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Marine Industrial Technology Papers

1

INDUSTRIAL UTILIZATION OF MARINE NON-LIVING RESOURCES

UNIDO

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Industrial Development Organization

(viii), 235 p.
tables
graphs
diagrams
maps
illus.

Marine Industrial Technology Papers

1

INDUSTRIAL UTILIZATION OF MARINE NON-LIVING RESOURCES

Proceedings of
the UNIDO Workshop on
Marine Industrial Technology for
the Utilization of
Marine Non-living Resources

Madras, India
27-30 September 1993

UNIDO

United Nations
Industrial Development Organization

Published in 1996 by the
United Nations Industrial Development Organization (UNIDO)
in cooperation with the Government of India and the Indian Institute of Technology (IIT), Madras.

Printed in India.

Preface

Industrialization is often viewed as only land-based and there is not enough awareness that oceans could present an unique industrial opportunity, particularly in the light of the assignment of Exclusive Economic Zones to each country. Sustainable industrial utilization of the resources of the oceans is a major challenge for the 21st century, especially for developing countries, which in many cases lag behind in terms of technological capabilities. A number of diverse existing technologies could be harnessed into systems for this purpose. "Marine industrial technologies" is a convenient term for the combination of a variety of technologies from different scientific and technological fields to explore and exploit marine resources.

In September 1993, UNIDO in cooperation with the Government of India, arranged a Workshop on industrial utilization of marine non-living resources, aimed at increasing the awareness of the potential for developing countries in this field. This publication contains the conclusions and recommendations of the Workshop together with the papers presented.

UNIDO thanks the Government of India, Department of Ocean Development and Department of Industrial Development, for having co-sponsored the Workshop. Appreciation is also extended to the Indian Institute of Technology, Madras, and the Confederation of Indian Industry for their professional and logistic support in arranging the Workshop.

K. Venkataraman
Managing Director
Investment and Technology Promotion Division, UNIDO

Contents

REPORT
OF THE MEETING

Opening of the Meeting

The Workshop was opened by Mr. J.V.R. Prasada Rao, Joint Secretary, Department of Ocean Development, Government of India. He indicated that the Workshop was jointly organized by UNIDO and the Departments of Ocean Development and Industrial Development, Government of India.

Opening addresses were also given by Mr. Anthony Bromley, Chief, New Technology Unit, UNIDO; Prof. Elizabeth Mann Borgese of Dalhousie University and Hon. President of the International Ocean Institute (IOI); Mr. A. Sankaranarayanan, Chairman, Manufacturing Technology Sub-Group, Confederation of Indian Industry (Southern Region); and Prof. N.V.C. Swamy, Director, Indian Institute of Technology (IIT), Madras. Prof. V.S. Raju, Ocean Engineering Centre, IIT, gave the Vote of Thanks.

Prof. P. Rama Rao, Secretary, Department of Ocean Development, Government of India, gave the keynote address for the Workshop. In his address, he emphasized the timeliness of the Workshop considering that the development of technologies for exploration and exploitation of marine resources has become extremely important for both developing and developed countries. He noted that participants at the Workshop came from both developed and developing countries and included representatives from industrializing countries in Asia, Africa and Latin America (List of Participants is attached as Annex 1). He hoped that this would provide the basis for stimulating discussions on the state of the art of technologies related to seabed mining and their applicability to the exploration of near-shore and Exclusive Economic Zone (EEZ) marine non-living resources and other industrial applications.

Prof. Rama Rao reviewed India's background and current status in marine technology, highlighting the fact that India has been given the status of Pioneer Investor under the United Nations Law of the Sea Convention. He noted the growing role and importance of the industrial sector in marine technology and the fact that the Confederation of Indian Industries, an important professional body representing the engineering industries in the country, was taking part in the Workshop. He concluded by stressing the importance of the exploitation of oceanic non-living resources considering the fact that the oceans occupy three-fourths of the planet's surface and that one half of the world's population live within 60 kilometers of the sea. Therefore, the developing countries should be ready with the necessary exploration and exploitation technologies to look towards the sea for resources both in their EEZ and beyond.

Organizational matters

The Workshop elected by acclamation Mr. B.K. Rao as Chairman and Messrs. Lenoble and Ihenyen as Vice-Chairmen.

The Workshop agreed on its objectives and expected outputs as a review of the industrial and technological aspects of the development of non-living resources within the EEZs as a means of enhancing industrial and economic development in industrializing countries. It was agreed that the Workshop should be action and policy oriented, and focus on the following themes:

- Existing and future potential of marine non-living resources, with particular focus on marine hard-minerals and ocean energy; necessary conditions for development of these sectors; and future role and potential for developing countries.

- Status of currently available technologies and the need for development of new technologies; technological similarities between related marine industrial sectors, and how this could affect the technology development process.

- Environmental impacts from marine industrial activities and their possible technological and industrial implications.

- The marine sector in developing countries: what are their technological capabilities, needs and priorities.

- Incentives and mechanisms for regional and international cooperation in transfer and co-development of marine industrial technology; joint ventures; regional technology development programmes; regional centers and industrial multidisciplinary networks; the role of international agencies and strategies for funding of technology development projects.

- Recommended follow-up to the Workshop: concrete strategies and action plans for development mechanisms in the marine sector, in particular related to the three themes of the Workshop: marine hard-minerals, ocean energy and environmental impacts.

Programme of Work

The Workshop agreed on its Agenda (See Annex 2), which included a presentation of the report *"Deep Seabed Minerals, Mining and Related Technology - A Status Report"*, which was specially prepared for the workshop by a UNIDO International Expert Mission. Other technical presentations were given on deep sea minerals, ocean minerals within the EEZ, ocean energy, environmental impacts of marine exploration and exploitation, and on technology transfer and co-development. Status reports on marine resource development and related technology were provided by the invited participants from developing countries.

Parallell Working Groups on (1) Ocean Minerals, (2) Ocean Energy and (3) Environmental Impacts, were formed to discuss the topics in detail and to recommend actions according to the following issues :

- Current status and potential
- Identification of end-users and technologies
- Cooperative mechanisms for technology and human resource development

Conclusions and Recommendations

General

The Workshop noted that the provisions relating to Exclusive Economic Zones (EEZ) and deep seabed mining, contained in the United Nations Convention on the Law of the Sea (UNCLOS), provides an international framework for the management and development of marine resources.

It was further noted that Agenda 21 of the United Nations Conference on Environment and Development (UNCED) provides the guidelines for sustainable development of the oceans. The programme areas of Agenda 21 related to EEZ and coastal areas, marine environment protection, international cooperation and development of small Island states, are considered to be particularly relevant for the industrial development of marine non-living resources.

The Workshop stressed the importance of marine resources, especially for developing countries, considering that in the coming decades the ocean and its resources will represent an important source of food, minerals, energy and coastal and sea space.

The Workshop identified the lack of information on marine non-living resource availability as a major constraint for the proper functioning of the market mechanism, which is recognized as the driving force for resource development.

National policy

The Workshop noted that, at the national level, very few countries have a comprehensive policy for exploration and exploitation of marine resources other than oil and gas. The Workshop, therefore, recommended that countries, especially developing countries, should formulate and implement national policies which, *inter alia*, take into consideration the need to stimulate involvement of industry by providing financial incentives, including direct funding for resource exploration and exploitation.

The Workshop identified the principal actors as the end-users (contractors, industry), national governments, R&D organizations and funding institutions. The Workshop recommended that as part of the national policy, a mechanism should be evolved to bring the various actors together.

International cooperation

The Workshop strongly felt that international cooperation plays a fundamental role in building the foundations for an economically viable industry for development of marine resources. For this purpose, there should be an agreement at the national and international level among the governmental agencies, industries, R&D organizations and funding agencies with the objective of developing marine resources. For specific geographical areas, the Workshop recommends the establishment of cooperative R&D programmes, joint training activities, technology demonstration programmes and pilot projects.

The Workshop identified the assessment of marine non-living resources within EEZs as a priority area for international cooperation.

The Workshop recommends that international and national networks should be established or strengthened between the various actors in marine resource development, facilitating interaction and information exchange related to awareness building, technology promotion, co-development of new technologies and environmental protection.

The Workshop recognized the immediate need to identify centres of excellence at national and international levels for the purpose of :

- Promotion of marine industries and technologies
- Technology development for exploration and exploitation
- Environmental impact assessment of marine industrial technologies
- Industrialization of technologies to be financed by the industrial sector and governments
- Human resource development and training

These centres should act as focal points in formal and informal national and international networking arrangements and should, wherever possible, be built around existing institutions.

Recommendations from Working Groups

The Workshop endorsed the specific recommendations of the Working Groups on Ocean Minerals, Ocean Energy and Environmental Impacts (See Annexures 3-5).

As ocean energy is renewable and non-polluting, the Workshop recommended that the Global Environment Facility should be approached for funding of assessment studies, technology development programmes and pilot-plant projects.

Follow-up actions for UNIDO

The Workshop recommended that UNIDO should constitute an international Task Force to ensure continued efforts in the promotion of international cooperation in marine industrial technology for the development of marine resources.

The Workshop also recommended that UNIDO should initiate activities to establish networks and national/ regional focal points for information exchange and promotion of marine industry and technology, with initial focus on specific sub-sectors such as ocean energy and hard minerals.

In particular, actions should be taken, through networking arrangement and cooperation programmes, to strengthen capabilities in environmental impact assessment and to establish this as an integrated activity in the development of ocean industry and technology.

List of Participants

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Agenda

Monday - 27 September

09.00 - 09.45 REGISTRATION

10.00 - 11.15 INAUGURAL SESSION

Welcome

Mr. J.V.R. Prasada Rao
Joint Secretary
Department of Ocean Development
Government of India

Addresses by

Mr. A. Bromley
Chief, New Technology Unit, UNIDO

Prof. Elisabeth Mann Borgese
Dalhousie University and
Honorary President, International Ocean Institute

Mr. A. Sankaranarayanan
Chairman
Manufacturing Technology Sub-Group
Confederation of Indian Industries (South Region)

Keynote Address

Prof. P. Rama Rao
Secretary
Department of Ocean Development
Government of India

Presidential Address

Prof. N.V.C. Swamy
Director
Indian Institute of Technology, Madras

Vote of Thanks

Prof. V.S. Raju
Ocean Engineering Centre
Indian Institute of Technology, Madras

11.45 - 15.00 INTRODUCTION AND ORGANIZATION

Introduction to the Workshop.

Mr. L.K. Braute, Industrial Development Officer,
UNIDO

Role of Education System and Research Institutions in Marine Technology Development

Prof. N.V.C. Swamy
Director
Indian Institute of Technology, Madras

Election of Chairperson and Vice Chairpersons
Self Introduction of Delegates

15.00 - 18.00 DEEP SEABED MINERALS

Deep Seabed Minerals - Mining and Related Technologies - A Status Report

Mr. M.M.K. Sardana
Leader of UNIDO Expert Group

Seabed Mining - A source of Metals in the 21st Century

Mr. J.P. Lenoble
President of Afernod, Ifremer, France

Exploration Technology for Seabed Minerals - Indian Experience

Mr. P.S. Rao
Marine Geologist
National Institute of Oceanography,
Goa, India

Deep Seabed Mining Technology

Dr. R.C. Bishnu
Deputy Director
Central Mechanical Engineering Research Institute
Durgapur, India

Continuous Line Bucket Mining and its Adaptability for Developing Country

Dr. Y. Masuda
Advisor
Ryokuseisha Corporation, Japan

Tuesday - 28 September

09.00 - 10.50 OCEAN MINERALS WITHIN THE EEZ

Hard Minerals From the Seabed

Mr. J.P. Lenoble
President of AFERNOD
IFREMER, France

Exploration for Offshore Heavy Mineral Placers on the East and West Coasts of India

Dr. B.R.J. Rao
Deputy Director General
Marine Wing, Geological Survey of India, Mangalore, India

Processing of Seabed Minerals

Dr. P.K. Sen
Senior. Manager
Engineers India Ltd., Gurgaon, India

11.00 - 13.00 OCEAN ENERGY TECHNOLOGY

International Development on Ocean Energy

Prof. M. Ravindran
Ocean Engineering Centre
Indian Institute of Technology,
Madras, India

Recent Development in the Utilization of Wave Energy and Potential for Developing Countries

Dr. Y. Masuda
Advisor
Ryokuseisha Corp., Japan

Indian Wave Energy Programme - The 150 kW Pilot Plant - Future Plans

Prof. V.S. Raju
Ocean Engineering Centre
Indian Institute of Technology, Madras, India

Offshore Technologies in the 1990s with particular emphasis on new premises for Ocean Wave Electric Power Generation

Prof. A. Rödland
Advisor
INDONOR A/S, Norway

14.30 - 16.00 ENVIRONMENTAL IMPACTS

Environmental Impacts of Marine Resource Exploitation within the EEZs

Dr. G. Schriever
TUSCH Research Group
Germany

Environment, Technology, and Information as Factors in the U.S. Development of Ocean Minerals

Dr. M. Cruickshank
Director
Marine Minerals Technology Centre, USA

Non-Fuel Mineral Resource Evaluation in Louisiana's EEZ and Potential Environmental Impacts of Resource Exploitation

Dr. C.J. John
Director of Research
Basin Research Institute
Centre for Coastal, Energy and Environmental Resources, USA

16.20 - 18.00 THE DEVELOPMENT OF MARINE INDUSTRIES AND TECHNOLOGY

Exploitation of Polymetallic Nodules - The Role of Developing Countries

Mr. J.M. Markussen
Programme Director
Ocean Mining Programme
The Fridtjof Nansen Institute, Norway

Developing Countries and the Transfer of Ocean Mining Technology - Some Key Issues

Mr. J. Fixdal
Research Fellow
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The role of the Industries in the Development of Marine Resources - Hypothesis for the Emerging Industry in Developing Countries.

Mr. G.M. Bozzo
Director
R&D Division
Tecnomare S.p.A., Italy.

Role of Education System and Research Institutions in Marine Technology Development

Prof. N.V.C. Swamy
Director, Indian Institute of Technology, Madras

Wednesday - 29 September

09.00 - 11.00 THE DEVELOPMENT OF MARINE INDUSTRIES AND TECHNOLOGY (Cont.)

Status Reports from Developing Countries (Presentations by participants from invited countries).

Opportunities for Indian Industry in Exploitation of Marine Non-Living Resources

Mr. Darshan Singh
Managing Director
CGG, Pan India Ltd., New Delhi

Introduction to the Working Groups

Mr. A. Bromley
Chief, New Technology Unit, UNIDO

14.00 - 16.00 PARALLEL WORKING GROUPS

A. Ocean Energy

B. Ocean Minerals

C. Environmental Impacts

16.20 - 18.00 PARALLEL WORKING GROUPS (Cont.)

A. Ocean Energy

B. Ocean Minerals

C. Environmental Impacts

Thursday - 30 September

09.00 - 11.00 REPORTS FROM THE WORKING GROUPS

11.20 - 13.00 DRAFTING OF FINAL REPORTS / VISIT TO THE OCEAN ENGINEERING CENTRE AND OTHER IIT FACILITIES

14.00 - 16.30 CLOSING SESSION

Presentation of Final Report by the Drafting Committee

Adoption of Conclusion and Recommendations

Closing Address

Mr. A. Bromley
Chief, New Technology Unit, UNIDO

Report of the Working Group on Ocean Minerals

Introduction

The Working Group only considered hard minerals, defined as mineral commodities excluding oil and gas, but including aggregate, phosphate and other non-metallic minerals. Hard minerals have been found at the bottom of the world oceans and seas. Several deposits have been intensively explored and mined (aggregate, tin, gold, diamond). Others are still waiting for more favourable economic and/or technical conditions to be exploited. Developing countries as well as developed ones have participated or want to participate in the development of these resources. The necessary technologies were originally elaborated in industrial countries that have already acquired a certain experience in these domains. Developing countries require their assistance to increase their own capability for the identification and management of these resources.

Identification of end-users

The end-users in general are metal industries and governments of all countries. But the "needs" of end-users vary depending on whether the country has already spent a lot of time and money in exploration and R&D on exploitation. The exploitation of shallow-water minerals in EEZ is technologically simpler and is a reality now or will be in the near future. But the exploration of deep-sea minerals is a big challenge and the development of the necessary technology is very expensive. The commercial system for deep-sea mining is at least a decade away. Therefore, the problems associated with deep-sea mineral exploitation will have to be discussed separately.

In order to identify the needs of developing countries in the field of marine hard-mineral resources, the Working Group distinguished between the two following areas:

- the international area with deep-sea polymetallic nodules, where the present actors are Pioneer Investors, potential applicants and those that have already decided to apply for their recognition as Pioneer Investors.
- the Exclusive Economic Zone.

Ocean minerals in international territories

The Group recognized that the Pioneer Investors and potential applicants have specific needs concerning the funding of their research and development (R&D), but also for exchange of information, access to the suitable technologies and organization of joint projects in the different domains of exploration, mining and processing. However, considering that these are specific and well-identified organizations, the Group considered that it is their own responsibility to organize cooperation and joint prospects. Nevertheless, the Gròup suggested that the organization of such joint projects is highly desirable to optimize the cost of technology development.

The developing countries that are contemplating the possibility of future access to these resources could seek assistance through the framework provided by the Law of the Sea.

Ocean minerals within the exclusive economic zones

Here again the Working Group identified two groups of countries:

- The countries that, until now, have not decided to adopt a marine hard-mineral policy concerning their EEZ or even are not yet aware of the potential of their EEZ;

- The countries that have already decided upon a marine hard-mineral policy concerning their (EEZ).

(i) Countries without a marine hard-mineral policy

The Group identified the needs of the developing countries that have not yet determined a marine hard-mineral policy as a preliminary help to decide upon the formulation of such a policy.

The Group suggested that countries in the same geographical and geological environment could organize a joint preliminary assessment of the potential resources of their EEZ's from competent advising organizations. This assessment should be made on the basis of the knowledge already acquired on the geology of the adjacent land and marine areas. The Working Group recommended that this preliminary study should be funded by international organizations.

If the potential of the EEZ seems to be promising, a programme for exploration of the promising areas could be organized and funded. This exploration would normally start with the mapping and the characterization of the nature of the sea bottom. Such surveys require mobilization of sophisticated equipment and vessels and, therefore, their cost should be shared by several neighbouring countries.

In the areas expected to contain mineral resources, a survey to study the internal structure of the superficial sediment should follow. The use of digitized recording and data processing was highly recommended by the Group as particularly adapted for the determination of fine sediment structures. The next step would then be the sampling of the areas considered to have valuable minerals.

The Group recommended that personnel from the respective countries should be trained before the beginning of these operations in order to be able to actively participate in the cruises, their planning, the processing and interpretation of the data and the final report.

(ii) Countries with a marine hard-mineral policy

The Group identified the needs of the developing countries that have already established a marine hard-mineral policy as a general improvement of their capability to carry out projects for the identification and the management of the hard-mineral resources of their EEZ. These needs are basically: better training of manpower with a view to operate the equipment, to process the data and to interpret the results, to exchange information and to access new technologies.

Other recommendations

The Group suggested that regional centres of excellence should be identified among existing institutes to facilitate the exchange of information and the training of personnel. These centres should receive support from international funding agencies.

To facilitate the access to the relevant technologies, the Group recommended the creation and funding of a Centre of Qualification. This centre should provide easy access and facilities to operate in areas where the producers of equipment and technology developers could test their equipment/methods on already well-known geological structures that constitute potential mineral deposits. The Centre will be entitled to distribute labels qualifying equipment/methods for defined purposes.

The equipment and technologies concerned are for the purpose of :

- positioning of floating and submarine equipment,
- mapping the topography of the sea-bottom,
- characterization of the nature of the surface of the sea bottom,
- analysis of the internal structure of the sediment,
- sampling of the different layers of the superficial sediments,
- determination of the composition of the sediment *in situ* and in laboratory,
- identification of the minerals subjected to future mining,
- measurement of the properties of the sediment,
- identification and measurement of the physical environment,
- identification and characterization of the ecosystem,
- determination of the volume and tonnage versus quality of identified deposits,
- conception and design of dredging equipment, and
- ore processing, etc.

Report of the Working Group on Ocean Energy

Introduction

Ocean energy is a large resource. It is renewable and highly variable from region to region. The energy density is low. While commercial tidal plants have been in operation for a long time, the other forms are not yet commercial.

Several countries at the Workshop have expressed an interest in ocean energy and seem to be wanting to give it priority. Considerable R&D has been done in the field and there are many technical solutions for the principles of energy transfer.

Ocean energy plants as a multi-functional system have better economical prospects, (e.g. impact on electricity supply, desalination, coastal erosion, etc). As of today, tidal energy, wave energy and Ocean Thermal Energy Conversion (OTEC), (not listed in order of priority), are most promising, though under specific conditions other forms such as ocean current and biomass could also be attractive.

Finally, it was observed that regarding ocean energy, one important obstacle to implementation frequently seems to be that the competition in terms of conventional technology repeatedly escapes fair terms of price comparison, i.e. rarely is the cost of environmental damage to the society included when conclusions are drawn on new, alternative energy sources.

Identification of end-users

The end-users of ocean energy technology are industrial and public enterprises, such as utility companies for electricity supply. For end-products such as electricity and fresh water the end-users in broad terms are private and industrial consumers.

The scale of size for an ocean energy plant is judged to be *large* if its output is above 20 MW, *medium* if between 0.5 and 20 MW and *small* if below 0.5 MW.

As relevant sites of utilization of ocean energy, in particular wave power, one should consider communities which are isolated, but not necessarily limited to island communities, and communities where supplementary power into existing grids is of importance. Lastly, the Working Group observed that a study made for the European Community recently concluded that in a medium- to long-term perspective, 10 per cent of its energy supply was projected to come from ocean energy.

Technologies for the exploration phase

Concerning the exploration (or assessment) phase of ocean energy development there are a number of factors to be mapped, of which the following are of primary importance:

- bathymetry
- isotherms

- wave climate
- morphology
- tidal variations

Technology and methods for collecting these data are considered to be well known, however, the existing data are not sufficient. Financial priorities and constraints are considered to be the prime reason for this, however, there are also operational complexities: Local tie-in in connection with buoy measurements is mentioned as an example in order to prevent equipment loss. There is a general need for both training and technology for the interpretation of raw data in all countries where data sampling is to occur.

Technologies for the exploitation phase

(i) Tidal Energy

Regarding exploitation, technology is considered available for tidal energy. The obstacle to implementation of projects is judged to be primarily related to a combination of economics and location; i.e. those countries which might have the financial means do not give priority to tidal projects and vice versa. There is scope for further technology development on the tidal energy to achieve economies, however, this is not further specified.

(ii) Wave Energy

Wave energy plants are already commercially available in the very small end of the product range in terms of KW-output. Several demonstration plants in the market segment defined as "small" have been built and have operated for periods of varying lengths. Commercial plants have been planned and are offered in the market place. It is expected that such plants may be operational within 3 years. The technology has been refined to a level of approximately 30 per cent efficiency, and there does not seem to be much more to gain on efficiency improvements in the foreseeable future. On the other hand, reduction in the cost of construction is necessary and also judged to be feasible and should be the main area for concentration of efforts in order to make wave power economical and viable at a commercial scale.

(iii) OTEC

Regarding OTEC, a few demonstration plants have been built and considerable R&D in relation to subsystems is being done. One important area is improved technology for cold-water pipes. As far as the Group knows, no commercial plant has been finalized yet, and technology may therefore be characterized to be on a pilot stage. The Group observed that the final economic viability of these plants will depend entirely on a multi-function return, such as fresh water production and mariculture applications.

Need for development of cooperative mechanisms

In the Agenda, the question was raised whether there was a need for cooperative mechanisms in the field of ocean energy (technology and human resource development), and the Group responded briefly and was affirmative. The reasons are apparent from the discussions and conclusions above and below.

Mechanisms of cooperation

Pre-commercial stage

Regarding the pre-commercial stage of events, or the exploration/assessment stage, as it may be called, the Group considered that there was a vital role to be played by UNIDO. This role may be described in terms of general improvement in the market awareness and assessment of ocean energy, i.e. exchange of information, facilitation of viability studies and surveys, promotion of pilot and commercial applications of ocean energy technology, sensitization of decision makers, motivation and bringing people together, and improvement of local capabilities through training and joint technology development projects, all prior to commercial stages.

Specifically, the Group emphasized the task for UNIDO, if requested by member countries, to create a *network* of relevant actors in the field of ocean energy and lead such a network into joint efforts in the preparatory stage and as a body of assistance to countries contemplating ocean energy as outlined above. This may include the establishment of national teams, that could finally involve research institutes, governmental agencies, industrial enterprises and financial institutions, and with support by a small international team, acting as a linkage to funding sources and technology holders world-wide. An important objective is to promote R&D based on the needs of the end-users. A mechanism for this could be developed in line with the conceptual models of the European EUREKA programme and the Latin American BOLIVAR programme.

Exploitation

The Group recognized that for the exploitation stage, initiatives for specific projects in the various countries would be in the hands of the countries concerned, however, the network then should be there and operational, for them to make use of it at their option as they pursue the project development. The network could be an important mechanism for promoting incentives and identifying partners for possible joint-venture projects, which could be established as off-springs from the networking activities.

Further actions

In order to move this process a step further, the Group expressed the recommendation that UNIDO, immediately upon closure of the Workshop, should commence work on the establishment of the Indian Ocean as a pilot region, with the aim of bringing together all interested countries in the region with the technology-holders among the developed countries in order to begin implementing the intentions and mechanisms expressed above.

Report of the Working Group on Environmental Impacts

Introduction

The search for new sources of raw materials within and outside the EEZs will inevitably have an impact on the region. Within shallow coastal waters, commercial activities such as mining, dumping or dredging sand and gravel can result in the total destruction of flora and fauna, creation of anoxic conditions, turbidity and sediment plumes, increasing coastal erosion, change of bottom currents and wave patterns, accumulation of radioactive minerals in the sediment and water column and change of conditions in the water column, resulting in drastic alterations of the food chain and lower fish recruitment and production. Sediment plumes may be transported by currents to the neighbour's front garden causing conflict situations. The set up of power plants and/or industry and their hotwater and tailing discharge would influence the water chemistry and have an impact on the benthic community.

After the exploration of new resources and the notification of possible exploitation, the following questions will have to be raised:

- what kind of impacts can be expected?
- which impacts are avoidable?
- how can we minimize these impacts?

Under the following three headlines, recommendations and requirements for further activities arising from mutual discussions within the Working Group were expressed.

Identification of end-users, needs and technologies

Before any commercial mining activity is initiated, the consortia should provide a comprehensive baseline study on existing environmental conditions and should send an application for mining permission or building license to the governmental agency concerned. With reference to ocean energy exploitation, environmental impacts of ocean wave plants have been considered negligible, and as far as the Group knows, no impact studies have been undertaken. However, in selecting sites for such plants one should consider environmental issues such as ecologically sensitive areas.

The baseline study should contain the following information:

- physical, hydro and geochemical parameters, including temperature, oxygen, salinity, currents and nutrient data;
- biological parameters, including faunal and floral composition of the water column and the sediment, biomass and identified key species;
- additional meteorological data (wind speed and direction, rainfall, etc.).

The baseline data have to be collected for at least a period of one year, at two-week sampling intervals. Critical habitats like mangroves, coral reefs or rocky shores close to the exploitation site should be identified.

During the baseline study, interaction between industry and the environmental agency is requested. Specific interest should be on available technology and new technologies should be used, where available, to reduce environmental impacts. Small- and large-scale experiments *in situ* or by computer modelling should be conducted during the baseline data collection and these will help to assess the expected impacts. From these results and the following discussions, industry can react by developing and producing appropriate equipment, e.g. for environmental "soft ocean mining".

The development of new techniques should be used to monitor the pre-pilot and pilot mining operations on small- and large-scale level to gain the maximum possible amount of information on their environmental impacts.

For standardization of methods and to gain comparable results, all investigations should be conducted with the following general set of equipment:

Physical-, hydro- and geochemical parameters:

- CTD with rosette sampler
- current meter chains
- equipment for evaluating nutrients
- multiple corer for undisturbed sediment samples

Biological parameters :

- USNEL box corer for macro-fauna analyses
- multiple corer for meio-fauna(?) and biochemical parameters
- multiple plankton net

The Group recommended that no exploitation permission should be granted before the applicant has submitted a full set of requested baseline data.

These data are the basis for a subsequently required monitoring programme of the commercial activities and should be open for everyone interested. To save time and reduce costs, the collected data may be used as baseline data for similar industrial activities in regionally close areas.

The Working Group pointed out that some of the information needed for the baseline study may be provided by nationally funded programmes, but underlined that today, environmental studies are an integral part of all industrial and technology development projects and that funding of such studies should be a standard part of their financial calculations.

Need for development of cooperative mechanisms

The necessity of cooperative and partnership research between developed and developing countries in the context of commercial activities and their risk assessment within the EEZs and the deep sea is recognized and acknowledged. Bi- and multilateral data collection should be carried out. Information and data transfer should be provided both on computerized level or in the form of hard copies, according to available access.

It was highly recommended to establish a local group of experts of environmental science, industry and government for discussion of the actual enterprise and problems arising for the benefit of all sides as soon as commercial activities are planned or initiated within the EEZ.

For activities in the deep sea and within the EEZs, which might have an impact on border country areas, the establishment of an international group of experts from academia, industry and government is requested of bi-national or international membership and the auspices of the UN or one of its organisations.

Mechanisms of cooperation

The establishment of joint ventures for risk assessment studies between developed and developing countries is highly recommended. As part of the joint venture activities and in addition to this, training programmes for scientists and especially technical staff are recommended. The creation of centres of excellence around institutions and capabilities of research and manpower training should be initiated in different regions. To establish and to run these centres, support and funds are requested from both the UN and developed countries.

Pilot projects should be conducted in different regional areas where several countries may benefit from the results. The establishment of an internationally accessible network through information exchange and/or computer network systems is absolutely necessary and highly recommended.

Most of the deep water investigations inside and outside the EEZs have to be conducted outside the capability of the working range of the research vessels of the developing countries. Therefore, the charter costs can be shared during multi-national cruises and the results gained will be of benefit to all participating nations.

All the above recommendations and comments are a first outline of the requirements and concerns of the environmental experts on the industrial activities within the EEZs. A brief evaluation and risk assessment can only be done when the preliminary industrial design of the Enterprise is known. One may miss suggestions or requirements for work in the deep sea. However, most of the requested investigations for the EEZs are transferable to deep-sea areas. These are dealt with under the jurisdiction of the UN Convention of the Law of the Sea and not especially treated here. The Group believed that those parts of the UN Law of the Sea dealing with environmental impacts should be open for additions based on newly gained results of ongoing environmental research in the deep sea.

A multi-disciplinary steering group should be involved in setting up additional regulations for the processing of minerals either within the EEZ or at land-based processing plants.

It is not the aim of the Group to refuse any commercial activity within the EEZ although the results of the requested impact studies may lead to the unacceptability of some enterprises. The prime target is to reach a mutual understanding and to discuss the problems related to these activities in order to minimize probable impacts at a very early stage for the benefit of the environment.

SPECIAL ADDRESSES

Opening Address

Prof. Elisabeth Mann Borgese
Dalhousie University and
Honorary President, International Ocean Institute, Halifax, Canada.

This is a most opportune moment to take a good look at the state of the art of deep-sea mining technology and its wider applicability and usefulness. The United Nations Convention on the Law of the Sea is about to come into force, and as we all know, this Convention provides a regime for deep-seabed mining, including numerous provisions about technology and technology transfer. I would like to discuss briefly this regime, the difficulties we have been encountering, and some prospects for the future.

Before doing this, however, I would like to make three points:

First of all, most of you are technologists; I am not. I am a political scientist, and if I say some things which strike you as obvious, or as wrong, please forebear with me. I shall be grateful if you will correct any errors I may commit, so that I can learn from you.

My second point concerns the importance of technology to contemporary economic life. This importance is twofold.

On the one hand, it is indeed noteworthy that economic growth today is based 80 to 85 percent, not on new inputs, material or financial, but on technological innovation, depending on research and development. The R&D division within each industrial enterprise, and within the national and global economy as a whole, has grown beyond what would have been imaginable 30 or 50 years ago. This is part of what today is called the Service Economy, meaning by this not the "tertiary sector" (banking; invisible trade; education, etc.), but the dominant role Service plays today in every enterprise in the so-called primary and secondary sectors. This all-pervasive service sector accounts today for 60 or even 80 percent of GDP, with many implications to which I shall return later.

On the other hand, technology is fundamentally important to our effort to make economic development environmentally and socially sustainable. This effort, again, could be examined under two headings: First, the development of technologies to abate pollution; to clean up oil spills, etc., and second, the development of environment friendly technologies which do not pollute in the first place, so that there is no need to clean up after them. Energy efficiency technologies, reducing the emission of green-house gases, are a good example. Obviously, the second category of technologies is, in the long term, far more important than the first. Sea bed mining technology should be developed so as to minimize its negative impact on the marine environment. What is equally important is that this environment friendly technology must be shared: it must be "transferred" to poor countries to enable them to make economic development environmentally and socially sustainable. The Brundtland Report, and all the documents adopted by the United Nations Conference on Environment and Development make this abundantly clear.

My third point, really connected with the second point concerns the very nature of contemporary high technology, which is qualitatively different from traditional technology.

If I may be allowed to over-simplify a bit: traditional technology was hardware oriented and capital intensive. You could take it, like a piece of hardware and, literally "transfer it". You could buy and sell it, with a turn-key. The "transfer" was a one-time, self-contained action. Contemporary high technology is soft-ware oriented people oriented. It is information-based, knowledge-based. You cannot buy it: You have to learn it "Transfer" can be effected only through the establishment of an ongoing contractual relationship, involving training, service, maintenance and repair, and updating, upgrading: the development of the next generation of the technology in question. As one expert put it, each transfer of technology today is really a joint venture. It requires, above all, the development of human resources.

Both its information - and knowledge base, and the joint-venture aspects of technology transfer, will make it necessary to rethink the traditional concepts of "patent" and "intellectual property." They are changing, as everything changes in this era of dramatic change.

All this, I think, is quite relevant for the future of seabed mining technology.

Let us now turn, quite briefly, to the Law of the Sea Convention and "the New International Technological Order" it might generate. There is no time to go into the details. I merely want to stress that the Convention explicitly states that the International Seabed Authority shall take measures to acquire technology and scientific knowledge relating to seabed mining in the international area; and that it is to promote and encourage the transfer to developing States of such technology and scientific knowledge so that all States Parties benefit therefrom. The articles on technology transfer have been discussed for a very long time, and are being discussed again now. They are among the most controversial Articles of the Convention, and one of the reasons for which industrialized States have been reluctant to ratify the Convention.

During the last ten years, the situation has radically changed.

The Convention had been conceived and written under the assumption, among others, that seabed mining would be a going, commercial concern by the time the Convention would come into force.

The Convention is about to come into force now: the last three missing ratifications are already assured and will be deposited during the next few weeks, certainly before the recess of the General Assembly. But due to the general economic situation as well as to uncertainties about the environmental impact of seabed mining, commercial mining has receded into the next century. There is no doubt that we will be faced with an interim period, which will last from the time the Convention comes into force to the time when commercial mining is about to begin.

The International Ocean Institute has done a great deal of work on the policy options for this interim period. In full support of the developing countries we have totally rejected the option of renegotiating Part XI of the Convention today. What we have proposed is quite simple and I am convinced it is the only solution on which we can have universal agreement now: It is to extend the mandate of the Preparatory Commission and the Pioneer Regime for the interim period; to authorize the Prepcom to exercise all the initial functions of the Authority and the Enterprise in an evolutionary manner. These functions, at this time are: Exploration, and the Prepcom has already adopted an excellent programme for joint Pioneer undertaking to explore a first mine site for the future Enterprise: training and development of human resources, and the Prepcom has already adopted an excellent training programme, which is being carried out by the Pioneer Investors, and supplemented by some other efforts, e.g., a programme for managers and project planners, which is being carried out by the IOI in cooperation with COMRA, the Chinese Pioneer Investor, and the IIT. The third major function should be the acquisition, or joint development of technology. The testing and upgrading of technology is always done in connection with exploration and training. Finally, we propose that a Review Conference should be called when commercial mining is about to begin, or fifteen years after the coming into force of the Convention.

All this is quite relevant for the future of Seabed mining technology.

The German ocean mining firm THETIS, which has made an in-depth study on the environmental impact of mining technologies, has come forward with another extremely interesting proposal: This is for a five-year joint venture which could best be carried out in the context of the existing joint Pioneer exploration programme,on assessing the environmental impact of the technologies now in use, and R&D for the upgrading of these technologies in accordance with the results of the environment impact assessment. This, it seems to me, would be a first-rate, highly useful and practical agenda for the joint Pioneer Undertaking during the interim period. It would be a confidence building measure. It would truly internationalise deep seabed mining technology development, with the full participation of developing countries; and it would prepare the efficient operation of the Enterprise, when the time comes.

The Convention has other articles which affect the development of marine industrial technologies for the exploration and exploitation of nonliving resources, including energy.

I only want to mention two; Articles 276 and 277, mandating the establishment of regional centres for the advancement, of marine science and technology. Here again, the International Ocean Institute has done some spade work, this time, in cooperation with UNIDO and UNEP, in the Mediterranean as well as in the Caribbean. Considering the very nature of contemporary high technology — coming back to my introductory remarks — the importance of Research and Development and the associated costs and risks, we came to the conclusion that what is needed is more than "Centres" in the traditional sense. It is "systems" with focal points within each country of the region. We carefully looked at the performance of such systems in Europe, in particular EUREKA with its subsystem EUROMAR, devoted to marine technologies, and we suggested that these could be adapted for introduction in other regions, opening them up to the full participation of developing countries. These systems promote international joint ventures in research and development in determined High Technologies, to be funded by Governments, participating private or public sector enterprises, and international funding agencies. This creates a tremendous synergism. The "systems" are decentralized, flexible, and cost-effective, they do not entail the establish-ment of big, new bureaucracies, because they build on existing institutions, and they enable developing countries fully to participate. On the request by the Government of Malta, UNIDO and UNEP, the IOI published a full blown feasibility study for such a system in the Mediterranean.

From UNIDO, the idea was picked up by the Government of Venezuela. Venezuela adapted the system to the requirements of Latin America and the Caribbean under the name "Project Bolivar." In spite of the political difficulties encountered within Venezuela, Project Bolivar is active and expanding. A marine sector, in analogy to EUROMAR we call it Technocaribe — is yet to be established.

We were happy indeed to hear about the interest of the Government of India in launching a Regional Centre, as a focal point of a regional system for the advancement of marine science and technology in the Indian Ocean. I think we should study the application of the same basic principles of operation and funding that we came up with for the Mediterranean and the Caribbean — needless to say, with the necessary regional and local adaptations. With the Law of the Sea Convention coming into force it is indeed timely to think about the most effective ways of implementing Articles 276 and 277 by creating new forms of joint technology development for the 21st century.

Keynote Address

Prof. P. Rama Rao
Secretary
Department of Ocean Development, New Delhi, India.

1. It gives me great pleasure to attend this Workshop on 'Marine Industrial Technology for the Development of Marine Non-Living Resources and its Industrial Applications' in this historic city of Madras. I must thank the UNIDO for choosing India and the city of Madras as the venue for holding this important Workshop particularly at a time when the development of technologies for exploration and exploitation of marine resources has become extremely important for countries both developed and developing, the world over. The presence of representatives from the developed countries and from developing countries of Asia, Africa and Latin America in this Workshop would facilitate a stimulating discussion on the assessment of the state of the art of technologies related to seabed mining and their applicability to the exploitation of near-shore and Exclusive Economic Zone marine non-living resources and other industrial applications.

2. The United Nations Convention on the Law of the Sea adopted on 30th April 1982 has established a new international order for the oceans. The economic jurisdiction of coastal states was extended to an area ranging from 200 to 350 miles from the coastline. As on January 15, 1993, 87 States proclaimed the Exclusive Economic Zones and 19 States fisheries zones ranging from 12 miles to 200 miles. The coastal States under the Convention have sovereign rights over all the resources to be found in this Zone and with regard to other activities for the economic exploitation and exploration of the ocean such as production of energy from the water, currents and winds. The other rights that the coastal States possess include the jurisdiction with regard to establishment and use of artificial islands, installation and structures; marine scientific research; and the protection and preservation of marine environment.

3. The non-living resources available for mankind in the seafloor include apart from the hydrocarbons, deep sea minerals, placer deposits and metalliferrous sand. Energy from ocean waves, tides and currents and Ocean Thermal Energy Conversion (OTEC) are possible sources of energy from the ocean. Exploration and exploitation of all these resources involve development of complex technologies and large capital investments. Land based technologies for exploitation of resources cannot have a parallel application and involve very complex innovations and modifications for ultimate application in marine environment. It, therefore, becomes more and more difficult for developing countries to develop these technologies indigenously. It should be necessary to identify the current status of technology for exploitation of marine non-living resources in developed countries and to assess to what extent the existing technologies can compliment technologies needed for developing non-living resources inside the Exclusive Economic Zones of developing countries.

4. India's position in this scenario is unique. We have an impressive record of development of marine industrial technologies both with regard to exploitation of non-living resources inside the Exclusive Economic Zone and also for deep seabed mining. In 1982, the Government of India had issued the Ocean Policy Statement in which control, management and utilization of the internal resources available in the Sea and development of appropriate technologies to

harness these resources have been emphasized. The main thrust of the Policy is for exploitation of non-living resources such as hydrocarbons, placer deposits, renewable sources of ocean energy and collection and processing of polymetallic nodules from the deep sea.

5. India's coastline extends over 7,500 kms. which is the seventh largest coastline in the world. It has an Exclusive Economic Zone of 2.02 million sq.kms. which is also the seventh largest in the world. The Maritime Zones Act, 1976, established the Exclusive Economic Zone of India to the limit of 200 nautical miles from the baseline for the purpose of exploration, exploitation and conservation of the resources of this area.

6. In August 1987, India became the first country in the world to be allotted 150,000 sq.km. of area in the Central Indian Ocean for exploration and exploitation of polymetallic nodules and was given the status of a Pioneer Investor under the Law of the Sea Convention. This status was given based on the pioneer work of exploration done by India in the Central Indian Ocean with the help of exploration technologies developed in the National Institute of Oceanography, Goa.

7. After allotment of the mine site, India launched a comprehensive programme for exploration of the mine site and to develop necessary technologies for mining of nodules from 5000 m. down on the ocean floor and for extraction of metals like manganese, copper, cobalt and nickel. The country has already invested above 650 million rupees on developing necessary technologies for exploration and exploitation of nodule potential, estimated to be about 380 million tonnes, which would eventually give 73 million tonnes of manganese, 3.2 million tonnes of nickel, 3 million tonnes of copper and 0.5 million tonnes of cobalt. At present, we import 60% of our total demand of copper and nearly the entire demand of cobalt and nickel by spending precious foreign exchange. Our commitment for ultimate extraction of these three metals from the polymetallic nodules in the Central Indian Ocean is, therefore, based on economic considerations.

8. Before dwelling further on the manganese nodules programme, let me briefly mention the other relevant technologies developed recently for exploitation of marine non-living resources in the Exclusive Economic Zone. The Geological Survey of India, through systematic survey and exploration have located placer deposits along the Indian coast which consists of important minerals like ilmenite, rutile, zircon and monozite. Lime deposits and calcarious sediments were also located both on the East and West coast of the country. There are ferro-manganese encrustations in the Andaman and Lakshadweep group of islands at a water depth of 1,500 m. which have good potential for exploitation. The ships of Geological Survey of India and the Department of Ocean Development are equipped with state of the art equipment for exploration of the seabed. We have now taken up a comprehensive programme for selective exploitation of these resources with the help of technologies which are a spin off of the deep seabed mining programme.

9. In the field of ocean energy, India made an impressive technological break-through by setting up a wave power plant on the West coast of the country for generation of electricity from sea waves. The plant which is based on the principle of Oscillating Water Column has a capacity to generate 150 kw of power and is regarded as the biggest experimental plant in the entire world. There are only two functioning wave energy plants elsewhere in Japan and UK. Based on experience with operating this plant, all aspects of the system will be upgraded for a possible commercial operation. The Ocean Engineering Group in the IIT, Madras, has pioneered this activity. There are areas on the West coast of the country where enormous potential exists for the exploitation of tidal energy and efforts are underway in the country to develop technologies in this sphere as well.

10. In the field of marine chemicals, the Central Salt and Marine Chemicals Research Institute (CSMCRI), Bhavnagar, had developed a technology for extraction of potassium chloride from sea water which is an important industrial raw material. This technology is in the process of being upgraded to industrial scale and transferred to potential manufacturers. Availability of potable drinking water is a chronic problem in some of the coastal villages in the peninsular region of the country. CSMCRI has a cooperative programme with BHEL for developing desalination systems.

11. Coming back to deep seabed mining, the technologies under development are basically for three purposes:

    1. Exploration technologies for survey and mapping of the Exclusive Economic Zone and the pioneer area in the Central Indian Ocean;

    2. Technologies for collection of nodules and delivery systems for transportation of nodules to a surface ship; and

    3. Metallurgical processes for conversion of the nodules into metallic grade, manganese, copper, cobalt and nickel.

12. National Institute of Oceanography, Goa, has developed expertise within the Institute for survey and exploration work and have successfully completed survey of the mine site in the Central Indian Ocean. The ships of the Geological Survey of India have mapped more than 60% of the two million sq.km. of area in the Exclusive Economic Zone. India has also conducted survey of EEZs for the Caribbean countries and the Indian Ocean countries of Mauritius and Seychelles.

13. The technology development programme for mining and transportation of nodules was entrusted to the Central Mechanical Engineering Research Institute, Durgapur, in eastern India. The first phase of the project is aimed at designing a sea-going collector unit and hydraulic and airlifting systems for delivery of nodules, development of a remotely operated vehicle for pipeline inspection and electrical power transmission and fibre-optic data communication system for underwater operations. Even though technology development is intended for eventual use in seabed mining there are a number of spin off benefits of these technologies for exploration of minerals within the Exclusive Economic Zone. Investigation of deep seabed sediment properties for studying the environmental impact has also been planned under this programme.

14. The extraction process for recovery of metals from the nodule are under development at the National Metallurgical Laboratory, Jamshedpur, and Regional Research Laboratory, Bhubaneswar. After identifying 15 process routes at the initial stage, the two routes namely, Roast Reduction Ammoniacal Leaching and Ammonia Sulphur Dioxide Leaching processes were adopted at these two laboratories. The processes are under test in pilot plants set up to establish optimum rate of recovery and material and energy balance. Efforts on process development need to continue for some more time before scaling up to semi commercial stage is taken up. Some of these technologies may, however, be useful for land-based nickel and cobalt producers also.

15. The economic viability of the deep seabed polymetallic nodules programme is causing concern for all countries who are engaged in technology development in this field. In January 1986, Australia conducted a study on the economic viability of deep seabed mining of polymetallic nodules which was followed by a French study by IFREMER in May 1989. A comparative study of both these reports was presented by the Chairman's Advisory Group on Assumptions in Special Commission II of the Preparatory Commission for the Law of the Sea and it generally recognized that deep seabed mining at least at the present level of knowledge and technology is relatively a high risk activity as it will be employing leading edge technology requiring

considerable capital investment. It is estimated by experts that at least a high rate of 20% return would be required to make the project economically viable. Only future development of technology or a sharp increase in the world metal prices can lead to a reduction of this high rate of return requirement. It is, therefore, essential that the technologies under development in various countries involved in deep seabed mining should find intermediate users within the country and outside. It is also being increasingly realised that no country on its own would be able to commit resources to the required extent for development of a fulfledged mining system at the current state of economic viability. The need to have collaborative mechanisms among pioneer investors and also with other developed and developing countries need, therefore, hardly be over-emphasized.

16. India's recent thrust in liberalization of its economy is now well-known. In 1991, major changes were effected in the industrial and trade policies of the Government which involve abolition of licensing system for all projects except for a few related to security and strategic areas. Foreign investment to the extent of 51% equity is allowed in priority industries including mineral processing industries. Clearance would be available if foreign equity covers the exchange requirement for imported capital goods. Even existing companies with foreign equity can enhance the equity share to 51% for major expansion needs.

17. The National Mineral Policy announced this year by the Government lays stress on development of integrated systems for exploration and exploitation, mining and processing of minerals both in the EEZ and in the deep seabed with the development of necessary technologies. Under the new Policy, induction of foreign technology and foreign participation in exploration and mining for high value and scarce minerals shall be pursued. Foreign equity investment in joint ventures in mining promoted by Indian companies would be encouraged. Enhanced equity holding can also be considered on a case to case basis.

18. The draft of the new technology policy which is now under discussion in various fora identifies the emerging and as yet unexploited resources like the oceans as an important area. By 2000 AD the share of industry in total R&D expenditure is sought to be raised and laboratory-industry partnership emphasized. With these measures of liberalization and other initiatives, India can now enter into two types of collaborative agreements, one for making available its technologies to the developing countries and another for seeking state of the art technologies from the developed countries. I hope this Workshop would afford an opportunity to interact with the countries from both the developed and developing world for this purpose. The Confederation of Indian Industry, which is an important professional body representing the engineering industries in the country, is taking part in this Workshop. I hope their representatives would be able to interact intensely with the participants and make them aware of the various advances made in the field of marine industrial technology in the country for developing cooperative mechanisms with other participating countries.

19. Development of a practical training programme in the context of cooperation among developing countries and between developed and developing countries is one of the objectives of the Workshop. I can say with confidence that India would be able to offer excellent facilities for training of manpower in its various R&D institutes and academic centres specialising in ocean sciences and technologies. Institutions like the National Institute of Oceanography, Goa, IIT, Madras, CSMCRI, Bhavnagar and a number of other institutions under the Council of Scientific and Industrial Research provide excellent facilities for manpower development. These institutes already participate in various collaborative programmes for capacity building in the developing world. As one of the obligations as a Pioneer Investor, India has offered to the Preparatory Commission for the Law of the Sea Convention a comprehensive

training programme to developing countries in three disciplines and the training programme will commence from October 1993 for a period of ten months.

Recognising the capabilities existing in IIT, Madras, the International Ocean Institute, Malta, a premier Non-Governmental Organisation, has recently set up a regional operational centre in IIT, Madras, for imparting specialised training in various ocean related matters to middle level civil servants, technologists and policy-makers from developing countries. In short, we have an enormous capacity within the country for offering training to scientific and technical manpower from developing countries and are ready to enter into collaborative agreements for this purpose. The UNIDO, an UN agency dedicated to technology development would, I hope, come forward to institutionalise this interaction to catalyse a fast emerging cooperative mechanism.

20. The Ocean Engineering Centre of IIT, Madras, figures prominently in the several initiatives referred to above. Recognising the existence of the excellent programmes in IIT, Madras, the Department of Ocean Development has recently established a National Institute of Ocean Technology in the premises of the IIT, Madras, for mission oriented technology development in specified fields like ocean energy, seabed mining, development of marine instruments and for developing necessary technologies in the fast emerging field of Integrated Coastal Zone Management. This is expected, in due course of time, to emerge as a premier centre for development of exploitation technologies in the ocean sector of the East Coast to complement the National Institute of Oceanography, Goa, which is India's premier institution for development of exploration technologies on the West Coast of the country as well as various scientific projects related to oceanography and ocean sciences.

21. Before I conclude, I wish to emphasize that deep seabed mining, though regarded as a leading edge technology and a high risk activity, has to evolve to cater to the needs of the developing world in the 21st Century. With Oceans occupying three-fourths of the planetary surface and with half of the human population living within 60 km. of the coast, exploitation of oceanic non-living resources is a matter of time. The developing countries should be ready with the necessary exploration and exploitation technologies to look towards the sea for resources both in their EEZ and beyond in times to come. Resolution 2749 of December 17, 1970 of the General Assembly declares that the area of the seabed and the ocean floor and the sub-soil thereof beyond the limits of national jurisdiction as well as its resources are a common heritage of mankind, the exploration and exploitation of which shall be carried out for the benefit of mankind as a whole irrespective of the geographical location of States. Let us hope we shall be able to realise this dream as the world marches into the next Century.

Thank you.

DEEP SEABED MINERALS

Deep Seabed Minerals - Mining and Related Technologies A Status Report*

M. M. K. Sardana
Leader UNIDO Group of Experts
Adviser (Industry) Calcutta, Govt. of West Bengal, India.

The Mission

As a prelude to the workshop on

"Marine Industrial Technology for the Development of Marine Non-living Resources and its Industrial Application"

Objectives

The Mission was required

- To prepare a state-of-the-art report on seabed mining and related technologies.
- To develop a Mechanism/Institutional framework for facilitating transfer of appropriate technology from developed countries to intermediately developed countries and not so developed countries technologically on remunerative returns.
- Bring out environmental concerns.

Members of the Mission

- Shri M.M.K. Sardana, former Joint Secretary Department of Ocean Development, Government of India.
- Dr. A. Gopala Krishnan, former Director, Central Mechanical Engineering Research Institute, Durgapur.
- Dr. P.K. Sen, Asst. General Manager, Engineers India Limited.
- Shri Rahul Sharma, Scientist, National Institute of Oceanography, Goa.
- Shri N.N. Prasad, Deputy Secretary, Department of Industrial Development, Government of India.
- Dr. Jan Magne Markussen of Nansen Institute, Norway, accompanied the Mission as representative of UNIDO.

