GEOCHEMICAL OCEAN SECTIONS

A U.S. program for the International Decade of Ocean Exploration

The GEOSECS PROGRAM

The OBJECTIVES

The PLAN

The BENEFITS

WHAT IS GEOSECS?

As man becomes increasingly aware of the ocean as a source of food, a disposal area for nuclear and industrial waste products, a strategic realm for national security and a controlling factor in the earth's climatic regime, he also recognizes how very little he knows about the sea. Until recently, oceanography has been a science of exploration, of mapping variables that are relatively easy to determine such as temperature and total salt concentration and of studying the pattern of wind-driven currents in the surface layers of the water. Yet, the ultimate use of the sea depends critically upon a detailed understanding of other processes in the deep sea -- the interchange of material between deep and surface water, the variation of organic productivity throughout the oceans and the exchange of water and gases with the atmosphere.

Meanwhile, rapid expansion of science and technology in recent decades has produced sophisticated and powerful tools for the study required. Shore-based laboratories have mass spectrometers, low level radioactivity counters, atomic reactors for neutron activation and gas and liquid chromatographs. All of these instruments have been used for the analysis of individual constituents of ocean water and some have been used successfully at sea. The development of well-trained geochemical oceanographers and of shipboard laboratories, however, has lagged far behind analytical techniques. Consequently, the potential for these new methods of studying the sea has only begun to be realized.

R/V KNORR, a 240' AGOR class research vessel equipped with cycloid propulsion, will be at sea nearly a full year as it sails from the Arctic to the Antarctic on the Atlantic Cruise of the GEOSECS project. The ship is the most modern in the fleet operated by Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, U. S. A. A subsequent Pacific Cruise will be made by her sister ship, R/V MELVILLE, operated by Scripps Institution of Oceanography, La Jolla, California, U. S. A.

The basic purpose of the Geochemical Ocean Section Study, GEOSECS, is the detailed measurement of oceanic constituents along Arctic to Antarctic sections at all depths to provide, for the first time, a set of physical and chemical data measured on the same water samples. Input of these data will permit quantitative studies of oceanic mixing and organic productivity and, at the same time, serve as a base-line for levels of pollutants and of fission and waste products being added to the sea.

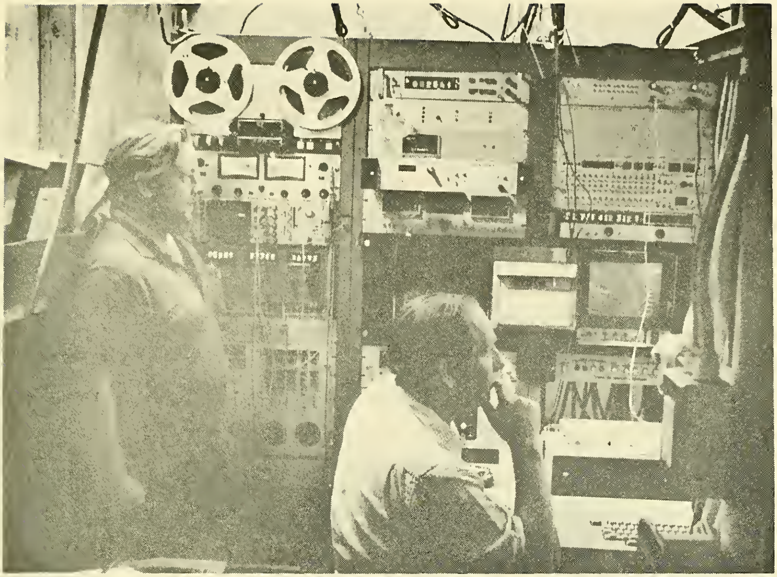
Exploration of temperature and salinity patterns together with theoretical work in fluid dynamics has already provided a qualitative understanding of large-scale processes in the ocean. We know, for instance, that the sea resembles a great convective cell in which the upper layers are stirred horizontally by wind-driven currents. In most areas, these upper layers have the highest salt content because of evaporation from the surface. Heat and salt are carried down to deep water by turbulent diffusion. While we know there is a return flow of heat and salt to the surface and that it must take place by vertically-rising advective currents, we do not know precisely how this takes place. The stirring mechanism which drives the vertical flow is provided by the sinking of cold water in the polar regions where surface waters radiate their heat and increase in salinity by the formation of sea ice. Bottom water thus formed flows to the deep basins of the oceans as an abyssal current which supplies the upward return to the surface. Oceanographic and geochemical studies have indicated that the abyssal current originates in two areas: the North Atlantic and the Weddell Sea in the Antarctic region of the South Atlantic. Where this current flows, how fast it travels, the nature of the flow in the different oceans and whether or not other sources exist are questions that remain to be studied.

In addition, we know that vertical and horizontal gradients of chemical constituents in the sea are smoothed by turbulent diffusion which acts at a rate some 100 times faster than molecular diffusion and we have a crude idea of the average rate of this process. Yet we know nothing of its vertical and horizontal variations or of the source of energy which drives it. A unique method of tagging which can be used to measure the rates of downward mixing from surface to intermediate depths has been provided, however, with the recent introduction of fission and nuclear products such as radiostrontium and cesium, tritium and man-produced carbon-14 into the surface waters. In the deep and bottom waters, concentrations of the natural radioactive isotopes including radium-226, silicon-32 and cosmic ray produced carbon-14 provide nuclear "clocks" for the study of rates of advection and turbulent diffusion.

We know that, ultimately, we must be able to predict how fast, and in what directions, a substance introduced at any depth and location in the sea will spread, over periods of hundreds to thousands of years. At the present time we are only beginning to understand the pattern of variation of these radioisotopes although precise analytical techniques for all of them exist.

