GEOSECS Programme - A Review

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GEOSECS (Geochemical Ocean Section Study) is a global base line data acquisition project, involving geochemists and oceanographers from institutions in USA, Canada, France, Germany, Italy & India. This programme was instituted (Stommel, et al. 1969) at a suggestion of Prof. Henry Stommel of the Woods Hole Oceanographic Institution. He expressed the desirability to obtain coordinated physicochemical data for the oceans, to delineate the important oceanic mixing processes. Many of these processes are at present understood only qualitatively. Stommel's idea was warmly welcomed by scientists all over the world, and an ad-hoc committee, set up to study this project, recommended the following (Stommel, et al. 1969, IDOE pub. 1971):

1. The basic task of the GEOSECS programme would be the measurement of the oceanic constituents along three traverses, from the Arctic to the Antarctic. Such an analysis of the chemical constituents of the ocean water would provide data for the first time for quantitative studies of oceanic mixing, air-sea exchange etc. The most important aspect of this programme is that all these measurements would be made in the same water sample.

Fig. 1 gives the station locations of the GEOSECS Atlantic leg. The detailed plans for Pacific and Indian oceans have not yet been finalised, though a tentative mapping of the stations has been made.

2. Maximum emphasis should be given to the self consistency and accuracy of the results. (To attain consistency and highest accuracy in results, detailed sampling programmes and intercalibration studies have been carried out.)

3. GEOSECS programme should be treated as a world wide cooperative study, open to all scientists and institutions working in this field.

Why the GEOSECS Programme?

Studies of properties like salinity and temperature patterns in the oceans, coupled with theoretical work has given a very qualitative idea of the large scale processes occurring in the ocean. However detailed insight into the rate of formation of deep water, its sources, their flow patterns etc. remain ambiguous even today. In fact, the presently available knowledge on the distribution of geochemical tracers in the oceans is too haphazard and it can offer only a very crude outlook into the general oceanic circulation. Even these studies have been made using oversimplified box models.

The presence of complex advective and diffusive motion as encountered in sea, superimposed by the interactions occurring across the air-sea and sea-sediment interface, the particulate transport etc. has led to the development of "dynamic models" for oceanic circulation. In order to obtain mean-

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ingful and self consistent values for the various parameters involved in such calculations, it is necessary to have simultaneous observations on the distributions of various tracers present in sea.

The studies that are being made under the GESECS are with a view to understand the advective and diffusive parameters governing the short and long term oceanic circulations, and their vertical, horizontal and time dependent variations.

Table I lists the various stable and radioactive tracers that are being studied on board in this programme and the various techniques that are being employed (IDOE Pub. 1971). To obtain quick results, the shipboard analytical systems used are partly or completely interfaced with a computer.

In addition to the above tracers which will be analysed on board, the following constituents will be studied in the same water samples in shore based laboratories:

**Table I**

*Details of Tracers and the Techniques to be used on Board the Ship*

<table>
<thead>
<tr>
<th>Tracer</th>
<th>Nature of Tracer</th>
<th>Techniques used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salinity, Temperature</td>
<td>SC</td>
<td><em>In-situ</em> measurements using a new temperature and salinity probe developed at Woods Hole—supplemented by frequent inter-check with bottle casts.</td>
</tr>
<tr>
<td>Ar, N₂</td>
<td>&quot;</td>
<td>Gas chromatograph using an ultrasonic detector.</td>
</tr>
<tr>
<td>O₂</td>
<td>SNC</td>
<td>Carpenter-Winkler titration and an oxygen sensor.</td>
</tr>
<tr>
<td>CO₃, alkalinity</td>
<td>&quot;</td>
<td>Gas chromatograph using a thermal detector and manual alkalinity measurements employing pH meters.</td>
</tr>
<tr>
<td>Nutrients</td>
<td>&quot;</td>
<td>Using Technicon Auto Analyser System. Manual spectrophotometry will be used frequently to check system calibration.</td>
</tr>
<tr>
<td>Rn²²²</td>
<td>RC</td>
<td>Extraction using He at liquid nitrogen temperature, followed by scintillation counting.</td>
</tr>
</tbody>
</table>

* For details see reference (2)  
SC = Stable conservative  
SNC = Stable non-conservative  
RC = Radioactive conservative
He^8, He^4
C^{12}, C^{32}, O^{18}/O^{16}, Ba
Ra^{226}, Ra^{228}, C^{14}, Si^{32}
Bomb produced activities: H^3, Si^{90},
Cs^{137}, Pu^{239}/Pu^{240}
Trace Elements: Sr, Cs, Rb, Co, Ni, Sc, Cu, Sb, Zn, Fe and U

A particulate matter sampling programme for surface waters has been incorporated in order to estimate the downward flux of various stable elements and radioisotopes into deep water.