Places Visited

Visit of the Mission to Germany, Finland, Norway, France, USA and Japan

Germany

- Thetis Technologie, Hanover
- Institute of Automotive Engineering
- Institute of Fluid Mechanics & Computer Application in Civil Engineering University of Hanover
- Geological Survey of Germany
- Centre for Marine Climate & Research Institute for Hydrobiology, University of Hamburg

* Presentation made on the report prepared by the UNIDO Group of Experts on Deep Seabed Minerals Mining and Related Technologies - A Status Report

Finland

- Rauma Repola Oceanics

Norway

- Simrad Subsea
- Simrad Albatross Geoteam
- Oceanor
- Seatex
- Marinetek
- Sintef Group
- Elkem Technology
- Klaveness Chartering and Barlinghaug
- Frank Mohn R&D Cent
- Aker Engg.
- Okland
- Nansen Institute

France

- Ifremer

USA

- Marine Minerals Technology Centre
- School of Ocean & Earth Science & Technology
- Department of Oceanography
- Hawaii Natural Energy Institute
- Hawaii Under Sea Research Laboratory
- National Energy Laboratory

Japan

- MITI
- Technology Research Associate of Manganese Nodules
- Mining Systems
- Metal Mining Agency of Japan
- Sumitomo Heavy Industries.

Polymetallic Nodules

Important as Metal Resources of Future

	Quantity (MMT)	Distribution Ocean (%)	Land (%)
Nickel	290	83.8	16.2
Copper	230	31.0	69.0
Cobalt	60	95.2	4.8
Manganese	6330	56.4	43.6

- Beyond National Jurisdictions of Territorial Waters
- New Legal Frameworks
- United Nations Convention on the Law of the Sea

Activities of R&D Groups

Development of Appropriate Technologies for

- Survey and Exploration Techniques
- Technology for mining of nodules/Transportation
- Environmental Impacts
- Processing Techniques

More than US$ 700 million spent

- No commercial mining in near future
- All activities include new fields of research
- Since 1985 new activities to explore other deep sea mineral occurrences (Cobalt Rich Crusts)

Possible Reasons for Delay

- Economic
- Technological
- Environmental
- Political

Economic Considerations

"Worst Case" Evaluation of mining ventures (unrealistic long term price)

For metals being considered, adequate land resources for immediate future (15-20 years)

Vigorous development if

- Supply disruptions occur
- Onland mining costs exceed deep sea mining costs.[1]
- Regional demand growth in unforeseen manner.

Technical Factors

- Significant changes in economics may result from technical changes
- Such changes to be discussed by other speakers.

Environmental Issues

- Impacts studied systematically by U.S. National Oceanic and Atmospheric Administration (Domes Programme - 1975 to 1980)
- Resuspension of sediments for nodule mining (Not important for crusts)
- Benthic biota destruction
- Bottom benthic plume
- Surface/near surface plume of sediments and particles.

  (Post Domes research - rapid dilution and dissipation of surface plume)
- Thermal shock to plankton and fish larvae in immediate vicinity of cold water discharge.

Political Issues

Decline of industry interest (Late 1970/Early 1980)

Larger role of Government support

- Deep sea mining research
- Marine environmental research for impact assessment
- Monitoring and enforcing environmental compliance
- Assess economic impact of environmental legislation

Future Work Directions and Conclusions

Technological Research Areas

- Efficient Sea floor collector (Reducing down time, manoeuvrability. Dynamic positioning)
- Reduction of size of mining system (Composite pipe materials)
- Semi-Submersible platforms (Handling subset mining system)
- Micro computers/Fibre optics
- Robotics/Artificial Intelligence
- Increased process efficiency
- In-situ processing possibilities
- Selective mining of high grade nodules

Economic Factors

- Proposed mining rates marginal. Increased economies of scale desired.

Environmental Factors

- Present studies on biota/impact of biota insufficient
- Impact of surface plume minimal
- Environmental base line studies to be undertaken
- Other issues (disposal of processed wastes)

Minimising R&D Costs (Policy Perspectives)

- Self sustaining R&D (can sub-systems be developed which yield returns)
- Industry/R&D co-operation for use of intermediate results

- International co-operation for pooling of experience
- Economic jurisdiction over vast area for developing countries. Need to be exploited
- Develop suitable technology for the above purpose

Role of UNIDO in Fostering Co-operation.
Framework of International Co-operation
Objectives

- Developing a mechanism under which developed nations help developing nations in ocean research.
- Undertaking R&D by developed countries in a cooperative environment.

Suggestions

- Identify an institution to develop an information system on global R&D efforts.
- Maintain an information system on the EEZ of various countries and their categorization with reference to level of details.
- Identify countries in various regions with capabilities in Ocean Research who can assist other countries in exploration / exploitation of their EEZ Resources.
- Initially, the developed countries in Ocean Research may act as Nodal Countries in their respective regions. However, for extensive/specialised programmes, respective nodal countries may seek the assistance of such countries outside the regions.
- A realistic scheme of assistance by developing nations must be based on cost plus basis in exploration stage and on commercial basis at exploitation stage. There is thus a need for developing an overall exploration / exploitation programme and a plan for financing in all regions.
- Profits earned by developed countries through such activities must primarily be directed for more intensive research for exploiting deep sea bed mineral resources.
- Need for an action plan based on recommendation during the seminar.

Seabed Mining - A Source of Metals in the 21st Century

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The paper was first presented at the 25th Annual OTC in Houston, Texas, U.S.A., 3-6 May 1993.

Abstract

In previously centrally planned economy countries, several deposits presents characteristics that would not allow them to be classified as mineable in market economy countries. The present production cost does not consider the actual value of energy, transportation and labor. Also the pressure of environmental concerns will imply new capital costs to improve the processing facilities. The political changes will progressively restore the actual costs. Consequently, some operations must close, others will have to reduce their production by concentrating on higher grade ore. On the consumption side, the decreased demand from the military, which presently allows export to the West, will be replaced by an increased demand from industrial sectors such as transportation and consumer products. In South Africa, the abandon of the apartheid policy will progressively involve the reappraisal of labor cost. Some operations will experience difficulties to maintain their activity. The global balance of demand-supply could change and the need for new sources of commodities could appear earlier than previously forecast. Economic feasibility studies demonstrated that polymetallic nodules have the same value as land-based low-grade nickel laterites and manganese deposits that are considered as the next-to-be developed resources. However, the technical risks inherent to deep sea operations require presently a higher rate of return. This gap could be reduced if research programmes are maintained that would ensure a better reliability of the different components of deep sea equipment. It will enable future investors to choose between political risks in developing land-based resources and reduced technological risks in deep sea mining. The technology required for deep seabed mining is, for the most part, available on the equipment market. But the dredging system, which must operate at the sea-floor at a pressure of 5 MPa and at a temperature near 0°C, would require special components. Most of them are already in use on small submarine equipment, but have not been tested in continuous industrial working conditions. Their development will require trials at sea during the feasibility studies.

Exploration Technology for Seabed Minerals - Indian experience

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Abstract

Marine mineral resources include both metallic and non-metallic minerals and fossil fuels that occur in a variety of environments ranging from shallow continental shelf areas to mid oceanic ridges and deep-ocean basins. Although some of the near shore deposits such as placers and hydrocarbons are being exploited commercially, many others are yet to be realised. The ideal exploration strategy to search marine mineral deposits would follow a procedure of closing range on a prospective target area by systematic progression from regional reconnaissance to site-specific methods. The seabed deposits are diverse in character, mode of occurrence and geographic distribution, hence, the techniques would be different for different mineral commodities. A critical evaluation of present day technology reveals that substantial progress has been made in the recent past with the advent of systems such as multibeam sonars, deep-towed instrumental packages and submersibles. However, there is a great need for new sampling technology that is inexpensive, reliable and rapid. The future potential for the development of marine mineral resources will be dependent upon the ability to adopt existing technology, improving and development of new systems. Besides, financial considerations are bound to influence the exploration activities. In this context, it is suggested that cooperative programmes might help to pool the resources and obtain high economic and scientific efficiency by sharing the technology and expertise. This approach proved to be successful in the case of Indian exploration programme for polymetallic nodule resources in the Central Indian Basin. Therefore, the mechanism of joint ventures through regional and international cooperation may be considered in planning for the development of marine non-living resources.

Introduction

Based on morphology the ocean floor can be divided into three major topographic provinces namely continental margins, ocean basins and mid-oceanic ridges. The continental margins lie between continents and ocean basins and subdivided into continental shelves, continental slopes and continental rises. The exploitable resources in this area are hydrocarbons, placer deposits, phosphorites and aggregates (sand, gravel and shell materials). A major portion of the sea floor is occupied by the ocean basins, which comprise of abyssal plains, abyssal hills and seamounts and guyots. Ferromanganese nodules and crusts are the main mineral deposits formed on the abyssal sea floor. The flanks of seamounts are favorable for the formation of cobalt rich crusts, while phosphoritic rocks of economic significance are found on top of the guyots from different ocean basins. The mid-oceanic ridges are belts of divergence where new ocean floor is created. Hydrothermal deposits have been reported from mid-oceanic ridges and also subduction zones where fore-arc and back-arc spreading is common. The exploration technology discussed here does not include petroleum hydrocarbons and dissolved minerals and is confined to hard minerals only.

Seabed Minerals

Placer deposits : Placer deposits are concentrations of economically important heavy minerals that have been eroded and transported from the source rocks and concentrated by winnowing and removal of unwanted lighter materials by flow of overlying water or wind. Placer deposits could have been formed on the continental shelf, when the shelf was exposed to subareal processes during the low stands of sea level. The nature and importance of the deposit depend on the present and paleo depositional settings of the shelf. Therefore the geological and oceanographic parameters govern the genesis of the placer deposits.

Phosphorites: Phosphorite rocks and nodules are reported from the continental shelves, bank tops and guyots. Phosphoric deposits occur mainly as carbonate flourapatite and contain fluorine and uranium along with some other rare elements in its lattice. Marine phosphate formation and deposition represents periods of low rates of sedimentation and high supply of nutrient phosphorus derived through upwelling. Nutrient enriched upwelling currents and microbial activity for concentrating the phosphorus at the sediment-water interface and within the sediment are considered pre-requisite mechanisms in the formation of phosphorites.

Aggregates: Aggregates comprise of mainly sand, gravel and shell materials. These are the product of hydrodynamic forces and occur on the continental shelves. Aggregates are used primarily in construction industry. However, high quality calcareous sands can be used in chemical, cement and paper industries.

Manganese nodules and crusts: Manganese nodules occur on the deep ocean floor as primary authigenic deposits. The economic importance of manganese nodules lie in their concentrations of nickel, copper and cobalt. Though manganese in the nodules is as high as 30%, it is relatively unimportant for economic exploitation on its own compared to land deposits at present. But metallurgical processes are being developed to recover manganese as a by product. Nickel and copper are present in excess of 1% each in ore grade manganese nodules. Of these nickel is particularly important because of limited economic deposits on land. Cobalt is present in low concentrations in nodules (0.2—0.3%), but it is as high as more than 1% in some of the ferromanganese crusts. Cobalt rich crusts are formed between water depths 1000 and 2000 m on flanks of seamounts, ridges and archipelagos, which are exposed to strong currents. Platinum has also been reported in considerable quantities in cobalt rich crusts.

Hydrothermal deposits: Hydrothermal deposits form at mid-oceanic ridges and back-arc-basins through the complex processes of volcanism, tectonism and hydrothermal circulation. There are two types of hydrothermal deposits; (i) metalliferous muds associated with hot brine pools and consist of layered unconsolidated sediments rich in sulfide minerals (found in the Red Sea) and (ii) massive sulfides that occur as chimneys and mounds (East Pacific Rise, Mid Atlantic Ridge, Lau Basin).

Exploration Techniques

Position fixing: The first step in marine mineral prospecting is defining the coordinates with desired accuracy. For near shore surveys, a variety of systems such as visual (sextant) and microwave position systems (mini ranger, syledis etc.,) give high degree of accuracy. In the deep-sea areas, land based systems are not accessible and the surveys in regions far away from coast are dependant on satellite based position systems. Initially transit systems of US Navy were used which could provide position coordinates with accuracy upto 200 m. This accuracy is regarded as inadequate for detailed exploration. However with the availability of Global Positioning System (GPS) facility positioning in deep seas has improved considerably.

Acoustic mapping: Bathymetric mapping is one of the most important aspects of prospecting in marine environment. The last two decades have witnessed tremendous advancement in bathymetric survey. Single beam echo sounders have given way to a variety of high resolution swath bathymetric systems enhancing accuracy and reliability of the maps produced. The cost effectiveness of multibeam systems is very high and oceanographic research and survey vessels of several nations are fitted with these systems. Multibeam systems have a swath coverage of twice the water depth and provide spatially correct and continuous data utilizing far less ship time. While some of the existing systems are developed for use in medium to deep waters some others have a coverage of 400% of depth and can be used only in shallow waters upto 1000 m.

Another type of mapping technique useful in marine exploration is side scan sonar survey. In this technique, the sound pulse returned from the sea floor is a function of roughness and composition. Therefore the sonographs readily provide information on morphology and texture of the seabed. A large number of near surface towed shallow water side scan sonar systems have found wide application in marine mineral and engineering surveys. Coupling of side scan images with bathymetric maps proved to be very useful in geologic investigations. Near surface towed deep water imaging systems cover large areas with a consequent reduction in resolution. However these systems because of their long range, are valuable for rapid reconnaissance surveys.

Sub-bottom profiling provides detailed information about stratigraphy and geological structures beneath the seabed. Various types of seismic techniques (refraction, reflection, single channel and multichannel profiling) are used depending upon the type of information required. The seismic records with constraints from borehole logs and sampling can be used to construct three dimensional picture of the geological formations.

Optical mapping: Several types of still and video cameras are being used to obtain visual pictures of the seabed. Surveying with deep-tow system is common atleast in the detailed exploration phase to demarcate the deposit. Initially the deep-tow systems are mounted with visual devices and the data is transmitted through coaxial cables on-line. However, the latest models are facilitated by fibre optic cables where large sets of data transmission from the tow body to the mother vessel is possible. This has given scope for providing both optical and acoustic sensors on a tow body, to collect visual and acoustic information simultaneously. One major shortcoming with the deep-tow systems is their limited coverage and slow tow speed, which requires greater ship time.

Sampling: A wide range of samplers (grabs corers, dredges and water samplers), depending upon the type of sample to be collected, are available in the market. As a result of increased interest in marine minerals, especially for manganese nodules and hydrothermal deposits, several new sampling equipment for deep-sea sampling have been designed and developed in the recent past. However, there is lot of scope to improve the reliability in the functioning of sampling equipment.

Future Developments

With the advent of swath bathymetric and deep-tow systems, non-destructive analytical instruments and computer based modelling applications, marine mineral exploration received a quantum jump. However, seabed sampling continues to be costly and time consuming. Some of the improvements required in seabed exploration technology are as follows.

1. Combination of various acoustic surveying techniques such as swath bathymetry and sub-bottom profiling, swath bathymetry and side scan imaging and swath bathymetry together with side scan imaging and sub-bottom profiling. Research is being carried out in this direction and the latest reports inform that systems capable of swath bathymetry and side scan imaging simultaneously are tested successfully.
2. Development of systems for optical imaging from increased distance above the seabed.
3. Development of in situ chemical and radioactive detection devices.
4. Improvement and development of sampling technology that is inexpensive and reliable.
5. Development and application of genetic models in estimating mineral potential.

Development of Marine Mineral Resources

Development of a deposit include exploration, exploitation and marketing of the mineral resource and require close interaction between R&D organizations, industry and end users. Marine exploration and exploitation needs capabilities in high technology areas and greater financial commitments. Often it is observed that the necessary technology is to be integrated from various sub-systems developed by different organizations. Therefore it is desirable to suggest the mechanism of regional and international cooperation to pool the resources and reduce the technology development costs. This approach not only helps in achieving high economic efficiency but also ensures the technology transfer between various partners of joint ventures.

Exploration for Polymetallic Nodules in the Indian Ocean: Indian Experience

Nodules cover an area more than 10 million sq.km. in the Indian Ocean. Analysis of available data indicated that high grade nodules mainly occur in the Central Indian Basin, which was selected for exploration. A study of exploration programmes for polymetallic nodules in the Pacific Ocean by other countries indicated that they are being operated by a consortia of companies specializing in different fields. Clearly many of these specializations lay outside the purview of a single institution and in ensuring the success of the programme, association with other agencies was desirable. India, with a wide scientific manpower and a chain of laboratories specializing in diverse fields under the Council of Scientific and Industrial Research provided an alternate programme for exploration and exploitation of polymetallic nodules by forming an association similar to that of consortia between the laboratories and other institutions. In all more than 40 institutes from R&D, academia and industry were involved of which the National Institute of Oceanography played the lead role. This necessitated a system of coordination at both national and institutional levels. The initial planning and coordination ensured that not only the work would be carried out smoothly and with desired accuracy but the time targets could also be adhered to. With this approach it has been possible to survey an area of 4 million sq.km in the Central Indian Basin and to file a claim for a pioneer area with the International Seabed Authority. With the decision of the General Committee of the Preparatory Commission which met on August 17, 1987, India became the first Pioneer Investor to be registered for the development of a mine site in the international seabed area.

The success of Indian programme for polymetallic nodules suggests that involvement of agencies specializing in various related fields is necessary and shall play an important role in the development of technology for the exploration and exploitation of marine non-living resources.

Continuous Line Bucket Mining and its Adaptability for Developing Country (for example Republic of Marshall Islands)

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Introduction

Seabed minerals include manganese nodules, poly-metallic crust, metalliferous sulfides, placer deposit of metalliferrous sand and construction sand. Several mining systems were studied to exploit them, Continuous Line Bucket (CLB) is one of them. Since 1970s CLB was tested often for nodule and crust and others, since it has superior point of simplicity, and applicable for mining in developing country, we will introduce present study condition and future plan.

VARIATIONS IN MINING METHODS TESTED

The three principal methods originally proposed and tested for deep seabed mining of manganese nodules were a two or three phase hydraulic lift with a passive or active miner, an autonomous mining vehicle to shuttle between the seabed and the surface platform, and a continuous line bucket (CLB) system operating with a continuous loop of drag buckets attached to a flexible line. The hydraulic system has been most widely tested and is highly rated for production operations based on large economies of scale; the shuttle system is highly sophisticated but has not been sufficiently developed to test in an operating mode; the CLB system employs the least sophisticated technology and because of its simplicity, adaptability, and low cost has been proposed for the mining of high-cobalt crust at moderate production rates in the Republic of the Marshall Islands.

The CLB system consists essentially of a long endless rope loop suspended from a surface vessel to the seabed and to which are attached standard drag dredging buckets at regular intervals. Each bucket moves across the seabed at a rate, and for a period of time, determined by a combination of the rope speed, the rope slack on the bottom, and the speed and direction of the vessel from which the rotating loop is suspended. The buckets full of seabed material are continuously raised to the surface, emptied on board the vessel and returned to the seabed on the downward passage of the rope. Production rate is determined by the rope speed and the spacing of the buckets on the line.

This system has been successfully tested at sea in four different configurations:

Original CLB: The original system separated the upward line from the downward line by the ship's length, suspending them from the bow and stern of the vessel, which was then caused to move sideways by thrusters or by drifting broadside to the prevailing current. Tests were carried out off Tahiti in 1970 from the 2,500 ton Chiyoda-Maru No. 2, and off Hawaii in 1972 from the 16,000 ton Kyokoyou-Maru No.2

Two ship CLB: In this case the separation of the ropes was adjusted by suspending the loop between two ships. Tests were carried out during the period 1974 - 76 by the French Center for Exploration of the Ocean (CNEXO).

Hydro-Dynamic CLB: Separator plates or specially configured buckets were used to separate the ropes using natural hydro-dynamic forces. Small scale tests were carried out in 1975 from the vessel Tokai University No. 2 in the Ogasawara area of Japan.

Turning CLB: By steering the mining vessel on a circular course, trailing the empty buckets over the stern and bringing up the loaded buckets amidships from inside the arc, good separation of the lines can be achieved. This method was tested in 1987 in model scale at a depth of 50 m (Figure 1) using a coastal fishing boat.

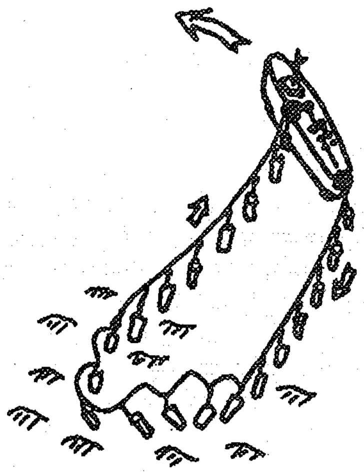

Fig.1 Principle of turining CLB

Of the four methods tested the Turning CLB is believed to be superior because of the simplicity of achieving a wide and safe separation of the two lines and the better control possible with the single, forward moving vessel.

The arc or the circular path taken by the vessel will be constrained by the nature of the deposit in which mining is taking place but it appears that seamount crust deposits may be well suited to the use of this approach.

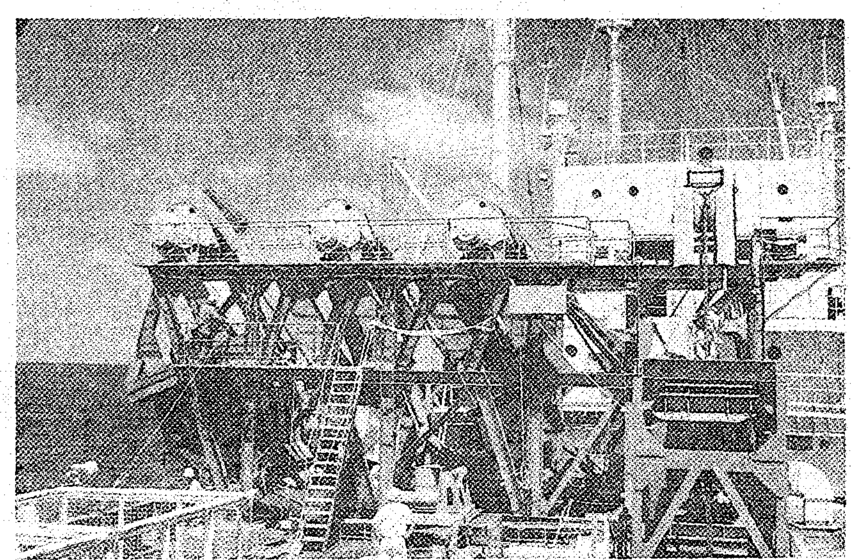

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Fig. 2. Front traction machine on Kyokuyou-Maru No.2

IMPROVEMENT OF THE CLB MINING SYSTEM

The design of the traction mechanism for the CLB is a critical factor in the efficiency of the system and has been varied in each of the tests.

The mechanism used in the 1972 Hawaii test at 5000 m depth (Figure 2) used 13 traction wheels, an 85 mm rope and buckets suspended from two bails at the front and rear of each bucket. The buckets and their suspension bails were able to dump on the first vertical drop and pass through the traction wheels without removal and re-attachment. Unfortunately the large size of the mechanism prevented its use on a smaller vessel and a more compact design was adapted for subsequent tests using multiple parallel wheels (Figure 3). The drive was powered by a 33 kw, 3 speed motor and factory tests confirmed available traction forces of 4 tons at 0.2 m/s, and 2 tons at 0.4—0.8 m/s. There was, however, no way to pass the buckets through the mechanism and they would have to be individually removed and re-attached to the line during the test. A "magic hand" crane was designed to remove the loaded buckets, dump them, and return them to the line beyond the traction mechanism. The awkwardness of this activity led to further improvements in design.

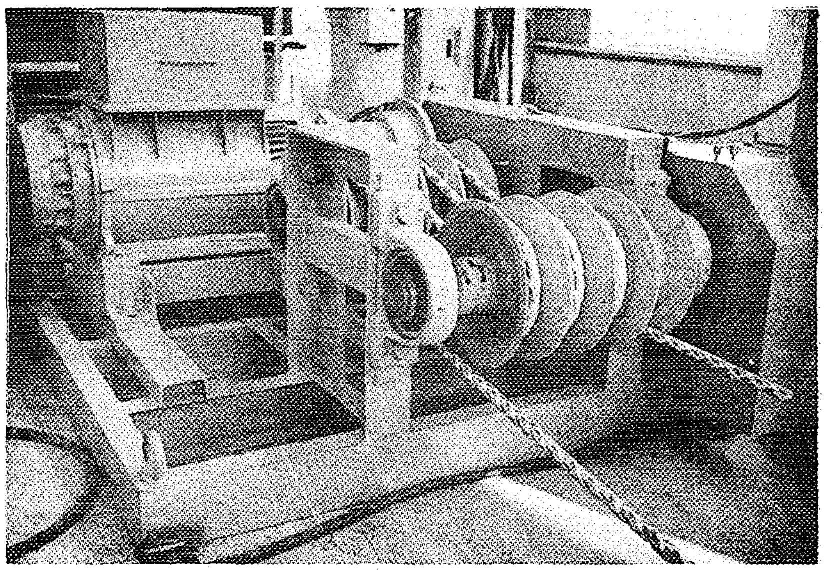

Fig. 3. Multi wheels traction machine

New Ball Roller Traction Machine

Ball rollers were developed by Kouyou Co. in Japan for hauling large and bulky commercial fishing nets. They were used in the 1972 Hawaii CLB test for rope handling, and during the 1973 and 1975 tests on board the Tokai University vessel they were used to hoist the CLB rope with the buckets attached. Since the results in each case were acceptable, plans were made to use the ball roller parallel drive system to replace the multi-wheel traction drive.

A cross section of a 5 ton, 60 cm ball roller for commercial CLB mining is shown in Figure 4. It consists of a pair of rubber balls inflated with high pressure air. The rope is passed between the balls and held in place by the air pressure which also supplies the holding force for the traction line. Operation is very smooth and the bucket suspension ropes can pass through the ball rollers easily (Fig.5) illustrates a factory test of parallel ball rollers driving a rope line with small buckets attached. In the full scale system eight ball rollers will be installed and driven by independent hydraulic motors in each parallel drive.

The French Center National Pour l' Exploitation des Oceans (CNEXO), in developing a two ship CLB study, tried to utilize the ball roller as a traction device. Testing of a large ball roller is shown in Fig. 5 as it lifts a pick-up truck into the air. The traction truss and attached ball roller constructed for the test is shown in Fig. 6. The test results were good, but the 2-ship CLB syndicate, managed by Dr. John L. Mero, did not continue the testing for other reasons.

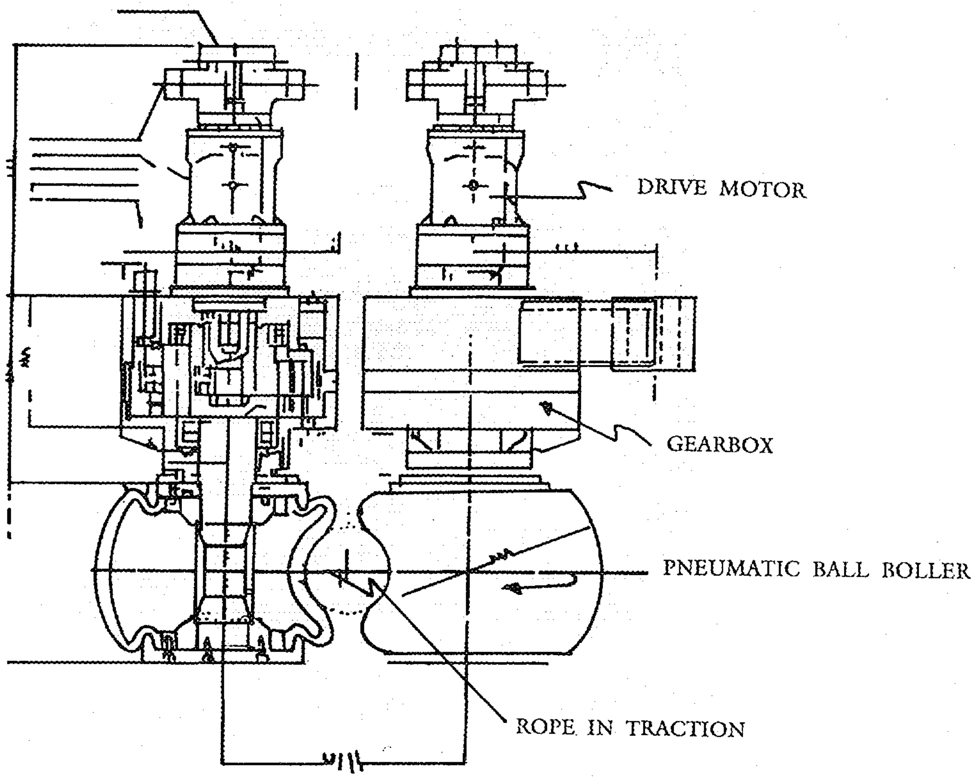

Fig. 4. Cross section of 5 tons, 60 cm ball roller

More recently the Kouyou Co, re-examined the use of the large ball roller for use of the large ball roller for use with the CLB for deep seabed and shallow water mining. A new 800 mm diameter ball roller is now under construction. The rope holding force is maintained by the air pressure in the adjacent pairs of balls and is calculated from

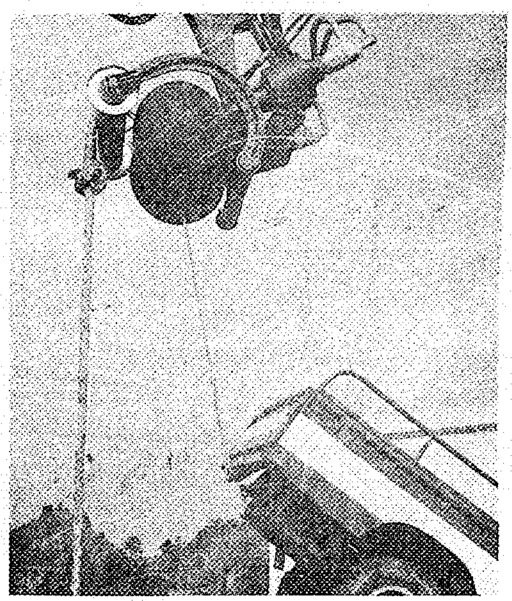

Fig. 5. View of pull up truck hoisted by large ball roller

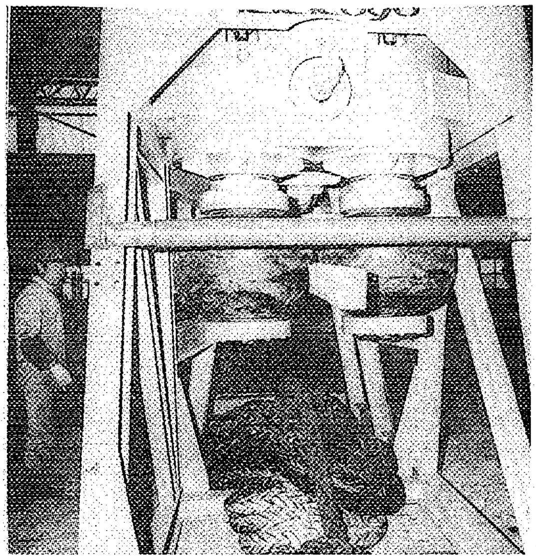

Fig. 6. Large ball roller truss to pull CLB rope.

W = 1 x d x D x p x 2

Where W	=	holding force(kg)
1	=	contact lentgh (cm)
d	=	rope diameter (mm)
D	=	air pressure (kg/cm^2)

Standard pulling force is reported according to the diameter of the ball.

150mm	230mm	3000mm	450mm	800mm
200 Kg	500 Kg	700 Kg	2,000 Kg	8,000 Kg

The ball roller can pull the rope easily with the hanging buckets attached, but to avoid the risk of bursting from too high an air presure (D), the balls are run in series generally with four pairs in line. Each of the ball rollers is driven by its owen prime mover, and is equipped with brakes to keep the rope line safe in case of failure of the drive, Using four 800 mm diameter rollers a pulling force of 32 tons is acheived which is sample for the commercial mining of crusts or sand.

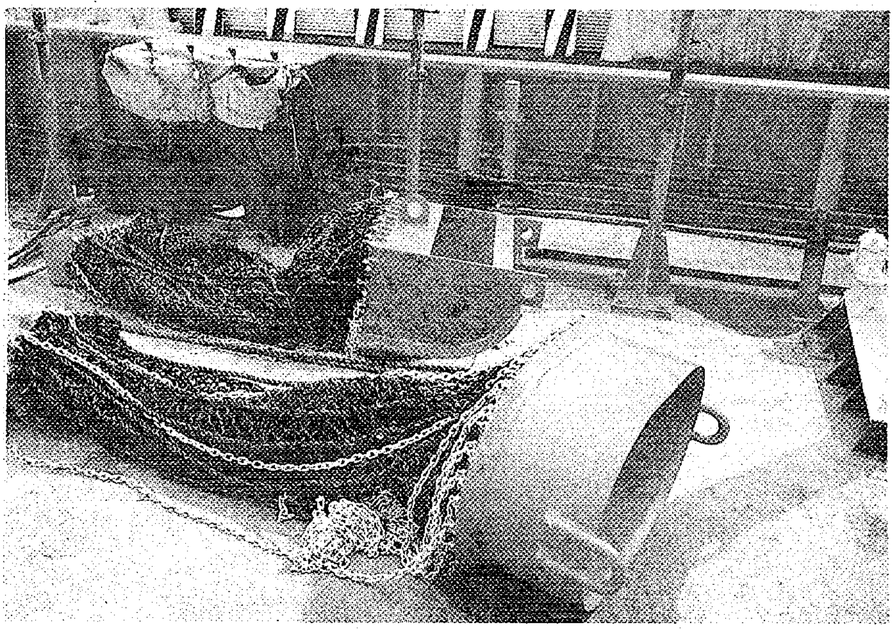

Fig. 7. Oval bucket and teeth bucket

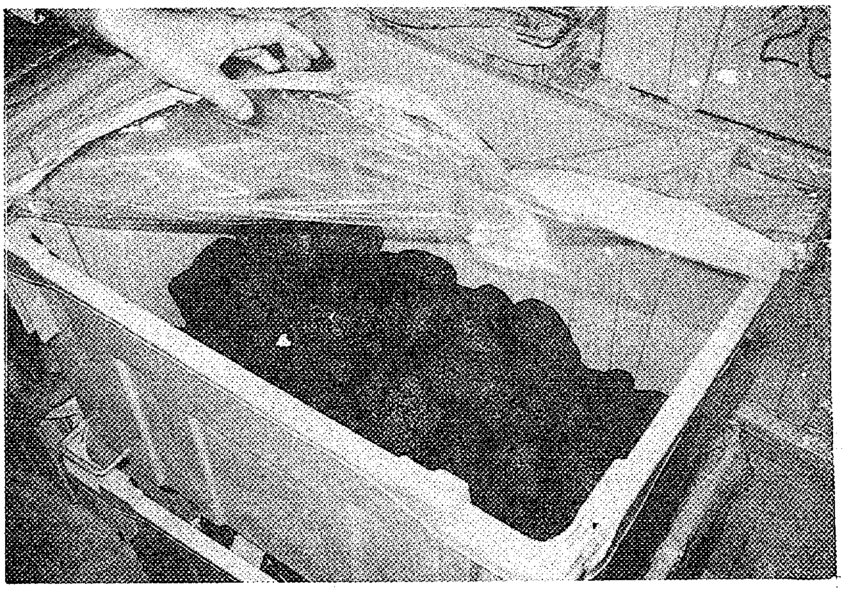

Fig. 8. Cobble crust dredged on seamount off Minami Torishima

BUCKET AND ROPE

The only underwater parts of the CLB system are the buckets and rope. This is a simple, but important part of the mining system.

Bucket Test

Tokai University conducted 24 single line bucket dredging tests on Minami-Torishima using two kinds of buckets. There were no empty buckets from these tests, and an average 100 kg/bucket of crust was dredged without bucket loss. Both bucket types which dredged cobbles, nodules and pavement during the tests would be suitable for the CLB.

Line

Polypropylene braided or plaited line was used for the CLB tests because of its buoyancy in the water. It is weak in creep characteristics, however, and polyester or nylon rope may be more adaptable and last longer.

Bucket Guide and Dumping

In many of CLB tests, a vertical axis swivel sheave, as shown in Fig. 9 was used to guide the incoming bucket line.

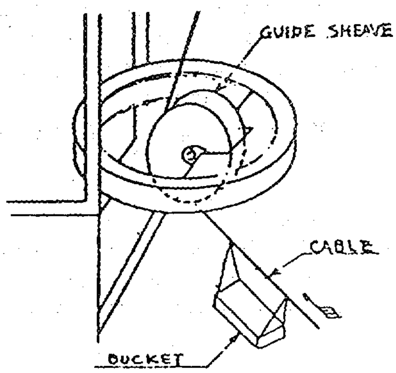

Fig. 9. Guide sheave in circular metal frame

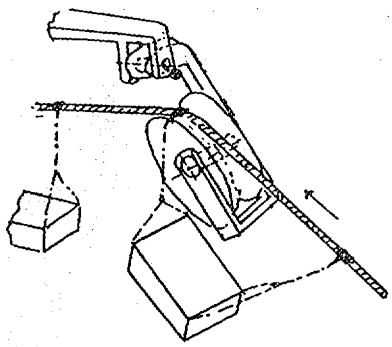

Fig. 10. Bucket side passing device with variable angle sheave

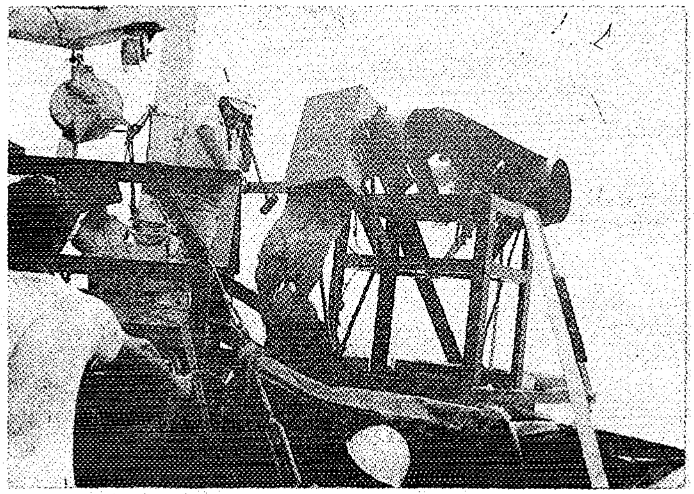

Fig. 11. Dumping of clay dredged from 800 m depth.

The vertical sheave faces the direction of the incoming rope with the loaded buckets and guides it in a vertical direction, without twisting, for passage to the traction machine.

The vertical axis swivel sheave in the circular metal frame required a servo mechanism to rotate the sheave and restricted the size of the bucket which could pass through a simpler mechanism, shown in Fig. 10 was therefore developed.

In this design the guide sheave is hung from an ecentric frame with one side open to allow the hanging buckets to pass easily. No servo is required and the mechanism is simple, and light weight.

Dumping is another action where design problems were encountered and up-ending of the attached buckets was method used effectively in number of tests.

The dumping of clay from an up-ended dredge bucket in the CLB truss during tests on Tokai University Ship No. 2 is shown in Fig. 11.

The new design for a dumping device uses the side passing guide wheel attached to a tower truss. The bucket, hanging by two balls, is overturned when it goes through the top sheave. It is a simple design resulting in a smooth upending and emptying of the bucket.

RESOURCES OF PACIFIC ISLAND SEAMOUNTS

Significant deposits of high-cobalt metalliferrous oxides containing potential ore grades of cobalt, nickel, copper, manganese and platinum group minerals have been identified on seamounts between the depth of 800 and 2400 meters in the Exclusive Economic Zones (EEZ) of many of

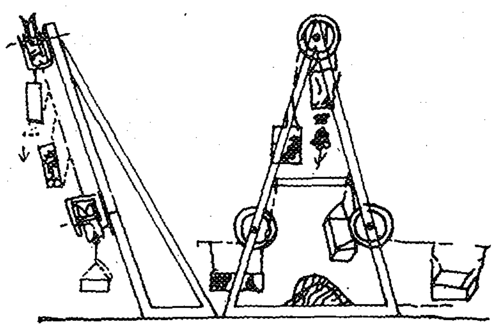

Fig. 12. New dumping device to overturn the attached bucket using the side pass guide wheel.

the Pacific Islands including the 5th Takuyou seamounts in the Japanese EEZ, Palmyra in the U.S. EEZ and Labibjet, Sylvania, and Jebro seamounts in the Republic of the Marshall Islands (RMI). The latter deposits are reported to have the highest commercial potential for any Pacific Island nation.

The cobalt content of these deposits is generally higher in value than that reported for deep seabed manganese nodules which are of similar composition but are found at depths generally between 5000 and 6000 meters. The amount of deposit characterization conducted to date by numerous countries including the United States, Japan, Germany, France, South Korea and others is sufficient to indicate that the high-cobalt encrustation presents a significant minerals potential, given an appropriate technology for recovery.

More important, however, is some new information concerning the physical nature of these deposits which affects the potential for their mining using the CLB system. A recent survey of the very large 5th Takuyou seamounts, which are for the most part flat topped, resulted in a series of dredge hauls recovering an average of 100 kg per bucket of cobbles, nodules, and broken pavement in a relatively short tow (Figure 7: author communication). This distribution of easily dredgeable oxide material mixed with nodules has been observed also in each of the flat topped seamounts referred to previously and may alter the concepts of dredgeability normally applied to the better known hard pavement type crusts most commonly described in the literature.

ECONOMIC ESTIMATES OF CRUST MINING AND PROCESSING IN (RMI)

Candidate seamounts with crust deposits in the EEZ of the Marshall Islands are shown in the map presented as Figure 13: Three of these, Labibjet (1), Sylvania (3), and Jebro (5), have been selected as prime candidates for economic evaluation. Labibject Seamount is narrow but has

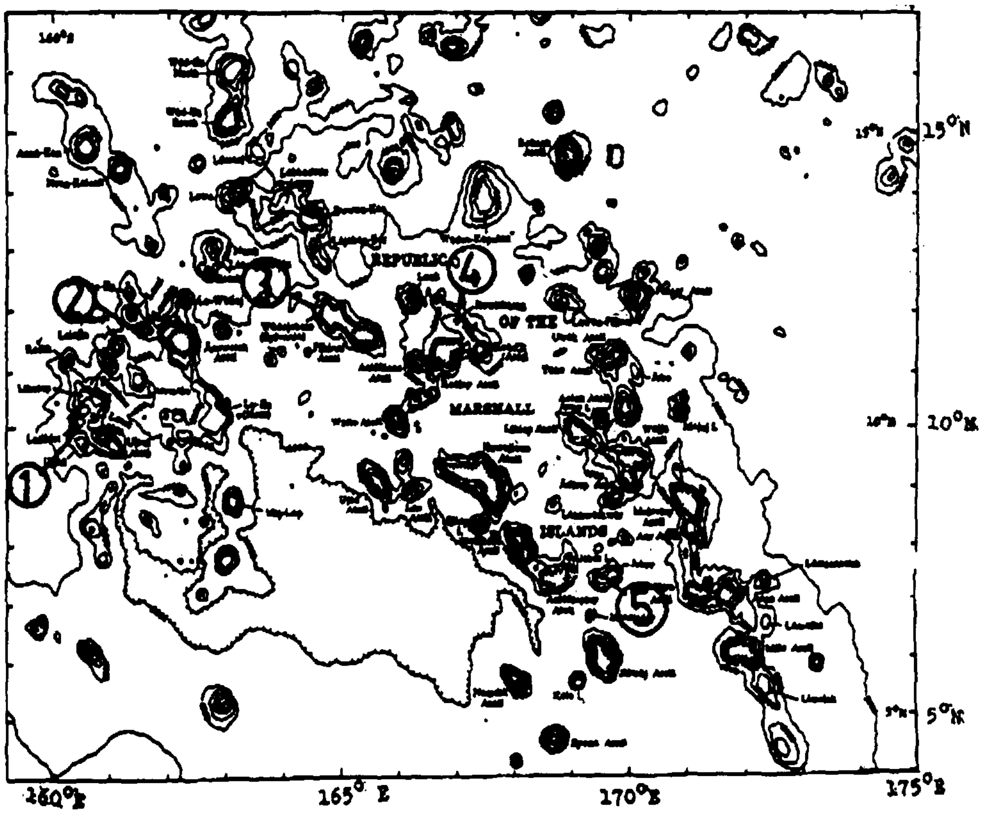

Fig. 13. Crust Deposits and islands in Marshall Islands

a rich distribution of cobble type crust; Sylvania Seamount, located ear Bikini atoll is very large and has an extensive distribution of 10–15 cm thick crust; and Jebro Seamount, located near to Majuro the capital of RMI, is well located for testing.

Tentative Crust Mining Proposal

It is proposed to plan for a 400 ton/day mining operation out of Majuro in the RMI. A 15,000 ton vessel conversion will be fitted with a ball roller traction system using 3,000 m of 90 mm diameter rope with 1.5 m^3 buckets attached every 50 m. A traction rate of 0.8 m/s will require 400 kw and the buckets will be discharged automatically on board the vessel. A monthly production cycle of 20 days over 11 months each year will result in an annual production of around 88,000 tons.

Tentative Estimated Costs

The following numbers are based on data from a U.S. Environmental Impact Statement for cobalt crust in the EEZ of the Hawaiian and Johnston Islands (USDOI, 1990) and are scaled down, for illustration, to a 400 ton/day CLB operation. At a cost of 15,600 Yen/t ($120) the annual operating costs are estimated to be about Yen 1.4 billion ($10.8 million). Capital needs for the mining system are estimated to be in the region of Yen 1.5 billion ($11.5 million) and for the processing system Yen 8.5 billion ($65.5 million), for a grand total of Yen 10 billion ($77 million).

Table 2. Comparisons of production rate, cost and spillage control for a CLB v crawler suction miner.

Income from sales, based on Table 1 are estimated to be Yen 9,540 million ($74 million).

With mining costs of approximately Yen 1.4 billion ($10.8 million) and processing costs of approximately Yen 4.5 billion ($34.6 million), total costs would amount to Yen 5.9 billion ($45.4 million). This would give a gross annual profit before taxes of Yen 3.6 billion ($27.7 million) and, on the same basis, an annual return on investment of over 30%.

Small Scale Test of the CLB

In order to verify the feasibility of the CLB system in the mining scenario proposed it is necessary to operate the system in a scaled test on the RMI deposits. This can be done at 1/10 scale to produce 40 t/d by the simple conversion of an ocean going vessel at small cost. Sea trials for hydraulic systems under these conditions are inevitably much costlier due to the scaling effects. About 1000 tons of crust material dredged during the proposed tests would be used to develop an appropriate system for processing, thus reducing the investment risks for development of the full scale production system.

Table 1. Income from saleable commodities

Commodity	Production (t/y) (Recovery @ 80%)	Price(Yen/kg)	Income (Y x 10^6)
cobalt	582	5,000 ($18/lb)	2,830
nickel	297	1,300 ($4.75/lb)	380
MnO_2	24,800	250 ($0.90/lb)	6,320
Total			9,540 ($74 x 10^6)

* Use of battery grade MnO_2 is proposed for this fraction, based on existing, verified markets in Japan.

OTHER USES OF CLB TECHNOLOGY

The CLB system has been tested for managanese nodule and crust mining in water depths as great as 5,000 m. The adapation of the system to mine placer deposits, or industrial materials such as phosphorites, sands, or gravels in coastal water depths of a few tens of meters should be quite straightforward. The mechanical improvement gained by use of the ball roller makes for a simple and reliable system of mechanical dredging in the oceans with few environmental effects.

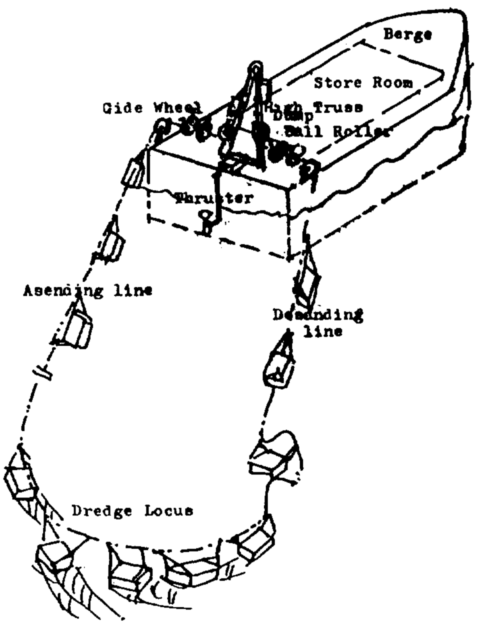

Fig. 14. Sand Mining barge

This system could well be applied to beach sand replenishment in Hawaii and other island communities where coastal protection and enhancement has become of significant economic importance.

We conducted case study for sand mining for HAWAIAN Beach and Removal of Polluted sediment from seabottom, using these study result, Mining of shallow water placer deposit by CLB is evaluated.

(CLB mining barge)

Using a traction device with four 800 mm ball rollers, and 2 m^3 buckets attached at 12 m intervel, 400 kw driving power is needed for a mining rate of $250m^{3/hr}$ or 6000 $m^{3/24}$ hr day from a water depth of 200m.

Fig. 14 shows sand mining barge, It uses turning CLB or other CLB with moving ahead in slow speed.

Of course, in very shallow water depth, there is no moving CLB opearation using barge length to sepearate two ropes.

Production rate, operating cost, and spillage control capabilities for the CLB were compared in table 4 with similar specifications obtained for a seabed craw ler suction device devloped in the United Kingdom, The CLB appears to have an advantage on all accounts.

Table 2. Comparisons of production rate, cost and spillage control of a CLB v crawier suction miner.

	CLB	Crawler suction
Production rate Production cost Spillage control	6000 m^3/day 280- y/m^3, ($1.68) sediment density unchanged by pickup	3600 m^3/day 636 y/m^3, ($3.82) volume of slurry increased x 10

Conclusion

1. Continous Line Bucket (CLB) system will be proposed instead of suction pump mining. There is considerable merit in CLB's simplicity by reducing the technical and economical requirement, Mining can be started on a much smaller scale than the plan utilizing suction pump mining. The CLB method will also save considerable startup capital.

2. Because the CLB system does not lift deep sea bottom water to the surface, pollution problems are held to a minimum.

3. By utilizing the CLB for crust mining, it has technical features of relatively low mining cost in small production speed. Therefore, we propose to begin mining 400 ton/day utilizing a 15,000 ton mining ship. Eventually, the scale of mining can be increased to 1,000 ton/day with a larger ship, or additional ships.

4. Previous plans such as the Hawaii state EIS report utilising a robot miner gathering up to 700.000 ton/year, Cobalt and Nickel were considered to be the main product and the manganese was discarded as wast. However, in this study of crust mining, manganese will be produced as one of the major products.

5. Technical feature of simplicity of CLB is adoptable not only crust mining but also for nodule mining and shallow sediment mining.

6. *Through many sea trial*, CLB *machinery* was completely improved, Ball roller traction with bucket dumping will be the best mining machine for marine mineral deposit which is relatively loose condition.

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OCEAN MINERALS WITHIN THE EEZ

Hard Minerals from the Seabed

J. P. Lenoble
Afernod/Ifremer, France.

1. Mineral Economy

Although some people are talking of the Electronic and Communication Age for the mankind, we are still at the Iron age. It should be better to say at the Mineral Age. Have a look around us and note the presence of those minerals; stones for building, siliceous or calcareous aggregates for concrete, clays for brick and tile, iron for reinforced concrete, table chair, car aluminium for many users including the cooking utensil, etc., but also coal, oil and gas to produce energy . . . and the geologists would add ground water which is considered by them as a rock!

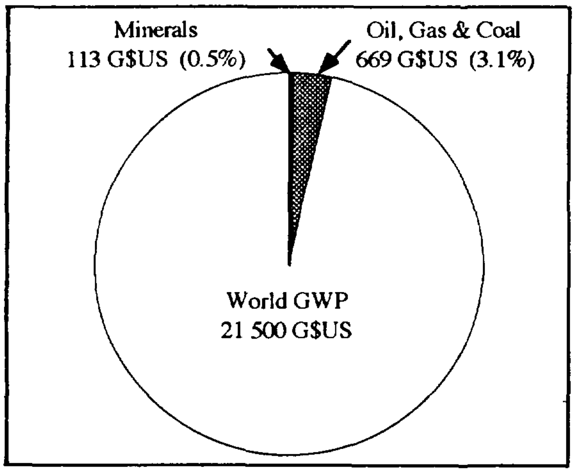

Fig. 1. Hard-mineral's share of Gross World Product.

Surprisingly, the extraction of minerals and their processing rèpresent a very small part of the Gross World Products: (GWP) approximately 3.1%. Excluding the energy materials, the share of the minerals is only 0.5% (Fig.1).

The history of the metal market during the past 40 years can be illustrated by the case of the nickel (Fig.2). During the sixties, the incredible rate of growth of our raw material consumption, brought the "Club de Rome", on the basis of MIT studies, to conclude that, before the end of this century, we would be in shortage of most commodities. Mining companies started to invest considerable amount of money in the search for new sources of minerals. The installed production capacity reached a peak during the seventies.