In addition, we need to know more about the return of nutrients to the surface of the ocean since this is perhaps the single most important factor in determining the organic productivity of various regions of the sea. The vertical distribution of many oceanic constituents is determined by interactions between physical processes which stir the water and biochemical ones which fix elements to, and release them from, particulate matter in the ocean. The particulate flux consists largely of the remains of organisms which live in the surface waters. As this debris sinks under the influence of gravity toward the sea floor, oxidation and solution gradually return the constituent elements to their dissolved form. This downward particulate transport process works against the homogenizing influence of physical mixing and tends to enrich the deep sea in many chemical species. Thus, in order to understand the dispersion of a given element through the world ocean, we must comprehend both physical mixing and particulate transport phenomena. Organic productivity studies tell us something of the generation of particles; and sediment studies, something of the fraction surviving destruction. Still, the details of the intermediate steps are essentially unknown. A large fraction of the phosphate, nitrate and other essential nutrients is redissolved and brought back to the surface by advection and diffusion, we recognize --- and it is this action that is so important in determining organic productivity in different regions of the sea.

How fast is the material returned to the surface? How do the particulate fluxes of the different trace elements, nutrients and isotopes vary in different parts of the ocean? How much of these constituents is oxidized at different depths and how much settles to the bottom? These questions, almost unanswerable today, can be settled by studies of the vertical and horizontal distribution of radioisotopes and trace elements. Since the radioactive isotopes themselves participate in the particulate and biological cycles, we must investigate the distribution of "coupled" radioactive and stable isotopes in order to separate the effects of fluid mixing and particulate flux. Thus, the



Derek W. Spencer of Woods Hole Oceanographic Institution, a member of the GEOSECS Executive Committee, and Arnold Bainbridge of Scripps Institution of Oceanography, project director, man the control console during a GEOSECS test cruise.

distributions of the cosmic ray produced radioisotopes C^{14} and Si^{32}, with half-lives of 5700 and 700 years respectively, must be compared with those of stable carbon and silicon in order to use the "clocks". Similarly, the distributions of the man-made fission products Sr^{90} and Cs^{137} can be corrected for particulate effects by observing the distribution of natural strontium and cesium in the sea. The GEOSECS program is designed to give the first detailed information of such distribution patterns by measuring simultaneously the distribution of all of the most important tracers and properties along oceanic sections.

PLANNED RESEARCH ACTIVITIES

The Geochemical Ocean Section survey will be made along north-south tracks through the oceans. The track follows, as far as is now known, the approximate trajectory of the bottom water current. The United States program will carry out the major survey work along this track in the Atlantic, Pacific, Antarctic and Indian Oceans. Additional programs now being planned by the German Federal Republic, Japan and other nations will add supplementary sections. (See section on International Coordination.)

The U. S. program calls for the occupation of oceanographic stations along main survey tracks as shown in Figure 4. Details will be worked out later for a proposed six-month cruise in the Indian Ocean. At each station vertical profiles of 50 samples, each measuring about 30 liters, will be taken while, at alternate stations, very large samples of 270 - 1000 liters will be taken at about 20 depths to measure trace constituents and low-concentration radioisotopes. Locations of the stations and nominal depths are shown in Table 1. The vertical spacing of all samples will be guided by continuous recording, on station, of temperature, salinity and dissolved oxygen. Particulate matter will be collected at all depths and dissolved gases will be extracted from sea water for on-board analysis by gas chromatography. Much of the analytical work will be done on the ships during the expedition. Remaining work on water samples will be done in laboratories of participating geochemists throughout the country, and a "water library" of water samples will be maintained for future work. Flow sheets typifying the

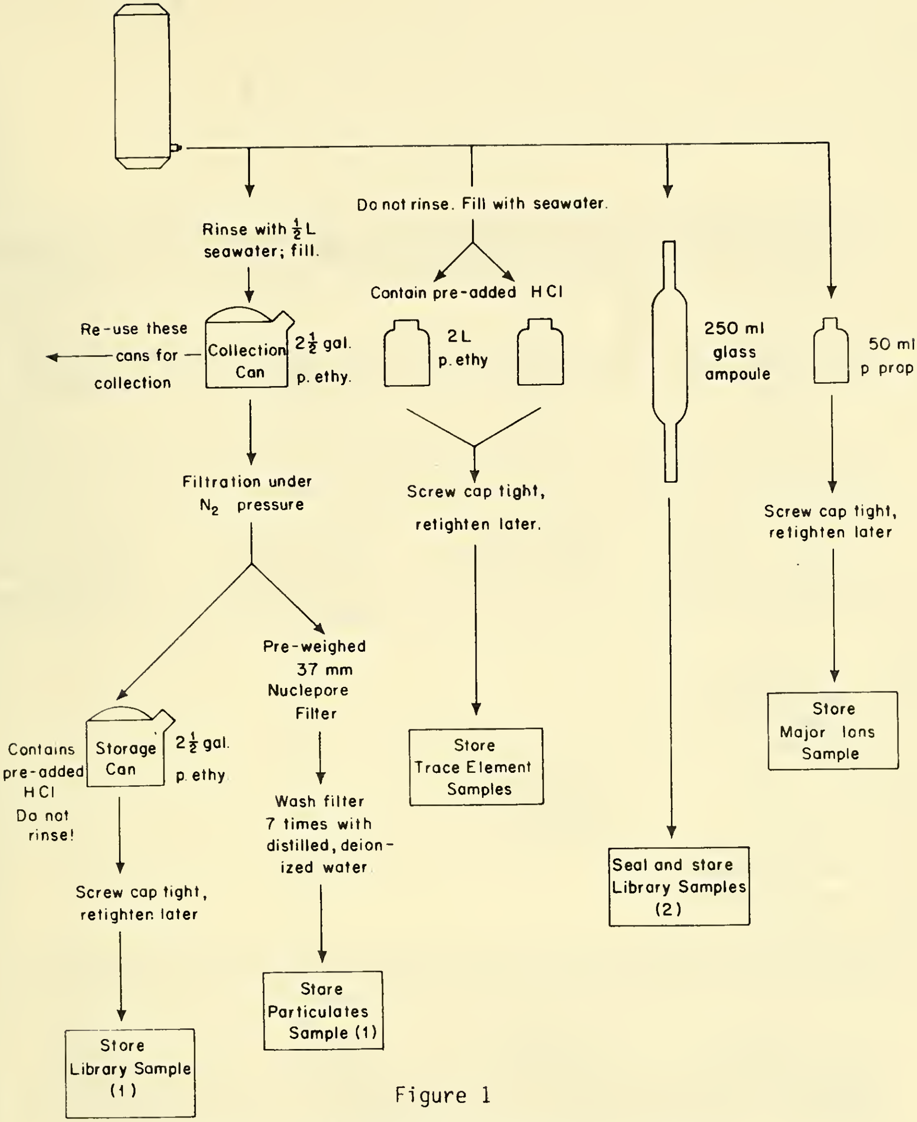


Figure 1

Flow Sheet: Collection and Storage of Library, Trace Element and Major Ion Samples

sampling procedure are shown in Figures 1 and 2.

