shikoku Basin the temperature remains almost constant with depth.

The salinity reaches a minimum value at a depth less than 1 km, then increases with increasing depth. In the shallower waters the increase is more rapid than in the deeper until a depth of about 6 km is reached.

The concentration of dissolved oxygen reaches its minimum value at a depth of less than 1.5 km and then rises with increasing depth. The concentration of dissolved oxygen also shows large local variations.

A discussion of the major water movement follows:

The Antarctic Bottom Water flows from the southern ocean into the North Pacific. Likewise the North Atlantic Deep Water flows into the southern Pacific Ocean. These waters flow north and westward in the southern ocean and spread northward in the western South Pacific. The North Pacific Bottom Water enters the North Pacific at around 15°N 170°E and divides into eastern and western flow. The former enters the Northeast Pacific Basin between the Northeast Seamounts and the Line Islands. The latter enters the Northwest Pacific Basin between the Marshall Islands and the Mid-Pacific Mountains.

The western flow is further divided into three streams: the first enters the Phillipine Basin near 11°N, 140°E. The other two spread along both sides of the Northwest Pacific Rise. The bottom water sometimes reaches 35°N on the Northwest Pacific Rise. From the properties of the deep water, it is possible to predict that the bottom water spreads east of the Northwest Pacific Rise and sporadically enters the Izu-Ogasawara Trench. The warmer water covering the trench is then forced to move eastward.

Except on the steeper slopes of sea rises, seamounts, and marginal areas of sea basins, the flow of deep water and bottom water generally has a very low average velocity. The water movement above about 4 km, however, may be greatly influenced by the currents and physical features of the upper waters. Recent hydrographic observations show indirect evidence of a northward deep flow east of the Northwest Pacific Seamounts (the Emperor Seamounts). It is likely that the deep water circulates clockwise along margins of basins and counterclockwise around seamounts. In these cases it is possible that the upwelling occurs along the slopes of seamounts and sea rises.

Initial current measurements in several areas under investigation have shown that the currents vary greatly and the mean velocity is very weak. In order to acquire a statistical data base, measurements should be continued for a long time (at least 1 yr).

In addition, observations in the benthic boundary layer and numerical modelling of ocean circulation and mixing processes are also required.

Biological Studies and Radioactivity Data in the Northwestern Pacific Ocean

The benthic community would be the first to come in contact with radionuclides from waste disposal. Very little information is available concerning the abyssal benthos in comparison with the shallow water organisms. The biomass of the sea bottom deeper than 3 km has never been evaluated by Japanese researchers.

It is known that the surfaces of the deep sea sediments are influenced by bioturbation, and this fact may have some relation to the absorption and transfer of radioactive materials. Some radioactive materials may be taken up by some detritus feeders, such as the sea cucumber.

By means of deep sea cameras, data concerning the number of species and the behaviors of these benthic organisms can be obtained. At present some data are available concerning the distribution and feeding behavior of animal plankton and micronekton. Areas of very high primary productivity and others of relatively low productivity have been found. The present knowledge of vertical distribution of primary productivity is still insufficient; however, it can be stated with some confidence that the food-chain relations in the northern seas are relatively simple compared to those in the temperate zone, because of the larger variety of species. From the viewpoint of fishery resources, the northwestern Pacific Ocean is very important. Thirty-seven percent of the production of the world fishery industry comes from this area.

Some data are available for the important radioactive nuclides such as ^{90}Sr, ^{137}Cs, ^{3}H, and ^{239}Pu, produced from nuclear tests. Most of the information, however, is for sea water, and only a limited amount of data has been obtained for the benthos and the sediments of the deep ocean.

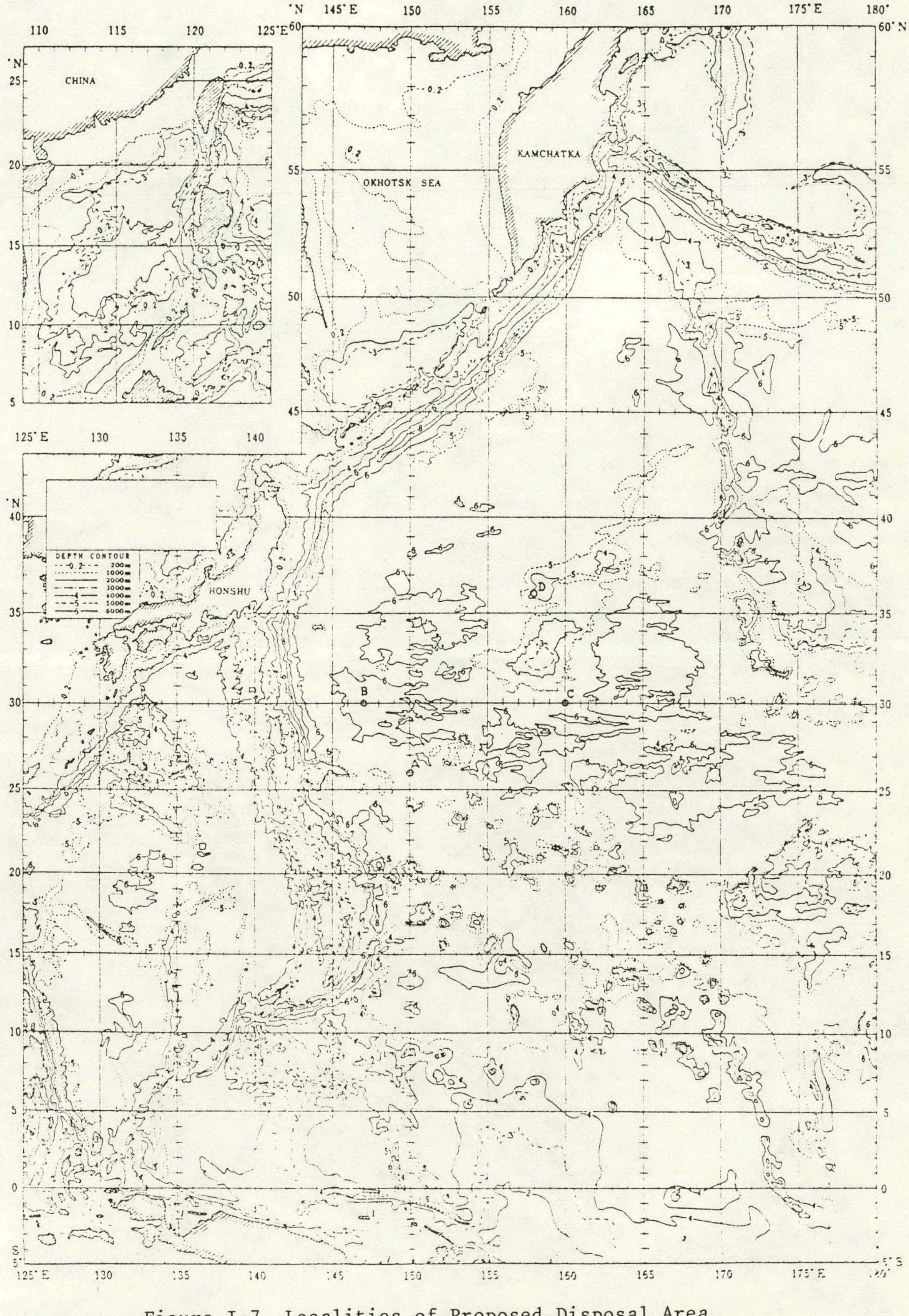

Figure I-7 Localities of Proposed Disposal Area

NETHERLANDS

The Netherlands have at present made only modest advances in the large-scale application of nuclear energy. To date only two nuclear power plants (producing a total of about 500 MeW) are in operation. There are no approved plans for an increase in the number of these plants in the near future. However, the Netherlands also has a potential nuclear waste problem, especially as regards high-level waste. For instance, under contracts valid to January 1, 1980, part of the spent fuel was sent for reprocessing to the French facilities at La Hague. The resulting high-level waste was retained. In future, the resulting high level waste may be returned to the Netherlands.

Disposal Philosophies

Since the early seventies, the Dutch authorities have been looking for sites that may be considered safe repositories for long-life high-level waste.

Salt pillars are present in the northern part of the Netherlands. A number of the shallower and larger ones onshore have been selected for detailed studies as to their shape, internal structures, lithological composition, and vertical movement, if any. So far, exploratory drilling in these salt pillars has been postponed, mainly because of opposition by the local population and authorities. A few salt pillars on the Dutch continental shelf have also been studied in the past years by means of available seismic records. Additional problems, in comparison to investigations of onshore sites, include the building of an artificial island, the danger of flooding of the salt mine that must be excavated, and nearby natural gas occurrences. Site-specific studies are planned for the near future.

Meanwhile, the search for other alternative sites for disposal of high-level nuclear wastes is continuing. In 1978, the Marine Geophysical

Department of the Vening Meinesz Laboratorium of the University of Utrecht was contacted by participants in the Site Assessment Task Group, because this department happened to possess a fairly detailed knowledge of areas of potential interest for the aims of the Seabed Working Group, i.e., large areas in the central Atlantic Ocean (see Figure I-8).

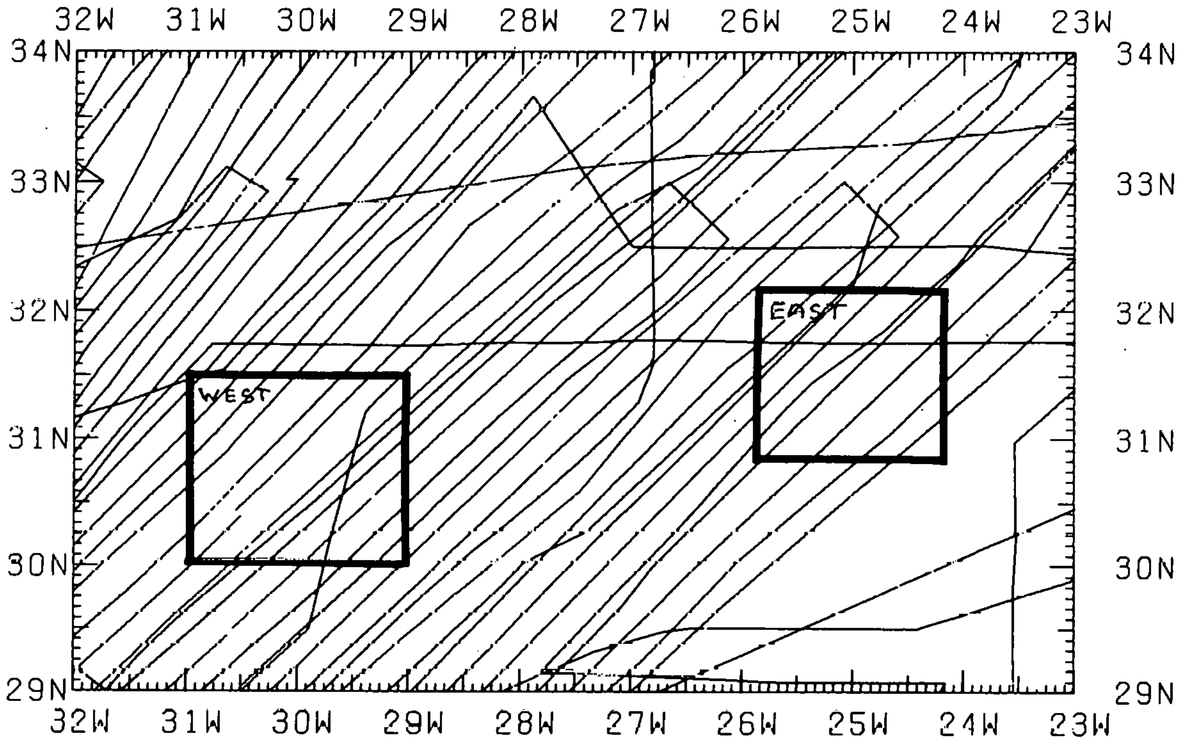

Figure I-8 Track Chart of the Vening Meinesz Laboratorium in the Great Meteor Bank Area. Boxes indicate the areas Meteor-West and Meteor-East.

The Dutch Oceanbed Disposal Program: Strategy and Timetable

The resulting contacts between the Vening Meinesz Laboratorium, the Site Assessment Task Group, and Dutch authorities in charge of the nuclear waste problem led a few months ago to a decision by the Dutch government to join the Seabed Working Group and to participate actively in some of its task groups. The Geological Survey of the Netherlands, as part of the Ministry of Economic Affairs, was instructed to coordinate the Dutch activities in the SWG and its Task Groups. The Dutch activities in the

SWG program are being discussed in the national commission for research on the possible burial of high-level nuclear waste in strata below the ocean floor. This commission is only considering the option of nuclear waste disposal under the ocean floor, at either shallow or greater depths. The present Dutch policy is based on the position that a geological medium should act as a first barrier for radionuclides migrating from the waste canister site. The Netherlands plans to participate only in those task groups in which, given the experience already present, a Dutch effort could contribute to the final result of the investigations.

Because of the experience of the Vening Meinesz Laboratorium (VML) in the geophysical reconnaissance of large areas of the central North Atlantic Ocean, it was an obvious choice to contribute to the program of the Site Assessment Task Group. The VML has already made available to other participants in the Task Group geophysical data from the King's Trough area, the area west of the Great Meteor Seamounts, and Site 2 in the Cape Verde Basin. Moreover, a plan has been made in cooperation with other Task Group members to study areas west and east of the Great Meteor Seamounts in more detail to find suitable sedimentary basins for possible shallow burial of nuclear waste. The sites that will be considered should preferably have a size of 1° x 1°, a sediment thickness of a few hundreds of meters, and a sediment fill that contains volcanic particles and sandy or silty turbiditic deposits. This plan has been approved by the appropriate Dutch authorities, i.e., the Ministry of Economic Affairs, which will sponsor these activities. The program will be carried out by the Geological Survey of The Netherlands, i.e., by the Department of Marine Geology, with the assistance and advice of the Marine Geophysical Department of the Vening Meinesz Laboratorium, under the joint responsibility of Dr. R. T. Schüttenhelm (Geological Survey) and Dr. B. J. Collette (VML).

Two cruises are scheduled for 1980 and 1982 to the area of the Great Meteor Seamounts, with HNLMS Tydeman. The geophysical and geological data obtained will be processed, evaluated, and reported by the end of 1983. Some 3.5 million Dutch guilders, the equivalent of 1.8 million US dollars, will be spent in four years to cover additional costs of the participating organizations, such as ship time, equipment, and additional manpower. It has been decided to actively follow the progress of the System Analysis Task Group, as this Task Group seems to be the forum for risk analysis and for the final evaluation of the results of the activities of all other Task Groups. Dr. F. van Dorp of the Association Euratom ITAL, one of the institutions in the Netherlands with experience in the field of risk analysis and model studies, has been appointed as the official Netherlands representative in the System Analysis Task Group.

At the moment there is a discussion about possible future Dutch participation in the Physical Oceanography and Biology Task Groups by the Netherlands Institute for Sea Research (NIOZ) and the Royal Dutch Meteorological Institute (KNMI). Representatives of both organizations have been asked to present joint research proposals. A limited interdisciplinary effort may be centered around studies of the benthic boundary layer. In a later stage of the SWG program, a Dutch participation in the Sediment and Rock Task Group will be considered in accordance with specific Dutch knowledge in the field of soil mechanics. There are no plans at present to join the Waste Form and Canister Task Groups.

SWITZERLAND

Switzerland has a disposal program underway that uses geological formations as natural barriers to assess safe disposal from the high-level wastes from its four nuclear power stations. For these wastes, a multi-barrier philosophy has been adopted to prevent future contamination of man's biosphere: the vitrified waste will be kept in containers of stainless steel, lead, and titanium that will be stored in a host rock most suitable for this purpose. Four different kinds of rocks are under consideration for a potential repository:

- Salt
- Anhydrite
- Clay and shales
- Crystalline rocks (granite, gneiss)

Within the next few years, crystalline rocks will be examined more closely by drilling a number of exploratory boreholes and by participating in an international crystalline rock research program at the Stripa Mine, Sweden.

The ocean option for disposal of high-level wastes has not yet been considered in detail, but the delegation of Swiss observers to the Seabed Working Group meeting this year signals a growing interest in this international disposal program. Conditions for possible cooperation and its implications on the management of the Swiss disposal program will be discussed in the near future with the Secretary of the Working Group. A promising entry point is the relatively high number of scientists in this country, working on relevant problems close to the topics of the Seabed program. However, it must be taken into account that Switzerland has no direct access to the sea--a unique situation among the participants of the International Seabed Working Group.

UNITED KINGDOM

System Analysis

The Department of the Environment has initiated a systems study of radioactive waste management, including sea disposal. The immediate objectives are:

- To describe the basic technical system for disposal of all UK wastes and establish the principles for its optimization.
- To identify the roles and responsibilities of the technical system and its management.
- To construct a program leading to establishment of the necessary range of disposal facilities and the packaging specifications appropriate to them.

Work has been proceeding on the development of the detailed models for the various elements of the entire systems model. This includes preliminary work on models for the behavior of the canisters and waste form under disposal conditions, the interactions with sediments of released radionuclides, transport through the benthic boundary layer, and physical and biological processes in the water column.

Much of the work in these particular areas has been carried out within the framework of other research programs, for example, on waste form and biology, but the systems modelling work is attempting to bring all the aspects together under a unified framework. There has been little published this year, but it is expected that at least preliminary results will be available.

Waste Form

The work on waste form has continued over the last year. Borosilicate glass is still the preferred form for solidification of high-level waste, and studies of its properties are being concentrated on the two reference compositions for vitrifying Magnox waste. Some work has been carried out to select a composition suitable for vitrifying the iron-rich waste from PFR fuel reprocessing at Dounreay. The properties studied include leach rate, thermal and electrical conductivity, and viscosity, as well as radiation stability.

A small program on the small-scale preparation and characterization of the crystalline waste-form SYNROC has been started with a goal of determining its suitability for solidifying UK wastes. There are no plans to expand this work into the difficult field of large-scale manufacture of wastes.

Canisters

No work on corrosion of canister materials under appropriate conditions for sea disposal has been carried out in the last year. Current effort is directed toward studying the properties of canister and overpack materials in geologic environments.

During this coming year we will carry out a review to identify materials which have properties suitable for the maintenance of canister integrity over 1000 years and to identify the elements of an appropriate research program. The research program will consider the water composition, temperature and pressure, the behavior of concrete cladding, effects of crevices, galvanic coupling and heat transfer on the metal containment, possible effects of radiation on the corrosion process, and radiolysis on the environment at the metal surface.

Site Selection

The report by the Institute of Oceanographic Sciences (IOS) on Site Selection Guidelines was completed for the Department of the Environment (DOE) in September 1979. Suggested guidelines for disposal on and under the seabed were included, together with an assessment of potential study areas in the North Atlantic. Some progress has been made on the study of the distribution of glacial erratics and other boulders, by conducting an analysis of pebble material recovered from dredge hauls below 1000 m. Under the Sediment Stability project, eight cores were collected from the King's Trough flanks area (41°-43°N, 21°-23°W) in September, and these will be studied in the coming year.

The proposed program for 1980-81 will include an evaluation of the distal abyssal plains of the Eastern North Atlantic for potential study areas; sediment stability studies in selected areas; study of the cores; continuation of the Glacial Erratics program; a start on Seismic Hazard Evaluation; and cooperative planning of cruises and analysis of results of UK, French, and Dutch expeditions in the eastern Atlantic.

An exploratory survey of a possible site in the King's Trough area is planned for October 1980. This cruise will include current measurements as well as collection of water samples, sediment cores, and abyssal fish. In addition, the 1981 UK shiptime will include the Discovery cruise 118 in February-March 1981.

Sediment and Rocks

Research into the nature of deep ocean sediments in a number of areas of the North Atlantic has begun. The objectives of this work are:

- To improve our knowledge of the sedimentary regimes in the areas studied: sedimentation rates, erosion, quaternary hiatuses, redistributive processes affecting the present day sediment surface, and the importance of glacial erratics in the higher latitudes studies

- To measure vertical pore-water movement within the sediment layer

- To study the chemistry of the pore-water and solid phases of the sediment in order to predict the rates of movement of radioactive species through the sediment barrier and to improve our understanding of the stability of the redox and pH environment.

A few days were spent coring over 40-million-year (my)-old crust to the south of King's Trough, an area which had been only sparsely sampled before. The newly developed 2-kHz profiling system, using high-resolution, shallow-penetration sediment profiling equipment, was tested.

Mathematical modelling of the temperature field around a hot canister buried in ocean sediments has been concluded. Reports on this work will be available later at this meeting.

Research continues on the adsorption by sediments of radioactive discharges, concentrating on the transuranic elements. This work is largely concerned with the continental shelf around the British Isles.

Physical Oceanography

Work has continued on the Northeast Atlantic Dynamics Study (NEADS) described in the 1979 Seabed Working Group report. Additional moorings were emplaced during the year and others were recovered. The analysis of data from the measurements is continuing, with an eventual aim of including some form of spatially varying diffusion coefficient in a model of diffusion and advection in the North Atlantic.

During 1980 further current moorings will be based on the NEADS positions. Slope processes will also be investigated, in particular the plumes of sediment-rich water at the 1500 to 2500 m depth.

Biology

There are three principal goals of the biological research program. These may briefly be summarized as follows:

- To learn more of the behavior of those radionuclides that constitute the radioactive waste, with special emphasis on ^{237}Np, ^{99}Tc, ^{129}I, ^{226}Ra, ^{126}Sn, ^{239}Pu, and ^{241}Am, particularly with regard to their biological availability from different sources--sea water and sediment--and their transfer from one trophic level to another

- To identify those food chains in the deep sea, the migrations of the biota that could constitute a means by which these radionuclides may be transferred to man, and the magnitude of any radionuclide transfer

- To assess the probable radiological impact of radioactive wastes on the deep-sea fauna.

The first two goals may be met by taking two different but complementary approaches. Studies are being made on the behavior of many of the more important radionuclides in the Irish Sea. This area is unique because of the presence of ^{99}Tc and ^{237}Np, and because the concentrations of transuranium nuclides generally are sufficiently high to allow their distributions in marine organisms to be studied in some detail. A number of laboratory studies are also being made, using such isotopes as ^{237}Pu and ^{95}Tc, and a wide range of biological materials.

Research on the potential biological pathways back to man is being undertaken by sequential sampling in deep water off the southwest coast of the UK. In comparison to the midwater zone, the deep-sea benthos has been but little studied. Particular emphasis will be placed on the quantitative aspects. Deep-water fish are also being studied in detail. Potential deep-water commercial fisheries will also be held under constant review by MAFF.

One of the principal difficulties is that of extrapolating data obtained in the Irish Sea to the conditions of the deep ocean. In order to bridge this gap, analyses are being made of naturally occurring elements in both coastal water and deep-sea samples. Elements with a presumed similar behavior will be studied in detail; for example, U and Th as homologues of the two principal oxidation states of Pu, Nd as a homologue of Am, and so on. Such analyses will be made on Irish Sea samples--together with analyses of the transuranium nuclides, etc--and on those samples obtained by a number of institutes from the deep sea. From the sampling mentioned above, matching sets of data will be obtained on the basic quantitative biological information, and on the capacity of these species to accumulate different elements from different sources.

In support of the third goal, the initial work has been to quantify the existing radiation regime in the deep sea. For many organisms, one of the principal sources is that of internally accumulated alpha-emitting nuclides, particularly ^{210}Po. A number of coastal water organisms have been analysed, and other species inhabiting depths down to about 1200 m have been analysed for comparison. These comparisons will be extended to organisms at greater depths. A great deal of data on the composition of deep-water sediments is already available, and has been used to calculate existing external dose regimes. These natural background dose rates will be compared with estimates of the likely dose regimes arising from either on-the-bed or in-the-bed emplacement of high-level waste.

UNITED STATES

This past year has been pivotal for the US Subseabed Disposal Program. The US government's waste management strategies are continuing to evolve and major initiatives are under consideration.

The Interagency Review Group (IRG) on Nuclear Waste Management submitted its final report to the President in March 1979. The IRG report delineates major objectives, strategies, policies, and options for national waste management. It has been used by the Department of Energy as a basis for planning.

On February 12, 1980, the President announced to Congress a national comprehensive waste management program. This program is consistent with the broad concensus that evolved from the IRG report. Following are the key elements of the President's program for high-level radioactive waste disposal:

- A State Planning Council is created to work with federal, state, and local government to implement decisions on waste management and disposal.
- Mined repositories in geological formations will be the first approach for radioactive waste disposal in the US.
- Technical conservatism will be used toward siting and opening repositories.
- A broad range of geologic media will be explored during the site selection process in order to have available several potential sites.
- The site for the first full-scale repository should be selected by about 1985 and operational by the mid-1990's.
- Storage of spent fuel will continue to be the responsibility of the utilities.
- Legislation will be pressed to acquire limited away-from-reactor facilities for both US and foreign spent fuel storage.

- Emplacement in ocean sediments and in very deep holes will continue to be assessed as longer range options to mined repositories.

The assessment of isolation of radioactive waste in geologic formations beneath the seabed has been incorporated into the Department of Energy's National Waste Terminal Storage (NWTS) Program. The overall goal of the NWTS Program are to identify and develop technologies which provide a high degree of assurance that existing and future radioactive wastes can be isolated from the biosphere in a safe, environmentally acceptable manner, and to provide necessary facilities to achieve such isolation.

The major thrust of the DOE NWTS program continues to be toward the isolation of waste within stable geologic formations, within the contiguous United States, at depths reachable by conventional mining methods. The geological formations of primary interest are rock salts, basalts, shales, and volcanic tuffs. Subseabed emplacement in red clay sediments will continue to be studied. The systematic assessment of subseabed geologic formations by Sandia Laboratories and its contractors has identified vast areas of deep ocean sediments which are considered some of the more stable formations on earth.

The Subseabed Disposal Program is continuing to investigate the feasibility of disposal within these sediments. The near-term objectives are (1) to assess the technical and enviromental feasibility of the concept of engineered emplacement of appropriately solidified and packaged high-level wastes within the stable deep sea sediments, and (2) to develop and maintain the capability to assess and cooperate with other nations' ocean disposal programs.

The NWTS program encompasses the work breakdown structures and strategies to investigate and develop the technologies for selection, design, construction, and operation of Federal repositories. The NWTS Program is composed of four subprograms, each investigating isolation systems centered on different host media and specific related technologies:

1. The Office of Nuclear Waste Isolation (ONWI) Program thus far has concentrated on systems associated with rock salt formations, with some work on granite and shale. The investigation into granite and shale formations is being expanded.

2. The Basalt Waste Isolation Program (BWIP) is investigating the basalt formations found within DOE's Hanford Reservation.

3. The Nevada Nuclear Waste Storage Investigation Program (NNWSI) is investigating potential systems involving primarily granite, shale, and tuffs at DOE's Nevada Test Site. It is currently focusing on volcanic tuffs.

4. The Subseabed Disposal Program (SDP) is investigating the deep ocean clay sediments (Figure I-9).

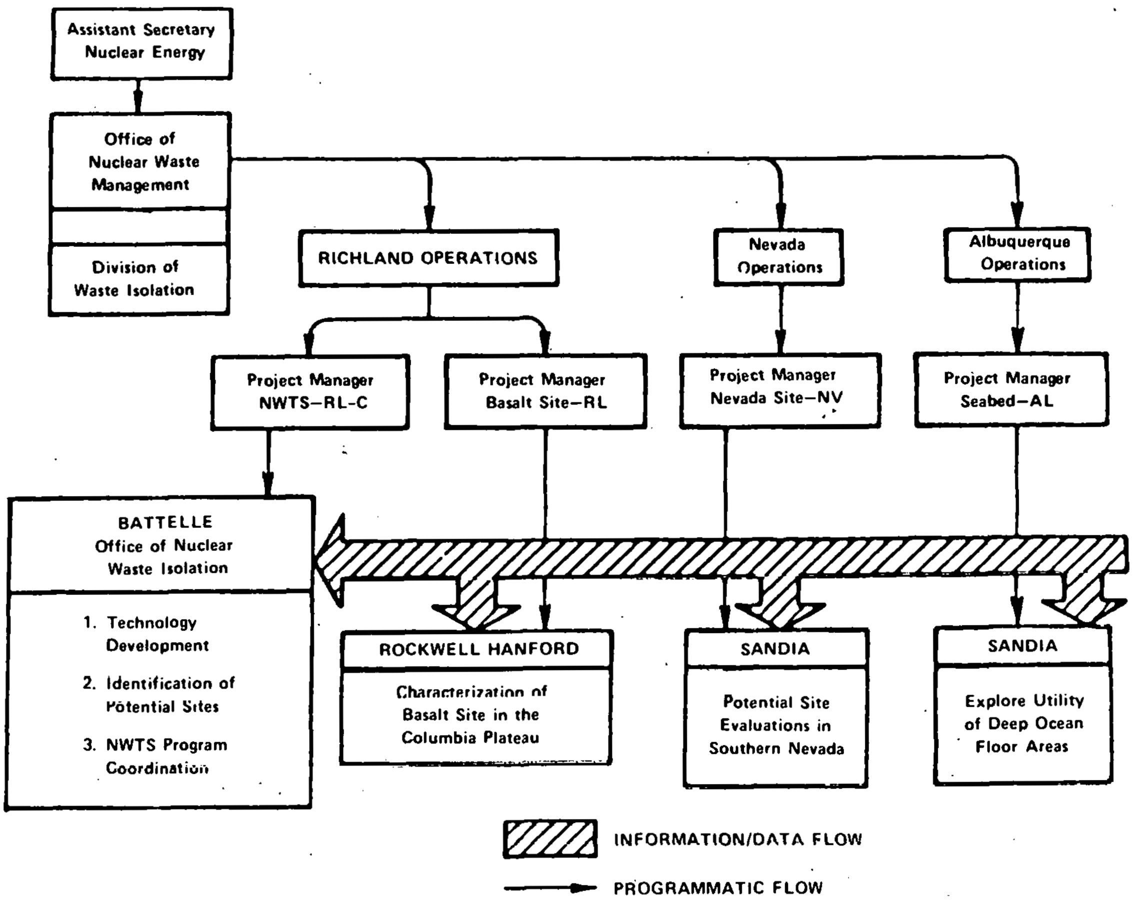

Figure I-9 NWTS Program Management

The primary goal of the composite NWTS program is to identify specific candidate locations that might be qualified as repository sites. The acceptance of these sites and associated systems will be gaged through comparison with criteria, guidelines, and regulations currently being formulated by the US Nuclear Regulatory Commission (NRC) and the US Environmental Protection Agency. In the case of subseabed disposal, consistency with appropriate international regulatory bodies and international treaties will also be required. In the meantime, DOE is providing direction for the NWTS program efforts by establishing general performance criteria[1] for the waste isolation system and general functional criteria for the site, repository, and waste package components of the system.

A multiyear Subseabed Program Plan[2] was issued in January 1980. It outlines in some detail the current and planned activities. It is governed by the awareness that, even though our understanding of subocean sedimentary geologic formations indicates that they are repository candidates, much additional specific research and development is needed before the feasibility of the concept can be considered as having been demonstrated. Copies of the Subseabed Program Plan are available for each of the SWG Task Group Leaders and Executive Committee members, and your comments would be welcomed.

The Subseabed Disposal Program (SDP) was originally divided into four phases:

Phase 1: Estimation of technical and environmental feasibility on the basis of historical data. Completion date: 1976.

Phase 2: Determination of technical and environmental feasibility from newly acquired oceanographic and effects data. Estimated completion date: 1985-1987.

Phase 3: Determination of engineering feasibility and legal and political acceptability. Estimated completion date: 1993-1995.

Phase 4: Subseabed disposal capability developed. Estimated completion date: 2000-2010.

To date, the plan has been to complete each phase sequentially; this allows optimal use of the limited funds. This assumes that institutional, licensing, and political issues are resolved in parallel with resolution of technical issues.

The main tasks to be accomplished before completion of Phases 2, 3, and 4 are listed below:

<u>Phase 2</u>: Technical and Environmental Feasibility

- Make operational all units of a predictive system model.
- Bracket (but not verify) all material and pathway properties.
- Complete verification tests on certain subsets of the system.
- Identify and initially characterize at least one study area in each of the northern Atlantic and Pacific oceans.
- Issue a Technical and Environmental Feasibility document.

<u>Phase 3</u>: Engineering Feasibility

- Develop and verify all subsets of the system predictive model.
- Verify all materials and pathway properties.
- Initiate long-term (10-15 yr) in-situ experiments.
- Complete conceptual system design.
- Complete and review engineering Feasibility document.
- Identify and characterize several study areas in the Atlantic and Pacific oceans.
- Establish national and international legal and political positions.
- Write and review draft Environmental Impact Statement and submit license application.

Phase 4: Demonstration of Disposal Capability

- Complete detailed engineering designs.
- Obtain necessary licenses or permits.
- Build and test required dock and ship systems.
- Develop and make operational land transportation networks.
- Develop long-term monitoring networks systems.

The estimated costs for Phase 2 programs are shown in Figure I-10.

Fiscal Year	Millions of Dollars
1979 (Actual)	3.6
1980 (Current)	5.9
1981 (Requested)	9.2
1982 (Planned)	13.6
1983	20.0
1984	24.0
1985	32.0
1986	32.0

Figure I-10 Subseabed Disposal Program: 5-Year Planning Budget

The multibarrier concept, conceived in 1974, assumes a continuously wet environment in which packaged radionuclides are placed. The purposes of the barriers are (1) to contain the wastes for sufficient periods so that the rate of decay of waste constituents is higher than the rate of nuclide migration, and (2) to keep man away from the wastes. The seabed sediments, together with any modifications to them, are considered very important until the geologic formation has returned to essentially ambient temperatures (~300 yr). The water column will disperse and dilute any nuclides released into it, and act as a barrier to man to discourage easy access to the wastes.

The major task is to determine whether any submarine geologic formation can contain radioactive waste long enough for the radionuclides to decay to acceptable levels. Attention is focused on the waste form and the canister for containment during the period of heat generation and on the sediments for long-term containment.

A reference system has been established for reasons of discussion and programmatic planning, even though that system may have to be altered as additional information is acquired. The reference system was chosen on the basis of simplicity, completeness of emplacement technology, and estimated cost.

The reference subseabed geological disposal system is the placement of appropriately treated waste or spent reactor fuel in a specially designed container which will be placed into clayey sediments away from the edges of oceanic tectonic plates (to avoid volcanic and seismic activity), and away from the edges of major circular surface currents (to avoid subsurface agitation caused by these currents). These are the abyssal hill areas of the ocean bottom, and we use the abbreviation MPG (mid-plate/gyre) to designate them.

Although several emplacement methods appear feasible, none has been developed in detail. For study purposes, our reference method is conceptualized as the use of either penetrators or winch-controlled injectors to emplace wastes at a substantial depth beneath the sediment surface. Other concepts include trenching and drilling. Selection of sites suitable for such emplacement is conceived as an iterative process involving interaction between historical data collection, increasingly detailed local observation, and laboratory studies of the sediments. By the use of near-bottom geophysical techniques, a detailed survey will be made of the disposal area in all relevant aspects; the survey vessel will be charged with identifying specific emplacement sites and marking them for sediment sampling, as well as for the later convenience of the disposal ship. The latter will be a specially designed vessel that will carry the wastes from a special port facility to the disposal site, and will emplace the waste canisters (also specially designed and fabricated) in the sediments. After emplacement, a monitor ship will confirm the location, attitude, and condition of individual disposal containers. By a combination of bottom-emplaced telemetering equipment and periodic resurveys by the monitor ship or its equivalent, surveillance of each disposal locale will be maintained as long as is decided necessary to protect or reassure the public.

The research approach for the SDP (Figure I-11) is (1) to develop the best predictive mathematical models for each scientific unit, using principles of physics, chemistry, mechanics, etc; (2) to extract from the existing literature and through laboratory measurements maximum and minimum estimates of needed input parameters (henceforth called properties); (3) to make response predictions using the best combinations of properties available at that time; (4) to compare these predictions with laboratory and field verification experiments; and (5) if the predictions and verification experiments agree, to use that model unit for sensitivity studies and for coupling with other units to prepare a predictive system model. If predictions and verification experiments do not agree, the model and the properties will be improved and again verified with appropriate laboratory and field tests. From the results of this process, risks and environmental impacts can be assessed.

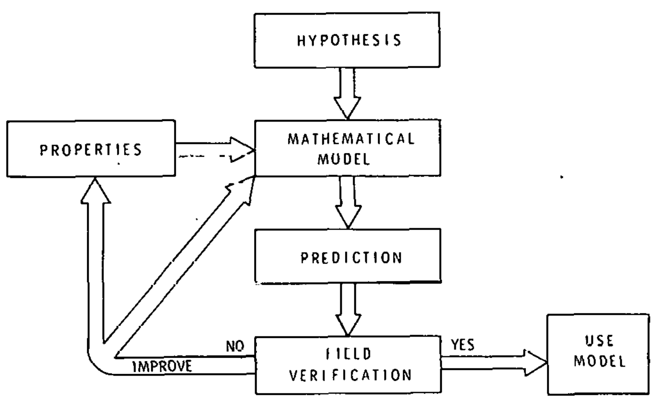

Figure I-11 Research Approach

The subseabed disposal concept differs appreciably from other disposal concepts by virtue of the relatively straightforward way in which predictive models can be verified. The reasons for this are as follows:

1. In-situ tests to increase our understanding of near-field responses and to verify predictive models for the most critical period can be run in real-time (no accelerations or extrapolations needed) for the following reasons:

   a. Canisters will be spaced horizontally on 100 to 300 m centers so that there will be minimal thermal or radiative interactions between canisters.

   b. The maximum temperature at the canister-wall/sediment interface will occur in the first 2 yr of the test. Long-term tests will then allow real-time studies of ear-field responses to be completed, not only for the heat-up period but for the initial cooling phase as well.