The technological improvements and the need to minimise production costs in a competitive world, led the manufacturers to reduce the amount of raw materials in their final products. New materials as plastics replaced metals in many uses. Thus a washing machine of the eighties weighs three times less than one built in the sixties. At the same time, the decrease of consumption rate, shifted the balance of demand and offer, on the over capacity side, producing a collapse of most commodities prices, at the beginning of the eighties.

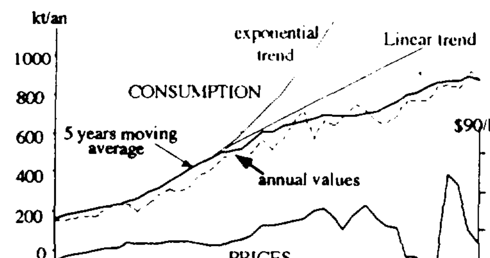

Fig. 2. Evolution of the metal prices:the nickel case.

Many mines were closed. A tremendous effort was done to reduce the production costs at minimum. In 1986, when the industrial growth slightly recovered, the mining industry was enable to face the demand and some of the metal prices went to an historical maximum. But that relief was not for long.

Due to the recent political changes, the Eastern Countries reduced their consumption of metals for the defence industries. The stocks, accumulated to avoid possible shortages, constituted a precious treasure to obtain hard foreign currencies. Metals were poured into the western market, with the immediate consequence of price collapse.

But this situation will not remain endlessly. After depletion of the stocks, the production will rely upon the actual mines. Many of them are operated from ore deposits that cannot fit the western economic standards. They will have to close or to limit their production at marginal cost. The total production is likely to decrease, may be at the very moment where the needs for consumer goods production will increase.

The effect on the world market could reverse the present balance of offer and demand, opening new possibilities to invest for alternative sources of metals. In this context the search for minerals should also pay attention to the marine minerals.

2. Importance of the Marine Minerals

Marine minerals have been discovered since a long time. When looking the value of the non-fuel mineral commodities, we can see that many of them are also present on the sea-bed (Fig. 3)

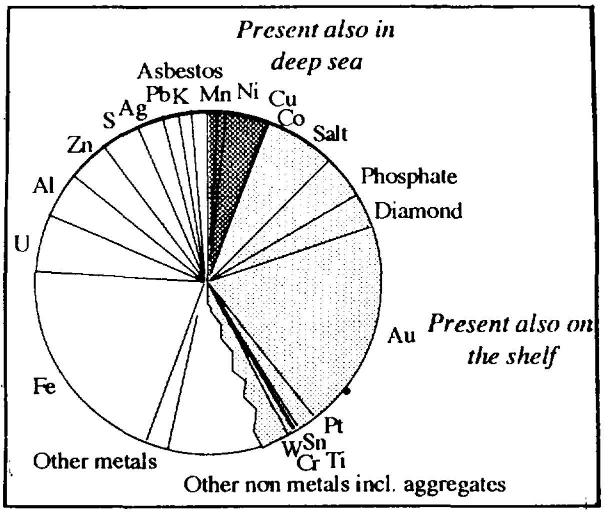

Fig. 3. Shares of the value of hard minerals

There is also ore deposits that are the continuation of land-based mines under the sea-level: coal in Great Britain and Canada, iron in Japan and Newfoundland (Canada), tin in Cornwall (GB), scheelite in Tasmania (King Island, Australia), uranium in France (continuation of the now closed Penaran mine near St Nazaire). But those are not considered hearby.

Few marine minerals were mined before the seventies, except salt that is produced from the sea-water since a very long time (Fig.4). In France for instance the sea provides 40% of the salt production. In tonnage, the most important are certainly the aggregates. The volume exceeds 20% of the total aggregates produced in the United Kingdom and in Japan. In France it is only 10%.

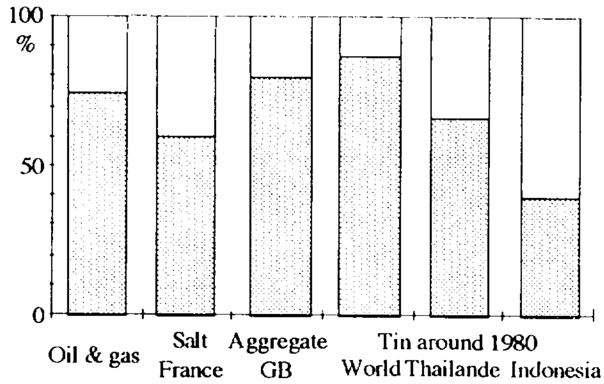

Fig. 4. Ratio of marine production to total production (in grey).

During the late seventies more than 12% of the tin was mined from the sea,mainly in Malaysia, Burma, Thailand and Indonesia. In these countries, still nowadays, most of the tin produced comes from the sea.

Gold was mined offshore Alaska in 1903 with a bucket dredge from the shore. From 1986 to 1990, Westgold, a subsidiary of Anglo-American extracted more than 3,000 tons of gold from the area, with the largest ever build dredge Bima. Infact this dredge had been built for tin operation in Indonesia, but it did not operate in this county due to the tin price collapse in 1985.

For several years, diamond has been extracted, by divers and small dredges, near the shore of Namibia and Namaqualand (South Africa). More recently, de Beers reported the mining of diamonds from 100 m water depth in the same area.

Estimation of the reserves of minerals is highly speculative. One must distinguish between resources and reserves, on defining the later as: Tonnage of ore than can be mined with profit under present economical and technical conditions. For those minerals, of which prices vary from one to several times under a few months period, the reserves should be reviewed constantly.

It has been said that deep sea polymetallic nodules resources equal three times the present known land-based reserves of manganese, nickel and cobalt. But the tonnage of nodules that should be considered as economically comparable to similar land-based deposits, as the low grade nickeliferrous laterites, is likely to be only 10% of the known land-based reserves of nickel and manganese and 23% of the cobalt ones.

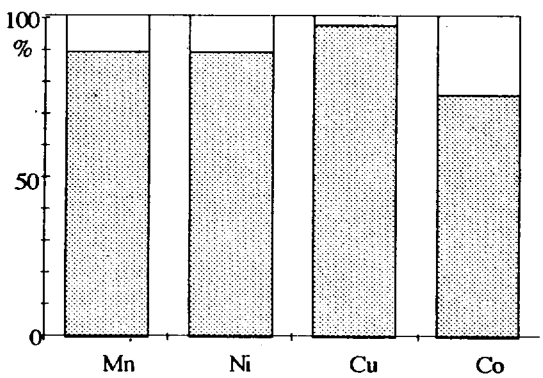

Fig. 5. Ratio of metal reserves in deep-sea polymetallic nod0ules to land-based reserves (in grey).

Most of the marine minerals have been discovered by hazard, during academic studies that were not oriented toward mineral resources assessment. Most of the surveys, that have been organised especially for mineral assessment during the seventies, were lacking of the precision level required for real efficiency.

The actual reserves are still to be discovered now that the required technology is quite attainable.

3. Minerals found in the Sea

The marine mineral deposits are classified by type of deposition between (1) primary minerals deposits that originate by direct genesis on the sea bed or inside the first layers of sediment and (2) secondary mineral deposits that are formed by the deposition of mineral fragments eroded and transported from other places.

3.1 Primary minerals

The primary minerals (also called autochthonous or authigenic or endogenic or formed in situ) comprise:

- the polymetallic nodules which contain Mn, Fe, Ni, Cu, Co and are founded in the deep oceanic basins at 5000 m deep;
- the massive sulphides which contain S, Fe, Cu, Zn, Pb, AU, Ag discovered along the ridges and the volcanic arcs;
- the metalliferrous muds found in deep through in the Red sea and which also contain the same metals;
- the calcium carbonates of the coral reefs in tropical seas, but also of the bryozorian sands and the Calcareous algaes as those found offshore Birttany in France;
- the phosphatic pellets found in black shales or phosphatic concretions in calcareous muds, and the massive beds of phosphate in the lagoon of coral islands as Mataiva in the South Pacific;
- the silica of the diatom oozes in high latitude oceanic basins
- the sea salt (chlorides, iodides, bromides, sulphates, Mg, Na, K, etc)

3.2 Secondary minerals

The secondary minerals (also called plastic or allochthonous or allogenic or exogenic) are mostly derived from the land through alteration, corrosion and transport by the rivers. One can distinguish :

the aggregates, siliceous or calcareous sands and gravels of the continental shelf;

the phosphatic sands, nodules and boulders formed by errosion of phosphate deposits;

and the placers which are quartz sand containing a certain amount (several percent in volume) of heavy minerals.

3.3 Placers

Heavy minerals are formed in crystalline or volcanic rocks by segregation during cooling of the magma. When exposed at the surface of the land, these rocks are decomposed by the weathering. The heavy minerals, more resistant, are separated from the matrix and transported by the rivers with the quartz sand. The more resistant are the minerals, the longer transport they will support before to be reduced to minus fragments or to settle.

The most fragile minerals are only found as eluvial or colluvial deposits closed to the sources rocks (10 m to some kilometers). Such deposits can be submerged during transgression of the sea.

★ tantalite (Ta, Nb)

★ columbite(Nb, Rare Earth)

★ xenotime (Th, RE)

★ samarskite (Y, Nb, RE)

★ pyrochlore (Nb)

More resistant but still brittle minerals can travel longer, several tons kilometers from the source rock. They can be left in the bed of the rivers as fluviatile deposits, than can be later submerged by the sea, or even arrived to the sea and be deposited along the beaches.

★ cassiterite (Sn)

★ wolframite (W tungsten)

★ scheelite (W)

★ gold

★ platinum minerals

The stronger minerals will resist to several phases of transport and deposition. They will constitute fluviatile and beach deposits, either recent or fossilised under a sediment cover: the paleoplacers

★ diamond

★ zircon (Zr)

★ monazite (Th, RE)

★ rutile (Ti)

★ ilmenite (Ti)

★ magnetite

★ chromite

4. Situation of the Minerals in the World Ocean

When considering the major divisions of the ocean, only deep seas contain polymetallic modules, metalliferrous muds and massive sulphides (Fig.6).

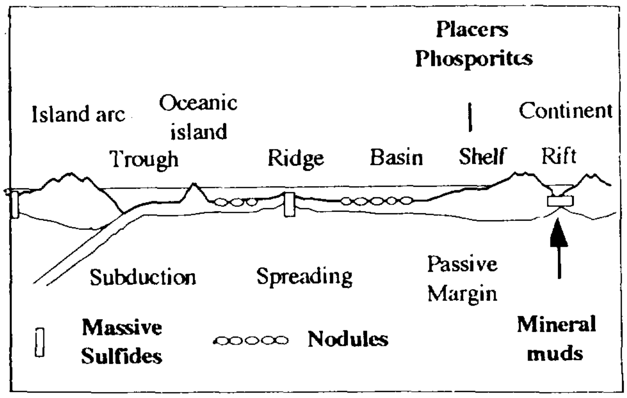

Fig. 6. The ocean divisions and their hard mineral deposits

Their exploitation is not to be considered, probably in this order, before the end of the century. However, as said previously, the metal market evolution could lead some investors to consider polymetallic nodules as an alternative source during the early years of the next century.

The other deposits, aggregates, phosphorites and placers can be found on the continental shelf at shallower water depth.

Aggregates are found as elongated lenses and terraces, in old valleys submerged during the last Quaternary period, but also as hydraulic dunes constantly re-shaped by the marine currents.

Fig 7. shows the location of the deposits that have been identified and are mined on the French continental shelf.

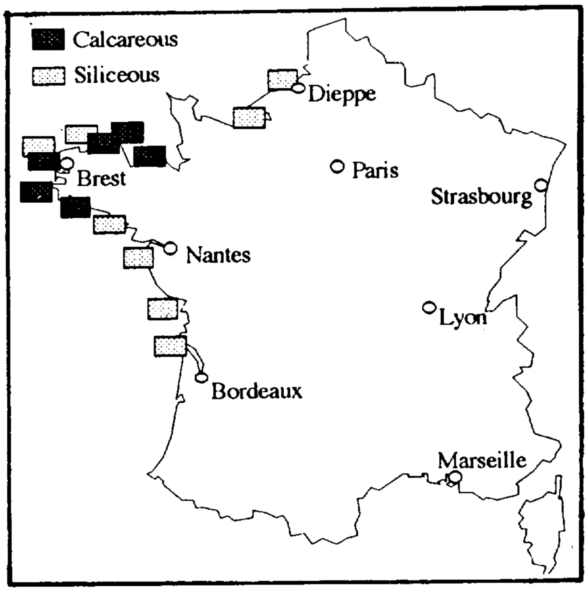

Fig. 7. Map of marine sand & gravel deposits mined in *France*

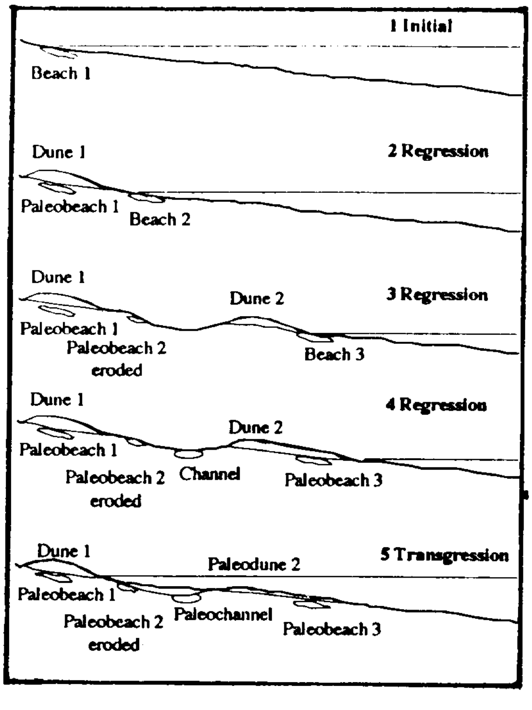

Fig. 8. Evolution of the continental shelf during regression and transgression stages

Placers can be concentration of heavy mineral at the bottom of ancient fluviatile channels in submerged valleys. They also can be ancient beaches buried by younger marine or eolian sediments, that protected them from erosion during the late quaternary transgression. Such paleo-beaches are known at different water depth on most continental shelves. They correspond to lower sea-levels during the quaternary glacial period (Fig 8).

Thus paleo-channels and paleo-beaches constitute the main targets for the discovery of shallow water marine mineral deposits.

5. Exploration Methods

Until recently the technologies available for the exploration of marine mineral deposits were lacking the sufficient accuracy to allow the identification of favourable structures. Furthermore sampling the sediments is both expensive and inaccurate.

The emergence of new technologies gives strong hopes for better success.

The GPS (Global Positioning System) allows to determine the location of any observation, measurement or sampling with a precision better than 10 m and even 1 m when using differential method. Thus it is possible to come back to any selected point for additional measurement or sampling.

Swath mapping, using multibeam echosounders and side-scan sonar imagery, gives interpretative maps of the seabed comparable to those obtain on land from aerial photographs at scales of 1 to 50 or 20,000. Such maps allow the identification of levees and channels that could correspond to paleo-beaches and paleochannels.

The internal structure of bottom morphological features can be scrutinized by high resolution seismic surveys, using digitized recording and re-processing with technics derived from the offshore oil exploration.

By using these techniques, the most favourable structures can be localised where further sampling will be concentrated.

However there is still to improve the efficiency of the sampling methods. Grap samplers does not penetrate sufficiently deep into the sediment. Gravity coring is similarly reduced to the first decimeter of sand. Vibro-coring, while it gives a deeper penetration to 2 to 4 meters, is badly accurate as far as recovery and conservation of sediment structures are concerned. One needs a fast drilling or coring machine that can sample several tens points per day, to at least 5 meters into the sediment. A fully automated rotary drill, with double barrel cover, than can be easily deployed by conventional vessel, is a likely solution.

6. Mining Methods

Marine dredging derives from river and harbour dredging[1]. They are extension of conventional dredging using a variety of bucket-chain dredges, suction hopper dredges, cutter suction dredges, under-water shovel dredges, and bucket-wheel dredges.

Most of these equipment are working in relatively calm waters near safe harbour facilities. The mining of submerged paleobeaches, offshore long strait coastlines submitted to heavy swell and far from safe harbour, requires more flexible system. In order to insure a more precise positioning of the dredge head to follow the high-grade sediment layers, a self propelled bottom vehicle should replace the guiding of the suction hedge from the surface ship. Rapid connection and deconnection will authorise the separation from the surface vessel when storms are announced, the surface vessel routing toward high sea to avoid to be pushed ashore. The mining vessel should be a platform large enough to operate ore processing facilities. The processed concentrates will then be loaded in ore carrier to be carried to the final processing plant on land.

7. Marine Mineral-Occurrence Database

Ifremer has undertaken an intensive bibliographic study of the marine mineral occurrence. The collected information has been stored in a computerised data base, from which descriptive summary files can be obtained. The type of deposit, contained commodities, location, legal status, operational stages, dimension of the deposit, can be

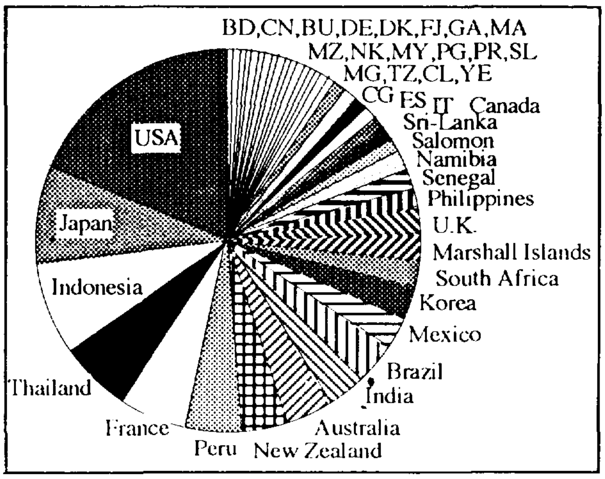

Fig. 9. Commodities of marine mineral occurrences recorded in the Ifremer data base

checked together with a literal description of the environment, the work performed and the geological characteristics.

More than 175 occurrences have been already recorded in 42 different countries (Fig 9)

Phosphate is the most frequently recorded occurrence (53), of which 33 are supposed to be linked to an up-welling of deep water, 7 situated in a coral island lagoon or an old coral sea mount, 10 are formed from the erosion of oldest deposits. Titanium is second (47) as ilmenite or rutile on beach or paleobeach, plus 27 titanomagnetite occurrences. The tin with 36 recorded occurrences, most of them being localised in South-East Asia. 14 gold occurrences have been recorded and 10 chromium (Fig 10).

1. The world's largest trailing dredger, built in the Netherlands, is capable to dredge in 50 metres water depth through a 70 cm suction tube at a rate of 800 cubic metre per hour. She is 113 metres in length with a maximum loading capacity approaching 10,000 tonns.

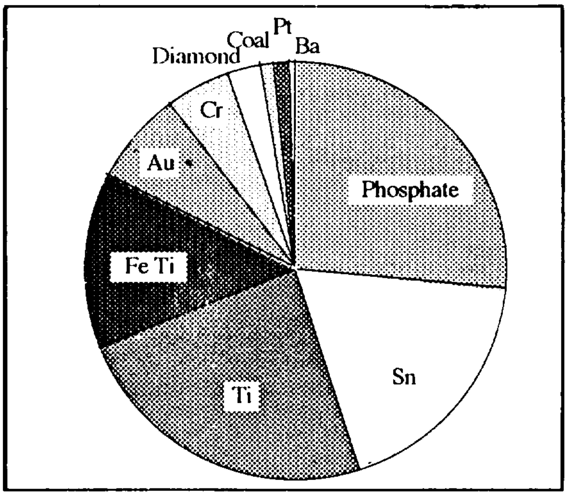

Fig. 10. Commodities of marine mineral occurrences recorded in the Ifremer data-base.

The most frequent type of deposit is beach and paleobeach structures (78), then paleovalley and paleochannel (45) (Fig. 11).

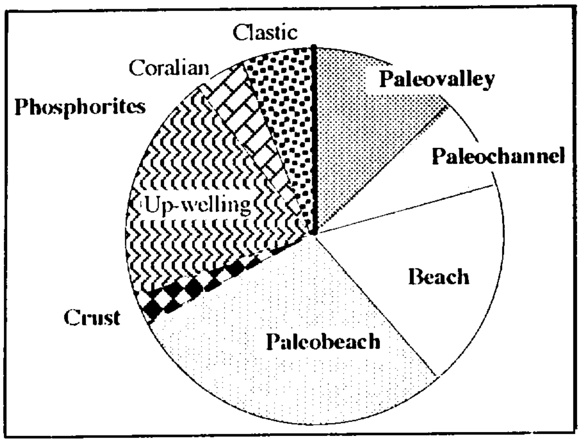

Fig. 11. Type of deposit of marine mineral occurrences recorded in the Ifremer data-base.

An offer has been made to Geological Surveys or Bureaux of Mines of all coastal states, to exchange information against a copy of the data base. Already 20% of the 140 organizations have answered favourably, but most of them recognised that they have no information available in the EEZ of their country. This confirms that most countries have not yet undertaken any appraisal of the hard-mineral resource potential of their EEZ.

This research will be carry on by enquiring the companies that have been recorded as investing or operating in this domain.

The analysis of the data will help to the designation of exploration targets. In these areas, the new exploration technics will be tested in order to determine their efficiency on identifying and estimating potential ore deposits.

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Exploration for Offshore Heavy Mineral Placers on the East and West Coasts of India

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Introduction

The occurrence of heavy mineral placers found in the beaches of East and West coast of India is well known (Brown and Dey, 1955; Mahadevan and Rao; 1960 GSI, 1949). They contain economically important heavy minerals like ilmenite, rutile, zircon, monazite, sillimanite and garnet along the coasts of Orissa, Andhra Pradesh, Tamil Nadu and Kerala. Essentially, ilmenite and titaniferous magnetite containing placers are known from Maharashtra coast (Roy, 1958). These occurrences prompted the Geological Survey of India to undertake exploration for possible heavy mineral bearing sands in the offshore sectors along this coast line to prepare a resource inventory of offshore placers for future utilisation. The fast depletion of the land resources and increased difficulties in mining the land resources due to human settlements are other contributing factors for evaluating offshore heavy mineral prospects. In addition, environmental protection requirements, particularly discouraging mining in the immediate vicinity of about 200 m belt along the coastal zone also emphasized the need to assess offshore heavy mineral sands on priority, in view of the strategic nature of these resources. The acquisition by GSI of two Research launches *R.V. Samudra Shaudhikama* and *R.V. Samudra Kaustubh* in 1984 gave impetus to this work in that these vessels have all the required navigational, geophysical and sampling equipments to undertake exploration in shallow water zones ranging in bathymetry from about 3 m to 200 m. An attempt is made in this presentation to highlight the exploration strategies adapted as they may be found useful by other developing countries in identifying and evaluating offshore placer and other nearshore resources.

Research Vessel

The Geological Survey of India has two coastal research launches of low draft which can cover shallow areas of the offshore having water depth from 3 m to 200 m. The coastal launches named as R.V. Samudra Shaudhikama and R.V. Samudra Kaustubh were built at the Delta Shipyard, Slidrecht, The Netherlands in 1983 -84. These launches are 35 m long and can accommodate 12 scientists each. The scientific equipments on board the coastal launches are given below:

Sample collecting equipments

1. Grab sampler (19 litre capacity) - Seabed
2. Piston corer (upto 25 m long core) - Seabed
3. Box corer (upto 40 cm long core) - Seabed
4. Vibro corer with electric motor and cable (for 5 m long core)
5. Boomerang Grab with radio marker -Preussag
6. Nansen bottles with reversing thermometer (for 1.7 litre capacity) - Plato B.V.
7. Corer winch
8. Hydrographic winch
9. Auxillary winches (2 off)
10. A-frame
11. Ships' crane (15 m tonnes capacity)
12. Grab sampler (160 kg)

Geophysical equipments

1. Nine element towed sparker system with hydrophone streamer winch - EG & G.
2. Hull mounted 3.5 KHz sub-bottom profiling system with EPC recorder - ORE Tech.
3. G-811 marine magnotometer with Analog recorder and interfacing to computer and winch EG & G Geometrics.
4. Record Annotator - Tech. Survey Services Ltd.
5. Side Scan Sonar System with EPC recorder - ORE Tech.
6. Under water TV camera with underwater strobe, frame, video recorder and frame monitor - OSPREY, Hitachi and Panasonic.
7. Depth recorder with digiter.

Position Fixing System

1. Trisponder master transreceiver and DDMU - Del Norte.
2. Remote transreceiver (3 Nos.) - Del Norte.
3. Computer with graphic monitor supply disc drive and graphic thermal printer - Hewlet & Packard.
4. Digital Plotter - Busch & Homb.

Exploration strategy

Initially mapping of the seabed in the territorial waters of India was taken up. Seabed mapping programme consisted of collection of grab samples on 5 km x 2 km grid and core samples on selected locations, geophysical survey and laboratory studies of samples (Senthiappan et al. 1986; 1987; Venkatesh et. al., 1987). This programme brought out (i) the nature and extent of offshore sand body, (ii) types of heavy minerals present and (iii) location of zones of higher concentration of heavy minerals. Core-sampling on wider grid (2 km x 2 km/1 km) from the area of higher concentration of heavy minerals helped in demarcating sectors with economic concentration of heavy minerals (Senthiappan et. al., 1989; Nambiar, A.R. et. al., 1991, 1989). These sectors were selected for close grid vibro core-sampling on 500 m x 500 m (Senthiappan et. al., 1991, 1992). Heavy mineral studies of these samples have brought out the nature and depth wise distribution of heavy minerals. Based on these data resources of various heavy minerals were estimated. A few bulk samples of five tonne each were collected for beneficiation studies. Lastly, a few core-samples were collected from selected locations to test the reliability of heavy mineral data.

The exploration for placer sands, in brief, involved the following stages:

Stage I : Geophysical surveys, grab sampling of seabed on 5 km x 2 km grid, rapid estimation of heavy mineral distribution and laboratory studies of heavy minerals.

Stage II : Core-sampling on wider grid (2 km x 2 km or 2 km x 1 km), laboratory studies and resource evaluation for demarcating sectors with potential economic concentration.

Stage III : Core-sampling on close grid (500 m x 500m) laboratory studies and resource evaluation in economically important concentration sectors.

StageIV : Bulk sampling (5 tonnes each) and beneficiation studies.

Stage V : Resampling and laboratory studies to test the reliability of data on heavy minerals.

The work under these stages are briefly given below:

1. Geophysical surveys

Sub bottom profilers including sparker are used to determine the sub-surface configuration of the seabed. A generalised demarcation of the geometry of the sand body is also attempted in these studies. During Pleistocene time, the sea level was very much lower than the present day. During the subsequent rise in the sea level, the beaches of past got drowned and buried under sediments deposited later. Palaeobeaches and buried river valleys which are good locales of placer accumulations can be deciphered using subbottom profilers. Scintillation probe was lowered to seabed surface at selected sampling site to know the distribution of radioactive minerals which also helps in demarcating the zones of placer mineral concentration. The presence of monazite in the Kerala beach sands and known increase of this mineral with increased heavy mineral percentage was the basis of this survey.

2. Sampling of seabed surface

In order to have a quick appraisal of the seabed and sand body disposition, the grid of 5 km x 2 km in the territorial waters was planned; the sample lines are spaced at an interval of 5 km and are perpendicular to the shore-line. Grab sampler was used for sampling. On this grid, survey of 100 km long shore line will generate about 200 samples for preliminary study of heavy mineral distribution.

3. Rapid evaluation of heavy mineral distribution

Scintillometer is useful to rapidly evaluate the distribution of heavy minerals where some radioactive mineral also occur along with other heavy minerals. All grab samples in plastic container are tested with scintillometer and classified into two groups depending on the value of scintillometer reading.

(a) Samples showing higher reading of scintillo meter.

(b) Samples showing lower reading of scintillo-meter.

Though scintillometer reading indicates the concentration of radioactive mineral like monazite, its readings are useful to interpret the distribution of other heavy minerals because the monazite always occurs along with other heavy minerals. Hence, when the scintillometer reading is higher, the total heavy mineral content of the sample will be higher. About 25% of samples from both the groups are processed in the laboratory and heavy minerals are separated using bromoform, the details of which are dealt under laboratory studies. Total heavy mineral content of these samples is calculated. Based on the total heavy mineral content of these grab samples, scintillometer readings of all grab samples are interpretted to give a general picture on the heavy mineral distribution of the whole area covered by the grab sampling. The target area of maximum concentration of heavy minerals, has been selected for detailed exploration.

Similarly, it has been found that bulk density of a sample is an indicator of its total heavy mineral content. When bulk density of the sample is more, its total heavy mineral content is also more.

These rapid methods of evaluation will be very useful when a large number of samples are generated in closer grid sampling due to the fact that grain counting practically becomes too time consuming.

4. Core sampling

Based on the results of scintillometer studies and heavy mineral studies of samples in the laboratory and geophysical survey, the target area is selected for core sampling.

Vibro-corer is used for collection of core samples of the seabed. Core samples of length upto 5 m can be collected using the vibro-corer on board GSI coastal vessels. Samples are collected on wider grid on 2 km x 2 km or 2 km x 1 km under stage II. Samples are collected on 500 m x 500 m under stage III.

5. Laboratory studies

In the laboratory, core samples are cut longitudinally and logged in details. Important features are photographed. Sandy horizon is sub-sampled at one metre interval. If there is variation in the nature of sand, it is sampled separately. Each sub-sample is dried and then thoroughly mixed. Representative sample of about 25 gm is selected using sample splitter.

The sample is treated with 15% hydrogen peroxide to remove organic matter, stannous chloride to remove iron coating and 10% hydrochloric acid to remove shell fragments. It is sieved and four fractions (-35 to +60, -60 to +120, -120 to +230 and -230 fractions of ASTM mesh size) are subjected to heavy mineral separation using bromoform (sp. gr. 2.89).

Magnetite is removed using hand magnet and ilmenite is separated through Iso-dynamic separator from the heavy mineral fraction. Sample fraction is weighed accurately to four decimals of a gram at every step of the laboratory study. More than 500 grains are identified and counted in each grain-mount of non-magnetic fraction. Weight percentage of total heavy minerals and various heavy minerals in each fraction and sub-sample is calculated.

Resource evaluation

In order to have a realistic appraisal of resources, area of influence cum polygon method and triangle method have been followed for resource estimation of heavy minerals. Resource from each method was calculated separately. Such evaluation, helps in giving resources on a reasonable confidence level for user agencies.

It is mentioned here that in the case of calculation of area, half the distance from sampling sites is taken as the area of influence. In case of polygon method, the outerline of sampling sites is the limiting factor for calculation of the area. Resource estimation of heavy minerals in each polygon/triangle has been based on the following formula:

$$R = \frac{A \times T \times D \times M}{100}$$

where R = Resource of mineral (in tonnes)

A = Area of influence of polygon/ triangle (in sq. metre)

T = Thickness (core-length of sub-sample in metre)

D = Bulk density (tonnage factor)

M = Content of mineral in sub-sample (% wt.)

In situ resource total for heavy minerals, ilmenite, rutile, zircon, monazite and sillimanite has been estimated for various slices of seabed viz. 0 to 1m, 1 to 2 m, 2 to 3 m and 3 to 4 m. These resources in the offshore sector are considered under "Inferred category" only in view of the sampling on 500 m x500 m grid.

The resources of heavy mineral sands estimated by Polygon method and Triangle method do not vary much. The differences are within +5%. However, the average value of resources of heavy minerals estimated by Polygon method and Triangle method may be taken as the nearest probable estimate of resources available.

CASE HISTORY

I West Coast of India

Mapping of seabed in the territorial waters over an area of 2390sq. km on 5 km x 2 km off west coast on board Research Vessel Samudra Shaudhikama during 1984 - 86 has revealed the extensive occurrence of sands off Quilon - Kanyakumari. The sands are medium to coarse grained and contain heavy minerals like ilmenite, sillimanite, rutile, zircon, monazite, garnet, leucoxene, kyanite and ferromagnesian minerals. The concentration of heavy minerals is 4 to 7% over 130 sq. km area off Quilon-Varkala and 4 to 8% over 150 sq. km area off Taingapatnam-Karichal. These areas of higher concentration in seven sectors were taken up for exploration under stage II and III.

Varkala sector

During 1986 - 87, an area of 48 sq. km was covered by vibro core sampling on 2 km x 2 km off Varkala under stage II. The water depth varied from 15 to 40 m. Twelve cores were collected and 73 sub-samples were studied for heavy minerals. At 0 to 1 m slice of seabed the raw sand contains 5 to 9% of total heavies over an area of 9.7 sq. km. At 1 to 2 m depth, it has 5 to 9% of total heavies over 4.4 sq. km. The concentration decreases at the deeper slices of seabed and is less than 5%.

Based on the results of heavy mineral studies of vibro cores collected under stage II an area of about 14 sq. km having maximum concentration of heavy minerals was selected for investigation under stage III. An area of 14 sq.km was covered by close grid vibro core sampling on 500 m x 500 m grid. The water depth in the area ranges from 10 m to 20 m. A total of 55 cores were collected, the length of which varied from 0.70 to 4.50 m. Logging and sub-sampling at 1 m interval of these cores generated 134 sub samples for laboratory studies.

Sediment : Medium to coarse grained sand with heavy minerals is the predominant constituent of the sediments in the cores. Clay, pebbles and pieces of laterite, peat and decayed wood are obtained at the bottom of many cores. The thickness of sand varied from 0.67 to 4.50 m.

Content of total heavy mineral : The total heavy mineral content in the sub-samples varied from 1 to 12%. To understand the nature and distribution of various heavy minerals at depth, contour maps have been prepared for various slices of seabed viz. 0 to 1 m, 1 to 2 m, 2 to 3 m and 3 to 4 m. At 1 to 2 m slice, most of the area is covered by 2 to 6% heavy minerals with isolated peaks of 8 to 9%. The content of heavies is generally less than 4% in deeper slices of seabed. The weighted average of heavy mineral content in vibro cores varies from 1.41 to 9.62% whereas most of the cores have 2 to 6%.

Distribution of various heavy minerals : Various heavy minerals have been identified and more than 500 grains counted in each of 552 grain-mounts. The dominant heavy mineral is ilmenite followed by sillimanite, rutile, zircon, leucoxene, monazite and garnet. Other heavy minerals in minor quantities include magnetite, limonite, pyroxenes amphiboles, kyanite, biotite, sphene, spinel, staurolite, epidote, zoisite, clinozoisite and pyrite.

At 0 to 1 m slice of seabed, about half the area contain more than 4% ilmonite. A noteworthy feature is that area along and near the shoreline contain less ilmonite compared to far off area. This feature continues at depth also. A major part of the area contain 0.2 to 0.5% rutile. The concentration of zircon varies from less than 0.1 to 1.33%. Monazite content varies from less than 0.05 to 0.29%. In major part of the area, 1 to 2% concentration of sillimanite is noted. Unlike other minerals, sillimanite is concentrated more in the area nearest to the shoreline.

At 1 to 2 m slice of seabed, the area is mainly covered by less than 4% ilmenite except in a few patches of higher values (4 to 7%). Major part of the area is covered by 0.1 to 6.4% rutile with high concentration of 0.4 to 0.6% of rutile in the western part. The content of zircon is less than 0.3%, monazite less than 0.15% and sillimanite less than 1% in major part of the area.

At 2 to 3 m and 3 to 4 m slices of seabed, number of samples available is less and the concentration of various minerals is less than top 0 to 1 and 1 to 2 m slices.

Factor analysis

R mode factor analysis of heavy mineral and grain size data was carried out to find out the probable factors responsible for the local variations in the distribution of heavy minerals. Factor-I is the result of contribution of sillimanite and zircon in fine sediments carried by two small streams draining the area. Factor-II is due to the positive association of hydraulically controlled variables like mean, standard deviation, skewness and kurtosis. Factor-III is due to the contribution of ilmenite, rutile, leucoxene and monazite following in mainly 120 fraction.

Geochemical aspects

An effort is made to see whether chemical techniques can be used to scan the area for the rapid estimation of heavy mineral content in the samples with a certain degree of confidence. The chemical data, particularly critical elements like TiO_2, TiO_2 FeO, P_2O_5 and Zr_2O_3 may be used for the estimation of rutile, ilmenite, monazite and zircon respectively in the samples. The bivariate plots drawn from the data viz. TiO_2 vs rutile, TiO_2 FeO vs ilmenite, etc. can be used for the rapid estimation of heavy mineral content in the samples from similar areas of known provenance.

Further, the chemical data can be correlated with the heavy mineral data derived from the heavy mineral analysis and grain counting. The TiO_2, FeO, Fe_2O_3 and P_2O_5 contents in the samples can be correlated with the weight percentages of the heavy minerals like rutile, ilmenite and monazite in the samples to delineate the relationship between the chemical and heavy mineral data. Matrices of correlation coefficient have been calculated to understand the relationship between chemical and heavy mineral data of the samples. TiO_2 shows positive correlation with ilmenite, ilmenite + rutile: ilmenite + rutile + leucoxene since TiO_2 is chiefly fixed in these minerals. Further, TiO_2 shows positive correlation with total heavies as ilmenite is the predominant heavy mineral in the samples.

The relationship between chemical and heavy mineral data was examined by bivariate plots viz. TiO_2 vs ilmenite; TiO_2 vs ilmenite + rutile and TiO_2 vs ilmenite + rutile + leucoxene. These plots show a broad, sympathetic relationship ($r = 0.48$)

between them which may be useful in rough estimation of ilmenite from the analytical value of TiO_2 in the samples.

The plots TiO_2 + FeO vs ilmenite ; TiO_2 + FeO vs ilmenite + rutile + leucoxene and TiO_2 + FeO + Fe_2O_3 vs rutile + ilmenite + leucoxene do not show any correlation. This may indicate that FeO has also been contributed by other heavy minerals like amphiboles, pyroxenes and iron oxides in the samples.

P_2O_5 does not show any correlation with monazite content in the samples. This indicates that P_2O_5 has been contributed by not only monazite but also by the other components like organic matter and calcareous matter in the samples.

Beneficiation studies

During the F.S. 1988 - 89 and 1989 - 90, a total of five bulk samples were collected from offshore sectors and sent to Indian Rare Earths Ltd., Chavara, Kerala for beneficiation tests (for separation of ilmenite, rutile, zircon, monazite, sillimanite and garnet). Each sample weighed about five tonnes. Out of the five bulk samples, three were from Chavara sector and two from the Varkala sector. Results of beneficiation studies of only one bulk sample from the Chavara sector are available and very encouraging. It contains 11% ilmenite, 3% rutile, 3% zircon, 0.2% monazite and 2.4% of sillimanite.

Resampling for reliability of data

To test the reliability of heavy mineral data available from the exploration carried out so far, resampling programme was taken up during F.S. 1989 - 90. Eleven vibro cores were collected from the sample locations from where core samples were collected during previous field seasons. Out of the 11 cores, seven were from Varkala sector and four from Chavara sector. The core length varied from 0.20 m to 3.87 m. Logging and sub-sampling generated 26 sub-samples for laboratory studies. Processing of laboratory data is under progress.

II East coast of India

The first generation work on board R.V. Samudra Kaustubh in the territorial waters off Gopalpur, Orissa enabled the scientists of GSI to collect vital seabed samples and morphological data which, when processed in the laboratory ashore, heralded a promising multi-mineral placer deposit within a stretch of seven kilometers off the coast. This was the dawn of a significance work in 1984 - 85 that presaged new hopes of hitting upon prospective offshore placers. The following years evidently put the northern shelf along the eastern coast as a target area for minerals like rutile, zircon, monazite, sillimanite and garnet that are known as economic heavy minerals.

Between F.S. 1984 - 85 and 1991 - 92 of G.S.I., an area of about 6300 sq. km in the territorial waters off the coast between Sonapurapeta, A.P. and Mahanadi estuary, Orissa has been covered over a stretch of about 280 km (Sengupta, R., et. al., 1985; 1986; 1988; 1989; 1990).

Sampling, methodology and results

Grab sampling on a grid of 5 km x 2 km was carried out during the cruises of first two field seasons covering an area of about 3800 sq km between Sonapurapeta, A.P. and Puri, Orissa. The first phase of sampling yielded 406 grab samples which were processed for size and heavy mineral analysis. Selected samples were taken up for geochemical analysis also. Heavy mineral content of these samples were found to vary between 1.54 and 30.85 wt.% over an area of about 2000 sq km. The heavy separates in different fractions between 165 u & 500 u were studied and counted under microscope to arrive at constituent-wise heavy mineral content of the sediments.

The encouraging results pushed the study further to carry out a closer grid (2 km x 1 km) grab sampling which was followed by vibro coring to delineate the subsurface extension of the placer and vis-a-vis its heavy mineral content. The collection and study of about 300 grab samples and 100 vibro cores enabled to identify a prospective target area of about 630 sq km in the inner shelf off Orissa. Laboratory work revealed that the HM content varies between 5 and 30 wt.% with persistence of sandy horizon atleast upto 4 m b.s.f.

In order to check the reliability of the data thus collected, bench scale on bulk sample was carried out in the IRE laboratory, Chatrapur. Initially 3 tonne of bulk sample -1 ton each from 3 zones of 5 - 10 wt.%, 10 - 15 wt.% & 15 - 20 wt.% were collected and total heavy mineral content was determined. Results matched well with the data obtained in our study. Subsequently, 5 tonne of bulk sample was collected on a grid of 1 km x 1 km over an area of 16 sq. km. This bulk surficial sample was analysed at the IRE laboratory. This analysis was carried out to obtain mineral-wise data. The comparison of the results obtained from the Marine Wing Laboratory of GSI, Calcutta and IRE, Chatrapur is furnished in the following table (Table-1).

Table 1: Total mineral-wise placer concentration Data (Wt. %)

Minerals	GSI Data	IRE Data	
	By bromoform separation and grain counting method	Sieving Data	Bench scale Data by pre-concentration test
HM content (Bulk)	9.31	9.3	10.1
Ilmenite	4.98	4.2	5.2
Sillimanite	1.92	1.6	1.7
Garnet	1.48	2.8	2.6
Monazite + Zircon + Rutile (MZR)	0.52	0.45	0.30
Others	0.41	0.30	0.30

The table presented above reveals that the data obtained in our laboratory with respect to initial sample of about 10 kg match well with the same obtained at the IRE Laboratory against bulk samples of 5 tonnes.

Study of the vibro core samples points to a strong vertical variation in concentration of heavy minerals between 0.74 and 10.14 wt. %. The lower level of the sand is generally poorer in grade and, as such, an area of 632 sq. km. with more than 5 wt.% HM in the surficial sediment reduces to about 22 sq. km with more than 5 wt.% HM at 1 m subsurface level. The potential area will be only about 31 sq km at 5 wt. % of HM if 2 m subsurface level is considered. Details of mineral value at different levels are furnished below (Table-2):

Table 2: Average bulk HM along with average constituent HM percentage (wt.%) at different levels

Mineral	Surface level	Subsurface level at 1 m	Subsurface level at 2 m
Average Bulk HM	9.31	5.46	4.37
Average Ilmenite	4.98	2.92	2.43
Average Sillimanite	1.92	1.15	0.90
Average Garnet	1.48	0.84	0.69
Average MZR	0.52	0.28	0.16
Average other minerals	0.41	0.27	0.19
Mutual Ratio	Ilm:Sill:Gt:MZR	9.6:3.7:2.8:1	10.4:4.1:3.1 15.2:5.6:4.3:1

Comparison of the range and mean of heavy mineral content of surficial as well as subsurface samples of different offshore sectors is presented below (Table-3 & 4).

Table 3: Comparison of the range and mean of HM content of different offshore sectors (surficial sample)

Sector	No. of sample	Area covered (sq.-km)	Wt. % of HM in bulk Low	Mean	High	EHM/C*	EHM/T+
A	157	450	0.32	7.17	30.85	76.75	6.84
B	25	300	1.09	5.54	16.79	70.51	5.20
C	56	720	0.30	4.68	21.90		
D	133	1345	0.03	3.57	13.52		
E	176	1140	0.42	2.47	7.49		

* EHM/C : Economic Heavy Minerals (defined as the sum of wt. percentages of ilmenite, rutile, zircon, sillimanite and monazite) expressed as a wt. percentage of total HM in the sample.

+EHM/T : Economic Heavy Minerals expressed as a wt. % of the total sample.

Table 4: Results of heavy mineral analysis of vibro core samples from the innershelf off Orissa coast, Bay of Bengal

Off-shore study area	No. of samples (Sub-samples)	Wt. % of HM Min	Mean	Max	Mean wt. % EHM/C	EHM/T section)	Average wt. %of HM (per
I	16 Vcs (62)	0.2	3.8	7.45	*80.74	+3.32	3.85/161cm
II	32 Vcs (164)	0.74	4.75	10.14	+82.49	+4.42	4.85/243 cm
III	23 Vcs (62)	0.32	4.76	16.53	-	-	4.67/210 cm

* Values for top 1 m involving 38 subsamples.

+ Values for top 2 m involving 100 subsamples.

- Data not available.

Mineralogy vis.a.vis. chemistry

Seabed samples were subjected to chemical analysis to know their trace and few RE elemental concentration. The heavy mineral content of sandy sediments is also reflected through the trace and RE elements chemistry. TiO_2 value varies between 0.75 and 4.00 wt. % for which minerals responsible are ilmenite (0.85 to 16.53 wt. %) and rutile (0.02 to 0.65 wt. %). Ce and La content of the samples vary between 500 and 1000 ppm, and 50 and 200 ppm respectively. Zr value is generally variable between 150 and 400 ppm when zircon proportion is between 0.10 and 0.80 wt. % but the sample containing 3.0 wt. % of zircon analyses more than 1000 ppm of Zr. Thorium content is below detection limit (i.e. 500 ppm) in most of the samples but 12 samples register the values between 500 and 800 ppm. Vanadium is generally variable between 20 and 60 ppm (average 40 ppm) but the samples which analyse Ce is slightly higher order viz. 700 to 1000 ppm or above, the V-value ranges between 80 and 150 ppm. Interestingly, this correlation is accompanied by higher values of La in the range of 100 to 700 ppm.

Chemistry of ilmenite

Ilmenite is the dominant member of the heavy mineral assemblage and as such, the commercial prospect of this deposit is fairly bright. The TiO_2 content of ilmenite in world's known economically viable deposits ranges from 50 - 55 in slightly, weathered assemblage to about 90% in deeply altered assemblages. The chemistry of ilmenite of beach as well as offshore occurrence in Gopalpur-Chatrapur are is presented in Table-5.

About 95% of ilmenite is used for pigment manufacture. TiO_2 pigment is produced commercially by sulphate and chlorination processes which require different chemical specifications of ilmenite. About 50\% or slightly less $TiO_2$2 content of ilmenite of the present area suggests that these are least affected by weathering which is also supported by observation of ilmenite grains under microscope. And these ilmenite are suitable for sulphate process pigment manufacturing as the TiO_2 content is well within the required specification of 45 - 58%. Other chemical parameters like Fe_2O_3, FeO, Al_2O_3, CaO also satisfy the requirement of sulphate pigment industry.

Table 5: Chemistry of ilmenite of beach and offshore occurrences in Gopalpur Chatrapur area

Oxides	1	2	3	4	5	6	7	8
SiO_2	0.56	1.06	0.50		0.64			
Al_2O_3	1.52	1.04	1.30	1.77	1.17	1.50	1.69	2.49
TiO_2	48.75	50.75	50.35	48.62	48.36	49.23	50.57	47.81
FeO	42.27	41.02	40.66	37.70	43.46	45.06	40.96	43.07
Fe_2O_3	2.23	2.46	1.12	4.52	3.21	1.14	2.10	1.46
CaO	0.20	0.29	0.17	0.35	0.26	0.35	0.39	0.31
MgO	0.81	0.34	0.71	0.34	0.73	0.32	0.41	0.34
MnO	0.54	0.60	0.80	0.75	0.54	0.59	0.49	0.59

Samples 1 - 4 : Offshore samples

5 - 8 : Onshore samples

Resource appraisal

Heavy mineral analysis of the surficial as well as vibro core sub samples from the inner shelf off the coast between Sonapurapeta, A.P. and Malud, Orissa over a stretch of 84 km reveals that the sand body with more than 5 wt. % of HM content occupies about 632 sq. km on the surface and reduces to about 232 sq. km at 1 m bsf. Isogram map at 1 m bsf measures a sand body of 600 sq km containing a cutoff grade of 3 wt. % of heavy minerals.

Offshore mining

The IRE is at present engaged in dredging and wet concentration of heavy mineral placers in the backwaters of Chavara at very shallow water depths. It has shown interest to venture into nearshore shallow waters of 10 to 20 m bathymetry with required changes in designing of dredgers and concentrators to suite the requirements of open sea conditions. The expertise therefore is not an unsurroundable hurdle to win these strategic mineral resources, though a period of experimentation and pilot studies have to preceed actual commercial scale operations. There is a scope for enterprising investors to collaborate with IRE not only for developing machinery for mining but also on board concentration of heavy minerals from raw sand similar or a variant of the ones deployed in shallow backwaters.The CMERI at Durgapur is engaged in developing unmanned undersea vessel which will perhaps be of use in dredging raw sand. Therefore, it is felt, expertise on these lines will open up vast scope of winning long stretches of heavy mineral sands with economic heavy mineral concentrates along the coastal stretches of Kerala, Andhra Pradesh and Orissa and also along Tamil Nadu.

Environmental aspects

It is needless to say that the zone within which the heavy mineral sands are delineated are also areas where intense fishing activity is prevalent. The environmental impact of mining heavy mineral sands as fishing is only known in sedimentation way in that the perennial food resource is likely to be last, if proper care is not taken in mining to minimise or eliminate sea pollution. Pilot scale studies to evaluate nature of pollution and remedial requirements or a revision of mining methods are called for, as winning these mineral resources also is likely to become imperative, in not distant a future. Such studies, being of promotional nature for utilisation of resources are bound to be sponsored by Governmental agencies. Geological Survey of India though, has all the capabilities, expertise and ship board equipments to undertake the studies, expects the studies to be sponsored by user agencies or by Department of Ocean Development. This is one of the fields where R&D efforts are needed in the near future.

Conclusions

Geological Survey of India, has, over ten years gained valuable expertise in prospecting offshore placer minerals and has the man power, ship and onboard equipments to undertake these studies, systematically and methodically starting from seabed mapping to resource evaluation. The need for improvised mining and concentration of heavy mineral placers from raw sand in an open sea domain is a field which needs further development of expertise both in terms of equipments, machinery and environmental studies to present the important food resources of this delicate shallow marine domain. UNIDO may consider exchanging expertise of GSI in offshore prospecting to studies on offshore mining and reducing a tundest adverse environmental impacts. This way both developing and developed countries can co-operate to utilise rich shallow offshore mineral resources in several developing countries.