A complete list of properties to be measured, together with the investigators, is given in Table 2.

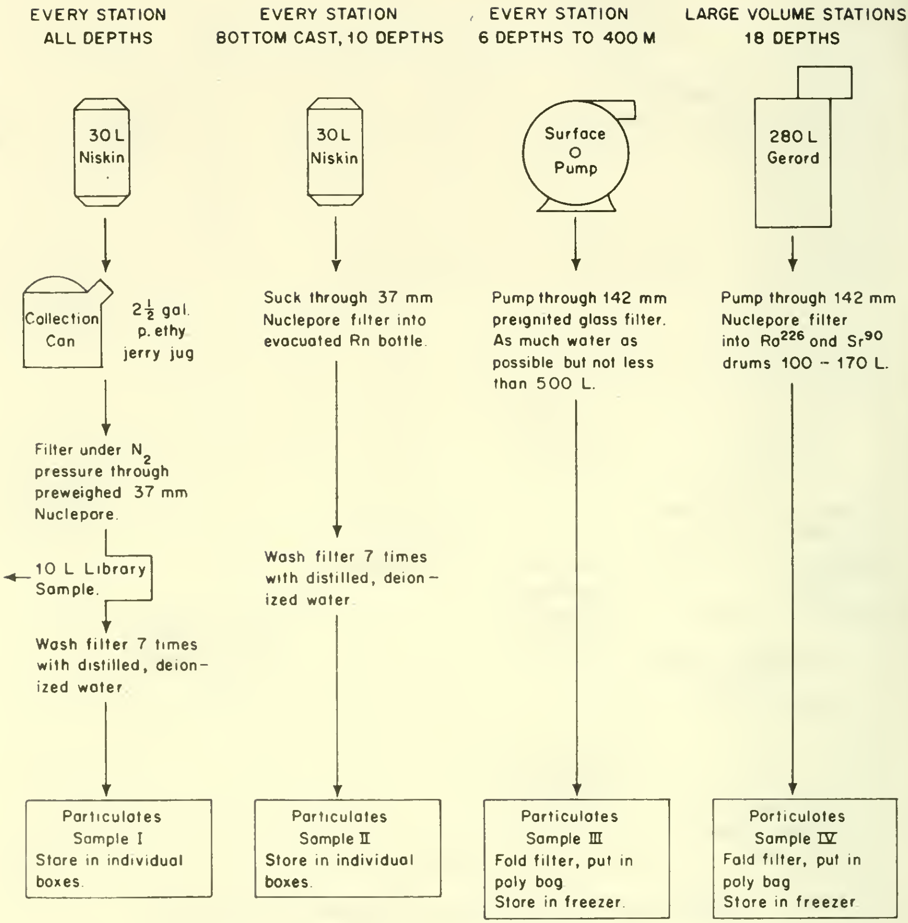


Figure 2

Flow Sheet: Particulates

Station	Lat.	Long.	Depth (meters)	Station	Lat.	Long.	Depth (meters)
1	45°N	42°W	4400	36	21°S	33°W	4250
2	48°N	42°30'W	4100	37	24°S	34°30'W	4350
3	51°N	43°W	4400	38	27°S	37°W	4400
4	54°N	43°W	3600	39	30°S	39°30'W	4400
5	57°N	42°30'W	3600	40	33°S	42°30'W	4400
6	60°N	40°W	2600	41	36°S	45°W	4800
7	63°N	35°30'W	2000	42	39°S	48°30'W	5300
8	66°N	27°30'W	900	43	42°S	51°W	5600
9	69°N	20°W	1100	44	46°S	51°W	6000
10	72°N	11°W	2300	45	49°S	45°W	6000
11	75°N	1°W	3700	46	56°S	45°W	3600
12	70°N	0°	3100	47	56°S	54°W	4400
13	66°N	5°30'W	3100	48	56°S	62°W	4000
14	60°N	20°W	2700	49	50°S	36°W	4400
15	42°N	42°30'W	4800	50	56°S	25°W	7800
16	39°N	44°W	4900	51	58°S	8°W	3900
17	36°N	47°W	4900	52	58°S	12°E	5200
18	33°N	50°30'W	5600	53	63°S	30°E	5100
19	30°N	52°30'W	5600	54	60°S	30°E	5500
20	27°N	53°30'W	5600	55	57°S	30°E	5500
21	24°N	54°30'W	5600	56	54°S	30°E	5500
22	21°N	54°30'W	5600	57	51°S	30°E	4600
23	18°N	54°W	4800	58	48°S	30°E	5500
24	15°N	52°30'W	5100	59	45°S	30°E	5500
25	12°N	51°W	5000	60	40°S	22°E	4800
26	9°N	48°30'W	4600	61	20°S	9°E	2000
27	6°N	46°W	4500	62	20°S	2°E	5200
28	3°N	42°W	4500	63	20°S	5°W	4700
29	0°	36°30'W	4500	64	20°S	13°W	3200
30	3°S	29°30'W	4800	65	20°S	20°W	5000
31	6°S	27°W	5200	66	20°S	27°W	5200
32	9°S	27°W	5200	67	36°N	53°30'W	5200
33	12°S	28°W	5200	68	36°N	58°W	5000
34	15°S	29°30'W	5100	69	36°N	64°W	4800
35	18°S	31°W	4650	70	36°N	69°W	4700