2. Long-term (10 to 15 yr) thermal experiments will allow testing of both near field and far field equilibrium in real-time to assess the possible failure mechanism (breachment of the geologic formation) caused by thermal heating and initial cooling. (The thermal pulse from a canister emplaced 50 meters deep in the sediments will take ≈10 yr to reach the sediment-water interface, where it will then be lost in the infinite heat sink of the ~1°C ocean waters.)

3. Since there are no canister-to-canister interactions and the geologic setting, compared to land geology, is very simple, studies and experiments using individual canisters and accepted scaling laws can yield a detailed understanding of the thermal and mechanical responses of the canister and sediments during the many hundreds of years envisioned for the total thermal heating and cooling cycle.

There is always a need for a note of caution for those with enthusiasm for the subseabed disposal concept. There are many technical and institutional issues yet to be resolved. Among them are: implantation systems; port and transport facilities; institutional management procedures; national and international institutional, legal, and regulatory requirements; and time to acquire sufficient data to assure technical feasibility of the concept.

The Master Program Work Breakdown Structure (WBS) is the framework for task and subtask descriptions established for the NWTS high-level nuclear waste subseabed disposal assessment program. This structure has been adopted for the purposes of organization, planning, and reporting the elements identified in the program outline and is also cross-referenced to the duties of the Technical Program Coordinators and Principal Investigators, as well as other NWTS programs. The two-level elements of the WBS are shown in Figure I-12.

The Subseabed Disposal Program Plan is designed to include all functions necessary to make a complete assessment of the subseabed disposal concept. It must be understood, however, that not all of the tasks identified are being funded through the SDP, but are being coordinated by both the SDP and ONWI management and supported by the NWTS program. Specific tasks and funding methods for the current fiscal year are identified in the programmatic work descriptions in Volume II of the Subseabed Program Plan. Retrievability is not included as a significant technical activity in the present program. If retrievability is deemed necessary, deep sea technology exists upon which to build the capability to over-core the canisters and retrieve them, together with some of the surrounding sediments.

An integral part of the Subseabed Disposal Program is the international cooperative research and development, as well as annual peer review of programs and tasks coordinated through the Seabed Working Group. We expect to continue the United States participation in the NEA/OECD Seabed Working Group and are looking forward to the sharing of ideas and suggestions which result.

References

[1]To be issued: NWTS Program Criteria for Geologic Disposal of Nuclear Waste:

ONWI-33-(1) General Program Policies and Criteria (under review)

(2) Site-Qualfication Criteria (Draft issued January '80 for comment)

(3) Repository Functional Design and Operating Criteria (in preparation)

(4) Waste Package Functional Criteria (in preparation)

[2]SAND80-0007/I & II, Subseabed Disposal Program Plan, Volume I: Overview; Volume II: FY1980 Budget and Subtask Work Plan. January 1980.

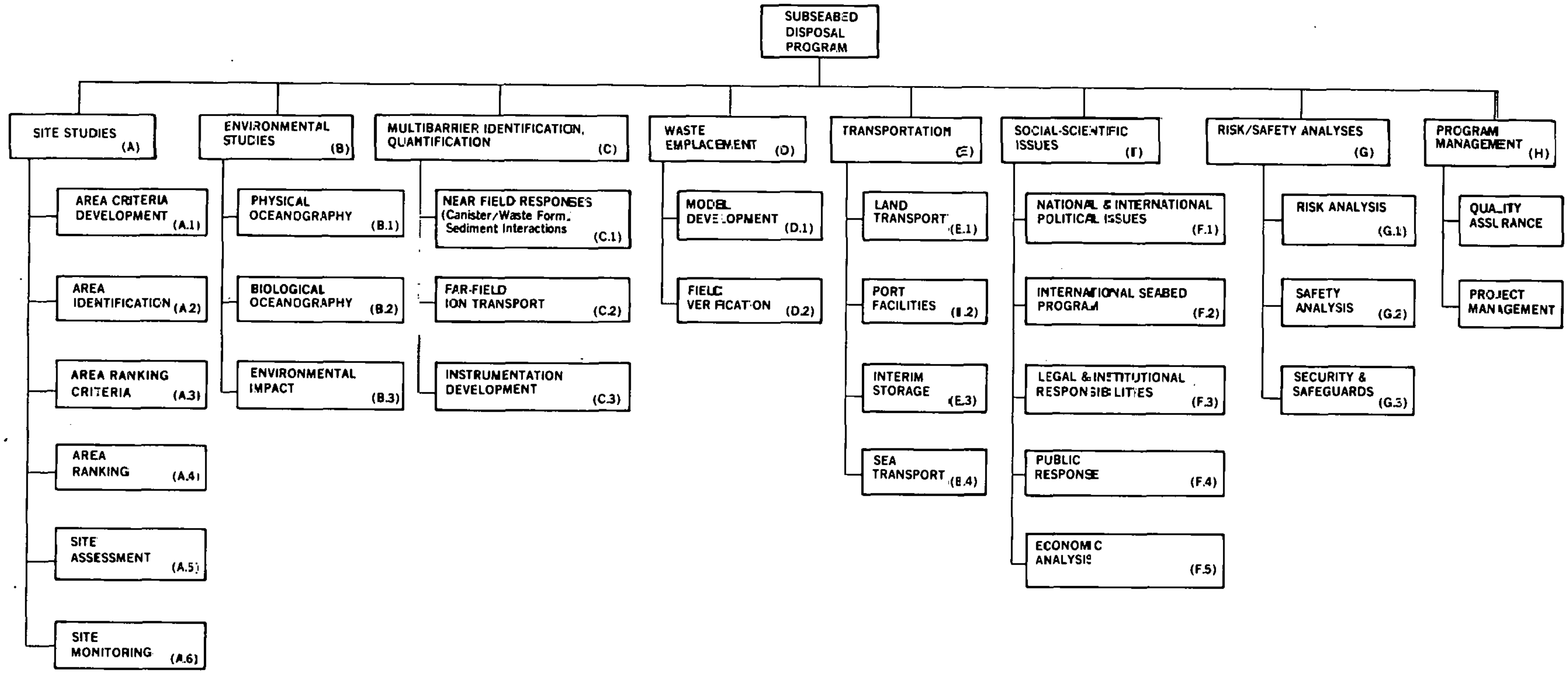

Figure I-12 Master Program Work Breakdown Structure

PART II: TASK GROUP REPORTS

EXECUTIVE COMMITTEE

Participants

D. Glen Boyer (USA), Chairman
G. Vilks (Canada)
A. Barbreau (France)
R. Ichikawa (Japan)
F. S. Feats (UK)
B. J. Collette (Netherlands), Advisor
D. R. Anderson (USA), Task Group Coordinator & Scientific Secretariat
F. Gera (NEA), Secretariat

Observers

C. N. Murray (CEC)
W. Feldt (Germany)
M. Sturm (Switzerland)

Introduction

The objectives of the Seabed Working Group Executive Committee meeting were (1) to review the national trends and policies regarding seabed disposal of radioactive wastes, the structure of the SWG and its Task Groups, and the objectives of the SWG over the next three years, and (2) to recommend the date and location for the next meeting of the SWG.

Discussion and Recommendations

The representative from each country summarized the national trends and policies regarding seabed disposal of radioactive waste. In general the seabed disposal concept is being considered as a possible alternative to land-based disposal. The amount of effort each country is putting into the assessment of seabed disposal is small in comparison to the total efforts being made to identify acceptable geological formations on land.

However, as special interest groups and individuals continue to express social and technical concerns about exploration and research leading to land disposal, each national representative indicated a strong need to continue to evaluate the technical and environmental feasibility of the seabed disposal concept.

The Committee concluded that the following roles and objectives of the SWG and its Task Groups are being met:

- To provide a forum for discussion, assessment of progress and planning of future efforts;
- To coordinate research vessel cruises and experiments;
- To share facilities and test equipment;
- To exhange information; and
- To maintain cognizance of international policy issues.

The structure of the SWG and its Task Group was reviewed:

- The SWG charter, as submitted to NEA following the Fourth Annual SWG Meeting (Albuquerque, March 1979), continues to be acceptable to NEA and to the SWG members.
- The SWG report is prepared by the SWG Task Group Coordinator. For report identification purposes it will continue to be issued with a Sandia National Laboratories report number. The title page will identify the work as the OECD/NEA Seabed Working Group Report to the NEA Radioactive Waste Management Committee. The disclaimer clause will state that the work is being funded by the individual SWG member countries.
- New members of the SWG will be encouraged to join through NEA. Member countries must have a funded program to assess the seabed disposal concept and be approved by their governments and sanctioned by their national representatives to the NEA Radioactive Waste Management Committee.
- Lead correspondents for each Task Group are selected by the members of the specific Task Group. It is expected that the lead correspondent will change from time to time. For example, G. de Marsily (France) was selected as the Lead Correspondent of the System Analysis Task

Group to replace G. Webb (UK), and D. Rancon (France) was selected as the Lead Correspondent of the Sediment and Rock Task Group to replace J. Lewis (UK), with T. Francis (UK) as Acting Lead Correspondent during the Fifth Annual SWG Meeting.

- The national representative to the SWG Executive Committee will designate the national members of each of the Task Groups. Any other individuals from SWG member countries attending Task Group meetings will be called "participants."

- A nonmember country may be invited by the SWG to attend as an "observer", with the concurrence of that country's national representative to the NEA-RWMC.

- Task Group Lead Correspondents are responsible for the effective exchange of information and cooperation within their own Task Groups, preparation of the Task Group reports, and identification of intra-Task Group needs.

- The SWG Task Group Coordinator (D. R. Anderson, USA) is responsible for overall coordination and data exchange between Task Groups within the framework of the SWG and for keeping the SWG informed.

- The Executive Committee decided to combine the Canister and Waste Form Task Groups. An Engineering Studies Task Group was established to begin the coordination of conceptual design and engineering studies of seabed disposal emplacement, and to identify objectives and criteria for laboratory and field test experiments.

- Each Executive Committee member is to designate a member to the Engineering Studies Task Group as soon as possible, and inform the SWG Chairman, with copies to NEA (Gera) and the Task Group Coordinator (Anderson). The Task Group Coordinator will take the lead in organizing the first Engineering Task Group meeting prior to the next SWG meeting.

- Consideration was given to establishing a Legal and Institutional Task Group. It was concluded that the SWG would at this time continue to keep the exchanges on a scientific level. In addition, there exists another NEA group which is assessing legal and institutional issues of waste management. The subject will be reviewed again at the next SWG meeting.

Retrievability was briefly addressed, and the Executive Committee concluded that the various concepts being considered by the individual countries were addressing radioactive waste seabed "disposal" rather than "storage." Therefore, retrievability as such was not a design objective. However, options for canister recovery on accident or from improper emplacement will need to be assessed.

An outline of objectives for the SWG over the next three years was discussed and established as follows:

- Exchange data on the North Pacific and North Atlantic study areas resulting from the planned national and cooperative research vessel cruises, e.g., Japan/USA to the North Pacific and Netherlands, and France, Canada, UK, and Germany to the North Atlantic.
- Compare properties of sediments resulting from laboratory and field tests, e.g., thermal, physical, and chemical.
- Complete sensitivity analysis of parameters assumed for the System Analysis models and revise the model assumptions based on newly acquired laboratory and field data.
- Define specific problem areas and objectives, such as reconsolidation of disturbed bottom sediment resulting from emplantation, and devise laboratory and field experiments to verify model assumptions.
- Initiate engineering studies of seabed disposal concepts and develop field test objectives and conditions in the laboratory and the field to demonstrate the engineering assumptions.
- Begin to scope and consider emplacement of long-term field tests, i.e., 10 yr or more.

The next meeting date was set for February 2-5, 1981, in France. A. Barbreau (France) and F. Gera (NEA) will determine the location. This date must remain firm to avoid conflicts with scheduled research vessel cruises and other commitments by the SWG members, participants, and observers.

SYSTEM ANALYSIS TASK GROUP

Participants

G. de Marsily (France), Lead Correspondent
D. M. Talbert (USA)
F. van Dorp (Netherlands)
G. Vilks (Canada)
G. A. M. Webb (UK)

Observers

M. D. Hill (UK)
C. N. Murray (CEC)
J. G. Shepherd (UK)
F. E. Taylor (UK)

Introduction

The System Analysis Task Group held an interim mid-year meeting in Fontainebleau, France, October 15-19, 1979. The report of this meeting (Attachment A) contained a number of recommendations on inter-Task Group meetings and on the structure of the annual Seabed Working Group meeting. The report was sent to members of the Executive Group and lead correspondents of other Task Groups. The structure of the Bristol Seabed Working Group meeting was largely based on the recommendations of this interim report. The most important task at this meeting was seen once again as encouraging and taking part in the joint meetings between other task groups. The program for the next year was also clarified, leading to the adoption of an overall model of the system and the production of a paper for the symposium mentioned in the "Future Work" section of this report.

Discussions With Other Task Groups

Members of the SATG attended a number of meetings with other task groups, mainly in the context of obtaining comment on the Base Case

Scenario and the models presented in Tables A-1 and A-2 of the interim report (Attachment A). In particular, we met with the Waste Forms/ Canisters Groups, the Waste Forms/Canister/Sediment and Rock Groups, and the Sediment and Rock/Physical Oceanography/Biology Groups. Some members attended meetings with the Site Selection, Biology and Physical Oceanography Groups. As a result of these discussions, we received written suggestions for the modelling and the parameters of the models from the Waste Form and Physical Oceanography Task Groups, reproduced in their report of the Bristol meeting.

We also revised our Base Case Scenario and included the ranges of parameters shown in Table II-1.

The Biology Task Group proposed several models of biological transport pathways to man (see their report to the Bristol Meeting) and agreed to provide the SATG with numbers for these models within two months.

Future Work

The objectives of the SATG, as set out in the report of the March 1978 meeting in Albuquerque, included the preparation of a complete model of the system, incorporating appropriate models for the system elements, and the use of this model (via sensitivity analysis) to identify the more important research areas. During discussions, it became clear that this objective should be accomplished rapidly, since many Task Groups need information from this approach. The SATG therefore agreed to work toward this during the coming year. It was apparent that a complete set of simple models would be developed by the UK during this year and that different models for some system elements are already available and will be used in the USA and France. The SATG would use these models in appropriate combinations with the aim of producing initial results by the next meeting of the Seabed Working Group.

Table II-1

Base Case Scenario Parameters and Values

System Element	Base Case Values	Range for Initial Sensitivity Analysis
Waste Form/Canister		
Power generation	1000 GW(e)y	
Reactor type	LWR	
Burnup	33 000 MWd t^{-1}	
Reprocessing	Purex process 360 days ex-reactor 0.5% Pu and U lost to HLW stream All Tc assumed to be in waste, I assumed to be in similar waste form	
Waste form	Borosilicate glass 10% by weight fission product oxides Density 2.5 gcm^{-3} Volume glass per canister 0.2 mg^3	5-20%
Interim storage	50 yr	10-100 yr
Canister dimensions	3 m long x 0.3 m diameter 2.5 m long x 0.5 m diameter	
Mean canister life	500 yr after emplacement	100-10^4 yr
Number of canisters		
Radionuclide release rate	Temperature dependent leach rate model (see Waste Form Management Task Group section of this report)	

Table II-1 (cont)

System Element	Base Case Values	Range for Initial Sensitivity Analysis
Disposal Medium		
Medium*	Uniform isotropic fine grained sediment	
	Porosity 75% by volume	50-90%
	Permeability 10^{-7} cms^{-1}	10^{-5}-10^{-9} cms^{-1}
	Molecular diffusion constant $1 \times 10^{-9} m^2 s^{-1}$	
	Bulk density 1.4 gcm^{-3}	1.2-1.7 gcm^{-3}
	Thermal conductivity 0.78 W m^{-1} $°K^{-1}$	
	Solids heat capacity 2.3×10^3 kJ m^{-3} $°K^{-1}$	
	pH 7.2-8.2 (undisturbed)	
Burial depth	30 m	10-100 m
Total sediment thickness	60 m	20-200 m
Canister spacing	100 m centers	10-100 m
Benthic Boundary Layer		
Thickness	0	
Transfer function	1	

*Parameters and their ranges are not independent in the case of the disposal medium.

Table II-1 (cont)

System Element	Base Case Values	Range for Initial Sensitivity Analysis
Water Column*		
Ocean structure	Uniform horizontally	
	Vertically 2 layers (surface down to 1 km uniformly mixed)	
	Overall depth 5 km	4.5-6 km
	Volume 10^{17} m^3	
Diffusion	Fickian Vertical eddy diffusion coefficient 10 cm^2s^{-1}	10^{-1} - 10^2 cm^2s^{-1}
	Horizontal eddy diffusion coefficient 3 x $10^6 cm^2s^{-1}$	10^5 - $10^8 cm^2s^{-1}$
Advection	Vertical velocity zero Horizontal velocity 5 cms^{-1}	1 - 10 cms^{-1}
Biological Transport (see Attachment C)		
Dose to Man		
Dosimetry	ICRP Publications 26 and 30	
Pathways and intake assumptions	IAEA Technical Report 211 and Attachment C	
Calculation aim	Maximum future annual effective dose equivalents to individuals and annual collective effective dose equivalents (as a function of time)	
Dose to Fauna		
No decision on parameters		

*See also Table II 3 and Fig. II-12 in the Physical Oceanography section of this report.

It was agreed that an interim meeting would again be needed and that it would take place at NRPB in the UK on September 22-26, 1980. Some representatives of other Task Groups would be invited to part of the interim meeting. The report of this interim meeting will be sent to lead correspondents of other Task Groups for comment and transmission.

The SATG discussed the provisional abstract of a paper which had been submitted to the IAEA/NEA Symposium on Radioactive Waste Disposal in the Marine Environment, Vienna, October 6-10, 1980. It was agreed that the authorship of this paper should reflect contributions to the work of the SATG, especially at the last interim meeting and the present meeting, and should include members and observers as appropriate. The list of authors was revised to de Marsily, Hill, Murray, Talbert, van Dorp, and Webb.

ATTACHMENT A

Systems Analysis Task Group
Report on Interim Meeting at Fontainbleau, France
October 15-19, 1979

Task Group Members

G. A. M. Webb (UK) Lead Correspondent
G. de Marsily (France)
D. M. Talbert (USA)
N. Murray (CEC)

In Attendance

M. D. Hill (UK)*
F. Van Dorp (Netherlands)*
M. D'Allessandro (CEC)*
M. Sibuet (France)**
Y. Belot (France)**

Apologies for Absence Received From

H. Kasukawa (Japan)*
H. Tammemagi (Canada)*

Introduction

The purpose of the second interim meeting was to address the items listed under the "Future Work" in the report of the Systems Analysis Task Group (SATG) prepared at the International Seabed Working Group (SWG) meeting in Albuquerque, March 1979. The items considered were the development of base-case scenarios, identification of type models for each element of the system analysis model, and a probabilistic/deterministic model for singular events.

Some time was devoted to a discussion of the status of relevant modelling work in the national programs as reported by SATG members.

*Invited to attend the entire Task Group Meeting.
**Members of Biological Task Group invited to attend one day of the Task Group Meeting.

The SATG members decided to prepare a paper for the IAEA/NEA International Symposium on Disposal of Radionuclides in the Marine Environment, Vienna, Austria, October 6-10, 1980 (Attachment B).

This paper makes recommendations on the interactions between other Task Groups. These interactions are considered useful in addressing particular problems, and they should be scheduled for the next International SWG meeting in March 1980.

It was decided that, in principle, the lead correspondent should change from time to time so that the original objective of the Task Groups to act as informal discussion groups should not be lost in a too-formalized structure. The SATG unanimously decided that G. de Marsily should replace G. Webb as lead correspondent from the meeting in March 1980.

Development of a Base Case Scenario

Parameters

The development of base case situations for the overall systems analysis model was identified as an important task during the meeting of the SATG at the 1979 Albuquerque SWG meeting. To this end the SATG has chosen a set of parameters to define an initial base case scenario. These parameters are presented simply as a list at this time and are given in Table A-1.

It is the intention of the SATG to use the chosen set of parameters together with the generic models described in the Generic Models section to proceed with the development of our overall system model and to stimulate the development of more suitable subsystem models by the other task groups.

The incompleteness of the table of parameters and somewhat arbitrary nature of the assumed values is recognized by the SATG. It is anticipated that a significant refinement of the set of parameters will occur as the scenario is applied; necessary additions and adjustment will be made during the initial stages of use. The members of the group also wish to encourage other members of the SWG to criticize and suggest improvements to the parameter list.

Table A-1

Base Case Scenario Parameters and Values

Parameters	Values
Waste Form/Canister	
Power generation	1000 GW(e)y
Reactor type	LWR
Burnup	33 000 MWd t^{-1}
Reprocessing	90 days ex-reactor
	Purex process 99.5% Pu and U Iodine assume to be included in waste form
Waste form	Borosilicate glass 20% by weight waste loading
	Density 2.5 gcm^{-3}
	Volume 0.2 m^3
Interim storage	50 yr
Canister dimenions	3 m long x 0.3 m diameter
Canister life	100 yr after emplacement
Radionuclide release	Uniform rate over 1000 yr
Disposal Medium	
Medium	Uniform isotropic red clay
	Porosity 75% by volume

Table A-1 (cont)

Parameters	Values
Medium (cont)	Permeability 9×10^{-3} m day^{-1}
	Molecular diffusion constant $1 \times 10^{-9} m^2 s^{-1}$
	Bulk density 1.4 gcm^{-3}
	Thermal conductivity 0.78 W m^{-1} $°K^{-1}$
	Solids heat capacity 2.3×10^3 kJ m^{-3} $°K^{-1}$
Burial depth	30 m
Total sediment thickness	60 m
Canister spacing	100 m centers
<u>Benthic Boundary Layer</u>	
Thickness	0
Transfer function	1
<u>Water Column</u>	
Ocean structure	Horizontal uniform
	Vertically 2 layers, surface down to 1 km
	Overall depth 5 km
	Volume 10^{17} m^3

Table A-1 (cont)

Parameters	Values
Diffusion	Fickian Vertical eddy diffison coefficient 10 cm^2s^{-1} Horizontal eddy diffusion coefficient 3 x $10^6 cm^2s^{-1}$
Advection	Vertical velocity zero Horizontal velocity 5 cms^{-1}
Biological Transport	
No decision on parameters	
Dose to Man	
Dosimetry	ICRP Publications 26 and 30
Pathways and intake assumptions	IAEA Technical Report 211
Calculation aim	Maximum future annual effective dose equivalents to individuals
Dose to Fauna	
No decision on parameters	

Generic Models

In order to proceed with the development of an overall system model the SATG has reviewed the generic models currently available. These are described in Table A-2.

Table A-2

Generic Models for System Elements

System Element*	Generic Model Type	Examples of Models Available
Waste form/canister	Waste form:	
	Diffusion	Many models available[1-5]
	Constant leach rate per unit surface area	
	Constant release rate	
	Canister: delay time model	Mean delay time and arbitrary distribution around mean can be assumed
Near waste environment (defined as the volume of disposal medium within the maximum 100°C isotherm)	Capable of prediction of radionuclide migration under the influence of coupled heat and water flow	SWIFT[6] TRISOPAR[7]
Disposal medium transport	Molecular diffusion, sorption and radioactive decay (including chain decay)	Many models available[1,6-8]
Benthic boundary layer transport	None identified	None available. Flux of radionuclides from disposal medium assumed equal to flux entering water column
Physical oceanographic transport	Diffusion, advection	"Shepherd model"[9]

*See previous report of Systems Analysis Task Group.

Table A-2 (cont)

System Element	Generic Model Type	Available
Biological oceanographic transport	None identified	Upward flux of biomass assumed equal to downward flux (concentrations of radionuclides in organisms derived from existing data on shallow water systems)
Dose/effects on man	Exposure pathways: IAEA publications	Ref 10
	Dosimetry: models currently recommended by ICRP	Refs 11, 12
Dose/effects on fauna	None identified	
Emplacement method		Model under development at Sandia Labs

References for Table A-2

[1]M. D. Hill and P. D. Grimwood, Preliminary Assessment of the Radiological Protection Aspects of Disposal of High-Level Waste in Geologic Formations, Report NRPB-R69 (1978).

[2]F. Laude, Le Verre Comme Premiere Barriere Pour le Stockage a Long Terme des Dechets de Haute Activite, Proc. NEA/CEC Workshop on Risk Analysis and Geologic Modelling in Relation to the Disposal of Radioactive Wastes Into Geological Formations, Ispra, May 23-27, 1977.

[3]F. Girardi, G. Bertozzi, and M. D'allessandra, Long-Term Risk Assessment of Radioactive Waste Disposal in Geological Formations, CEC Report EUR-5902 (1978).

References for Table A-2 (cont)

[4]KBS (Karnbranslesakerhet) Project, Handling of Spent Nuclear Fuel and Final Storage of Vitrified High-Level Reprocessing Waste, Stockholm (1977).

[5]KBS Project, Handling and Final Storage of Unreprocessed Spent Nuclear Fuel, Stockholm (1978).

[6]Intera Enironmental Consultants, Inc., Development of Radioactive Waste Migration Model, Document prepared for Sandia Laboratories (1977).

[7]P. Goblet, E. Ledoux, and G. de Marsily, Etudes des Modalites de Transfert des Produits Radioactifs dans L'Environment, Ecole Nationale Superieure des Mines de Paris Report LHM/RC/78/5 (1978).

[8]P. Bo., Column, Numerical Solution of Migration Equations Involving Various Physico-Chemical Processes, Riso National Laboratory Report (1978).

[9]J. G. Shepherd, A Simple Model for the Dispersion of Radioactive Wastes Dumped on the Deep-Sea Bed, MAFF Fisheries Research Technical Report No. 29 (1976).

[10]IAEA, The Radiological Basis of the IAEA Revised Definition and Recommendations Concerning High-Level Radioactive Waste Unsuitable for Dumping at Sea, IAEA-211 (1978).

[11]ICRP Publication 26 (1977).

[12]ICRP Publication 30 (1979).

Singular Events and Probability Analysis

The SATG recognized at the 1978 SWG meeting the need to consider singular events, their probability of occurrence, and their consequences.

A number of singular events were identified. These were grouped according to the affected parameter of the overall system model. These parameters are listed below:

- Sediment thickness: Many events could lead to changes in sediment thickness.
- Canister delay time: Many events could occur to decrease this.

- Release rate: Thermal, physicochemical reactions with sediment could cause changes in the release rate.

- Properties of sediment: Unforeseen interactions between waste and sediment could cause changes in some of these parameters.

It is proposed that possible events leading to alterations in these parameters be defined by categories. On the basis of experience in assessing the reliability of geological waste disposal in continental formations, processes such as faulting, magmatic occurrences, and erosion, have been identified as possibly being amenable to probability analysis. A study will thus be made to identify those categories suitable for probabilistic assessment in the case of disposal in deep-ocean formations.

<u>Proposed Paper for the International Atomic Energy Agency/NEA Symposium on Radioactive Waste Disposal in the Marine Environment, Vienna, October 6-10, 1980</u>

The SATG decided to submit a Task Group paper to the IAEA/NEA symposium (Attachment B). The proposed paper will outline the concept of deep-ocean disposal and the application of systems analysis. The system model developed within the framework of the International Seabed Working Group to consider the necessary inputs and outputs between different system elements compartments will be presented. An example of the model development in national programs will be given and areas which require more detailed study indicated.

Recommendations to the Seabed Working Group Executive

Emerging from their discussions with each of the other Task Groups at the Meeting in Albuquerque in March 1979, the SATG concluded that more time should be allowed for exchanges between Task Groups of future meetings. All the groups recognized the need for such exchanges. The SATG discussed this matter further and recommended that time be set aside at the International Seabed Working Group meeting in March 1980 for the following specific intergroup meetings:

- Waste Form/Canister Groups - to discuss the Base Case Scenario assumptions.
- Canister/Sediment and Rock Groups - to discuss the near waste environment with particular emphasis on the input - output requirements 4 and 5 as shown in the overall system analysis model in the report of March 1979 Seabed Working Group meeting.
- Sediment and Rock/Physical Oceanography/Biology Groups - to discuss the benthic boundary layer transport mechanisms and responsibility for further progress in this area.

It appears to the SATG that the discussions within the individual task groups would be focused more clearly if the SATG had an opportunity, early in the March 1980 Seabed Working Group meeting, to present the conclusions of their interim meeting on the base case scenario, generic models for system elements, and probabilistic analysis. The SATG recommends that this presentation should form the introduction to an early round table discussion.

ATTACHMENT B

Systems Analysis Approach to the Disposal of High Activity Waste in Deep Ocean Sediments*

G. de Marsily, M. D. Hill, C. N. Murray, D. M. Talbert, F. van Dorp, and G. A. M. Webb

ABSTRACT

Among the different options being studied for the final disposal of high-level solidified waste, increasing attention is being paid to the emplacement of glasses containing the radioactive elements in deep oceanic sediments. Such a concept has an advantage in that areas under investigation such as mid-plate/mid-gyre regions of the oceans appear relatively unproductive biologically and relatively devoid of cataclysmic events; natural processes there are quite slow. Thus because of the stability and predictability of the environment, a set of barriers against the dispersion of the radioisotopes can be defined.

Task groups set up in the framework of the International Seabed Working Group are studying all aspects of this option and have been carrying out conceptual design, laboratory, and in-situ work since 1976. In order that the various component elements be investigated within an integrated framework, the concept of systems analysis has been applied to this option. In the present article the System Analysis Task Group reports the development of an overall system model for the assessment of possible consequences of the emplacement of high-level waste in deep oceanic sediments.

System analysis provides an overview of the entire problem structure and of the interactions between various problem elements. A major responsibility of the System Analysis Task Group is to ensure that other task

*Submitted to the IAEA/NEA Symposium on Radioactive Waste Disposal in the Marine Environment, Vienna, October 6-10, 1980.

groups have identified all assessment requirements and are producing necessary parameters to feed into the complete system. This will be done by an iterative process in which a preliminary analysis and a sensitivity analysis are used to identify the parameters and data of most importance. These studies will form the basis by which the Seabed Working Group can direct overall progras of the task groups. The other task groups should then focus on these parameters and data so that improved results can be fed back into the overall systems model. The process will be repeated until the predictions of the system model achieve the required precision and confidence.

The major requirement for the development of a systems analysis model needed as a first step for a complete study, is that the problem be separated into identified elements and that the interfaces between the elements be clearly defined. The model that has been initially evolved is a deterministic one, and describes the problem elements involved in arriving at the estimates of effects on man. Estimates of the effects on faunal species will also be needed for subsequent decisions on the overall feasibility of the system. The system elements identified at present are the following:

- Waste definition - the quantity and composition of waste to be disposed of.
- Site selection - the generic or specific site information required as input to system elements.
- Waste form and canister - the initial physical and chemical form of the waste.
- Near waste environment - the region considered to reach to the limit of mineralogical alterations caused by radiation and temperature fields of the waste.
- Disposal medium - the geological medium surrounding the canisters.

- Benthic boundary layer - the interaction of chemical, biological, and physical processes on the movement of radiological and chemical activity across the sediment-water interface.

- Physical oceanographic model - the physical (water) transport mechanism of dissolved species and suspended sedimentary particles on a regional/global scale.

- Biological oceanographic model - the biological transport mechanisms, including uptake and loss pathways, recycling, and transfer between different trophic levels within the water column.

- Doses and effects on faunal species - the estimates of the radiation dose to faunal species both in the disposal site and throughout the oceanic region are required. Assessment of the impact of these doses on faunal species should be attempted for comparison with their impact upon man.

- Doses and effects on man - the calculating of individual and collective doses through all exposure pathways. The generic and somatic effects of these doses are determined using an agreed dose-response relationship.

The model developed by the Systems Analysis Task Group will be described in detail and the necessary inputs and outputs between elements are given.

In order that the initial iteration of the model can be undertaken it is important that base case situations are developed. The use of chosen set of parameters, together with the generic models describing the system elements, should stimulate the development of more suitable subsystem models. An example of the model developments in national programs is given and areas which require more detailed study indicated.

Parallel to the base case systems analysis model there is a clearly defined need to consider singular events, their probability of occurrence and the consequences; these are briefly discussed.

Attachment C

Biological Transport

Table C-1

Inventory of the Longer Lived Radionuclides in High Level Waste Approximately 50 Years After Reprocessing

Radionuclide	Radioactive Half-Life (yr)	Activity in Waste (Bq)
Fission products:		
^{79}Se	6.5×10^{4}	1.28×10^{10}
^{87}Rb	4.7×10^{10}	7.52×10^{5}
^{90}Sr	28.6	7.71×10^{14}
^{93}Zr	1.5×10^{6}	1.02×10^{11}
^{94}Nb	2.0×10^{4}	4.44×10^{6}
^{99}Tc	2.1×10^{5}	4.05×10^{11}
^{107}Pd	6.5×10^{6}	3.83×10^{9}
^{113m}Cd	13.6	7.94×10^{10}
^{121m}Sn	50.0	2.47×10^{9}
^{126}Sn	1.0×10^{5}	1.81×10^{10}
^{129}I	1.6×10^{7}	9.83×10^{9}
^{135}Cs	2.3×10^{6}	8.95×10^{9}
^{137}Cs	30.2	1.16×10^{15}
^{147}Sm	1.1×10^{11}	1.12×10^{5}
^{151}Sm	90.0	2.65×10^{12}
^{152}Eu	12.4	1.22×10^{9}
^{154}Eu	16.0	5.54×10^{12}

Table C-1 (cont)

Radionuclide	Radioactive Half-Life (yr)	Activity in Waste (Bq)
Heavy Isotypes:		
^{210}Pb	22.3	1.05×10^4
^{226}Ra	1600.0	2.06×10^4
^{228}Ra	5.75	0.96
^{227}Ac	21.8	4.88×10^5
^{228}Th	1.91	4.89×10^3
^{229}Th	7340.0	5.72×10^3
^{230}Th	7.7×10^4	1.10×10^6
^{232}Th	1.4×10^{10}	0.98
^{231}Pa	3.2×10^4	6.09×10^5
^{232}U	71.7	4.76×10^5
^{233}U	1.6×10^5	1.70×10^6
^{234}U	2.5×10^5	9.88×10^8
^{235}U	7.1×10^8	3.25×10^6
^{236}U	2.4×10^7	4.37×10^7
^{238}U	4.5×10^9	5.85×10^7
^{237}Np	2.1×10^6	7.85×10^9
^{238}Pu	87.8	4.92×10^{12}
^{239}Pu	2.4×10^4	5.36×10^{10}
^{240}Pu	6540.0	2.18×10^{11}
^{241}Pu	14.8	2.49×10^{12}
^{242}Pu	3.9×10^5	4.77×10^8
^{241}Am	433.0	7.62×10^{12}

Table C-1 (cont)

Radionuclide	Radioactive Half-Life (yr)	Activity in Waste (Bq)
Heavy Isotyes (cont)		
^{242m}Am	152.0	2.24×10^{11}
^{243}Am	7380.0	7.23×10^{11}
^{243}Cm	28.5	1.75×10^{11}
^{244}Cm	18.1	9.94×10^{12}
^{245}Cm	8500.0	5.56×10^{9}
^{246}Cm	4730.0	1.00×10^{9}
^{247}Cm	1.6×10^{7}	2.86×10^{3}
^{251}Cf	898.0	1.96×10^{3}

NOTES:
1. 1 Bq = 2.703×10^{-11} Ci.
2. Activities are given for 1 t fuel.
3. Fuel required to generate 10^3 GW(e)y = 3.35×10^4 t.