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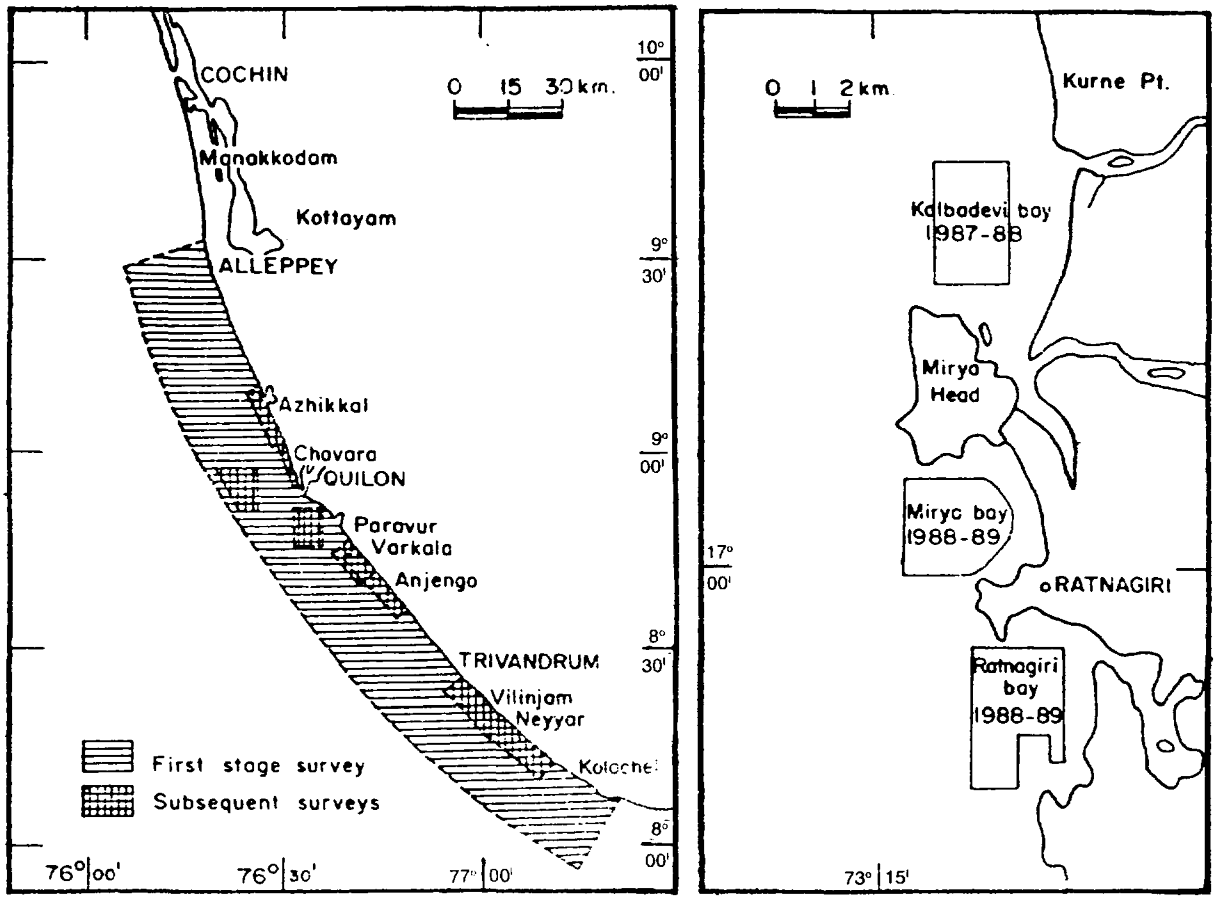

Fig. 1 . Status of heavy mineral investigation off West coast of India a. off Kerala coast, b. off Konkan coast

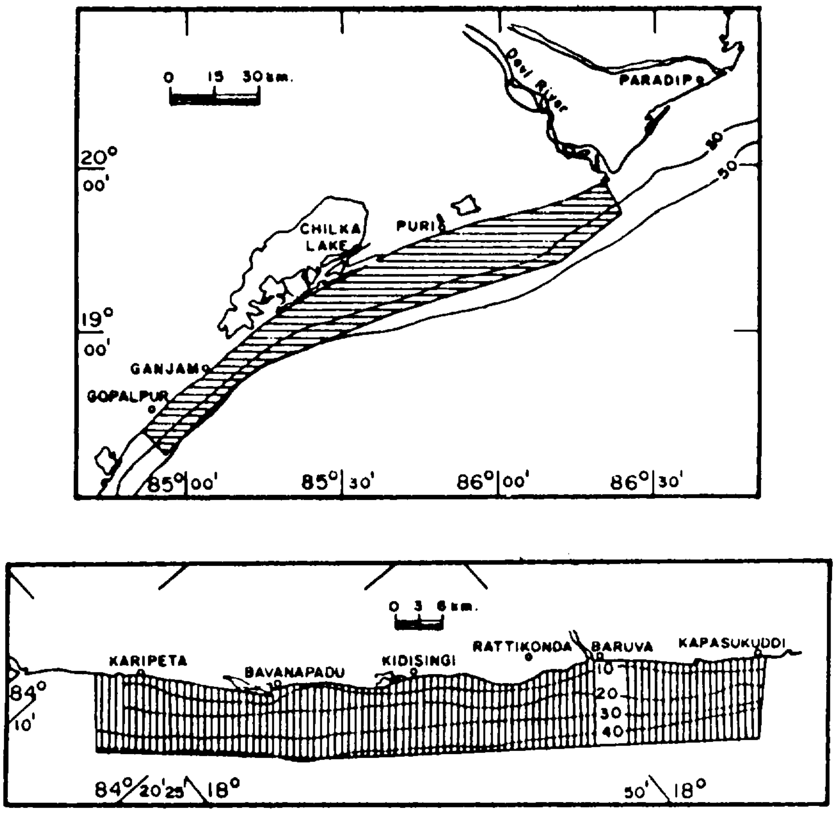

Fig. 2 . Status of heavy mineral investigation off East coast of India a. off Orissa coast, b. off Andhra coast

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Processing of Seabed Minerals

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1. Introduction

Manganese nodules represent the largest metal bearing seabed deposit. Exploitation of nodules assumed importance because of the metal production potentialand because the developed technology can begainfully utilized for the processing of similar sea bed minerals, such as cobalt crusts.

During period of 1970 to 1980, the world over witnessed large involvement of several research institutions, laboratories and consortia for development of viable process routes. Subsequently the pace of activities had considerably slackened because of various factors like slow growth of nickel market vis-a-vis economic viability, development of mining capabilities, high costs of R&D etc. Till date no one has processed nodules continuously over a long interval of time at pilot plant scale. As against the stage of development related to process development for nodules, metal extraction from commercial processing of land based copper, nickel or cobalt bearing materials have incorporated various process improvements. The last few years have witnessed the introduction of several new reagents for metal processing. Some of the earlier nodules processes developed may have already reached some stage of obsolescence. Since most of the cost of producing metals from nodules are related to the processing sector, constant updation of R&D efforts is required to keep the developed process competitive in the volatile metal markets.

2. Processing Options

Both pyrometallurgical and hydrometallurgical processes for nodule treatment have been examined. As a result of the complexity and polymetallic nature of nodules, it is not possible to use purely pyrometallurgical techniques to produce separate metallic products of the contained metal values. However, as a pretreatment step, pyrometallurgy can be used to concentrate the metal values and alter the physical, chemical and mineralogical characteristics to achieve enhanced selectiveness and dissolution rates during subsequent hydrometallurgical processing. Also the total amount of material sent to leaching can be decreased thereby affording reduction in processing costs.

Pyrometallurgical processing options examined include reductive roasting, reductive roasting and smelting, chloridising roast and sulphate based treatment process. Hydrometallurgical treatment options without a pretreatment step at high temperature includes direct ammonical leaching, hydrochloric acid leaching and sulphuric acid leaching. Reagent recycling may be elegantly conceived in a hydrochloric acid leaching system through the use of suitably designed pyrohydrolysis reactors. Reagent recycle assumes particular importance in cases where reagent consumption/ costs are high, for example consumption of HCL for manganese dissolution in the chloride leach route. The energy costs involved in reagent recycle are often substantial and are to be minimized through suitable process design.

Further description for the various process alternatives are given in the following sections. The names of various companies cited may be linked to the concerned consortium by reference to Table 1.

Table 1: Consortia and Pioneer Investigators

NODULES CONSORTIA	
"	KENNECOTT CONSORTIUM (KCC)
"	OCEAN MINING ASSOCIATES (OMA)
"	OCEAN MANAGEMENT INC. (OMI)
"	OCEAN MINERALS COMPANY (OMCO)
REGISTERED PI'S	
"	INDIA
"	JAPAN
"	FRANCE
"	RUSSIA (ERSTWHILE USSR)
"	CHINA
"	INTER OCEAN METAL

3. Pyrometallurgical Treatment

Several treatment options exist. These consist of reduction roast, reduction roasting and smelting, chloridising roasting, seggregation roasting and sulphation roast. Descriptions of different variants involving reduction roasting option are abundantly available in the literature. The status with regard to the various options are given below:

3.1 Reduction Roasting, Solubilisation

3.1.1 Reduction Roasting

In the early seventies, Kennecott Copper Corporation had carried out detailed work at fairly large scale of operation for pre-treatment of nodules by the reduction roasting option. The effects of different roasting variables utilizing synthesis gas mixture have been described in details (1). The basic studies show the relatively lower extraction recoveries for cobalt as compared to copper, nickel and molybdenum. Subsequent patents (2) and (3) indicate a preferred embodiment for larger scale of operations involving drying, calcination and reduction steps. The plant feed at Kennecott Copper Corporation consisted of wet nodules introduced into fluid bed dryer/calciner (12", propane/air fired) and then subsequently reduced by synthesis gas in the reducer. Palletisation of nodules utilizing Bunker C- oil/coal with/without bentonite (4) (5) produced pellets ranging from 1/2" to 3/8" size which has been conceptually suggested to be reduced in a travelling grate furnace. Several variants of the reduction/roast technology exists: for a version that was followed at Sumitomo Metal Corporation (6), the reducing agent (coal) was mixed with the pellet and the mixture reduced. Alcohol/aldehyde containing reducing agent has also been described (7). Effect of carbonaceous reducing agents has been explicitly described by Wilder (8). International Nickel Company (9) has also reported selective reduction of nodules under different reducing atmospheres, although the company emphasis had subsequently shifted to reduction roasting/smelting route. Recent Indian work has been also reported on reduction roasting subsequent to pelletisation (10). Haynes et. al (11) have reported an updated process flow sheet based on bench scale work at USBM on this route and the configuration suggested is substantial the same as reported by Kennecott Copper Corporation. It may be noted that cobalt recoveries reported by various investigators have scarcely exceeded 70%.

The reduction roasting studies carried out by different research organisations/consortia have largely assumed that a 3-metal recovery route is preferred. Kennecott Copper Corporation reports that the process economics would have to be viable without the manganese recovery option. (12) Kenecott Copper Corporation claimed to have finished nodules research in early 1974 (13). During 1973, a 1/2 ton per day pilot plant was successfully run for about 40 days and no process shutdown conditions were reported.

3.1.2 Solubilisation of Reduced Nodules

The reduced nodules are solubilised through ammonical medium leach. Different leaching media have been used. Typical leach solution Composition for an ammonical-ammonium carbonate leach is (14) : Cu - 5.7 gpl, Ni - 6.2 gpl, Co - 0.2 gpl, NH_3 - 9.0 gpl and CO_2 - 55.0 gpl. It is to be noted that such compositions would result only when high recycle solution loads are used typical of processing of laterite leach liquors. Detailed solution compositions are scarcely reported : the impurity build up for high solution recirculation loads needs to be closely monitored.

3.1.3 Further Comments

Large scale test work has been reported by Kennecott Copper Corporation and equipment scale up considerations have received attention. It may be noted that out of the various consortia members, only Kennecott Copper Corpn. has reported large scale work. Presently, no activities are reported by any of the different consortia members.

3.2 Reduction Roasting, Smelting, Solubilisation

3.2.1 Reduction Roasting & Smelting

Sridhar et. al have reported (15) the work carried out by International Nickel Company wherein the nodules were dried, dehydrated and selectively reduced at 1000° C at a total residence time of about two hours in a counter currently heated kiln using substoichiometrically fired fuel oil and then transferred to an electric furnace for smelting the prereduced nodules at 1400° C producing a fluid slag and molten alloy. Prior to smelting, prereduced nodules were blended with coal for additional reduction as well as maintaining reducing atmosphere during smelting. Alloys with 1.5% Mn were produced for optimizing metal recoveries. Some impurities in the nodules were substantially reduced showing that it would be necessary to subject the alloy to further processing.

The further processing steps consisted of oxidation (for manganese removal), sulfidization and converting for elimination of iron. It was not feasible to remove iron completely for ensuring high recovery of cobalt. Typical matte and slag compositions attained were: 25% Cu, 40% Ni, 5% Co, 5% Fe, 20 - 25% S (matte) and 0.04% Ni, 0.08% Cu, 0.12% p, 2.3% Fe, 34.3% Mn (slag). The slag was further smelted at 1620° C for producing ferromanganese, although stockpiling of the slag is equally possible.

M/s. Elkem have also reported (16) studies on a identical process route. However, these were more oriented towards production of the alloy and recovery of Fe-Si-Mn from the slag. Large scale tests are known to have been conducted for the smelting step.

Messers Societe Le Nickel, France (Presently Imetal) have reported (17) prereduction smelting studies production an alloy of 47.3% Ni, 35.1% Cu, 10.2% Fe and 0.47% Mn using anthracite coal as the reductant. Contrary to other approaches, the alloy is directly solubilised.

US Steel as a part of a consortium have carried out smelting tests (18). The USBM have also conducted laboratory scale smelting tests (19), Simulating reduction, Smelting and alloy oxidation steps. Smelting tests conducted by minemet Recherche, a subsidiary of Metal Europe have reportedly given excellent recoveries on four metals (45).

3.2.2 Solubilisation

Information on solubilisation of matte from nodules are scantly available. Sridhar et. al (15) cites pressure digestion (110° C, 1.0 MPa oxygen pressure, 120 gpl H_2SO_4)which resulted in 99% dissolution of Cu, Ni, Co and Fe. A solution containing 40 gpl Ni, 24 gpl Cu and 5 gpl Co resulted for further treatment (impurity removal), metal recovery). Dissolution of the alloy during aqueous chloride leaching has been described by societe Le Nickel (17) producing a solution containing large quantities of iron.

Although large scale work on matte leaching has scarcely been reported, it is interesting to note that virtually an identical material is being commercially leached by the Sheiritt sulfuric acid pressure leaching process (20, 21, 22) which involves two stage leaching for maximising Cu and Ni recoveries.

3.2.3 Further Comments

The reduction roast smelting route uses conventional equipments the like of which are available in commercial scale at the desired scale of operation. No major equipment scale up consideration are likely to be limiting towards commercialisation of a nodule process. No activities are reported at present on this route.

3.3 Seggregation Roasting, Solubilisation

3.3.1 Seggregation Roasting

Seggregation roasting has been studied by Hoover (23) using $CaCl_2$ and batch retention time of two hours at different roasting temperatures. Beil (24) and Sridhar (25) used sulfur/sulfur bearing reagents along with a reducing agent at around 1100 deg.C. Sridhar (25) reports a concentrate composition of 15 - 30% Cu, Ni and Co. Grigoryeva et. al (26) used coke, $CaCl_2$ and NaCl mixture at 900° C and reported recoveries between 80 - 90% for Cu, Ni, and co and a concentrated alloy phase. Amodified process(27) involving recycling of magnetic separation middlings yielded a Concentrata Containing as high as 35% Ni, 2% Cu and 3% Co with overall metal recoveries exceeding 80%.

Equipment development and lowering of process energy requirements are constraints to be overcome during repetition the developmental phase. Pilot plant studies have been reported for seggregation roasting of laterite ores (28) and scale up considerations have featured.

3.3.2 Solubilisation

No work has been reported on further solubilisation of the nodules concentrate; presumably this would involve a pressure leaching step similar to the treatment of metal concentrate from smelting.

3.4 Sulphation Roasting, Solubilisation

3.4.1 Sulphation Roasting

Messrs Deep Sea Ventures which had an earlier operating agreement with OMA have reported results on sulphalisation roasting utilizing iron sulphide (29). Roasting in the pressure H_2SO_4 and a reductant has been described in a patent assigned to UOP (30). Sulphatising roasting for nodules has also been described by Brooks et. al (31) in which batch fluidized bed roasting was conducted using a mixture of 10 - 20% SO_2 and air. Water soluble sulphates for Co and Mn exceeded 90% whereas for Ni and Cu, a maximum of 77% sulfatisation was reported.

Sulfation temperatures were between 400° C to 625° C with variable holding times.

Messrs Deep sea Ventures have also reported results (32) on SO_2 roasting, preferable in a fluid bed reactor under ambient conditions using pure SO_2 gas and subsequently carrying out differential solubilisation of the sulphated nodules.

3.4.2 Solubilisation

Solubilisation of sulphated metal values have been reported (31) either through use of an acidic aqueous medium pH 2 in single stage or in two stages using aqueous leach at pH 5 and SO_2/air leach of the leach residue. The objective of the later approach is to solubilise the manganese preferentially during first stage of leaching. Detailed description of others solubilisation procedures are scantly reported.

3.5 Chloridisation Roasting, Solubilisation

A typical scheme studied by Messrs Deep Sea Ventures using either HCl or Cl_2 vapours in the presence of carbonaceous material has been described in a patent (33). When chlorine vapours are utilized, the nodules are crushed, blended with carbonaceous material, palletised and chlorinated in a suitable reactor. Overhead vapours are condensed and mixed with leach solution obtained by further leaching of the residue. Leaching may be conducted by using aqueous HCl having a pH of around 2. A typical pregnant liquor compcsition(in gpl) reported is Mn - 68, Cu - 405, Ni - 96, Co - 0.065. Bench scale studies conducted at USBM (19) have also reported results obtained by using HCl gas as the chlorinating agent followed by dilute HCl leach.

4.0 Hydrometallurgical Processes

The hydrometallurgical process options include direct leaching of nodules involving ammonia, chloride or sulphate media. The ammonical system consist of processes such as "Cuprion" (Kennecott Copper Corpn.) and ammonium sulphur-di-oxide leach. The chloride systems involve direct leaching in hydrochloric acid medium with subsequent variations in the downstream processing of chloride solutions. Sulphate medium investigations include high temperature - high pressure leaching or moderate pressure conditions of acid leaching. Another variant uses of SO_2 as an aqueous phase reductant in the acidic medium. Depending on particular process and its conditions, manganese may be recovered in solutions or left back in the tailings. Descriptions of various processes are given below.

4.1 Acid Leaching

Han et. al (34) and Ulrich et. al (35) have examined acid pressure leaching of nodules. With oxygen partial pressure of 100 psi (total pressure 300 psig) and initial pH of 1.63, reactions time of 60 minutes, substantial nickel and copper recoveries were obtained by Han (34) and still higher recoveries by Ulrich (35) at different leaching conditions. Cobalt recoveries were, however moderate (35). The Bureau of Mines (19) have published results at higher pressure of leaching (35atm) at 245° C. claiming 90% recovery of Ni, Cu and Co. With a view to minimise scale formation effects at higher temperatures of leach, Subramaniam et. al (36) have studiea a two stage acid leaching procedure involving first stage leaching at temperature of 100° C.

Messrs Duisberger Kupperhutee have reported that 3 hours of dissolution at 200° C and acid concentration of 90 gpl results in approximately 90% dissolution of Ni and Cu and 77% dissolution of Co. USBM report (19), however, suggests that cobalt recoveries may be higher when higher temperatures of dissolution and increased residence time are considered, akin to the Moa Bay conditions of leaching laterites. It is not clear from the published data at what temperatures the nodules commenced reacting with the repetition acid: substantial dissolution may also occur at lower temperatures during the start up period of the autoclave if the nodules are exposed to the reactant during this period (38).

Messrs OMINCO during 1973 contracted the Colorado School of Mines for undertaking process development of H SO based leaching (39). Pilot scale testing was also undertaken but the results of the tests are not known.

Acid consumptions for various studies ranged from 3 kg/kg to 5 kg/kg of nodules, except for the work of Han et. al (34) showing that high oxygen pressures are required to minimise acid consumption. Work carried out by CEA, France (40) has been reported in a patent in which the nodules are attacked by a sulfur-di-oxide-sulfuric acid mixture. Khallafalla et. al (41) have carried out nodules dissolution in acidic sulphur-di-oxide solution and it was shown that reductive manganese dissolution could be effectively achieved. Messrs CEA, France have operated, other than the pilot scale work carried at Colorado School of Mines, a pilot plant on the early 1980's based on reductive leaching in H_2SO_4 medium at a capacity of 5 Kg/hr. of nodules feed based on pressure leaching at moderate temperatures. The ground nodules is partly attacked with a sulphur bearing gas to form Mn ions for catalysing recovery of cobalt. The rest is preleached in counter current leaching unit. The two parts are combined and leached with sulphuric acid at 180° C for two hours.

4.2 Chloride Leaching

Messrs Deep Sea Ventures have concentrated their efforts on direct leaching of manganese nodules in hydrochloric acid (42, 43). The nodules are ground to -500 m and then condtacted counter currently with 11 M HCl at 100° C in a five stage leaching system. Approximately half of the hydrochloric acid is oxidized to chlorine which has to be sold or reconverted to HCl by reaction with H. Messrs MHO (Metallurgic Hoboken-Overpel) of Belgium (44) have suggested that chlorine from the leaching reactors is passed to the end of the process for oxidation of manganous chloride solution with continuous addition of magnesium oxide. Subsequently, $MgCl_2$ is subjected to pyrohydrolysis for recycle of chlorine.

The hydrochloric acid solubilisation process has been tested in a pilot plant of 1 TPD capacity as early as 1968 by Deep Sea Ventures (DSV). The choice of HCl process locked DSV in manganese recovery for recovery of the chloride ion. Further scale up to 40 tpd was considered, but the idea was abandoned because of the high capital costs (46). There were plans to test the MHO process in a pilot plant at Belgium, but this was not eventually conducted. In any case, confidence level in scale up of the process seemed to be high.

4.3 Ammoniacal Leaching

The Kennecott Copper Corporation's "Cuprion Process" is perhaps the best studied process in this group (47). The process has been tested on a continuous scale involving cage mill, hydrocyclone, co-current leaching tanks, clarifier and counter current decantation units. Basic metalcarbonate recycle has been preferred for monitoring the desired level of cuprous ions in the reactor (48). Process modelling of the leaching step has been undertaken (49).

The Department of Ocean Development, India has sponsored research on an ammonicalsulfur-dioxide leach process at Regional Research Laboratory, Bhubaneswar (50) and a pilot plant of 250 Kg/day capacity for testing the process is soon to be commissioned. Reaction mechanisms pertaining to an identical system of leaching have been studied by Okuwaki et. al (51).

5. Solution Treatment

The pregnant metal bearing solution through the various processing options may be treated through different alternatives. These include ion-exchange solvent extraction and precipitation schemes used in different combination. These schemes differ as per the initial solution composition. Various possibilities have been examined for the ammoniacal, chloride and sulphate beating solutions and are discussed below.

5.1 Ammoniacal Solution

A typical solution composition (in gpl) examined by Kennecott Copper Corporation is (14): Cu - 5.7, Ni - 6.2, Co - 0.2, NH_3 - 90 and CO_2 - 55.0. At the time of process development, LIX 64N, being marketed by General Mills was used as the preferred solvent. The process consisted of Cu-Ni coextraction, ammonia scrubbing, nickel stripping and copper stripping.

40% LIX 64N was used and extraction and stripping steps were carried out in mixer settlers at a temperature of 40° C. Concentration differentials of 25 gpl and 10 gpl were maintained for the nickel and copper stripping stages. The development and optimisation of the Kennecott flow sheet was aided by the use of a computer model developed (52).

Although considerable efforts was spent for optimizing the extraction flow sheets, the company has completely given up efforts in this direction since 1977/1978. In the meantime, several new solvent have been introduced in the market by Henkel Corporation (earlier General Mills) and it would be necessary to look into the process parameters afresh utilizing the newer generation of solvent. Also, Kennecott Copper Corporation have not explicitly mentioned the cobalt recovery process. However, one patent (53) describes the use of 2.5 HCl solution for selective stripping of cobalt from the solvent. Subsequent patents (54) have examined cobalt stripping by mixtures of concentrated sulphuric acid with glacial acetic acid, methanol or other lower alcohols. USBM (11, 55) have suggested another variant of the Kennecott process in which the LIX raffinate was treated with ammonium hydrosulphide for precipitation of cobalt along with residual Cu, Ni and Zn. The sulfide mixture was pressure leached with air for preferentially dissolved Ni and Co, leaving the copper and zinc sulphides in the residue. After filtering off the residue, hydrogen sulfide was used to polish' off residual Zn and Cu impurities and the purified solution was hydrogen reduced to produce nickel powder. The cobalt sulphate solution was purified by the cobaltic pentamine process and about 98% of the cobalt was recovered in the refining process.

The solutions treated in USBM and Kennecott process did not contain manganese. Brooks and Martin (56) have given a scheme for precipitation of manganese from manganese bearing nodule solution (32 gpl) followed by selective copper, iron and mixed nickel-cobalt carbonate precipitation. However, sufficient details on preferred treatment parameters are not available.

A French patent (57) has explored a different route involving precipitation of a metallic concentrate from the ammoniacal leach solution by driving off NH_3,dissolution of the concentrate in hydrochloric acid producing a solution of high metallic tenors (Nickel, 100 - 120 gpl, Cu, 80 - 100 gpl, Co. 14 - 21 gpl). This is contacted with TBP and Solvesso (removal of Fe, Zn, Cd, etc.), Tri-iso-octyl-ammine and Alamine 336, Hostarex A 324 for a copper-cobalt separation step and electrowining of nickel from purified $NiCl_2$ solution. The scheme proposed has been covered in sufficient details.

5.2 Sulfuric Acid-Leach Solution

5.2.1 Relatively Dilute Solutions

A typical leach solution composition (58 a) obtained by nodules leach is : Cu - 3.6, Ni - 4.3, Co - 0.6, Mn - 4.5 Fe - 0.3, SO_4- 2 - 20.0 (in gpl), pH - 3.5. Such solutions could be treated through different level of NH_3 additions for selective copper extraction and cobalt-nickel co-extraction (14). When the leach solutions contain relatively high levels of Mn, after copper is extracted (say, by LIX 64N), an ion-exchange step (Lewatit TP 207) removes nickel and cobalt (58 b). Mixed nickel-cobalt chloride solution is obtained by a 5% HCl strip which then is processed for nickel and cobalt separation through differential precipitations. Alternatively, cobalt-nickel separation may be carried out through solvent extraction (59). The ion exchange used separates the manganese and further concentrates the metal tenors. A French study (40) have suggested a different scheme of treatment of such solutions in which copper is first extracted by a LIX reagent and FeAl/cr is separated from the raffinate by precipitation using CaO. The purified solution is then contacted with 20% D2EHPA - 50% TBP - 75% Solvesso combination (D2EHPA was put in Na form) and the impurities extracted were stripped in different sequences. Cobalt was extracted by a mixture of oxime and carboxylic acid (say LIX 63 and 0.1 M versatic acid); nickel was then extracted only by an oxime. The raffinate was treated at pH 8.5 by a basic reagent(MgO) for precipitation $MgSO_4$ and recycling SO_2 by roasting of the $MgSO_4$. Detailed results on any of the above schemes are not available to permit evaluation of the process.

5.2.2 Concentrated Metal Solutions

Sulfuric acid solutions of concentrated metal tenors would result when precipitated metal sulfide products obtained during various process options are subjected to acid leaching under pressure. Data on solvent extractions separation applied to such acidic concentrated leach liquor solutions are rare. However, procedures developed by Sheritt for mixed nickel-cobalt sulphides (60) may be applied to concentrated leach solutions derived from acid pressure leaching of mixed sulphides from nodules. Again, information on actual systems is scanty.

5.3 Chloride Leach Solutions

5.3.1 Relatively Dilute Solutions

Bulk of the work reported in literature has been carried out by Messers Deep Sea Ventures (61, 62, 63). The basic steps consist of selective extraction of iron with a secondary ammine, selective extraction of copper with LIX 64N, nickel cobalt co-extraction with Kelex 100, stripping of nickel with weakly acidic nickel electrolyte stripping of cobalt with strong HCl. A Modified treatment procedure suggested by Metallurgic-Hoboken-Overpelt (44) removes Fe, Zn, Mo and V with TBP and subsequently re-extracts Mo and V from the strip solution using LIX 63. The other metals (Cu, Ni, Co) are separated as sulphides for further treatment.

5.3.2 Concentrated Metal Solutions

Treatment of concentrated metal solutions arising out of chloride leaching of alloy/precipitate in various process routes is exemplified by various commercial applications such as Falcobridge process/SLN process. A French patent assigned to CEA (57) also gives a detailed description of the solvent extraction treatment procedure adopted for precipitates dissolved in hydrochloric acid, as described under Section 5.1. During pilot plant trials conducted at CEA pilot plant (45), mixed sulphides precipitated from sulphuric acid solution were attacked by chlorine, the sulfur recovered and the meal chloride subjected to solvent extraction separation outlined under section 5.1. Chloride bearing solutions would also result when matte generated during smelting studies (45) is dissolved by controlled oxidation with chlorine. The copper rich residue may be dissolved in cupric chloride and subjected to oxidative solvent extraction. The nickel-cobalt-iron solution is subjected to solvent extraction separation procedure as outlined above.

Problems arising out of materials of construction for the extraction battery have been largely resolved as exemplified by various successful commercial applications.

6. Tailings Characteristics and Processing

6.1 Tailings Characteristics

Processing and characterisation of nodules tailings and slags for proposed first generation processes of USBM have been extensively investigated (55, 64). The tailings were generated through bench scale testing and pilot plant tailings were available for characterisation only for one process (Cuprion)/ The results of leachate testing using the environmental protection Agency extraction procedure (Ep) toxicity test, the ASTM shake extraction test, the EPA-US Army Corporation of Engineers Sea Water elutriant test showed very low to negligible leaching of metals from the tailings and slags.

6.2 Processing of Tailings

Reports on further processing of the tailings for manganese recovery are scarce. A patent granted to INCO (65) indicates that the ammonium carbonate leach tailings could be further leached with sulfur-di-oxide. Recovery of manganous oxide from the leached solutions has been indicated through evaporation/crystallisation of the solution. However, Cuprion process tailings treatment is cited (66 a) to lead to low manganese recovery. Here the manganese is recovered by a simple flotation technique of (66 b). The flotation concentrate would presumably be thickened and filtered to produce a relatively pure manganese carbonate cake which could be calcined and smelted.

The manganese sulphate containing residue from sulphuric acid leaching has been dried, palletized with coal addition and ignited in a rotary furnace (45). The pellets were then smelted in an electric furnace with anthracite where phosphorous was eliminated. Subsequently, silico-manganese was produced by smelting further the alloy in a second electric furnace producing 81% Mn, 14% Si, 2.5% Fe and less than 2% C. There are indications that the recovery of manganese via this process route is a difficult proposition and the French Consortia efforts have been redirected towards recovery of manganese from slag.

6.3 Recovery of Manganese from Slags

Messers Elkem (16) have conducted large scale studies on recovery of silico-manganese from nodule smelting slags. Laboratory scale smelting trials have been reported by Haynes (19) and Sridhar (15) for production of ferromanganese. Ferro-manganese slag containing about 42% manganese has been smelted with silicieous flux to yield silico-manganese (45).

7. Comments on Status of Process, Gap Areas

7.1 Process Status and Alternatives

The above paragraphs have summarised the activities undertaken by different laboratories or consortia members earlier/at present. Active research on nodules processing is being pursued presently only by some Indian laboratories and Japanese Firms/Laboratories.

Earlier work has led to piloting of certain key steps in the processing operation as has been brought out in the text. Pilot operations have been run for limited time periods and there are no references to suggest that these have been sustained. Only the processes studied by Kennecott Copper Corporation (KCC) and Deep Sea Ventures (DSV) have been tested till the end phase along with aspects such as reagent recycle (Table II). No pilot plants have operated during 1980 other than the CEA plant.

It is interesting to note that the various updated flow sheets presented by USBM (11) reflect preferred versions of five processes described therein (Gas reduction/ammoniacal leach, Cuprion, high temperature sulfuric acid leach, reduction/ hydrochloric acid leach, smelting/sulfuric acid leach) and these need not represent the most optimised versions of the various alternatives. For example, subsequent to gas reduction and ammonical leaching, the solution may be stripped of ammonia and then concentrates leached in hydrochloric acid medium. Alternatives also exists with regard to mixed sulfide precipitation, pressure leaching and metal separation. Only the front end operations resemble caron process for laterite ore processing. Whereas the sulfuric acid pressure leach operations may be similar to Moa Bay laterite leach operations. Variants already exist with regard to lower temperature of leaching under pressure and dissolution of manganese in leach solution (45). Major variations are possible regarding the processing of sulphate solutions involving use of both iron exchange and solvent extraction operations. Smelting may produce an alloy which could be leached in chloride medium similar to commercial SLN operations instead of a matte being produced which is then pressure leached. Flow sheet options of solution treatment after matte leaching include practices being followed by Outokompu Oy, Amax Corporation, Fatconbridge, Sumitomo and Nippon Mining Corporations.

In essence, the updated flow sheets presented by USBM is an excellent example for undertaking order of magnitude cost estimates for a preferred process embodiment and starting point of further research/updating efforts on nodules processing. It is interesting to note that some Japanese Companies have recently undertaken further

Table 2: Status of piloting activities

Name of the * Company	KCC	DSV	INCO	ELKEM	IFREMER
Piloting Capacity	1/2 TPD	1 TPD (Lexington) 350 kg/day	unknown (Virginia)	Tenscde	120 Kg/day (Fonte-nanyauxroses) CEA)
Whether all steps tested on continous basis	Yes	Yes	No	No	Yes
Further scale up	No	Planned 40 TPD, did not materialise	No	No	No
Technological difficulties in Piloting	Nil	Nil, but costly operation indicated			Solvent extraction rectifed

* Also Messrs OMINCO, subcontracted research to Colorado School of Mines, details unknown.

activities on nodules processing based on the starting points presented by the USBM updated process flow sheets (67).

7.2 New Reagents for Metal Separation

Various patent literature information makes it abundantly clear that research organisations have been alive to the problem of impurity distributions in solutions and have suggested ways and means to treat the impure nodules leach solutions utilizing reagents available then.

A large number of new reagents have been released in the market subsequent to the early 1980's. For example, Henkel Corporation have started marketing LIX 860, LIX 984, LIX 622, etc. and many of these reagents are being used commercially in copper plants. Similarly, a number of others reagents (Acorga M5397, M5640, PT 5050, PT 5100, etc..) have been marketed and it is indeed necessary to evaluate various reagents for optimizing a particular separation process. An example of such efforts is found in the work of Nilsen et. al (68) for nickel and copper separation from laterite bearing ammonia liquor. While production of chelating extractants has been the most exciting development in the application of solvent extraction in hydrometallurgy, all the major developments so far had copper recovery as the incentive. With regard to further reagent development, the collective view of reagent manufacturers at a panel discussion at ISEC'80, Liege, in September, 1980 was that new reagents would only be developed if the economics looked favourable. Based on the above factors, and also because of the fact that there has been a recent shift in emphasis towards reducing capital costs (staging requirements) of solvent extraction circuits and compromising higher operating costs, it is particularly necessary to review whether a chosen solution treatment route through solvent extraction based on some older version of reagent is optimal and worth considering for further scale up for nickel-cobalt-copper separation. It is of some significance to note the various recent developments in reagents for cobalt-nickel separation in sulphate solutions. The Nippon Mining Company uses alkeyl phosphoric acid (M2EHPA marketed as PC88A), the Sumitomo Company Versatic-10 and Trialkyl ammine and the Mathey-Rustenburg Refiners phosphoric acid (D2EHPA) for achieving cobalt-nickel separation from purified leach liquors. The phosphinic acids may have even larger selectivity of cobalt-nickel separation (Cyanex reagents). The possibilities of using ion-exchange resins such as XFS-4195 (69) for such separations are also under study for synthetic nickel-cobalt bearing solutions containing small quantities of nickel. Keeping in view such commercial scale and other developments, it may be necessary to redesign a nodules solution treatment process.

7.3 Equipment and Scale-up

The front end of various processes have been tested at pilot scale as noted above wherein specific equipment concepts related to the process have been subjected to some sort of scrutiny. However, such pilot plants have not been run for sufficiently long periods to enable testing of equipment performance (for example, if sulphuric acid pressure leach for nodules is to be tested, the problem of autoclave scaling, shutdown, etc. need attention). Also, prototypes of all industrial scale continuous equipments have not been tested in the various pilot campaigns. This may be because of confidence level in equipment performances of the industrial scale version Vis-a-Vis the scaled down version used during piloting. The equipments to be used for a commercial nodules treatment plant (say 3.0 million tonnes of dry nodules per annum) would perhaps have the maximum capacities conceivable from an engineering point of view because of the large flow rates of process streams. Scale up practices to such large capacities have to be carefully worked out.

Table 3: Typical Equipment sizes for a Plant treating 150,000 TPD of Nodules

Proposed Capacity Scale up Factors	150,000 TPD Nodules		
	Capacity	Largest Commercial Capacity	Scale up ratio
- Reduction furnace	500 TPD	700 TPD	1.4
- Autoclave	130 M3	130 M3	1.0
- Solvent extraction Electrowining	75 M3/Hr	800 Mr/Hr	10.0

Table 3 shows for a proposed capacity of 150,000 TPD of nodules,largest sizes of commercially available equipments would be used.Further scale up of various equipments to an envisaged capacity of 3.0-million dry tonnes per annum would require considerable effort as is apparent from scale up strategies adopted for certain equipments (Table 4) during processing of lateriteores.

Table 4: Typical scale up stages for commercialisation

EQUIPMENT	COMPANY	REMARKS
Shaft Furnace	Falconbridge nickel production	1.Pilot shaft furnace 0.68m * 1.37m * 8 M (1.5 T/hr product) 2. Pilot shaft furnace 1.37m * 1.37 m * 8.2 m (5.4 T/hr. product) 3.Commercial furnace 1.32m * 5.49 m * 8.38m(20 T/Hr. product)
Rotary Kiln	INCO Guatemala-Indonesia	1. Pilot Kiln 1.5m*12.2 m (1 T/Hr. product) 2. Commercial Kiln 5.5 m * 100m (100 T/hr. product)
Multiple Hearth	Sherritt Gordon	1. Pilot plant Mines 0.9m, 6 bert (4 TPD) 2.Pilot plant 2.6m, 12 hearth (100 TPD) 3. Commercial (Surigas) 7.6, 17 berth (800 TPD)
Multiple Hearth Roaster	Freeport Minerals Company	1. Pilot Plant1.37 m, 8hearth (5TPD) 2. Commercial (Yabulu) 7.6m, 17 hearth (800 TPD)

7.4 Further Prospectives in Technology Development

In view of the various uncertainties in the development of a viable process route and the stage of piloting with regard to different processes, it is extremely difficult to justify one process route for eventual commercialisation. Besides techno-economic viability, (70, 71, 72, 73) the choice of a process route would critically depend on whether manganese is to be recovered.

It is possible to compute unitized capital and operating costs for the processing sector for higher capacity and lower capacity nodules processing plants (3.0 million tonnes and 1.5 million tonnes respectively) based on published literature. Process plant capital and operating costs and it is possible to work out expected profits for a known composition of nodules. The required metal recovery efficiencies for the processing sector may be derived from such computations (74) so that the techno-economics is viable. The R&D efforts may then be directed towards achieving the desired recovery efficiencies.

It is also useful to develop capital cost and operating cost break up for different sectors of the processing plant. A typical break up is shown in Table V for the roast reduction-leaching-solvent extraction/electrowining processing route. It is apparent that major cost reduction potentials exist with regard to plant services (capital costs) and fuels (operating costs).

Table. 5: Typical capital and operating cost breakup

*. CAPITAL COST BREAKUP	(%)
– MATERIAL STORAGE HANDLING, PREPARATION	17.1
– NODULES REDUCTION &METAL LEACH	11.4
– SOLVENT EXTRACTION SEPARATION	10.0
– REAGENT RECOVERY	10.1
– COPPER & NICKEL ELECTROWINING	18.4
– MIXED SULPHIDES PRECIPITATION COBALT RECOVERY	2.70
– PLANT SERVICES	30.6
* OPERATING COST BREAKUP	(%)
– MATERIALS & SUPPLIES	4.0
– UTILITIES & FUELS	47.7
– & LABOUR	16.6
– CAP.RELATED CHARGES	31.6

8. Conclusions

It is suggested that efforts be continued in different countries for continuation of work on process development at least on a scale which is commensurate with updation of various routes developed at the laboratory/bench scale keeping in view the developments achieved on similar land based operations. In view of the global resource crunch affecting nodules research, it is important to draw the land based metal producers for nickel and cobalt into the arena of nodules research; in many instances, modifications of existing land based commercial operations would lead to faster process development for various gap areas cited in this paper. However, it would be necessary to step up international cooperative efforts since purely national initiatives would mean costly development programs; also, several portions of the technology to be developed can be intelligently linked to a diverse set of land based operations, the technology ownership for which rests with different organisations. It is also necessary to recall that comprehensive technological developments have earlier resulted through cooperation of internationally composed industrial groups through various consortia. In the light of such envisaged changes, government support for development oriented programmes for nodules and other seabed minerals would go a long way in attaining the broad objectives of the overall programme.

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OCEAN ENERGY TECHNOLOGY

International Development on Ocean Energy

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Abstract

Among many possible sources of renewable energy, ocean energy is the most important renewable energy source. The ocean, which occupies approximately two-third of the earth surface, receives tremendous amount of solar energy continuously, stores it and makes it available in various forms of ocean energy as listed below:

1. Ocean Thermal Energy Conversion
2. Wave Energy
3. Tidal Energy
4. Marine Biomass Conversion
5. Salinity Gradient Energy
6. Marine Current
7. Offshore Wind Energy

Among the above seven different forms, the energy developing system using the thermal, wave and tidal energy have been demonstrated on large scale commercialization.

This paper presents the developments in the area of OTEC and tidal energy since there are other papers dealing with wave energy. This paper first discusses the principle of open cycle and closed cycle systems, their relative merits and demerits. Further, the latest developments using 'Hybrid cycles' and the 'Mist flow cycle' also have been discussed and compared with the closed and open cycle systems. After discussing the various subsystem of OTEC plant, the paper discusses the global development right from mini OTEC to the open cycle OTEC plant in Hawaii which was commissioned in 1992. This paper also gives brief information on the two proposals for installation of OTEC plants being considered in India, one in Lakshadweep Island and the other, off the mainland of Tamil Nadu Coast.

On Tidal Energy, the paper discusses the various possibilities of generating power from tidal variation with a single flow and double flow turbines with single or double basins. The paper also gives a brief account of world's activity on tidal power development and gives a brief presentation of the details of the proposed tidal wave power plant in Gulf of Kuchch in India.

1. OCEAN THERMAL ENERGY CONVERSION

1.1 Principles & Systems

Ocean thermal energy is the most important form of ocean energy for countries like India having a long coast of tropical waters. The principle behind OTEC is simple. It utilizes the temperature difference existing between warm surface sea water of around 28°C and cold deep sea water of around 5 to 7°C, which is available at a depth of 800 to 1000m in tropical waters.

1.2 Two Alternative OTEC Systems

The open cycle system which uses sea water as the working fluid. In this system the warm surface sea water is flash-evaporated in a chamber maintained under high vacuum and the generated vapour is utilized to drive a low pressure turbine connected with the generator. The exhaust steam is condensed using cold sea water.

The closed cycle system utilizes a low boiling point liquid like Freon or Ammonia as the working fluid. The fluid is evaporated using the warm surface sea water. After the vapour drives the turbine, it is condensed by cold sea water. This condensate is pumped back to the evaporator.

1.3 Comparison of the Two Cycles

The most obvious advantage of the open cycle is that warm sea water is flash evaporated and the need for having a surface heat-exchanger is eliminated. The other major advantage is that potable water is obtained when the exhaust steam from the turbine is condensed. The major dis-advantages are :

a. Steam is generated at very low pressure (approximately 0.02 bar). The volume of steam to be handled is very high leading to a very large diameter for the steam turbine. For example. IMW OTEC plant requires a steam turbine of about 12m diameter.

b. To maintain vacuum in the flash evaporator, massive vacuum pumps will be required.

   On the contrary, the closed cycle system requires expensive working fluids like Freon or Ammonia. But the major advantage of this system is that the fluid evaporates at around 25°C does not require vacuum pumps. The pressure at the turbine will be of the order of 4 to 5 bar resulting in compact turbines. For example for 1 MW plant, requires a Ammonia turbine of about 0.6 m diameter only. The fabrication of such a turbine is technically easier than that of very large steam turbines for open cycle system.

Hybrid Cycle :

A new 'Hybrid cycle' has been developed combining the advantages of both open and closed cycle. In this cycle, warm sea water is flash evaporated. The energy released during flash evaporation is used to heat a refrigerant liquid which flows in a closed loop as in the normal closed cycle mentioned above. Such a cycle has a compact turbine as in closed cycle but also gives fresh water output as in the open cycle. The efficiency of the system is likely to be lower than the open or closed cycle.

Mist Flow Cycle :

A new concept of 'Mist flow cycle' for OTEC has been proposed with a water turbine in the system because the physical size of a gas or steam turbine in much larger than the hydraulic turbine for the same power rating. The concept proposed has a concrete hull of height around 100m in which a hydraulic turbine is located at the bottom. This water turbine is fed by warm sea water drawn from the surface. The water after passing through the turbine is flash evaporated since the down stream side of the turbine is kept under vacuum condition. The cost of such a system is likely to be one-third of the conventional open cycle or closed cycle system.

1.4. Location of OTEC Systems

Depending upon the availability of deep sea near the coast, the OTEC system could be installed in three possible types of locations.

1. Where the distance of deep sea from coast is large, OTEC plant could be placed on a floating platform with a cold water pipes suspended from it. (Fig. 1). An underwater cable is needed for power transfer to shore. Alternately, the generated power may be utilized to produce energy intensive materials like Ammonia or hydrogen from the sea water. The products then have to be transported to the main land by ships.

2. If the distance is around 10 km, the OTEC plant could be floating in the near shore area and the generated power can be transmitted to the main land by underwater cables. (Fig. 2)

3. If the deep water conditions are available within 2 to 3 km of the coast, the entire plant could be situated on land with the cold water pipe line running along the ocean bed to a depth of 800 to 1000 metres. (Fig. 3)

1.5 Advantages of OTEC Systems

1. Power from an OTEC system is continuous, renewable and pollution free.

2. The cold deep sea water is rich in nutrients and can be utilized for aquaculture.

3. An open cycle OTEC system provides fresh water as by product. The closed cycle system can also be combined with desalination plant to get fresh water.

4. OTEC is an important alternative source of power for remote islands.

5. A floating OTEC plant could generate power even at mid-sea, and can be used to provide power for operations like offshore mining and processing of manganese nodules.

1.6 Global OTEC Potential and Development

The world wide area with annual average temperature difference of about 22°C is approximately 60 million sq. kilometres. It is estimated that an OTEC plant with a grazing area of about 2000 sq. kilometres can have a continuous output of around 325 MW. Based on this, estimated global power potential from OTEC alone is about 10 million MW.

The basic concept of OTEC was proved on a very small scale atleast half a century back by George Claude. But it was United States of America, which started a major R & D activity in the last decade. Their funding grew from $ 85,000 in 1972 through $ 8.5 million in 1976, to 38.5 million in 1979. Two demonstration plants have been tested so far. The first of this named 'Mini OTEC' (designed to produce 50 kW of power) was a private venture of a consortium and was deployed off Hawaii. It was deployed in August 1979 and operated for 4 months without trouble and the output being as predicted. The second demonstration plant, again off Hawaii, known as OTEC-1 was intended to test heat exchanger for 1 MW energy. An old ship was converted to a floating platform to house shell and tube type heat exchanger. A 1.2m diameter cold water pipe was installed to a depth of 650 m. The experimental results for the condenser and the evaporator agreed excellently with the theoretical predictions. Ammonia was the working fluid. The experiments were completed in March 1981. The US time table of OTEC development envisaged at that by the end of this century, an OTEC capability of 10,000 MW will be achieved in the USA. But, no major OTEC activity is in progress in USA excepting 150 kW Open Cycle Plant in Hawaii.

The other country which is concentrating on OTEC development is Japan. The Tokyo Electric Power Service Company in association with Shimizu Construction and Toshiba have successfully built and operated a trial plant on the Pacific Islands of Nauru. The plant of capacity 100 kW was operation from September 1981 to September 1982. The entire plant was on land with the cold water pipe line running to a depth of 700 meters.

1.7 OTEC Potential in India

Government of India organized a feasible study to install a 1 MW plant in the Lakshadweep Island in the Arabian Sea. The feasibility study was conducted by IIT Madras. The study recommended that a shore based plant for the island of Kavaratti where the ocean bed is steep upto 700 m water depth within 1000 m distance from the shore. A detailed engineering project report for this plant was prepared by M/s. MECON Ltd., Ranchi. The cost per unit of the electricity generated was expected to be two-third of the present power cost from diesel electrical generators. But decision has not yet been taken.

M/s. Sea Solar Power, USA has offered to install a 100 MW floating OTEC plant off Kulasekarapatnam on the eastern cost of Tamil Nadu. This unit is expected to have eight modular units of 12.5 MW with closed loop system with Propane as the working fluid. The proposal is being reviewed by Government of India and Tamil Nadu.

2. TIDAL ENERGY

2.1 Global potential and development

Tidal development has gone through long stages of development. The first one to go into commercial production is the Rance Plant in France. It is operational since 1966 and the installed capacity is 240 MW. A mini experimental plant of 400 kW was tried at Kislaya Guba in Russia. A 3 MW tidal was commissioned China during 1982.

The energy potential of a tidal plant can be estimated as

$$E[\frac{kW-hr}{year}]-0.017R^2S$$

Where R = Tidal range (m)
S = Area of basin (m^2)

assuming that power could be developed both during the neap and flood tides using one basin.

In spite of the fact that two tidal plants are in operation for more than 10 years, more plants have not been built because plant construction is highly capital intensive. But the world oil price hike has drawn greater attention towards tidal power development. The important points in favour of tidal power are:

1. The life of plant is of the order of 75 to 100 years and is high compared to 25 to 35 years for a nuclear or thermal power plant.
2. The technology of power development in tidal power plants is as simple as a hydro-electric power stations.
3. Improved construction technology like pre-fabricated plants being sunk at site and development of straflow turbines (with generator rotor mounted on the rim of the wheel) have considerably reduced construction cost.

   A tidal range of 3 to 4 m is considered viable for installing a tidal power plant. But there are hundreds of sites around the world having a tidal range of more than 10m. Several estuary projects in UK and Bay of Fundy projects in Canada are under serious considerations.

2.2 Tidal power potential in India

There are quite a few sites in India suitable for tidal power development but all these sites are clustered in two or three areas only. The Gulf of Kuchch and the Gulf of Cambay on the west coast of India have maximum tidal ranges of around 11m and annual average of around 6m. In the Sundarbans area of West Bengal, the annual average is around 3.5m. A study conducted in 1975 by an U.N. expert Mr. E. Wilson indicated a theoretical possibility of installing very large tidal power station in the Gulf of Cambay and Kuchch but smaller power stations in Sundarbans area. Installed capacities of about 7300 MW, 1000 MW and 15 MW in the Gulf of Cambay, Gulf of Kuchch and in Sundarban areas respectively are possible. The corresponding estimated costs (1975) are Rs. 1925 crores, Rs.600 crores and Rs.15 crores respectively (Rs.1 crore = 10^7 Rpees; 1 US$ = Rs.32/-). The Gulf of Cambay scheme may require a barrage of 40 m height and about 30 km long.

Realizing the great potential in Gujarat, the Central Electricity Authority of Government of India and Gujarat State Government jointly taken up a detailed project study in collaboration with Electricite de France, the pioneer who built the Rance Plant. The cross section through a typical turbine caisson is shown in Fig. 4. The construction of a power plant of about 800 MW rating is awaiting sanctions from Government.

3. CONCLUSION

Ocean has tremendous potential as a renewable energy source. The design and construction of an ocean energy plant is prohibitively very expensive right now. Since the cost of import of foreign technology is also expensive, it is necessary that one should first work on indigenous technology development of system which has multiple benefits along with energy. OTEC has many advantages other than the energy. Work is going on wave energy systems which are being built as a part of breakwaters for harbours. Similarly, tidal energy systems have other benefits like transport and road linkages in marshy areas.

Any new technology development is expensive in initial stages till large scale plants could be designed and developed successfully. It is very unfair to question the relative cost of energy generation from such new and renewable energy systems comparing them to conventional systems for which world wide technology development has been completed at a tremendous cost. Therefore, it is strongly recommended that R&D efforts in ocean energy development should be encouraged so that the countries could go in for more and more demonstration plants to arrive at a reduction in the cost of such power plants.