Table 1

Station Locations - Atlantic Leg

MANAGEMENT OF THE PROGRAM

The ultimate responsibility for decisions regarding the scientific program rests with the GEOSECS Scientific Advisory Committee. This committee's members are:

Dr. W. S. Broecker	Lamont-Doherty Geological Observatory
Dr. Harmon Craig	Scripps Institution of Oceanography
Dr. H. Gote Ostlund	University of Miami
Dr. J. L. Reid	Scripps Institution of Oceanography
Dr. D. W. Spencer	Woods Hole Oceanographic Institution
Dr. H. M. Stommel	Massachusetts Institute of Technology
Dr. Taro Takahashi	Queens College, City Univ. of New York
Dr. K. K. Turekian	Yale University
Dr. H. L. Volchok	Health and Safety Laboratory, U. S. Atomic Energy Commission
Dr. Klaus Wyrtki	University of Hawaii

From this group, three members, Dr. Broecker, Dr. Craig and Dr. Spencer, have been appointed to the Executive Committee which is responsible for overall direction of the operations of the program. At the present time Dr. Spencer is acting as coordinator of all matters concerning the program with the International Decade of Ocean Exploration, National Science Foundation.

A. E. Bainbridge of S. I. O. has been appointed project director and is responsible for organizing, staffing and maintaining ship-

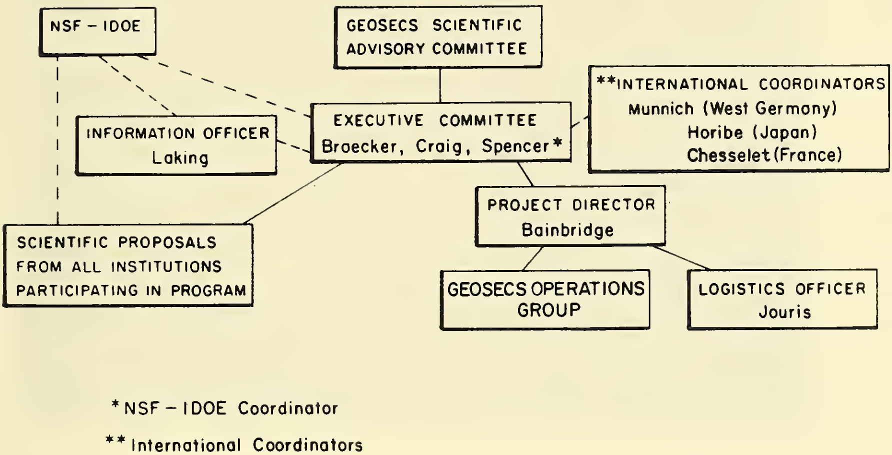
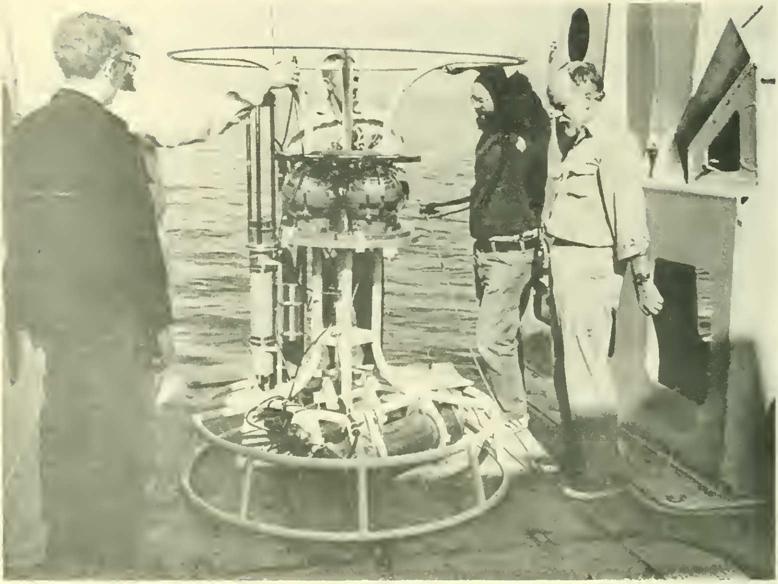


Figure 3
Management Structure

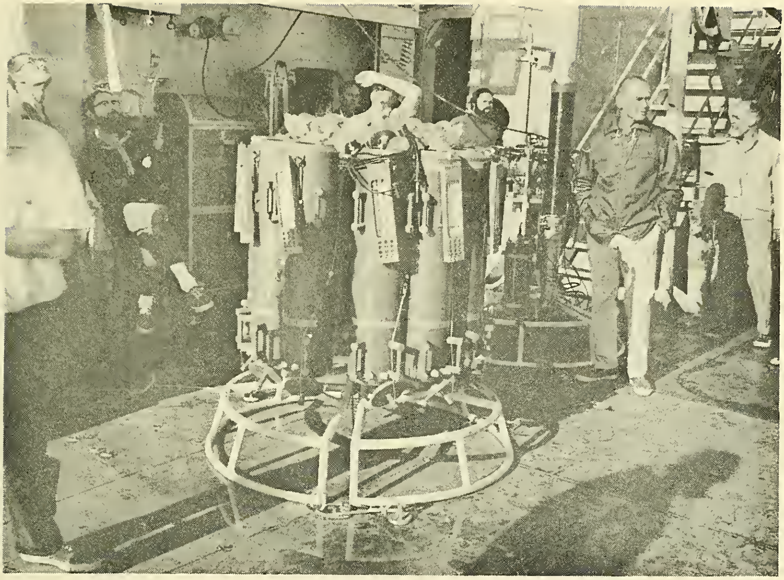
board operations. A diagram of the management structure is given in Figure 3. The GEOSECS Operations Group, under A. E. Bainbridge, will build, operate and maintain the sea-going equipment. W. E. Jouris of W. H. O. I. is logistics officer and responsible for supervising the supply of scientific equipment and sample containers to the ships, for cataloging and distributing samples returned for shore-based analyses and for general operations at the W. H. O. I. GEOSECS Building.