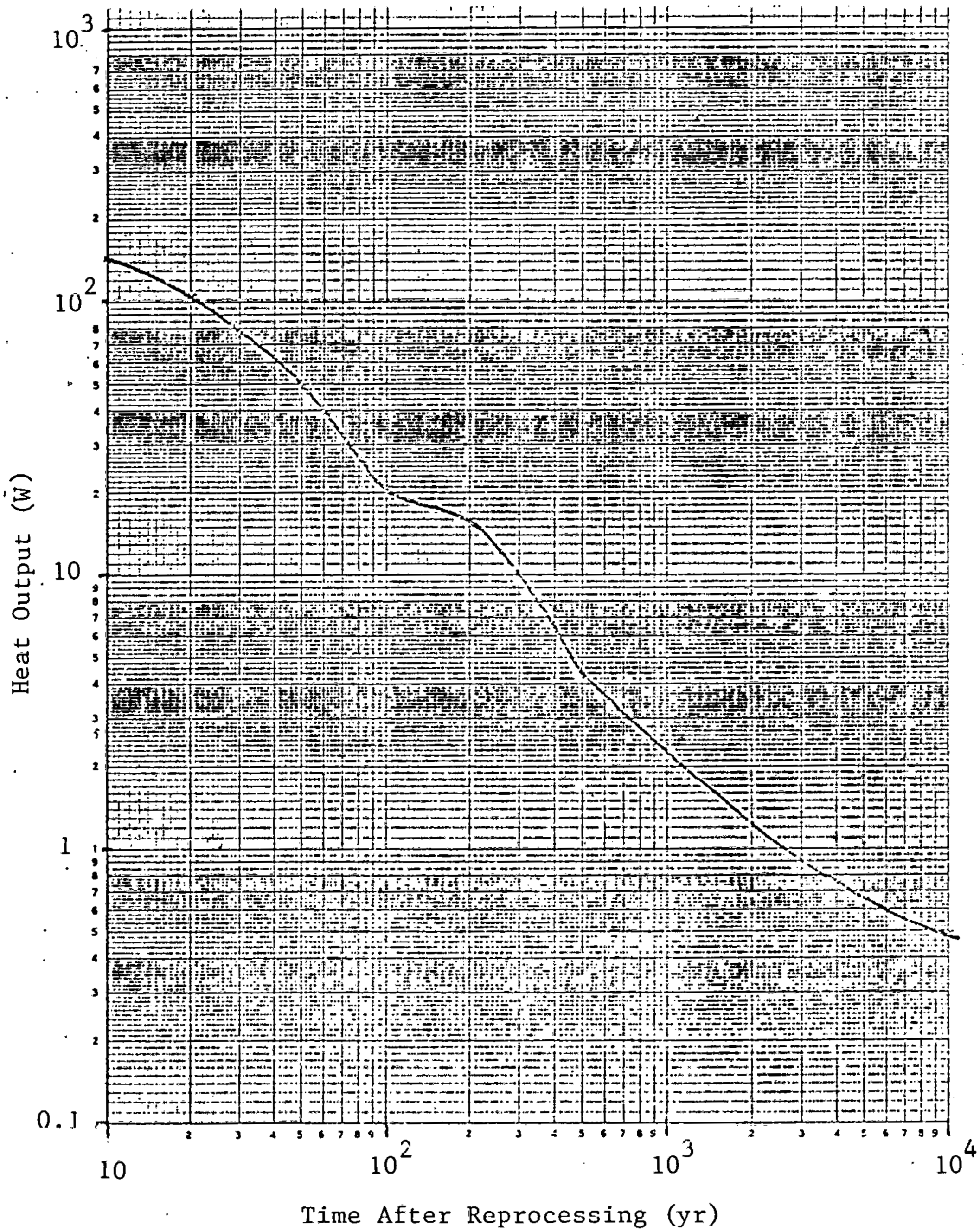

Figure C-1 Heat Output of Waste From 1 t LWR Fuel

Table C-2

Commited Effective Dose Equivalents per Unit Intake by Ingestion

Nuclide	Effective Dose Equivalent per Unit Activity Ingested (Sv Bq^{-1})	Nuclide	Effective Dose Equivalent per Unit Activity Ingeste (Sv Bq^{-1})
^{210}Pb	9.7×10^{-7}	^{240}Pu	1.2×10^{-7}
^{212}Pb	6.7×10^{-9}	^{241}Pu	2.4×10^{-9}
^{210}Bi	1.5×10^{-9}	^{242}Pu	1.1×10^{-7}
^{210}Po	4.4×10^{-7}	^{241}Am	6.0×10^{-7}
^{223}Ra	1.7×10^{-7}	^{242m}Am	7.0×10^{-7}
^{224}Ra	9.2×10^{-8}	^{242}Am	3.3×10^{-10}
^{225}Ra	9.5×10^{-8}	^{243}Am	6.0×10^{-7}
^{226}Ra	4.0×10^{-7}	^{242}Cm	1.8×10^{-8}
^{228}Ra	3.5×10^{-7}	^{243}Cm	4.0×10^{-7}
^{225}Ac	2.3×10^{-8}	^{244}Cm	3.0×10^{-7}
^{227}Ac	5.0×10^{-7}		
^{227}Th	1.0×10^{-8}	^{245}Cm	6.2×10^{-7}
^{228}Th	1.1×10^{-7}	^{246}Cm	6.2×10^{-7}
^{229}Th	9.6×10^{-7}	^{247}Cm	5.6×10^{-7}
^{230}Th	1.4×10^{-7}	^{248}Cm	2.4×10^{-6}
^{231}Th	4.2×10^{-10}	^{251}Cf	6.4×10^{-7}
		^{79}Se	7.1×10^{-10}
^{232}Th	7.4×10^{-7}	^{90}Y	2.7×10^{-9}
^{234}Th	3.7×10^{-9}	^{90}S	3.3×10^{-8}
^{231}Pa	4.6×10^{-5}	^{93}Z	2.6×10^{-10}

Table C-2 (cont)

Nuclide	Effective Dose Equivalent per Unit Activity Ingested ($Sv\ Bq^{-1}$)	Nuclide	Effective Dose Equivalent per Unit Activity Ingested ($Sv\ Bq^{-1}$)
^{233}Pa	1.1×10^{-9}	^{93m}Nb	1.1×10^{-10}
^{232}U	4.2×10^{-7}	^{99}Tc	2.5×10^{-10}
^{233}U	8.6×10^{-8}	^{107}Pd	4.2×10^{-11}
^{234}U	8.4×10^{-8}	^{113m}Cd	4.4×10^{-8}
^{235}U	7.9×10^{-8}	^{121m}Sn	5.5×10^{-10}
^{236}U	8.0×10^{-8}	^{126}Sn	4.4×10^{-9}
^{237}U	9.0×10^{-10}	^{126m}Sb	2.1×10^{-11}
^{238}U	7.5×10^{-8}	^{126}Sb	2.7×10^{-9}
^{237}Np	1.1×10^{-5}	^{129}I	9.9×10^{-8}
^{238}Np	2.0×10^{-9}	^{135}Cs	2.0×10^{-9}
^{239}Np	1.0×10^{-9}	^{137}Cs	1.4×10^{-8}
^{238}Pu	1.0×10^{-7}	^{151}Sm	8.2×10^{-11}
^{239}Pu	1.2×10^{-7}	^{152}Eu	1.2×10^{-9}
		^{154}Eu	1.9×10^{-9}

Table C-3

Mean γ Energies per Disintegration

Nuclide	Mean γ Energy (MeV) per Disintegration	Nuclide	Mean γ Energy (M per Disintegratio
^{210}Pb	2×10^{-3}	^{241}Pu	5×10^{-6}
^{212}Pb	1	^{242}Pu	0
^{210}Bi	0	^{241}Am	2×10^{-2}
^{210}Pu	9×10^{-6}	^{242m}Am	3×10^{-4}
^{223}Ra	7×10^{-1}	^{242}Am	5×10^{-2}
^{224}Ra	1×10^{-2}	^{243}Am	5×10^{-2}
^{225}Ra	1×10^{-2}	^{242}Cm	3×10^{-5}
^{226}Ra	2	^{243}Cm	1×10^{-1}
^{228}Ra	7×10^{-1}	^{244}Cm	1×10^{-5}
^{225}Ac	5×10^{-1}	^{245}Cm	4×10^{-2}
^{227}Ac	2×10^{-3}	^{246}Cm	0
^{227}Th	9×10^{-2}	^{247}Cm	4×10^{-1}
^{228}Th	2×10^{-3}	^{248}Cm	0
^{229}Th	3×10^{-2}	^{251}Cf	4×10^{-2}
^{230}Th	2×10^{-3}	^{79}Se	1×10^{-4}
^{231}Th	2×10^{-2}	^{90}Y	3×10^{-4}
^{232}Th	3×10^{-4}	^{99}Tc	0
^{234}Th	3×10^{-2}	^{90}Sr	0
^{231}Pa	3×10^{-2}	^{93}Zr	7×10^{-3}
^{233}Pa	2×10^{-1}	^{93m}Nb	3×10^{-2}
^{232}U	2×10^{-4}	^{107}Pd	1×10^{-4}
^{233}U	8×10^{-4}	^{113m}Cd	1×10^{-1}

Table C-3 (cont)

Nuclide	Mean γ Energy (MeV) per Disintegration	Nuclide	Mean γ Energy (M per Disintegratio
^{234}U	7×10^{-4}	^{121m}Sn	2×10^{-1}
^{235}U	1×10^{-1}	^{126}Sn	5×10^{-2}
^{236}U	0	^{126m}Sb	1
^{237}U	1×10^{-1}	^{126}Sb	3
^{238}U	4×10^{-5}	^{129}I	0
^{237}Np	3×10^{-2}	^{135}Cs	1×10^{-4}
^{238}Np	6×10^{-1}	^{137}Cs	0
^{239}Np	1×10^{-1}	^{151}Sm	4×10^{-4}
^{238}Pu	3×10^{-3}	^{152}Eu	6×10^{-1}
^{239}Pu	2×10^{-4}	^{154}Eu	1
^{240}Pu	2×10^{-5}		

The values assumed for consumption rate for each pathway are shown in Table C-4.

Table C-4

Seafood Consumption Rates

Pathway	Consumption Rate (g/day)
Fish	600
Crustacea	100
Molluscs	100
Seaweed	300
Plankton	30

The fish pathway includes all mobile fish species, whether pelagic or benthic, since the water concentrations produced by the oceanographic basis are specifically intended to cover all these possibilities. The concentration factors used are for fish flesh and the consumption rate chosen is intended to accommodate critical groups in all areas. We have at present no detailed information on the concentration factor for cephalopods or deep-living fish and for the present assumed that they are sufficiently similar to those for surface fish for inclusion in this pathway.

The crustacea pathway is intended to embrace many similar organisms, including brill. The molluscs pathway is representative of sessile filter-feeders and is characterized by relatively high concentration factors.

Consumption of seaweed is an established pathway, and the high consumption rate is intended to cover critical groups for whom this is a staple food.

The larger macroplankton are covered in other pathways. The plankton pathway is characterized by concentration factors appropriate to micro-zooplankton, and consumption rates are based on this as a processed food or additive rather than a staple diet.

<u>Pathways Involving Exposure of Beach Dwellers</u>

Two of these pathways involve external exposure and two inhalation of radionuclides in different forms. The release rate limit based on external exposure is given by:

$$L_{ij} = \frac{D_i \times 3.4 \times 10^{11}}{K_{ij}\ E_j\ T_i\ F_i} \text{ Ci/yr}$$

where

D_i is the appropriate dose limit (rem/yr)

E_j is the mean energy per disintegration (alpha, beta or gamma, as appropriate) (MeV)

T_i is the occupancy time (hr/yr)

F_i is a modifying factor whose purpose is described below.

This formula is based on the dose-rate at the surface of an infinite half-space contaminated uniformly, without attenuation. The modifying factor F may be used to take account of other circumstances, and is 0.1 for irradiation of the hands of fishermen handling nets, since the source in this case is not an infinite half-space. The occupancy times assumed for external gamma irradiation of beach or shore users and for handling fishing nets or other gear are shown in Table C-5.

Table C-5

Beach Dwellers Occupancy Times

Pathway	Occupancy Time hr/yr
Beach	1000
Handling	300
Sediment	Continuous
Evaporation	Continuous

The limiting release rates for inhalation pathways may be calculated using the same formulation as for ingestion pathways under seafood, but with the appropriate value of A_j and Q_i as the quantity of contaminated material inhaled rather than ingested. The concentration factor is also used differently depending on the specific pathway.

The sediment pathway allows for inhalation of contaminated sediment which has been turned into a suspended aerosol by some process. In this case the intake is assumed to be 2 μg/day, corresponding to an assumed respirable dust burden in the atmosphere of 10 $\mu g/m^3$, of which 1% is of sea-sediment origin. Occupancy is assumed to be continuous. The concentration factors are for concentration in the sediment, and are given in pCi/g per pCi/ml.

The evaporation pathway covers inhalation of radionuclides which reach the atmosphere directly from the sea water. The intake in this case is assumed to be 200 g/day, and occupancy is assumed to be continuous. For tritium the concentration factor is taken as unity, so the calculation corresponds to the inhalation of 200 g/day of evaporated or suspended water containing tritium. For other radionuclides the pathway can better be thought of as representing the inhalation of sea salt in the atmosphere. A typical figure for this concentration in air is 3 $\mu g/m^3$, so to give an inhalation figure of 60 μg/day and take account of the 3% salt content of seawater, a nominal concentration factor of 10^{-5} pCi/g per pCi/ml is used for most radionuclides. There has been a suggestion that enrichment by up to a factor of 10^3 may occur in a thin layer on the sea surface for trace elements; thus for trace elements and their analogues a nominal concentration factor of 10^{-2} is taken.

Since all of these pathways could apply to the same critical group they have been summed to derive an overall release rate limit for beach dwellers.

Miscellaneous Pathways

Certain other pathways have been suggested. These are modifications of pathways involving either intake or external exposure and are therefore formally calculated using the appropriate formulae given in the previous sections.

Consumption of salt obtained by evaporation from sea water has been assessed using the consumption rate in Table C-6. The concentration factor in this pathway is taken as unity for tritium since tritiated water would be evaporated during the salt extraction. For all other radionuclides it is taken as 30 pCi/g per pCi/ml to allow for the 3% salt content of sea water.

Desalinated water may form the only water source for some groups of people, giving the consumption rate in Table C-6. The concentration factor in this case is taken as unity for tritium and 10^{-4} pCi/g per pCi/ml for all other radionuclides, based on at least a two stage desalination plant and a decontamination factor per stage of at least 10^{-2}.

Swimming in the sea may also lead to external exposure. The calculation of release rate limit is based on the occupancy time shown in Table C-6 and a modifying factor of 2 to allow for total immersion rather than an infinite half-plane. The dose limit used was 0.5 rem/yr.

Table C-6

Miscellaneous Pathways

Pathway	Intake/ Occupancy Time
Desalination	2000 g/day
Salt Consumption	3 g/day
Swimming	300 hr/yr

For convenience of calculation and presentation all three miscellaneous pathways have been combined, even though the same people are unlikely to comprise the critical group for all three pathways. The concentration factors for radiological assessment in the primary pathways are given in Table C-7.

Table C-7

Concentration Factors Used for Radiological Assessment

Element	Fish	Crustacea	Molluscs	Seaweed	Plankton	Desal'n	Sea Salt	Sediment	Evaporation
H	1.0E 00	1.0E 00	1.0E 00	1.0E 00	1.0E 00	1.0E 00	1.0E 00	1.0E 00	1.0E 00
C	5.0E 04	4.0E 04	5.0E 04	4.0E 03	3.0E 03	(1.0E-04)	3.0E 01	(1.0E-02)	(1.0E-05)
Na	1.0E-01	3.0E-01	2.0E-01	1.0E 00	1.0E 00	(1.0E-04)	3.0E 01	(1.0E 02)	(1.0E-05)
P	2.0E 04	1.0E 04	1.0E 04	1.0E 04	1.0E 04	(1.0E-04)	3.0E 01	(1.0E 02)	(1.0E-05)
S	1.0E 00	1.0E 00	1.0E 00	1.0E 00	1.0E 00	(1.0E-04)	3.0E 01	(1.0E 02)	(1.0E-05)
Cl	1.0E 00	1.0E 00	1.0E 00	1.0E 00	1.0E 00	(1.0E-04)	3.0E 01	(1.0E 02)	(1.0E-05)
Ca	1.0E 00	1.0E 01	1.0E 00	1.0E 00	1.0E 01	(1.0E-04)	3.0E 01	(5.0E 02)	(1.0E-02)
Cr	1.0E 02	5.0E 02	5.0E 02	(3.0E 04)	(3.0E 03)	(1.0E 04)	3.0E 01	(1.0E 04)	(1.0E-02)
Mn	5.0E 02	1.0E 04	1.0E 04	1.0E 04	1.0E 03	(1.0E 04)	3.0E 01	1.0E 04	(1.0E-02)
Fe	1.0E 03	1.0E 03	1.0E 03	1.0E 04	1.0E 04	(1.0E 04)	3.0E 01	1.0E 04	(1.0E-02)
Co	1.0E 02	1.0E 03	1.0E 03	1.0E 03	1.0E 03	(1.0E-04)	3.0E 01	1.0E 04	(1.0E-02)
Ni	5.0E 02	1.0E 02	1.0E 02	5.0E 02	1.0E 03	(1.0E 04)	3.0E 01	1.0E 04	(1.0E-02)
Zn	2.0E 03	4.0E 03	1.0E 05	1.0E 03	1.0E 04	(1.0E-04)	3.0E 01	1.0E 04	(1.0E-02)
Se	1.0E 02	1.0E 03	1.0E 03	1.0E 03	1.0E 04	(1.0E-04)	3.0E 01	1.0E 04	(1.0E-05)
Br	(3.0E 00)	(1.0E 01)	(1.0E 01)	(3.0E 01)	(3.0E 01)	(1.0E 04)	3.0E 01	(1.0E 02)	(1.0E-05)
Sr	1.0E 00	1.0E 01	1.0E 01	1.0E 01	(1.0E 01)	(1.0E-04)	3.0E 01	5.0E 02	(1.0E-05)
Y	1.0E 00	1.0E 03	1.0E 03	1.0E 03	1.0E 02	(1.0E-04)	3.0E 01	1.0E 04	(1.0E-02)
Zr	1.0E 00	1.0E 02	1.0E 03	5.0E 02	(1.0E 04)	(1.0E 04)	3.0E 01	1.0E 04	(1.0E-02)
Nb	1.0E 00	1.0E 02	1.0E 03	5.0E 02	(1.0E 03)	(1.0E 04)	3.0E 01	1.0E 04	(1.0E 02)
Tc	1.0E 01	1.0E 03	1.0E 03	1.0E 05	1.0E 03	(1.0E-04)	3.0E 01	1.0E 04	(1.0E-02)
Ru	1.0E 00	6.0E 02	2.0E 03	2.0E 03	(1.0E 03)	(1.0E-04)	3.0E 01	1.0E 04	(1.0E-02)
Pd	(3.0E 02)	(3.0E 02)	(3.0E 02)	(1.0E 03)	(1.0E 03)	(1.0E-04)	3.0E 01	(1.0E 04)	(1.0E-02)
Ag	1.0E 03	5.0E 03	1.0E 05	1.0E 03	1.0E 03	(1.0E-04)	3.0E 01	1.0E 04	(1.0E-02)
Sn	1.0E 03	3.0E 02	1.0E 02	1.0E 02	1.0E 03	(1.0E-04)	3.0E 01	1.0E 04	(1.0E-02)

Concentration factors in parentheses are based on educated guesswork only.

Table C-7 (cont)

Element	Fish	Crustacea	Molluscs	Seaweed	Plankton	Desal'n	Sea Salt	Sediment	Evaporation
Sb	1.0E 03	3.0E 02	1.0E 02	1.0E 02	1.0E 03	(1.0E-04)	3.0E 01	1.0E 04	(1.0E-02)
Te	1.0E 03	1.0E 03	1.0E 03	1.0E 04	1.0E 03	(1.0E-04)	3.0E 01	1.0E 04	(1.0E-05)
I	1.0E 01	1.0E 02	1.0E 02	1.0E 03	1.0E 03	(1.0E-04)	3.0E 01	1.0E 02	(1.0E-05)
Cs	5.0E 01	3.0E 01	1.0E 01	1.0E 01	1.0E 02	(1.0E-04)	3.0E 01	5.0E 02	(1.0E-05)
Ce	(1.0E 01)	1.0E 03	1.0E 03	1.0E 03	1.0E 03	(1.0E-04)	3.0E 01	1.0E 04	(1.0E-02)
Pm	1.0E 02	1.0E 03	1.0E 03	1.0E 03	1.0E 03	(1.0E-04)	3.0E 01	1.0E 04	(1.0E-02)
Sm	(1.0E 02)	(1.0E 03)	(1.0E 03)	(1.0E 03)	(3.0E 03)	(1.0E-04)	3.0E 01	(1.0E 04)	(1.0E-02)
Eu	1.0E 02	1.0E 03	1.0E 03	1.0E 03	1.0E 04	(1.0E-04)	3.0E 01	1.0E 04	(1.0E-02)
Au	1.0E 02	1.0E 03	1.0E 03	1.0E 03	1.0E 04	(1.0E-04)	3.0E 01	1.0E 04	(1.0E-02)
Pb	3.0E 02	1.0E 02	1.0E 02	1.0E 03	1.0E 04	(1.0E-04)	3.0E 01	1.0E 04	(1.0E-02)
Po	2.0E 03	2.0E 04	2.0E 04	1.0E 03	1.0E 04	(1.0E-04)	3.0E 01	1.0E 04	(1.0E-02)
Ra	1.0E 02	1.0E 02	1.0E 02	1.0E 02	1.0E 02	(1.0E-04)	3.0E 01	5.0E 02	(1.0E-05)
Ac	3.0E 01	1.0E 03	1.0E 03	1.0E 03	1.0E 04	(1.0E-04)	3.0E 01	1.0E 04	(1.0E-02)
Th	1.0E 03	1.0E 03	1.0E 03	1.0E 03	1.0E 04	(1.0E-04)	3.0E 01	5.0E 06	(1.0E-02)
Pa	1.0E 01	1.0E 01	1.0E 01	1.0E 02	1.0E 03	(1.0E-04)	3.0E 01	5.0E 03	(1.0E 02)
U	1.0E-01	1.0E 01	1.0E 01	5.0E 00	5.0E 00	(1.0E-04)	3.0E 01	5.0E 02	(1.0E-02)
Np	(1.0E 01)	(1.0E 02)	(1.0E 03)	(1.0E 03)	(2.0E 03)	(1.0E-04)	3.0E 01	(5.0E 04)	(1.0E-02)
Pu	1.0E 01	1.0E 02	1.0E 03	1.0E 03	(2.0E 03)	(1.0E-04)	3.0E 01	5.0E 04	(1.0E-02)
Am	1.0E 01	2.0E 02	2.0E 03	2.0E 03	(2.0E-03)	(1.0E-04)	3.0E 01	5.0E 04	(1.0E-02)
Cm	(1.0E 01)	(2.0E 02)	(2.0E 03)	(2.0E 03)	(2.0E 03)	(1.0E-04)	3.0E 01	(5.0E 04)	(1.0E-02)
Cf	(1.0E 01)	(2.0E 02)	(2.0E 03)	(2.0E 03)	(2.0E 03)	(1.0E-04)	3.0E 01	(5.0E 04)	(1.0E-02)

Concentration factors in parentheses are based on educated guesswork only.

SITE ASSESSMENT TASK GROUP

Participants

C. D. Hollister (USA) Lead Correspondent
H. Hotta (Japan)
B. J. Collette (Netherlands)
B. Buckley (Canada)
R. Schüttenhelm (Netherlands)
R. C. Searle (UK)
J. Wannesson (France)

Observers

A. S.Laughton (UK)
W. Bowden (UK)
A. Barbreau (France)
R. Le Suave (France)
G. Vilks (Canada)

Introduction

Objectives

The objectives of the Site Assessment Task Group are (1) to identify from historical data a number of study sites (on the order of 10) that might satisfy the site suitability criteria to field-verify the lateral and vertical uniformity of the sedimentary formations, and (2) to obtain core samples for measurement of laboratory properties. This effort is being made in an iterative fashion by all participating delegates in an open scientific-exchange forum.

Working Assumptions

- Site identification is being made solely for the purpose of subseabed insertion of HLW or spent fuel.
- The site selection guidelines published in the 1979 SWG report (and further refined in parts of the IOS Report 91, 1979, by R. Searle) are being followed.

- Sufficient time exists (more than 5 yr) for a thorough site evaluation process, including appropriate in-situ measurements.

- Before candidate sites are seriously considered, core samples must be obtained to at least the depth of waste burial.

- Cruise planning and participation will be done jointly with all interested members of the SWG.

- Canister recovery is not considered by the site selection task force.

Discussion

Distal Abyssal Plains (DAP)* - Eastern Atlantic

Since the last SWG annual meeting, the Site Assessment Task Group has agreed to include and assess the geologic formations of the DAP as another generic sediment type that could be used to isolate high-level waste (HLW) or spent fuel (SF). These sediments are generally clay to silty clay with some thin (millimeters to centimeters) silt beds deposited by turbidity currents. The sand layers of the Proximal Abyssal Plains** are still believed to be more permeable than desired. The DAP are extensive in the Atlantic, whereas thick smooth blankets of pelagic sediments are not. Thus, we conclude that at least a representative DAP be surveyed and sampled, and a report on the findings be presented at the next annual meeting of the SWG. Historical data compilation north of 30°N is nearly completed (Searle). Special attention will be paid to the problem of glaciomarine erratics during this cruise. Some ship time (*Tydeman*-Collette)

*The portion of the Abyssal Plains most distant from the continental slope where the smaller particles of erosional debris are deposited in a layered conformation.

**The portion of the Abyssal Plains near the continental slope where the larger particles of the erosional debris are deposited in layered, Lense-type formations.

will be allocated for geophysical and eological surveying in 1980 on a small portion of the Madeira Abyssal Plain east of Great Meteor Seamount. Special attention will be paid to the problem of glacid marine enatics.

Historical data for the DAP south of 33°N (Figures II-1 through II-4, Canada section) has been compiled (Le Suave, Collette, Hollister), and an IFP cruise using the Resolution has been completed. The data by Wannesson for this area show that a small 20 x 20 km area near the southern portion of Cape Verde (CV1 Figure II-3) appears promising as a site for deep waste emplacement. A more complete G&G survey, with biologic sampling and current meter deployment, is planned for 1980 (Charcot-Le Suave).

Distal Abyssal Plains - Western Atlantic

Historical data has been complied for the western Atlantic (Laine, Tucholke), and a Canadian cruise on the Hudson in 1980 will concentrate on the southern Sohm Abyssal Plain (Buckley, Vilks, Laine). Data taken by the Canadian ship Dawson in the northern Nares Abyssal Plain has been presented (Vilks and Buckley), and the results distributed. Certain areas (~23.6°N, 61.5°W) appear promising as a site for shallow (~50 m) waste emplacement; however, detailed core analysis has not been completed.

Western Cape Verde Plateau - Eastern North Atlantic

New data from the IFP/CEA (Resolution) cruise revealed an area west of the Cape Verdes (CV2) of about 50 x 50 km that is more or less evenly bedded with about 250 meters of calcareous ooze. East-west seismic lines show evidence of faulting. The Charcot (Le Suave), equipped with narrow beam swath mapping capabilities, will visit this area in 1980 to further delineate the most attractive areas and to produce very detailed bathymetry.

Western North Pacific

A 30 day US-Japan G&G cruise on Vema (Hayes) is planned for the summer of 1980 in the Western Pacific, west and south of the Shatsky

Plateau. Three areas with the best historical data will be visited with special emphasis placed on coring and 3.5 kHz acoustic profiling.

Great Meteor Seamount - Archipelagic Apron - Eastern Atlantic

A reconnaisance G&G survey will be conducted in late 1980 on the distal Archipelagic Apron, west of the Great Meteor Seamounts (Tydeman-Collette). The principal concern here is the sediment texture (permeability) on this very smooth apron that slopes gently away from this Seamount Chain.

Research Vessel Plans for 1980/1981

Tydeman (Netherlands), 20 days on station October-to-December 1980, vicinity of Great Meteor Seamount Geology and Geophysics. No space available.

Charcot (France), 8 days on Station September-October, vicinity Cape Verdes Geology and Geophysics (Le Suave). 10 spaces available.

Suroit (France), 30 days on station, Vicinity Cape Verdes, Physical Oceanography and Biology.

Hudson (Canada), 12 days in May 1980 on station, Vicinity Sohm Abyssal Plain, Geology and Geophysics. No space available.

Vema (USA and Japan), 20 days on station, June-July 1980, vicinity West Central Pacific, Geology, and Geophysics. No space available.

Discovery (UK), 40 days on station 1981, vicinity easter Atlantic, Geology and Geophysics. Some space available.

Recommendations

To Sediment and Rocks Subgroup

- Obtain Kd's for anions and cations in oxidizing and reducing conditions such that site selection efforts can be further refined as to desirable sediment types.

To Executive Committee

- There will be a requirement from the Site Assessment Task Group that a deep (50 to 100's of meters) sampling technology be available, e.g., Hydraulic Piston Core

(HPC) and the Long Coring Facility (LCF), within the next few years to acquire sediment samples. These samples will be used to verify vertical coherence and determine sediment properties to, and below, the proposed canister position. We recommend that this requirement be made widely known.

- We recommend that there be semi-annual meetings of the Site Assessment Task Group and that the next meeting follow the 1980 season. We propose January 6-7, 1981 Brest, France.

- There will be a need for near-bottom high resolution side-scan and sub-bottom sonar systems for lateral coherence and surface microphysiography (e.g., ice-rafted boulders) determinations. We recommend that this requirement be made widely known.

General Recommendations

- An additional generic siting criteria be included. A site should be not only as flat as possible, but also well removed from steep slopes (on the order of degrees).

- For siting considerations, we will not concern ourselves with near field effects, defined as that portion of the geologic formation inside the 100°C isotherm.

- Siting considerations will not consider the 4 km (or any other) isobath as an exclusionary criterion.

Northeast Atlantic Distal Abyssal Plains - A Compilation of Geophysical and Geological Data*

5

Introduction

A meeting of the East Atlantic Planning Group of the SWG Site Selection Task Force at IOS in September 1979 identified a need for further studies of distal abyssal plain environments in the Northeast Atlantic. At that meeting, it was agreed that the French ships Resolution and

*This study was financed by the UK Department of the Environment.

Jean Charcot would study one such Area (CV1), 24°55'-25°55'N, 24°55'-25°55'W, in November 1979 and September 1980. It was also agreed that the Dutch ship Tydeman would study a distal abyssal plains area east of Great Meteor Seamount (Gt. Meteor East).

It was also agreed at that meeting that a compilation should be made of existing data within the distal abyssal plains province. This report presents part of that compilation; the rest is being prepared by R. Le Suave, of Centre Oceanologique de Bretagne, Brest.

Data

This study covers the Northeast Atlantic distal abyssal plains from 30°N to 45°N. The region from 30°N to the equator is being studied by Le Suave; however, we have looked at one area south of 30°N where we have data which may be unavailable to him.

Seismic Reflection Profiles -- We have compiled all the seismic reflection profiling data currently available to us in the UK. These consist of:

- All IOS data
- Lamont Doherty Geological Observatory data to 1970
- All Glomar Challenger data
- All data from the Vening Meinesz Laboratorium

In the short time (2 mo) available for this study we have not been able to consult the Woods Hole Oceanographic Institution, Centre Oceanologique de Bretagne, or post-1970 LDGO data sets. However, we have plans to acquire those data in the future if it appears they can add significantly to this reconnaissance study.

Three types of interpretation were made:

1. Tracks were annotated according to sediment morphology and reflection

2. The limit of the abyssal plain was determined, on the basis of seabed morphology and acoustic character sediments

3. Isopachs were drawn.

All of these interpretations were made on 1:1 000 000 scale working sheets; in addition, (2) and (3) have been compiled at 1:2 400 000.

Sediment Samples -- All available sediment sample positions have been compiled, and all available core descriptions utilized. Most of the useful data in the region are from RRS. *Discovery*, project NAVADO, and *Glomar Challenger* cores. Positions of cores and brief core descriptions have been compiled at 1:1 000 000; core positions and some preliminary contouring of sediment properties are available at 1:2 400 000.

Bottom Photographs -- Positions of known bottom photographs have been compiled at 1:1 000 000, but to date we have only been able to study the *Discovery* ones.

Selection of Further Study Areas for High-Level Radioactive Waste Disposal

Areas South of the Azores --

1. Gt Meteor East (31°00'-32°00'N, 24°30'-25°30'W)

B. J. Collette (Netherlands) has suggested this area for his 1980 *Tydeman* cruise. Compilations show that the edge of the abyssal plain just passes through the northwest corner of the area, with two small isolated outcrops in the north. Sediments thicker than 0.4 s two-way time occur over most of the area, with a maximum thickness of 1.4 s in the southeast.

One core has been described in this region: NAVADO H6 (30°53'N, 23°08'W). This was 1.7 m long, and revealed pale brown clay and sand with some pebbles. This suggests fairly strong turbidity current activity; however, the core is some 200 km southeast of the centre of the proposed study area.

It is concluded that this would be a suitable area for further studies. Early priorities are obtaining cores in the area, and additional reflection lines perpendicular to the basement grain.

2. 'Madcap' area (28°40'-29°40'N, 24°00'-26°00W)

This area was studied in detail with echo-sounder and cores by Belderson and Laughton (1965). They showed that the edge of the Madeira abyssal plain passes through, or just northwest, of the area. However, there are many outcropping abyssal hills, and no large expanse of undisturbed sediment. All six abyssal plain cores in the west of the area showed turbidites (with sandy, but not pebbly, layers) in the upper 2.5 m. Only one abyssal plain core, from the east of the area, contained no turbidite. That core contained 1.2 m of brown-pink clay. Twenty-nine photographs from one area on the abyssal plain show a flat seafloor with numerous biogenic mounds, but no sign of current activity. This area does not appear to be suitable for further study.

If another area in this general region is required, we would suggest the area 28°-29°N, 27°-29°W.

Areas North of the Azores -- The principal abyssal plain north of the Azores is the Iberian abyssal plain. Although there are other isolated areas of ponded sediments, most are too small and too near the continental margin, the coast, or seismically active areas, to be of interest for waste disposal. The southern margin of the Iberian abyssal plain is near 39°30'N; its western margin is near 15°W from 39° to 41°N, and near 16°W north of there. So far, only very limited data is available north of 42°N. Within this region, only one area looks promising for further studies.

3. 'Iberia I' (40°40'-41°40'N, 13°30'-14°30'W)

The edge of the abyssal plain passes through the western edge of this area, and one isolated outcrop occurs in its centre. Mean sediment thickness is about 0.8 to 1.0 s, deepening to over 1.4 s in the northeast.

This region received a relatively detailed sedimentological study by Davies (1967) using Discovery II cores. A line of 12 cores between 40°29'N, 13°13'W and 41°12'N, 12°52'W (immediately to the east of this study area) showed abundant turbidites, some with truncated beds indicating erosion. A single core to the west of this line, at 41°01'N, 13°57'W (near the centre of the study area) showed 2.7 m of clay and silts, probably representing the distal portions of the turbidites seen in the line of 12 cores. Sediment input was inferred to be from the Navarre and other canyons to the Iberian continental margin to the east. Four out of five cores at the western margin of the abyssal plain near 41°30'N, 14°-15°W indicated quiet deposition with no turbidites, but the fifth showed 10 distinct turbidite layers (Keen, 1961). Finally, a set of six cores between 41°50'N-42°20'N and 14°00'-14°30'W showed a series of turbidites containing coarse sands. These are distinct from the turbidites seen in the first line of 12 cores, and may have been derived from an independent source, possibly the Biscay abyssal plain via Theta Gap.

Many tens of sea-floor photographs in this region show intense biological activity, but no signs of current activity on the abyssal plain.

We conclude that this area is worthy of further study. Research priorities include carefully controlled seismic reflection profiling and coring to study the precise sedimentary environment and to recover material for chemical and physical properties studies.

Other Areas -- It is possible that other study areas might be found north of 42°N, but at present our data are too limited to make an accurate appraisal.

Further Information

The following references may be consulted for further information on the Northeast Atlantic DAP:

T. A. Davies, 1967. Recent Sedimentation in the Northeast Atlantic. Ph.D. Thesis, University of Cambridge.

M. J. Keen, 1961. Ph.D Thesis, University of Cambridge

R. H. Belderson & A. S. Laughton, 1965. "Correlation of Some Atlantic Turbidites," Sedimentology, 7, 103-116.

Sediment Stability Studies at Institute of Oceanographic Sciences

This newly-commissioned HLRW disposal project is aimed at studying the stability of sediment sequences in the Northeast Atlantic. The IOS has recruited a micropaleontologist, Dr. Philip Weaver. New coring equipment (a Driscoll piston corer) has been purchased, and a system has been tested for shipboard description, photography, and sampling of cored materials along with microscope analysis and measurements of carbonate content.

Eight gravity cores were recovered from the King's Trough study area during the course of the RRS Shackleton cruise 8/79 (Table II-2). Initial findings are that the sediments are high carbonate pelagic oozes with interspersed volcanic ash layers.

RRS Discovery cruise 106 has been planned to undertake reconnaissance coring and seismic profiling studies in the study area west of Gt. Meteor Seamount. Unfortunately no work on the study area could be completed as a result of sailing delays and bad weather. However, significant progress was made on this cruise in development and testing of the 2-kHz high-resolution seismic profiler, and it is now felt that this tool will eventually be sufficient for our needs in this project.

Contacts are being made with university groups with research interests in paleomagnetic and oxygen isotope research to provide background stratigraphy for this project.

Table II-2

Summary of Seismic Data*

	Area 2	Area 1
Latitudes N	23°30'-23°48'	25°30'-25°57'
Longitudes W	61°12'-61°36'	61°24'-61°42'
Area surveyed (km^2)	1204	1355
Line spacing (km)	~15 and ~7	~9 and ~3.5
Line length (km)	80	198
Average depth (m)	5734	5377
Range depth (m)	5690-5730	5440-5790
Area flat (%)	78	26
Average sediment thickness (m)	At least 130	83
Range sediment thickness (m)	50-170	0-220

*The areas were surveyed with 40 $in.^3$ bolt air gun and 12 kHz sounder with transducer core angle of 30°.

Preliminary Results of the IFP-CEA Cape Verde Seismic Survey

The Cape Verde seismic survey, made by IFP under contract from CEA, was carried out with R/V Resolution in the east central Atlantic from November 24 to December 11, 1979. Eleven hundred eighty-six km of 24-fold seismic profiles, plus magnetics and a few 3.5 kHz, were recorded over two sites, CV1 and CV2, some 400 nautical miles apart.

Location of the survey was discussed during a site selection task force meeting last September in IOS, based on an IFP proposal. Each site, extending over an area of approximately one square degree was first surveyed on a 50 x 50 km grid basis, with an additional 15 x 15 km grid in selected areas.

A general NNE-SSW line orientation was chosen in order to best fit with expected structural trends in that part of the Atlantic. Because of rough sea conditions, (waves up to 25 ft high) the stay on site CV1 was shortened a little.