**Our Participation in GEOSECS**

**I. Large Scale Oceanic Circulation Using Si^{32}**

Until now detailed study of the large scale oceanic circulation has been restricted to C^{14}, a cosmic ray produced radioactive isotope of half life of 5730 years (Broecker 1963). The C^{14}/C^{32} ratio in sea water can be measured fairly accurately and easily by evolving CO_2 from about 200 litres of sea water. The results thus obtained on C^{14} specific activities have been used to calculate 'mummy ages' for various water masses with respect to source water and/or surface water. However, recently it has been shown that the rate of supply of C^{14} as a result of dissolution of particulate matter is very close to its depletion by radioactive decay rate (Craig 1969). Thus C^{14} addition due to 'biological' effect partly resets the 'C^{14} clock' in deep waters. This by itself does not invalidate the use of C^{14} for studying large scale mixing problems; only it requires that both C^{32} and C^{14} concentrations in the water masses should be measured with a very high precision > 0.2–0.3‰ to evaluate the advective-diffusive parameters. Additional restrictions in the use of C^{14} have been introduced due to input of bomb C^{14} into the ocean.

Two other radioisotopes which are being used for large scale oceanic circulation studies are, cosmic ray produced Si^{32} and U^{238} series nuclide, Ra^{226}. Of these two, studies using Ra^{226} is problematic since it does not have a stable isotope which could be used to estimate its 'particulate transport' to deep water.

The advantage of using Si^{32} over C^{14} lies in the fact that (i) its half life is an order of magnitude lower than that of C^{14} and (ii) there has been no appreciable bomb injection (Somayajulu et al., 1973). However it must be mentioned here that the available data on Si^{32} distribution in ocean waters is too sparse to make a critical judgement of other problems, for instance, its non-uniform injection from the atmosphere. The main drawback of using Si^{32} is its low concentration in sea water which makes its measurement tedious and time consuming. The problem of collection of Si^{32} from large volumes of sea water have become much easier with the development of the in situ trace element extraction techniques developed at TIFR. This technique is based on the preferential adsorption of chemically reactive elements on ferric hydroxide loaded acrylic fibres (Krishnaswami et al., 1972). This technique is a considerable improvement over the previous work, which used spongin matrix (Lal et al. 1963) as the supporting frame work for Fe(OH)_3. The major advantage of the fibre technique is the very low inherent contamination levels. The results
obtained so far show that for Si, the pick up capacity using Fe(OH)₃ loaded acrylic fibres is about 100 and 1000 litres/kg of fibre for deep and surface waters respectively, a result comparable to that observed for ferric hydroxide loaded spongin. We intend to use 20 kg processed fibre for each depth. It is planned to collect samples from 7 depths for each vertical profile. We expect to obtain a total of about 20 vertical profiles, 7 in Atlantic, 7–8 in Pacific and 5–6 in Indian Ocean, during the next 3–5 years of GEOSECS cruise. This programme will be carried out in collaboration with Scripps Institution of Oceanography.

2. Bottom Water Diffusion Studies

Although the usefulness of Ra²²⁸ (half life = 6.7 yrs) to study the upward diffusion of bottom water has been demonstrated (Moore 1969), until today it has been used only to a very limited extent. This is mainly because the Ra²²⁸ concentration of sea water is very low, (1–10 dpm/10³ litres) which makes its measurement tedious and time consuming.

With the advent of in situ extraction technique employing Fe(OH)₃ loaded acrylic fibres it has become possible to concentrate Ra isotopes from sea water very easily. During a six hour period of sea water flushing, a kilogram of fibre is found to concentrate Ra isotopes from about 500–1000 litres of sea water (Krishnaswami et al., 1972).

During the GEOSECS expedition, we expect to collect about 20 bottom profiles using this in situ extraction technique for the measurement of Ra²²⁸/Ra²²⁶ activity ratios. Each vertical profile will consist of about 7–8 samples collected from the bottom 1500 m of water column.

The results obtained will be used to estimate bottom water diffusion coefficients.

This programme is to be carried out in collaboration with the Scripps Institution of Oceanography and Lamont Doherty Geological Observatory.

3. Surface Water Particulate Matter Sampling

Recently the importance of oceanic suspended matter as a transport medium for various elements and radioisotopes from surface to deep water is being increasingly recognised (Craig 1969, Lal 1971, in press). The purpose of this programme is to study the concentrations and isotopic ratios of various constituents in particulate form.

The experiments will be carried out during the GEOSECS cruise between stations. Sea water will be filtered continuously through a 29 cm diameter TAMIL filter enclosed in a plexiglass frame at a rate of about 20 litres/min. The trapped materials will be analysed for C¹³, C¹⁴, Fe⁵⁵, Sr⁹⁰, Pu²³⁸, Pb¹²⁷, Th and Ra isotopes.

The analyses will be carried out at TIFR, Scripps and a few other laboratories in US.
REFERENCES


International Decade of Ocean Exploration. publication NSF 71-34 (1971).