An empty rosette showing the laser nephelometer, glass sphere encapsulated batteries and bottom package containing bottom pinger, oxygen probe and salinity-temperature-depth profiler was photographed during a GEOSECS test cruise.

OPERATION AND LOGISTICS OF THE PROGRAM

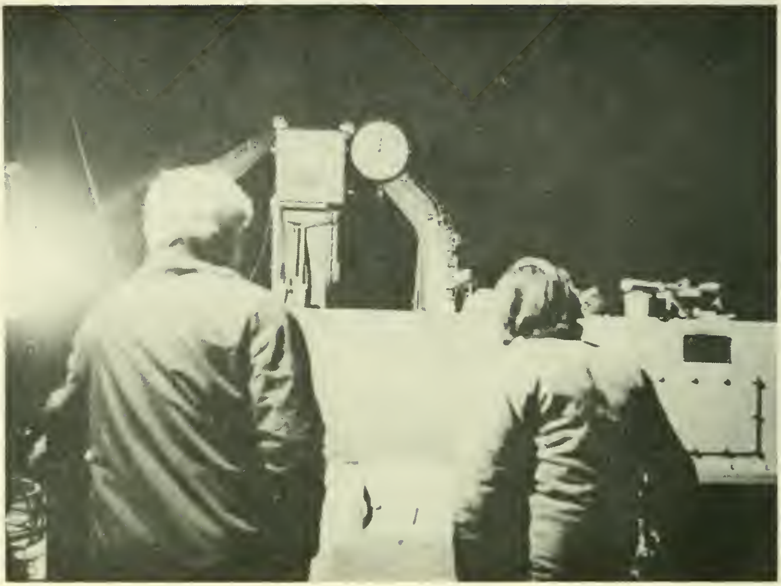
The operation of the program is focused around two major cruises: one in the the Atlantic scheduled for July, 1972 - March, 1973 and a second in the Pacific set for June, 1973 - March, 1974. On each, shipboard measurements listed in Table 2 will be performed by two rotating crews of four analysts each while sample collection and water handling will be done by two five-man rotating crews. In addition to the chief scientist, the scientific complement will include two associate chief scientists, a computer operator and an elec-



The rosette pictured above contains 12 reversing thermometer-equipped 30-liter Niskin samplers. Samplers of this type will be used on every cast during the entire GEOSECS cruise.

tronics engineer. The whole program will involve the collection of water from about 140 stations. Of these, about 70 will be made during the first Atlantic cruise. A schedule for this portion of the project is given in Table 3. Details of the Pacific cruise are now being formulated but have not been completed.

The magnitude of the sampling program precludes storing all of the larger sample bottles on board the ship at the outset. Even those that must be carried for a single leg would take up all of the available storage space below deck. Consequently, special pallets have



The new GEOSECS hydrowinch was photographed while in use during night operations on a project test cruise off the coast of California.

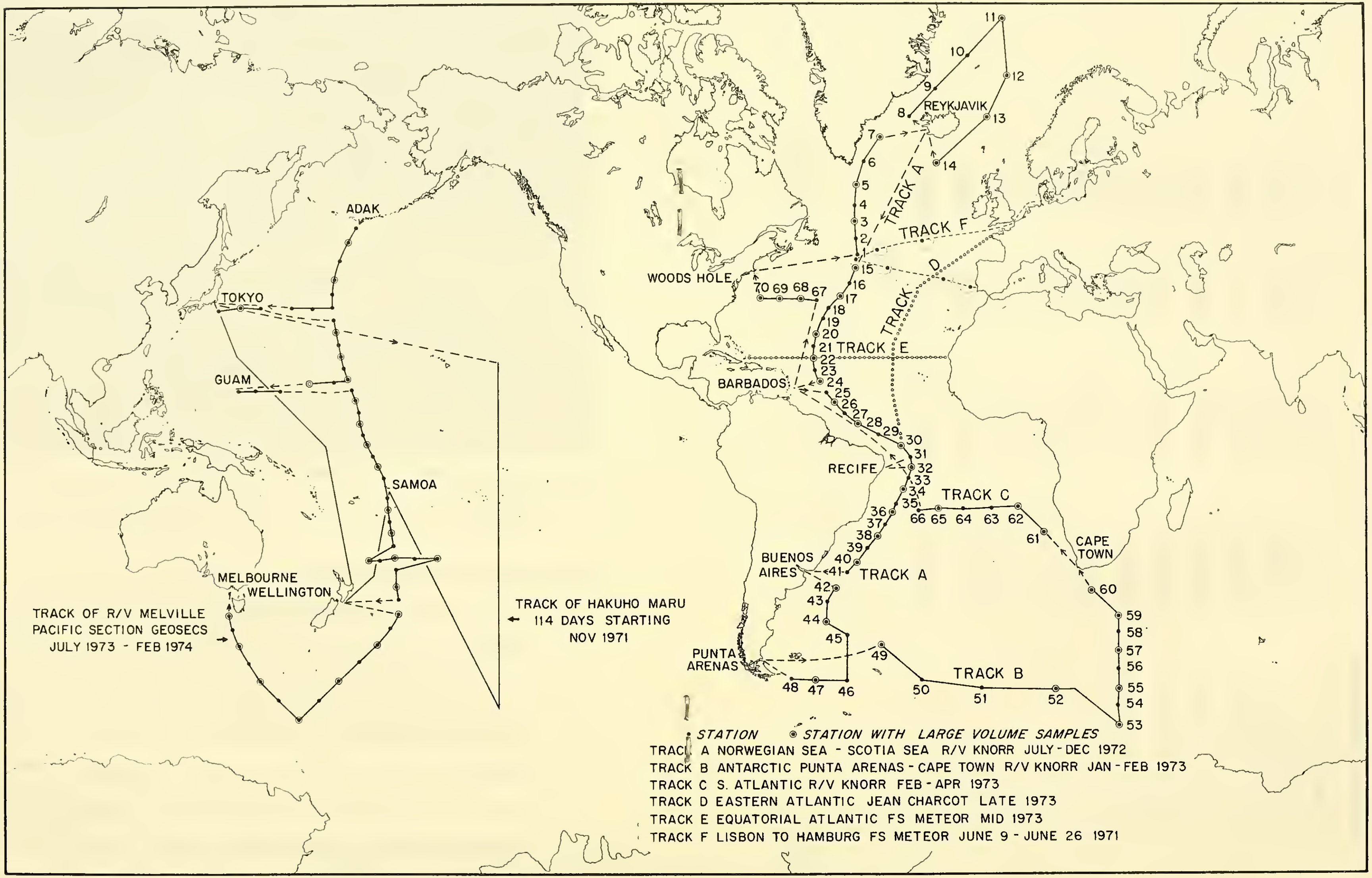
been constructed so that the larger bottles may be carried in the open on the forward 02 deck of the ship. The water samples will be pumped from the fantail to the bottles in order to avoid the necessity for transporting heavy samplers fore and aft. At each port call the full pallets will be off-loaded and empties, previously shipped for the purpose, will replace them. Table 4 gives an idea of the magnitude of the logistics involved.