Site CV1

Site CV1 is located 450 nautical miles southwest from the Canary Islands on the distal part of the Cape Verde-Madeira abyssal plain, in the vicinity of DSDP hole 138. The survey at this site was to investigate the general feasibility of a distal abyssal plain environment for waste storage. The main results may be summarized as follows:

- Topography of the sea bottom was extremely smooth, with an average slope of about 1/1000 towards the southwest, except in the western and northwestern part of the survey, where the flat bottom was pierced by basement highs considered the easternmost topographic expression of the abyssal hills.

- In contrast, topography of the oceanic basement is very rough, with reliefs up to 2 km and slopes over 20°. This feature is already well-known, especially in this part of the Atlantic.

- The sedimentary series thickens regionally toward the southeast from 600 m at DSDP 138 to nearly 2 km, thus burying more and more of the oceanic basement in that direction. The thickening is mostly due to the lower part of the series which fills basement depressions. The upper part thickens much more progressively, on a regional basis.

- The seismic aspect of the sedimentary series suggests that it results from progressive burial of oceanic basement highs with further draping by differential compaction. Sedimentation was not continuous during the whole geological record, as outlined by some overlap strata termination on older series. These internal discontinuities tend to disappear toward the thickest deposit area.

- Seismic facies of the series shows many subparallel, moderate- to high-amplitude reflectors, but this does not imply necessarily strong lithologic variation within the series.

- Stratigraphic correlation with DSDP hole 138, made from velocity analysis of the multichannel seismics, confirms that this hole bottomed at 437 m in a Cenomanian basalt sill and that true oceanic basement could be found there at a depth of about 600 to 650 m below sea bottom. From known sedimentation rates, this would give a fundamental Cretaceous age for this basement, in accordance with magnetic anomalies distribution. Due to piercing basement highs east and south from DSDP 183, true stratigraphic correlation is restricted to a small area. However, three main horizons were recognized over the entire area, as bases of Neogene turbidites and two intra-Upper Cretaceous horizons (the paucity of cores in DSDP 138 allows no better stratigraphic accuracy).

- The two lower horizons are locally associated with erosional events, restricted to the western part of the survey area, close to the abyssal hills province. These events are interpreted as strong contour currents during early Cretaceous times. No other major disturbance is to be seen, especially in the areas of thick deposits where the whole series appears conformable.

- From a structural standpoint, spacing of the lines is too wide for a precise picture of the structural trends of this area. The presence of fracture zones cannot be confirmed.

In conclusion, this site looks favorable both from sedimentary and structural points of view when the sedimentary thickness exceeds 10 km, i.e., far enough from basement outcrops of the abyssal hills. We have a complete series of mostly clayey sediments from DSDP cores down to the Cenomanian. In the Neogene stratas high-penetration cores should confirm the predominance of thin, low permeability sediments.

Site CV2

Site CV2 is located on the West Cape Verde plateau, 300 nautical miles northwest of the Cape Verde archipelago. Previous seismic lines revealed a thin sedimentary blanket of pelagic aspect in a relatively high position compared to the surrounding Cape Verde and Sierra Leone abyssal plains. The Resolution seismic survey on this site brought us the following results:

- There is a striking structural anisotrophy between north-south lines with smooth topography and structure, and east-west lines with a much more complex and disturbed structure. We have found a structural pattern of subparallel ridges extending northeastwards with a relief of about a hundred meters.

- The sedimentary series has a rather constant thickness of about 200 m and seems to have molded basement topography.

- Sediments are mostly seismicaly transparent except for two ubiquitous reflectors in the middle of the series and some others of very restricted extent at the base. The lithology of this series is known from neither drill-holes nor high-penetration coring, but its seismic facies suggests a pelagic character, probably clayey. The two above-mentioned reflectors are interpreted as cherts, volcanic ashes, or due only to minor changes in compaction or lithology. From the published magnetic anomaly maps, the age of this series extends from present to Aptien-Barremian, which implies a very slow rate of sedimentation. It rests on a volcanic basement of a much smoother topgraphy than that of site CV1, showing some internal reflections.

- A migration processing of the seismic profiles shows that the basement topgraphy is associated with normal faults and volcanic mounts or ridges. On this site, spacing of the lines does not allow a precise coorelation of these features. The Charcot seabeam survey would be helpful there, too.

- As the series of moulding basement topography gives no clear evidence of faulting, it seems that no major recent tectonic movement has occurred in this area. However, sediments overlying fault zones seem often affected by slump phenomena.

- No fracture zone is obvious in this area from our lines. We therefore conclude that the sedimentary facies in this area, though not confirmed by drilling or coring, mostly pelagic clays, a facorable medium for waste storage. Deformation of the strata, though mostly of depositional origin, is relatively intense. It is not unlikely that other areas of the West Cape Verde plateau, a very small part of which was surveyed during this cruise, could show a much simpler and smoother structure.

Canadian Deep Sea Program

The Canadian Deep Sea Program is entirely devoted to the problem of site assessment. The report of this program can be found in Section I, the national reports, under CANADA.

CANISTER TASK GROUP

Participants

N. J. Magnani (USA), Lead Correspondent
G. P. Marsh (UK)

Observers

R. D. Shaw (UK)
G. P. Rothwell (UK)
J. P. Menzies (UK)
J. E. Antill (UK)

Introduction

The Canister Task Group continues to believe that a corrosion-resistant canister can be a valuable part of a multibarrier seabed program. This type of canister would protect the waste form from the hydrothermal environment and would reduce and delay the level of radio nuclide release. The objective of both the US and UK canister programs is to develop materials which will survive on the seabed for 500 to 1000 yr. Current results suggest that this objective can be achieved in a cost effective manner.

Before the members of the Canister Task Group can undertake a complete evaluation of materials there is a continued requirement for a more quantitative definition of the seabed/subseabed disposal environment. The information required covers the following:

Temperature - maximum and profile with time

Chemistry - concentrations of Br^-, I^-, F^-, NO_3, $S^=$, HCO_3, SO_4, heavy metals
- pH
- oxidation potential

- how the chemistry may change with time
- how the chemistry may change with temperature

Biology
- influence on environment chemistry
- transfer of materials including corrosion products

It is requested that the Task Coordinator request this information from the other Task Groups.

Progress Report

Combined results from the US program have shown that Ti alloys such as TI-50A (nominally pure TI), Ti-0.2%Pd, and TI Code-12 (Ti-0.8% Ni-0.3% Mo) might survive for the desired 500 to 1000 yr lifetime. To date the program has not identified any viable failure mechanisms which would lead to earlier failure. However, further study is necessary to verify a long-lived canister. Work in both the UK and US has shown that radiation will have an important effect on the corrosive nature of the disposal environment. The UK work involved in-situ electrochemical measurements which showed conclusively that the redox potential of solutions containing sodium chloride is modified by radiation. This has important implications for corrosion behavior. The Canister Task Group feels that this is perhaps the most important unknown facing the canister program and that continued work is need on determining the effect of radiation on the corrosive nature of the environment.

The need for very sensitive corrosion monitoring techniques was recognized once again. This and the radiation-effect work are areas where international cooperation will be especially beneficial to all participants.

WASTE FORM TASK GROUP

Participants

J. Krumhansl (USA), Lead Correspondent
J. A. C. Marples (UK)
P. E. Pottier (France)

Introduction

Three main topics were reviewed during the course of Waste Form Task Group discussions: (1) the various national programs being carried out in the participant countries, (2) the straw man parameters suggested by the System Analysis Task Group, and (3) the possibility of implementing a joint experimental program in the upcoming year.

It was generally found that the national programs differed from those summarized at length in last year's Waste Form Task Group report. The parameters tentatively suggested by the System Analysis Task Group received considerable discussion. Rather than providing a single "typical" value for some parameters, it was decided in a number of cases to list the value anticipated by each country. It was intended that this would provide the system analysis group not only with a "typical" value for the parameter but with an idea of over what range the different parameters might reasonably be varied. As regards a joint experimental program, it is anticipated that initially this would be largely a UK-France effort, since the US Subseabed Program has at this time no funds specifically designated for either waste form development or assessment.

Progress Reports

France

The French programs related to waste form were presented in detail in the proceedings of the fourth SWG meeting (SAND79-1156). Research and development studies are in progress as follows:

- Technical permanent assistance for the A.V.M. plant

- Development of improved solidification matrices for decanning and dissolution residues and for incineration ashes from bearing wastes

- Technological studies for pretreatment, prior embedment, or vitrification (compaction, incineration, calcination)

- Preparation and definition of future vitrification plants with increased capacities, easier maintenance in active operation, and longer life for the equipment

- Definition and application of criteria for the selection and qualification of high-level solidified wastes, including glasses

- Testing of the different parameters used as a basis for the final disposal safety evaluation: long-term leaching (high pressure, elevated temperature, devitrification, irradiation stability, recoil degradation and its effect on long-term leaching resistance, etc.

A new method to simulate the recoil degradation with the use of heavy ion beams is under study. All the programs are not specifically dedicated to the Seabed Disposal waste form evaluation, but a large part of their results may be conveniently used for that objective.

UK

No report since SAND79-1156.

USA

No work underway.

Waste Parameters and Values

Time Till Disposal

France	UK	US
50-100 yr	0-100 yr	>10 yr

Glass Composition

1. Iodine is removed almost completely.

2. A portion of the Tc may or may not be lost during reprocessing.

3. As an upper limit about 0.2% of the Pu is included in the waste. For magnox fuel one has substantially better recovery, so that only about 0.02% of the Pu and 0.005% of the original uranium ends up in the glass waste.

4. Reprocessing of fuel results in a second category of wastes - fines, hulls, etc, that may contain as much or more activity as the borosilicate glass.

5. Loading of fission product oxides in the glass waste form.

France	UK	USA (Subseabed)
9-12%	10%	18%

Canister Dimensions

Variable, but the 0.3 x 3 m long canister suggested is a lower limit on the canister volume. From a European point of view a reference canister 0.5 m in diameter and 2.5 m long would be more accurate.

Canister Life Following Emplacement

France	UK	USA
500+ yr	500+ yr	500-1000 yr

Maximum Temperature Following Emplacement

France	UK	USA (Subseabed)
<100°C	100°C	200°-250°C

Proposed Release Rate Model

The philosophy of the proposed model is to provide an upper limit on the release rate, because a truly accurate model is not going to be available in the foreseeable future. The model assumes the waste has been divided (broken) into an assembly of spheres having a total volume equal to that of the initial canister and between 5 and 10 times the surface area of a right cylindrical canister of waste.

The model also is based on the assumption that the glass dissolves congruently and that once in solution the material is translated immediately across the canister sediment interface.

Dissolution rates (g/cm^2 day) are a function of temperature only.

1. Hypothetical sphere radius = $\frac{3\ R\ H}{2\ a\ (H + R)}$

   a = the factor of increase in surface area over that of the cylinder

   R = radius of initial cylindrical canister

   H = height of initial cylindrical canister

2. The functional relation will be of the following form:
   Long (bulk dissolution rate) = log (rate) = $\left[A/\theta(°K)\right] + B$

3. To get the release of a particular radionuclide, i, multiply the bulk leach rate by the percentage of i in the sample at the time of leaching, i.e., release rate of i = (area) (bulk leach rate at a time, t).

   $$\text{(Initial wt\% of i)}\ (1/2)^{\exp\left(\frac{t}{\text{half life of i}}\right)}$$

Representative Leach Rate Data (g/cm^2 day) for the model.

Glass No.	0°	100°	
209_1	5×10^{-7}	5×10^{-5}	$\log \text{rate} = \frac{-2.04 \times 10^3}{\theta(°K)} + 1.26$
189_1	5×10^{-7}	2×10^{-4}	$\log \text{rate} = \frac{-2.65 \times 10^3}{\theta(°K)} + 3.40$
$76\text{-}68_2$	5×10^{-6}	2×10^{-5}	$\log \text{rate} = \frac{010.23 \times 10^3}{\theta(°K)} + 2.76$

Limitations of the Model

- The effects on solution chemistry that may be introduced by canister corrosion, sediment water interactions, and saturation effects caused by corrosion of the adjacent glass materials are not included.
- Devitrification and hydration of the bulk material at low temperatures is ignored.
- The ionic specification of the liberated materials is not known.
- The model assumes uniform solution of the glass.

1981 Goals

- Update parameters used in model (second limitation above)
- Add new physical processes to the release model as quantitative predictive data becomes available
- Plan and implement experiments to deal with the effects of:

  (1) Glass alteration in the localized environment adjacent to a flaw in the canister (a pinhole)

  (2) Leach rates from a glass surface where access of water is restricted by the presence of (low permeability) sediment or a pinhole in the canister.

Further Information

Further information on the development of corrosion-resistant canisters can be found in the following references:

1. K. A. Boult, et al., The Leaching of Radioactive Waste Storage Glasses, AERE Report R-9188; and in Ceramics in Nuclear Waste Management, CONF-790420, May 1979, Cincinnati.
2. J. H. Westsik and R. P. Turcome, Hydrothermal Reactions of Nuclear Waste Solids: A Preliminary Study. PNL 2759, September 1978. (Leach tests done over short time spans in brine.)

SEDIMENT AND ROCK TASK GROUP

Participants

T. J. G. Francis (UK), Lead Correspondent
D. Rancon (France), Lead Correspondent Designate
R. Cranston (Canada)
G. Ross Heath (USA)

Observers

M. Sturm (Switzerland)
J. B. Lewis (UK)
D. Kinsey (UK)
R. B. Whitmarsh (UK)
A. Avogadro (CEC)
D. B. Smith (UK)
H. Richards (UK)

Introduction

Dr. Francis has replaced Dr. Lewis as the UK member and has assumed the job of Lead Correspondent. Dr. Rancon is the Lead Correspondent Designate. The Task Group reviewed progress, discussed future plans and in particular attempted to identify areas where more work is needed. Discussions were held with members of the Waste Form, Canister, Physical Oceanography, Biology, and Site Assessment Task Groups.

Progress Reports

USA

Summary -- Dr. Heath described the ion transport (IONMIG) computer program, which is the first comprehensive numerical model for the migration of ions away from a canister placed in sediment. From the output of the completed thermal models, the sedimentary properties and laboratory-measured

Kd values (themselves functions of temperature and concentration), the program calculates the concentration field of radionuclides around the canister as a function of time (see Attachment A).

The In-Situ Heat Transfer Experiment (ISHTE), planned for deployment in the North Pacific in 1982-3, will provide a field verification of the thermal transport assumptions and models. C. M. Percival, Sandia National Laboratories (SNL), coordinates ISHTE.

The Long Coring Facility (LCF) will provide the SWG with the capability of acquiring 50 m undisturbed sediment in late 1981. This will be useable on about a dozen different US oceanographic ships.

Ion Migration--Model Development -- D. McVey, A. Russo, and C. Hickox (SNL) are working on the development of IONMIG, a two-dimensional, axisymmetric computer code which solves the transport equation and includes convection, axial and transverse dispersion, molecular diffusion, concentration dependent sorption, and radioactive decay. This equation uses a finite difference solution (see Attachment A).

E. Nutall, University of New Mexico (UNM), is working on the development of analytical solutions to diffusion/sorption transport. These solutions should provide rapid nondimensional sensitivity analysis, and allow checking of IONMIG for simple cases.

Ion Migration--Sorption Studies -- K. Erickson (SNL) is measuring fission products and actimide Kd's, and will complete batch and one-dimensional column diffusion studies using profiling detectors on subsurface oxidized North Pacific clays.

S. Fried, A. Friedman, and F. Schreiner, Argonne National Laboratories (ANL), will complete experiments with actinides, and stability studies of Pu oxidation states using North Pacific oxidized and reduced clays.

R. Heath, Oregon State University (OSU), will complete batch and column Kd experiments using a broad range of types of deep-sea sediments (all oxidized), and Eu as the sorbent. These studies will also include concentration and temperature.

Ion Migration--Sediment Properties -- A. Silva, University of Rhode Island (URI), is measuring permeability of red clays as a function of temperature; D. McVey and C. Hickox (SNL) are acquiring thermal properties of red clays; C. M. Percival (SNL), T. Ewart, University of Wisconsin (UW), A.Silva, et al. are designing and developing (ISHTE). This experiment is designed to validate laboratory material property data and predictions of thermal computer models, as well as develop the capability to carry out sophisticated sea floor experiments.

Emplacement--Model Development -- P. Dawson, Cornell University (CU), and J. Lipkin and W. Brown (SNL) are developing finite difference and finite element computer codes covering one- and two- component deformation behavior of clay-water systems and are acquiring the necessary material properties.

Emplacement--Sediment Properties -- A. Silva (URI) is measuring some of the necessary geotechnical properties. J. Lipkin (SNL) is acquiring high P-T thermal properties. To better understand the creep of sediments, D. Talbert (SNL) is developing penetrometers for acquiring in-situ material properties.

Near Field Geochemistry -- W. Siefried, University of Minnesota (UM), and J. Krumhansl (SNL) are carrying out hydrothermal experiments with oxidized North Pacific clays and seawater to assess the effect of heating on eH and pH, dissolved species, and clay minerology.

Long Coring Facility -- C. Karnes (SNL) is developing an understanding of the dynamics of coring to aid in the development of the 50-m core. A. Silva and A. Driscoll (URI) are designing the facility (winch, cable, corer design, core-head instrumentation).

France

Dr. Rancon described the work being done on continental rocks and sediments. Experiments to quantify the mobility of actinides in rocks have been started, using ground water taken from granite formations in columns containing quartz and quartz plus 2% clay. Mobile forms of Pu have been found which are thought to be in colloidal form. The quantity of mobile Pu decreased with time to 0.1% after 6 mo. No oceanic sediment has yet been studied. The experiments beginning this year using continental water will be duplicated with sea water if necessary.

Canada

Dr. Cranston described work on box cores obtained in the western North Atlantic in 1980 by the Dawson. The development and improvement of methods for the sampling and analyzing of pore waters is under way.

United Kingdom

Work has recently begun at the Institute of Oceanographic Sciences on a range of projects related to the physical and chemical properties of ocean sediments. Staff has been recruited for this project.

A report on the basic constitutive relationships for the elasto-plasticity of clays has been completed by Davis and Banerjee and will be issued soon by UKAEA Harwell.

Dr. Pentreath of the Fisheries Radiobiology Laboratory at Lowestoft is determining Kd values for Pu, Am, Cu, Np, and Tc isotopes in muds and clays sampled from the vicinity of the outfall of the Windscale pipeline into the Irish Sea. The effect of the changing speciation of isotopes on their re-mobilization is also being studied.

CEC

Dr. Avogadro described the CEC's work on the leaching of actinides from borosilicate glass and passing of the solution through a column of sandy clay. The water velocity through the column was 20 m/yr. The experiments lasted several months. The pH and oxidation potential were carefuly controlled. Mobile species of actinides were found. Preliminary analyses indicate that they are moving as carbonate complexes.

Discussion

The following areas need special attention:

Measurement of Kd values for a wide range of radionuclides in clays suggest that factors of safety are very high--with the exception of the anions of technetium and iodine. However, if complexes or colloids of actinides are involved, the large Kd values from batch experiments might be giving a false picture of radionuclide mobility. Column diffusion experiments should give operationally correct Kd's, however.

The effect of radiation on water and sediment is known, but not the combined effects of temperature, radiation, and pressure. Radiolysis experiments under realistic conditions should be carried out. In particular, the influence of radiation on the interaction of the canister with its environment needs to be studied. Radiation will affect the corrosion of the canister through its effect on the chemistry of the sediment/pore water system. The corrosion resistance of the canister might be enhanced by use of a suitable overpack.

Natural pore water movement in the sediments should be better understood. Flow rates inferred from nonlinear temperature-gradient measurements appear to be up to three orders of magnitude larger than those indicated by chemical gradients. Determination of pore water pressure gradients in-situ, or of the isotopic content of the water itself, might throw fresh light on this problem.

While the LCF might provide an adequate sampling capability for Pacific red clay sites, Atlantic sites may require deeper sampling. At present only the Hydraulic Piston Corer (HPC) developed by the Deep Sea

Drilling Project for the Glomar Challenger can do so with adequate quality. This project is likely to cease operation in 1981. With some development the HPC could be adapted to almost any deep drill platform. An internationally funded program to sample a number of Atlantic sites should be considered for 1983 or 1984, making use of a chartered drill ship with expanded HPC capability. Such a cruise would also provide the opportunity for in-situ downhole measurements in undisturbed material. In-situ measurements of physical properties are necessary to give us confidence in the properties measured in the laboratory.

Finally, so work seems to be planned for analysis of the sorption properties of reducing sediments such as will be found beneath the top few meters of the Atlantic Ocean floor. The most important nuclides to be studied are Pu, Np, Am, Tc, and I.

A. Rancon comments that "The choice of the radio-elements to be studied is an important point of concentration; the number of elements should not be too large considering the difficulties and the cost of each operation.

"Np, Pu and Am are necessary; the case of Tc should also be discussed (and also Cm). It may not be important to undertake experiments on the ^{129}I retention.

"Let us consider the following examples:

The total volume of oceans and seas = $1.4x10^9$ km^3

The total quantity of potassium (380 g/m^3) = $5.3x10^{20}$ g

The total quantity of ^{40}K ($1.2x10^{-4}$ of K) = $6.4x10^{16}$ g
= $4.3x10^{11}$ Ci.

^{40}K is the main factor of the natural radioactivity of the sea waters.

"A 1200 mW reactor produces on an average of 10 Kg ^{129}I per year or 1.7 Ci per year.

"1000 reactors (!) would produce 1700 Ci per year.

As the totality of this estimated world production of ^{129}I would be directly discharged into the ocean, the increase of the total radioactive background would be about 4.10^{-9} Ci per year; considering the various barriers between the waste and the seafloor, the contamination by ^{129}I appears negligible."

Further information on studies related to the Sediment and Rock Task Group's work may be found in the "Associated Projects" section of the Canadian report, Part I, p. 18.

ATTACHMENT A

SAND79-1666
Unlimited Release

PREDICTION OF THE MIGRATION OF SEVERAL RADIONUCLIDES IN OCEAN SEDIMENT WITH THE COMPUTER CODE IONMIG: A PRELIMINARY REPORT*

A. J. Russo
Fluid Mechanics and Heat Transfer Division 5512
Sandia National Laboratories**
Albuquerque, NM 87185

May 1980

ABSTRACT

A computer code, IONMIG, which is used to calculate the far-field transport of radionuclides through ocean sediment by diffusion and convection is described. The code uses a two-dimensional, axisymmetric, explicit finite difference formulation. Preliminary results for several species (Cs, Pu, I, Tc) are given.

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**A U.S. Department of Energy facility.

ACKNOWLEDGEMENTS

The author would like to thank David K. Gartling, who developed the fluid-thermodynamic code, MARIAH, and provided calculations of velocities and temperatures used in obtaining these preliminary results.

(3-4)

CONTENTS

INTRODUCTION

As part of a study to determine the feasibility of radioactive waste disposal in seabed sediment, a radionuclide migration code, IONMIG, is being developed. This code is a two-dimensional planar or axisymmetric code which solves the transport equation including convection, axial and transverse dispersion, molecular diffusion, concentration dependent adsorption and radioactive decay. Assumptions used in its formulation are that the presence of the radionuclides does not change the fluid properties or the behavior of other nuclides and that absorbtive processes are reversible and describable in terms of an empirically determined equilibrium constant. Near-field details are not treated and species are injected as volumetric source terms. A brief description of the code is given in the CODE DESCRIPTION section of this report.

IONMIG differs from another Sandia nuclide migration code, SWIFT,[2] which was developed with Intera Corporation to analyze transport through hydrologic formations, in that it is much simpler to use (SWIFT input requirements are about 30 times greater than IONMIG's). IONMIG can use concentration dependent adsorption coefficients and is part of a modular solution system (IONMIG interfaces with the incompressible fluid thermo code, MARIAH, and the plot code, SEAPLT).

The purpose of this report is to describe some preliminary results on several species which are representative of the elements of concern in a waste canister inventory. These are ^{137}Cs, ^{99}Tc, ^{129}I, and ^{239}Pu.

CODE DESCRIPTION

Theory

The equations describing the migration of contaminant ions in a porous saturated bed are of the form:

$$\frac{\partial (C_i \varepsilon K_i)}{\partial t} + \nabla \cdot (C_i \vec{v}) = -\sum_{k=1}^{N} (\lambda_{ik} K_i \varepsilon C_i) + \sum_{k=1}^{N} \lambda_{ki} K_k \varepsilon C_k + S_i \quad , \qquad (1)$$

where,

C_i = the ion species concentration (kg/m^3)

ε = the porosity of the medium

K_i = the species equilibrium coefficient for species i = $(1 + \frac{1 - \varepsilon}{\varepsilon} \rho_{soil} K_{d_i})$ where K_d is the equilibrium distribution coefficient

λ_{ik} = the radioactive decay rate from species i to species k

S_i = a source term for continuous or step function addition of ions corresponding to the leach rate

$\vec{v}$ = the total ion velocity which is assumed to be of the form:

$$u - \frac{D_x}{C_i} \frac{\partial C_i}{\partial x} \vec{i} + v - \frac{D_y}{C_i} \frac{\partial C_i}{\partial y} \vec{j}$$

u = convective velocity in the x-direction

v = convective velocity in the y-direction

$D_{x,y}$ = diffusion dispersion coefficient in the x,y-direction

$D_x = \alpha_L |u| + \alpha_T |v| + D_o$

α_L, α_T = longitudinal and transverse dispersion coefficients

D_o = molecular diffusion coefficient

(6)

The equilibrium distribution coefficient, K_d, is a function of species concentration and assumed to be of the form:

$$K_d = \frac{k_2}{1 + k_1 C} + \frac{k_4}{1 + k_3 C} \quad . \tag{2}$$

Equation (1) is written in finite difference form according to MacCormack's method[1] as follows for the ith species.

Step 1:

$$C^{\overline{n+1}}_{\ell,m} = \left(\alpha 1 C^n_{\ell+1,m} + \alpha 2 C^n_{\ell,m+1} + \alpha 3 C^n_{\ell-1,m} + \alpha 4 C^n_{\ell,m-1} + \alpha_{01} C^n_{\ell,m} + \sum_{k=1}^{N} \lambda_{ki} \varepsilon_{\ell,m} K_i C^n_{\ell,m} + S_{\ell,m}\right) \Big/ \left(\alpha 9 + \varepsilon_{\ell,m} K_i \sum_{k=1}^{N} \lambda_{ik}\right)$$

Step 2:

$$C^{n+1}_{\ell,m} = \left[\alpha 5 C^{\overline{n+1}}_{\ell+1,m} + \alpha 6 C^{\overline{n+1}}_{\ell-1,m} + \alpha 7 C^{\overline{n+1}}_{\ell,m+1} + \alpha 8 C^{\overline{n+1}}_{\ell,m-1} + \alpha_{02} C^{\overline{n+1}}_{\ell,m} + \tfrac{1}{2}\left(\sum_{k=1}^{N} \lambda_{ki} \varepsilon_{\ell,m} K_i C^n_{\ell,m} + S_{\ell,m} + \alpha 9 C^n_{\ell,m}\right)\right] \Big/ \left(\alpha 9 + \tfrac{1}{2}\varepsilon_{\ell,m} K_i \sum_{k=1}^{N} \lambda_{ik}\right)$$

where all αN are evaluated at space indices ℓ,m and time n, and where,

$$\alpha 1 = rDx_{\ell,m}/(x_\ell \Delta x_p) - U_{\ell,m}/\Delta x_p + Dx_{\ell+1,m}/\Delta x_p^2$$

$$\alpha 2 = Dy_{\ell,m+1}/\Delta y_p^2 - V_{\ell,m}/\Delta y_p$$

$$\alpha 3 = Dx_{\ell,m}/\Delta x_p \Delta x_q$$

$$\alpha 4 = Dy_{\ell,m}/\Delta y_p \Delta y_q$$

$$\alpha 5 = \tfrac{1}{2}\alpha 3_{\ell,m}$$

(7)

$$\alpha 6 = \tfrac{1}{2}(Dx_{\ell-1,m}/\Delta x_q^2 + U_{\ell,m}/\Delta x_q - rDx_{\ell,m}/x_\ell \Delta x_q)$$

$$\alpha 7 = \tfrac{1}{2}\alpha 4_{\ell,m}$$

$$\alpha 8 = \tfrac{1}{2}(v_{\ell,m}/\Delta y_q + Dy_{\ell,m-1}/\Delta y_q^2)$$

$$\alpha 9 = (\epsilon_{\ell,m} K_i + \frac{dK_d}{dC} C^n_{\ell,m})/\Delta t$$

$$\alpha_{01} = \alpha 9 - \alpha 1 - \alpha 2 - \alpha 3 - \alpha 4$$

$$\alpha_{02} = \tfrac{1}{2}\alpha 9 - \alpha 5 - \alpha 6 - \alpha 7 - \alpha 8$$

$$r = \begin{cases} 0 & \text{Cartesian Coordinates} \\ 1 & \text{Polar Coordinates} \end{cases}$$

and,

$$\Delta x_p = x_{\ell+1} - x_\ell \ , \ \Delta x_q = x_\ell - x_{\ell-1}$$

$$\Delta y_p = y_{m+1} - y_m \ , \ \Delta y_q = y_m - y_{m-1}$$

Stable integration of the finite difference form of Equation (1) requires that the Courant-Friedrich-Lewy condition be met. In terms of the previously defined coefficients this means,

$$1 \leq \text{MIN}_{\ell,m}\left[\alpha 9/(|u|/\Delta x + |v|/\Delta y + rDx/(x\Delta x))\right] \quad . \qquad (3)$$

Since $\alpha 9$ is a function of the equilibrium distribution coefficient, K_d, which may be different for each species, efficient integration requires a different time step for each species. This is accomplished by selecting a global time step based on decay rate and output data considerations, and an integration time step for each species which is an integer subdivision of the global time step and satisfies Equation (3).

Decay chain species which are short lived compared to the other chain members may be omitted by merely bypassing them in the definition of the decay chain matrix, λ_{ik}, which is the array of decay constants for transition from the ith to the kth species. If such elements are included in the chain, the code will artificially reduce their decay constant (increase their half life) to a level in which they will disappear in several global time steps. This permits the inclusion of transition species in the chain without going to excessively small time steps, but of course, the instantaneous concentrations of such short lived species will be greatly overestimated and should not be considered as part of the useable output of the code. Any element for which $\lambda\Delta t > 3$ is treated as such a transition species.

In order to retain the flexibility of use provided by the options of axisymmetric geometry and variable mesh calculations, conservation differencing, which becomes rather unwieldy for those options, was not used. It is possible, therefore, that discretization and truncation errors may introduce some source error into the calculations. To partially correct for that possibility, a separate and more accurate time integration of the global quantities is performed and compared with the mesh point summations. An option to correct the mesh point values at each time step is included in the code.

Geometry and Boundary Conditions

The computational domain is a rectangular region, with boundary conditions as indicated in Figure 1, which represents a cross section of an axisymmetric region with x as the radial coordinate. The concentrations and sources are initially specified and the code computes subsequent distributions. If an external convective velocity field is not provided, an internally generated conservative convective cell field is assumed with its peak velocity specified as input data (peak may be zero).

The rectangular region shown in Figure 2 represents a cross section of the axisymmetric computational domain, as in Figure 1, with the dimensions used in the calculations and the canister location indicated. The streamlines shown in Figure 2 are those calculated with the finite element code, MARIAH, at 100 years after burial. The canister is assumed to be 3 m long and 0.3 m in diameter and to contain 10 year old reactor waste. It is buried with its center 30 metres below the ocean-sediment interface.

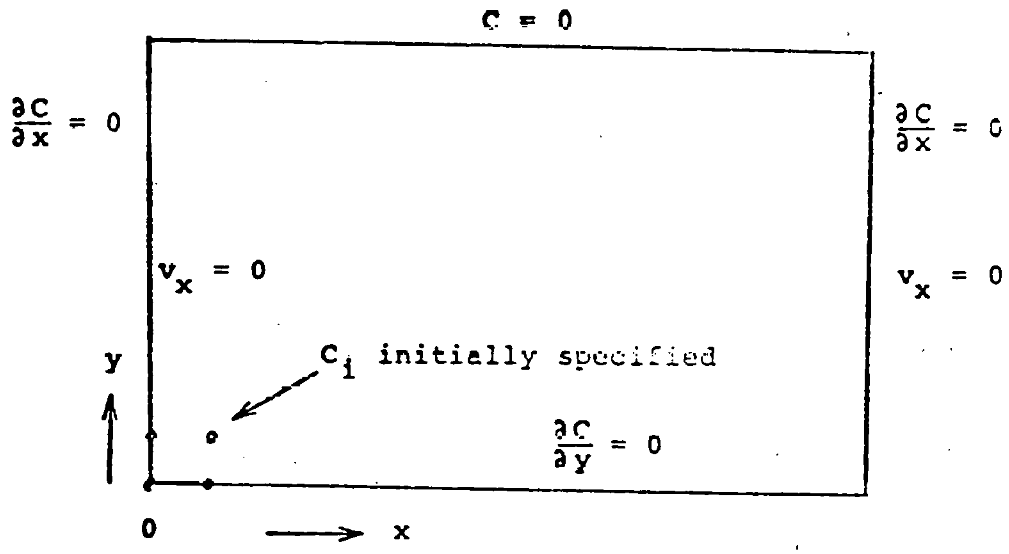

FIGURE 1. Geometry and Boundary Conditions Assumed in IONMIG.

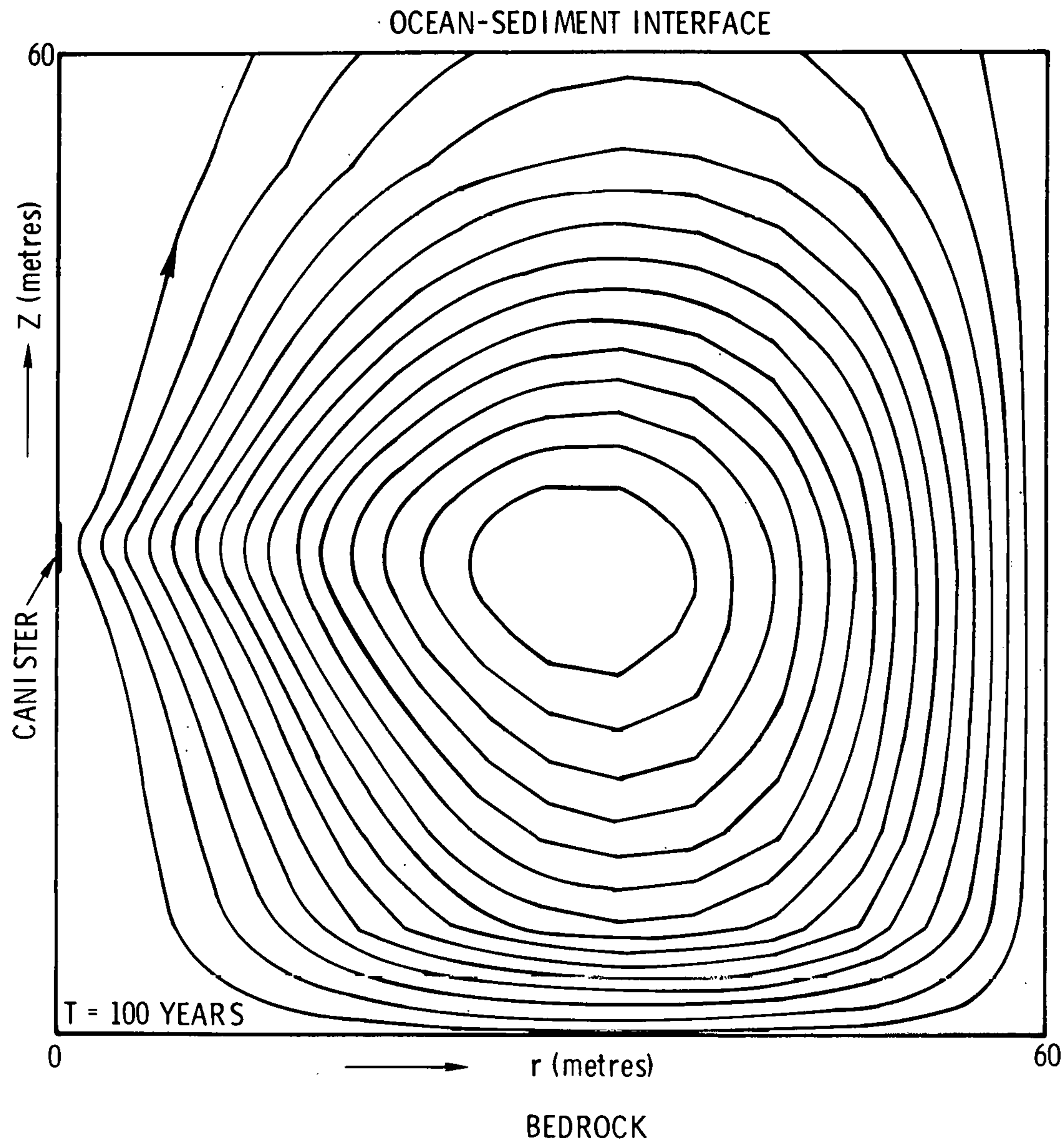

FIGURE 2. GEOMETRY AND STREAMLINES IN THE SEDIMENT COMPUTATIONAL REGION.

Input Parameters

The heat generated by the canister is assumed to be 1.5 kW at burial and to be decaying according to a schedule given in the ORIGEN code.[3] The temperature history near the canister surface is shown in Figure 3. In a few hundred years, the temperature is within a few degrees of the ambient (1.5°C). The same is true for all points in the region.