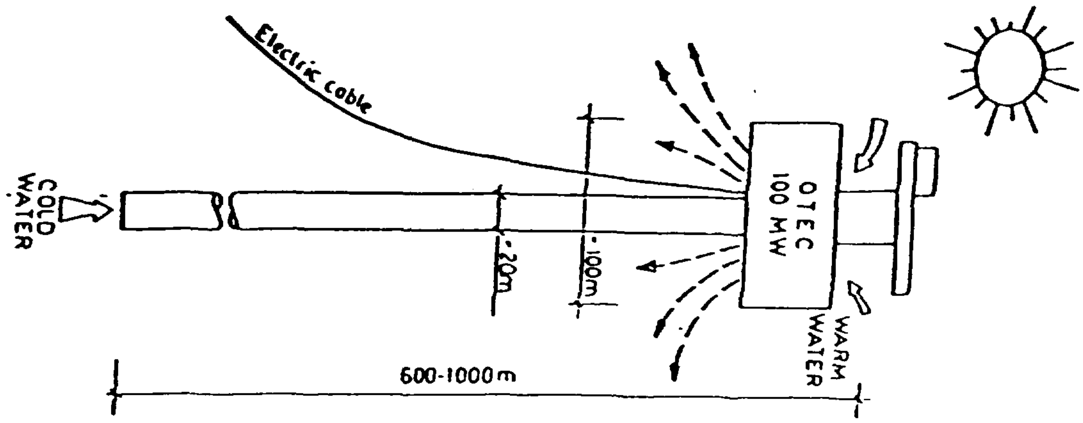

Fig. 1. A Schematic Representation of a Floating OTEC System

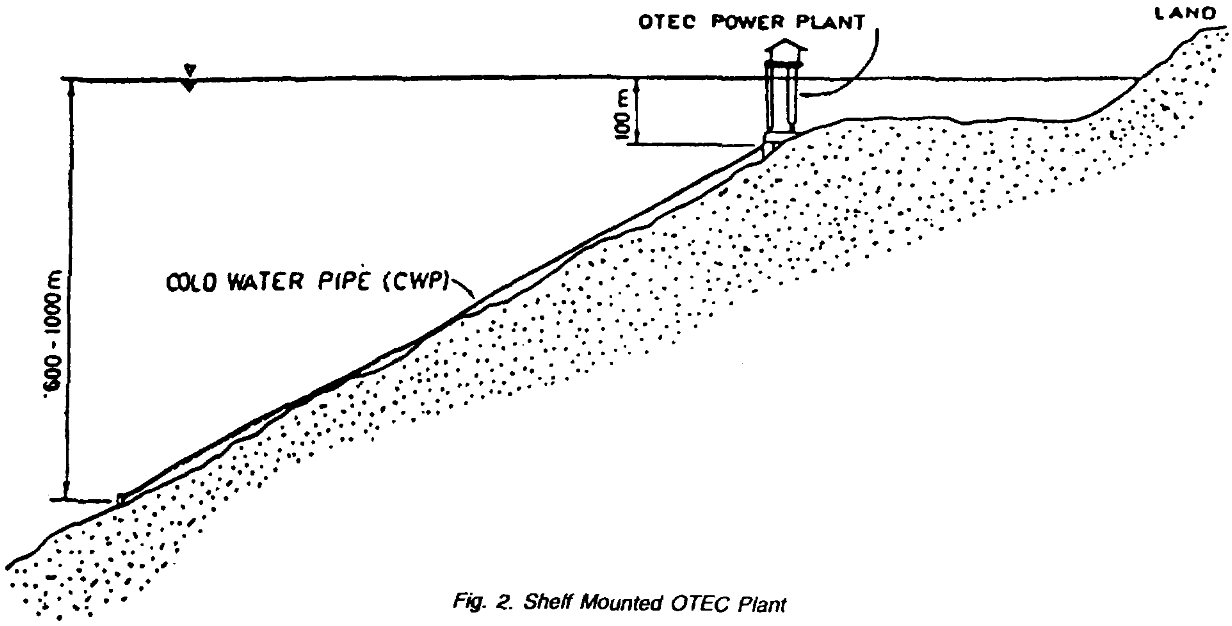

Fig. 2. Shelf Mounted OTEC Plant

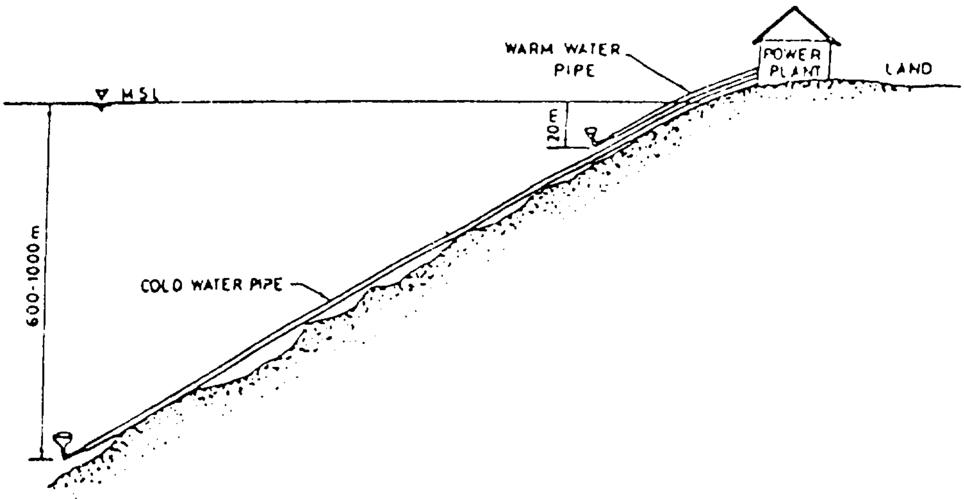

Fig. 3. Concept of Shore Based OTEC plant

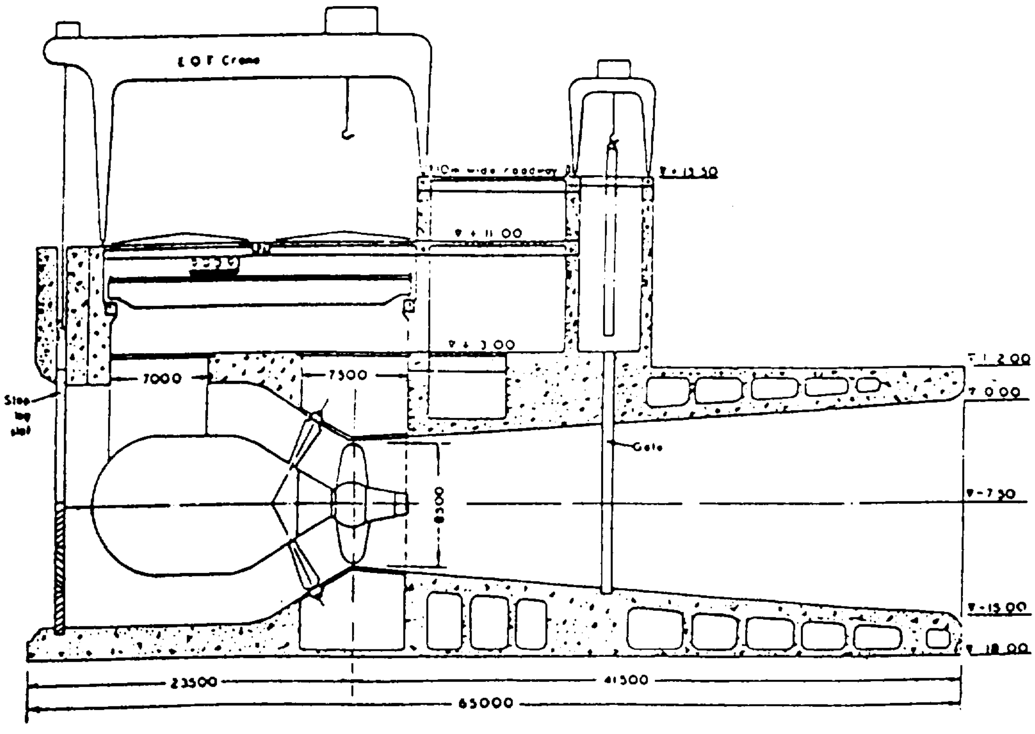

Fig. 4. Cross Section of Kachch Tidal Power Plant

Recent Development in the Utilization of Wave Energy and Potential for Developing Countries

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Introduction

The European Wave Energy Symposium was held on July 1993 at Edinburgh, UK. Non-nuclear Energy (Joule II) by EC started to exploit wave power of EC Energy supply.

Wave energy is perhaps the only marine resource that a majority of the countries having oceanic coastlines can take advantage of. Many devices for wave energy conversion have been developed during the last hundred years, but those which are most likely to contribute to satisfy the needs of humankind belong to a relatively small set of different technologies. Using references by EC and UK study reports and my experiences for Wave Power study, I will introduce wave power concepts, and I wish to select some devices for use in developing countries in this report.

Distribution of Wave Energy

Wave Energy is one of natural energy by sun, Energy of sun generates wind. The energy is transferred from the wind to the waves, Amount of energy transferred depends on wind speed, the length of times of wind blow, and the distance over which it blows (the fetch).

At each stage in the process power is concentrated so that solar power levels of typically about 100 w/m² can be eventually transformed into waves with power levels of over 100 kW per metre of crest length waves within or close to areas where they are generated (storm waves) form a complex as shown in Fig. 1. However waves can travel out of these area changes to swell in more regular shape.

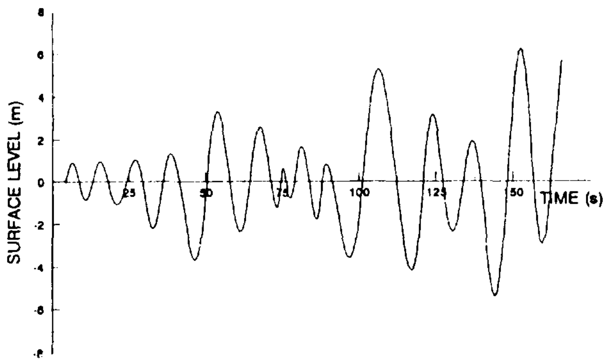

Fig. 1. Typical Shapes of Storm Wave

Wave energy is highest in high latitude, particularly east coast of large ocean such as UK Atlantic coast (Over 50 kW/M).

Second higher wave energy area is subtropical sea by trade wind (25 kW/m class). In general wave energy is concentrated to island and cape, it's interest as power for island or isolated coast area. Fig. 2 shows wave power density and directionality factor by water depth in UK coast.

It means when wave approaches to shallow depth, wave energy is lost, and changes direction to perpendicular to shore line. And so water depth is another important factor to decide power density.

Introduction of Wave Power Concept

I will introduce different wave power concepts by A Review of Wave Energy and EC Conference reports.

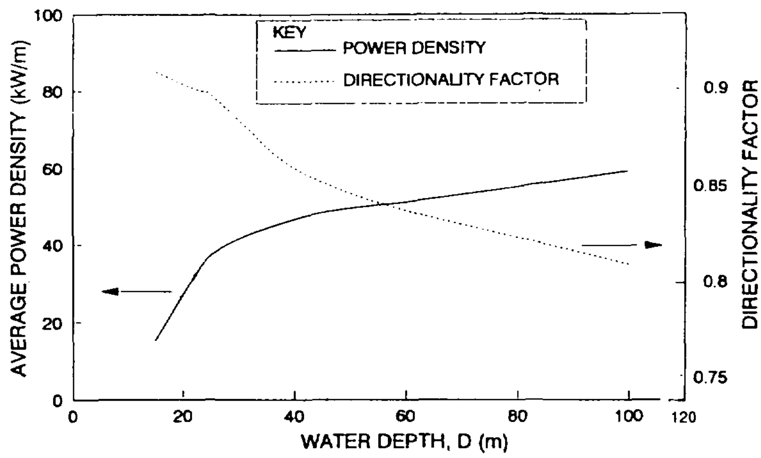

Fig. 2. Wave Power by water depth

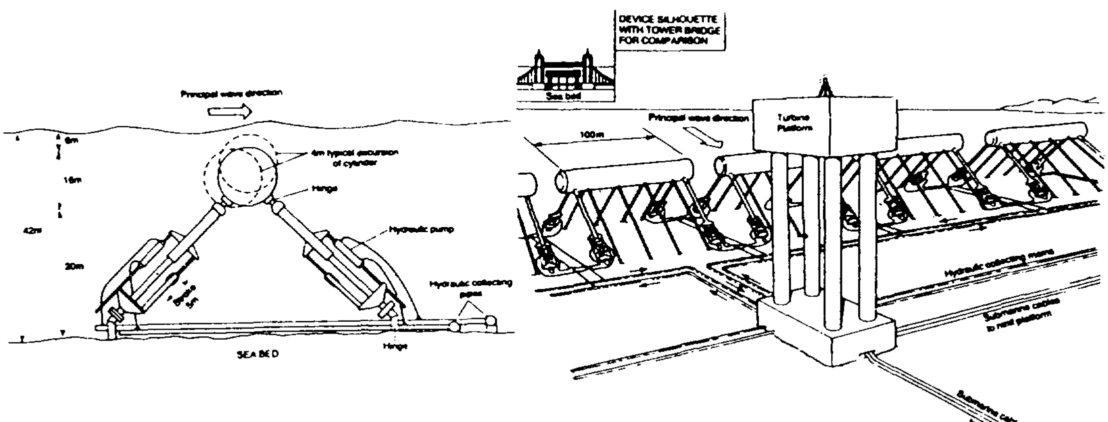

Fig. 3. Schematic diagram of Bristal Cylinder

Description of each concept may not be enough, but figure and simple description only are prepared for your understanding.

Bristal Cylinder

This was proposed by Professor Evans at Bristol University as a result of various theoretical studies on oscillating bodies. The device extracts wave energy using a large (100 m x 16 m) buoyant concrete cylinder, which is moored below surface as shown in Fig. 3, and front mooring line has pumping rode, and high pressure oil is transmitted to shore through pipe, and pelton wheel generates electricity on shore. (1982 Design).

Recently design is changed to use linear pump and generates electricity on the sea floor without long pipe, and electricity is sent to shore by cable.

Edinburgh Duck

The spine based wave energy device known as the Duck developed from work initiated by Professor Salter at Edinburgh University in the early 1970s.

The Duck wave power scheme consisted of eight spine strings, each comprising 54 floating concrete cylinders of spine sections, which are moored in 100 m water depth via flexible tether (Fig. 4).

Each cylinder is 90 m long, 14 m in diameter and weighs 11,000 tonnes.

Hydraulic rams mounted in the joints between each section of the spine allow the whole spin to flex in stormy conditions. Two 36 m-long duck bodies are attached to each spine section by retaining straps (the Duck-spine bearing). Which

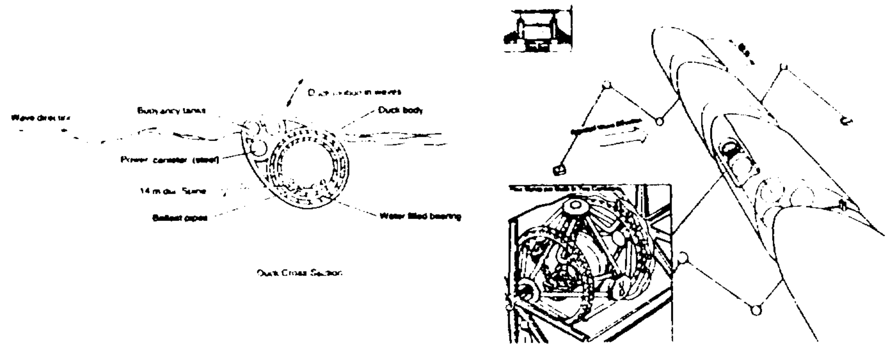

Fig. 4. The Edinburgh DUCK

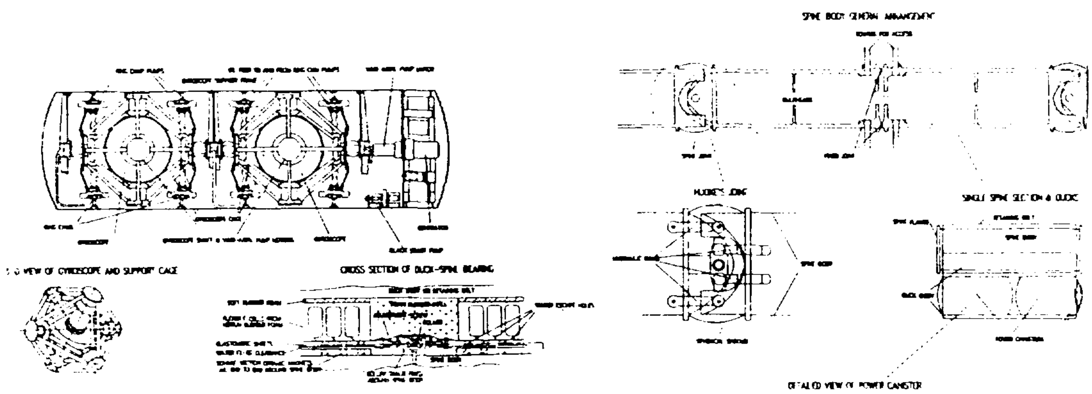

Fig. 5. Details of The Edinburgh DUCK

allow the Ducks to rotate around the spine and hence to nod in response to waves.

Each Duck body contains two independent power canisters, which are completely self-sealed units housing the main mechanical and electrical plant (Fig. 4). The nodding motion of the duck is reacted against a reference frame provided by gyroscopes with each power canister. A series of ring cam linepumps is attached to the gyroscope frame. As the duck nods, the Gyroscopes, Gimbal frame and pump moves with respect to the power canister. High pressure oil rotates pump motor, and generates electricity by generator.

In addition, other pump units are attached between connection of Spines, it can be used for power generation and dumping between spins.

Another design point is the bearing between spine and duck body, water bearing, etc., was designed (Fig. 5)

The Nel OWC

The design philosophy adopted by NEL UK was to use, as far as possible, proven technology, equipment and techniques.

An OWC consists of a partially submerged, hollow concrete structure, which is open to the sea below as shown in Fig. 6. The 1982 NEL OWC comprised 606 concrete modules joined together to form breakwaters or continuous barriers. The structure was fixed to the sea bed in a water depth of 21 m using rock anchor, each module is 22,500 tonnes and contained three individual OWC each measuring 15 m square.

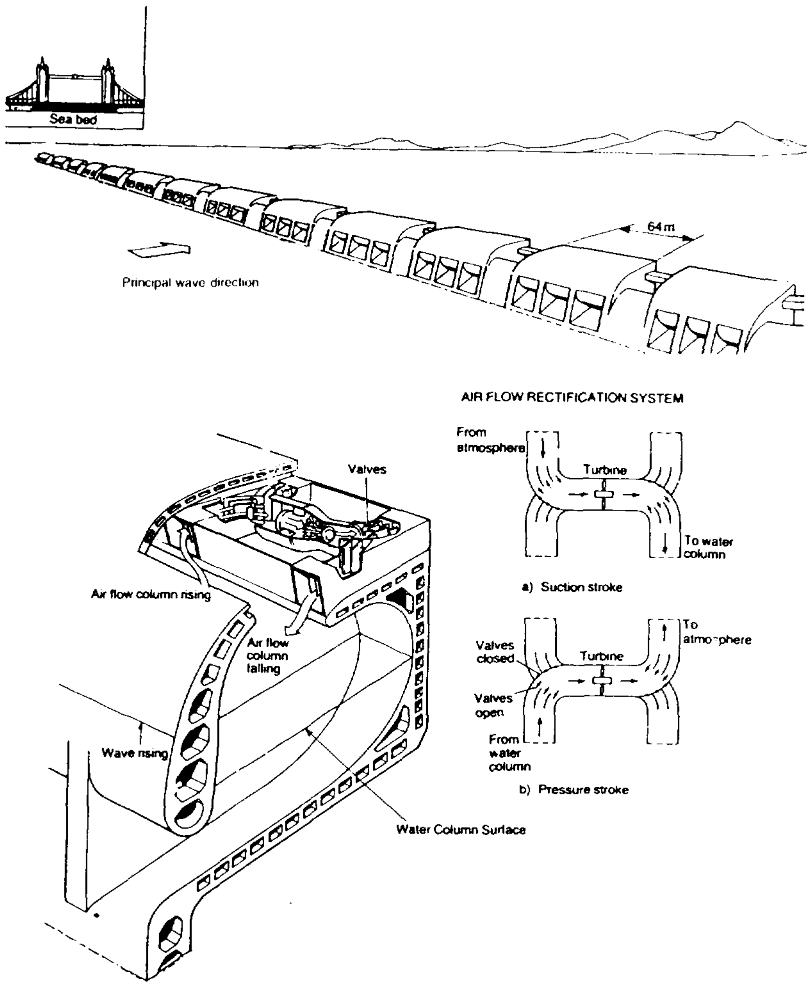

Fig. 6. The NEL OWC

This system uses rectification/axial turbine without Wells turbine.

The Sea Clam

Design team at Coventry University together with Sea Energy Associates (SEA) developed SEA CLAM. The 1986 design of CLAM was floating toroidal dodecagon 60 m across and 8 m deep (Fig. 7). The 12 rectangular air cells covered by reinforced rubber membrane are attached around the CLAM. Each flexible bag filled by air at an average pressure of 15 kPa, and wave compress and expand these flexible bag, and self-rectifying well's turbines were mounted in the ring. The 1991 design of CLAM adopted reinforced concrete from steel construction.

Capture efficiency for circular sea CLAM is shown in Fig. 8, peak period is 7 second with 100%, but it decreases with increasing wave period.

The Shoreline Gully OWC

The Queen's University of Belfast began work on the development of a shoreline gully OWC device for the Scottish Isles in 1985. Fig. 9 Shows general view of Isles wave power station. Fig. 10 shows turbine and generator (60 kW wound rotor Induction generator, and double rotor wells turbine).

The wave energy available at the shoreline is less than at greater water depth. So the design uses the gully to focus and concentrate the available wave energy into relatively small OWC. Principle of operation is the same to NEL OWC except natural gully. It is constructed as shown in Fig. 11. Construction of air chamber may be easy to cut natural rock in dry condition by remaining front wall rock, after the air chamber is completed, the front wall rock will be removed.

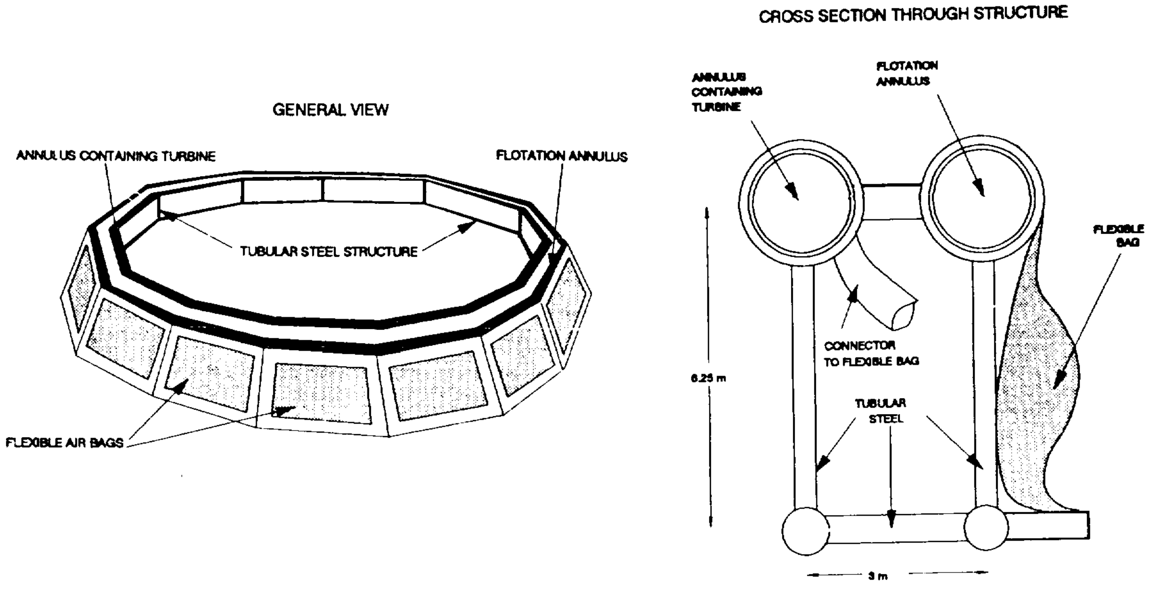

Fig. 7. The 1986 Circular Sea Clam

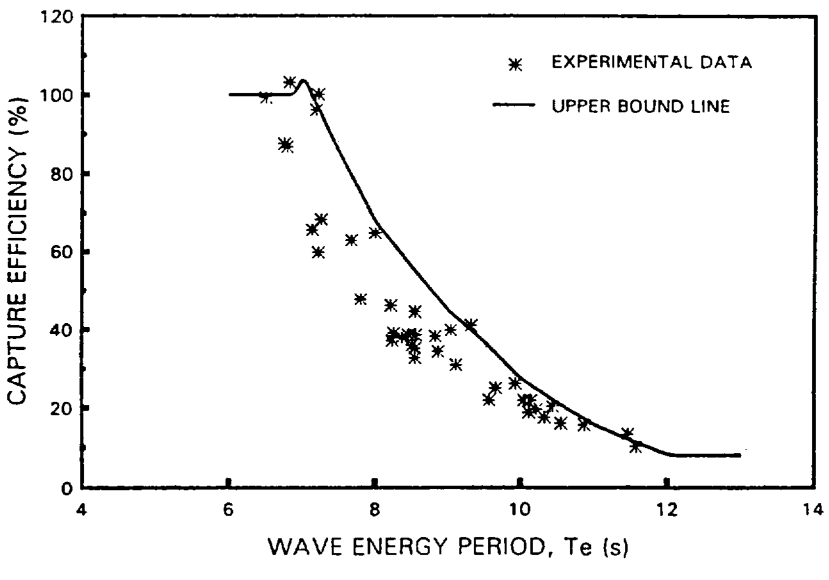

Fig. 8. Capture efficiency of Sea Clam

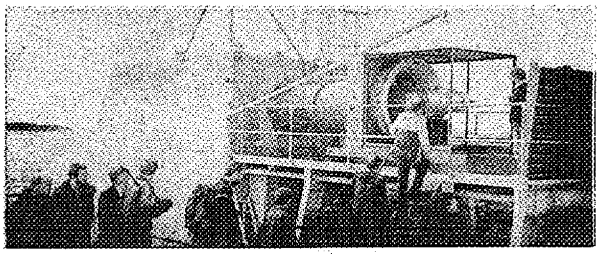

Fig. 9. Islay shoreline gully OWC station

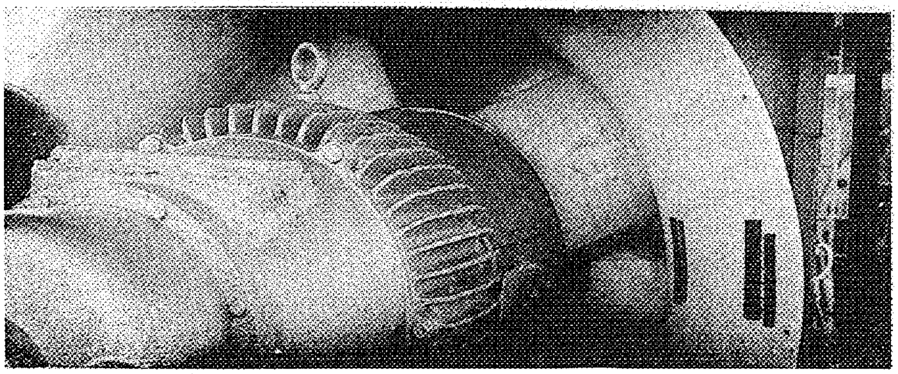

Fig. 10. Turbine and generator

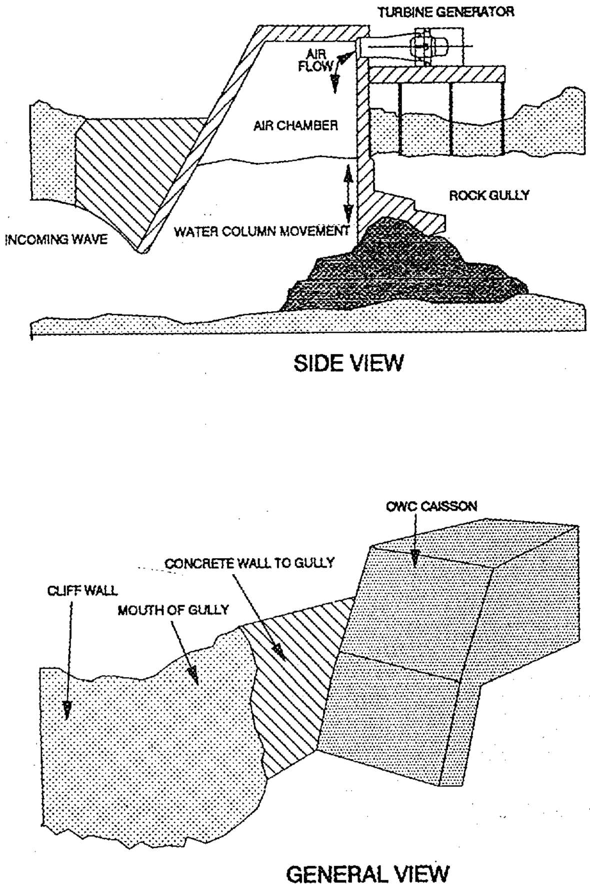

Fig. 11. Shoreline gully OWC

Double rotor wells turbine, and wound rotor induction generator approve rotation speed within 1500 RPM with flywheel capable of storing 2 MJ at 1500 RPM. It can smoothen power output, and it can connect to grid line with constant voltage and constant cycle.

When 1,000 kW Shoreline Gully OWC is constructed, breakdown of capital costs is shown in Fig. 12, and summary of productivity is shown in Table 1.

Table 1. Summary of productivity for the designer gully OWC

Item	
Average Wave Power Level (kW/m)	18
Width of Device (m)	10
Capture Efficiency (%)	280
Turbine Efficiency (%)	55
Generator Efficiency	95
Transmission Efficiency	98
Availability (%)	97
Average Power/Device (kW)	250
Annual Output from Device (MWh/year)	2186

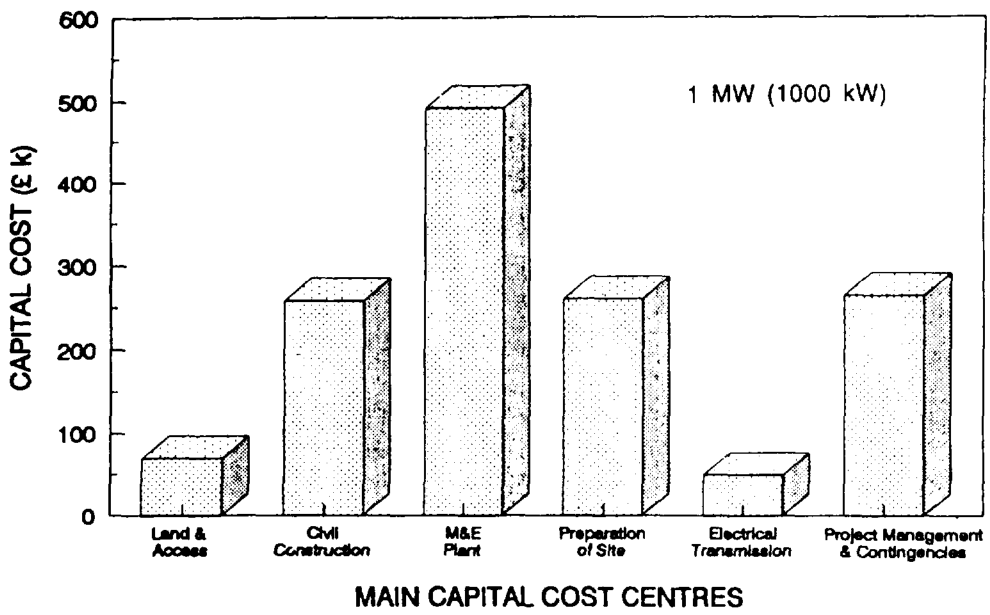

Fig. 12. Breakdown of capital costs for the designer gully OWC

The Ecovision Lilypad

The LILYPAD wave energy device was developed by Ecovision Ltd. It consists of a rectangular floating membrane (about 60 m x 200 m), and submerged membrane and number of axially operated pumps as shown in Fig. 13.

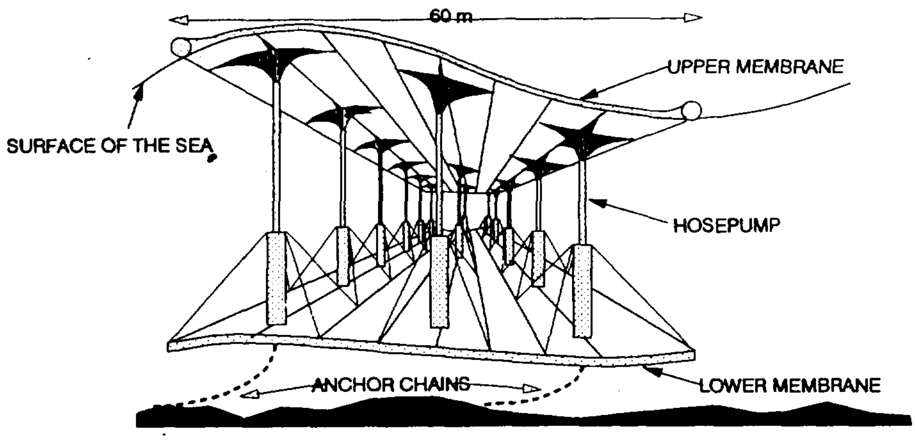

Fig. 13. General view of the lilypad.

The Lancasterps Frog

This device was developed by Professor Frances of Lancaster University. The PS FROG is paddle-shaped device, the steel hull with height of 22.8 m and a displacement of 1,625 tons. Cylinder can at bottom has 1,250 ton reaction mass which slide back along guide rail, and extract energy by pump.

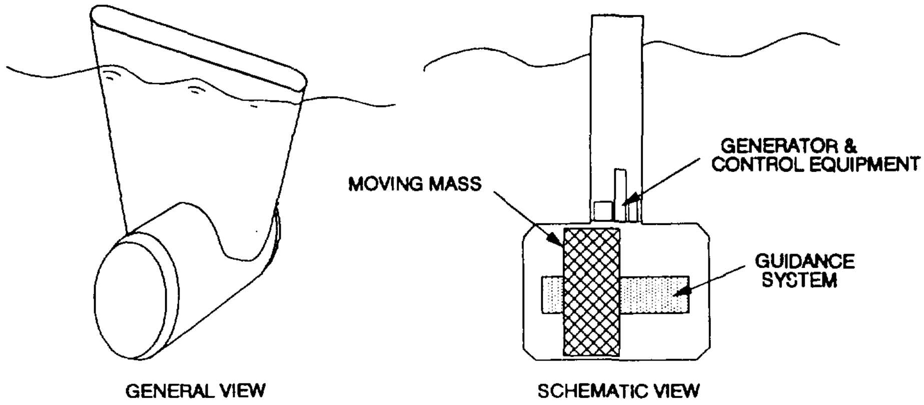

Fig. 14. Outline of THE PS FROG.

The Art Osprey

This device was developed by Queen's University and Scottish Hydro-Electric Plc. This is bottom mounted OWC, the hull is about 20 m in diameter has two OWCs, each room is controlled by phase control, and one wells turbine is mounted between two chambers. It is estimated to get cheap power at 7-10 p/RWh.

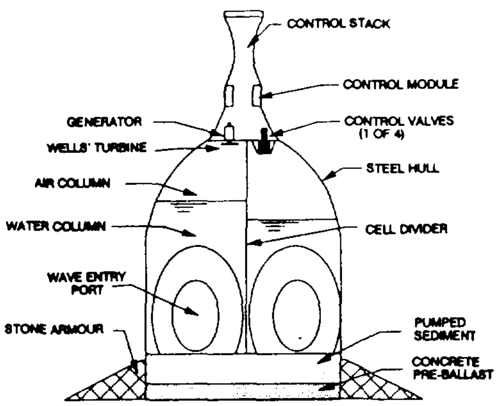

Fig. 15. Outline of the art osprey

Danish Wave Power Device (DWP)

Dr Kim Nielsen, Danish Wave Power APS developed a concept of the floating buoy. 9 m cylindrical concrete float is retained on the sea bed, by a piston as shown in Fig. 16 is pulled by float up by wave, and hydraulic force operates submersible hydroturbine rated 45 kW.

Test was conducted in North sea, but it failed after 1 month operation.

Wave Energy R&D in India

Ocean Engineering Centre of Indian Institute of Technology (Madras) succeeded in 150 kW power take off by wells turbine on caisson.

Wave Energy R&D in Norway

The Multi-Resonant OWC

Steel bodied OWC constructed by Kvaerner Brug on the Island of Toftestallen, It generated rated at 600 kW, but the device was destroyed after running for several years.

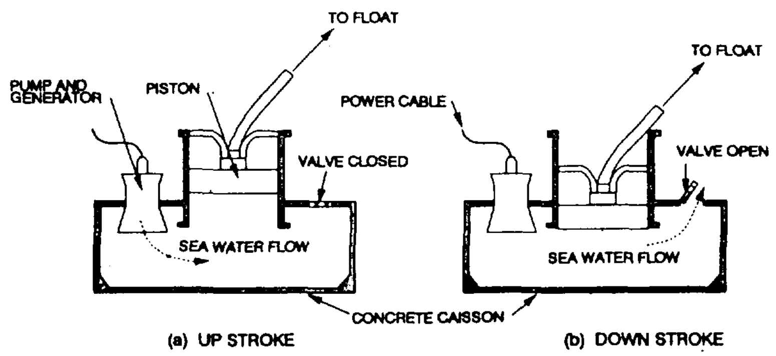

Fig. 16. Danish Wave Power Device.

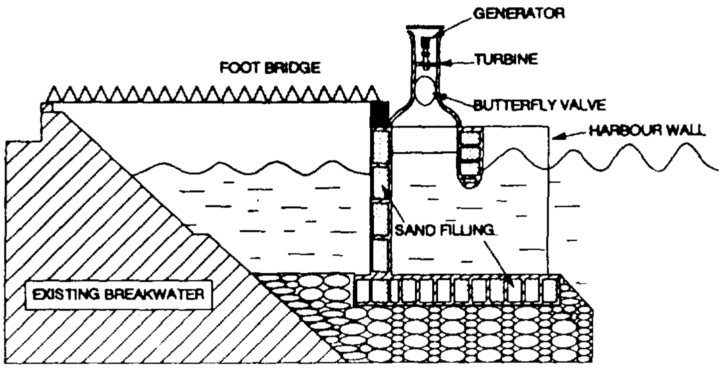

Fig. 17 Cross section of Indian breakwater OWC device

The Tapered Channel Device (TAPCHAN)

This was novel a shoreline device constructed by Norwave A.S This scheme has three main elements; tapered channel of wave collector, reservoir and water turbine generator. Test site has surface area of the reservoir as 8,500 m^2 giving a storage capacity of several minutes, power is generated to flow back to the sea from elevated reservoir through a vertical Kaplan turbine with a 3 m nominal head driving 350 kW asynchronous generator.

Attempts are made to develop this device in several locations. Main limitation was reservoir should be between 3m to 5m above mean sea level with low tide area. Since topography controls the amount of rock excavation, which is a major cost centre. Therefore the cost of such system is very site-dependent.

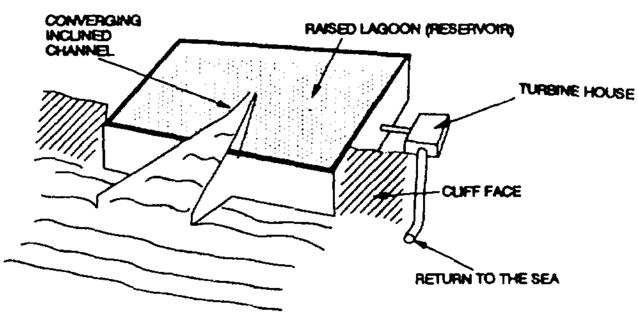

Fig. 18. The tampered channel device tapchan

Wave Energy R&D in Portugal

Technical University of Lisbon etc is progressing development of Shoreline OWC with Wells turbine. From 1993, 2000 kW unit will be constructed as EC project.

Wave Energy R&D in Sweden Horse Pump

Chalmers University progressed theoretical study. One of the main device is Hosepump, which has been developed by Swedyard Corporation (now Celsius Industries) and by Gotaverken Energy.

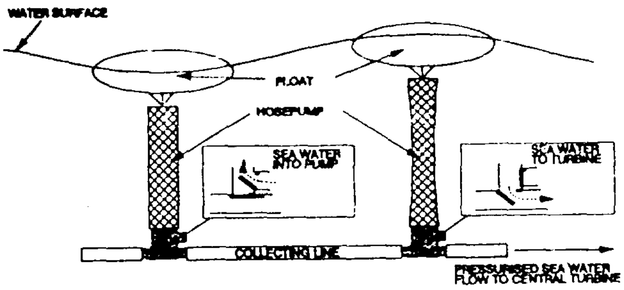

Fig. 19. The Swedish hose pump device

It is reinforced elastic hose, whose internal volume decreases as it stretch. They are tested in Norwegian coast, or Navigation buoy.

Wave Energy R&D in Japan

Sakata Port OWC

This was a five chambered OWC built as part of harbour wall. Caisson was built in Sakata harbour. It has capacity of 200 kW unit, but 60 kW is operating.

Pendular

This is a pendulum flap device by hydraulic device, developed by Muroran Industrial University.

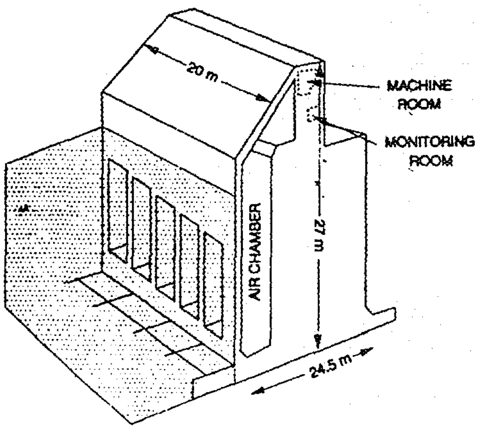

Fig. 20. Sakata port OWC

Floating type Kaimei OWC

This was a single floating structure, similar to a ship, which acted as a test bed for OWCs and their associated technology. Several countries participated in the testing programme within the framework of IEA. Safety of turbine generator, ship hull, cable, mooring were confirmed, but conversion efficiency from wave to air output was poor performance.

Cylinder Float Backward Bent Duct Buoy (BBDB)

Backward Bent Duct Buoy (BBDB) in Fig. 23 has an air chamber bent backward from wave direction. BBDB can design in a shallow draft, in addition, duct opening does not face to wave and current, this means that BBDB has a low-drag design. BBDB was studied by me and MR Liang and Gao, Guangzhou Institute of Energy

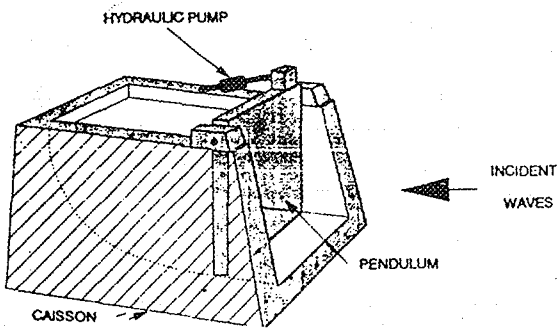

Fig. 21. Japanese pendular device

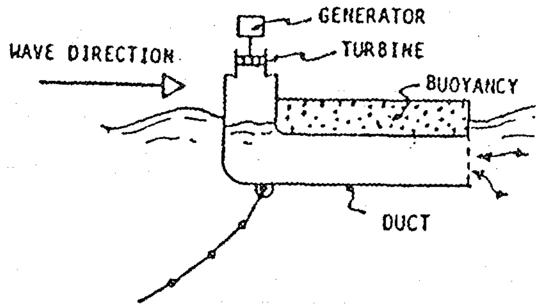

Fig. 23. Backward Bent Duct Buoy.

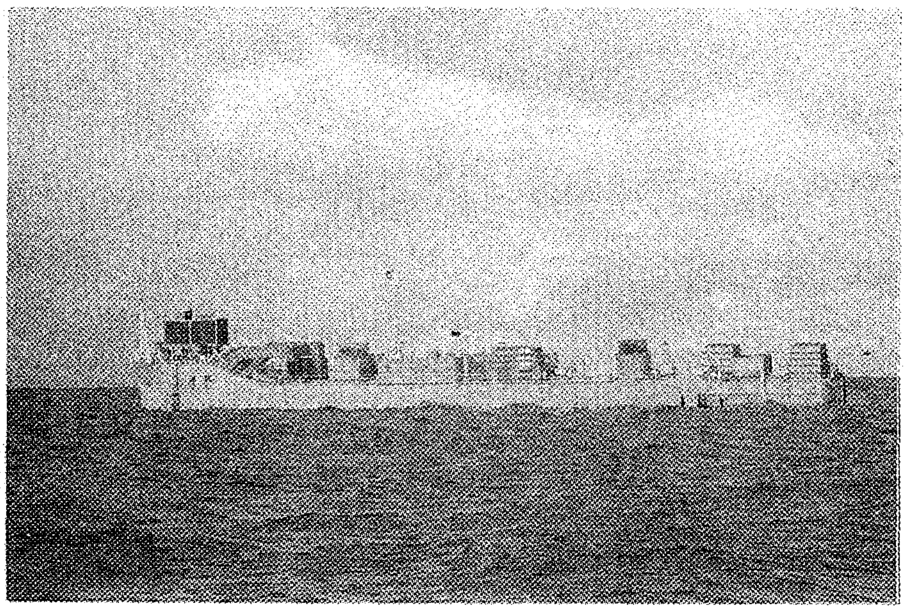

Fig. 22. Kaimei

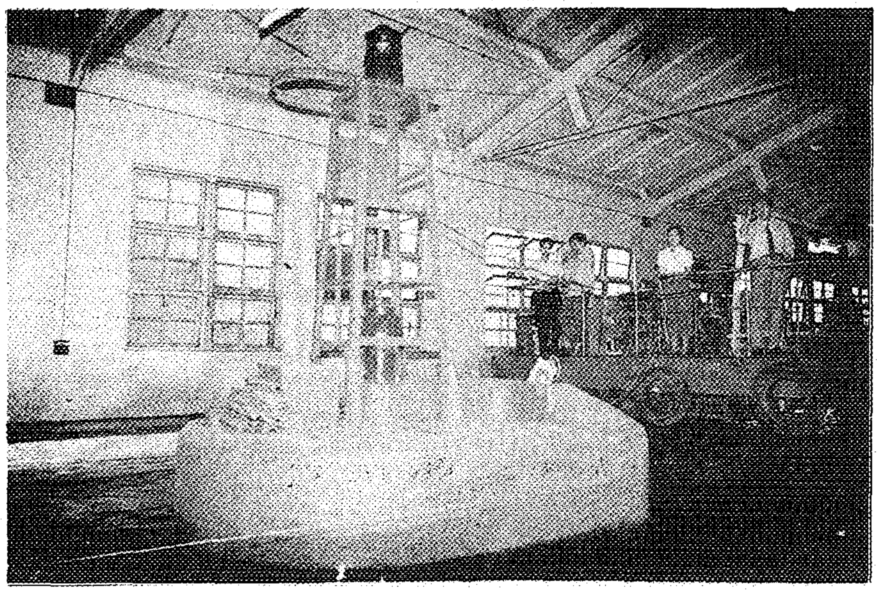

Fig. 24. Larger water tank of cylinder float BBDB

Conversion, Chinese Academy of Science. At present practical use for navigation buoy and light ship is about 10 numbers. BBDB have much larger output than the other floating type buoy, 3 times of centre pipe buoy, 10 times of Kaimei.

Another improvement was obtained recently by changing float shape from box float to cylinder. float. Fig. 24 is large water tank test in China, it is 2.85 m in length, 2.2 m in width, 2.4 ton in weight, float shape is half cylinder. Conversion efficiency of this new BBDB is very high, and it has wide band width as shown in Fig. 25. BBDB has 3 oscillation periods, heaving, pitching and duct oscillation period. BBDB with box shape float has one peak, but cylinder float BBDB has two peak with wide band width.

As shown in Fig. 26 Kaimei needs I wave length, but Cylinder float BBDB needs 1/6 in minimum, and high efficiency. This improve economy of wave power.

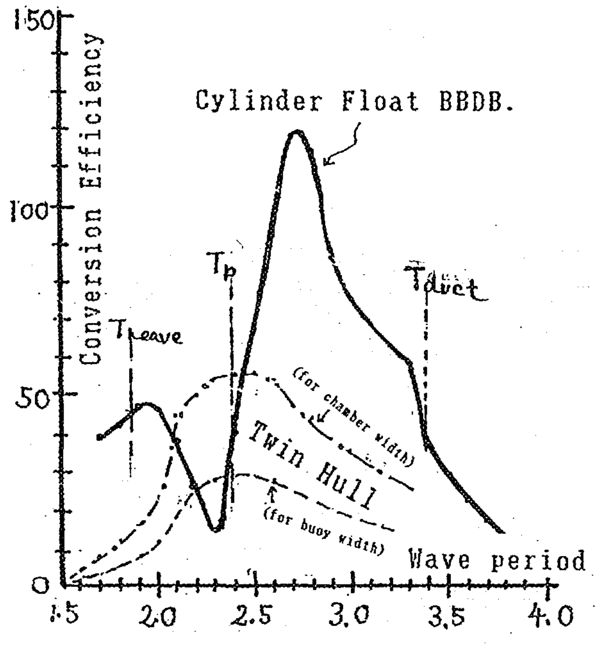

Fig. 25. Comparison of Conversion Efficiency by kindness of BBDB

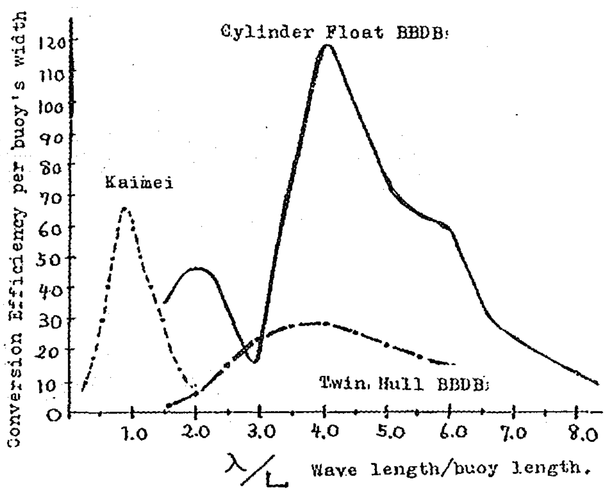

Fig. 26. Comparison of wave length/buoy length and conversion efficiency

And Conversion efficiency is very high in cylinder float BBDB it is 120% in peak.

Since Kaimei needs to use 10 turbines, but BBDB is enough to use only one turbine and Twin hull BBDB is only one peak, but cylinder Float BBDB has three peak in wave periods.

10 times large buoy, 28.34 m in length, 22 m in width, 15 m in height, half cylinder float BBDB as shown in Fig. 27 was proposed. It will be 400 ton constructed by steel.

2 units of 500 kW wound rotor induction generator rotated by double rotor wells turbine. When it is operated in North Atlantic off UK, power cost is estimated 10.7 cent/kWh.

Economic Status of Wave Energy

Based on UK major wave power concept, it is estimated as shown in Fig. 28 in it cylinder float BBDB is based on my estimation, and now it is under check by Dr T W Thorpe ETSU UK.

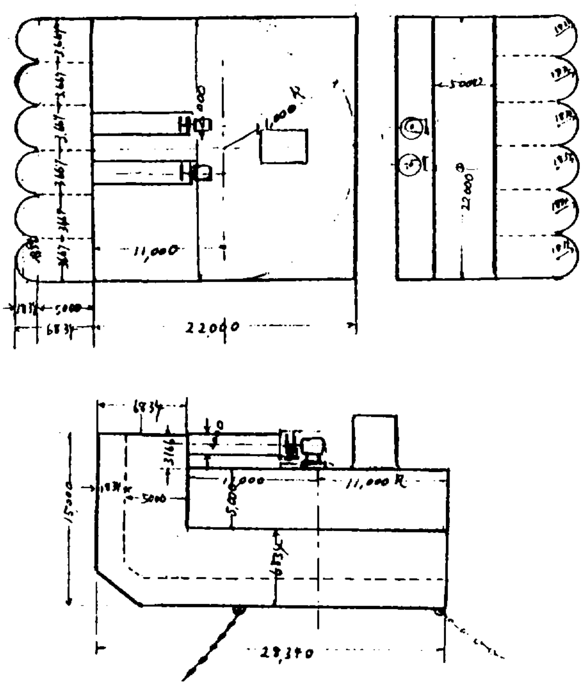

Fig. 27. 10 Times larger cylinder float BBDB

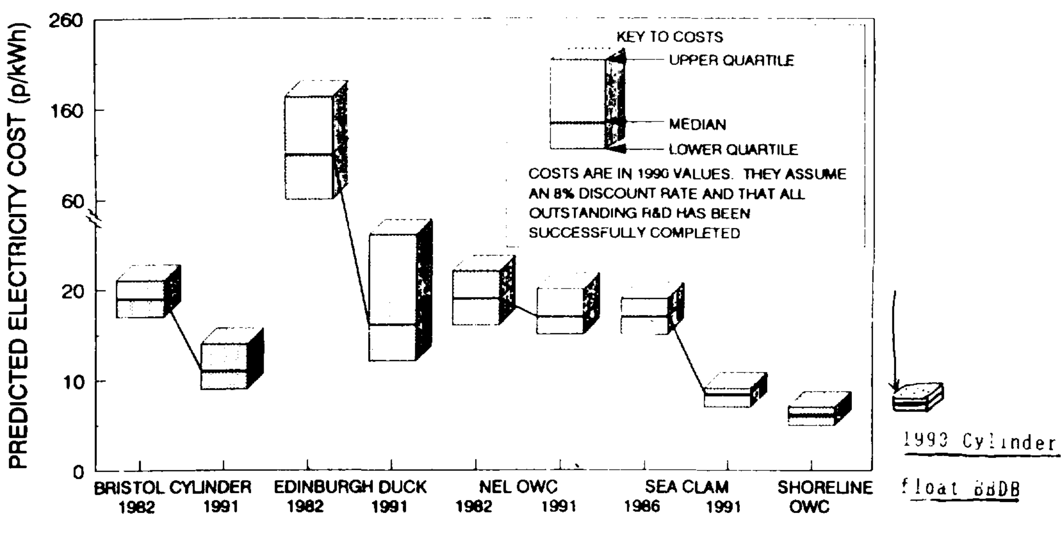

Fig. 28. Summary of predicted electricity costs for the main wave energy devices

Table 2. Electricity Costs for the main wave energy devices at SOUTH VIST

Device	Electricity Cost at 8% Discount Rate (p/kWh*)	Electricity Cost at 15 % Discount Rate (p/kWh*)
Bristol Cylinder	12	20
Edinburgh Duck	16	26
NEL OWC	16	29
SEA Clam	8	12
Shoreline OWC	6**	9**
Cylinder Float BBDB 7 p/kWh		

In major wave power devices, SEA CLAM, Shoreline OWC and Cylinder Float BBDB are cheap device for future use.

Note :

These are median costs expressed in 1990 prices and assume successful completion of all outstanding R&D.