All physical and chemical measurements made at sea will be coupled with the shipboard computer. Data will be logged from principal and auxiliary sources and brought together in a Real Time System to compute final values of the parameters. This data will be available before moving off station and will thus be evaluated at that point by the Chief Scientist. A complete description of the Real Time System is included in the proposal from U. C. S. D., Scripps Institution of Oceanography, A. E. Bainbridge, principal investigator, and a block diagram is presented in Figure 5.

Prior to the cruises major efforts of many of those associated with the program have gone into construction projects and the testing of equipment as well as into planning scientific investigations. For the operation of the project, each of the major oceanographic institutions has been assigned certain areas of responsibility. They are detailed in individual proposals but are summaried briefly here. The listing does not, however, include the specific analytical commitments given in Table 1.

Woods Hole Oceanographic Institution

1) Provision of shiptime, R/V KNORR, for shakedown cruise, June, 1972 and for Atlantic cruise, July, 1972 - March, 1973.
2) Provision of logistics support and facilities for shipment of equipment, samples and personnel to and from ship during first cruise.
3) Provision of center for collection and distribution of samples for shore based analytical work together with facilities for establishing and maintaining a "water library" for the entire



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PROPOSED GEOSECS CRUISE TRACKS

Figure 4

COMPONENT	INVESTIGATOR	INSTITUTION	SAMPLE SIZE	APPROXIMATE NO. SAMPLES
I. Seawater Components				
A. Chemical				
1. Salinity	Shipboard	(SIO)	280ml	12,000
2. Temperature	Shipboard	(SIO)		12,000
3. Dissolved O_2	Shipboard	(SIO)	100ml	6,700
4. Total CO_2	Shipboard	(SIO)	50ml	6,700
5. Alkalinity, pH	Shipboard	(SIO)	250ml	6,700
6. pCO_2	Shipboard	(LDGO-SIO)		Continuous
7. Na	Mangelsdorf	WHOI	50ml	2,000
8. Ca	Mangelsdorf	WHOI	50ml	2,000
9. Mg	Mangelsdorf	WHOI	50ml	2,000
10. K	Mangelsdorf	WHOI	50ml	2,000

TABLE 2

LIST OF CONSTITUENTS TO BE ANALYZED

COMPONENT		INVESTIGATOR	INSTITUTION	SAMPLE SIZE	APPROXIMATE NO. SAMPLES
11.	Fe	Spencer	WHOI	4 l	2,000
12.	Ni	Turekian	Yale	4 l	2,000
13.	Cu	Robertson	Battelle NW	4 l	2,000
14.	Zn	Broecker (Ba only)	LDGO	100 ml	2,000
15.	Ba				
16.	Dissolved N_2	Shipboard	(SIO)	50 ml	6,700
17.	Dissolved Ar	Shipboard	(SIO)	50 ml	6,700
18.	Dissolved He	Craig	SIO	250 ml	2,000
19.	Dissolved Ne	Clarke	McMaster	250 ml	2,000
20.	Organic C	Park	OSU	250 ml	6,000
21.	SiO_2	Shipboard	(OSU)	250 ml	6,700
22.	PO_4	Shipboard	(OSU)	250 ml	6,700
23.	NO_3	Shipboard	(OSU)	250 ml	6,700

TABLE 2 cont.

COMPONENT	INVESTIGATOR	INSTITUTION	SAMPLE SIZE	APPROXIMATE NO. SAMPLES
B. Radioactive Isotopes (Seawater)				
1. C^{14}	Ostlund	Miami	500 ml	1,100
	Stuiver	U. Washington	500 ml	
2. Ra^{226}	Broecker	LDGO	55 l	1,500
	Craig	SIO		
	Ku	USC		
3. Ra^{228}	Broecker	LDGO	20 l	1,000
4. Si^{32}	Lal and Somayajulu	Tata Inst. (India)		100
5. H^3	Ostlund	Miami	1 l	600
" (deep water)	Clark	McMaster (Canada)	1 l	200
" (" ")	Craig	SIO	1 l	200
6. Sr^{90}	Volchok	HASL	55 l	1,100
	Bowen	WHOI		
7. Cs^{137}	Bowen	WHOI	55 l	1,100
8. Rn^{222}	Shipboard	(LDGO-SIO)	20 l	1,000

TABLE 2 cont.

COMPONENT	INVESTIGATOR	INSTITUTION	SAMPLE SIZE	APPROXIMATE NO. SAMPLES
C. Stable Isotopes (Seawater)				
1. H^2	Craig	SIO	120 ml	3,000
2. $O^{18}(H_2O)$	Craig	SIO	120 ml	3,000
3. $O^{18}(PO_4)$	Longinelli	Pisa (Italy)		100
4. $O^{18}(SO_4)$	Longinelli	Pisa (Italy)		500
5. O^{18}(Dissolved O_2)	Kroopnick Craig	Hawaii SIO	250 ml	600
6. C^{13}(Total CO_2)	Kroopnick Craig	Hawaii SIO	250 ml	3,000
7. He^3(Dissolved He)	Craig Clarke	SIO McMaster (Canada)	250 ml	2,000
II. Particulate Matter				
1. Concentration	Shipboard	(WHOI)		Profiles

Table 2 cont.