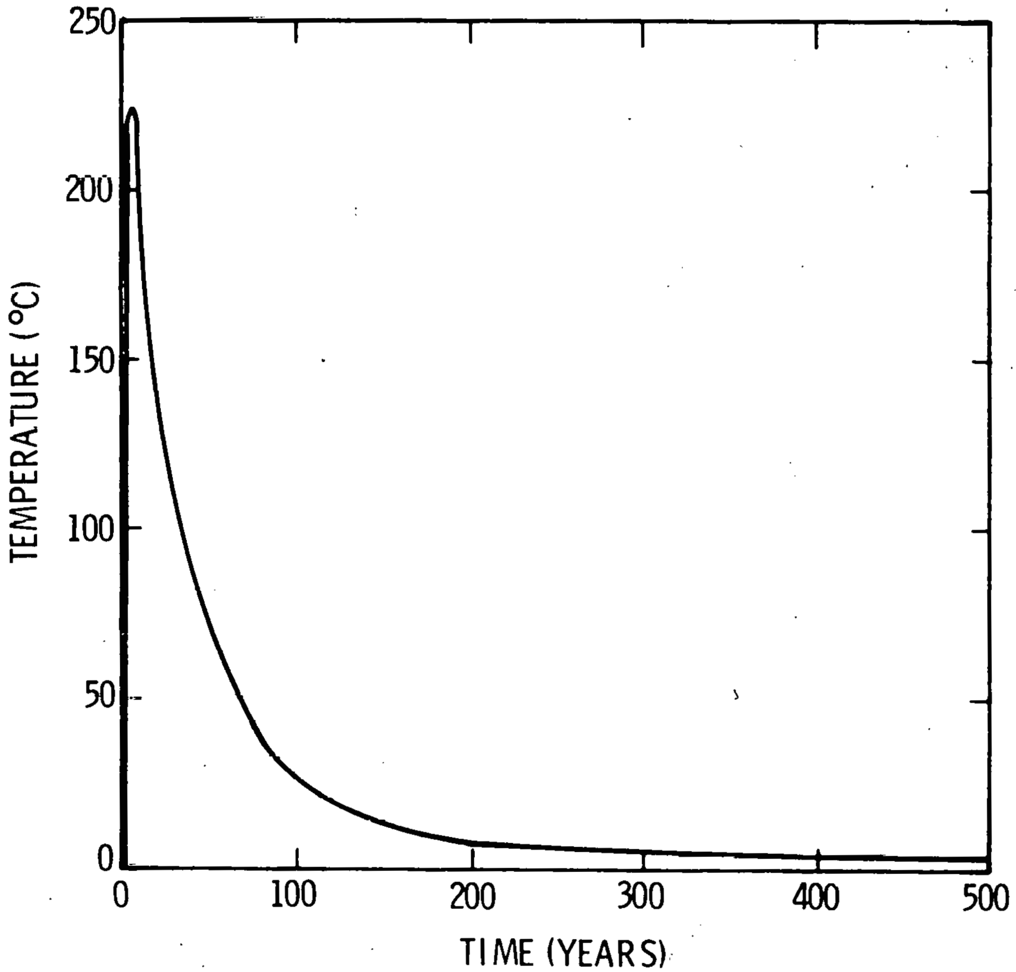

FIGURE 3. TEMPERATURE HISTORY ADJACENT TO A WASTE CANISTER 30 METRES BELOW THE SEDIMENT SURFACE.

The velocity variation with time at its maximum point adjacent to the canister is shown in Figure 4. It is seen that this velocity is very small, and after 100 years, convective transport is negligible compared to molecular diffusion.

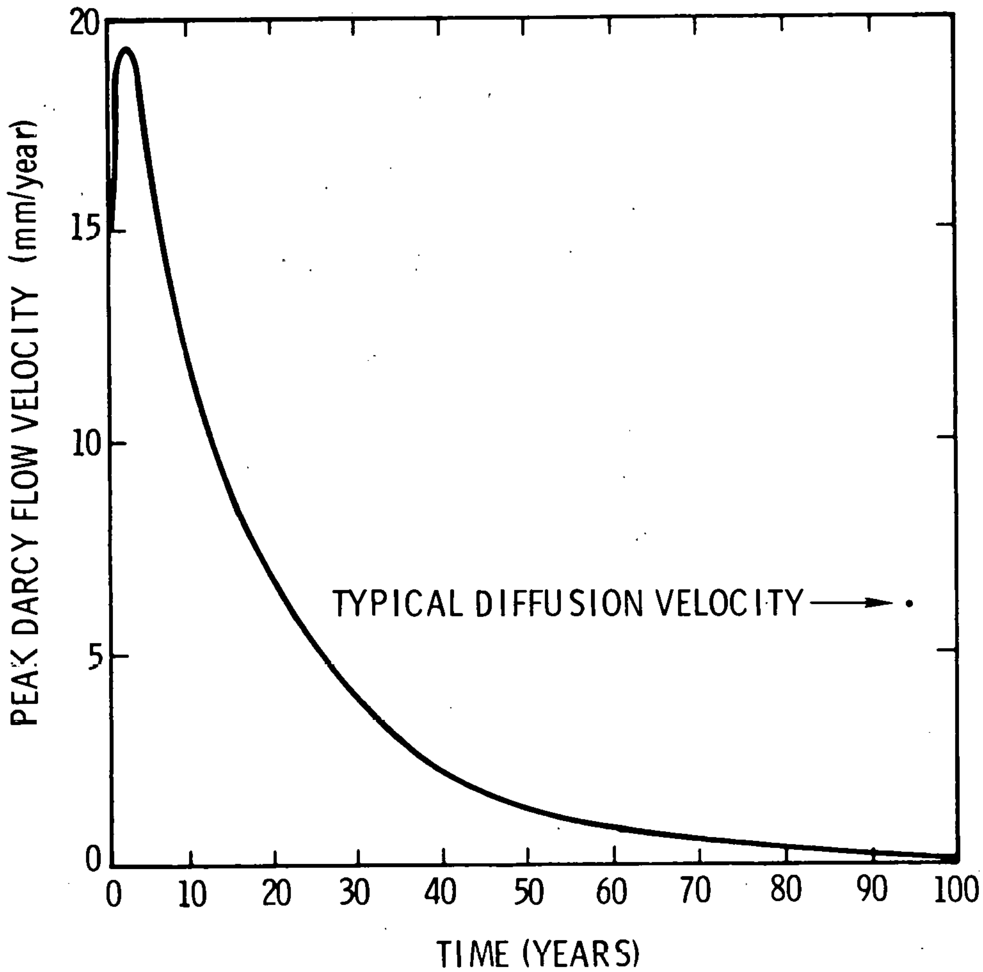

FIGURE 4. FLOW VELOCITY ADJACENT TO A WASTE CANISTER 30 METRES BELOW THE SEDIMENT SURFACE.

For all elements, except iodine, it is assumed that the molecular diffusion coefficient is 0.01 m^2/year (3.0 E - 10 m^2/s), longitudinal dispersivity factor is 6.1 m,* the transverse dispersivity factor is 0.61 m, the porosity of the sediment is uniform and equal to 0.75. For iodine, the molecular diffusion coefficient is 0.018 m^2/year. Values for the equilibrium partition coefficient K_d, were obtained by fitting a limited amount of laboratory data, and were approximated as follows:

Plutonium: $$K_d = \frac{100}{1 + 3E8C} + 0.01$$

Cesium: $$K_d = \frac{10}{1 + 200000C} + 0.1$$

Iodine and Technetium: $$K_d = \frac{0.0001}{1 + 10000C}$$

where C is the fluid ionic concentration in kg/m^3 (K_d values are in m^3/kg; to obtain ml/g multiply by 1000). Valence states of Cs and Pu are assumed to be +1 and +4, respectively.

The fluid properties used by the code MARIAH to calculate the convective velocities vary with temperature and plots of these quantities are shown in Figure 5. A nominal fluid density of 1000 kg/m^3 was used. Additional sediment property values used in the MARIAH calculations are:

Density - 2950 kg/m^3

Specific Heat = 880 J/kg°C

Thermal Conductivity = 1.92 exp(-6.376 E-6 T) W/m°C

Porosity = 0.8

Horizontal Permeability = 5 x 10^{-16} m^2

Vertical Permeability = 5 x 10^{-17} m^2

*This conservative overestimate of dispersivity factor is used because good data is not currently available, and the low velocities calculated make dispersion very small compared to molecular diffusion so that errors in this factor do not affect the results.

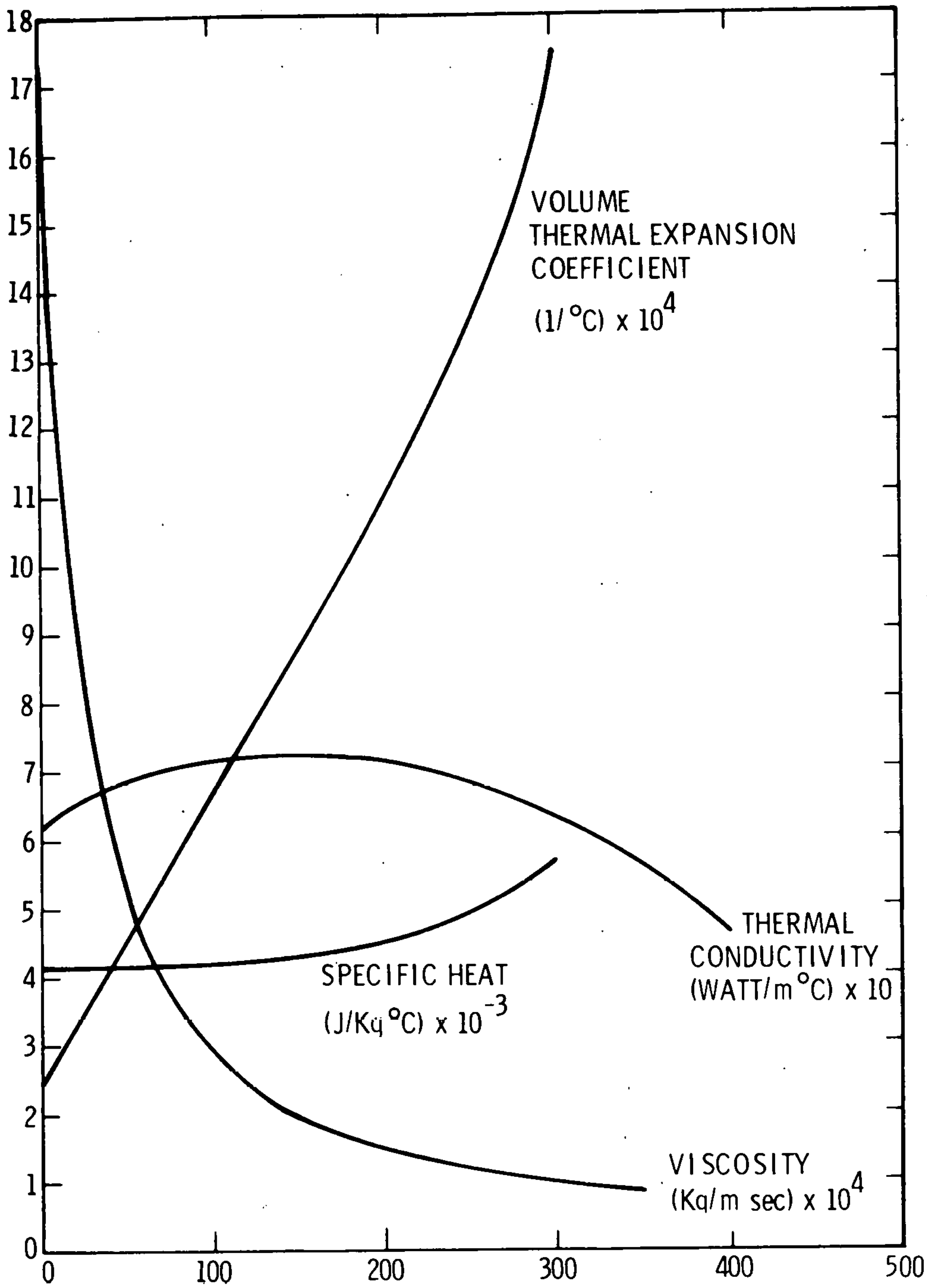

FIGURE 5. VARIATION OF FLUID PROPERTIES WITH TEMPERATURE AT 600 BARS.

The release in each case is assumed to be of the whole canister inventory at zero time. At the bedrock and the outer periphery of the computational domain, a zero flux condition is assumed so that all nuclides released from the canister (which do not decay) will eventually diffuse to the surface.

Although the results of only four nuclide migration calculations are discussed, in order to obtain those results parent and daughter nuclides were considered simultaneously. Table 1 lists all the nuclides associated with each calculation and their assumed canister inventory value at zero time.

TABLE 1

INITIAL CANISTER INVENTORIES OF ISOTOPES USED IN THE CALCULATIONS

Radionuclide	Mass in Canister (kg)
^{243}Am	0.121
^{239}Np	1.0 E-7
^{243}Cm	6.92 E-5
^{239}Pu	3.58 E-2
^{235}U	1.0 E-5
^{129}I	0.305
^{129}Xe	1.178 E-4
^{99}Tc	1.13
^{99}Ru	4.32 E-5
^{137}Cs	1.33
^{137}Ba	2.01 E-7

RESULTS

Calculations for ^{137}Cs were run out to 3500 years to verify that little motion took place prior to decay. Since the half-life of ^{137}Cs is only 30 years, in a few hundred years virtually all the ^{137}Cs has decayed to ^{137}Ba in place, and none reaches the surface. The same behavior is expected of other short-lived species with moderate values of K_d such as ^{90}Sr.

For long-lived isotopes having a high K_d, such as many forms of ^{239}Pu, the situation is similar except over much longer time scales. Figure 6 shows the distribution of ^{239}Pu over an axisymmetric symmetry plane containing the buried canister after 100,000 years. Although 4.1 half-lives of ^{239}Pu have elapsed, the remaining plutonium is a little less than one-third of the original inventory because of the decay of ^{243}Am to ^{239}Np and then to ^{239}Pu. In this calculation, the Am and Np were assumed to have the same K_d as the plutonium. Data currently available indicate this is a reasonable assumption for Am but may be non-conservative for the short-lived Np. The migration rate of plutonium is so slow (a few metres per 100,000 years) that even after 10^6 years, less than 10^{-20} percent of the depleted inventory has crossed the surface. At that time, less than 10^{-10} grams of ^{239}Pu remains.

For anionic nuclides having a long half-life and a very small K_d, such as ^{129}I and ^{99}Tc, the behavior is quite different. Without the retarding action of adsorption, these substances diffuse through the sediment in a relatively short time (5000 years or less). Figure 7 shows the release rate of radioactivity associated with the decay of ^{129}I as a function of time. The release rate reaches a peak of 1.01 μCi/year at about 8,000 years and then declines to approximately one-fifth of that value in 100,000 years. ^{129}I has a low specific activity, decaying to ^{129}Xe by beta decay with a half-life of 15.9 million years.

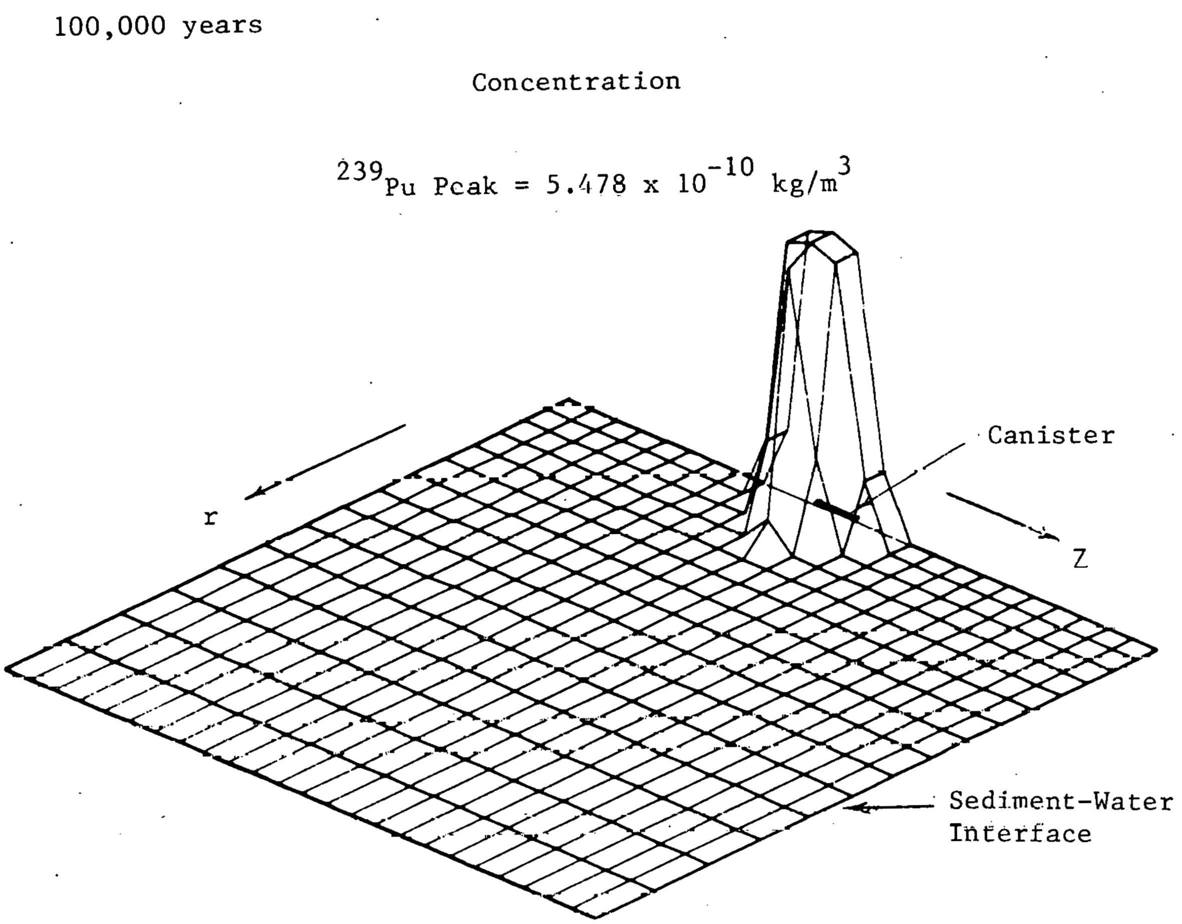

FIGURE 6. Plutonium Concentration in the Sediment at 100,000 Years.

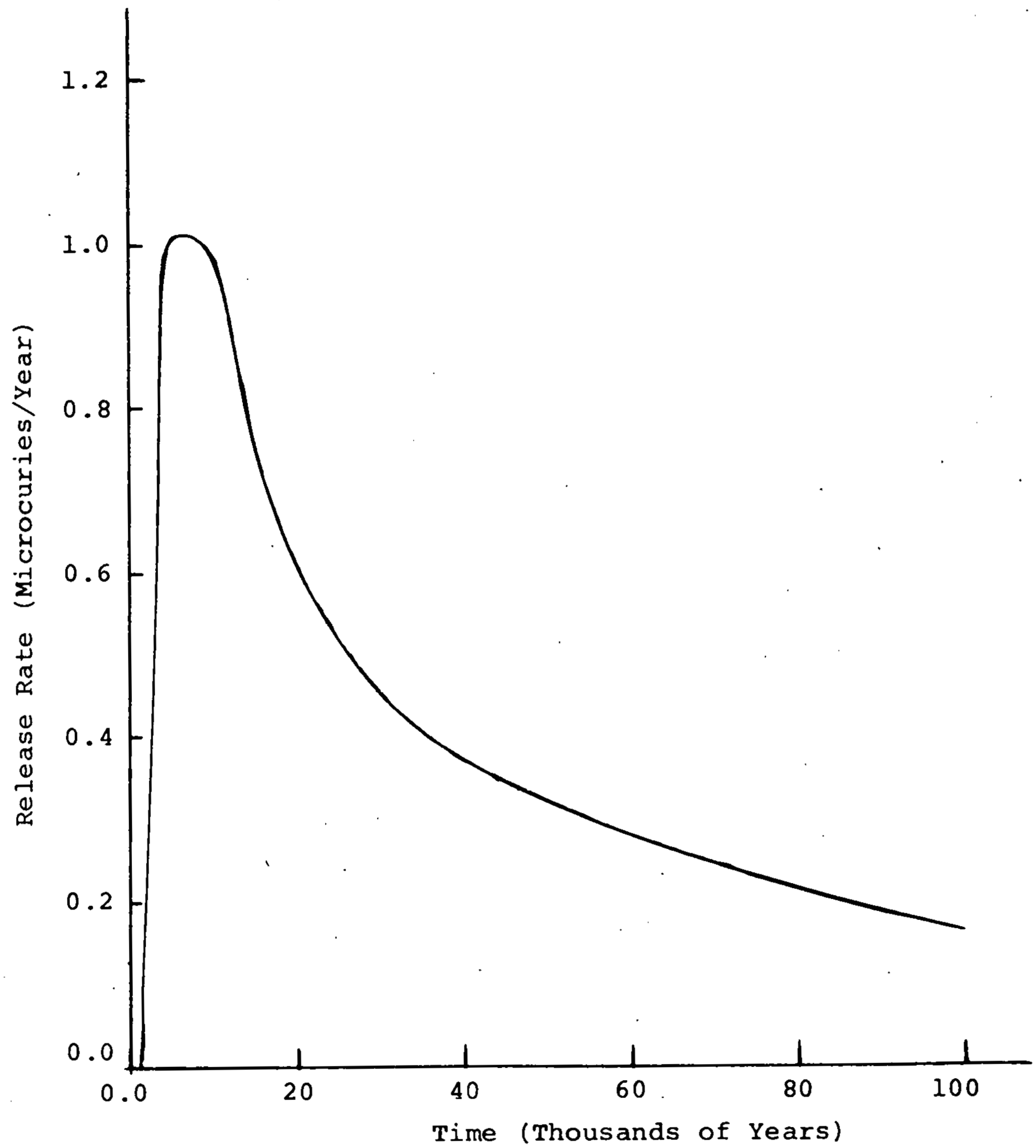

FIGURE 7. Release Rate of ^{129}I from the Sediment Surface Covering a Single Canister at 30 m Depth.

Figure 8 shows a similar release rate profile for ^{99}Tc. The peak value of 180 μCi/year is much higher than that for ^{129}I because both the initial canister inventory and the specific activity of ^{99}Tc, which beta decays to ^{99}Ru with a half-life of 213,000 years, are higher.

The significance of such release rates in terms of human or ecological hazards can only be determined by a comprehensive analysis of the water column transport mechanisms and marine bio system concentration mechanisms. Some perspective on the predicted release rates can be obtained, however, by a comparison with other oceanic radioactive sources. A single storm in the mid-sixties could wash out more than 10^6 μCi of beta activity from residual atmospheric sources.[4] Total oceanic atmospheric deposition of ^{90}Sr alone in 1978 exceeded 8×10^{10} μCi.[5] Such rates are very much higher than the worst calculated predictions (even for thousands of canisters). In addition to atmospheric deposition, natural radioactive substances are constantly diffusing from the pelagic clay sediment. For the axisymmetric case for which the IONMIG calculations were made, the per canister area is based on a canister spacing of 120 m. This results in an average per canister release of 8.9×10^{-5} μCi/year-m^2 for ^{129}I and 1.6×10^{-2} μCi/year-m^2 for ^{99}Tc. These fluxes compare to natural radium and radon fluxes of 3.5-8.8×10^{-4} μCi/year-m^2 for ^{226}Ra and 0.26-0.88 μCi/year-m^2 for ^{222}Rn.[6,7] Based on this comparison, one may hypothesize that the immediate exposure effects of the released ^{129}I and ^{99}Tc on benthic organisms would be negligible in as much as they evolved in a much more intense field. Confirmation of this hypothesis awaits completion of ongoing research and experimentation on biological concentration, water column transport mechanisms, and development of pathways-to-man models.

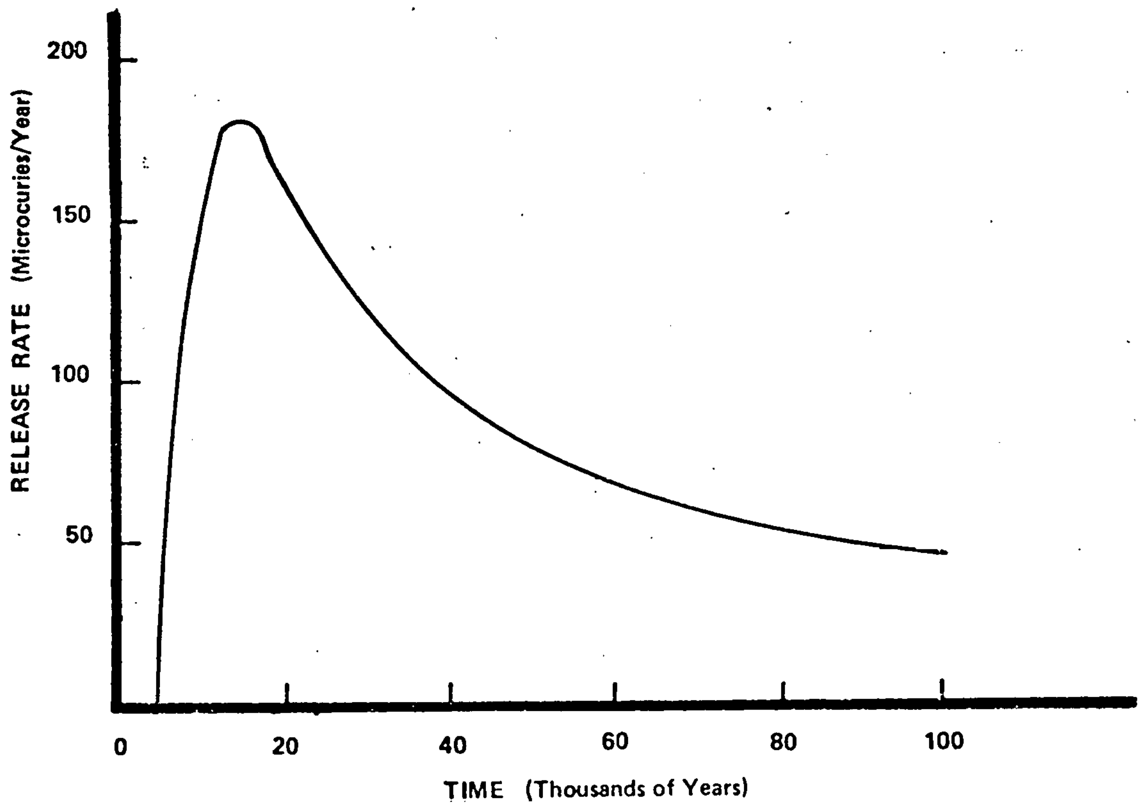

FIGURE 8. Release Rate of ^{99}Tc from the Sediment Surface Covering a Single Canister at 30 m Depth.

CONCLUSIONS

The development of a computer code to be used as a tool in assessing the transport of waste nuclides through ocean sediment is proceeding satisfactorily. Preliminary calculations of the migration of Cs, Pu, I, and Tc from a point 30 metres below the sediment surface have been made. Elements with short half-lives (less than 500 years) such as ^{137}Cs decay to negligible values before reaching the surface. Actinides many of which have large values K_d (above 10,000 gm/ml) move very slowly and also do not reach the surface until beyond 1,000,000 years. Long-lived fission products with low adsorption coefficients, such as ^{129}I and ^{99}Tc, are the most difficult to contain. For those nuclides, it must be shown that the low release rate and low specific activity reduce the hazards from them to an acceptable level, or additional engineered barriers must be provided.

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PHYSICAL OCEANOGRAPHY TASK GROUP

Participants

H. W. Hill (UK), Lead Correspondent
S. Horibe (Japan)
F. Madelain (France)
A. Robinson (USA)

Observers

J. Crease (UK)
P. A. Gurbutt (UK)
K. G. Prangsma (Netherlands)
F. Nyffeler (Switzerland)
P. M. Saunders (UK)
J. G. Shepherd (UK)
J. C. Swallow (UK)

Introduction

The task group began by considering progress reports and plans for work during the next 12 months for each country.

Progress Reports and Plans

France

In France during 1979 work has been carried out in three different areas:

- Bibliographical study
- Measurements at sea
- Plans for future cruises

A bibliographical study dealing with deep processes in the ocean linked with the bottom boundary layer has been started. An inventory of existing data and measuring techniques is in process.

During the Anglo-French experiment TOURBILLON, which took place in September-October 1979, various measurements were made. A deep mooring with 5 current meters in the bottom 700 m was also deployed, and should be recovered in June 1980. Several CTD casts to the bottom have also been made in order to obtain preliminary information on the existence of a bottom thermocline.

Based mainly on geological considerations, two small areas (60 x 60 nautical miles) located in the Cape Verde basin have been selected and will be studied during a multidisciplinary cruise (end of 1980). They are centered on 25°N, 25°W (CV1) and 18°N, 30°W (CV2).

The main objectives in physical oceanography are:

- The determination of the mean deep circulation and its low frequency variability. One mooring will be deployed in each area for a period of 6 to 9 mo.
- The description of hydrological conditions in the deep layers. Nine CTD profiles will be made in each area.

If the rate of technical development permits, long term measurements of the temperature profile should be obtained in the bottom 100 m by means of a thermistor chain.

Vertical profiles of suspended matter will be developed with a nephelometer, which will be linked to a CDT/0_2 probe.

Japan

Current Measurement -- The current measurements at the proposed low level radioactive waste dumping site (SITE B: 30°N, 147°E) were started in September, 1978, and since then, the recovery and deployment operations were carried on three times at Station TA, TB, TC, TD, TF and TG (Figure II-1, Table II-3). Aanderra Model 5 (RCM5) current meters and AMF acoustic release/pingers, Model 255, were used in all operations.

Table II-3

Description of the Mooring Stations

Mooring Station	Location	Water Depth (m)	Nominal Depth of Current Meter (m)	Deployed	Recovered	Duration in Days
	First Setting (Hakuho Maru KH-78-4; Hakuho Maru KH-79-1)					
TA89	29°59.4'N, 145°45.1'E	5810	3000 4000* 5000 5410 5610 5710** 5760	30-IX -78	16-III-79	167
TD8A	29°35.2'N, 146°40.3'E		6040 4000*	1-X -78	19-III-79	169
	Second Setting (Hakuho Maru KH-79-1; Hakuho Maru KH-79-3)					
TA93	29°59.3'N, 145°45.3'E	5850	4000 5000 5450 5650 5750† 5800	20-III-79	23-VII-79	126
TB93	30°08.3'N, 145°45.0'E	5930	5815 5765	20-III-79	24-VII-79	127
TC93	30°45.1'N, 145°48.0'E	6040	4000 5000	20-III-79	24-VII-79	127
	Third Setting (Hakuho Maru KH-79-3; Keiten Maru KE-79-10)					
TA97	30°00.4'N, 145°46.7'E	5830	4000 5000 5220 5420† 5630 5780	26-VII-79	31-X -79	98
TC97	30°48.1'N, 145°46.6'E	5950	4000 5000*	24-VII-79	31-X -79	100
TF97	29°59.5'N, 144°59.8'E	5930	5000 5420 5820	27-VII-79	30-X -79	96
TG97	30°00.2'E, 144°03.2'E	5720	5000 5450 5650	22-VII-79	30-X -79	101
	Fourth Setting (Keiten Maru KE-79-10,‡)					
TA9A	30°02.9'N, 145°43.1'E	5800	4000 5000 5200 5400 5600 5750	31-X -79		
TC9B	30°49.5'N, 145°45.8'E	6000	4000 5000	1-XI -79		
TF9A	29°59.8'N, 145°01.3'E	5900	5400 5800	30-X -79		

*Data were not completely obtained because of a battery trouble.
**The pressure case was crushed soon after the deployment.
†Current speed data were not obtained.
‡Recovery is scheduled for May 1980 during the Hakuho Maru Cruise KH-80-2.

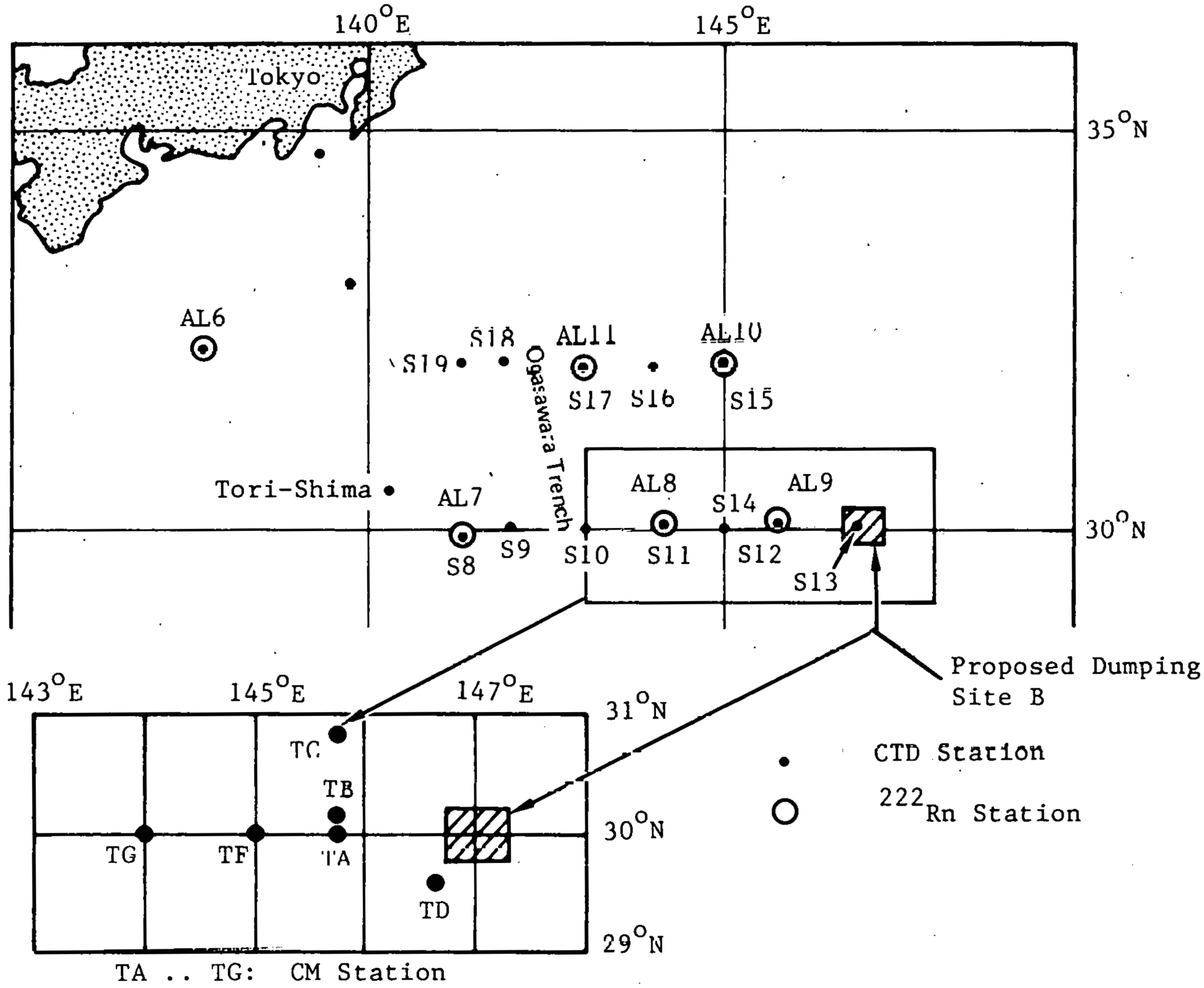


Figure II-1 Station Map Near Site B

The sampling interval for current speed and direction measurement was 30 min or 1 hr. The daily average velocity of the current at depths of 4 and 5 km is shown in Figure II-2. The longest record was obtained at a depth of 5 km at Station TA (391 days). The most striking feature was that the direction of current was almost always southward, and the maximum speed was more than 10 cm s^{-1} at 5-km depth. The results obtained so far show that the current velocity decreased with decreasing depth. The frequency of the velocity change was between several tens of days and one hundred days.

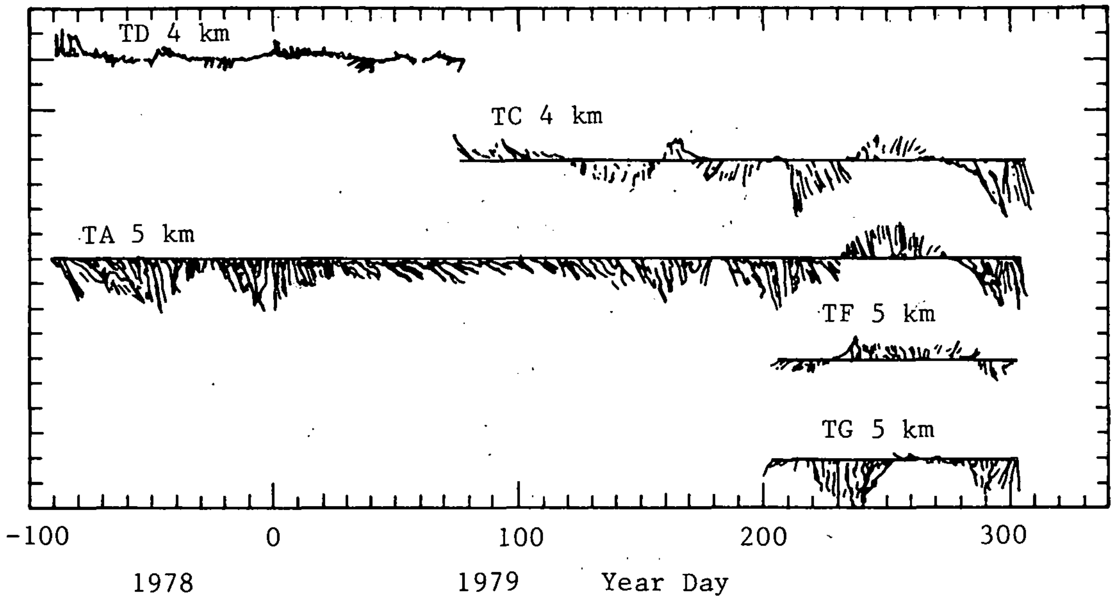


Figure II-2 Variation of Current Velocity at 4- and 5-km Depth

Eddy Diffusion and Vertical Profile of Temperature Near Bottom -- ^{222}Rn concentrations 300 m from the bottom to the bottom were measured on board with a Rn-scintillation counter at stations near the proposed low-level radioactive waste dumping site in the western Pacific. Also, detailed near bottom temperature profiles were obtained at these stations with a NBIS MARK III CTD system.