** Shoreline costs are very site specific being dependent on shoreline geology, local topography, wave focusing etc.

Table 4. Summary of The Environmental Impacts of Wave Energy

Environmental Effects	Shoreline	Nearshore	Offshore
Land use/sterilisation	S		
Construction/maintenance sitescr	S		
Recreation	S	S	
Coastal erosion	S	S-M	S-M
Sedimentary flow patterns		S	S
Navigation hazard		S	S
Fish & marine biota	S	S	S
Acoustic noise	S		
Working fluid losses	S	S	
Endangered species	S	S	
Device/mooring damage	S-M	S-M	

Key : S - Small
M - medium
L - large

EC Selected Devices

From different devices, 10 devices are selected in EC study as follows.

Table 4

NEAR-SHORE WAVE POWER CONVERTERS			OFFSHORE WAVE POWER CONVERTERS			OFFSHORE WAVE POWER CONVERTERS		
Bottom-standing			Tight-moored			Slack-morred		
Air	Water	Oil	Air	Water	Oil	Air	Water	Oil
OWC				DWP	B&F 1978	Sea Clam	Hose Pump	ISP Mark IV
				Bristol	BBDB			PS Frog
				Cylinder				
								The Duck

EC schedule to study wave power is as follows.

(Phase I)

1994-1995, Shorelines OWC are constructed in Portugal. UK and others in Europe, Its capacity is 2000 kW–500 kW in each. Other devices are studied in Water tank etc.

(Phase II)

1995-1998 one device selected from 10 devices is tested on sea.

Environmental Aspect of wave power Energy

Wave Energy is generally a clean source of renewable energy, there is no emissions of CO_2. Its effect is shown in Table 4

For Developing Countries

1. There are many islands and isolated shore lines in the developing countries. Wave energy is rich in these area, for example, wave record in Tongatapu is shown in Fig.

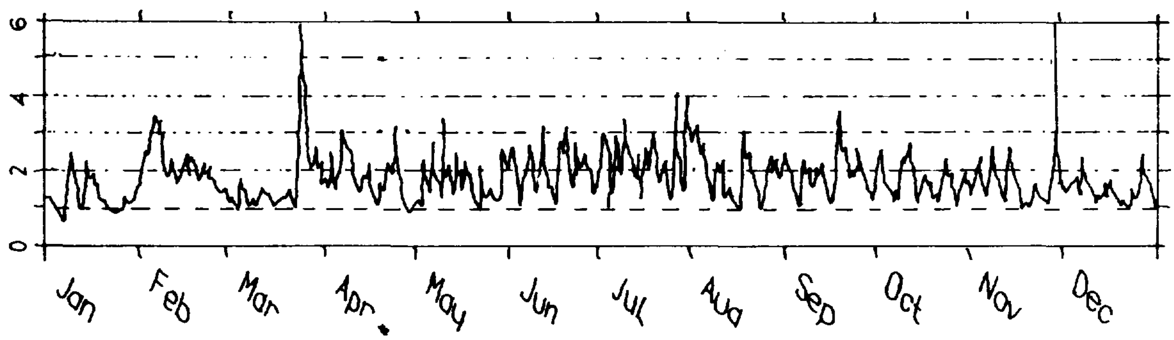

Fig. 29. Time series of Signifficant Wave height at Tanogatapu at 1900.

29, this record was measured by Norway's Group, it is relatively constant natural energy.

Electrical power supply for such islands is presently being supplied by diesel generator at a cost of 30-50 cent/kWh, Some of Wave Power Device such as shoreline Gully OWC, Caisson OWC, Cylinder Float BBDB, Sea Clam, Horse Pump will be adoptable to such demands.

2. Wave power study by EC or UK is a development plan to supply 10% of electricity of their demand, and 2 GW plan etc are discussed, but, it will be started in 1,000 kW capacity from shoreline Gully OWC in Portugal and UK to supply electricity to weak grid line in island, and it will follow floating device after selection study. Those developing efforts will be useful not only EC, but also developing countries.

3. Wave power use for small buoy also interested target, developing countries must improve harbour and ship transportation for himself, wave power use for such buoy is reliable and economical way, I wish to recommend new cylinder float BBDB buoy developed for buoy use, it can use strong light and Beacon on the buoy.

4. As my private opinion, Cylinder Float BBDB in larger scale will be able to compete in economical terms with conventional generating station (i.e. oil and coal fired stations).

Reference

A review of Wave Energy by T W Thorpe, ETSU (ETSU-R-72)

Indian Wave Energy Programme - The 150 kW Pilot Plant - Future Plans

Prof. V. S. Raju
Ocean Engineering Centre, Indian Institute of Technology, Madras 600 036, India.

Introduction

Development of technology for renewable sources of energy is very important for any developing country. Wave energy is one of the promising forms of renewable energy sources which has received considerable attention. Sponsored by the Department of Ocean Development, Government of India, theoretical and laboratory investigations which commenced at Indian Institute of Technology, Madras in 1982, culminated in the installation of a 150 kW pilot wave power plant off the South West coast of India near Trivandrum.

The conversion of wave energy to electrical energy to pilot plant is based on the Oscillating Water column (OWC) principle (Fig. 1). It consists of a chamber exposed to waves with an opening in the front. Under wave action, air inside the chamber gets compressed and ramified which in turn rotates a special air turbine. The turbine is coupled to an induction generator to produce power.

The pilot project which is an inter-disciplinary one has been a joint effort of several Governmental & non-governmental agencies (Appendix-A). Based on the experience gained so far, several such systems are proposed to be installed as part of breakwaters of new harbours.

Laboratory Investigations

The prototype dimensions were selected based on extensive laboratory investigations, to make the device resonate for the most predominant period of the incident wave. Since the wave parameters vary from time to time and from place to place, it is very important to see that the device absorbs energy more or less equally well over the range of waves predominant at the site. This means that the device should effectively absorb power from a broad band width of wave spectrum.

The studies conducted at IIT Madras showed that a multipurpose OWC type wave energy device is suitable for Indian coast. A number of such devices can be arranged to form a barrier or breakwater of a harbour. This can provide berthing facility for boats apart from power generation.

Sea Trial

A site near a fishing harbour in Trivandrum was chosen for the location of the prototype device. The choice of site was made based on the power availability, extreme wave conditions, construction facilities available and the sea bed characteristics.

The prototype device is a reinforced cement concrete caisson structure of dimensions 23.2 m x 17.0 m in plan and 15.3 m high (Fig. 1). Over it, is a dome which supports the turbine and an induction generator.

The construction of the 3 m high bottom portion was done in a pit on the beach. Subsequently, it was pulled out and brought near a jetty for construction of walls and the dome, in floating mode. After the construction was completed, the structure was towed out of the harbour and installed on a prepared sea bed. Later, the turbine and the generator were mounted on the caisson and connected to the main grid. The plant was commissioned in October 1991.

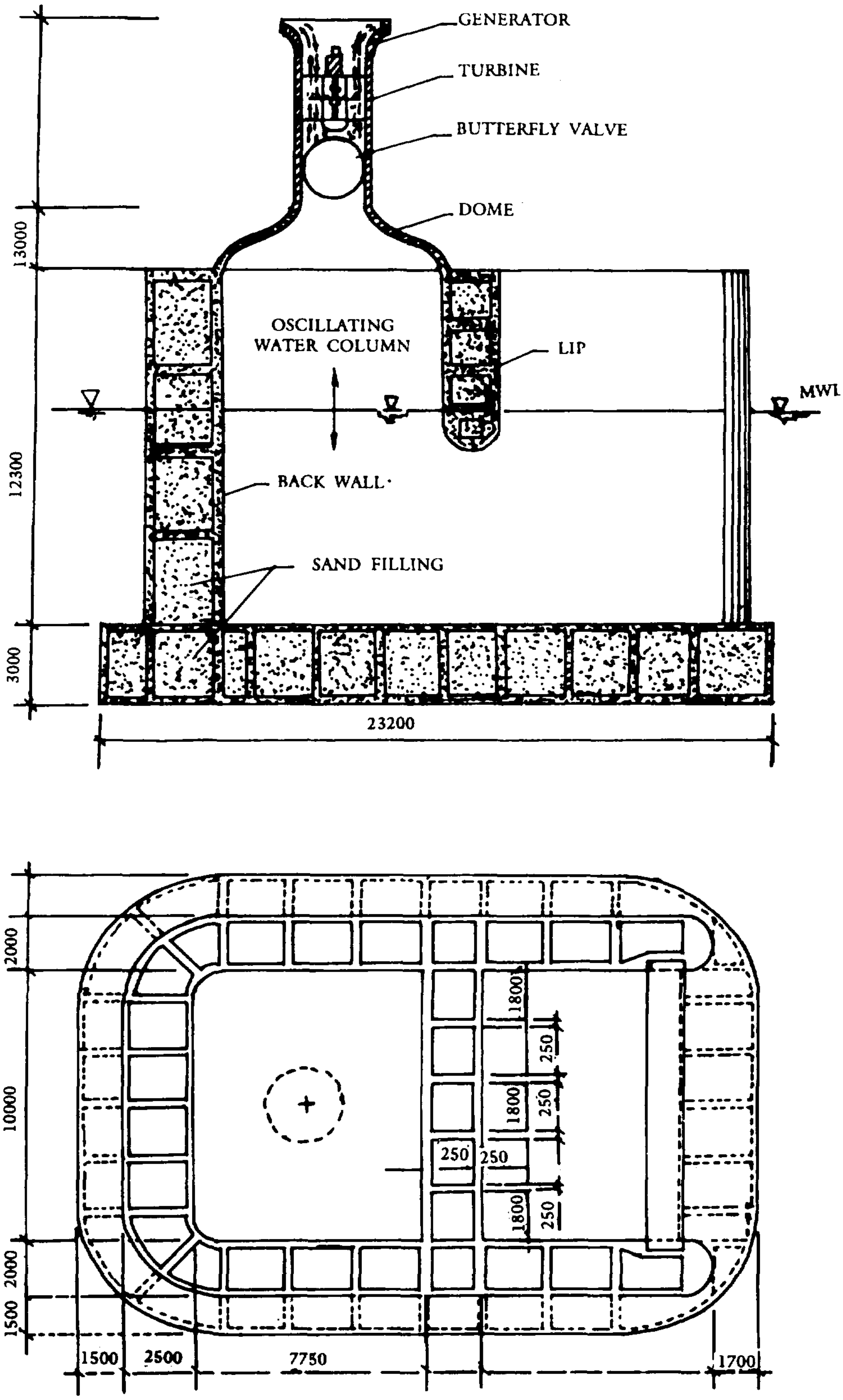

Fig. 1. Cross Sectional Elevation and plan of Wave Energy Caisson (Set No. 1. Indian wave energy programme).

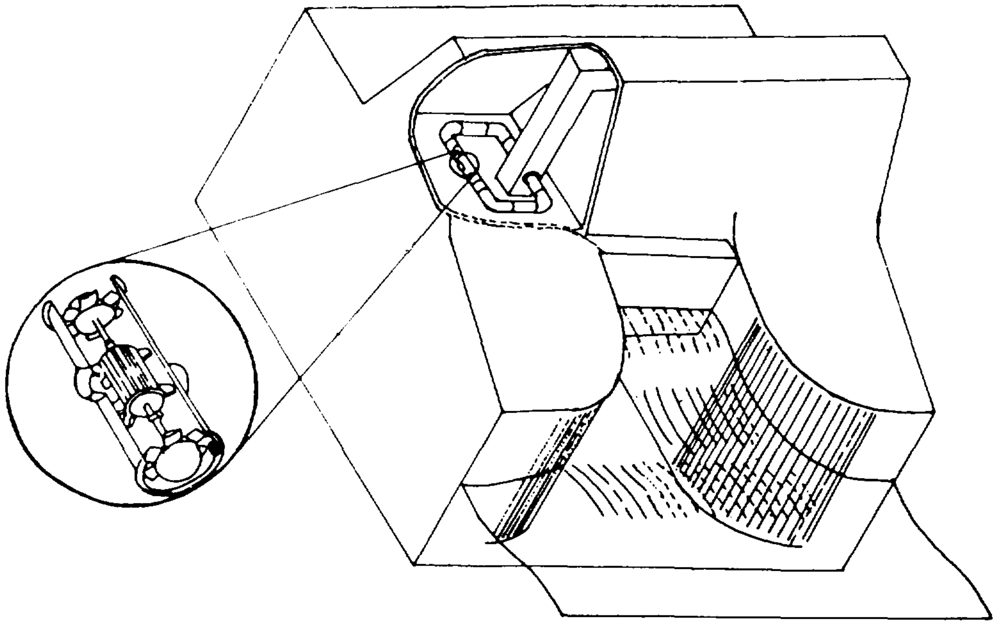

Fig. 2. Perpective View of future wave energy cassion

Performance Monitoring

The prototype plant was instrumented and provided with a Data Acquisition and Control System for its performance monitoring. Sufficient data have been gathered on various parameters viz power, turbine speed, torque, air pressure, air velocity, wave induced pressures on the structure, incident water surface elevations, etc.

The structure has survived severe monsoon waves for three consecutive years. The wave induced pressures measured on the structure were within the theoretical values predicted earlier for the design purpose. From the measurement of power, it was noticed that during the lean period, the average power input along the 10 m width of the device was of the order of 20 to 30 kW only. But the losses in the turbine and generator were also of the same order resulting in apparently negligible output. At the same time, when average power of 20 to 30 kW was generated, the energy output was seen to vary from 10 kW to about 80 kW within few seconds. This meant, that a single large turbine/generator will not be able to cater to the varying energy inputs. Based on the results of the performance monitoring, studies are being carried out to design the power module to absorb from a wide range of energy.

Future Plans

Two locations viz, Thangassery in Kerala and Musbay of Nicobar Islands, where harbours have been proposed are chosen for the installation of wave energy devices on commercial basis. The devices are planned to be put in combination with breakwaters of these harbours. The design is proposed in such a away that the leeward side of these devices can be used for berthing of vessels. (Fig.2)

Experimental investigations on wave forces and determination of optimum spacing of the devices have been conducted and structural designs are finalised.

THE PROJECT IS A TOTALLY
INDIGENOUS EFFORT
INTER INSTITUTIONAL & INTER DISCIPLINARY

Major Contributors

SPONSOR	:	DEPARTMENT OF OCEAN DEVELOPMENT
DESIGN & CO-ORDINATION	:	INDIAN INSTITUTE OF TECHNOLOGY, MADRAS
CONSTRUCTION SUPERVISION & INFRASTRUCTURE	:	HARBOUR ENGINEERING DEPARTMENT, GOVERNMENT OF KERALA
CONSTRUCTION OF STRUCTURE	:	L & T, ECC CONSTRUCTION GROUP
POWER MODULE	:	K.C.P. LTD., MADRAS AND KIRLOSKAR ELECTRIC LTD., BANGALORE

Offshore Technologies in the 1990s with Particular Emphasis on New Premises for Ocean Wave Electric Power Generation

Prof. Arild Rodland
Norwegian Institute of Technology Indonor As, P.O. Box 207, Vagsbygd, Norway.

1. Background

Norway began the development of its offshore non-living resources by the end of the 1960's. The drafting of the legal framework by this time had just been completed allowing the mid-line between bordering the offshore areas to apply as borders between the countries in regard to the exploitation of the continental shelf resources. The fact that this was completed prior to the first discovery of economically viable resources later has been regarded of high importance since several finds otherwise might have caused dispute among the nations.

Prior to this time Norway had virtually no activity nor competence in the fields of offshore technology. True, the country had a strong maritime community with long traditions of shipping and fisheries with a number of related activities, such as ship-building and technology for equipment related to these activities, but nothing in regard to minerals exploitation or ocean energy. As late as 1965 the idea that Norway would have a strong national oil company among the largest in the world on offshore oil and gas export would have been about as likely as for the moon to fall down.

The first discovery of oil on the Norwegian Continental Shelf, later to be deemed commercial, occurred in 1969. First production commenced in 1971 from 4 very modest offshore wells in the southern part of the North sea, incidentally sub-sea completed already at this early point in time. Sub-sea completions later as you know have been at an innovative level for about all the years up until this time. By 1972 the state oil company was formed to look after the national interests at an operational level and further big discoveries were made in 1974 and following years. Norway become a gas exporter and already in 1983 supplied about 25% of the gas consumption in the United Kingdom and about 12 - 13% of Continental Europe.

This has later been expanded further and as of today Norway has an off-shore oil and gas production of about 135 mill tons of oil and gas and exports more than 10X the country's own need for crude oil and oil products. Pipelines have been laid on the ocean bottom to all the major consuming countries in Europe, such as Germany, BeNelux and France as well as England.

2. The Technology Background

Existing technology on offshore mineral exploitation at the time when Norway came into the picture was largely American Technology. Since the end of WW II there had been a growing development in the US of offshore oil and gas resources with a related development of technology. Firstly onshore technology expanding into the near shore regions, such as drilling derricks erected on jetties, and subsequent production wells located on these jetties. Thereafter slanted boreholes, directional drilling from one geographical location to tap reservoirs underlying another geographical location. This opened up for platform based development of offshore resources and subsequently there was a rush of such development, particularly in the Gulf of Mexico.

By 1980 this had evolved to a state where platforms could be built and installed in water depths down to 350 m in climatewise not too harsh areas. Drilling could be done from such platforms at angles slanted up to 60 degrees from the vertical thereby tapping large areas around the platforms. Pipelines were laid in these water depths, but for big trunklines there was a more shallow depth-limitation, approx 150 m.

This technology created a good starting point for the Norwegian offshore mineral exploitation activity. Actually it was US companies who made the first discoveries and produced the first oil and gas. But it soon became clear that further development was needed. The stormy waters and cold climates off the Norwegian coast called for stronger structures to drill and produce from. And the desire to reach Europe and England with subsea pipelines from Norway meant that big trunk lines would have to be installed in 3-400 m water depth.

The challenge became particularly severe in 1986 when the world market prices for oil and gas dropped from the high level they had previously held. There were widely held opinions at that time that Norway would not be able to maintain its position as an oil and gas producer in the new, low level price regime. The answer was further development of technology.

The drilling technology evolved from slanted holes to horizontal drilling. Capability now is to reach 6-8 km sideways out from a platform with boreholes having a diameter of 8-10", thereby being able to tap large reservoirs with only one platform which earlier needed three platforms. And as we will see, the drilling technology has not yet reached its limits.

The pumping technology was developed to open up entirely new perspectives. No longer was it needed to take the mixture of oil and gas up to the platform for separation before pumping. New pumping concepts are able to transfer the mixture as it comes to the sea bottom, through subsea pipelines to processing centers which may be located in more shallow waters.

And the platforms themselves changed. No longer do they have to sit on the sea bottom. Instead they may be flexibly anchored to the bottom, by tension legs and anchors and yet be able to withstand the same climate conditions as before. And of course be made much lighter and less expensive.

Behind each of these macro changes there are a number of less visible improvements. With the long horizontal distances that originated from the 1-platform development concept came the deficiencies of existing technology on control systems. No longer could they be hydraulic as they used to, for hydraulic energy would not give rapid enough response over long distances. So electric control and actuation systems had to be developed.

And weights of course had to be reduced on the platforms, if what was previously on three platforms one would be on one and particularly as sea bottom steel and concrete platforms were exchanged for floating and tension leg platforms. The heaviest equipment pieces came under fire first. Consequently mud pumps are no longer mechanical, but hydraulic since that provides for a 60% weight reduction.

All these examples are just to substantiate the technology background. Mineral exploitation below the sea, from the sea bottom or below the sea bottom, is something which more than anything else over the past 20-30 years has been carried forward by the search for oil and gas. Because of its rich resources and the policies adopted for exploitation of them, Norway has become one of the leading nations in terms of ocean technology. No longer is this technology necessarily expensive for the low world oil price regime does not allow that. Numerous techniques have been developed in the oil field offshore which in time may also be used for other mineral prospects. This paper will develop that aspect further.

3. The Energy Background

Norway burns oil for the automotive segment of the economy and to some extent for industrial domestic heating. But the dominating energy source in Norway is by far Hydroelectricity. The country has a hydroelectric potential of approx 165 TWh (=160,000,000,000 kWh) of which approx 105 TWh has been developed, 35 TWh has been permanently set aside for conservation and environmental purposes and the remaining 25 TWh is due for development in the future. This is more than the country needs, and consequently there is a considerable export of electric energy to neighbouring countries, primarily Sweden, Denmark and Continental Europe.

The principal point in this has to do with the environmental and historic impact of the use of energy. Using non-renewable resources deprives future generations of energy. Among the non-renewable resources those which pollute the least should be used first. Renewable, non-polluting energy resources should be given priority whereever and whenever possible. Technology-holders around the world carry a particular responsibility to direct the development of technology so that cleaner energy sources may come into use, and particularly so that renewable, non-polluting energy sources may take a larger portion of the overall energy supply.

In this line of thinking Norway in 1977 embarked on a comprehensive technology development program in favour of new energy sources. Foremost among them was wave power based on the proximity in Norway of the maritime environment and the development of offshore technology which by then could be foreseen.

The development program culminated in 1986 by the construction of a full scale ocean wave electric power plant on the Norwegian west coast. This plant has later produced considerable amounts of electric power which has been delivered into the local domestic supply market, and also been a demonstration object for numerous visitors from various countries.

Numerous technologies exist for the transformation of wave power into electric power. The Norwegian alternative has given full priority to simplicity and the quality of the electric power. Total absence of components supposed to be moving in the sea environment and use only of machine elements with a proven record in the production of electricity.

A **tapered channel,** with a wide angle opening into the ocean where the waves come from, built in steel or concrete, leading the waves inward through successively narrower cross sections causing the wave amplitude to lift higher and higher until it lifts over the edge into an adjoining water basin. This is the hydropower reservoir from which the water flows back to the sea through a conventional low-pressure/high volume turbine thereby creating electric energy.

This is the **Tapchan concept** in its basic form. Approx 30% efficiency which means that 30% of the energy contained in the oceanwaves is transformed into electric power. A 2 m ocean swell normally will contain 20 kW/m which indicates that such a wave climate may produce approx 1 MW per 150 m of Coast line.

4. Indonor AS; A Norwegian corporation contributing on technology for exploitation of ocean resources.

The company was incorporated in 1986 with the purpose to undertake the necessary actions to see the technology developed in Norway on utilization of ocean resources into active service or coordinate others to do so, primarily dedicated in favour of areas in the Far East.

Behind the company was a combine of Norwegian large and medium sized Norwegian industries, today under the leadership of TWH/Oil Industry Services of Krishtiansand, a large offshore contracting company working in conjunction with Norwegian authorities. The company today constitutes the main effort of official Norway to bring out an up to date technology for utilization of the ocean energy in favour of countries which may thereby be able to replace non-renewable energy sources.

The Indian ocean was considered as a prime source for ocean energy. After some initial surveys priority was given to an ocean energy plant in Indonesia, on the south coast of Central Java. The first wave climate survey was undertaken in 1988 and later followed up by a more comprehensive study involving a waverider buoy exposed for an extended period of Cilacap on the South Java Coast in conjunction with Geosat analysis. Site surveys were conducted in a number of locations in south Central Java with preliminary engineering studies undertaken for 3-4 of the locations finally focusing on Parangrachup, a peninsula just west of Baron Bay in South Central Java as the place for a 1,1 MW wave power plant. A confirmation study was undertaken there and completed only a month ago with positive results. The detailed engineering then had already been completed and the necessary documents submitted to the Indonesian authorities. The project had gained an A-priority in Indonesia and final settlement on the details of the construction contract is on the way. We now expect that this settlement will be completed in 3-6 months so that construction may actually commence during the first of half 1994.

The wave climate studies and analysis concluded a wave climate with an energy content of 20-30 kW/m primarily constituted by long ocean swells coming from far away in azimuth directions 190-240 degrees and with a very good endurance profile. A conservative estimate on the endurance indicates that the plant will be producing for 4000-5000 hrs/yr. With a total investment of approx US$ 7 millions this adds up to energy capital costs of US cents 7-8 per kWh based on the actual financing package which has been negotiated for the project. This compares quite favourably with the electricity supply in this area and actually will produce directly into the existing electricity grid at a price which is lower than the price seen locally by the small consumer.

The plant is a **Tapchan** ocean wave electric generating plant with 1,1 MW installed capacity. The principal dimensions are approx 200 x 200 m including both the tapered channel and the reservoir. The construction has been adapted into the local topography which has thereby also to some extent been indicative of the plant dimensions. Part of the construction thereby is blasted directly in the rock formations while other parts are cast in concrete. As we will see later an important feature of the Tapchan concept is the adaptability to local terrain, both above and underwater. In most kinds of topography and bathymetry viable adaptations will be found, and in some, as we will see they will be quite interesting.

Lately and as a consequence of the construction techniques used in the wave power plant development, Indonor has also taken up work with underwater mining technology. This is based on offshore drilling technology developed in Norway for the benefit of the oil and gas industry, and particularly with the goal of achieving gravity independent, remotely controlled drilling.

★ The Kolibomac system is presented on overhead, no written text.

A study has been made to explore at what cost minerals may be brought to the surface based on this technology. It appears that relevant figures are approx US cents 3-4 per kilogram of cuttings, such cuttings being up to 1-2" in size. The waste content may be kept at a very low level, since mineral extraction by such a method may be kept entirely in the mineral string, even though the string may have very small cross section. The study was based on an onshore project where the longest extraction occured over a distance of approx 1 km. However, there is nothing in the concept to prevent it from finding utilisation on underwater deposits. Actually to the contrary in oil and gas extraction the concept already works on underwater deposits, with water depths of 150-400 m, extracting deposits from drilling depths of 2.5 km with gravity independent, horizontal drilling as an integrated part. Utilizing this technology for such pruposes therefore would seem to be a natural development.

This leads up to a comment on yesterday's discussion on deep sea mining which seemed to concern itself with the options of mechanical versus hydraulical lifting systems, or lifting the nodules by air or gas lift as that is called in the oil field. The comment to be made here is strongly in favour of the latter methods. Within drilling there is lots of experience built on solid transport in fluid suspensions, including quite sophisticated manipulation of viscosity and mechanical agitation to keep solids suspended. Circulating fluids may be treated so that viscosity is low when low pressure losses are desired while the same fluid changes in favour of an elevated viscosity when it arrives at the point where the maximum lifting capability is given priority. Within the field of petroleum production there is correspondingly extensive experience on gas lift, and among them surely the method may be found for the lifting of manganese nodules to the surface.

The field of petroleum engineering may be the only one with extensive experience in general on the management of operations which are located several miles away, into the earth's crust under high temperature and pressure. Like operating as a dentist on some poor patient at ground level, with a string of macaroni from the fifth floor as someone put it at one time. Working on the Oceanfloor is like a mild exercise compared to the deep boreholes even though it may be 5 km away. No temperature problems, reasonable pressure, definitely predictable and no danger of blowout. Mechanical systems are successively being replaced by hydraulic, electrical and in some cases pneumatic systems in the oilfield. That's why we think mechanical transfer systems may be a blind alley in ocean mining.

There is another possible way though. Norwegian fishermen are expert trawlers, including trawling for shells embedded in sediments at the seabottom. Combining their trawling technology with hydraulic lifting from the oilfield might be a new cheap, high capacity alternative for oceanfloor nodule sampling. The lifting string should very definitely be slim and flexible. There exists a good alternative for oilfield use, of French origin even though it may have to be modified as does also deep sea fluxgate magneto-meters possibly a missing alternative for navigation along the most dense pattern of deposits on the sea bottom. Should any of this be of interest, I would be happy to co-operate and establish contact with the right entities in the oil industry, in Norway and elsewere.

5. The Indonor Tapchan Concept for Ocean Wave Energy Sedimentary Regions and Improved Reservoir Characteristics.

Simplicity and ruggedness were the main criteria for the Indonor to select the Tapchan Ocean Power Technology as the basis for its ocean wave power business concept. But not exclusively. Important also was the power quality. If wave power were to be taken seriously for electric supply, domestic or industrial, it would have to produce with stable frequency and an even and predictable performance level. The Tapchan concept inherently does that, to a far greater extent than any other technology considered at the time. The difference is the holding volume in the reservoir. Even though a conventional Tapchan reservoir only contains enough for minutes of full production, it effectively smoothens out all variations in frequency and output which could otherwise originate from the individual wave impacts. If the Tapchan plant produces into an existing grid, there is no need for any bigger reservoir because automatic load distribution systems will tap the plant when it produces and eliminate it from the grid when it does not.

However, for wave power to become an alternative also for isolated communities with no backup, or where backup may only be obtained at a high premium something had to be done on the energy storage capacity. In 1990 Indonor embarked accordingly, on a technology development program based on the Tapchan technology and focused on construction concepts, methods and materials to facilitate an energy storage capacity large enough to catch at least the 24hr consumption cycle and possibly go beyond to build up reserves for extended low spots in terms of wave climate, and yet not increase the investment needed for a certain installed generator capacity.

Most people consulted early in the project considered this an impossible task, since common knowledge seemed to be that wave power was already struggling to have a competitive price structure, even without a reservoir.

The project yielded interesting results. Focus was placed on sedimentary regions, sandy beaches or beaches with mixtures of sand and shale, or pebble beaches with or without a sedimentary hinterland. The Tapchan plant was firstly moved into the sea, a shallow water offshore construction drawing on the experience gained in the Norwegian offshore oil and gas industry in regard to hybrid steel/concrete constructions; however not changed in terms of physical dimensions. A proprietary method of construction was invented which created a tapered channel with wave collector and holding reservoir with the same proportions as before. A detailed cost/benefit engineering study concluded that this proprietary design could be constructed at approx 60% of the cost of the previous, conventional design including the turbine/generator-installation which of course had not been reduced in cost. There is a patent pending for this design, and we are therefore not able to show details. However, with it came an easy option for multiplication of an initial plant insofar as it could be step wise repeated in one or both sideways directions with an even greater saving on cost since the holding reservoir would be partially in common with the units previously built.

The problem of the storage capacity was addressed separately using modern polymer materials in combination with basic dam building technology, the principle employed being related to a switch of cost proportionality factor, from the volume of the reservoir in favour of the reservoir perimeter. The search for a solution, on this basis was successful. It yielded two different solutions, one applicable for reservoirs located onshore in a sedimentary region and another for a reservoir placed offshore, immediately adjacent to the shore. Both are considered proprietary designs and therefore will not be described in further detail. Patent is pending for both of them.

Using the conventional design as a benchmark in terms of cost limit for economic design that is US$.07-.08 per kWh, and inquire to find out what size reservoir might now be had within the limit of this price, the answer is somewhat dependent on the exact topography and constitution of the sedimentary ground where construction is to occur. However, under not too unfavourable circumstances the engineering studies show that the new design may provide for the 24 hr consumption cycle to be reached.

The implications of this are quite important. No longer is it necessary to design the wave power plant for the peak consumption level. It is not even necessary to design it for the average daytime consumption level. Night time consumption is normally at a much lower level. This is the time when the reservoir will be filled up, then to be drained during the following day. Inherent in this is the implication that another threshold has been established for wave climates which may be considered adequate threshold for economic wave power. Previously accepted was approx 20 kW/m in wave energy content. If the problem is simplified to a 12/12 hr-cycle and for the sake of argument the night time consumption is set at zero, that threshold has now been reduced to 10 kW/m.

The development study yielded another quite favourable solution, special in the sense that it applies only to regions where high elevation locations may exist to a sedimentary shoreline. High is not an absolute term in so far as any elevation from 40-50 m above sealevel will be significant, and close means within distances of reasonable pipeline hydraulic losses i.e up to 1 km. **The Tapchan concept** provides for an intermediate step in the energy transformation. Water lifted to say 4 m elevation above sea level is sent back where it came from, not through the generator but a pressure converter. The design and efficiency of this device is well known from down hole use in the oil field and converts an energy flow characterized by high volume/low pressure to the opposite low volume/high pressure. The concept now becomes capable of lifting the small volume of seawater to a reservoir at a higher elevation, thereby reducing the volume of that reservoir which is needed in order to cater for a certain consumption cycle. Certainly within reach for this specialized Tapchan concept is the 24 hr cycle. What may be within reach beyond that is not yet fully evaluated. But it is not totally inconceivable that annual cycles may thereby have become relevant in conjunction with ocean wave power.

This UNIDO workshop is actually the first time these results are made public. They have only been known to us for a short time. They enter the scene at a time when ocean wave power by many have been nearly written off as a viable source for renewable energy. The message very clearly is that the old premises for these conclusions are no longer good. New technological results have appeared and must be recognized. They indicate not only that the wave energy threshold for economic design has become significantly lowered, but also that wave power may now be seen in conjunction with energy storage which qualifies it as a base supplier of electric energy. The message goes primarily to all nations bordering oceans where this change in circumstances may make a difference, such as the nations bordering the Indian ocean, that they under- take to reevaluate what use they may now make of ocean wave power as a renewable energy source.

ENVIRONMENTAL IMPACTS

Environmental Impacts of Marine Resource Exploitation within the EEZs

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Mining the ocean shelves and continental slope areas, that is mining the exclusive economic zones, for economic reasons develop into large scale actions and it will inevitably impact the region. We must ask:

> What will be severe impact?
> How can we minimise them?
> Are there any sources e.g.., living resources?
> What steps have to be taken to avoid unacceptable impacts?

Let me start with an example: Phosphorite concretions from the Chatham Rise in the EEZ of New Zealand.

The Chatham Rise is a 150 km wide and 1000 km long hill which is submerged to a water depth of about 400 m and extends from the south islands of New Island in the west to the Chatham island in the east and yields about one third of the deep water fishery of New Zealand (Dawson 1984). Phosphorite gravel intermixed on the sea floor with muddy sands were reported first in 1952 (Reed and Hornbrook) and brief exploration of its commercial feasibility was carried out during a German/New Zealand joint venture in 1981 (Von Rad and Kudrass 1984). The area between 179° E and 180° E was identified as the most promising site for exploitation. The mean phosphorite concentration varies between 10 and 17% of the total sediment weight or approximately 54 kg m^2. The patchiness of the phosphorite rich areas complicate the assessment of the total reserves. Current measurements resulted in an average speed of 1-3 cm/sec in eastern direction. The maximum speed recorded was 25 cm/sec at 7 m above the sea bottom.

Figure 1 shows the different impacts to be expected. First of all the sediment surface of the sea bottom and the fauna on and in the sediment will be totally destroyed, depending on the penetration depth of the collector system into the sediment. Additionally the created sediment plume will transport finer particles over far distances according to the currents. Normally, water currents close to the coast are faster in the deep sea and along most continents we find upwelling regions with stronger current regimes. If commercial mining starts close to these areas, far distant areas can be smothered and the benthic fauna may be impacted. Nearshore shallow water areas as coral reefs or rich fishing grounds may be severely impacted. Natural food resources of coastal human populations or commercial fishing grounds as basis for international trade may perish. Potentially significant economic and social effects can arise and may change from being beneficial to detrimental.

Other areas of direct impact are surface or intermediate water layers due to the necessary discharge of tailings. The transport of the mined material to the surface will result additionally in the discharge of cold deep water, fine sediments and abraded particulates from the ore transport and can badly influence life in surface layers. Lower right penetration created by the plumes discharged from the mining platform and the transport vessels can influence the growth rate of planktonic algae and lead to tremendous alterations in the food chain, for e.g. fish larvae resulting in lower fish recruitment and production. Sinking parties may severely influence zoopankton also in and from deeper water layers because it is known that these animals show a normal diurnal migration according to the diurnal migration behavior between deep and shallow water layers. According to Dawson's conclusions (1984) of an impact on the benthic fauna, "the Chatham Rise is an essential part of the New Zealand EEZ's fisheries scene and any environmental disturbance on the Chatham rise might have widespread ramifications beyond the Rise itself".

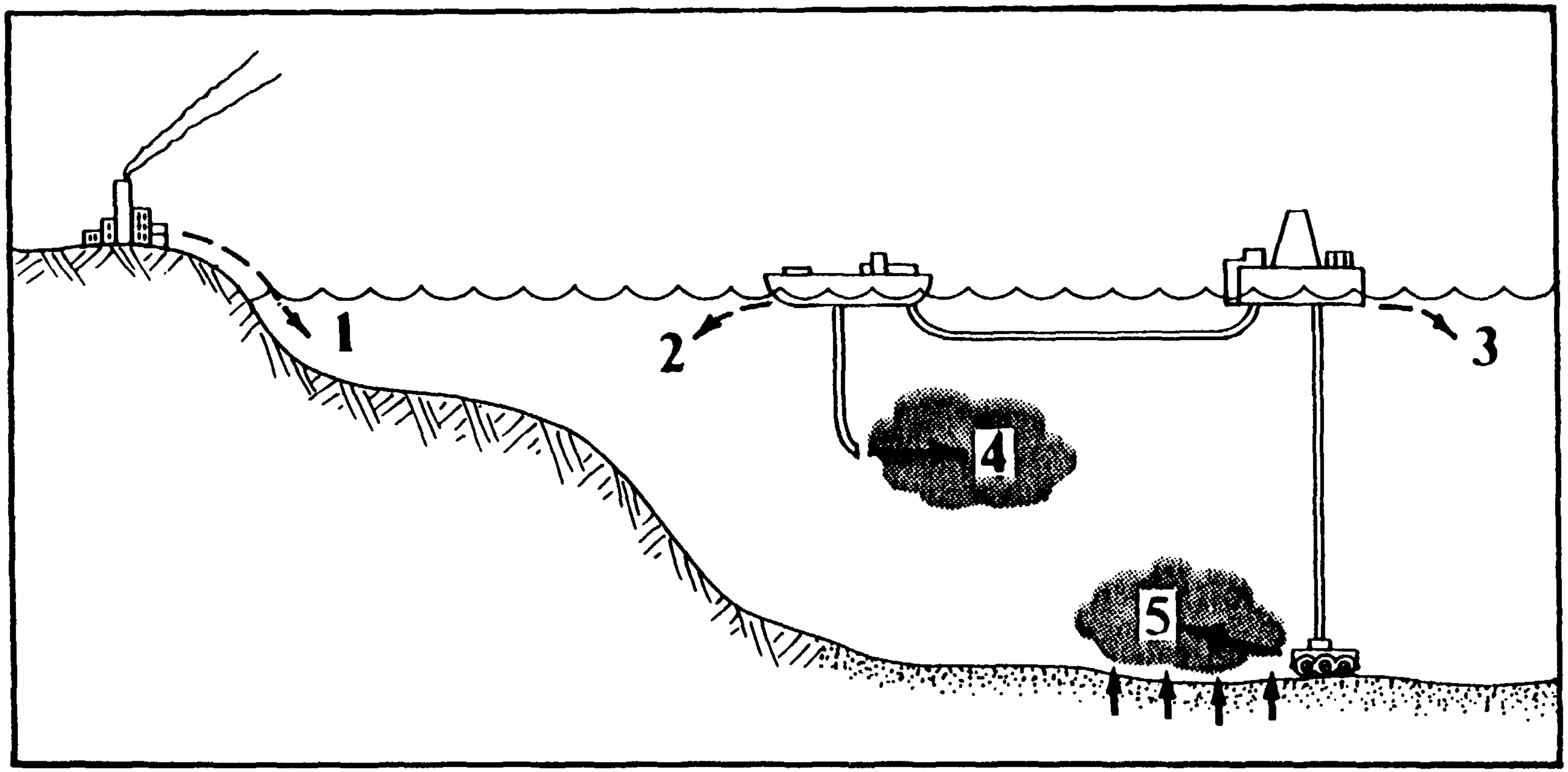

Fig. 1. *Diagram showing potential impact sites associated with deep seabed mining. Surface plumes due to processing waste disposal (1), as well as discharges from the transport vessels (2) and mining platform (3), can and should be avoided. Impacts associated with discharges at intermediate water levels (4) and attributable to direct interaction of the mining system with the sea floor (5) cannot be totally eliminated (not to scale) (from Thiel et al. 1991).*

Tailings and rejects discharge from land based processing plants or from swimming platforms close to the mine site into the sea must be avoided. Mine sites may be close to the neighbours' EEZ and currents may transport much material into their front garden.

Risk evaluation of any potential impact on the environment is demanded by the precautionary principle. It requires thoughtful examination of any planned action that may have environmental consequences and they should be long in advance before commercial activities will start. For example information about the physical, sedimentological and biological conditions in the planned mining area must be gathered far ahead. Based on the experiences during planning our impact study DISCOL for future manganese nodule mining in the deep sea I wish to introduce our local German TUSCH group, TUSCH is the German acronym for Tiefsee Umwelt SCHutz (Deep sea Environmental protection).

This group (Table 1) includes specialists from all oceanographic disciplines (physics, chemistry, geology and biology) from the engineering and technical professions, from the legal and economic spheres, and also includes members of national and state governments. Early discussions and mutual information about planned activities are necessary within such an interdisciplinary group of experts to plan, prepare and conduct baseline studies well in advance before commercial activities will start. The relationship between engineering/technological issues and environmental/ecological problems are even more direct. Engineers will design and build mining system technologies which may be more or less ecologically harmful depending on the parameters and functional requirements of the equipment. Environmental scientists can constructively influence such developmental processes through supplying permissible standards and operating limits to the designers based on sound ecological reasoning.

All different groups of this forum benefit from these discussions resulting in a better understanding between industry, government agencies and academia. The aim of this group is to come to an interdisciplinary management organization to be prepared for all necessary activities which will arise when commercial mining will occur. Any planned industrial activity in the marine environment within or outside EEZ should be notified to this group well in advance so that necessary negotiations

*Table 1. Members of the inter disciplinary German TUSCH * - Group.*

Science	Economy	National / State Government
Institut fur Hydrobiologie und Fischereiwissenschaft der Universitat Hamburg	Thetis Technologie GmbH	Senat der Freien and Hansestadt Hamburg
Institut fur Meereskunde der Universitat Hamburg	Arbeitasgemeinschaft Metallischer Rohstoffe	Bundesamt fur Seeschiffahrt und Hydrographie
Institut fur Biogeochemie und Meereschemie der Universitat Hamburg		Ministry of Science & Technology
Institut fur Meereskunde an der Universitat Kiel		Minstry of Economy
Geologisch-Palaontogisches Institut der Universitat Kiel		Ministry of Environment
Forschungszentrum fur Marine Geowissenenschaften (GEOMAR) an der Universitat Kiel		Foreign Department
Institute fur Stromungsmechanik and Electronisches Rechnen im Bauwesen der Universitat Hannover		
Fachbereich Geowissenschaften, Fachrichtung Rohstoff-und Umweltgeologie der Freien Universitat Berlin	*TUSCH-Acronym from German	
Versuchsanstalt fur Wasser- und Schiffbau Berlin	Tiefsee-Umwelt - Schutz Deep sea environmental protection	
Bundesanstalt fur Geowissenschaften und Rohstoffe Hannover		
Bundesamt fur Seeschiffahrt und Hydrographie Hamburg		

and investigations can be started. Our group has not only the objective of carrying out environmental studies of direct relevance to ocean mining but also of serving in a facilitating function to improve communication and exchange of ideas among its member all of whom share a common interest in the environmentally safe development of economic activities in the marine environment (Thiel et. al 1993). It should be the task of such a group to check the concordance of the planned commercial activities within the EEZ with the existing international legal framework e.g. the London Dumping Convention and the UN Law of the Sea convention. As recently pointed out by Jenisch (1993) the "Maritime Industries Forum (MIF)" of the European community has prepared a comprehensive report. The report addresses maritime activities such as ship building, shipping, marine resources and environmental protection. Five working groups are established to discuss and report on 1. Short sea transport, 2. Marine resources. 3. Ship financing 4. Marine & environmental safety and 5. Research & development.

Another reason for careful industrial activities within the EEZ are the state borders. In contrast to land based activities, created impacts in the marine environment do not remain within the limits of the area. Information to and discussions with neighbours about possible problems and co-operation during exploration and exploitation should be started well in advance to prevent conflicts.

Environmental problems need really broad consideration and it could result in tremendous efforts when all mining consortia of the EEZ would start a new project with thoughts, information search, discussions and negotiations. Environmental problems are not a matter of economic competition and we therefore propose an international bureau and an advisory group to help in the development of the EEZ uses. We would be happy to offer our experience and co-operation.

We are offering our expertise gained during last 15 years in planning and establishing a group of experts and to setup scientific programmes for the evaluation of environmental risks of commercial exploitation of marine resources. This may be realised by consultation or joint ventures and by workshops for interested persons from different countries.

In context with future manganese nodule mining from the deep sea we have started our impact study DISCOL about which I have reported. Additionally our group has prepared a study on "Potential Environmental Effects of Deep Seabed Mining" (Thiel et al. 1991). This study was introduced to the UN-Prepcom of the UNCLOS in August 1992. To underline our further activities, to stimulate the international discussion on environmental issues and to express the necessity of an international expert group to share the time and cost consuming investigations of impact studies we are in the process of organising a Symposium and Workshop on "Deep Sea Environment Assessments" together with the Deutsche stiftung fur International Entwicklung" in 1995 on deep sea environmental issues related to the use of the deep sea. Most of the problems discussed during the symposium will arise as well during the exploitation of resources within the EEZ's. The first annoncement will be distributed in 1994 and I wish to invite your participation in this meeting. If you are interested in further information, please write your name and address on a list at the conference desk.

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Environment, Technology, and Information as Factors in the U.S. Development of Ocean Minerals

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Our common future: United Nations Commissions on Environment and Development.

Sustainable development is a process of change in which the exploitation of resources, the direction of investment, the orientation of technical development, and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations. Apart from the political posturing that accompanies nearly all official government statements on seabed minerals, there are three major factors affecting their development in the United States: these are the environment, the technology and the information base.

Environment

The Environment has been used fairly consistent by groups opposed to ocean development as a negative factor in the ocean mining equation. Even the mining industry may not look on the advent of marine minerals development as a positive outcome where there is a potential threat to an existing market or infrastructure. Since Brazil conference in 1992, however with its strong emphasis on environmentally sustainable development, it has become more apparent that the effects of mining the sea beds may be substantially less than the effects of equivalent recovery operations on land. Even though considerable effort has been directed to the examination of Draft document not to be quoted environmental effects (Gesamp 1977, USDOC 1981, USDOI 1983), most of the conclusions drawn are based on sparse or inadequate data. It is thus of the utmost importance that valid and defensible data be gathered to support the contention that, from an environmental stand point there is much to be gained by the recovery of seabed materials. In the US recent or ongoing activities in this regard cover both continental shelf and deep oceans. The Minerals Management Service (MMS) of the Department of the Interior, in cooperation with the Corps of Engineers and local Universities, has a recolonization study in progress to examine the extent of benthic organism repopulation in an area which has undergone dredging for sand used to restore beaches on the West coast of Florida. The sampling plan includes two sites within each dredging area and a control site outside. Sampling and instrumentation techniques utilise box coring otter trawls, towed video and side scan sonar. Benthic fauna identified include some 340 different species made up of over 40% annelids and about 25% molluscs and arthopods. The MMS which oversees all the oil and gas activities on the U.S Outer Continental Shelf recently completed the first minerals environmental study funded under the oil and gas environmental studies program. The purpose of the study (Cruickshank and Morgan 1993) was to survey, analyze and synthesize existing literature, both domestic and foreign, regarding the potential environmental impacts of marine mining on the environment and to have the information summarized in a single manuscript. The search included all types of mining operations and offshore minerals. A second study is planned to undertake an extensive and detailed analysis of marine mining technologies, presently available or proposed, and to estimate and evaluate the degree of potential impact to the marine and onshore environments associated with each extraction technology. Mitigation methods will be examined to determine the degree to which these impacts can be lessened or eliminated altogether. In the deep ocean there are two ongoing environmental studies directed to the effect of mining operations on the benthos. The U.S National Oceanic and Atmospheric Administration (NOAA) in cooperation with scientists from Russia, Japan, China, Korea and several other nations is carrying out a Benthic Impact Experiment (BIE) within a "stable reference area" of over 1200 square miles donated from the license areas of three of the licensees in the Clarion Clipper ton Fracture zone. This continuing and well considered experiment is designed to simulate the effect of commercial mining under tightly controlled conditions. Previously proprietary data also donated by the licensees were used in the planning of the work using the Russian research vessel R.V. Yuzhmorgeologiya. Specially designed equipment was tested at sea in 1992 and 1993 and cruises to acquire experimental data were planned for 1993 & 1994 with follow up analysis modelling and verification beginning in 1995. The First tests in the summer of 1993 have been very successful and resulted in the lifting and dispersion of some 5000 m^3 of sediment in the test area. Sampling of the biota was carried out immediately before and immediately after the tests and will be followed up with additional sampling starting 6 months after the tests. This type of multinational, multi-year, environmental research is exactly the type of effort that is needed to determine the effects of mining on the benthic fauna. Similar activities in the German area have been carried out in an experiment entitled DISCOL.

Technology

Technology needs for marine mining have been analysed in a number of studies but the general assumption in the U.S is that state of the art technology is available for mining in the continental shelf and on the deep seabed (USOATA 1987). Known marine mineral resources for which it is technically feasible to mine are, in order of priority to the U.S at this time; sands for coastal remediation, and beach protection and enhancement; aggregates for infrastructure remediation and construction in the highly populated coastal zones; mineral sands for production of tin, titanium, rare earth metals, gold, platinum, and diamonds; manganese nodules or crusts for the production of nickel, cobalt, manganese and other by-products; hydrothermal sulfides for the production of copper, lead, zinc, gold, silver and other metals; and marine phosphates for fertilizers. Marine Minerals Technology is also directly transferable to the relocation and remediation of toxic waste disposal sites on the sea beds. Efforts by US industry resulted in a significant technology lead in the nineteen seventees, and now the need is seen to enhance the obviously critical focus on environmental control of mineral development operations on the sea beds.

The status of each of the resources of interest to the United States is briefly discussed:

Sands : The most ubiquitous of coastal offshore minerals are the sands derived from erosion of the adjacent lands by glaciers, rivers and waves. The protection of coastlines and enhancement or maintenance of natural beaches throughout the U.S has drawn heavily on terrestrial sources of sands at great economic and environmental cost. It has been shown properly designed and managed operations which use offshore sand resources can be accomplished at considerably lesser cost. There are many improvements in resource characterization that are still needed particularly in areas of tropical reef sands.

Aggregates : Remediation of the U.S infrastructure of roads, bridges and public works is a critical aspect of the public need which has been well documented and the development of residential commercial and industrial buildings continues to increase with national economic progress. Any area within 30 miles of access to coastal waterways, which includes most of the heavily populated areas of the U.S is likely to see economic and environmental cost advantages in the use of marine aggregates. At the present time, due mainly to a restrictive regulatory for infrastructure, there are no such operations in the U.S. This is in marked contrast to other environmentally concerned countries such as Japan and the United Kingdom which produce approximately 20% and 15% of their annual aggregate needs from marine sources.

Mineral Sands : Sands and gravel laids down over the years by natural process frequently contain commercial deposits of economically critical minerals or metals of such commodities as tin, iron, titanium, rare earth metals precious metals and precious gemstones. These types of deposit are widespread and many are known to exist in the Pacific northwest and Alaska. Like other marine mineral deposits, their economic extraction, in comparison with similar sourceses on land, would likely be environmentally begin. Few data are available, however to prove such assertions and the development of environmental demonstrations programs is badly needed.

Manganese nodules and crusts : United States industry led the technical development of mining and processing for manganese nodules in the international sea beds of the Pacific Basin in the nineteen seventies. Over $500 millions has been spent on this effort which is being continued at the present as a catch-up game by countries such as India, Korea, China and Eastern Europe. The nodules are minable using current technologies. Their economic viablity is price dependent, mainly based on the price of nickel. The environmental effects of production from the seabed, based on existing data, compares very favourablly with equivalent production from the land. In the absense of actual operations substantiating data are not available, however. Some Pacific island countries notably the Republic of Marshall Islands, are seriously interested in the recovery of cobalt crust occuring at lesser depths on seamounts and island slopes. Although chemically similar to nodules, the economics of crusts are largely dependent on the price of cobalt, rather than nickel. Both crusts and nodules have the probability of high byproduct usage for the waste material remaining after the removal of the useful metals. This aspect is being studied by both division of MMTC; in Hawali as it is of particular importance to the small island nations and in Mississippi currently looking at using nodules as stack gas filter material with subsequent recovery of stratergically valuable metals. Past studies have shown manganese nodules to be highly effective in removing sulphur di-oxide effluent from flue gas. Such application has near term interest as a viable alternative for meeting Clean Air Act Amendment compliance deadlines, with the economic enhancement of metal recovery from spent filter material.

Hyderothermal sulfides : These potential ores of many metals are more recently discovered than the oxides and are in the most need of additional discovery and characterization. The bulk of the deposits will be found beneath the seabeds and will require quite a different technology than the oxides, both for environmental characterization and for development. These deposits which have the potential for being very extensive and widespread are regarded as major resources for the long term.

Marine Phosphates : New understanding of the uses of direct application phosphate ores for crop fertilization has indicated an important niche for marine phosphate deposits which are widespread in many parts of the seabeds, in both deep and shallow waters, and frequently occur along with, or immediately beneath, cobalt crusts. Sub-seabed marine phosphorites of potentially vast extent have been indicated off the eastern coast of the United States off the Carolinas, and are receiving major attention by MMTC/CSD in Mississippi. These significant resources need to be characterized for economic and environmental evaluation.

Waste dump remediation : Relocation and remediation of marine waste disposal sites can be accomplished using the same technology applicable to the discovery and development of marine mineral deposits.