COMPONENT	INVESTIGATOR	INSTITUTION	SAMPLE SIZE	APPROXIMATE NO. SAMPLES
2. Mineral phases	Spencer Biscaye Chesselet	WHOI LDGO C. F. R./C. N. R. S. (France)		700
3. $C^{14}(CaCO_3)$	Lal	Tata Inst. (India)		100
III. Atmospheric Gases				
1. Water Vapor	Shipboard	(SIO)	20 ml	Continuous
2. CO_2	Shipboard	(LDGO-SIO)	250 ml	Continuous
3. N_2O	Craig	SIO	2 1	250
4. H^2 (vapor)	Kroopnick Craig	Hawaii SIO	120 ml	250
5. O^{18}(vapor)			250 ml	250
6. $O^{18}(CO_2)$			250 ml	250
7. $C^{13}(CO_2)$			250 ml	250

Table 2 cont.

Sampling and Analysis

120 casts (30 l bottles) x 50 depths = 6,000

60 casts (280 l bottles) x 18 depths = 1,080

Hydrographic casts (T, S): 120 x 40 depths = 4,800

Bottom water samples: 120 x 6 depths = 720

Si^{32} and particulate sponge casts: 91

Atmospheric-discrete sampling: $\sim 1.5^{o}$ intervals

Table 2 cont.

Leg No.	Starting Date	No. of Stations	Station Numbers	Ports	No. of Large Vol. Stations	Chief Scientist	Asso. Chief Scientist	Asso. Chief Scientist
1	July 18, '72	7	1 - 7	Woods Hole to Reykjavik	3	Spencer	Edmond	Bainbridge
2	Aug. 12, '72	6	8 - 13	Reykjavik to Reykjavik	4	Spencer	Edmond	Weiss
3	Sept. 2, '72	11	14 - 24	Reykjavik to Bridgetown	5	Broecker	Weiss	Kroopnick
4	Oct. 2, '72	8	25 - 32	Bridgetown to Recife	3	Craig	Park	Bainbridge
5	Nov. 2, '72	9	33 - 41	Recife to Buenos Aires	5	Broecker	Brewer	Takahashi
6	Dec. 1, '72	7	42 - 48	Buenos Aires to Punta Arenas	3	Park	Spencer	Biscaye
7	Dec. 27, '72	12	49 - 60	Punta Arenas to Cape Town	8	Craig	Edmond	Longinelli
8	Feb. 9, '73	6	61 - 66	Cape Town to Bridgetown	3	Reid	Brewer	Gordon
9	March 16, '73	4	67 - 70	Bridgetown to Woods Hole	2	Takahashi	Chung	Bainbridge
		70 Stations Occupied			36 Large Volume Stations			

STD casts will be taken between stations ------ Estimated time: 2 hours each

Table 3

GEOSECS Atlantic Leg

Port	Dates	Pallets Going	Weight Going lb.	Volume Going ft^3	Pallets Returning	Weight Returning lb.	Volume Returning ft^3
Reykjavik, Iceland	8/ 8 - 8/12, '72	16	5120	640	12	17,130	480
Reykjavik, Iceland	8/29 - 9/ 2	20	6400	800	16	22,840	640
Bridgetown, Barbados	10/ 2 - 10/ 7	12	3840	480	20	28,552	800
Recife, Brazil	10/29 - 11/ 2	20	6400	800	12	17,130	480
Buenos Aires, Argentina	11/27 - 12/ 1	12	3840	480	20	28,552	800
Punta Arenas, Chile	12/21 - 12/28	32	10240	1280	12	17,130	480
Cape Town, South Africa	2/ 4 - 2/ 9, '73	12	3840	480	32	45,685	1280
Bridgetown, Barbados	3/11 - 3/16	8	2560	320	12	17,130	480

Table 4

Ports Schedule - GEOSECS Cruise

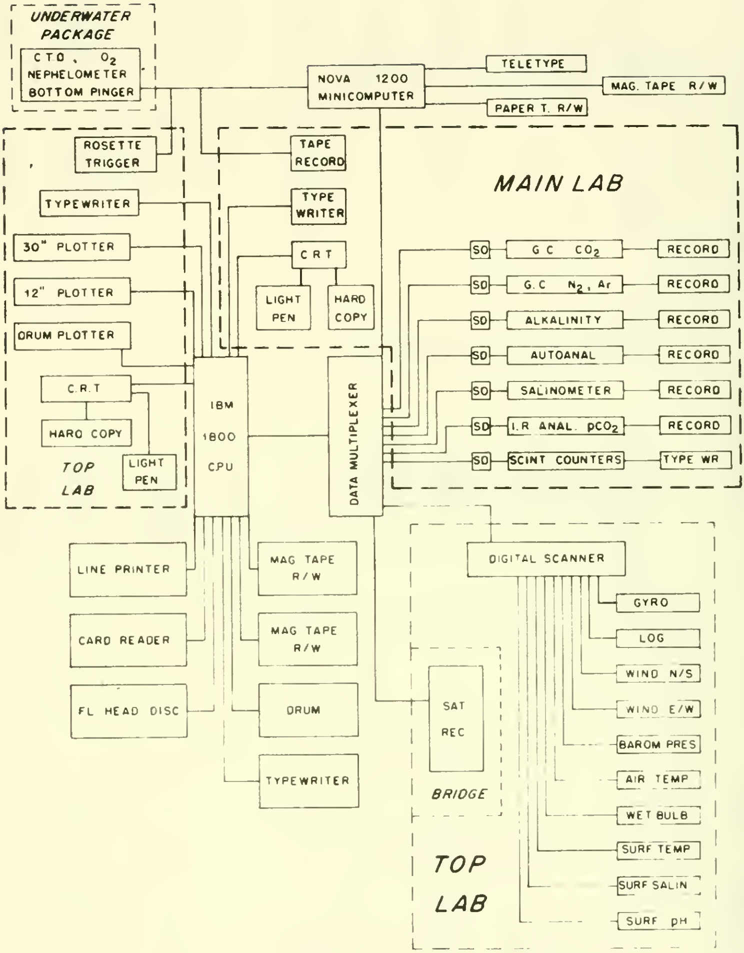

Figure 5

GEOSECS Shipboard Analytical and Computer Systems program.