Figure II-1 shows the stations at which ^{222}Rn (AL 6, 7, 8, 9, 10, and 11) and CTD (S 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, and 19) profiles were obtained. The application of a simple diffusion model to the vertical distribution of ^{222}Rn gave eddy diffusion coefficients of the order of 10 to 102 cm^2s^{-1}, with a relatively large standard deviation (Table II-4). CTD observations in the same area showed that the potential temperature in the bottom water was not uniform. For example, at Station AL 8(S 11), S 14 and Al 11(S 17), the potential temperature dropped by 0.01°C near sea floor (Figure II-3). An abrupt temperature change could be observed at other stations. These ^{222}Rn and temperature data suggest that there is a boundary layer(s) separating the bottom water into two (or many) layers in which rapid vertical mixing occurs. The bottom topography may play an important role in the mixing of bottom water. The temperature change near the bottom is clearly observed in the western part of the area shown in Figure II-1.

Table II-4

Eddy Diffusion Coefficient by the Simple Diffusion Model

Station	Position	K ($cm^2 s^{-1}$)
AL 6	32.3°N, 137.6°N	106±922
AL 7	29.8°N, 141.7°E	123±156
AL 8	30.0°N, 144.2°E	33±12
AL 9	30.0°N, 145.8°E	150±135
Al 10	32.0°N, 145.0°E	70±54
AL 11	32.0°N, 143.0°E	9±7

^{14}C, ^{90}Sr, and ^{137}Cs analyses of intermediate and deep waters in this area are now underway. Further ^{222}Rn distribution studies and CTD observations will be carried out between 147°E and 157°E; 30°N and in the northwestern Pacific from April-June 1980. On this cruise (R/V Hakuho Maru), two scientists from WHOI (Dr. Bowen's Lab) will collect sediment and seawater samples for Pu analysis.

Netherlands

In the Netherlands, no approved physical oceanographic research plans exist in relation to seabed disposal. As far as physical oceanography is concerned, possible research would concentrate on the physics of the benthic boundary layer, including observations of currents (e.g. three moorings in the bottom 500 to 1000 m, at 10 to 50 km spacing) and deep CTD casts. The addition of a thermistor-chain to one or two of the moorings would seem to be valuable for longer term (up to 6 months) observations.

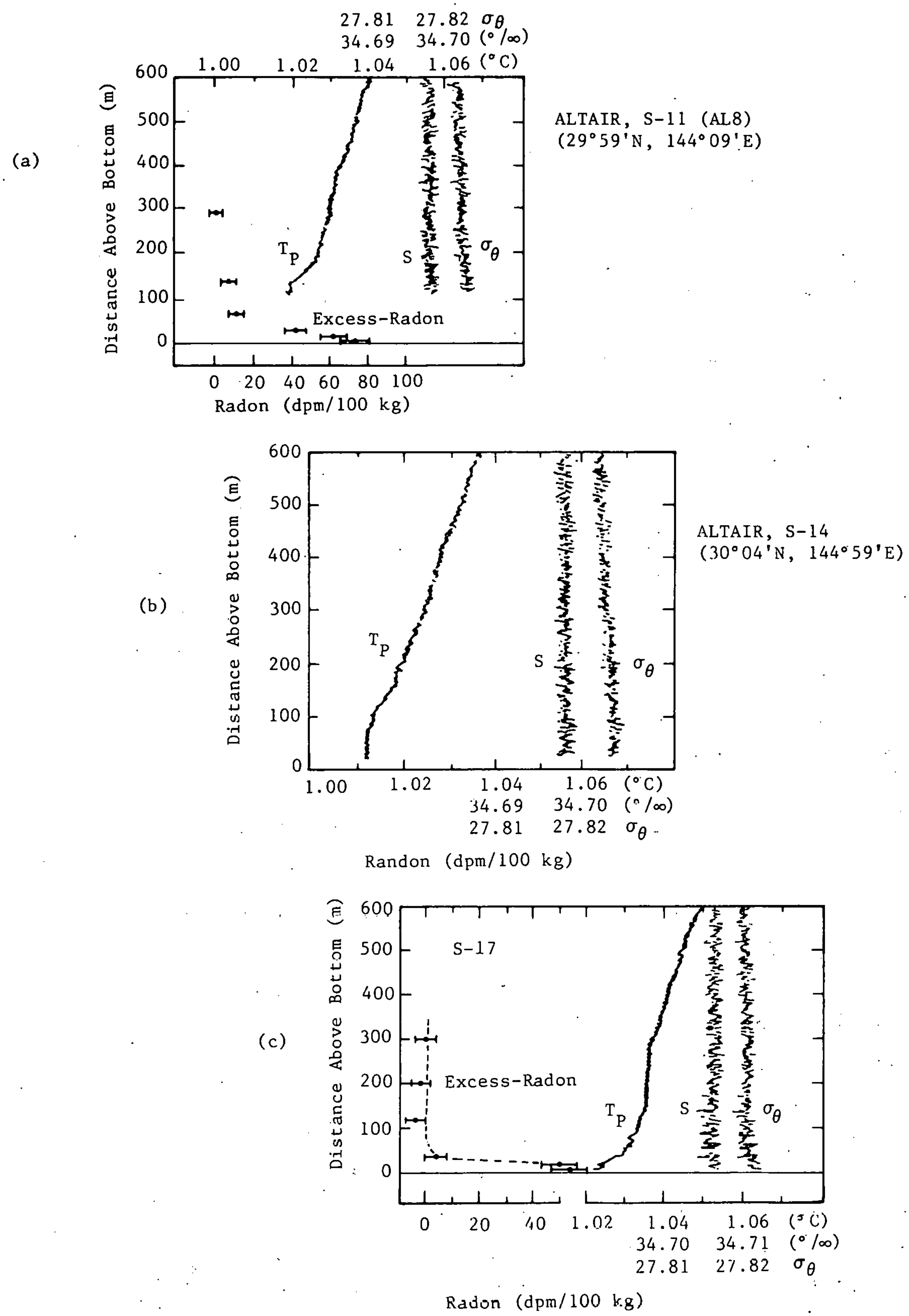


Figure II-3 Vertical Profiles of ^{222}Rn and Potential Temperature

Switzerland

For the first time, Switzerland was present as an observer at the Seabed Disposal Group Meeting. The aim of this participation is mainly to evaluate a further Swiss contribution to the program, taking into account that this country has very limited oceanographic activities (since Switzerland has no direct access to the sea). It appears, nevertheless, that some joint research could be done, perhaps related to the benthic boundary layers, using specific competence available in this country. This possibility will be evaluated as soon as possible based on the results of the present meeting.

United Kingdom

Progress Over the Last 12 Months: Fieldwork -- During a cruise in June 1979, RV *Cirolana* recovered the upper bottom current meter mooring at NEADS-6 (See Appendix 1979 report for positions and background to NEADS stations) and replaced it with a full-depth mooring (currently there are 2 yr of MAFF data from NEADS 6). A further seven upper bottom moorings were laid between the European Continental Slope and the NEA dumpsite at 46°N 17°W (NEADS 5) in the array shown in the 1979 SWG Report (p. 65). At NEADS 5 there are three instruments within 750 m of the seafloor to compensate for previous failures of bottom meters at this position.

On the same cruise five of the seven moorings laid NNE of the Azores along 41°N in July 1978 (see p. 65, 1979 SWG Report) were recovered, a detailed hydrochemical survey of the water column at the NEA dumpsite was carried out with particular emphasis on conditions in the bottom 1 km. Three successful deployments of amphipod traps were made.

In September-October MAFF Lowestoft worked with three other European laboratories (COB, MNHN, and La Spezia) in the detailed study of an eddy which lay within 100 miles of the NEA dumpsite. Figure II-4 shows early versions of some of the results. Only the MAFF participation was in direct support of the deep sea dumping program (DSDP). The other three laboratories looked at the purely scientific problem of a mesoscale eddy and its relation to the mean circulation. However, within this timescale, the COB also took the opportunity to add one deep mooring and carry out several deep casts in order to obtain specific results for the DSDP. This work was funded by CEA. It is expected that our French colleagues will be reporting on the results of this exercise in greater detail.

Analysis and Presentation of Moored Current Meter Data -- The two deployments at the NEADS-6 site have provided energetic, highly coherent records in the bottom kilometers of the water column, with dominant periods between 1 week and 1 month and with little sign of seasonal or annual changes in the kinetic energy spectra. These results are in keeping with Philander's theory of atmospheric forcing to the seabed beneath the midlatitude "storm belt."

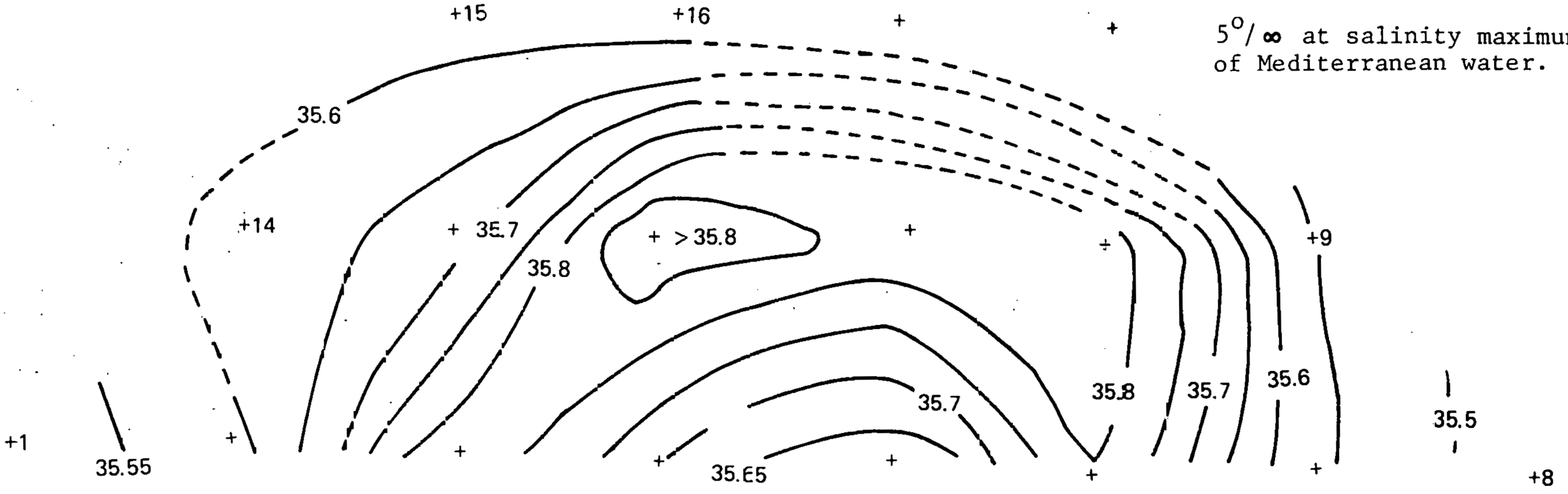
Continued analysis of the 1978 data from the Charlie Gibbs Fracture Zone shows relative rates of change of eddy kinetic energy (K_E), with depths similar to those reported by Schmitz and Hogg from the northern trench 330 km distant when the total eddy kinetic energy is partitioned into four component frequency bands. K_E for the lowest frequency bands increases sharply upward, while the highest frequencies are bottom intensified.

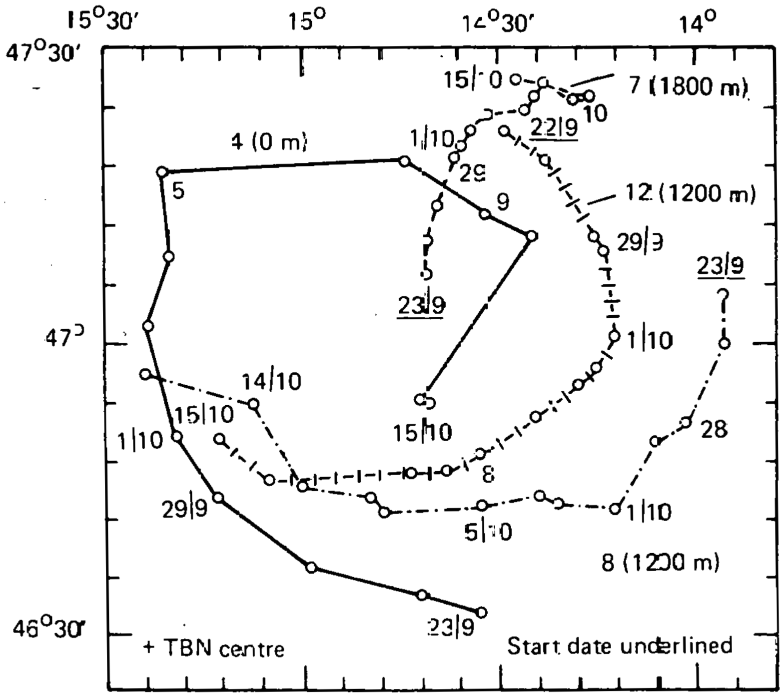
Preliminary analysis of results from the 41°N array indicates a very slow southward drift west of 25°W and a predominantly northerly drift east of that longitude, with weak eddy kinetic energies of 0.2-1.8 cm^2s^{-2}.

A previous three-dimensional plot of eddy kinetic energy per unit mass has now been expanded into four Atlantic charts covering the depth layers 0 to 800 m, 800 to 1800 m, 1800 to 3800 m, and 3800 to 4300 m, incorporating statistics from some 170 moorings of 9-months-plus duration from all available sources. Up to 70 further records are in prospect from current moorings. The eventual long-term aim is the inclusion in North Atlantic diffusion-advection models of some form of spatially-varying diffusion coefficient that has been derived from these charts. Copies of the individual charts in their present form are available on request from Dr. R. R. Dickson at Lowestoft.

Figure II-4a TOURBILLON Cirolana Grid C.

S°/∞ at salinity maximum of Mediterranean water.





Selected trajectories
22 Sept - 15 Oct 1979.

b. Floats.

Modelling -- The Lowestoft Laboratory now has two models related to the disposal of radioactive waste: a three-dimensional general circulation model of the Atlantic Ocean based on Bryan's work, and a two dimensional meridional circulation model of the western Atlantic recently developed by Shepherd.

The three-dimensional model, which has 10 depth levels and a 2° x 2° horizontal grid, is run as a diagnostic calculation, i.e., it is spun up from rest with a prescribed fixed density field, wind-stress and realistic bottom topography. As there are open boundaries in this model, various areas have been tried. The region currently being examined is 20°S-66°N, 0°-80°W. The model has been run with an homogeneous density field; the results agree with those published by Holland and Hirschman (1972).

The two-dimensional model works in isopycnal coordinates and is currently concerned with the region below the thermocline between the American continent and mid-Atlantic ridge from 50°S-60°N. The flow field is determined by the requirement that the temperature and salinity fields should match the observed (GEOSECS) data. Using the best-fit flow field other naturally occurring (nonconservative) tracers are being studied to discover more about their production and consumption rates in the deep ocean.

Plans for the Next 12 Months -- The main components of MAFF Lowestoft's 1980 field program are:

1. Recovery of the 10 current meter moorings deployed as part of the Anglo-French exercise of 1979-80. (See 1979 SWG Report, p. 64-65);

2. Redeployment of a full-depth mooring at NEADS 6, and deployment of eight year-long moorings across the Continental Slope on the spur between Whittard and Shamrock Canyons (Figure II-5);

3. An initial survey via CTD and nephelometer of slope processes between the tail of the Rockall Plateau and the Bay of Biscay region (Figure II-5); and

4. An exploratory survey of a possible dumping site south of the King's Trough at 41°-43°N, 20°-23°W, (Figure II-5).

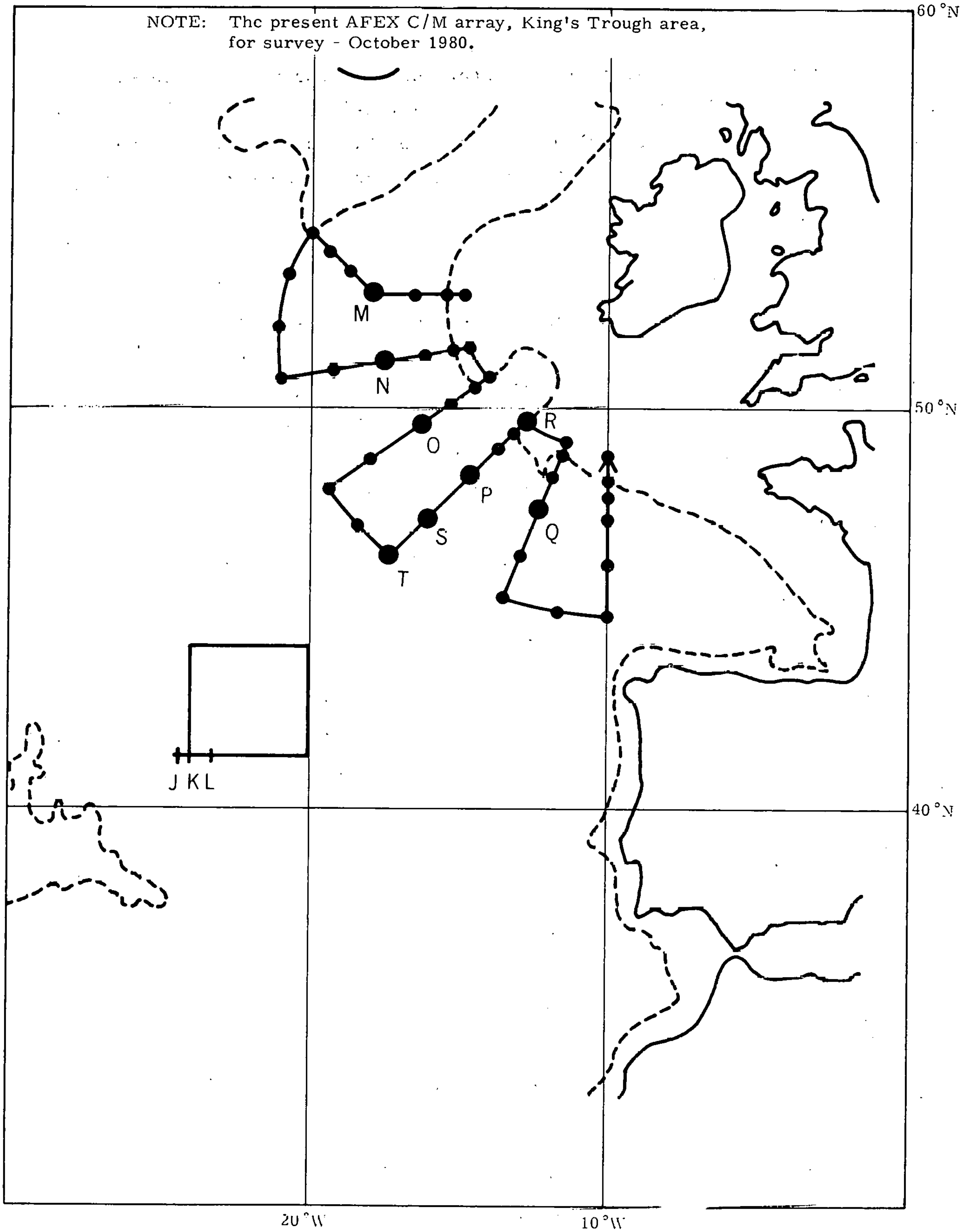


Figure II-5 MAFF NEPH/CID Grid, June 1980

There are two research vessel cruises planned: one in June (items 1-3) and the second in October (item 4). The June cruise is primarily designed around an extensive CTD and nephelometer grid west of the Continental Slope (Figure II-5), with special emphasis on the northern part of the grid where nephel plumes at 1.5- to 2.5-km depth give evidence of slope erosion and offshore dispersion of suspended sediment. In this northern area the grid will extend westward to the North Atlantic Current front west of 20°W, and some 300-litre samples for $226/228_{Ra}$ analysis will be taken along the plume. Particle size distributions above, below, and in the plume will be determined via a HIAC system. Dr. Kilho Park of the Ocean Dumping and Monitoring Division of NOS/NOAA, and his colleagues, Drs. R. Newman and J. Bisagni, will bring their DOMES nephelometer on the cruise. Amphipods will be collected at a number of points along the survey grid and the line of Continental Slope moorings will be laid as part of the overall schedule.

The October cruise will complete a preliminary survey of the area 41°-43°N, 20°-23°W, which has been designated by the SWG site selection task force as a possible site for further study. There are a number of current meter moorings around this area (MAFF moorings J, K, L of the 41°N array, NEADS 4, NEADS 3.5), together with sediment cores (IOS) and XBT sections (MAFF/IOS). A number of year-long "upper bottom" current meter moorings will be deployed in 1980 together with at least one full depth mooring. A grid of STD stations will be taken, and water samples will be collected for on-board analysis for a number of parameters, including oxygen, nitrate, and silicate. Some sediment cores will be taken via a boomerang corer to the northeast of the area to supplement those already collected by IOS. Isaacs-type abyssal fish traps will be deployed and recovered. Both T4 and T7 probes will be deployed on passage. The route to be followed will take in the Shamrock Canyon region visited by the June cruise.

Modelling.

The three dimensional model will be run with a fixed observed temperature and salinity structure and observed wind stress in order to provide a reasonably realistic, self-consistent velocity field. Once any necessary adjustments have been made, this velocity field will be held fixed and the temperature and salinity equations allowed to represent, with suitable modification, various tracers both conservative and nonconservative and radioactive and nonradioactive. Initially the temperature and salinity fields will themselves be used as a consistency check. The dispersion of "pollutants" from point sources will also be studied.

The two-dimensional model will be used to study the naturally occurring tracers in the Western Atlantic. It is hoped that over the long term absolute flows in the water masses in the model can be determined once Carbon-14 data has been included. A similar model may be developed for the eastern Atlantic and possibly later for the other oceans.

Institute of Oceanographic Sciences.

In recent months, the Institute of Oceanographic Sciences has begun an interdisciplinary program on behalf of the UK Department of the Environment concerned with some of the environmental questions related to the disposal of high level radioactive waste into or under the sea. The scientific background from which the program is developed is described in IOS Report No. 77, "Oceanography Related to Deep Sea Waste Disposal."

This report proposed physical oceanographic work in two major areas. First, we recognized that for both sea-disposal options a description (and models) of the dynamics of the ocean immediately adjacent to the bottom was required. Some illuminating experiments have recently been performed by US scientists, but for much more experimental work in a variety of localities. Second, we proposed that, as the role of the ocean in this problem is to act as a dispersant, it is necessary to obtain data in the deep ocean on the efficiency of the diffusion process.

Of these two components the first has commenced in the last few months and the second is still under discussion. The projects are outlined briefly in the following text.

Dynamics of the Benthic Boundary Layer. The objective is to examine, by measurement near the sea floor, the processes which control the structure and spatial and temporal variability of the benthic boundary layer. This will provide information which will enable models to be devised of the response of the layer and its diffusive characteristics to the variable forcing of low-frequency motions, including the tides and mesoscale eddies, in regions of differing topography or parameter regimes defined by the comparison modelling program.

Measurements will be made of the temperatures, currents, and turbidity of the lower 200 m of the water column. Two new instruments will be constructed and deployed. One is intended to measure temperatures and currents within the lower 2 m of the water column and thereby assess the stress on the sea bed, a quantity fundamental to diffusion and sediment stability. The instrument will carry a camera which may be used to identify the nature of the sea bed and detect any signs of sediment movement. The second instrument will be a vertical array of thermistors to measure the temperatures at several levels up to about 200 m from the sea bed. This array will also carry instruments to measure the turbidity and be used to obtain information about the nature and effectiveness of mixing processes which act through the depth of the benthic boundary layer. In the early stages the instruments will be capable of recording for a few days only. A third development will be to adapt and improve the existing IOS float tracking system for the purpose of measuring (Lagrangian) currents, current shear, and dispersion.

Within the first 3 yr of the project, it is intended that the instruments will be deployed at sea in an abyssal plain area and the first assessment of their measurements will be made.

Several of the instruments will be needed to provide information on the horizontal coherence of structures, and their data recording capacity will be extended. In the light of growing knowledge of the boundary layer structure, it may be necessary to conduct conditional sampling experiments of long duration in which only data measured during periods of extreme currents will be retained.

The objective of the numerical and theoretical work is to complement the experimental studies of the dispersion of radioactive material from the sediment, through the benthic boundary layer, and into the main water column. The models will be designed to reproduce known physical processes for comparison with the experimental results, to identify regions requiring further experimental work, and to extrapolate to scales in which experimental observations are impractical.

Initially, we intend to concentrate on a model of the benthic boundary layer over an abyssal plane. This first model will include the effects of large-scale oceanographic eddies, density differences within the ocean, tides, and also the turbulence produced by currents at the ocean floor. Consideration should also be given to the effects of internal waves and of small abyssal hills. The work will take account of that carried out by meteorologists on the atmospheric boundary layer.

The model will be designed to identify which processes are most important in the observed changes in thickness of the mixed layer and in the initial dispersal of radioactive material. Further work will depend on how the models and experimental work affect our ideas on where vertical mixing occurs. If mixing on continental slopes or abyssal hills followed by isopycnal mixing is found to be most important, attempts will be made to model this process.

There has been good progress on the construction of the instrument for estimating bottom shear stress and temperature fluctuations near the sea floor (BENCAT-benthic current and temperature recorder). It has been tested successfully under free-fall conditions in a test tank, and in the coming months pressure tests on current and temperature sensors will be completed. After a shallow water trial in the summer an open sea trial will be scheduled in October, followed by a deep water deployment in January. The 200-m thermistor array is in the engineering design stage; the most significant new development for the IOS float tracking system will permit, through echo-sounding from the float, measurement of the height of the float from the bottom to an accuracy of 1 m, which is felt to be necessary for useful exploitation of the float data. Work on the boundary layer modelling will commence during the summer.

Dispersion in Deep Water. The dispersive properties of the deep water of the eastern North Atlantic will be studied above the benthic boundary layer by tracking Sofar floats over distances of the order of 1000 km, using moored listening stations. Existing models of dispersion of dissolved waste depend heavily on eddy-diffusion coefficients derived from large-scale distribution of properties. It is doubtful to what extent this approach is valid.

Current measurements have shown that, away from certain strong quasi-steady currents, much of the kinetic energy is in eddies having dimensions on the order of 100 km and more, and time scales on the order of weeks to months. In the eastern North Atlantic, what is known about the statistics of these eddies has been learned largely from observations with moored current meters at a few specific locations. Very few observations of the separation of pairs of floats have been made, and then only for short periods of time. These are more relevant to the present problem than the single-point observations with widely spaced current meter moorings. Moreover, the description of the larger scale (mean) circulation that can be made from information from floats is complementary to that given by the current meters. They highlight regions of intense currents, and their statistics over many trajectories closely relate to the probability information we wish to acquire on dispersion of parcels of water in the basin.

This proposal is still under discussion. If funded, this long range float tracking will naturally be linked to the benthic work and, where possible, to the Sofar float program being operated in the North Atlantic by the Woods Hole Oceanographic Institution (WHOI) and the University of Rhode Island. A member of IOS staff is presently at WHOI gaining experience in the design and construction of Sofar floats and listening stations.

A 6-month deep array experiment is planned near Needs Site 1 (33°N, 22°W), to observe the coherence scales of processes within the boundary layer in an abyssal plane region. This experiment will also attempt to observe connections between the boundary layer and external flows.

Seven moorings with rotor-vane current meters will be deployed with instruments at height 10 m above bottom and horizontal spacings between 5 and 50 km; three of the moorings will have instruments at 700 m above the bottom to observe the external flow. A central mooring will be densely instrumented at 10 to 15 m spacing in the vertical. The array will be deployed in November 1980 and recovered in April 1981.

United States

The United States activity in physical oceanography consists presently of program development, a modelling project initially related to the bottom boundary layer being initiated by M. Marietta, and preparation for moored current measurements to be carried out during site exploration cruises also coordinated through that laboratory.

A significant step in program development was taken during the past year in terms of a workshop on Physical Oceanography Research Required for Seabed Disposal of High-Level Nuclear Wastes* which was held under Department of Energy sponsorhip at Big Sky, Montana, from January 14-16, 1980. This was a systematic and substantial step in planning considered necessary to improve the overall structure and to develop the many-faceted details of the Research Plan presented by the US to the Fourth International Meeting and published as part of the Physical Oceanography Task Group report. The application of physical oceanographic science to the high-level disposal problem has novel and difficult aspects. Because of the global, long-term character of the problem and because of the importance to society of the results, almost all aspects of the science involved is to quantify answers to questions which in part cannot be answered in terms of existing knowledge.

*In press, Sandia National Laboratories

The workshop, which involved 28 highly qualified expert participants, was organized around eight physical topics preselected to focus the scientific field on the application area. These included (1) BBL, (2) mixing and small scale turbulence, (3) mesoscale processes, (4) circulation models, (5) descriptive oceanography, (6) islands and coasts, (7) experimental work and floats, (8) ocean and sediment chemistry. In each case, the relevance of the topic to the application was assessed, and required research efforts identified, prioritized, the length of time required to carry them out estimated, and the degree of feasibility judged. In addition, the interfaces with chemistry and biology were discussed, overlap with other applicable research including chemical dumping and low-level waste disposal noted, and on-going or future research programs relevant but dedicated primarily to other purposes (e.g., climate) identified. The findings, which are presently being analyzed and synthesized, will be issued as a Sandia report during the coming year and will be made available to the Physical Oceanography Task Group for their information. The report should serve as the basis for the initiation of an expanded US research program.

General Discussion

The Task Group had a wide-ranging discussion on various aspects of modeling, parameterization, and mixing processes out of which a number of points arose which it thought worth bringing to the attention of the other Task Groups of the Seabed Working Group.

Modelling and Parameterization -- The physical fields in the ocean are known to vary energetically over a wide range of time and space scales. Nonlinear dynamics and thermodynamics are known to contribute to the interactions among scales and physical influences from one scale range to another, e.g., turbulent transports and large-scale advection of mesoscale vortices. Thus, although information may be required over one scale range, physical processes at quite another range may be of crucial importance. Unfortunately, the ocean is a complex physical system, and many fundamental processes remain to be identified, described, understood, or even discovered. For example, the problem of modelling the evolution of concentration fields over thousands of years may require adequate modelling of small-scale cross-isopycnal mixing motions and/or mesoscale motions which stir, interleave, and tear off blobs of the source material long before true mixing occurs.

Because of the inherent complexity of the multiscale system and also because of the present state of the science of physical oceanography, a realistic model of the circulation of the ocean does not exist. There does, however, exist a variety of special purpose models constructed for studies of particular processes, regions, or scale ranges. In some cases, the models are intended simply as abstract idealizations. In other cases, the model fields are intended to represent analogs of real oceanic fields. In the latter case, it is necessary for the modeler to specify the space-time averaging procedure to be performed on observational data when he attempts model verification. Relevant processes which are smaller and faster than those explicitly resolved within, or which occur in a region external to, a special purpose model require parameterization. Such parameterizations themselves require verification. Because of the great number of physical processes which are probably involved in circulation modelling, and because of the long time scales of interest, the Physical Oceanography Task Group has identified parameterization as a reseach area to be particularly encouraged; for example, the attempt to reproduce without eddy-scale resolution mean fields obtained previously in EGCM's and compare these with coarse grid models is a serious research task, requiring considerable commitment.

The Mark I elementary circulation model formulated for use by the System Analysis Task Group (described below) is an abstract special purpose model intended for idealized representation of physical transport processes. It is regarded as suitable for preliminary system studies over a wide range of parameters in order to develop experience with processes and in the interpretation of results of coupled components. It is an unrealistic circulation model and the model fields are not intended as real ocean analogs.

The use of the prototype Mark I physical model as a component in the System Analysis Task Group model will allow prototype sensitivity studies to be carried out in simplified, idealized circumstances. This is not the same as the sensitivity of the real system of interest, because one learns only the sensitivity to the variations of the parameters appearing explicitly in the prototype model, and not to changes in the structure and complexity of the model itself.

Further relevant modelling is being carried out and developed in the various national research programs. It is form this set of special purpose process and circulation models that relevant processes and parameterization will be drawn for future models for the Systems Analysis Task Group.

Mark I Elementary Model of Physical Transport Processes --

Purpose.

A simple model of physical transport processes within the water column is required as part of the overall systems model, the first goal of which is sensitivity analysis. For this specific purpose only, we propose the simplest possible transport model in which one can represent in idealized form certain processes which we believe to be relevant (Figure II-6). The intention is to provide a basis for the study of the dependence of the results of the whole system model, to the variation of parameters over the full range of possibilities.

We have deliberately constructed the crudest and most elementary model so that it cannot be confused with a realistic model of ocean circulation or transport. It is probably unsuitable for any other purpose, and should not be used for a proper hazard assessment. Other models of physical transport are being developed and will become available for that purpose in due course, and may then be incorporated in the overall systems model.

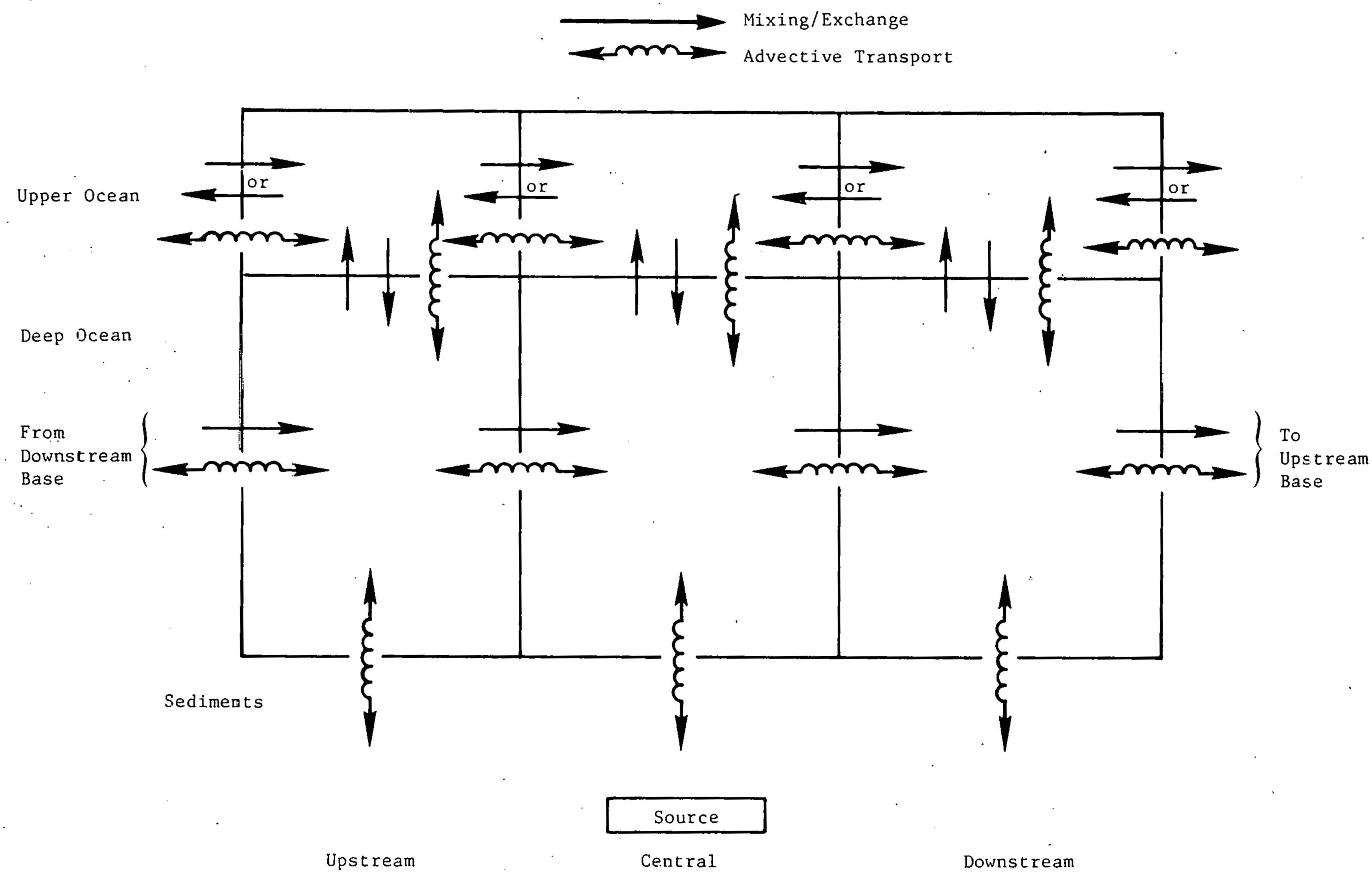


Figure II-6 Elementary Physical Transport Model

Description.