Information Base

As more work is completed in the mineralised areas the need for development of more effective data and information bases becomes evident. Shared data between the different organization involved, even at a price, is an effective way of utilising the resources expanded in the development efforts. In the U.S much misinformation is in the public domain with regard to marine minerals development. Concepts, which include exagerated fears of environmental include exagerated fears of environmental degradation or pollution due to mining are highly effective in delaying or stopping the progress of marine mining development. Information by itself is of no value unless it is received and acted on by a qualified user. In this case even negative information is useful and the advent of large data bases are of significance in the furthering of co-operation between the agencies and industrial groups in the U.S. For example, much of the data collected by Ocean Minerals Company (OMCO) during their testing activities for manganease nodules is now available for use in further studies through the Marine Minerals Technology Center at the University of Hawaii.

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Non - Fuel Mineral Resource Evaluation in Louisiana's EEZ and Potential Environmental Impacts of Resource Exploitation

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Introduction

The United States Exclusive Economic Zone (EEZ), established by Presidential proclamation on March 10, 1983, covers approximately 3.9 billion acres compared to the 2.3 billion acres of onshore U.S. territory (Rowland et., al 1983). Since that time great interest has been generated with regard to research connected with evaluation of potential non-fuel mineral deposits in the EEZ. Approximately 15% of this area is occupied by the continental shelf (upto 200/m depth). The continental slope and rise (200 - 400/m) covers another 10-15% and the rest of the area is abyssal plains at depths of 315 Km (Crwickshank et., al., 1987). Several types of mineral deposits are known to occur in the U.S. EEZ area. Among these those having near term economic potential include heavy mineral placers containing gold, chromium, platinum group minerals, titanium, phosphorite, and sand gravel and shell used for construction, fill and coastal beach nourishment. The largest non-fuel mineral industry by volume in the United States is sand and gravel production, nearly all of which is from onshore sources. However, due to increasing land - use restrictions resulting from environmental concerns as well as resource depletion there is a growing interest in sand and gravel resources in the EEZ by commercial producers.

Resource evaluation, both regional and site specific, and the leasing of non-fuel mineral resources of the EEZ in the United States falls under the general jurisdiction of the Minerals Management Services (MMS), U.S. Department of the Interior. The Marine program is carried out by the Office of International Activities and Marine Minerals (INTERMAR) within MMS. The INTERMAR program has established task forces technical working groups in different geographic areas where States and other interested parties in marine resources were organised to consider offshore mineral development issues. Presently there are nine technical working groups, involving sixteen East coast and Gulf Coast States which are actively conducting EEZ non-fuel mineral resource evaluations. Six of these groups are mainly evaluating offshore sand resources for coastal restoration. (Groat, et. al., 1993).

Louisana participated as a member of the Gulf Task Force, Established in 1986, including the states of Alabama, Mississippi and Texas, in the preliminary evaluations of non-fuel mineral resources in the EEZ area of the respective coastal states. Sand is the most abundant non-fuel mineral resource offshore off these States and other coastal states of the United States. Other potential non-fuel minerals offshore Louisiana inlcudes salt, sulphur, heavy mineral placers, gravel and shell deposits, but very little information is presently available on these mineral resources. Other sand resources investigations were also carried out through co-operative agreements between Louisiana State University (LSU), Centre for coastal, Energy and Environmental Resources (CCEER) personnel and the U.S. Geological Survey and the Louisiana State Department of Natural Resouces. The preliminary studies identified the most suitable areas for exploitation of sand in terms of quantity and quality, mainly for restoration purposes. Of the many areas identified one (Ship Shoal, see Figure.1) was chosen for detailed site specific analysis of the geologic, engineering, environmental and economic consideration associated with the sand dredging and placement on

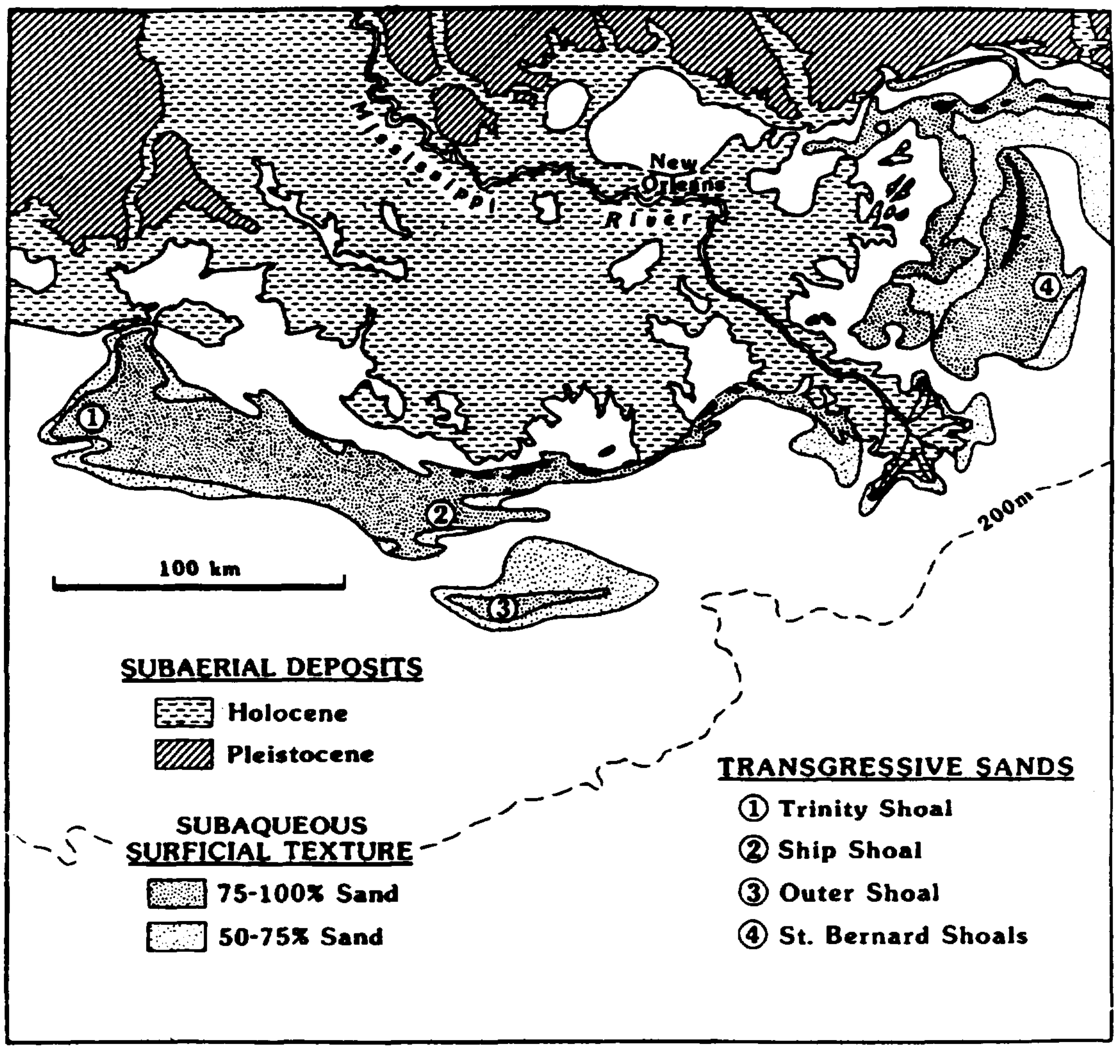

Fig. 1. Generalised sediment distribution map in the EEZ area offshore Louisiana showing sediment texture and location (Modified from Frazier, 1967, Penland, et. al., 1986.)

the shoreline. Site selection criteria, in addition to the preliminary evaluations of volume and quality, included data availability, proximity to an eroding shoreline area, and the near term possibility of the resource exploitation. It will be necessary to gather more information in order to fully evaluate its viability as a commercially economic venture. The inclusion of the major barrier island restoration projects in the ongoing coastal restoration program will enhance the potential for the development of Ship Shoal and other offshore sand resources.

Regional Geologic Framework

Sand distribution in the EEZ area off Louisiana's coastline is controlled primarily by pre-existing and present fluvial and deltaic channel systems and the effects of sea level rise during the Holocene Transgression. The width of the Louisiana continental shelf varies from less than 20 km off the active Mississippi River delta 240 km off the Coast of Wetern Louisiana. Since early geologic time (Jurassic - cretaceous) the Mississippi and smaller rivers have carried and deposited huge volumes of sediment from the continental interior in the Gulf of Mexico basin. The evolutionary history of the Mississippi River delta along with sea level changes have affected depositional patterns on the Louisiana continental shelf (Coleman, 1988; Coleman and John, (1988). Workable sand resources occur in many depositional environmental, including shoals, buried fluvial channels submered barrier islands and barrier platforms, tidal deltas, and distributory channels. The regional sediment distribution map in the EEZ area of the Louisiana coast is shown in Figure (1).

Data for Resource Site Identification

Preliminary data for identification of exploitable sand resources in the EEZ area off the Louisiana coast were obtained by running extensive high resolution reflections seismic survey grids. A large number of vibrocores were also taken along the seismic profile lines to obtain information on the sediment type, texture, and deposit thickness to aid in the interpretation of the seismic profiles. The data orginiated from research programs at Louisiana State University in co-operation with and funded by the United States Geological survey, Minerals management Service and the Louisiana Department of Natural Resources. As the result of these surveys over 20,000kms of data on a 5.5km x 5.5km grid spacing was obtained for the southwest Louisiana shelf, approximately 15,000km of data with a grid spacing of 5.5km x 5.5km and 3km x 3km was obtained for the southeast and south central Louisiana shelf, and about 3200/km of data with a girid spacing of 5.5km x 5.5km was obtained in the eastern Louisiana-Mississippi-Alabama and Florida shelf.

Other data used included offshore foundation boring logs, and pertinent published literature. Detailed evaluation and description of the vibrocores and interpretation of the high resolution seismic data profiles were carried out at the laboratories situated at the Centre for Coastal, Energy and Environmental Resources.

Potential Sand Resources

References giving preliminary information about potential and resources in the EEZ area offshore Louisiana are given under selected Bibliography at the end of this paper. During the course of these investigations many km line miles of high resolution seismic data were analysed, in the general manner

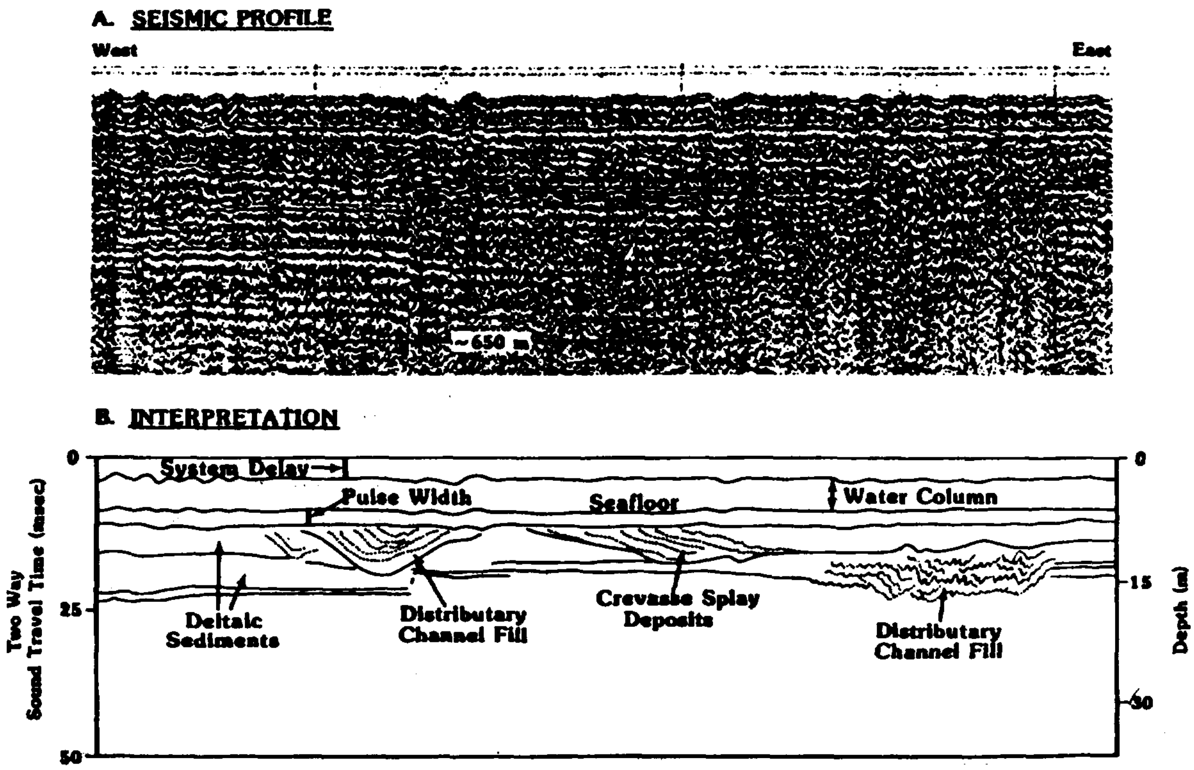

Fig. 2. A representative example of a high resolution seismic profile over the Trinny Shoal area and interpretation from Suter and Peniand, 1987

illustrated in Figure 2. In the western Louisiana continental shelf the best sand resources were found to be located in pleistocene fluvial channels, shelf margin deltaic deposits and transgressive Fluvial, deltaic and shereline deposits. Overburden in channel areas ranged from 1.6 - 5.2m made up mostly of clay and silty clay. Sand varied from 2.4 - 8.8m with 54% average sand. Over 175,000,000 m^3 of sand with silt are present in the buried channel environments in this area. Estimates of over 90,000,000 m^3 of sand have been made for the transgressive, fluvial, deltaic and shoreline deposits which are buried under fine grained shelf deposits. Further, 160m thick shelf margin, deltaic sand and silt deposits with a real extent of about 5000 km have been determined to occur on Louisiana's western continental shelf margin. However all these sources currently represent only long term resource targets and detailed site specific investigations must be conducted in order to evaluate the viability of commercial exploitation (Penland et.al. 1986, 1988; Suter et.al. 1985, 1987; Louisiana geological survey, 1988; John et.al 1989).

The EEZ area off central Louisiana has recoverable sand resources in inner shelf shoals, numerous buried channels, tidal channel and tidal deltas. In this area, Ship Shoal and Trinity Shoal (Figure.1) represent near term potentialy usabie sources of sand, Ship Shoal has been determined to be the best prospective sand resource target as there is no overburden and the sand is compatible to that found on the adjacent, rapidly eroding Isle Dernieres and Bayou Lafourche shoreline which are in need of nourishment. Ship Shoal has been estimated to contain over 1,200,000,000 m^3 of sand (penland et.al., 1986). Preliminary data evaluation indicated at least fifty-five sand resource targets in commercial exploitation begins Except in the case of ship Shoal, which was selected for detailed geologic, Engineering

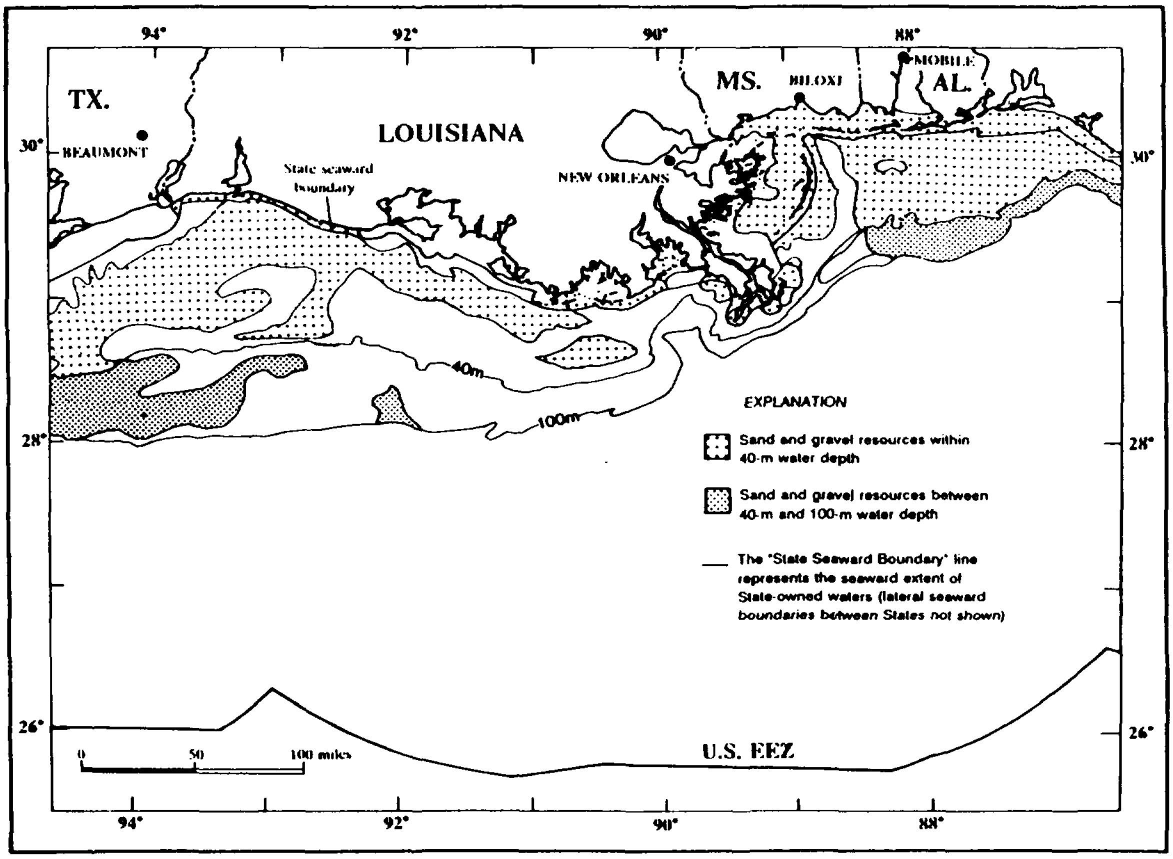

Fig. 3. Generalised map of the EEZ areas of the Louisiana, Mississippi and Alabama Coastline Showing Potential Sand and Gravel resource areas (from Graot et.al. 1993)

environmental, and economic evaluation based on the preliminary investigations. Ship Shoal is about 50 Km long with width ranging from 5-12 Km water in depth of 2-7 m on the western side to 7-9 m on the eastern side with 3-6 m of relief. Detailed characterization of this shoal showed that the most economical minable area was at the leading edge of the shoal migration which also is the area of greatest sand thickness and water depth (Byrnes and Groat, 1991) Wave refraction studies showed no detrimental environmental impacts on adjacent shorelines for scenarios involving one and ten million cubic yards of sand. A computer simulation model (Montol Carlo) was used to investigate economic viability of dredging. Results indicated that this project was economically feasible relative to onshore sand resources, volume and availability. However futher environmental impact evaluations for selected areas on the shoal must be done in order to better understand and define effects of mining on the shoal itself, the coastline and ecosystem of the area, in the Chandelour Islands area on the eastern side of the EEZ area of Louisiana (Figure 1) sand resources are located in ancestral distributory channels which may be up to 15 m thick and 400m wide, in submerged beach ridges, tidal inlets-deltas and submerged barriers (Suter and Penland, 1987). The Chandelour Islands itself represent the oldest barrier Island arc in the Mississippi River delta plan. A generalized map showing sand resources in the EEZ area off Louisiana shown in Figure 3.

Coastal Erosion and Offshore Sand Resource Utilization

Coastal erosion is a problem faced by almost all coastal regions around the world and shoreline has become a siginificant issue needing an economically satisfactory solution. Because of the large volumes of sand required for beach restoration, and inland resources are becoming depleted, offshore sand is fast becoming an alternative location for obtaining, resource. In the United States, some of the highest

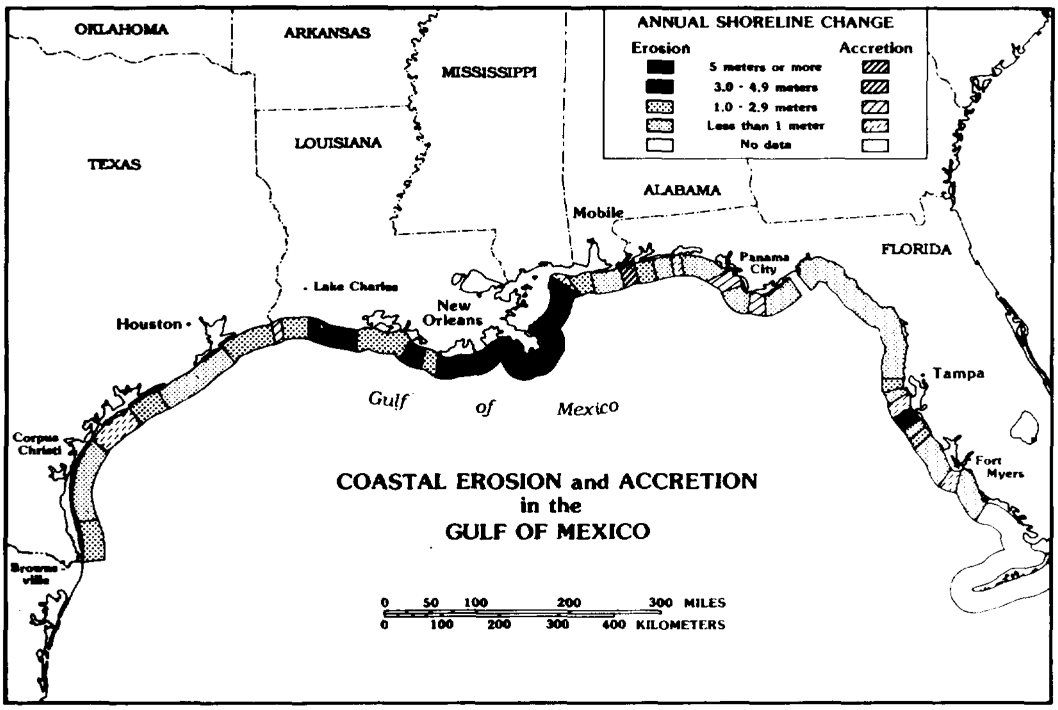

Fig 4. Map showing coastal croston rates along the U.S. Gulf Coast States of Texas Louisana Mississippi Alabama and Florida (Modified from USGS, 1988).

rates of the coastal erosion are found at the Louisiana Coastline (Figure 4). Minimising land loss in the future will require tremendous volumes of sand and it is suggested that the sand resources identified in the EEZ are off shore Louisiana will in the near future become the source for mining sand to combat coastal erosion and land loss.

Environmental Impacts

Depending on the location, extent and time period of mining activity, environmental impacts resulting from marine aggregate dredging vary from minimal to severe and can have short to long term effects. In most cases the site-specific impacts should be evaluated before making any decisions regarding the level of severity. Generally there are five categories of impacts produced as a result of aggregate mining activity in the offshore areas and these are 1) turbidity, 2) sedimentation, 3) seafloor disturbance, 4) coastal erosion and 5) effects of facilities and mineral processing onshore (Groat et. al., 1993)

Turbidity plumes are created by the dredging of aggregate material due to the resuspension of fine materials in the water column. Though some natural turbidity occurs in nearshore areas due to the fishing, harbour dredging etc., these are of short duration and generally do not have any serious impacts on the plant and the animal species occupying the area, Biological effects of turbidity during sand and gravel mining operations in the deeper water EEZ areas are not well understood at the present time. It could seriously affect the fisheries in the area and increased sedimentation can smoother dwelling organism. Enrichment of the water column, depending on type of seabed material disturbed, may cause increased plankton productivity. However such efforts would generally be localised decreasing with distance from the source and would end soon after cessation of mining activity. Secondary problems like contaminated material, increased concentration of radioactive material etc. are unlikely to create any Environmental Problems due to the factor of seawater dilution (MMS, 1988).

Sedimentation on the seafloor as a result of sand and gravel mining operations is caused as a result of turbidity plume dispersal with time. Environmental impacts of this process would be the potential destruction of biota and possibly some change in seafloor topography, depending on the amount of sediment of settling from the water column. Minimization of the area affected could be achieved by surface discharges (Cruickshank et. al 1987) The likelihood of detrimental impacts on commercially valuable bivalve mollusks which are often founds inhabitating potential sand and gravel mining sites should be carefully evaluated. The potential of mining areas being spawning grounds for commercially valuable fishes should be reviewed and such impacts should be minimised or avoided.

Seafloor disturbances by dredging at the mining site will result in destruction of benthic organism and modification of habitat. After mining operations are completed the return to original or pre-mining conditions and recolonization by the various species which existed in the area could take many years. If mining results in lowering the seabed and the creation of pits and trenches, it could alter bottom current and wave patterns. Further large boulders exposed on the seabed due to aggregate mining could pose problems for bottom trawlers used by fisherman. Other negative effects of mining are the possible conflicts with other uses of seafloor, for example commercial oil and gas pipelines, shipping lanes, recreation and fishing, archaeological sites, military or defence related activities and oil and gas exploration and production activities. Marine mining activities within view of the beaches are likely to adversely affect recreational and hence economic values of coastal areas, but marine sand mining out view from the shoreline for beach replenishment is likely to result in increased popularity of the beaches for the recreation and tourism industry.

Increased coastal erosion due to offshore mining activities can result if sand mining is conducted too close to the shoreline. Increased depth caused by mining results in increased wave energy which intensifies shoreline erosion. As demonstrated in investigations mentioned earlier in this paper on ship shoal, very little environmental impact on the shoreline takes place if mining activities are carried out beyond the zone where removal of sediment would not affect the waves impinging on the coastline. It is very important to fully evaluate the potential effects of sand and gravel mining on a site-specific basis of resulting changes in wave patterns and wave energy under various conditions to prevent or minimise shoreline erosion.

Onshore impacts and activities as a result of marine mining for sand gravel production result mainly from the need to process the material depending on its use and transportation to market areas. Though sand and gravel for beach nourishment generally do not need processing, it is necessary to separate the fine sand, silt, clay and chlorides in order to meet specifications for other uses. Such processing cannot be carried out abroad the dredging vessel on a barge due to the volumes of material and fresh water involved. Separation of chlorides results in brackish water discharges for which proper deposal methods should be used to minimise environmental impacts. Possible impacts from such activities on the local community includes the increased nose, dust and traffic and effects associated with the discharge of brackish water: all of which could be minimised with appropriate regulatory control (Groat et. al. 1993)

Before mining takes place in the EEZ, a lease for the area has to be obtained through a competitive bid process under specific terms and conditions regulated by the Minerals Management Service (MMS) under the authority of the Secretary of the Interior. In addition, many coastal state and local governments regulatory agencies have various levels of statutory authority regarding mining activities permits and approval are required from all the agncies before any EEZ mining activities can commence. Industry's perspective currently is that the legal framework in place is not suitable for developing offshore non-fuel mineral resources and the current permitting process is too time consuming and complex.

Conclusions

1. The demand for sand for beach nourishment is likely to increase significantly in the near term. Sand and gravel mining from the EEZ area offshore Louisiana will become economically viable as onshore resources become depleted and land use restrictions increase. Sand and gravel resources of the Eastern coast of the U.S are receiving increasing attention from commercial interests.

2. Sand supplies are plentiful in the EEZ area offshore Louisiana to meet market demands and could provide environmentally preferable sources to onshore alternatives.

3. Although the general distribution of exploitable offshore sand in the EEZ area off the Louisiana coastline is known, site-specific detailed information to support development of the marine sand mining industry is lacking.

4. A properly structured environmental studies program with adequate funding is necessary to support proper decision making regarding the development of the sand and gravel or any other non-fuel mineral industry in the EEZ area

5. Environmental site - specific studies are crucial to the successful development of the EEZ non-fuel mineral exploration industry.

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THE DEVELOPMENT OF MARINE INDUSTRIES AND TECHNOLOGY

Exploitation of Polymetallic Nodules - The Role of Developing Countries

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Aim

The aim of this paper is to evaluate the status and prospects for commercial exploitation of deep seabed minerals. I will pay special attention to aspects of interest to developing countries. I will begin by providing a brief review of international status, and then go on to look at deep seabed technology, environmental consequences and political-legal aspects. Finally the prospects for commercial exploitation, including the economic aspects, are viewed.

The paper is multidisciplinary, Technological, economic, environmental, political, legal and to some extent also psychological and ideological factors are investigated as interdependent. Moreover, a distinction is drawn between the various groups of actors since varying motives underlay the engagement of the actors.

Polymetallic Nodule Deposits

Commercially interesting deposits of polymetallic nodules have been identified at depths of 4500-5500 meters in the Clarion clipperton area of the Central Eastern Pacific Ocean, and in the Central Indian Basin of the Indian Ocean, to be regarded as commercial, the deposits should have an average contents of nickel and copper of at least 2.25%, and a nodule density of approx. 10 Kilograms per sq meter. The nodules contain some 50 metallic and non-metallic elements, of which nickel, cobalt, copper manganese, molybdenum and zinc are the most important metals. Cautious analyses show for instance that there is twice as much cobalt in the Clarion Clipperton area alone as in total land based reserves[2].

The 60s and the first half of the 70s were characterized by optimism, economic growth and rapid technological development. It was during this period that interest in deep seabed minerals was seriously awakened. The introductory exploration of the nodule deposits took place in the 60s, while the 70s were mainly characterized by the investment of hundreds of millions of dollars by private companies in exploration and development of mining and processing technology, from which they expected to make a quick profit. In the course of this period four internationally composed industrial groups and one French company were formed. High technology, mining and petroleum companies from the US, Europe and Japan invested between 50 and 120 million USD (1981 dollars) in each of the industrial groups, all of which were registered in US. The 70s were also characterized by the law of the sea negotiations which in turn were influenced by the ideas of a new economic world order.

The beginning of the 80s proved to be a disappointment to the privateinvestors; metal prices were down due to a general decline in the world economy, the technological challenges had probably been underestimated and there was strong disatisfication with Part XI of the United Nations Convention on the Law of the Sea. The industrial groups felt the convention provided too little scope for private enterprise, while they also feared the development of a costly and comprehensive UN bureaucracy. This resulted in a change of actors participating. Private investments were replaced bynational state programmes-actor able to think in the long term, and whose motives were mainly supply considerations and political factors. Japan and India started up their own national programmes in 1981. Development programmes were going on in France and West Germany. The People's Republic of China and South Korea joined in earnest at the end of 80s and these two countries also established separate national programmes.

At present we find the highest level of activity in Asia. Japan is preparing an integrated test of complete mining system in 1996. India, the leading developing country in the area, has progressed, for both in exploration and in development of processing and mining techonology. Though China, starting later than India, has not come quite so far, its program for exploration and technology development seems to be very well ogranized. South Korea has made a good start on exploration of polymetallic nodules in the Pacific ocean. What is new now is thus the active role played by technologically and economically strong developing countries and newly industrialized countries.

Deep Seabed Mining technology - Are the cencepts of Today the Technology of Tommorrow?

The basic work in mining and processing technology was carried out in the 70s. As far as mining technology is concerned, the concepts developed by Ocean Minerals Company (OMCO) have in a way become the industrial standard. There seems to be general agreement that a system consisting of a self-propelled collector unit, a buffer storage unit and a riser with pumps installed at various depths represents the best solution. The development projects of the 80s represented more or less copying of this concept and only to a small degree technological improvements or renewals. The attempt by the French to develop the Shuttle to system that is a system consisting of a number of free-swimming shuttles reperesented the good exception to this lack of fresh thinking and innovation.

There is no doubt that the OMCO concept as such represents a realistic alternative for first generation projects . However, the paradox here is that the underlying principle is to collect the entire nodule, tranport it ashore, and perhaps utilize no more than a few percent of the module. A further integration of the mining and processing technology - that is complete or partial processing on the deep seabed in an environmentally safe manner is undoubtedly not only technologically more efficient, but also economically more rational than the above mentioned concept. Land based processing could take as much as 60 or 70 percent of the investment costs. An integrated mining and processing system could be capable of fundamentally changing the economy of the projects.

It is interesting in this context to speculate whether the 'new' countries India, China and Korea will again copy the mining concepts of the 70s, or whether they will come up with something new. All these countries are characterized by well educated and skilled scientists and engineers working for salaries that are a fraction of what their counterparts in the West are earning. The technological concepts of the 70s and 80s are well documented and known. The leaders of the Indian, Chinese and Korean programmes would be wise to prepare the ground for new thinking and international collaboration. Here they have something to learn from the 80s and the way in which the national programmes were organized. Exaggerating only slightly, we may say that in addition to copying the concepts of the 70s, the national programmes in the 80s insisted on spending a lot of money on reinventing the wheel, and they were little prepared to collaborate with other. There is no reason to make the same mistake again.

Various hydrometalurgical and pyrometallurgical processses have been developed for extracting the metal content from the nodules. In a hydrometallurgical process - a leaching process - chemical additives and electrowinning are used to refine the mineral material. In a pysometallurgical process - a smelting process - the miniral material is smelted to a crude alloy before the metal products are extracted comprehensive development work in this area and is to my mind one of the front runners when it comes to processing technology.

The basic technology of mining and processing of nodules has thus been developed. However, much development work remains before the stage is reached when it can be employed on a commercial scale. The 1996 Japanese test mining may prove imporant for further technological development. Only through integrated tests of the complete system can we learn which subsystems to select for further development and which to reject.

Claims have been made that seven to ten years of further development work will be required subsequent to an integrated mining test in order to develop that can be utilized in a Commercial Project. This is not necessarily correct however since others maintain that a government or company which has decided to exploit the resources and which has developed the basic technology and completed test mining will hardly need more than three or four years to have a technology that works. What then about the question of to what extent the concepts of today will be the technology of tomorrow?

Today's technology has two main characteristics. In the first place, we must realize that assumptions regarding reliability and efficiency are based upon theoretical analysis and testing on a minor scale. Secondly, the concepts are not only the result of research and development in deep seabed mining, but stem from other areas as well. The concepts to today show, in my opinion, that the deep seabed mining engineers can apply to their own area elements of the available technology and know-how in the offshore oil and gas sector, shipping and landbased metal production. The question is however; Have they managed to free themselves from conventional lines of thought and think afresh in order to develop technology precisely fitted for the purpose?

No one can say to what extent tomorrow's technology will be different from that of today. There is, however, reason to beleive that we may expect to see radical changes in many areas - including greater integration of the mining and processing phases. Complete or partial processing on the deep seabed in an environmentally safe manner would clearly be no only technologically more efficient , but also economically more rational.

There are a number of driving forces behind the development of technology. 'Market pull' is governed by need, while the 'Technology Push' part is less predictable since new technological solutions are not necessarily prompted by any particular need. A third driving force is the 'pull of society' - meaning that technological development is influenced by the demands of society concerning for instance safety and the environment. The market pull factor was undoubtedly present in the 70s and it will re-emerge when the time for commercial exploitation approaches. During the 80s and so far in the 90s we have witnessed primarily a gradual adoption of parallel technology prompted by the Technology Push effect. Stringent environmental demands will be made on those wishing to exploit these resources commercially. The Pull of socieity effect will therefore also prove more and more important as the time for commercial exploitation approaches[5].

These observations apply to mining and processing technology. When it comes to exploration technology, we see clearly that the market pull forces are in full swing. Here we have an economically interesting market for suppliers and considerable technological development takes place. In this connection I may mention that there is every reason to believe that the exploration technology that will be employed in 10 years' time will be fundamentally different from the technology employed today. Current exploration is time consuming and costly, because we have to employ different equipment for different functions. The technology of the future will characterized by multifunctionality and integration where hydroacoustics will be combined with laser technology.

Environmental consequences of Deep Seabed Mining

The USA and Germany have long been the leading nations in terms of studies of environmental consequences of deep seabed mining. The USA was the pioneer; In 1975 the US National Oceanic and atmospheric Administration (NOAA) initiated the Deep Ocean Mining Environmental Study (DOMES). This five year project was organized as a collaborative effort between NOAA and four US reigstered industrial groups. The project consisted of two phases; the first to characterize the region environmentally, and the second to monitor the effects of industrial pilot-scale equipment test therein. In 1981, NOAA published the first comprehensive Deep Seabed Mining Environmental Impact Statement[6].

The Deep Ocean Mining Environmental Study concluded inter alia that there was a need to book more closely into the environmental impacts on the deep seabed-including the effects of the collector unit in and near the mining tracts, and the effects of the benthic (bottom) plume on benthic life, and its food supply, away from the mining activity. In line with these recommendations, the organization has over the past 10 years concentrated its work on the deep seabed. NOAA has worked actively to establish collaboration has been established with Japan, the Commonwealth of Independent States and France; and exchange arrangement for scientists with the German project (see below) has taken place. The collaborative project between the USA and the commonwealth of Independent States is a large- scale Benthic Impact Experiment. Japan and the USA plan to carry out joint monitoring of the Japanese mining tests in 1996, where Japan focuses on the surface problems, while the US side concentrates on the deep seabed. The Japanese scientists plan to create a model illustrating what happens at the surface level and in the water column. The planned monitoring is a part of a comprehensive Japanese environmental impact study, initiated in 1990 and coordinated by the Metal mining Agency of Japan[7].

The German Disturbance and Recolonization Experiment (DISCOL) was commenced in 1989 as the first long-term large-scale disturbance recolonization project. The programme is financed by the German Ministry of Research and Technology and is coordinated by the University of Hamburg[8]. After obtaining preimpact baseline environmental data, an area of 10.8 sq. km in the eastern South Pacific was disturbed in February - March 1989 using a "plow harrow" device. An initial post-impact sampling series was carried out immediately after disturbance; the site was revisited again for renewed post-impact sampling six months after the disturbance. Plan call for repeated visit to the site at two-year intervals to monitor the anticipated slow recolonization process until the area is inhabited by a new, stabilized community[9].

The Disturbance and Recolonization Experiment is one of several projects in the German Tiefsee - Umweltschutz- programme for research for the precautionary environmental protection of the deep sea. DM 17 million has been invested in the programme from 1989 to 1993[10]. Currently Germany has the highest level of activity in deep sea environmental research.

To summarize; comprehensive work is currently being carried out to study the environmental consequences. This type of research is not new; it has been conducted is parallel with developments in technology. During the last four years we have seen considerable growth in efforts in this area. Environmental consequences thus constitute a major area of research in deep seabed mining today. Moreover, research in this area is far more than mere office work, the greater part of it being practical scientific work carried out at sea. However, it should be emphasized that up to the present it has, generally speaking, only been possible to study the effects of small-scale, short-term mining. Not unitl very recently have long-term, large-scale disturbance-recolonization projects been started. The results from this research are already emerging, but many decades will pass before we can say anything certain about what actually happens on the deep seabed with regard to repopulation and recolonization. A large-scale project like the German project will, however, never be able to take the place of actual mining. There is broad agreement among scientists that only under long-term pilot mining operations will it be possible to study the environmental consequences satisfactorily.

There are three main environmental problem areas to be expected from exploitation of nodule deposits[11].

- *The first relates to what happens on the seabed.* As the collector unit gather nodules, it will seriously destroy the top few centimetres of the seabed, causing major disturbance and disruption to the flora and fauna in mining tracks. In addition, the propulsion system of the collector unit will stir up sediments; as a result, organisms in and around the tracks will be partially or entirely buried. In the mining tracks for instance, a mortality rate of 95-100% may be expected for organisms found there.

- *The second relates to the discharge of waste water from the mining ship.* Aftger the nodules have gathered by the collector unit, they will be washed clean by water jets. The nodules will then be crushed and brought to the surface as slurry containing both crushed nodules and water. When the slurry reaches the surface, there will be a partial discharge of waste water containing particular matter and trace metals. This discharge may interfere with light penetration and reduce photosyn- thesis in the surface layers. Furthermore, the waste water will be considerably colder than the surface water.

- *The third relates to onshore processing.* This includes waste water, tailing and slag. Here roughly the same problems will be encountered as in land-based mining operations.

It is important to distinguish between problems that are manageable and possible to live with, and significant adverse changes that cause serious harm to the environment. A significant adverse "environmental impact" may be defined as: important adverse changes in ecosystem diversity, productivity of the biological communities with the environment, or threat to human health through direct exposure to pollutants or through consumption or exposed aquatic or aquatic organisms or important loss of aesthetic, recreational, scientific or economic values[12].

The most significant environmental impacts will be those caused by the collector unit on the deep seabed. It is however too early to say how serious the environmental consequences on the deep seabed will be. US researchers have studied the effects of pilot mining operations conducted in the late 1970s, but these were limited and short-term test operations, As mentioned, Comprehensive long-term studies started only three or four years ago, so we have limited empirical data available. There is broad agreement on the need for more research such as investigation of the direct bottom disturbance by the collector system and its indirect influence through resedimention of the plume.

US investigations have concluded that discharge of waste water is unlikely to represent any serious problem. Particles have been found to sink more rapidly to the bottom than had been anticipated. It will be interesting to see if the Japanese study fully confirms these results. The Germans have recommended further research in this area as well[13]. This discharge depth for the waste water is a much debated subject. Rather than discharge every thing at surface level, several sources have recommended a depth of 200 meters or even 1000meters. By choosing the former, disturbing the most productive part of the water column, the epipelagic zone, would be avoided. Those recommending a discharge depth of 1000 meters or more justify this by the need to avoid disturbing the processes going on in the mesopelagicus now turn zone as well[14].

To summarize : The effects of onshore processing are in many ways similar to those caused by land-based production. Mining deep seabed minerals thus represents no new source of environmental impacts, but rather an alternative source of supply of the same end products. However, this does not apply to the effects on the seabed and the water column. Here deep seabed mining will create new type of environmental impact. Future exploitation of the nodules will represent the first large-scale activity ever attempted at such depths, and considerable uncertainly attends the environmental consequences. The greatest uncertainly concerns the deep seabed. Scientist describe themselves as cautious optimists, however, so there seems to be no reason to prohibit planned test mining. In fact, long-term pilot mining operations will probably be the most important source of knowledge about the environmental consequences of deep seabed mining.

Political and Legal Factors

Considerable efforts are currently underway under the auspices of the secretary-General of the United Nations to create a basis for universal acceptance of the 1982 United Nations Convention on the Law of the Sea. As of August 1993, 56 countries have ratified the convention, which will enter into force one year after 60 rectifications have been received. The remaining four ratifications may come early in 1994. The Convention consists of 18 parts. Board agreement exists on 17 of these. Part XI dealing with the Area (the deep seabed) is the problem. The USA, Germany and Great Britain have refused to sign the Convention, holding that part XI does not allow sufficient room for private enterprise while also paving the way for sizeable United Nations bureaucracy. Here I may add that none of the industrialized countries except Iceland have ratified convention.

The Secreatary-General has a list of eight so called hard-core issues, which forms the basis for his informal consultations on outstanding issues relating to the deep seabed mining provisions of the conventions; Cost to states Parties, the Enterprise, Decision Making, Review conference, Transfer of Technology, Production Limitation, compensation Fund and Financial Terms and contracts.

The Secretary-General's informal consultations on outstanding issues have entered a new phase with the United States as an active participant from April 1994. The aim is to conclude these negotiations before 60 ratifications have been achieved. There seems to be a definite chance of obtaining consensus on Part XI, which should pave the way for a universally acceptable LOS convention. The best means to achieve agreement on the remaining issues seems to be to establish limited institutional arrangements and formulate general principles that can be accepted by all. The Draft Regulations and the removal of environmental considerations from the list of hard-core issues signify to some extent that environmental effects have now been put on a 'waiting list' and one area of conflict has thus been 'frozen' Here we may note obvious parallels with the Antarctic Treaty negotiations, where the decision was to 'freeze' the most difficult issues and formulate general guidelines.

The Prospects for Commercial Exploitation

Let us now turn to the prospects for commercial exploitation of polymetallic nodules. Is it realistic to assume that a decision concerning commercial projects can be made in the course of the present decade? In the short term., this hardly seems realistic. Most of the countries of Europe and North America, and to a certain extent Japan find themselves in a state of economic recession. Moreover, metal prices are low due partly to western policy of allowing East European states to dump metals on the market. There is reason to expect that western countries will not oppose this practice in the next few years, simply because it is not in the interests of the West to contribute to the further collapse of the economy in for instance Russia.

In the somewhat longer term-perhaps as early as towards the end of the 90's - the situation may be different. Japan as mentioned is due to test its mining system in 1996. The question is what will happened when they have concluded their tests - and at this point we have to look at the economic aspect of such projects. Not infrequently, claims are heard that the economy of such projects is hopeless. Let us examine this assumption.

The prospects - The economy of the projects

Investment cost for a commercial project with an annual production capacity of 4.5 million tons of nodules over a 20 to 25 year period was according to the MIT-Model, at approximately 1.5 billion U.S. Dollars. Some regard this as a huge amount. But is it realy that large? Let me compare it with some investments currently being made in my own country. The Winter Olympic Games are to be held in Norway next year. This arrangement lasting 14 days in a country with 4.5 million people involves costs corresponding to a commercial project. A new Airport is being built near OSLO. Investment Cost here is the double of a module Project. Moreover, investment in a nodule project will be no more than loose change in relation to the money invested in oil and gas production activities in the Norwegian sector of the North Sea. One May of course argue that Norway invests in this way because it is a wealthy country and because there is economy in such projects. True Norway enjoys sound economic conditions - and these projects would not have been initiated if there had been doubt about their economic viability. Nevertheless, I feel there is a need to kill the myth that the investments involved in deep seabed mining are that huge. Which brings to me to the next question- which is more important to what extent will deep seabed projects be profitable.

A study carried out by IFREMER in collaboration with French companies indicates that commercial nodule projects may be profitable with in the next decade or so, However, from time to time strong scepticism is expressed with regard to the economic of deep sea bed mining. Some maintain that it will take thirty to forty years or even longer before commercial exploitation can start. On what basis are such statements founded? - obviously not upon comprehensive techno economic modules. It is a paradox that we today have no techno economic modules which are up to date and which is based upon realistic preconditions a model that for instance takes into account the effect of extensive state substation of technological development in Europe and Asia and Which distinguishes between the various groups of actors. The development of such a model is in my opinion one of the most important tasks confronting us in this area in the immediate years to come. The ideal arrangement would be for an internationally composed group of experts from research, industry, shipping and the United Nations to draw up such a model. I may mention that the Fridtjof Nansen Institute is working on such a plan.

In this context, I would like to emphasize that I do not necessarily believe that first generation projects will give great profitability the possible big money will probably not emerge before later generation projects. The point I wish to make is that much of what is said about the profit aspect of such projects is based on speculation not on facts and knowledge.

And we ought, and can, do something about this. Let me in this context mention that the optimists of the 70s were wrong in their assumptions of a quick profit. The pessimists of the 90s may well suffer the same fate.

The Prospects - Possibilities for international co-operation

Let us then look more closely at possible future developments and the possibilities of establishing a degree of international co-operation. Japan has plans to test a complete mining system with riser, pumps and collector unit at 2000 meters depth on a seamount off Japan in 1996. The Japanese test may prove to be of great importance both technologically, economically and organizationally.

The Japanese have surprisingly enough persisted in the development and building of a passive or towed collector unit despite the fact that several senior engineers in the Japanese programme have long been of the opinion that a self propelled, not a towed unit will be the type eventually used for commercial exploitation. Nevertheless, the Japanese test will be important because it will be of significance when choosing which subsystem to go in for and which to abandon in the years to come. An important question then is what will happen when the tests have been completed. Will the Japanese halt the project after the tests, because they do not believe the project will be profitable? Will they decide to continue the developing technology without necessarily deciding on the time for commercial production Or will they decide to commence preparations for commercial exploitation?

Regardless of whether the Japanese choose alternative 2 or 3, they face the choice of doing the work alone or commencing a stronger collaboration with others. My guess is that they will in such case choose collaboration. We have witnessed a clear change in the attitude of Japan in the direction of collaboration with others since they started the development project back in 1981 and up to today. During the first five to six years it appeared almost unthinkable for the Japanese to co-operate with other nations. Towards the end of the 80s the attitude to cooperation was different, and Metal Mining Agency of Japan commenced for instance collaboration with the US National Oceanic and Atmospheric Administration on joint studies of environmental consequences of deep seabed mining. And today, my impression is that the Japanese are genuinely interested in discussing collaboration with others in this field. The change in attitude has doubtless something to do with the fact that the development of the deep seabed project has taken far longer time than originally expected, while at the same time the Japanese have generally come gradually to see both the need for and the necessity of international cooperation.

Even though uncertainty exists as to the time commercial exploitation will start indicates that the further development of technology may be characterized by stronger international cooperation. Many factors point to be advisability of such cooperation.

★ Firstly, purely national initiative mean costly development programmes.

★ Secondly, the majority of the potential Co-operative partners have a sound technological base and actors who feel strong are often capable of co-operating.

★ Thirdly there is an increasing willingness to cooperate with others.

★ Fourthly it is worth recalling that the 70s and the initial development of deep seabed techno- logy was characterized by good cooperation between companies and research institutions in the U.S.A, Europe and Japan.

Needless to say there will also be problems attached to a possible co-operation for instance as to choice of minesite for tests, selection of technology, project progress and so on. Nevertheless, on balance there is far more to gain by such co-operation. The point I would like to make is thus as follows Japan's test planned for 1996 could be followed later by an international collaborative project in the Pacific, Where the aim would be to further develop technology for use on a commercial scale and where private as well as state interests from Asia Europe and North America participate. It should be emphasized that Japan has made no decision concerning any collaboration subsequent to completion of their test mining in the pacific, and that any collaborative arrangement need not necessarily be commenced directly after completion of the tests.

Environmental studies will of course have to be included as a natural element of any co-operation. In this context it is important to emphasize that it is only in the course of pilot mining operations of long duration that it is possible to satisfactorily study environmental consequences particularly the effects on the deepseabed. Moreover, environmental studies should be an obvious area for closer international co-operation.

What then will be the attitude of the new actors as to a possible future co-operation project in the pacific. Without having discussed the matter with them. I would guess that both China and Korea could show a positive attitude to the idea. As far as India is concerned and India cannot be described as a newcomer in any way the situation would probably be a little different. It would be natural for them to concentrate on their minesite in the Central Indian Basin. My impression is that India for the next few years at any rate will concentrate on use of their own resources. This is not to suggest that they in principle are against collaboration with other nations. Cooperation will most likely be established within limited technological fields. The fact that India has developed expertise in a number of fields that it is "inexpensive" to use its own scientists and engineers, India's wish to retain full control over the programme, combined with a relatively weak foreign economy, would support this assumption. In the somewhat longer term perhaps towards the end of the 90's - the situation may well change for the same reasons as I have already mentioned.

Deep seabed Minerals and Developing Countries

I have in this account dealt primarily with technologically and economically advanced developing countries and recenty industrialized countries such as India, China and South Korea. These countries must necessarily be placed in a separate division when it comes to developing countries and their opportunities of taking an active part in the future exploitation of the deep sea bed minerals. Here we find an infrastructure, a good technological and economic point of departure as well as the political determination to go in for the activities. Again there are other countries which in time should have good chances of being able to participate here I have in mind countries like Brazil and Mexico, which doubtless could employ their experiences gained in the offshore oil and gas industry also in deep seabed mining. Both these groups, which we may call first and second division countries in a deep seabed context, comprise however the privileges sector of the developing countries. It is appropriate to ask what chances the other - that is to say the majority of the developing countries - have for participating in and benefiting from what is called the common heritage of mankind. They have obviously no possibility whatsoever of going in for such activities on their own. Any engagement would have to take place under the direction of the United Nations, through regional collaboration or by establishing a collaboration with the developing countries which are strong technically and economically or with industrialized countries.

Let me in this context mention that UNIDO and the Fridtjof Nansens Institute plan to carry out a comprehensive study of Seabed Minerals and Developing countries. The study will deal with shallow water mining and deep seabed mining and analyse the possibilities in the various types of developing countries have for engaging in these field in the short, intermediate and long term., Focus will also be directed on the extent to which engagement in seabed mining would provide spin-off effects in other areas.

Notes

1. Exploration for nodule deposits in the Central Indian Basin started earnest in 1982. India's interest for deep seabed minerals dates back to the mid 60's, however When the Geological survey of India (GSI) carried out the first preliminary studies. In 1978, scientists from the National Institute of Oceanography (NIO) and GSI published a comprehensive analysis of the metal content of nodules in various parts of the Indian Ocean, the co-variation of different metals, rate of sedimentation, etc, (H.J Siddiquie, Dr Da Gupta., N.R. Sengupta, P.C. Shrivastava and T Malik `Manganese iron Nodules from the Central Indian Ocean' Indian Journal of Marine Science Vol.7 December 1978). The analysis was based on mainly data which the Indian scientists had received from colleagues aborad. In the following two years, foreign report were also published concluding that the Central Indian

Basin probably contained commercially interesting nodule deposits. The Indian research vessel 'Gaveshani' of NIO carried out the first successful expedition in search of polymetallic nodules in 1981 in the Arabian Sea.

By 1982, the nodule deposits in the Pacific Ocean were explored far more thoroughly than deposits in the Indian Ocean. There were several reason for that, Firstly, industrial groups and western research institutions realized relatively early that deposits in the Clarion-Clipperton area in the Pacific satisfied requirements for the first generation projects. Exploration work was therefore concentrated to this area. Secondly, exploration activities based in the United States have better access to the Pacific than to the Indian Ocean. Thirdly, many of the nations in the Pacific Regions possess advanced technology and are advanced economically. The same does not apply for many of the nations in or around the Indian Ocean. More than half of the nations belonging to the third world are located in this area. The world Bank defines 30 of the 36 nations in the regions as developing countries J.M. Markkussen (1986). Polymetallic Deposits in the Indian Ocean' New letter No 2-1986. the Frittjit Nansen Institute, pp, 12-31.