4) Provision of shipboard equipment for water sampling.

5) Provision of equipment for preliminary shipboard processing of water samples for trace elements and particulates.

6) Organization and provision of facilities for GEOSECS Summer Institutes.

Scripps Institution of Oceanography

1) Provision of shiptime, R/V MELVILLE, for ANTIPODE Expedition, July, 1971; for initial tests of instrument console, December, 1971; for Pacific cruise, June 1973 - March, 1974.

2) Provision of shipboard computer system, IBM-1800 computer, on loan from S. I. O., for both major cruises. Interfacing of shipboard instrumentation to the computer.

3) Procuring and training of central technical staff for the shipboard operation.

4) Provision of winch-wire Nansen bottles, etc. for hydrographic work. Provision of STD system.

5) Construction of shipboard gas chromatographs, automated titration systems, etc. for N_2, Ar, O_2, alkalinity and total CO_2.

6) Construction of bottom water profiling system for precise temperature data and water sampling close to the sea floor. Together with W. H. O. I., interfacing this system with the nephelometer.

Lamont-Doherty Geological Observatory

1) Development of procedures and equipment for collection and analysis of *in situ* Rn^{222}, both in surface and bottom profiles.

2) Development of procedures for determination of Ra^{226}.

3) Development of shipboard and shore based extraction systems for large volume water samples -- for Ra^{228}, Ra^{226}, C^{14}, Cs^{137} and particulates, together with W. H. O. I.

4) Participate in testing and perfecting of large volume water sampling and shipboard handling techniques, with W. H. O. I.

5) Construction of equilibrators, infrared analysis system for CO_2 partial pressure measurements. Construction of gas chromatographs for shore based CO_2 measurements.

Oregon State University

1) Provision of facilities for shipboard analysis of nutrients, autoanalyzers.

2) Provision of facilities for shore based analyses of dissolved organic carbon.

University of Miami

1) Provision of shore based facilities for high precision determinations of C^{14} and H^3.

University of Washington

1) Provision of shore-based facilities for high precision determinations of C^{14}.

University of Hawaii

1) Development of stripping systems for gases, O_2 and CO_2 for later isotopic measurements.

INTERNATIONAL COORDINATION

A number of investigators for other countries are participating directly in the GEOSECS program or are carrying out programs of a similar nature which are coordinated with the U. S. program. In the case of countries which are using their own ships for a similar program and are coordinating their efforts with ours, we have designated the program organizers as International Coordinators for that particular country and we are maintaining direct contact with them through a member of the Executive Committee. In other cases, the investigators are Collaborating Investigators participating in the U. S. program.

International Coordinators

German Federal Republic, International Coordinator, Prof. K. O. Munnich, University of Heidelberg

Professor Munnich took the F/S METEOR on a GEOSECS-type cruise in the Atlantic during the summer of 1971, studying the dissolved inorganic carbon system and measuring total CO_2, C^{13}, C^{14}, nutrients, tritium, etc. The expedition was financed by the German Research Association (DFG). Present plans are for the METEOR to make several east-west cross sections in the Atlantic during the north-south Atlantic GEOSECS expeditions. Professor Munnich has participated in both the Pacific (1969) and Atlantic (1970) GEOSECS trial sections. Contact is maintained through Dr. Broecker.

Japan, International Coordinator, Prof. Yoshio Horibe, Ocean Research Institute, University of Tokyo

Professor Horibe has just finished two sections of the Pacific (30°N, 65°S and east-west, Japan to Seattle) with the Institute's new ship Hakuho Maru with a program similar to GEOSECS. The north-south section - the "Southern Cross Expedition - report has been published. The program involves measurements of the CO_2 system parameters, use of a mass spectrometer aboard ship for dissolved gas and many other parameters. Professor Horibe and another Japanese investigator participated in the 1971 GEOSECS Pacific shakedown expedition on R/V MELVILLE (ANTIPODE). Japanese expeditions are being planned by this group for the Pacific during the GEOSECS sections there. Contact is maintained through Dr. Craig.

France, International Coordinator, Dr. Roger Chessellet, Centre des Faibles Radioactivites, Gif-sur-Yvette

Dr. Chesselet will participate in the particulate matter studies of the GEOSECS program. He also is serving as coordinator for a proposed east-west cruise of the JEAN CHARCOT which has been tentatively scheduled for late 1973 as a part of the total GEOSECS program in the Atlantic. Contact is maintained through Dr. Spencer.

Collaborating Investigators

1) Professor Devendra Lal, Tata Institute of Fundamental Research, University of Bombay, India, is collaborating on Si^{32} studies with the S. I. O. program. He is spending one quarter of each year at S. I. O., financed by the University of California. Dr. B. K. Somayajulu of the Tata Institute will be working on Si^{32}, both at S. I. O. and in Bombay. Krishna Swami of the Tata Institue is collaborating with S. I. O. on studies of Ra^{226} and Ra^{228}.

2) Professor A. Longinelli, Laboratory of Nuclear Geology, University of Pisa, Italy, is measuring O^{18}/O^{16} ratios on dissolved sulfate and phosphate in collaboration with the S. I. O. program. His work is financed by Italian NSF. He will also serve as associate chief scientist on one leg of the GEOSECS Atlantic cruise.

3) Professor W. B. Clarke, McMaster University, Hamilton, Ontario, Canada, is measuring He and Ne concentrations and He^3/He^4 ratios in dissolved He in collaboration with the S. I. O. program. Each group will analyze about half of the samples.

Attempts are now underway to organize GEOSECS type programs in Canada (C. S. Wong, P. Wangersky, W. B. Clarke, A. Walton).