The processes included are

- Horizontal motion (advection)
- Horizontal mixing
- Vertical mixing
- Vertical motion (upwelling and downwelling)
- Interaction with sediments

These are represented with a box model containing six boxes, three representing deep water below the main oceanic thermocline and three representing shallow water above it (Figure II-6). Three boxes at each level are required to distinguish advection from mixing.

The release of radionuclides from sediments is treated as an input to one of the deep boxes. Interchange between sediments and water is included in each deep box.

Advective processes are specified as water mass transports between boxes. Water leaving the downstream box is returned immediately to the upstream box. Vertical transport up or down through the thermocline must be added to or subtracted from horizontal transport in order to conserve water.

Mixing processes are specified as transfer coefficients, having the dimensions of a water transport, defined as

$$R = KA/X$$

where K is the eddy diffusion coefficient, A is the interfacial area, and X the typical base dimension. Advective exchanges are unidirectional, whereas "diffusive" exchanges are bidirectional.

With this model, the magnitude of advective processes may be varied at will. The situation in which surface circulation is in the same direction as the deep circulation should be considered, as well as that in which it is in the opposite direction.

The range of parameter values which should be studied should cover the full range of possible model applications--not only those applicale to a particular ocean basin. Suggested parameter ranges and values are set out in Table II-5 which may need extension, and a nondimensional formulation might be preferable. Certain special cases should also be considered, namely:

- Complete vertical mixing between upper and lower boxes (the upper layer is absent, corresponding to the outcropping of the thermocline at the surface of that region.
- Localized intense vertical transport and exchange (by making one pair of boxes small in volume).

Table II-5

Parameter Values and Ranges

Parameters	Exchange Time	Typical Parameter Values
Volume of each deep box		3E16 m^3
Volume of each shallow box		1E16 m^3
Thickness of deep boxes		3000 m
Thickness of shallow boxes		1000 m
Deep water transport	30 yr to ∞	0 to 30 SV
Shallow water transport	3 yr to ∞	0 to ±100 SV
Horizontal eddy diffusion	30 yr to ∞	0 to 1E8 cm^2/s
Vertical eddy diffusion	30 yr to ∞	0.1 to 100 cm^2/s
Vertical water transport	30 yr to ∞	0 to ±10 SV

Stirring and Mixing.

With the advent of better resolution measurement systems in recent years, it has become evident that the ocean does not mix uniformly in space and time. Recent results have shown that blobs of water, on the order of hundreds of meters in depth and tens of km in diameter, can retain their water mass characteristics over long distance and time scales, and may retain isolated biological populations. This is a very real and important advance in our physical oceanographic understanding. The frequency of occurrence and persistence of these blobs is not known, but it is already known that they may contain self-contained planktonic populations, and it may be that these persistent blobs of water would also attract a predatory species higher in the food chain. We have thought of this problem in physical oceanography in terms of the difference between uniform mixing vs stirring, where blobs or ribbons of water retain their characteristics.

The Physical Oceanography Task Group wants to call particular attention to this phenomenon. The ocean appears to mix differently from previously studied fluid systems. We have to consider the importance of this difference in mixing and stirring to the radiological assessment in physical oceanography model terms, and would request that the Biology Task Group also consider this phenomenon and inform the Physical Oceanography Task Group of their views on the biological consequences. It may be that the appropriate space and time scales for averaging will ultimately be determined by such biological aspects, rather than by physical processes.

From physical considerations, the existence of these phenomena and their investigation lead us to think in terms of probability distributions of concentrations, rather than average concentrations such as those obtained from simple diffusion models.

Source terms -- The task group also discussed the source functions which should be introduced into the physical model. These comprise four possible types ranging from a long slow continuous release from the sediments, through the small accident situation (a single broken canister), to the big accident situation (a sunken ship and numbers of containers on the seabed), and finally to a situation where serious mistakes may have been made in the sediment assessment calculations. All of these situations really reduce to basic forms within the two extremes of a long continued release and a short-term pulse. Discussion covered the possible chemical, thermal, and biological effects of these sources in the water column: for the long releases there should be no significant nonlinear chemical or thermal effects. In the pulse-release case, it was still felt that the chemical effects would probably be linear perturbations to the system, but that there ought to be a simple but more detailed calculation to consider the localized heating effects. The accident situation produces new habitats (changed bottom topography and temperature regime) for benthic fauna, and serious consideration by the Physical Oceanography and other task groups should be given to these effects.

Long Term Changes -- As a general point to be borne in mind when planning or undertaking research cruises, it should be remembered that it is now 20 yr since the last comprehensive coverage was made of a wide range of oceanographic parameters in many areas of the deep ocean-(The International Geophysical Year). A reasonable distribution of deep-sea oceanographic measurements of similar parameters using modern equipment would be a very useful set of comparability data.

Advice and Communication -- The Physical Oceanography Task Group finally considered what further advice it should give to other task groups (particularly the System Analysis) and how to improve communication both within the Physical Oceanography Task Group and between Task Groups. It was agreed:

- The system analysis interim report would be re-circulated to members and that an attempt would be made to update the base case scenario parameter ranges.

- A list of selected references to pertinent papers (including internal reports not yet in the published journals) on the BBL and on oceanic circulation models be prepared, and offered to the Systems Analysis Task Group for general reference.

- To recommend to the Executive Committee that a similar list of selected references be prepared by the other Task Groups and circulated to all task groups.

- That cruise plans, including a brief outline of the aims of the cruise, be submitted each year by each member, for circulation by the lead correspondent to all members of the Physical Oceanography Task Group.

- That progress reports be submitted more often than annually within the Physical Oceanography Task Group although it was considered that an intersessional meeting would not be appropriate before the next meeting of the SWG.

BIOLOGY TASK GROUP

Participants

A. A. Yayanos (USA), Lead Correspondent
B. Hargraves (Canada)
Y. Belot (France)
R. Ichikawa (Japan)
R. J. Pentreath (UK)

Observers

W. Feldt (Federal Republic of Germany)
D. Schnack (Federal Republic of Germany)
H. Thiel (Federal Republic of Germany)
M. Sibuet (France)
H. Ishikawa (Japan)
A. W. Van Weers (Netherlands)
W. G. Cadee (Netherlands)
M. Angel (UK)
A. L. Rice (UK)

Introduction

The fifth meeting of the Biology Task Group was held in Bristol, England. The meeting was the first one thus far in which six radioecologists and deep-sea biologists were assembled.

During the workshop the following was achieved:

- Data, concepts, and national research plans related to aspects of radioactive waste in the marine environment were exchanged or updated by the SWG nations.
- The Task Group agreed to assist the System Analysis Task Group in finding a simple radioactive transport model to be used by the System Analysis Group as part of their overall systems model. The Biology Task Group will also prepare estimates of the needed parameters for the mathematical model.
- In addition to reviewing the research themes proposed in past Biology Task Group meetings, new topics were identified and in some cases plans for implementation developed.

The following sections address each of the above items in detail.

Information Exchanged

The Biology Task Group met and provided updated plans on how research into biological and radioecological research should proceed. The data exchanged formed a basis for comparison with and evaluation of the recommendations of the Biology Task Group in previous years. Models of the deep-sea ecosystem are being prepared by several nations and properties (primary production, biomass vs depth into the sea, and benthic community respiration) are being determined as well as estimated from the literature. A breakdown of last year's accomplishments by country follows:

Canada

At the Marine Ecology Laboratory of Bedford Institute, experiments to measure the vertical transport of particular organic matter by gravitational settling and by the migration of planktonic crustaceans has been completed. Traps were suspended for variable time intervals at fixed depths in the ocean to intercept suspended particulate matter and planktonic organisms. Estimates of material flux from these studies were compared with in-situ measures of gas and nutrient exchange across the sediment/water interface to quantify the fraction of the deposited organic matter which decomposes in sediments and is released. Up until 1979, these studies were carried out in coastal areas off Nova Scotia. Similar experiments are planned for the continental shelf and slope off Nova Scotia in 1980.

France

Since the Fourth Annual International Seabed Working Group Meeting, the following major programs were conducted by the abyssal biological team at Centre Océanologique de Bretagne (COB) in France:*

*See also the Rapport Scientific, 1979, of the C.O.B.

Estimation of Benthic Biomass for Meio-, Macro-, and Megafauna -- During the last cruises (Walvis 79 and Biogas VII 1979), intensive sampling in a small area was completed using acoustical navigation in order to obtain estimates of the length of time required to get statistical data using towed cameras and trawl tracks on the sea floor. Comparisons of the biomass of the macrofauna with the organic matter in the sediments in different abyssal basis has shown that the $CaCO_3$ in the sediments has a major influence on the amount of organic matter present. This research program will continue during the subseabed cruises scheduled for 1980 in Cape Verde basin. In addition, some of these animals will undergo trace element analysis to determine concentration factors.

Bioturbation Studies -- The relation between the density of epifauna and bioturbation of the sediments was determined at two depths: 2 km and 4.5 km, in the Bay of Biscay. Detailed results will be forthcoming in a report from COB.

In-situ Respiration -- A technical analysis of the in-situ respiratory measurement is now in progress.

Sediment Traps -- The first set of sediment traps has been constructed at COB, and the first mooring will be made in the Bay of Biscay in 1980.

Modelling -- A rough sketch of a global model for biological transfer of radionuclides was prepared during meetings with the System Analysis Task Group and with the radioecologists of the CEA of La Hague. Important points for the model include:

- The quantity of radionuclides ascending to the photic zone cannot be greater than the quantity of organic material produced in the benthic level (taking into account the concentration factor). That is, if we assume that the benthic biomass remains a constant, then energy available to move the radionuclides cannot be greater than the quantity entering the benthic biomass minus the quantity of energy lost by respiration and by burial within sediment. The sedimentation rate may be estimated by the use of a sediment trap, and the energy lost by respiration may be estimated by in-situ measurement.

- Radiological studies are continuing in France, addressing the behavior of technetium and plutonium in sediments and their transport to benthic organisms. The sediment and biota were taken from coastal waters, since some of the questions concerning deep-sea disposal are similar to those related to coastal water releases. The behavior of technetium in sediments depends on their organic content and on the bacterial activity. Distribution coefficients as high as 10^3 mg were observed for some types of sediments. The concentration factors for technetium in polychaetes and molluscs were obtained.

- The effects of chemical speciation of plutonium on sorption on the sediments was studied. Concentration factors were measured for benthic species placed in contaminated sediments in order to examine the transfer of radionuclides between biota and sediments. One of the main programs for next year will be to initiate similar studies for americium.

Federal Republic of Germany

A cruise on the Anton Dohn was made to the old and new NEA low level waste (LLW) dumping areas in the Atlantic Ocean. Samples of plankton, nekton, and benthos were taken. Results of radiochemical analyses were presented. Fission and activation products were found in all samples. The measured concentration factors compared favorably to those found with stable element analyses. Another cruise to the LLW dump site is planned for this year.

Japan

During 1979, the taxonomy, biomass, and distribution of the deep-sea benthic fauna was investigated in the Northwest Pacific basin. Many samples were taken and a photographic survey of deep-sea fauna was made. Neutron activation analysis of stable elements was done on cephalopods and mesoplagic fishes to determine the concentration factors for Co, Zn, Mn, and Cs. Concentration of ^{60}Co was measured in the liver of cephalopods.

Most of the work for the radioecological and oceanographic characterization of several Pacific Ocean sites which may be suitable for LLW dumping has been completed. The information was presented and will be published in the Third Seminar on Marine Radioecology, NEA/OECD (1979). Among the papers of interest is "A Preliminary Assessment of Biological Transport of Radionuclides Dumped at Sea Bottom" by Doi et al., which estimates the rate of radionuclide movement in the deep ocean. In the same volume there is a paper by Nakahara et al. which describes the concentration factors for mesopelagic organisms. Ueda, Nakahara, Ishii, Suzuki and Suzuki have also published a paper entitled "Amounts of Trace Elements in Marine Cephalopods" in the Journal of Radiation Research, 20 (1979), 338-342.

United Kingdom

During the last year the United Kingdom has completed studies in radioecology and in oceanography. In addition, there is an extensive and continuing radiobiology program at the Ministry of Agriculture, Fisheries, and Food (MAFF). Much of this work is with radionuclides in the environment as a consequence of the discharges from the Windscale Nuclear Reprocessing facility. These studies are very relevant to HLW, since the nuclides being discharged are some of the ones that are in HLW and spent fuel.

A range of biological organisms--echinoderms, molluscs, crustacea, fish, algae--from the Irish Sea are being analyzed for Pu, Am, Cm, Np, and Tc in order to estimate their relative biological availabilities in relation to rate of discharge and their partitioning in the nonbiological components of the environment. Laboratory experiments are being made using ^{95}Tc and ^{237}Pu to evaluate the importance of different routes of intake in the accumulation of these two elements by fish and crustacea; for example, their availability from contaminated sediments. Experiments with ^{241}Am and ^{237}Np are planned for 1981.

A limited number of analyses are being made to determine the concentrations of U and Th (to compare with Pu) and Nd (to compare with Am) in Irish Sea species--principally echinoderms, crustacea, and fish. If sufficient deep-sea materials are obtained from NERC institute cruises, comparative analyses will be made. Deep sea materials will also be analyzed for ^{210}Po in order to calculate absorbed dose rates received at depths greater than 1 km. Preliminary calculations are also being made on the expected absorbed dose rates in the vicinity of disposal waste containers. Finally, the exploitation potential of deep-sea fisheries will be kept under review by MAFF. MAFF issues detailed Aquatic Environment Monitoring Reports on radioactivity and other reports on fisheries.

The oceanographic effort of the Institute of Oceanographic Sciences (IOS) was described in two parts: the benthic and the midwater programs. It was noted that IOS has issued an unpublished manuscript, Report No. 77, entitled "Oceanography Related to Deep Sea Waste Disposal."

The benthic program at IOS is concentrated on the larger macrofauna and megafauna. Although we ultimately expect to work on "potential" dump sites, our efforts are currently based entirely on the Porcupine Sea Bight to the southwest of Ireland. The intent of the benthic program is

- To prepare general descriptions of the benthic communities within the Porcupine Sea Bight and on the adjacent abyssal plains.
- To improve the quantitative sampling gears for this part of the benthic community.
- To complete the investigation of temporal changes in the benthic community for evidence of seasonal or longer-term phenomena.
- To initiate the investigation of small-scale distribution patterns of epibenthic animals based on simultaneous photography and sampling.
- To complete the study of the presence and significance of mobile, near-bottom scavengers.

- To complete in collaboration with the IOS midwater program, the investigation of the relationship between the benthic and midwater communities, particularly for evidence of biological transport mechanisms between the two.

We have sampled in the Sea Bight on four separate occasions since November 1977. In July and November 1980 we intend to sample the area twice on separate cruises. Two short cruises are also planned for 1981.

In the midwater program, total water column sampling has been carried out at two positions: 49°40'N, 17°W and 20°N, 21°W. The material has been partially worked up to provide biomass (displacement volume) profiles of total micronekton and plankton, and to identify the important groups that make up these communities to depths up to 4 km.

Near-bottom sampling (to within about 10 to 15 m of the seabed) has been carried out in the Porcupine Sea Bight down to depths of 4 km. Marked increase in biomass (i.e., by a factor of about 3) occurs within 100 m of the seabed down to depths of about 1.6 km. Midwater organisms rather than a special bentho-pelagic fauna form the communities to depths of 2.5 km, but deeper there is evidence of novel specialized fauna.

Future field work (autumn 1980 and summer 1981 Biology/Physical Oceanography cruises) is planned for an area south of the Azores (in the region of 30°N 35°W) to investigate the distribution profiles of organisms across the boundary of the 18°C Sargasso Sea water, and the distribution of organisms with mesoscale eddies that we believe are spawned from this boundary. Biological sampling will be concentrated in the surface 1 km.

United States

The research in the biological portion of the US Subseabed Disposal Program was in the following areas this past year. Details are in the publications referenced at the end of this section.

Study of the Population Biology of Deep-Sea Amphipods -- This analysis included the determination of the relative age structure of the populations, their species composition, vertical distribution of the species, and gut content analyses. Some of the results are in the 1978 Annual Report of the Subseabed Disposal Program. Additional samples were collected during a 30-day cruise in 1979 to the central North Pacific Ocean. Also, more tagging of amphipods by using vital dyes was conducted and attempts were made to recover tagged animals.

Determination of the Metabolism of Deep-Sea Communities -- The free vehicle grab respirometer (FVGR) was deployed into the central North Pacific Ocean during the above-mentioned cruise and several measurements of benthic community respiration and of nutrient exchange rates across the sediment-water interface were conducted. The FVGR was also used to add nonradioactive cesium to the benthic community at 5.8 km. Samples were taken after allowing the cesium to interact with the community for several days. The samples will be bombarded with neutrons and analyzed for Cs uptake.

Determination of the Presence of Large and Mobile Deep-Midwater Animals -- Trapping of deep-midwater animals was again done by using the free-vehicle midwater trap system in the central North Pacific Ocean. This approach reveals the presence of mobile large animals in deep midwater.

A giant conical net with a diameter of 100 m was made, and several short cruises have been conducted to test its deployment and recovery and to evaluate its behavior in water. This net will be deployed to the sea floor in a closed state and will open as it rises through the water column. It should thus sample a column of the ocean 100 m in diameter. We imagine that net avoidance will not be a difficulty with a net having such a large diameter, and thus large midwater animals should be caught.

Microbiology of Deep Water and Sediments -- Isolation of deep-sea bacteria from water and sediment samples is continuing. The occurrence of sediment bacteria that divide as rapidly as those associated with animals is being confirmed. Studies on the radiation biology of deep-sea bacteria has been initiated with the determination of the radiation sensitivity of one of the isolates.

Methods for the determination of the standing stock of microorganisms were further developed. We have acquired an image analysis instrument to quantitate microscopic methods and to allow for the expeditious development of autoradiographic and flourescent labelling techniques.

Development of a Nuclide Migration Model -- A multi-compartment model is being developed that includes both biological and physical oceanographic considerations. A workshop was convened to address the physical oceanographic aspects of the model. Plans for this year include a workshop to address the needs of the biological aspects of radionuclide transport. The computer model is being tested as it is being developed with data from shallow water ecosystems where deep-sea data is unavailable.

Biological Publications of the US SDP

1. Subseabed Disposal Program Annual Report, January-December 1978. Volume II: Principal Investigator Progress Reports, SAND79-1618, printed October, 1979. Available from NTIS, US Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161.

2. Biological Studies of the US Subseabed Disposal Program, Subseabed Biology Team. Presented at Third Seminar on Marine Radioecology, sponsored by the NEA/IECD, Tokyo, Japan, October, 1979.

3. R. R. Hessler and P. A. Jumars (1979), "The Relation of Benthic Communities to Radioactive Waste Disposal in the Deep Sea," Ambio Special Report, No. 6, 93-96.

4. K. L. Smith, Jr., et al. (1979), "Free Vehicle Capture of Abyssopelagic Animals." Deep Sea Research, Vol. 26A, 57-64.

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Modelling

Two types of dose assessment models need to be developed: the collective effective dose equivalent commitment model to be used for the purpose of optimization, and the discrete pathways model to critical groups to be used to ensure that dose limits are not exceeded.

Models for Optimization -- For the purposes of optimization modelling we are concerned with the mass transfer of radionuclides from the disposed waste, via biological pathways. The difficulty in making such an assessment is our almost total lack of knowledge of biological transfer processes from depths of 4000 to 6000 m up to near the surface. Recognizing our ignorance of this biological "gap," it is suggested that in the first instance, for the purposes of "plugging the hole" in the system analysis model, the following preliminary outline be considered:

Optimization Model A: Assumptions

1. At the sediment/water interface there is an immediate transfer of radionuclides into the bottom water layer, plus a contamination of the surface sediment.

2. Physical processes alone transfer the radionuclides into the near surface.

3. Within the surface water (1000 to 2000 m depth), biological accumulation occurs, resulting in a transfer of radionuclides back to man via four different pathways:

   - mid-oceanic organisms (principally fish)
   - coastal water fish
   - coastal water invertebrates (principally crustacea and molluscs)
   - edible marine plants (principally algae).

4. It will be necessary to estimate the annual consumption rates of these four pathways separately.

5. Using the concentrations (e.g., fCi l^{-1}) for individual radionuclides, and using concentration factor values derived from coastal water studies, the annual transfer of radionuclides along the four separate pathways could be estimated. It is expected that in general those radionuclides which strongly adsorb to materials will dominate along the last three pathways listed, but that they will be substantially less important along the first two.

6. The immediate needs for this model are concentration factor data for some nuclides, e.g., ^{232}Np.

Additions to Model A

Although no direct biological pathways of significance from the ocean floor to the top 2 km are known, it is possible to postulate hypothetical pathways. It is therefore suggested that some of these be numerically evaluated, using the "worst case" radionuclides (e.g., those known to have the highest concentration factors, and half-lives relevant to different time scales) in order to see if such additional routes to the surface substantially alter the predictions arising from Model A alone. The pathways suggested are:

- Floating lipids. Taking available estimates for biomass as 4- to 5-km depth, assume that 10% of this per year is converted into fat globules which float to the ocean surface. This pathway may only involve nuclides likely to be fat soluble.

- Floating eggs. Assume that 50% of the biomass per year is converted into gametes which float to the ocean surface. As an example, concentrations of nuclides in gonads of echinoderms likely to arise as a result of the surrounding water levels of radionuclides could be used, based on coastal water data.

- Assume that 10% of the biomass per year moves directly into the surface 2 km, and stays there.

- Assume that 10% of the biomass per year is transferred to the top 2 km by being transferred through food chains up the continental slope and onto the continental shelf, allowing for changes in biomass at 1-km intervals.

Models for Estimating Doses to Critical Groups -- The difficulties envisaged in estimating mass transfer also apply to estimating doses to critical groups, in particular the "biological gap" between 2 and 6 km. So once again a number of pathways have to be hypothesized and the appropriate scenarios developed.

Scenario B1. It is assumed that filter feeding links exist at 1000 intervals. At each link a nuclide would be ingested and absorbed from the surrounding water. Transfer coefficients could be estimated from what is known of the absorption of different nuclides by, for example, fish; the size ratio of predator over prey; the feeding rates; and conversion factors for some nuclides.

Scenario B2. It is assumed that all of the benthic biomass consists of crustacea which release fat globules which float to the surface, are taken up by krill, and then transferred directly to man.

Scenario B3. It is assumed that certain migratory species, such as eels, lay their eggs in deep water, the larvae move from surface oceanic waters to coastal waters, and are then eaten by man. Similar assumptions could be made for other species, such as salmon, which feed in open ocean water on organisms which had migrated directly from the bottom into surface waters.

Scenario B4. It is assumed that some of the deep water fish which are caught commerically, such as Aphanopos, feed directly on organisms with concentrations equivalent to those expected on the ocean floor.

Periodic Events and Long Term Processes -- Are there any known long term or cyclical processes which could affect the transport of radionuclides in a quantity significantly greater than that predicted by models based on the structure of the present ocean? The US CLIMAP program* and Climate: Past, Present and Future, H. H. Lamb** may be good sources for evaluating the long term effects of fishery changes, ice ages, etc.

An In-Situ Irradiation Experiment -- Some think that deep sea ecosystems are composed of diverse species, complex and fragile. These qualities could lead to substantial and unpredictable kinds of damage. Although such damage may perhaps be localized and of no consequence to man, it may be important to demonstrate the localized nature of such effects. The easiest and safest way to determine the effects of radiation on the benthic community may be to place a ^{60}Co source on the sea floor and design a sampling program. Experiments such as the installation of wood panels spaced at distances from the source could determine the pattern of colonization of the wood as a function of distance from the source (^{60}Co). Food other than wood could also be used.

Speculation also occurred on the possible autocatalytic nature of a localized lethal source of radiation. That is, if an organism died at a source of gamma rays, would then others come to scavenge and

*International Decade of Ocean Exploration, Progress Report Vol 7, April 1977-1978. Superintendant of Documents, US Government Printing Office, Washington, DC 20402.

**London: Metheun Inc. 2 Vols 1972, 1977.

thus meet a similar fate? Could a pile of dead organisms accumulate or would other factors keep this from happening? Additional thought and a long-range experimental plan is necessary to answer these questions. It may be very timely to begin such an experiment.

The short half-life (5.25 yr) of ^{60}Co would virtually assure that the experiment itself would have time- and space-limited effects on the environment that would make an in-situ experiment a safe one.

APPENDIX A

Letter Report to NEA

Department of Energy
Washington, D.C. 20545

APR 1 1980

Dr. E. Wallauschek, Head
Radiation Protection and Waste Management Division
Nuclear Energy Agency
38 Boulevard Suchet
75016 Paris, France

Dear Dr. Wallauschek:

Enclosed is a summary report to the NEA Radioactive Waste Management Committee (RWMC) on the Fifth Annual Workshop of the OECD/NEA Seabed Working Group held on March 3-6, 1980, in Bristol, England.

The Seabed Working Group (SWG) members from Canada, France, Japan, Netherlands, the United Kingdom, and the United States participated. Observers from the Federal Republic of Germany and Switzerland participated with concurrence of their respective RWMC members. Observers from the Commission of European Communities also participated.

Specific areas of cooperation were reported by the SWG Task Groups and future joint activities were planned.

A detailed report of the meeting will be prepared by the SWG Technical Secretariat and submitted to OECD/NEA and the RWMC.

Yours sincerely,

D. Glenn Boyer

D. Glenn Boyer, Chairman
Seabed Working Group
Division of Waste Isolation

Enclosure

cc: J. Coady, Canada
Y. Sousselier, France
H. Ishikawa, Japan
B. Verkerk, Netherlands
K. D. B. Johnson, U.K.
A. F. Perge, U.S.
R. Randl, Germany
U. Niederer, Switzerland
F. Gera, NEA
Members and Attendees

REPORT TO THE NEA RADIOACTIVE WASTE MANAGEMENT COMMITTEE (NEA/RWMC)

The NEA Seabed Working Group (SWG), its secretariat, and its Task Groups met in Bristol, England, on March 3-6, 1980. The SWG members from Canada, France, Japan, Netherlands, the United Kingdom, and the United States participated. Observers from the Federal Republic of Germany and Switzerland participated with the concurrence of their respective NEA/RWMC members. Observers from CEC, Ispra were also present.

The objectives and role of the SWG and its Task Groups as established at the 2nd Annual SWG Meeting (Washington, D.C., March 1977) are being met; i.e.,

- to provide a forum for discussion, assessment of progress and planning of future efforts;
- to coordinate research vessel cruises and experiments;
- to share facilities and test equipment;
- to exchange information; and,
- to maintain cognizance of international policy issues.

The specific objectives of the Fifth SWG Meeting were:

- to coordinate a total systems approach to assure data are being acquired that can be used as parameters in predictive models of seabed disposal concepts;
- to continue the multinational coordination of research and development within the specific task groups; and,
- to review the status and significant changes in national seabed disposal programs.

The composition of the SWG (Executive Committee) and its various Task Groups is shown in Figure 1. The Task Group members from each country are designated by the countries' Executive Member of the SWG. The Task Group members designate one from their group to act as Task Group lead correspondent. It is expected the lead correspondent will change from time to time. The Task Group member is responsible for coordinating exchange of data in his area of expertise within his own country. The Task Group lead correspondent acts as a group leader, and coordinates exchange between Task Groups and within the specific Task Group.

A SWG Task Group coordinator (D. R. Anderson) is responsible for overall coordination and data exchange within the framework of the SWG.

Summaries of the individual Task Group meetings and reports on specific areas of cooperation, plans, and activities are attached as Annex 1.

The Seabed Working Group Executive Committee met to discuss the items on the Agenda shown as Annex II.

The participants included:

G. Vilks, Canada
A. Barbreau, France
R. Ichakawa, Japan
B. Collette, Netherlands (Advisor)
F. S. Feates, U.K.

D. G. Boyer, U.S. (Chairman)
F. Gera, NEA (Secretariat)
D. R. Anderson, SWG Task Group Coordinator and Scientific Secretary
N. Murray, CEC (Observer)
W. Feldt, FRG (Observer)
M. Sturm, Switzerland (Observer)

1. The representative from each country summarized the national trends and policies regarding seabed disposal of radioactive waste. In general the seabed disposal concept is being considered as a possible alternative to land based disposal. The amount of effort each country is putting into the assessment of seabed disposal is small in comparison to the total efforts being made to identify acceptable geological formations on land. However, as special interest groups and individuals continue to express social and technical concerns about exploration and research leading to land disposal, each national representative indicated a strong need to continue to evaluate the technical and environmental feasibility of the seabed disposal concept.

2. The structure of the SWG and its Task Groups were reviewed.

   a. The SWG charter, as submitted to NEA following the 4th SWG Meeting (Albuquerque, March 1979), continues to be acceptable to NEA and to the SWG members.

   b. The SWG report will be prepared by the SWG Technical Secretariat. For report identification purposes it will continue to be issued with a Sandia Laboratory report number. The title page will identify the work as the NEA/OECD Seabed Working Group Report to the NEA Radioactive Waste Management Committee. The disclaimer clause will state the work is being funded by the individual SWG member countries.

   c. New members to the SWG will be encouraged to join through NEA. Member countries must have a funded program to assess the seabed disposal concept and be approved by the government and sanctioned by the national representative of the NEA Radioactive Waste Management Committee.

   d. Lead correspondents for each Task Group will be selected by the members of the specific task group. It is expected that the lead correspondent will change from time to time. For example, Messr. de Marsily (France) was selected as the lead correspondent of the Systems Analysis Task Group to replace Geoff Webb (U.K.), and Messr. Rancon (France) was selected as the lead correspondent of the Sediment and Rock Task Group to replace John Lewis (U.K.), with T. Francis (U.K.) acting during the 5th SWG Meeting.

   The national representative to the SWG (Executive Committee) will designate the national members to each of the Task Groups. If more than one individual from a SWG member country attends, for clarification, he will be called a "participant."

Non-member countries may be invited to participate as "Observers" if invited by the SWG, and with the concurrence of the country's national representative to the NEA-RWMC.

e. Task group lead correspondents are responsible to effectively exchange information and cooperation within their own task group members and to identify and initiate intra-task group needs and exchanges.

   The Task Group Coordinator (D. R. Anderson, U.S.) is responsible to effectively coordinate exchange of information and coordination between Task Groups and to keep the SWG informed.

f. The structure of the Task Groups were reviewed. It was decided to combine into one Task Group the "Canister and Waste Form Task Groups." An "Engineering Studies Task Group" was established to begin the coordination of conceptual design and engineering studies of seabed disposal emplacement, and to identify objectives and criteria for laboratory and field test experiments.

   Each SWG (Executive Committee) member is to designate a member to the "Engineering Studies Task Group" as soon as possible, and inform the SWG Chairman, with copies to NEA (Gera) and the Task Group Coordinator (Anderson). The Task Group Coordinator will take the lead in organizing the first Engineering Task Group meeting prior to the next SWG meeting.

   Consideration was given to establishing a "Legal and Institutional Task Group." It was concluded the SWG at this time would continue to keep the exchanges on a scientific level. In addition, there exists another NEA group which is assessing legal and institutional issues of waste management. The subject will be reviewed again at the next SWG meeting.

3. Retrievability was addressed briefly and it was concluded that the various concepts being considered by the individual countries were addressing radioactive waste seabed "disposal" as opposed to "storage." Therefore, retrievability as such was not a design objective. However, recovery from improper emplacement will need to be assessed, and the capability for corrective actions available.

4. An outline of objectives for the SWG over the next three years was discussed and established as follows:

   a. Exchange data on the North Pacific and North Atlantic study areas resulting from the planned national and cooperative research vessel cruises; i.e.

      o Japan/U.S. to North Pacific
      o Netherlands, France, Canada, U.K., and Federal Republic of Germany to North Atlantic

   b. Compare properties of sediments resulting from laboratory and field tests; i.e.

      o Thermal, Physical, and Chemical

c. Complete sensitivity analysis of parameters assumed for the systems analyses models and revise the model assumption based on newly acquired laboratory and field data.

d. Define specific problem areas and objectives such as reconsolidation of disturbed bottom sediment resulting from emplantation, and define laboratory and field experiments to verify model assumptions.

e. Initiate engineering studies of seabed disposal concepts and develop field test objectives and conditions in the laboratory and the field to demonstrate the engineering assumptions.

f. Begin to scope and consider emplacement of long-term field tests, i.e., 30 years or more.

5. The next meeting date was set for February 2-5, 1981, in France. Messr. Barbreau (CEA) and Dr. Gera (NEA) will determine the location. This date must remain firm to avoid conflicts with scheduled research vessel cruises and other commitments by the SWG members, participants, and observers.

NUCLEAR ENERGY AGENCY–RADIOACTIVE WASTE MANAGEMENT COMMITTEE

SEABED WORKING GROUP

CANADA	G. VILKS
JAPAN	R. ICHIKAWA
FRANCE	A. BARBREAU
NETH.	TO BE APPOINTED
UK	F. S. FEATES
US	D. GLENN BOYER (CHM)

NEA SECRETARIAT
F. GERA

TASK GROUP COORDINATOR
D. R. ANDERSON (US)

TASK GROUP	CANADA	JAPAN	FRANCE	NETHERLANDS	UK	US
PHYSICAL OCEAN	–	HORIBE	MADELAIN	PRANGSMA	HILL*	ROBINSON
CANISTER	–	–	CHAUVIN	–	MARSH	MAGNANI*
WASTE FORM	–	–	POTTIER	–	MARPLES	KRUMHANSL*
BIOLOGY	HARGRAVE	ICHIKAWA	BELOT	CADEE	PENTREATH	YAYANOS*
SEDIMENT & ROCK	CARSTON	–	RANCON*	–	FRANCIS	HEATH
SITE CRITERIA	BUCKLEY	HOTTA	WANNESSON	SCHUETTENHELM	SEARLE	HOLLISTER*
SYSTEM ANALYSIS	–	H. ISHIKAWA	DE MARSILY*	VAN DORP	WEBB	TALBERT

*LEAD CORRESPONDENT

Figure 1

ANNEX I

SWG TASK GROUP WORKSHOP SUMMARIES

Site Criteria Task Group

1. It is proposed that on the order of ten study areas be identified from historical data and that field and laboratory tests be carried out in an iterative fashion in an open science forum to obtain properties related to nuclear waste isolation.

2. Site selection criteria were revised to delete the requirement that the disposal depth be greater than 4000 meters, to include some areas on the deep abyssal plains and to stipulate that the area be as flat as possible.

3. Data from the R/V Resolution cruise to the eastern north Atlantic was reviewed and plans presented for the R/V Churcot and R/V Tydeman cruise to the region in the upcoming year.

4. As a consequence of the R/V Resolution cruise and historical data a 20x20 km area near the southern portion of the Cape Verde appears promising for deep penetration and more geophysical (G&G) surveying.

5. Data taken by the R/V Dawson in the western Atlantic was reviewed and the R/V Hudson cruise in the upcoming year was discussed.

6. A joint thirty day U.S.-Japanese cruise is planned for the summer of 1980.

System Analysis Task Group

1. Comments were solicited and obtained from all task groups regarding parameters suggested in the base case scenario that was set forth in the Systems Analysis Task Group Interim Report, and a revised set of parameters were tabulated.

2. Programatic activities for the next year were clarified and this led to adoption of an overall model of the seabed disposal system.

3. As a consequence of joint meetings with other task groups, models were suggested pertaining to the rate of radionuclide release from the waste form, the life of a canister, biological transport, and pathways back to man.

4. The goal was set to have the first series of calculations of the overall system study completed within a year.

5. The need for feedback to the various other task groups at the earliest possible date is noted.

6. An interim task group meeting was tentatively scheduled for September 22-26, 1980 and is to be held at the National Radiation Protection Board in the U.K.

Canister Task Group

1. The Canister Task Group believes that a corrosion-resistant canister can be a valuable part of the multibarrier concept by virtue of its ability to protect the solidified waste from the enhanced degradation that is characteristic of a hydrothermal environment.

2. The ultimate objective of both the U.S. and U.K. programs are to qualify materials to last in the seabed environment for 500 to 1000 years.

3. It should be possible to construct canisters with a 500 to 1000 year lifetime in a cost effective manner.

4. A variety of chemical and biologic effects were identified whose variability with time could influence the corrosion rates of potential canister materials.

5. Work in both the U.S. and U.K. confirms that radiation is an important factor in assessing the corrosive characteristics of the disposal environment. This is one area of study where international cooperation will be especially beneficial to all participants.

6. The development of sensitive corrosion monitoring techniques is once again identified as an area where international cooperation would facilitate progress.

Waste Form Task Group

1. A review of the systems analysis task group recommendations was conducted and revised values for selected parameters suggested.

2. A temperature dependent radionuclide release model was suggested that is intended to provide an upper limit rather than an absolute value for the actual release of various radionuclides.

3. Borosilicate glass was reaffirmed as the reference waste form to be studied and guidance regarding its Pu, U, and fission product content was given .

4. It was again reemphasized that at least half of the alpha activity lost to the environment may be in waste forms other than borosilicate glass, e.g., hulls, fines from reprocessing, etc.

5. Note was made of the fact that the vast majority of the canisters may be expected to last for sufficient time that the waste will be at almost ambient temperatures by the time of canister breachment.

6. Responsibilities were assigned for planning and implementing experimental activities to assess:

   a. glass alteration in the localized environment adjacent to a flaw in the canister, and

   b. leach rate from a glass surface where access of water is restricted by the presence of a low permeability covering of sediment.

7. The various national programs were found to not have changed significantly from those summarized in last year's Waste Form Task Group report.

Sediment and Rock Task Group

1. It was noted, except for substances which form colloidal particles or anions in solution that the sorptive properties of marine clays suggests that very high safety factors exist.

2. The effect of radiation on the sediment, particularly in the near field, is noted as being an important unknown.

3. The discrepancy between natural pore water motion as deduced from geochemical and geothermal gradient computations needs to be resolved.

4. A facility for sampling at depths greater than will be possible using the long coring facility may be required to treat sites in the Atlantic in an appropriate manner. A cruise, perhaps in 1984 or 1985, equipped with a hydraulic piston core would be a region where international cooperation could be fruitful.

5. The various national programs dealing with the modeling of ion migration, sorptive properties of sediments, physical properties of sediments, methods of emplacement, sediment mechanical response and near field sediment seawater interactions were reviewed and data exchanged.

6. The dearth of historical data and anticipated work pertaining to the sorptive properties of reducing sediments was noted and the recommendation is made that this deficiency be corrected at least as far as Pu, Np, Am, I and Tc are concerned.

Biology Task Group

1. Information was exchanged among the various participants regarding data obtained in the various national programs. Topics receiving particular discussion were: primary biomass production, vertical transport of particulate organic matter, the migration of planktonic crustaceans, the rates of gas and nutrient exchange across the sediment surface, the development of navagational and sampling technologies, modeling of biologic transfer, and biologic concentration factors.

2. It was agreed that the Systems Analysis Task Group would be aided in constructing simplified radionuclide transport models. Particular topics to be addressed were the effective dose equivalent and the problem of direct pathways to mankind.

3. It was noted that the upcoming CEC/IAEA technical meeting "Behavior of Transuranics in the Aquatic Environment and Sediment-Water Exchange Techniques for Speciation" might provide information for one in the experimental study of the seabed disposal option.

4. Inquiry was made into whether any long-term or cyclical processes could affect the transport of radionuclides beyond that which would be predicted on the basis of the structure of the present ocean.

5. The possibility of doing an in situ irradiation experiment was explored.

Physical Oceanography Task Group

1. A special idealized model will be constructed of the physical transport processes in the ocean for use in assessing the relative importance of various coupled parameters and a range of parameters were supplied, and were to be updated as the year progresses.

2. The various scales of descrete water masses in the ocean were discussed along with their implications to oceanic mixing and biologic radionuclide uptake.

3. Ongoing cooperative field activities include:

   a. placing of additional NEADS moorings and analysis of data from moorings recovered this year,

   b. a joint Japanese-American effort in the Pacific to look at near bottom mixing processes and transport across the sediment-water interface, and

   c. continued work on the joint Anglo-French field program to study mesoscale eddies in the northeastern Atlantic.

4. Results for the last year of the physical oceanography programs presently underway in the Atlantic (FR, UK, US) and the Pacific (US, Japan) were reviewed.

5. A list of selected references pertaining to the benthic boundary layer and oceanic circulation will be prepared and offered to the systems analysis task group.

6. It is recommended that each of the task groups prepare a selected bibliography of relevant references for use by the systems analysis task group.

7. It is recommended that cruise plans, including a brief outline of the aims of the cruise be submitted each year by each member and that the lead correspondent circulate these to each task group member.

8. It was suggested that progress reports be submitted annually within the Physical Oceanography Task Group.

Annex II

SEABED WORKING GROUP - EXECUTIVE MEETING

March 4, 1980

1:30 - 5:00 pm

Items for Discussion:

1) National Trends and Policies Regarding Seabed Disposal of Radioactive Wastes.

2) Structure of the SWG and Task Groups

   a) Review the SWG Charter
   b) SWG Reports to NEA/RWMC
   c) Mechanism for Adding New Members
   d) Designation of Task Group Lead Correspondence
   e) Function of Task Groups
   f) Structure of Task Groups

3) Retrievability

4) SWG Objectives for the Next Three Years

5) Time and Place for Next Meeting

APPENDIX B

Participants and Observers
Seabed Working Group Meeting

March 3-5, 1980
Bristol, England

APPENDIX B

Participants and Observers
Seabed Working Group Meeting

SEABED WORKING GROUP

EXECUTIVE COMMITTEE

Canada	Mr. G. Vilks* Atlantic Geoscience Centre Bedford Institute of Oceanography P.O. Box 1006 Dartmouth Nova Scotia B2Y 4A2 Canada Tel: (902) 426-7734
France	Mr. A. Barbreau Institut de Protection et de Suerte Nucleaire Centre d'Etudes Nucleaires BP no 6 92260 Fontenay-aux-Roses France Tel: (331) 657-13-26/3076
Netherlands	Dr. B. J. Collette Vening Meinesz Laboratorium Budapest Laan 4 3584 CD Utrecht Netherlands Tel: (030) 535135 Telex: 40704 vmlru nl
Japan	Dr. R. Ichikawa** Division of Environmental Health National Institute of Radiological Sciences 9-1 Anagawa-4-chome Chiba-shi Chiba-ken 280 Japan Tel: (0472) 51-2111

*Also member of Task Group on Site Criteria
**Also member of Task Group on Biology

EXECUTIVE COMMITTEE (cont)

United Kingdom

Dr. F. S. Feates
Department of the Environment
Becket House
1 Lambeth Palace Road
London SE1 7ER
United Kingdom Tel: (01) 211-8736
Telex: 22221

United States

Dr. D. Glenn Boyer (Chairman)
US Department of Energy
Division of Waste Isolation
Washington, DC 20545
United States Tel: (301) 353-5437
Telex: 710-828-0475

Dr. D. R. Anderson
Task Group Coordinator and
Technical Secretariat
Sandia National Laboratories
Division 4536
P.O. Box 5800
Albuquerque, NM 87185
United States Tel: (505) 844-6553
Telex: 6-60446

NEA

Mr. Ferruccio Gera
Nuclear Energy Agency
38, boulevard Suchet
75016 Paris
France Tel: 011-(33-1)-524-9658
Telex: 62160

OBSERVERS

C. N. Murray (CEC)
W. Feldt (Federal Republic of Germany)
M. Sturm (Switzerland)

SYSTEM ANALYSIS

PARTCIPANTS AND OBSERVERS

Canada	Mr. G. Vilks Atlantic Geoscience Centre Bedford Institute of Oceanography P.O. Box 1006 Dartmouth Nova Scotia B2Y 4A2 Canada Tel: (902) 426-7734
CEC	Dr. C. N. Murray Division of Chemistry Joint Research Centre 21020 ISPRA (Varese) Italy Tel: 332-78-0271 Telex: 380-427 380-58 EURATOM
France	Mr. G. de Marsily* Centre d'Informatique Geologique Ecole des Mines de Paris 35 Rue St Honore 77305 Fontainebleau France Tel: (1) 422-4821 Telex: MINEFON 600736
Netherlands	Dr. F. van Dorp Foundation Institute for Atomic Sciences in Agriculture (ITAL) P.O. Box 48 6708 Wageningen Netherlands Tel: 08370-10127
United Kingdom	Mr. G. A. M. Webb National Radiological Protection Board Harwell Didcot Oxon oxll ORQ United Kingdom Tel: 0235-831600 Telex: 837124
	Dr. J. G. Shepherd Fisheries Laboratory Lowestoft Suffolk NR33 OHT United Kingdom Tel: 0502-62244 Telex: 97470

*Lead Correspondent

PARTICIPANTS AND OBSERVERS

United Kingdom (cont)

Miss F. E. Taylor
Becket House
Room 309
1 Lambeth Palace Road
London SE1 7ER
United Kingdom Tel: 01-211 8581
Telex: 22221

Ms. M. D. Hill
National Radiological Protection Board
Harwell
Didcot
United Kingdom Tel: 0235 831600
Telex: 837124

Dr. J. Menzies
Department of the Environment
BRE
Garston
Watford
Herts
United Kingdom Tel: Garston 74040

Dr. R. Butlin
Building Research Establish
Garston
Watford
Herts
United Kingdom Tel: Garston 74040

United States

Mr. D. M. Talbert
Sandia National Laboratories
Division 4536
P.O. Box 5800
Albuquerque, NM 87185
United States Tel: (505) 844-3323
Telex: 910-989-1600

SITE CRITERIA ASSESSMENT

PARTICIPANTS AND OBSERVERS

Canada

Mr. D. Buckley
Atlantic Geoscience Centre
Bedford Institute of Oceanography
P.O. Box 1006
Dartmouth
Nova Scotia B2Y 4A2
Canada Tel: (902) 426-7732

Mr. G. Vilks
Atlantic Geoscience Centre
Bedford Institute of Oceanography
P.O. Box 1006
Dartmouth Nova Scotia B2Y 4A2
Canada Tel: (902) 426-7734

France

Mr. J. Wannesson
IFP
Synthesis Geologiques et Geochimie
BP 311
92 506 RUEIL MALMAISON - CEDEX
France Tel: 749-02-14 Ext 2441

Mr. R. le Suave
CNEXO
Centre Oceanologique de Bretagne
BP 337
29273 Brest
France Tel: (98) 45 80 55 Ext 592
Telex: 940627F

Mr. A. Barbreau
Institut de Protection et de Suerte Nucleaire
Centre d'Etudes Nucleaires
BP no 6
92260 Fontenay-aux-Roses
France Tel: (331) 657-13-26/3076

Japan

Dr. H. Hotta
Marine Technology Department
Japan Marine Science and Technology Centre
(JAMSTEC)
2-15 Natsushima-Cho
Yokosuka 237
Japan Tel: 0468 (65 2865 649 155)

SITE CRITERIA ASSESSMENT (cont)

PARTICIPANTS AND OBSERVERS

Netherlands

Dr. R. T. Schüettenhelm*
Geological Survey of the Netherlands
P.O. Box 157
2000 AD HAARLEM
Netherlands Tel: 023-319362
Telex: 71105 geold nl

Dr. B. J. Collette
Vening Meinesz Laboratorium
Budapest Laan 4
3584 CD Utrecht
Netherlands Tel: (030) 535135
Telex: 40704 vmlru nl

United Kingdom

Dr. R. C. Searle
Institute of Oceanographic Sciences
Wormley
Godalming
Surrey GU8 5UB
United Kingdom Tel: 858833

Dr. A. S. Laughton
Institute of Oceanographic Sciences
Wormley
Godalming
Surrey GU8 5UB
United Kingdom Tel: 042-879-4141
Telex: 858833

W. Bowden

United States

Dr. C. D. Hollister**
Woods Hole Oceanographic Institution
Woods Hole, MA 02543
United States Tel: (617) 548-1400
Telex: OCEANINST

*Leader of Dutch delegation
**Lead Correspondent

CANISTER

PARTICIPANTS AND OBSERVERS

United Kingdom

Dr. G. P. Marsh
Materials Development Division
Building 393
AERE
Didcot, Oxon AOX11 ORA
United Kingdom Tel: 0235-24141 Ext6078
Telex: 83135

Dr. G. P. Rothwell
National Corrosion Service
National Physical Laboratory
Teddington
Middlesex TW11 OLW
United Kingdom

Dr. J. Menzies
Building Research Establishment
Garston
Watford, Herts
United Kingdom Tel: Garston 74040

Dr. J. Shaw
British Nuclear Fuels Limited (BNFL)
Windscale and Calder Works
Sellafield
Sea Scale, Cumbria
CA 20 1A6
United Kingdom

Dr. J. E. Antill
Central Electricity Generating Board
Berkeley Nuclear Laboratories
Berkeley
Gloucestershire GL13 9PB
United Kingdom Tel: 0453-810451

United States

Dr. N. J. Magnani*
Sandia National Laboratories
Dept 5840
P.O. Box 5800
Albuquerque, NM 87185
United States Tel: (505) 844-3475

*Lead Correspondent

WASTE FORM MANAGEMENT

PARTICIPANTS

France

Mr. P. E. Pottier
CEA
Centre d'Etudes Nucleaires de Cadarache
Department de Chimie Appliquee (BECC)
BP No 1-13115
St Paul Lez Durance
France Tel: (42) 25-70-00 Ext 73-64
Telex: CEACA A No 440678F

United Kingdom

Mr. J. A. C. Marples
Chemistry Division
Building 220.22
AERE Harwell
Didcot
Oxon OX11 ORA
United Kingdom Tel: 0235-24141 Ext 4890
Telex: 83135

United States

Dr. J. L. Krumhansl*
Sandia National Laboratories
Division 5541
P.O. Box 5800
Albuquerque, NM 87185
United States Tel: (505) 844-7146

*Lead Correspondent

SEDIMENT AND ROCK

PARTICIPANTS AND OBSERVERS

Canada	Dr. R. Cranston Atlantic Geoscience Centre Bedford Institute of Oceanography P.O. Box 1006 Dartmouth Nova Scotia B2Y 4A2 Canada Tel: (902) 426-7732
CEC	Dr. A. Avogadro Division of Chemistry Joint Research Centre 21020 ISPRA (Varese) Italy Tel: 332-78-0271 Telex: 380-427 380-58 EURATOM
France	Mr. D. Rancon* Department de Surete Nucleaire-SESTR CEN Cadarache BP No 1 - 13115 St Paul-Lez-Durance France Tel: (42) 25-90-00 Poste 34-26
Switzerland	Dr. M. Sturm EAWAG Federal Institute for Water Resources and Water Pollution Veberlandspt 133 8600 Dubendorf Switzerland Tel: 01/823 55 11 Telex: 53 817
United Kingdom	Dr. T. J. G. Francis** Institute of Oceanographic Sciences Wormley Godalming Surrey GU8 5UB United Kingdom Tel: 042-897-4141 Telex: 858833

*Lead Correspondent Designate
**Lead Correspondent

PARTICIPANTS AND OBSERVERS

United Kingdom (cont)

Mr. H. J. Richards
Department of the Environment
2 Marsham Street London
London SE1
United Kingdom Tel: 01-212 4988

Dr. H. D. St. John
Building Research Establishment
Garston
Watford
Herts
United Kingdom Tel: Garston 74040

Mr. D. B. Smith
NERC
Polaris House
North Star Avenue
Swindon
Wilts SN2 1EU
United Kingdom Tel: 0793-40101

Dr. J. B. Lewis
Building 175
Chemical Technology Division
AERE Harwell
Didcot
Oxon OX11 ORA
United Kingdom Tel: 0235-24141 Ext 2720

Dr. D. Kinsey
Chemical Technology Division
Building 151
AERE Harwell
Oxon OX11 ORA
United Kingdom Tel: 0235-24141 Ext 2741

Dr. R. B. Whitmarsh
Institute of Oceanographic Sciences
Wormley
Godalming
Surrey GU8 5UB
United Kingdom Tel: 042-879 4141
Telex: 858833

PARTICIPANTS AND OBSERVERS

United States

Dr. G. R. Heath
School of Oceanography
Oregon State University
Corvallis, OR 97331
United States Tel: (503) 754-4763

PHYSICAL OCEANOGRAPHY

PARTICIPANTS AND OBSERVERS

France	Mr. F. Madelain GNEXO Centre Oceanologique de Bretagne BP No 337-29273 Brest France Tel: (98) 45-80-55 Ext 567 Telex: 940627F
Japan	Prof S. Horibe Ocean Research Institute University of Tokyo Nakano-ku 164 Japan Tel: (03) 376-1251
Netherlands	Dr. G. J. Prangsma Royal Netherlands Meterological Institute (KNMI) P.O. Box 201 3730 AE De Bilt Netherlands Tel: 030 766 911 Telex: KNMI nl
Switzerland	Dr. F. Nyffeler Universite de Neuchatel Lub Geologic Nl Rue E Argand 2000 Neuchatel Switzerland Tel: 0322 23 2287 Telex: 34333 TC KB CH
United Kingdom	Mr. H. W. Hill* Fisheries Laboratory Ministry of Agriculture, Fisheries and Food Lowestoft Suffolk NR33 OHT United Kingdom Tel: 0502-62244 Telex: 97470

*Lead Correspondent

PARTICIPANTS AND OBSERVERS

United Kingdom (cont)

Dr. J. C. Swallow
Institute of Oceanographic Sciences
Brook Road
Wormley
Godalming
Surrey GUS 5UB
United Kingdom Tel: 042-879-4141
Telex: 858833

Dr. P. M. Saunders
Institute of Oceanographic Sciences
Brook Road
Wormley
Godalming
Surrey GUS 5UB
United Kingdom Tel: 042-879-4141
Telex: 858833

Mr. J. Crease
Institute of Oceanographic Sciences
Brook Road
Wormley
Godalming
Surrey GUS 5UB
United Kingdom Tel: 042-879-4141
Telex: 858833

Dr. P. A. Gurbull
Ministry of Agriculture, Fisheries
and Food
Fisheries Laboratory
Lowestoft
Suffolk NR33 OHT
United Kingdom Tel: (0502) 62244
Telex: 97470

Dr. J. G. Shepherd
Fisheries Laboratory
Lowestoft
Suffolk NR33 OHT
United Kingdom Tel: (0502) 62244
Telex: 97470

PHYSICAL OCEANOGRAPHY (cont)

PARTICIPANTS AND OBSERVERS

United States

Dr. A. Robinson
Harvard University
Pierce Hall
Cambridge, MA 02138
United States Tel: (617) 495-2819

BIOLOGY

PARTICIPANTS AND OBSERVERS

Canada	Dr. B. Hargrave Atlantic Geoscience Centre Bedford Institute of Oceanography P.O. Box 1006 Dartmouth Nova Scotia B2Y 4A2 Canada Tel: (902) 426-3188
Federal Republic of Germany	Prof. D. Schnack Universitat Hamburg Institut fur Hydrobiologie und Fischereiwissenschaft Zeiseweg 9 D-2000 Hamburg 50 Federal Republic of Germany Tel: 3807-2621
	Prof. W. Feldt Isotopen Laboratorium Der Bundesforschungsanhalt Fur Fisherei Wvstlasnd 2 D-2000 Hamburg 55 Federal Republic of Germany Tel: 040/871026
	Dr. H. Thiel Universitat Hamburg Institut fur Hydrobiologie und Fischereiwissenschaft Zeiseweg 9 2000 Hamburg 50 Federal Republic of Germany Tel: 040-6448403
France	Mr. Y. Belot Centre d'Etudes Nucleaires Department de Protection Service d'Etudes et Recherches sur l'Environment BP No 6-92260 Fontenay-aux-Roses France Tel: (1) -657-13-26 Poste 33-46

BIOLOGY (cont)

PARTICIPANTS AND OBSERVERS

France (cont)

Mme. M. Sibuet
CNEXO
Centre Oceanologique de Bretagne
BP 337
Brest 29273
France Tel: (98) 45 80 55 Ext 505
Telex: 940627F

Japan

Dr. R. Ichikawa
National Institute of Radiological Sciences
9-1 Amagawa-4-Chome
Chiba-Chi 260
Japan Tel: 0472-51-2111

Mr. H. Ishikawa
Nuclear Safety Research Association
1-2-2 Uchisaiwai-Cho
Chiyoda-ku
Tokyo
Japan Tel: (03) 503-5785
Telex: 222 6623
JAIFRM J

Netherlands

Dr. A. W. van Weers
Energy Research Foundation
Postbox 1
1755 ZG
Petten
Netherlands Tel: 02266-6262
Telex: 57211 reacp nl

Dr. G. C. Cadee
Netherlands Institution for Sea Research
P.O. Box 59
Texel
Netherlands Tel: 02220-541

BIOLOGY (cont)

PARTICIPANTS AND OBSERVERS

United Kingdom

Dr. R. J. Pentreath
Directorate of Fisheries Research
Fisheries Radiological Laboratory
Hamilton Dock
Lowestoft
Suffolk NR33 OHT
United Kingdom Tel: 0502-4381
Telex: 97470

Dr. M. Angel
Institute of Oceanographic Sciences
Brook Road
Wormley
Godalming
Surrey GU5 5UB
United Kingdom Tel: 042-879-4141
Telex: 858833

Dr. A. L. Rice
Institute of Oceanographic Sciences
Brook Road
Wormley
Godalming
Surrey GU5 5UB
United Kingdom Tel: 042-879-4141
Telex: 858833

United States

Dr. A. A. Yayanos*
Scripps Institution of Oceanography
University of California
La Jolla, CA 92093
United States Tel: (714) 452-2935
Telex: SIOCEAN

*Lead Correspondent

DISTRIBUTION:

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US Congress
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Division of Fuel Cycle and
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Washington, DC 20555
Attn: Asst. Mgr. for Waste
Management

US Dept. of Energy
Div. of Waste Management,
Production and Reprocessing
Washington, DC 20545
Attn: A. F. Perge, Sr. Tech. Asst.

US Department of Energy (27)
Office of Waste Isolation
NE/961, MS-B107
ONWM
Washington, DC 20545
Attn: D. G. Boyer, Chairman (25)
C. R. Cooley
C. Heath

Office of Science and Technical Policy
Natural Resources & Commercial Services
Washington, DC 20500
Attn: P. M. Smith

Environmental Protection Agency
Technology Assessment Div.
Office of Radiation Programs
AW-458 Waterside Mall East
Washington, DC 20545
Attn: A. D. Smith, Director

National Ocean Science Administration
6001 Executive Blvd
Rockville, MD 20852
Attn: A. Malahoff

Cornell University
254 Upson Hall
Sibley School
Mech & Aerospace Engr
Ithaca, NY 14853
Attn: P. R. Dawson

Lamont-Doherty Geo. Observatory (2)
Palisades, NY 10964
Attn: D. E. Hayes
J. E. Damuth

Harvard University
Pierce Hall
Cambridge, MA 02138
Attn: A. Robinson

Oregon State University
School of Oceanography
Corvallis, OR 97331
Attn: G. R. Heath

50 Congress St., Rm 1045
Boston, MA 02109
Attn: H. Herrman

Woods Hole Oceanographic Inst. (2)
Woods Hole, MA 02543
Attn: C. D. Hollister
V. T. Bowen

Battelle Memorial Institute
Office of Nuclear Waste Isolation
505 King Avenue
Columbus, OH 43201
Attn: R. Best

Pacific Northwest Laboratories
Battelle Blvd
Richland, WA 99352
Attn: K. Harmond

DISTRIBUTION: (cont)

University of California (3)
Scripps Inst. of Oceanography
La Jolla, CA 92093
Attn: A. A. Yayanos
K. L. Smith
R. R. Hessler

School of Oceanography
Oregon State University
Corvallis, OR 97331
Attn: G. R. Heath

Marine Physical Laboratory
Scripps Inst. of Oceanography
University of California
San Diego, CA 92132
Attn: V. C. Anderson
Deputy Director

Harvard University
Graduate School of Business Adm.
Boston, MA 02163
Attn: I. C. Bupp

Harvard University
Program for Science & Int'l Affairs
9 Divinity Avenue
Cambridge, MA 02138
Attn: D. A. Deese

University of Washington
Ocean Physics Group
Applied Physics Lab
1011 Northeast 40th Street
Seattle, WA 98195
Attn: T. E. Ewart
Program Manager

Argonne National Laboratory (2)
Chemistry Division
9700 South Cass Ave.
Argonne, IL 60439
Attn: S. M. Fried
A. M. Friedman

Battelle Columbus Labs
505 King Avenue
Columbus, OH 43201
Attn: E. L. Foster

University of Rhode Island
Graduate School of Oceanography
South Ferry Road
Narragansett, RI 02882
Attn: E. Laine

Bettis Atomic Power Lab
PO Box 79
West Mifflin, PA 15122
Attn: C. Detrick

University of Rhode Island
Department of Civil Engineering
Kingston, RI 02881
Attn: A. J. Silva

Marine Geotechnical Lab, 17
Lehigh University
Bethlehem, PA 18015
Attn: A. F. Richards, Director

Osterreichische Studiengesellschaft für Kernenergie
Lenaugasse 10
A-1082 Vienna, Austria
Attn: P. Krejsa, Head, Waste Management

Int. Atomic Energy Agency
Div. of Nucl. Safety & Environ. Protection
PO Box 590
Kärtner Ring 11
Vienna, Austria
Attn: W. L. Lenneman

Australian Atomic Energy Commission
Uranium Fuel Cycle Assessment and Planning Unit
Cliffbrook
45 Beach Street
Coogee, NSW, Australia
Attn: J. M. Costello

Société Eurochemic
200 Boeretang
B-2400 Mol
Belgium
Attn: E. Detilleaux, Directeur

DISTRIBUTION: (cont)

Centre d'Études de l'Energie Nucleaire
200 Boeretang
B-2400 Mol-Donk, Belgium
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Commission des Communautés Européennes
Direction générale des Affaires
industrielles et technologiques
200 rue de la loi
B-1040 Bruxelles
Belgium
Attn: S. Orlowski, Chef de la
Division Cycle du Combustible
Nucleaire

Atomic Energy Control Board
Waste Management & Environment Group
Research & Coordination Directorate
PO Box 1046
Ottawa, Ontario, Canada
Attn: J. Coady

Atlantic Geoscience Centre (4)
Bedford Institute of Oceanography
P.O. Box 1006
Dartmouth
Nova Scotia B2Y 4A2
Canada
Attn: B. Hargrave
C. Vilks
D. Buckley
R. Cranston

Danish Energy Agency
Research Establishment Risø
Chemistry Department
DK-4000 Roskilde, Denmark
Attn: B. Skytte Jensen, Head

Prof. D. Schnack
Universitat Hamburg
Institut fur Hydrobiologie und
Fischereiwissenschaft
Zeiseweg 9
D-2000 Hamburg 50
Federal Republic of Germany

Dr. F. Nyffeler
Universite de Neuchatel
Lub Geologic
Nl Rue E Argand
2000 Neuchatel
Switzerland

Swiss Fed. Inst. for
Reactor Research (2)
Health Physics Division
CH-5303 Wurenlingen
Switzerland
Attn: F. Alder, Head
H. Brunner, Asst. Head

Cekmece Nukleer Arastirma Merkezi
Health Physics Dept.
PO Box 1
Airport
Istanbul, Turkey
Attn: S. Goksel, Head

Fisheries Laboratory, MAFF (2)
Pakefield Road
Lowestoft, Suffolk
United Kingdom
Attn: M. J. Holden

N. Keen
UK AEA Fuel Processing Directorate
Harwell, Didcot, Oxon
United Kingdom

Institute of Oceanographic Sciences (3
Brook Road, Wormley
Godalming, Surrey GU8 5UB
United Kingdom
Attn: A. S. Laughton
J. C. Swallow
A. L. Rice

British Nucl Fuels Ltd.
Reprocessing Division
R&D Program
Risley
Warrington
Cheshire WA3 6AS
United Kingdom
Attn: D. W. Clelland, Mgr.

DISTRIBUTION: (cont)

Prof. W. Feldt
Isotopen Laboratorium Der
Bundesforschungsanhalt
Fur Fisherei
Wvstlasnd 2
D-2000 Hamburg 55
Federal Republic of Germany

Dr. H. Thiel
Universitat Hamburg
Institut fur Hydrobiologie und
Fischereiwissenschaft
Zeiseweg 9
2000 Hamburg 50
Federal Republic of Germany

Bundesministerium des Innern
Sub-Division of Radiation Protection
Rheindorfer Str. 198
D-53 Bonn
Federal Repbulic of Germany
Attn: H. C. Breest, Regierungsdirektor

Bundesministerium für Forschung und
Technologie
Nuclear Fuel Cycle Section
Stresemannstrasse 2
D-53 Bonn 12
Federal Republic of Germany
Attn: R. P. Randl

Insitute of Radiation Protection
Dept. of Reactor Safety
PO Box 268
SF-00101 Helsinki 10, Finland
Attn: S. Väisänen, Chief Inspector
Radiological Safety

Mr. J. Wannesson
IFP
Synthesis Geologiques et Geochimie
BP 311
92 506 RUEIL MALMAISON - CEDEX
France

Mme. M Sibuet
CNEXO
Centre Oceanologique de Bretagne
BP 337
Brest 29273
France

Mr. D. Rancon
Department de Surete Nucleaire-SESTR
CEN Cadarache
BP No 1 - 13115
St Paul-Lez-Durance
France

Mr. Y. Belot
Centre d'Etudes Nucleaires
Department de Protection
Service d'Etudes et Recherches
sur l'Environment
BP No 6-92260
Fontenay-aux-Roses
France

Mr. A. Barbreau
Institut de Protection et de Suerte Nucleaire
Centre d'Etudes Nucleaires
BP no 6
92260 Fontenay-aux-Roses
France

Netherlands Delegation to OECD
12-14 rue Octave-Feuillet
75016 Paris, France
Attn: L. M. J. van de Winkel
First Secretary

Mr. R. le Suave
CNEXO
Centre Oceanologique de Bretagne
BP 337
29273 Brest
France

Japanese Delegation to the OECD
7 avenue Hoche
75008 Paris, France
Attn: T. Bito, First Secretary

Mr. Ferruccio Gera
Nuclear Energy Agency
38, boulevard Suchet
75016 Paris
France

DISTRIBUTION: (cont)

Dr. C. N. Murray
Division of Chemistry
Joint Research Centre
21020 ISPRA (Varese)
Italy

C.N.E.N.
Reprocessing Division
Impianto Eurex
I-13040 Saluggia, Italy
Attn: G. Rolandi, Head

Dr. A. Avogardo
Division of Chemistry
Joint Research Centre
21020 ISPRA (Varese)
Italy

Dr. R. Ichikawa
National Institute of Radiological Sciences
9-1 Amagawa-4-Chome
Chiba-Chi 260
Japan

Mr. H. Ishikawa
Nuclear Safety Research Association
1-2-2 Uchisaiwai-cho
Chiyoda-ku
Tokyo, Japan

Dr. H. Hotta
Marine Technology Department
Japan Marine Science and Technology Centre (JAMSTEC)
2-15 Natsushima-Cho
Yokosuka 237, Japan

University of Tokyo
Ocean Research Institute
Nakano-Ku, 164, Japan
Attn: Y. Horibe

Science & Technology Agency (2)
Nuclear Safety Bureau
2-2-1 Kasumigaseki
Chiyoda-ku
Tokyo, Japan
Attn: M. Ishizuka, Director
Radioactivity Division
H. Nakato, Director
Nuclear Safety Division

Mr. G. de Marsily
Centre d'Informatique Geologique
Ecole des Mines de Paris
35 Rue St Honore
77305 Fontainebleau
France

Mr. F. Madelain
GNEXO
Centre Oceanologique de Bretagne
BP No 337-29273
Brest
France

Mr. P. E. Pottier
CEA
Centre d'Etudes Nucleaires de Cadarache
Department de Chimie Appliquee (BECC)
BP No 1-13115
St Paul Lez Durance
France

Coordination gestion déchets
Centre d'Etudes Nucléaires
B.P. N° 6
92260 Fontenay-aux-Roses, France
Attn: Y. Sousselier

Greek Atomic Energy Commission
Nuclear Research Center "Demokritos"
Aghia Paraskevi Attikis
Athens, Greece
Attn: S. Amarantos

Nuclear Energy Board
27 Upper Fitzwilliam St.
Dublin 2, Ireland
Attn: J. Cunningham

AGIP Nucleare
68 Corso di Porta Romana
I-20122 Milan, Italy
Attn: G. Ghilardotti, Coordinator
Science & Technology Activities

C.N.E.N. - C.S.N. Casaccia
Radioactive Waste Laboratory
Casella Postale N° 2400
I-00100 Roma A.D., Italy
Attn: W. Bocola

DISTRIBUTION: (cont)

Prof. S. Horibe
Ocean Research Institute
University of Tokyo
Nakano-ku 164, Japan

Dr. G. J. Prangsma
Royal Netherlands Meterological
Institute (KNMI)
P.O. Box 201
3730 AE De Bilt
The Netherlands

Dr. G. C. Cadee
Netherlands Institution for Sea Research
P.O. Box 59
Texel
The Netherlands

Dr. F. Van Dorp
Foundation Institute for Atomic Sciences
in Agriculture (ITAL)
P.O. Box 48 6708 Wageningen
The Netherlands

Dr. B. Schüettenhelm
Geological Survey of the Netherlands
P.O. Box 157
2000 AD HARRLEM
The Netherlands

Netherlands Energy Research Foundation
Industrial Relations
Westduinweg 3
Petten (N.H.)
The Netherlands
Attn: B. Verkerk, Coordinator

Dr. B. J. Collette (Advisor)
Vening Meinsez Laboratorium
Budapestlann 4
3584 CD Utrect
The Netherlands

Dr. A. W. Van Weers
Energy Research Foundation
Postbox 1
1755 ZG
Petten
The Netherlands

Ministry of Health & Environmental Hygiene
Radiation Protection Division
10 Dr. Reyersstraat
Leidschendam, The Netherlands
Attn: J. L. Baas, Director

New Zealand Atomic Energy Committee
c/o DSIR
Private Bag
Lower Hutt
New Zealand
Attn: J. T. O'Leary
Executive Secretary

Institutt for Atomenergi
Postboks 40
2007 Kjeller
Norway
Attn: N. G. Aamodt, Asst. Director

Junta de Energia Nuclear
Chemico-metallurgial Pilot &
Industrial Projects
Avenida Complutense 28
Madrid 3, Spain
Attn: L. Gutierrez Jodra,
Director

AB Atomenergi
Studsvik
Fac
S-611 01 Nykoping 1
Sweden
Attn: L. A. Nojd,
Deputy Gen. Director

Swedish Nuclear Power Inspectorate
Box 43058
S-100 72 Stokholm 43, Sweden
Attn: A Larsson

Dr. M. Sturm
EAWAG
Federal Institute for Water Resources
and Water Pollution
Veberlandspt 133
8600 Dubendorf
Switzerland

DISTRIBUTION: (cont)

Atomic Energy Research Establishment
Process Technology Division
Harwell, Didcot
Oxfordshire OX11 ORQ
United Kingdom
Attn: K. D. B. Johnson, Head

Australian High Commission
10-16 Maltravers Street
London WC2R 3EH, United Kingdom
Attn: R. Smith, Counsellor (Atomic Energy)

Dr. F. S. Feates
Department of the Environment
Becket House
1 Lambeth Palace Road
London SE1 7ER
United Kingdom

Mr. G. A. M. Webb
National Radiological Protection Board
Harwell
Didcot
Oxon OX11 ORQ
United Kingdom

Dr. J. G. Shepherd
Fisheries Laboratory
Lowestoft
Suffolk NR33 OHT
United Kingdom

Miss F. E. Taylor
Becket House
Room 309
1 Lambeth Palace Road
London SE1 7ER
United Kingdom

Ms. M. D. Hill
National Radiological Protection Board
Harwell
Didcot
United Kingdom

Dr. M. Angel
Institute of Oceanographic Sciences
Brook Road
Wormley
Godalming
Surrey GU5 5UB
United Kingdom

Dr. R. Butlin
Building Research Establish
Garston
Watford
Herts
United Kingdom

Dr. R. C. Searle
Institute of Oceanographic Sciences
Wormley
Godalming
Surrey GU8 5UB
United Kingdom

Dr. G. P. Marsh
Materials Development Division
Building 393
AERE
Didcot, Oxon AOX11 ORA
United Kingdom

Dr. G. P. Rothwell
National Corrosion Service
National Physical Laboratory
Teddington
Middlesex TW11 OLW
United Kingdom

Dr. J. Menzies
Building Research Establishment
Garston
Watford, Herts
United Kingdom

Dr. J. E. Antill
Central Electricity Generating Board
Berkeley Nuclear Laboratories
Berkeley
Gloucestershire GL13 9PB
United Kingdom

Dr. J. Shaw
British Nuclear Fuels Limited (BNFL)
Windscale and Calder Works
Sellafield
Sea Scale, Cumbria
CA 20 1A6
United Kingdom

DISTRIBUTION: (cont)

Mr. J. A. C. Marples
Chemistry Division
Building 220.22
AERE Harwell
Didcot
Oxon OX11 ORA
United Kingdom

Dr. T. J. G. Francis
Institute of Oceanographic Sciences
Wormley
Godalming
Surrey GU8 5UB
United Kingdom

Mr. H. J. Richards
Department of the Environment
2 Marsham Street London
London SE1
United Kingdom

Dr. H. D. St. John
Building Research Establishment
Garston
Watford
Herts
United Kingdom

Dr. R. B. Whitmarsh
Institute of Oceanographic Sciences
Wormley
Godalming
Surrey GU8 5UB
United Kingdom

Dr. D. Kinsey
Chemical Technology Division
Building 151
AERE Harwell
Oxon OX11 ORA
United Kingdom

Mr. D. B. Smith
NERC
Polaris House
North Star Avenue
Swindon
Wilts SN2 1EU
United Kingdom

Dr. J. B. Lewis
Building 175
Chemical Technology Division
AERE Harwell
Didcot
Oxon OX11 ORA
United Kingdom

Mr. H. W. Hill
Fisheries Laboratory
Ministry of Agriculture, Fisheries
and Food
Lowestoft
Suffolk NR33 OHT
United Kingdom

Dr. P. M. Saunders
Institute of Oceanographic Sciences
Brook Road
Wormley
Godalming
Surrey GUS 5UB
United Kingdom

Mr. J. Crease
Institute of Oceanographic Sciences
Brook Road
Wormley
Godalming
Surrey GUS 5UB
United Kingdom

Dr. P. A. Gurbutt
Ministry of Agriculture, Fisheries
and Food
Fisheries Laboratory
Lowestoft
Suffolk NR33 OHT
United Kingdom

Dr. R. J. Pentreath
Directorate of Fisheries Research
Fisheries Radiological Laboratory
Hamilton Dock
Lowestoft
Suffolk NR33 OHT
United Kingdom

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