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Developing Countries and the Transfer of Ocean Mining Technology - Some Key Issues

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1. Purpose

This presentation aims to discuss some potential problem areas relating to technology transfer in ocean mining. It starts by giving a short introduction to polymetallic nodules and an explanation why these may represent an important future mineral supply source for developing countries. The term 'technology transfer' is thereupon defined as three different flows of technology and expertise. A brief description is then given of three frequently encountered problems of technology transfer: the lack of long term effect on the recipient's production and technology capabilities, the long term dependency on hired, skilled personnel to operate and maintain the transferred technology, and the extremely high costs the transfer process involves. A tentative explanation is then given to explain why the complex system character, and then to some extent limited availability of ocean mining technology, may influence developing countries with poorly developed technological and managerial skills exposing them to such problems if they should engage in technology transfer of ocean mining technology, and why this necessitates distinguishing between various categories of recipient countries.

2. Introduction - polymetallic nodules as a future mineral supply source

With the world's population growing at an alarming rate, and land-based mineral deposits declining rapidly, there is an evident need for new sources of mineral supplies. Faced with the largest population growth, developing countries will have a particular need for new sources of supplies.

Minerals extracted from polymetallic nodules could wel represent an important future reserve. The nodules are "potato" shaped balls of 0.5 to 25 cm in diameter, paved on the sediment on the deep seabed. Each nodule is an oxide consisting of more than 30 metals, of which manganese predominates.[1] Thereafter follow copper, nickel, cobalt, zinc, iron, etc.

During the last 20 years, exploration work carried out by international mining consortia and through national development programmes, has made it possible to determine the commercially most interesting mining areas as well as the resource potential.[2] Presently by the most interesting mining areas are found in the Clarion-Clipperton area between the US West Coast and Hawaii, in the South Pacific, and in the Central Indian Ocean Basin. Conservative estimates of the earth's total reserves based on these surveys indicate that marine deposits of nickel, cobalt and manganese are in fact more common than terrestrial deposits. The respective figures applying to marine and terrestrial deposits are; Nickel 83.8% and 16.2%, Cobalt 95.2% and 4.8%, manganese 56.4% and 43.6%, while the figures for copper are 31.0% and 69.0%[3].

However, from a technological viewpoint ocean mining is extremely demanding and requires an efficient organisational infrastructure. Most developing countries will find it difficult to meet these requirements, and consequently limited possibilities of exploiting the nodule deposits. The transfer of technology and expertise from industrialised to developing countries will be an important means of improving these prospects. However, experience clearly shows that technology transfer is a complicated process, and successful transfers require carefully conceived strategies.

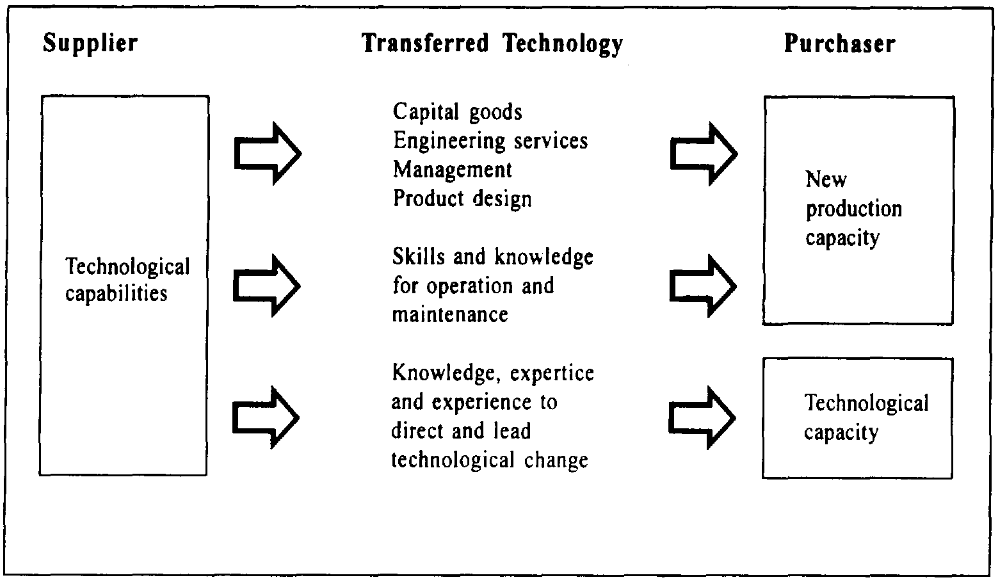

Fig. 1. Different flows in technology transfer

3. Some important aspects of technology transfer

3.1 Three different flows of technology and competence in technology transfers

Technology transfer is a collective term for several different flows of technology and competence from a supplier to a recipient. Before discussing some of the potential problem areas of technology transfer in relation to ocean mining, it may thus be appropriate to distinguish between three of these flows, as illustrated in figure 1.[5]

1. Transfer of capital goods, engineering and management services and product design, to supply new and/or improve existing production capacity.
2. Transfer of knowledge and competence necessary to operate and maintain technology, and hereby improve existing production capacity.
3. Transfer of knowledge, competence and experience to stimulate, create and lead technological change and development in the recipient country thereby improving their technological capacity.

There is thus an interesting distinction between the first two categories and the third. While the first two are meant to improve existing production capacity, that is the human and physical resources devoted to manufacturing products and the efficiency with which those resources are produced, the latter should have an impact on the technological capacity. This means improving the level of technical education necessary to understand the physical processes underlying the purchased technologies and producing the necessary knowledge and competence required to choose appropriate technologies, to operate and maintain these and to perform R & D-work for further development. While technology transfer operations traditionally concentrated on the first two categories there has been an increasing focus in recent years on the third aspect, the reason being that transfers have frequently resulted in three closely related and equally undesirable consequences for the recipient country.

3.2 Well known problems of technology transfer

Experience shows that transfer of technology and knowledge often has little or no long-term effect on the production or technological capabilities of the recipient country. During the contract period and shortly after its completion, one may observe some effects, but in the long run these tend to deminish. Secondly the lack of such long term effects has made recipients dependent on the supplier to operate and maintain the transferred technology, thus necessitating an extension of contract periods. Consequently, it becomes difficult for the recipient to act independently when trying to achieve further technological developments in areas related to the transferred technology. He will be bound to the first supplier, and restrictions are thus made on future technological choices. Finally, the combination of buying advanced technology and long-term dependence on hired, skilled personnel doing the work that much cheaper local manpower was meant to do, has made the overall costs to the transfer process disproportionately high in terms of the outcome.

In order to reduce the effect of these problems, there has been increasing concern for how the technological and organisational infrastructure in the recipient country may influence the outcome of the transfer process.

3.3 The technological and organizational infrastructure in the recipient country.

By the term technological infrastructure we mean the 'support system' required for the transferred technology to function efficiently. It should include both hardware and the underlying technological capabilities, as described above.

The organizational infrastructure should be responsible for managerial tasks such as planning technology strategies and decision-making support for political bodies, as well as organizing, monitoring and leading the transfer operation. Strategic planning means analysing the existing situation constraints, resources and objectives to be achieved. The function of organising means to assign different tasks to different actors engaged in the transfer process, and coordinate their activities. Monitoring means the continuous review and adjustment of the transfer process, while leading refers to the way in which policies are formulated, formal standards are set and the different actors motivated to perform their tasks. Finally, the function of decision making support means to provide the information and data required to implement the management functions.[7] The organizational infrastructure should include all private and governmental organizations and institutions involved in one way or another in the transfer operation. Moreover, it should be responsible for the organizational frame work set up for the transfer process. In general, this may either be a permanent organization, often a part of the technological infrastructure, or a temporary organization established for that specific transfer process, or a combination of the two.

What is interesting about this perspective is that it emphasizes the fact that the transfer process should be `studied in a larger context, where the position of the transferred technology in the social and productive context of the developing country are focused, and the effect of the transfer should be evaluated on the position of the recipient country.[8] It is reasonable to believe that the level of development of the above infrastructures will have a particularly strong impact on the outcome of any technology transfer process in ocean mining. This is due to two basic characteristics of the mining technology.

4. Aspects of particular importance to technology transfer in ocean mining.

4.1 The complex system character of ocean mining technology

When talking of technology transfer in ocean mining, one should first of all keep its complex system character in mind. The complete technological concept of a commercial system will be composed of a number of different components from a variety of fields of technology. To mention a few, the prospecting and exploration stage involves knowledge about oceanography and operation of echo-sounders and side-scan sonars, the mining stage requires knowledge about dynamic positioning, underwater vehicle design and operation and pump technology, the transport stage neccessitates expertise and experience from shipping, and in the processing stage, knowledge about processing of oxides will be a prerequisite. Each of these can be characterised as separate fields of high technology, the development, operation and maintenance of which require highly specialized knowledge.

4.2 The limited availability of ocean mining technology

Secondly, the technology used in ocean mining may still be characterised as new and emerging, and the availability of the technology is limited. Even though extensive research and development work has been carried out during the past 20 years, and the basic technical concepts are known, quite some work remains to be done before the technology for a commercial system is readily available.[9] Thus, at present, complete commercial systems cannot be purchased in any market.

If we look at different systems components separately, some of them, for instance, the technology for dynamic positioning and pump technology for the riser system, are fairly readily available and well tested in related industrial areas. With some minor adjustments these may be used in ocean mining. Still, it is important to note that these technologies are so specialised that there are only a few possible suppliers. Other system components, and in particular some of those used in the mining stage, will require original designs, meaning that an original, technological solution will have to be developed for specific purpose of exploiting polymetallic nodules. Diffusion of knowledge about the particularities of original designs is generally limited, and in the case of a new and emerging technology such as ocean mining, this is even more so. It may thus be useful to take a brief look at the different actors who have previously been, or are currently engaged in development of these less readily available technologies.

First of all, we have the mining consortia which during the 1970s and 1980s performed test mining at sea, and which of course have extensive knowledge about the particularities of ocean mining technology design and development. Traditionally, such large transactional cooperation have been important supply sources of various kinds of ocean technology to developing countries.[10] But due to the lengthy and complicated discussions on the political, economic and legal aspects of Part XI of the 1982 United Nations Law of the Sea Convention, where technology transfer is one of the key issues, it is an open question whether those actors will engage in technology transfer before problems have been resolved.[11]

Today, we find the highest level of activity in Asia, with development work being carried out in China, India Japan and Korea[12]. Japan is due to perform an integratred test at a seamount outside Japan in 1996, using a towed collector unit. India is today the leading developing country in ocean mining, and has done considerable exploration and surveying work. India has also progressed far in developing processing techniques, and is at present doing research and development work on the collector unit and the riser system. The Chinese have, since the beginning of the 1980s, performed detailed exploration work. A new national long-term programme lasting from 1991 until the start of the next century will have exploration as its main focus, but will also carry out feasibility studies concerning the design and development of a test seabed mining system and the processing techniques.[13] Finally we have the Korean programme, consisting of three stages over a period from 1990 to 2010. The first stage will focus on exploration in order to achieve Pioneer Investor status, pursuant to the Law of the Sea Convention, the second (1994 - 2001) will continue with more detailed exploration as well as technological development of exploitation and processing techniques, while the third (2001 - 2010) will concentrate on developing a full-scale commercials system[14].

It is evident that these studies are still in their early stages. These countries should therefore, at present, not be looked upon as possible suppliers, but rather as potential purchasers of certain components or specific knowledge or skills that may speed up their development projects.

4.3 Three stages of a technology transfer operation

The complex system character and the limited availability of ocean mining technology will affect any purchaser carrying out three tasks crucial to the outcome of the transfer process. First of all, prior to any technology transfer operation, the purchaser must be able to identify his technological needs[15]. The more precisely these are identified, the better the possibility of purchasing appropriate technologies. But the more complex the technology in question is, the more knowledge is required to define the needs, and the higher the demands on the purchaser's technological capabilities. Keeping in mind both the system character and the limited knowledge about the final technological concept of ocean mining technology, identification of such needs will doubtless require great technological expertise.

Having identified his technological needs, the purchaser will have to carry out a market survey of possible suppliers. The more the technology in question is based on well-known technological principles and the more it is readily available in the international market, the easier it will be for the purchaser to get a clear overview of potential suppliers and to choose technologies that are appropriate for his technological needs. For the most readily available parts of ocean mining techno- logy, this study keeps in mind that it is not enough to be able to identify the requirements or the appropriate suppliers. Successful transfer will still be totally dependent on well-developed systems for maintenance and operation.

If we then look at the less available components, one may wonder whether it will be possible to help a potential purchaser develop these parts of the mining technology. The 'solution' to this problem will probably be that some industrialised states have technological capabilities from the offshore oil and gas industry, shipping and the land-based mining industries. The technological and organisational infrastructures required for an ocean mining system will have many, important similarities to already existing infrastructures in these industries. The knowledge and skills embodied here may therefore doubtless be used when developing the mining technology. It is very likely that for a long time to come, technology transfer in ocean mining will involve capabilities from these related industrial areas, that are further developed and adapted to the specific needs of this industry[16]. Consequently, market surveys will be difficult, since the purchaser must possess detailed knowledge of the related fields of technology, and also know how these may be assembled into an operational ocean mining system.

However, one important advantage of this form of technology transfer should be mentioned. Many of the countries engaged in, or aiming to engage in, ocean mining are also involved in exploitation of shallow water oil and gas resources. Transfer of technologies from these sectors in industralised countries should thus have potential short-term spin-off effects to these activities in the recipient country.

Finally, the purchaser must know how the purchased technologies should be adapted to the specific needs of ocean mining and assembled into an operational mining system. It is quite likely that the needs of the purchaser will differ somewhat from the technological specifications underlying the purchased technology. Before ocean mining technology gets readily available internationally, and as long as technology transfer will imply transfer of technologies from related industrial areas, the adaptation phase will be an extensive part of any such process. Hence, fairly high technological skills will be a prerequisite for a successful engagement. And even if the mining technology should be more readily available, it has been emphasized that the more a technology is based on specialised skills for designing dedicated machines for special tasks etc., the more difficult it will be to imitate them unless the purchaser first goes through a very thorough process of knowledge building. In relation to the above, it may be worth noting that most of the potential suppliers having knowledge from related industrial areas at present have limited knowledge about the particularities of ocean mining technology design and development. If they should wish to assist a purchaser in any stage of the transfer operation, they will first have to go through a stage of knowledge accumulation.

4.4 Transfer of ocean mining technology and incremental technological development

In addition to influencing the purchaser's ability to identify his technological needs, perform market surveys and adapt the purchased technology to his specific needs, the level of development of the technological and organizational infrastructures will influence his ability to use the technology transfer operation as a tool for further incremental development, and thus to ensure long-term effects of the transfer operations. Generally, one may say that the better these capabilities are developed, the greater are the potential increments that can be achieved through a transfer project. Knowledge and competence gained throughout the contract period may improve the purchaser's ability to carry out technological changes after termination of the period, and thus successfully engage in future technology transfer projects. One may thus observe a 'favourable cycle': countries having fairly well-developed technological capabilities before entering into a technology transfer operation will have a better chance of ensuring a successful outcome of the process, and thus engage in new projects and thereby promote continual technological development. Nations lacking these capabilities, risk suffering from constant 'underdevelopment'.

Secondly, when transferring high tech products, the transferred technology is taken out of a specialized, advanced technological infrastructure and transplanted into another. The more complex the technology in question is, the more specialized and advanced the corresponding infrastructures tend to be, and also greater the necessity of these capabilities being present in the recipient country.

The long term effect of the transfer process will also be affected by the organizational framework set up for the transfer process. Technology transfer usually means improving the knowledge and skills of specific individuals employed by an organization or a project group responsible for the transfer process. In order to promote long-term effects of the transfer process, it is essential that these individuals remain available for the purchaser. Thus, if the organization employing these individuals is integrated in the overall organizational infrastructure, there is a better chance of keeping the transferred knowledge available after completion of the contract period.

5. Some comments on the organization of technology transfer in ocean mining

Based on the above discussions, two important conclusions seem to emerge. First of all, the level of development of the recipient's technological and organizational infrastructures will most probably have a strong impact on the outcome of the transfer process. In order to avoid the three basic problems of technology transfer mentioned above, any technology transfer process should thus start with a detailed analysis of the purchaser's basic capabilities before planning the scope of the transfer process. Keeping the wide diversity of developing on the possibilities different countries will have to participate in ocean mining as well as in their possibility to successfully engage in transfer of ocean mining technology. When talking of technology transfer in this field, it thus seems necessary to distinguish between different categories of recipient countries.

Secondly, even though the availability of ocean mining technology at present is limited, it is reasonable to believe that the availability will improve during the next 10 year period. This is first of all due to the fact that India and Japan will perform test mining at sea during this period, and thereby most probably provide new information about technological as well as organizational aspects of ocean mining. The availability is also likely to be improved by a solution to the political and legal problems concerning the Law of the Sea, since this may make it more favourable for the mining consortia to participate in technology transfer projects. It should be emphasized that a certain optimism seems to be present about achieving an universally acceptable convention[17].

Consequently, when talking of technology transfer in ocean mining, it is therefore also necessary to distinguish between different time aspects for each category of recipient countries.

5.1 Different categories of developing countries

Many indicators may be used when dividing developing countries into different groups, but it is not within the scope of this article to make a final classification. However, these should enable us to characterize present technological and managerial skills within a potential purchasing country, to indicate how much these may be improved during a specified time period, and finally to indicate which form of technology transfer will be most convenient to acheive the goals[18].

Considering indicators of technological capabilities, it seems obvious that existing capabilities in terms of ocean mining and related industrial areas, as well as in other high technology sectors, should be taken into consideration. Secondly the national orientation of the purchasing country will be important. This should tell us to what extent the country is taking directed action to improve technological and managerial capabilities in relation to ocean mining as well as other relevant sectors of industry.

As far as organizational capabilities are concerned, let me repeat that ocean mining requires cost-intensive technologies whose development must be based on long term, large scale R&D programmes, where research institutions, commercial enterprises and governmental agencies should cooperate. In order to support such strategies, UNCTAD has stated that a

"...... comprehensive policy framework for mobilization and allocation of resources to strengthen research and development activities, both at the institutional and enterprise level, may be necessary. Specific policy measures might include a larger allocation of national resources to research and development centres, tax concessions and financial incentives for R&D activities at the enterprise level, suitable forms of organizational structure such as joint research, co-operative research, the provision of expertise[19].

It will thus be necessary to analyze how experienced the purchasing country is in establishing and operating such large organizational frame works, and to what extent they have tried to establish an infrastructure for the sole purpose of ocean mining. This should include studies of capabilities at both the macro (i.e. governmental) level and the micro (i.e. enterprise) level.

Keeping these indicators in mind, the classification proposed by Markussen seems appropriate[20]. He distinguishes between the technologically and economically strong countries in ocean mining (China, India and Korea), the newly industrialized coastal states (Brazil, Mexico and Chile), and the large majority of poor nations in, for instance, Asia and Africa.

5.2 Group one - the economically and technologically strong developing countries

Compared to most other developing countries, the countries in the first group are technological 'superpowers'. They are all aiming to become independent actors in ocean mining, and have started large-scale, long-term R&D programmes to develop complete ocean mining systems. These are all national programmes based on close co-operation between government agencies and research institutions, where the challenge now is to integrate industry in the projects. Even though all three nations have expressed interest in cooperating with foreign expertise, they seem fully aware of the need to develop basic technological and managerial capabilities before entering into any such cooperation. If they manage to keep to this strategy they should have a good chance of successfully engaging in technology transfer projects. These may be aimed at improving basic technological capabilities, as well as solving more specific problems arising as a result of ongoing development projects. In other work, all the three different flows of technology may be relevant. These countries are also in the lead in technological development. In a longer perspective, they may therefore also act as suppliers of ocean mining technology to other developing countries.

5.3 Group two - the newly industrialized coastal states

The countries in the second category should, in the longer term, have a good possibility of participating independently in ocean mining. But in order to avoid the above mentioned problems, technology transfer should first and foremost focus on improving basic technological and organizational skills in relation to ocean mining. However, due to the complexity of ocean mining technology this wil generally be a long -term process, and problems may thus arise due to the differing motives of supplier and recipient. Technology suppliers are frequently hesitant to participate in transfer projects unless the prospects for short-term profit are good, and they may thus be unwilling to finance such long-term projects.

In order to avoid this problem it seems necesary to distinguish between two different stages of a technology transfer process. This means first to develop technological and organizational skills, and thereafter to use more 'commercial' technology transfer operations to supply specific technologies to meet particular needs that have arisen.

However, possible suppliers from industrialized countries could well regard participation in long-term projects as an investment in future market positions. By engaging in transfer projects they will improve their own technological capabilities in ocean mining, and when the market in some years turns commercial, these companies may have obtained a good position in the market. In the long-term it may thus be profitable to support long-term development projects aimed at developing basic capabilities.

5.4 Group three - the large majority of poor developing countries

Concerning the countries of the third group, it is unlikely that they, within the foreseable future, will be able to act independently in ocean mining. They will lack the required technological and managerial skills, nor will any of these nations alone be able to finance a deep seabed mining project. Perhaps we face the greatest challenges in trying to develop ways in which the capital intensive, complex ocean mining technology may be adapted to suit the conditions of these capital-short but labour-rich developing countries. Their participation will most probably be organized through cooperation with other actors, either through regional or international cooperation. Here the UN and international development aid organizations should play a crucial role in assisting these countries to establish, lead and finance the necessary cooperative networks.

6. Summary

Ocean mining technology is characterized by its complex system character and its partially limited availability. These characteristics will influence a potential purchaser when carrying out such tasks as identification of technological needs, market surveys for suitable suppliers and adaptation of the purchased technology to his specific needs. If lacking sufficiently developed technological and managerial skills, the purchaser risks being confronted with lacking long-term effects in his production, and technological capabilities long-term dependency on hired, skilled personnel to operate and maintain the transferred technology, and extremely high costs. Therefore, when planning the scope of a transfer process, the purchaser's capabilities should serve as a starting point. And keeping the large diversity of developing countries in mind, it seems necessary to distinguish between different categories of recipient countries. However the availability is likely to improve during the next 10 year period, and it is therefore also necessary for each category to distinguish between different time periods.

The technologically and economically strong developing countries China, India and Korea, should have a good chance of successfully engaging in technology transfer projects. Newly industrialized coastal states, like Brazil, Mexico and Chile, should in some years have a good possibility of participating independently in ocean mining. But in order to avoid the above problems, the transfer should focus first and foremost on improving basic technological and managerial skills. As to the large majority of poor developing nations, these will probably not be able to act independently in ocean mining. Participation should thus be organized through cooperation with other actors, and the UN and international development aid organizations should assist them in establishing, leading and financing the necessary cooperative networks.

Notes

1. Having manganese as the primary element, the nodules are often referred to as "manganese nodules".

2. Development and testing of systems for exploration and prospecting has been carried out by the international mining consortia Keenecot Consortium (KENCON), Ocean Management Inc. (OMI), Ocean Minerals Company (OMCO) and Ocean Mining Associates (OMA), as well as through national programmes in China, France, Germany, India, Japan, Korea and Soviet Union.

3. Manganese Nodules Mining System-The Large Scale Project Information Brochure from The Technology Research Association of Manganese Nodules Mining System, Tokyo, 1990.

4. An ocean mining process may be divided into five different stages. The exploration stage is meant to procure general information as well as detailed information about the resources potential at a possible mining site. Thereafter follows the mining stage, through which the nodules are lifted from the seabed up to a surface mining ship. Then, through the transport stage, the nodule material is transferred from intermediate storage tanks on board the mining ship to a bulk cargo vessel for shipment to a port and terminal. Here the minerals are stored before they are transferred to the processing plant, where the refining process is the final phase in that mineral's journey from the seabed to refined end product.

   For a more detailed description of the different stages, see Berge, Stig. Jan Magne, Markussen and Gudmund Vigerust Environmental consequences of deep seabed mining problem areas and regulation'. The Fridtjof Nansen Institute, Lysaker, 1991.

5. Aasen Berit, Knut M. Onsager and Martin Bell: Challenges for a Global Climate Policy: Energy and International Transfer of Technology. Report No.22, 1990. Norsk Institute for By-og Regionsforskning, Oslo, 1990.

6. Roessener, J.David and Alan L. Porter: `Achieving Technology-based Competitiveness in developing Countries. In Chatterji

M.(ed) Technology Transfer in the Developing Countries. Macmillan press, London, 1990.

7. For a more detailed discussion of the aspects, see `Transfer and Develoment of Technology in Developing Countries - A Compendium in Policy Issues' United Nations publication UNCTAD/ITP/ TEC/4, ISBN 92-1-112284-4, New York 1990.

8. Aasen Berit, Erik Hansen, Ann-Therese Lotherington, Aasmund Stenseth and Harold Wolhite: 'Analytical Perspectives on Technology Transfer'. In Chatterji, M. (ed) : Technology Transfer in the Developing Countries. Macmillan Press, London, 1990.

9. The system developed by the American-Dutch Ocean Minerals Company (OMCO) seems to have set a standard for the technological development. Their system consists of a self-propelled collector unit, moving along the seabed and collecting the nodules. The nodules are crushed into a slurry in the collector unit, and transferred to a mining ship through a riser system where hydraulic pumps at various depths are used to lift the slurry. (cf. Markussen, Jan Magne: 'Polymetallic Nodules: a status report', in Bulletin of Korea Ocean Research. Korean Ocean Research and Development Institute, Seoul, 1993.

10. See Gopalakrishnan, Chennat: Transnational Corporations and Ocean Technology Transfer'. In Chatterji, M. (ed): Technology Transfer in the Developing Countries. Macmillan press, London, 1990.

11. The United Nations Law of the Sea Convention consists of 18 parts. Broad agreement exists on 17 of these. The controversial part is part XI, dealing with the deep seabed. The US, Germany and Great Britain and most other industrialized nations have refused to sign the convention, claiming i.a. that the proposed regulations for technology transfer will deprive enterprises from the industrial world the competitive advantage they have gained through substantial investments in research and development.

12. Markussen, Jan Magne 'Exploration and Exploitation of Polymetallic nodules - an international and multidisciplinary overview'. Paper presented at the 27th Annual Conference of Law of the Sea Institute. Seoul, Korea, 13-16 July, 1993.

13. Jiancai, Jin: 'Deep Seabed Mining in China', International Challenges volume 13 nol, 1993. The Fridtjof Nansen Institute Lysaker, 1993.

14. Kang, Jung-Keuk and Seoung-Yong Hong: 'Current Status of Deep-Seabed Exploration Activities in the Republic of Korea'. International Challenges, Volume 13 no.1, 1993. The Fridtjof Nansen Institute, Lysaker, 1993.

15. Of course, prior to identifying his technological needs the purchaser will have to choose which technology to go for. This is without doubt also a crucial phase of any technology transfer process, and developing countries choosing inappropriate technologies will always risk encountering the above mentioned problems. However, this presentation focuses on the problems of technology transfer of ocean mining technology, and is thus based on the assumption that the purchasing country had decided to try to develop ocean mining technology and competence.

16. In Norway, close collaboration has been established between 20 industry and shipping companies and research institutions. The group is coordinated by The Fridtjof Nansen institute, and aims to offer services for exploration, mining, transport and processing.

17. In April 1993 the US ambassador to the United Nations stated that the Clinton Administration intended to play a more active role in searching for a solution to the problems related to Part XI of the convention. This will most probably be an important incitement for more active participation by other central actors. (See: Ocean policy News, May, 1993. Council on Ocean Law)

18. Of course, a complete analysis will also have to include indicators of economic capabilities.

19. 'Transfer and Development of Technology in developing countries - A Compendium in policy Issues'. United Nations Publication UNCTAD/ITP/TEC/4, ISBN 92-1-112284-4, New York 1990.

20. Markussen, Jan Magne: 'Commercial Exploitation of polymetallic Nodules: When, Why, Who and How'. Materials and Society. Vol. 14, no. 3/4 1990.

The Role of the Industries in the Development of Marine Resources - Hypothesis for the Emerging Industry in Developing Countries

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FOREWORD

This presentation, rather than being a technical speech on Marine Resources, aims to :

- ☆ Summarize a successful example of the development of a marine resource: offshore hydrocarbons
- ☆ Identify the key factors and the role of different actors involved in that development
- ☆ Propose hypothesis for the transferrer of that positive experience to the exploitation of other marine resources, taking into account analogies and differences
- ☆ Underline the role oї the emerging industry in developing countries
- ☆ Focus the importance of international cooperation in promoting the development of marine resources

MARINE RESOURCES

Living resources

- ☆ Fish
- ☆ Algae

Non Living resources

- ☆ Hydrocarbons
- ☆ Minerals
- ☆ Sand and Gravel
- ☆ Desalinated sea water

Renewable energies

- ☆ Wind
- ☆ Wave
- ☆ Current
- ☆ Tide
- ☆ Thermal gradient

Coastal and sea space
Used for

- ☆ Maritime transport
- ☆ Industrial activities
- ☆ Civil activities
- ☆ Scientific activities
- ☆ Leisure and recreation

OFFSHORE HYDROCARBONS EXPLOITATION

MAIN FIGURES

Offshore hydrocarbons production (with respect to world - wide production)	28%
Proven offshore hydrocarbons reserves (with respect to world -wide reserves)	24%

GEOGRAPHICAL AREAS
(by production)

Middle East
North Europe
Gulf of Mexico
South East Asia-Pacific
South America
West Africa
East Europe
Mediterranean Sea

PROGRESSIVE STEPS FOR IMPLEMENTATION

From terrestrial to marine solution
From shallow to deep water
From mild to extreme environmental conditions
From fixed platforms to floating systems
From surface plants to subsea systems
From existing, or available, to new technologies for:

- ✰ Structures
- ✰ Topsides Facilities
- ✰ Marine Operations
- ✰ Production Operations
- ✰ Inspection, Maintenance and Repair

DEVELOPMENT SCHEME

Exploration:

- ✰ Survey
- ✰ Drilling

Exploitation :

- ✰ Economic Feasibility
- ✰ Environmental Impact Assessment
- ✰ Fabrication
- ✰ Start-up, Drilling and production
- ✰ Decommissioning and Removal
- ✰ Conceptual Development
- ✰ Detail Design
- ✰ Installation
- ✰ Operations and Management

MANAGEMENT OF TECHNOLOGICAL DEVELOPMENT

Project Organization

- ✰ System Approach
- ✰ Feasibility of Critical Technologies
- ✰ System Integration
- ✰ Prototype Testing
- ✰ Pilot Case in Real Operating Conditions

Planning and control

- ✰ Work Breakdown Structure
- ✰ Critical Path
- ✰ Milestones
- ✰ Intermediate Evaluation
- ✰ Critical Review

Transfer of the R&D results to the industrial applications

ACTORS INVOLVED

Oil Companies

Governmental Authorities and Agencies

Contractors (Engineering Firms, Constructors, Marine Operators)

R&D Organizations (Companies, Universities, Laboratories, Others)

R&D Funding Institutions (National and International)

KEY FACTORS OF THE SUCCESS

Clear Need : Securing the energy supply

Market Push :

and, as a consequence, Technology Pull Activities
Common understanding among the different Actors
Adequate economic and temporal support of R&D activities to overcome the technological challenges
Solutions compatible with the requirements of the industry and Government Authorities

SUMMING UP

The spectacular success achieved in Offshore Hydrocarbons Exploitation world-wide has:

- ☆ Proven the possibility of performing safety and economic activities at sea
- ☆ Provided a solid background for the industrial development of other marine resources
- ☆ Allowed a significant growth of local industries
- ☆ Strengthen international cooperation

HYPOTHESIS FOR TRANSFERRING THE OFFSHORE HYDROCARBON EXPERIENCE TO THE EXPLOITATION OF OTHER MARINE RESOURCES

- ☆ Identification of real needs and constraints
  Characterization of the market (local, national and international)
- ☆ Definition of the actors involved
- ☆ Identification of common understanding on
  - ◆ Problem
  - ◆ Priorities
  - ◆ Reciprocal roles of the actors
- ☆ Definition of the progressive steps for implementation
- ☆ Appropriate development scheme
- ☆ Management of technological development

PROGRESSIVE STEPS FOR IMPLEMENTATION

(when applicable)

- ☆ From shallow to deep water
- ☆ From simple to complex solutions
  - ◆ Infrastructures
  - ◆ Facilities
  - ◆ Marine Operations
- ☆ From mild to extreme environmental conditions
- ☆ From existing, or available, to new technologies for
  - ◆ Production Operations and Management
  - ◆ Inspection, Maintenance and Repair

DEVELOPMENT SCHEME

Exploration

- Survey
- Appraisal

Exploitation

- Economic Feasibility
- Conceptual Development
- Environmental Impact Assessment
- Technology Development
- Pilot Project
- Detail Design
- Fabrication
- Marine Operations and Installation
- Exploitation, Operations and Management

Industrial Exploitation and Commercialization:

- Local
- National
- International

MANAGEMENT OF TECHNOLOGICAL DEVELOPMENT

☆ **Project Organization:**

- System approach
- Feasibility of Critical Technologies
- System Integration
- Prototype Testing
- Pilot case in Real Operating Conditions

☆ **Planning and Control**

- Work Breakdown Structure
- Critical Path
- Milestones
- Intermediate Evaluation
- Critical Review

B Transfer of R&D results to pre industrial or large scale application

ACTORS INVOLVED

☆ End User

☆ Government Authorities and Agencies

☆ Contractors (Engineering Firms, Constructors, Marine Operators)

☆ R&D Organization (Companies, University, Laboratories, Others)

☆ R&D Funding Institution (National and International)

ROLE OF THE INDUSTRIES END USERS

☆ Identify the market of the marine sources (local, national and internatonal)

☆ Identifiy the limiting factors for the economic development

☆ Identify the commercial barriers for the exploitation

☆ Stimulate the involvement of local, national and international authorities (R&D programmes, tax incentives, etc.)

☆ Cooperate with contractors and R&D organizations at national and international level

ROLE OF THE INDUSTRIES CONTRACTORS

(Engineering Firms, Constructors, Marine Operators, etc.)

★ Identify and develop the necessary technologies (both existing and new technologies)

★ Define and design cost effective solutions identify the technological barriers for the exploitation

★ Stimulate the involvement of local, national and international authorities (R&D programmes, tax incentives, etc.)

★ Cooperate with end users at national and international level.

ANALOGIES AND DIFFERENCES WITH RESPECT TO OFFSHORE HYDROCARBONS

ACTORS	OFFSHORE HYDROCARBONS	LIVING RESOURCES	MINERALS	RENEWABLE ENERGY	OCEAN SPACE
End User	-oil company	-industry local markets	-intern, and -local community	-national energy authority -local community	-local authority industry
R&D Organic., Contractors... (Supplier of technologies)	-intern, firms -local firms	-local firms -intern, firms	-intern, firms -local firms	-intern, firms -local firms	-local firms -intern, firms

FEATURES	OFFSHORE HYDROCARBONS	LIVING RESOURCES	MINERALS	RENEWABLE ENERGY	OCEAN SPACE
Market Main output	worldwide -fuel (oil & gas)	local/regional -food -fuel (biomass) - by Product	worldwide -metals -materials	local regional -electricity -by product	local -artificial islands
Initial Investment	medium/high	low	high	low	high
Exploitation Progress	gradual	gradual	not gradual	gradual	gradual
Initial Technology Needs	-cost reduction technology -new technology	-cost reduction technology -new technology	-new technology -cost reduction technology	-new technology	-cost reduction technology -new technology

ROLE OF THE INTERNATIONAL COOPERATION

☆ The exploitation of Offshore Hydrocarbons has been based on significant development of new technologies

☆ The success of the hydrocarbons industries in tackling the offshore challenge in the last decades, illustrates the effectiveness of cooperation between Oil Companies, Governmental Authorities, Contractors and R&D Organizations world-wide.

☆ It is expected that International cooperation shall also play a fundamental role in building the foundations for a self sustaining industry for the exploitation of new marine resources

☆ Considering the current and future market and economic expectations for these resources, substantial public and private funding shall be necessary for research, development and demonstration activities.

ROLE OF THE INTERNATIONAL COOPERATION POSSIBLE MECHANISM

Common Research, Development and Technological Demonstration programmes by:

☆ Governmental Authorities

☆ International Organization

International pilot projects for the exploitation of Marine Resources in specific geographical areas

Agreement national and international level, among:

☆ End Users
☆ Contractors
☆ R&D Organizations

International Networks for:

☆ Transfer of existing technologies and development of new technologies

International Centres for:

☆ Marine science and technologies development

☆ Industrialization of technologies for the exploitation of marine resources

CONCLUSIONS

In the coming decades Marine Resources will represent an important source of:

☆ food
☆ minerals
☆ energy
☆ coastal and sea space

☆ International agreements and conventions illustrate the importance of the exploitation of marine resources

☆ Existing know-how and experience available from the Offshore Hydrocarbons already represent a solid base for the new ocean challenges

☆ Emerging Industry in developing countries and international cooperation shall be key elements for the development of marine resources in a sustainable manner

Role of Education System and Research Institutions in Marine Technology Development

Prof. N.V.C. Swamy
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(1) Educational and research institutions have a specific role to play in the development of any technology. This role is usually of four types:

(a) Training Programmes,
(b) Research and Development Activities,
(c) Technology Transfer to Industries, and
(d) Technology Watch.

(2) Educational institutions are eminently suited for imparting training programmes depending upon the needs of the trainees. This is especially so in the case of institutions which have Centres for Continuing Education. The usual practice is for the institutions to prepare modules of lectures based on written material as well as audio and video aids. The modules are usually prepared in such a way that they form units of presentation. Any programme can be organized by assembling the proper units suited to the requirement of that programme.

(3) The most important role of educational and research institutions is, of course, in research and development. Research implies a careful study of existing knowledge with an extrapolation into the future, resulting in either new products and processes or information. Development implies either improvement of an existing product and process or the discovery or invention of new products and processes. Research and development need a particular temper of mind to be effective. People involved in R&D should be basically inquisitive in nature and should not be afraid of taking risks in their activities. It is obvious that not all attempts at R&D can be successes. It is more often the case that only one among ten attempts leads to a successful product and process. However, the knowledge-base created by the failures is as important as success stories. Failure analysis thus forms an important aspect of research and development.

(4) It is not adequate if educational and research institutions develop products or processes at the laboratory level. It should be possible to upscale these to actual prototypes of a larger magnitude. It is here that a close interaction between educational and research institutions and industries becomes mandatory. Without participation by the industries, it is not possible to incorporate laboratory scale developments into industrial environment. This process of technology transfer from educational and research institutions to the industrial sector is one of mutual trust and coordination.

(5) It is much easier for educational and research institutions to anticipate future developments than for industries. The latter have a short-range approach to any problem because of immediate needs for upgradation of products and processes. However, the educational and research institutions can anticipate future developments because of the facilities of international contacts. It is also possible for research workers in such institutions to sense the possible direction in which developments are taking place. There is a network of international conferences, workshops and seminars, in which the seeds of future growth can be easily identified and watched.

This is a very important activity of educational and research institutions.

(6) It is thus seen that in any industrial development, the role of educational and research institutions is central.

COUNTRY PAPERS

The Development of Marine Non-Living Resources in Madagascar

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1. Country Background

A. Generality

Madagascar is one of the biggest islands in the world, located East of the African Continent in the Indian Ocean.

Previously colonised by the French Government, the country acquired its independence since 1960.

The economic activities are based on agriculture and breeding.

The mining exploitation has begun since antiquity.

In fact, Madagascar has a remarkable mining potential, according to the results of the geological researches and the mining work productions.

B. Agriculture and Breeding

The Malagasy people practice the alimentary agriculture: rice, coffee, vanilla, corn. Like most developing countries, the artisanal activities dominate in this sector. However, some area is exploited with industrial technology as sugar-cane, rice. The breeding of oxen, pigs, poultries also constitutes the main activity of people.

C. Mining Activities

With its intricate geological constitution, the underground of Madagascar presents miscellaneous rocks and minerals. Therefore, the country has got a good fame in the world for its mining resources: beryllium, gold, amethyste, tourmalline, and graphite, chromite, quartz, mica, and so on.

Graphite, chromite and quartz are the first mining production for export.

Now, the Government tries to develop mining in order to improve the efficiency of this sector for national economic recovery. The Mining Administration must help mining operators to give them the know-how in their exploitation.

Therefore, a new mining law is actually evolved to rectify many handicaps which are known on the different lines of these economic activities such as: research, extraction, flow-sheet, exportation. However, the country has not done many researches about marine non-living resources but for gas and oil. Anyway, the result of the researches of gas and oil which are undertaken with the other international firms is not incentive.

Moreover, the Government has made some effort since 1975 in the industrialisation of the country. But most of these industries cannot operate for different reasons.

So, the economical life of the country remains on the agriculture and mining activities.

D. Development Plan

About the development plan, the Government leans over the problem of agriculture, breeding and mining exploitation.

In fact, 85% of population are countrymen and practice breeding and agriculture. The Government tries to get alimentary self sufficiencies.

So, it encourages the countrymen to increase their production by a technological method. It also distributes fields to these countrymen.

A development plan of the mining sector is also prepared. It concerns until now the mining deposits inside the country.

The mining sector would have the main place in the economical life of Madagascar, in front of the national economic development. So, the Government will incite the mining operators to diversify and to improve their production quality. The mining Administration must reorganize the different structures used until now in this sector.

2. National Marine Resources and Policies for Development

As we have said, many geological explorations have been undertaken. However, the survey is most intensive inside of the island than in the ocean.

The researches of marine resources concern mainly the living resources. But the exploration of hydrocarbons had been hastened ten years ago. The result is not promising to undertake their exploitation.

Otherwise, some metalliferous sand deposit has been known at the East Coast.

Now, it's time to look forward to exploiting other minerals on the sea bed. For instance, South of the country has a big problem to get water and the process to get water from the sea must be thought of.

3. Status of Industry Based on Marine Non-Living Resources

Before undertaking the exploitation of these resources, Madagascar must start the geological survey. Practically, the country has no industries based on the marine non-living resources. In fact, the exploration of oil and gas (drilling of offshore oil) is suspended. However, the survey for metalliferous sand in the East Coast is in progress with international firms.

Madagascar has a cracking plant. The unrefined oil is imported from other countries.

The Government must make some emphasis in order to diversify the mining exploitation, especially for the marine non-living resources.

4. Marine Industry and the Environment

Like other developing countries, the problem of the destruction of environment is not alarming. Nevertheless, these countries lean over this problem especially when they look forward to fitting up some factory or to realizing an industrial project.

For the mining exploitation, the main problems which are considered concern the atmospheric pollution, the radioactivity of some mineral substances, and the protection of the fauna and the flora.

5. Capabilities in the Development of Marine Technology

It's more than likely that Madagascar has a good potential of marine resources deposits. Therefore, the development of marine technology seems interesting for the economic life.

This sector is forsaked particularly for non- living resources, because the underground mining deposits are very diversified and most of them are still intact.

However, the problem of water above all on the South is worth working out from the sea water. Of course, other marine resources deposits must be studied. And Malagasy technicians need some training in this scope.

6. Linkages between Research Activities and Marine Industry

The national policies in Madagascar wish for economic development based mainly on agriculture. The sector of the mine comes in the second place.

Regarding the metalliferous sand deposits and the research of oil and gas, marine industry would be developed.

Now, the Government tries to develop mining exploitation with a liberalism policy. The private mining operators work with their financial and technical capabilities. The Administration supervises their exploitation in order to improve their production. And as Madagascar has considerable mining reserves inside of the country, the mining operators disregard the marine resources. In fact, mining inside the country needs less investment than marine resources valorization.

7. Regional and International Cooperation in Marine Technology

A cooperation between the islands of the Indian Ocean will be welcome for marine non-living resources exploration.

This scope needs a transfer of technology. And the cooperation must regard the other marine non-living resources which can be exploited, in the Indian Ocean.

8. Conclusion

In the case of Madagascar, although the mining potential is very large inside the country, it's worth is to lean on the valorization of various mineral substances on the sea bed, besides the gas and the oil.

This workshop is very interesting because it can incite the country to diversify the mining project in order to increase the contribution of this sector to the economic recovery. We would like to wish this workshop to be reorganized every year to improve our know-how in this field.

Status of Marine Non-Living Resources Industry in Malaysia

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Introduction

Malaysia straddles across the South China Sea with Peninsular Malaysia at the tip of mainland Southeast Asia while the states of Sabah and Sarawak are in the north-western coastal area of the island of Borneo (Figure 1). The two regions are separated at the closest point by about 530 km of South China Sea and the total land area is about 329,293 sq km.

With the Proclamation of the Exclusive Economic Zone of Malaysia on 20 April 1980 followed by the Exclusive Economic Act No. 311 of 1984 which entered into force on 31 December 1984 Malaysia acquired an additional 898,540 sq km (148,307 sq km of Territorial Waters and 450,233 sq km of EEZ) for the purposes of exploitation and management. Malaysia has a coastline of approximately 4,800 km encompassing 1007 islands.

Malaysia, being a maritime nation, conducts nearly 95 percent of its trade by sea. In 1992, Malaysia achieved a GDP growth of 8% and the nominal per capita income increased to about Ringgit Malaysia 7,541 or US$2,780. During the past 10 years, Malaysia has transformed itself from being an agricultural based country to a well known, sought after manufacturing base in South East Asia. In terms of the composition of exports, manufactured goods remain the major earner, followed by primary commodities, agriculture and mining.

Malaysia presently has no National Ocean Policy and has not ratified the 1982 United Nations Convention on the Law of the Sea. However, to derive optimum benefits from the EEZ, Malaysia is laying the foundations for an Integrated Ocean Policy. To do so in an integrated manner, a National Maritime Council was established under the Chairmanship of the Chief Secretary to the Government to prepare national policies on marine issues and to examine laws and regulations in every sector with a view to harmonizing them according to the provisions of the 1982 United Nations Convention. With regards to the regime of the seabed and ocean floor beyond national jurisdiction, Malaysia has endorsed the concept of the common heritage of mankind and the regime of exploitation established by the Convention.

Marine Resources and Policies for Development

This paper addresses the marine mineral resources industry and excludes the living resources like fisheries where there is a national policy and the industry better established. In addition, as currently there is sufficient supply of surface and groundwater to meet the needs of the approximately 17 million inhabitants of Malaysia, there is no need for desalination as yet. Likewise, since sufficient energy or power is obtained from oil, gas, hydro and coal to meet the nation's needs, the tapping of ocean energy may become an option for the future.

Mineral Resources

Available bathymetric charts indicate that most of the Malaysian offshore areas are within the continental shelf (0 - 200 m) and with some extending into the continental slope (200 m - 2000 m). The continental shelf is wide, shallow and productive.

Generally, as an extension of the continent, the shelf areas may be expected to exhibit the range of mineral deposits found on land. These can be classified as lodes or ore bodies similar to land deposits and are their sea-ward extensions or are the recent unconsolidated deposits which commonly blanket the bedrock and form the seafloor itself. The minerals expected in the continental shelf of Malaysia are cassiterite (including the associated minerals such as ilmenite, wolframite, columbite, tantalite, zircon, monazite and xenomite), gold, chromite, platinum group minerals, sand and gravel.

Oil and gas accumulations are found in the offshore tertiary sediments and have been exploited since the sixties. In 1992, 32 oilfields were in production, 13 in Peninsular Malaysia, 12 in Sarawak and 7 in Sabah. The production of crude petroleum, including condensates, was 659,000 bpd in 1992.

Deep sea mineral (non-hydrocarbon) deposits (e.g. manganese nodules, massive sulphites) have not been recorded in Malaysia. Thus, based on bathymetry and sea bottom morphology, it appears that the chances of finding rich or sizeable deposits of massive sulphides, cobalt-rich manganese crusts or polymetallic ore nodules (manganese nodules) appear limited. Phosphorite and manganese nodules have been found in the continental shelf areas of some countries but generally they are more commonly found in deeper waters.

In 1991, the Geological Survey of Malaysia set up a Marine Geology Section to map the EEZ and to assess the mineral potential of the offshore areas. The Geological Survey of Malaysia initially will carry out reconnaissance offshore geophysical and geological surveys in shallow, coastal waters of less than 90 m in depth where previous surveys and on land geology indicate prospects for placer deposits. Drilling to depth to assess the economic potential of selected target areas will be contracted out and subsequently if a deposit is proven it will be left to the private sector to undertake detailed studies and to develop the deposit.

Marine Non-Living Resources Industry

Malaysia has a well established, diversified and technologically advanced private sector operations to service the offshore petroleum industry. However, the technology and industry for the minerals sector is limited presently to sand dredging and other coastal operations like harbour development or land reclamation which are done by local companies or in joint ventures with foreign companies.

The techniques for drilling, sampling and mining offshore placer tin in shallow waters is well known in the three Southeast Asian tin producing countries. Miners use pontoon or ship-mounted banka drills (percussion type) and counter flush drills to sample in shallow waters. Suction dredges, similar to those used on land, are employed to mine tin. These techniques can be used for all placer type operations.

The Geological Survey of Malaysia through bi-lateral technical assistance from developed countries or on short-term contract basis obtains experts to train its staff in the operations of equipment, interpretation of results and others during the various reconnaissance surveys. Presently, it is the policy of the Geological Survey of Malaysia to tender out to the private sector all offshore drilling opreations. Our experience shows that many of the sediment coring devices in the market were designed for scientific use and few are available (besides the banka drill) that can economically and efficiently recover undisturbed or slightly disturbed samples needed to determine commercial feasibility of a prospect.

Thus it appears the growth or future development potential of the industry in Malaysia is dependent on the discovery of economically exploitable mineral deposits in the EEZ, particularly with respect to placer deposits.

Marine Industry and the Environment

The Government has formulated laws to protect the environment and, since 1987, an Environmental Impact Assessment is a pre-requisite for mining and other offshore projects.

In Malaysia, besides sand mining there is no commercial mining of minerals by which one can visualize the effects of environmental damage.

Since nearly 75 percent of the population live in the coastal areas, guidelines pertaining to the protection and management of the coastal environment have been drawn up by various experts. These guidelines are being incorporated into the proposed 'National Coastal Resources Management Policy' that is being formulated by the Government of Malaysia.

Research and Development

Science and Technology has been recognised as a vehicle which will help Malaysia attain the objectives of Vision 2020, an era of self-reliance in the development and generation of indigenous technologies. With this in mind and besides the private-sector Research and Development programmes, the Government has worked out several strategies, such as the creation of the National Science and Technology Policy (NSTP), IRPA (Intensification of Research in Priority Areas) Scheme, IMCERT (the Itensification of Commercialisation, Exploitation and Technology), the MTDC (Malaysian Technology Corporation) and MIGHT (the Malaysian Industry-Government Group for High Technology). For example, MIGHT has a membership of 24 private firms and 8 government departments and its functions include providing a platform for industries to collectively undertake technology prospecting activities, to stimulate research and technology exploitation and to identify areas of opportunity and action. In Malaysia, thus there are many avenues, funds and opportunities to carry out Research and Development.

Since 1985, at least eighteen government, semi-government, university and private organisations have or are involved in marine science research in the country. The thrust of research in each organisation is normally limited to their area of jurisdiction. For example, University Technology Malaysia is involved in Coastal Erosion and Engneering Studies, and Navy in Hydrography.

Petroleum research is carried out by Petronas Research Institute and private oil companies. However, for the non-hydrocarbon mineral sector R&D activities are carried out by the Geological Survey of Malaysia, Mines Research Institute of Malaysia, South-East Asia Tin Research Centre and the Universitites. Systematic studies have not been carried out on the effects of sand dredging to the environment (physical and biological), dredging and coastal erosion and exploration and exploitation in water greater than 100 m in depth.

Regional and International Co-operation

Malaysia is a member country of CCOP (Committee for Co-ordination of Joint Prospecting for Mineral Resources in Asian Offshore Areas) and, since 1969, has been receiving technical assistance from developed countries like Japan, Norway, Netherlands, Germany, United Kingdom and others. To date, more than 500 Malaysians have received training through CCOP in the hydrocarbon and non-hydrocarbon fields. Member countries of CCOP have been kept informed on the Law of the Sea and the progress and technological development of the offshore exploration and mining industry. Malaysia would co-operate and appreciate greatly any assistance that could be given by any country, institution or organisation to upgrade and improve its capabilities in offshore exploration, exploitation and management technology.

In Malaysia, mining is carried out by the private sector and not the government. However, certain government bodies or agencies through equity sharing have teamed up with the private sector in mining ventures.

The present policy of the government is also to invest overseas especially in developing countries. For example, Petronas through one of its subsidiaries has invested in offshore petroleum activities in Vietnam. Similarly, Malaysian mining companies would look favourably at offshore mineral ventures (upstream and downstream) and share its know-how if the investment conditions are favourable.

Conclusion

Studies have shown that several offshore areas in Malaysia have gold, tin, various types of heavy minerals and construction materials. Tin and sand/gravel have been mined from offshore sources.

The Geological Survey of Malaysia has set up a Marine Geology Section to map the EEZ of the country and to ascertain the offshore mineral potential. The local offshore mineral industry is

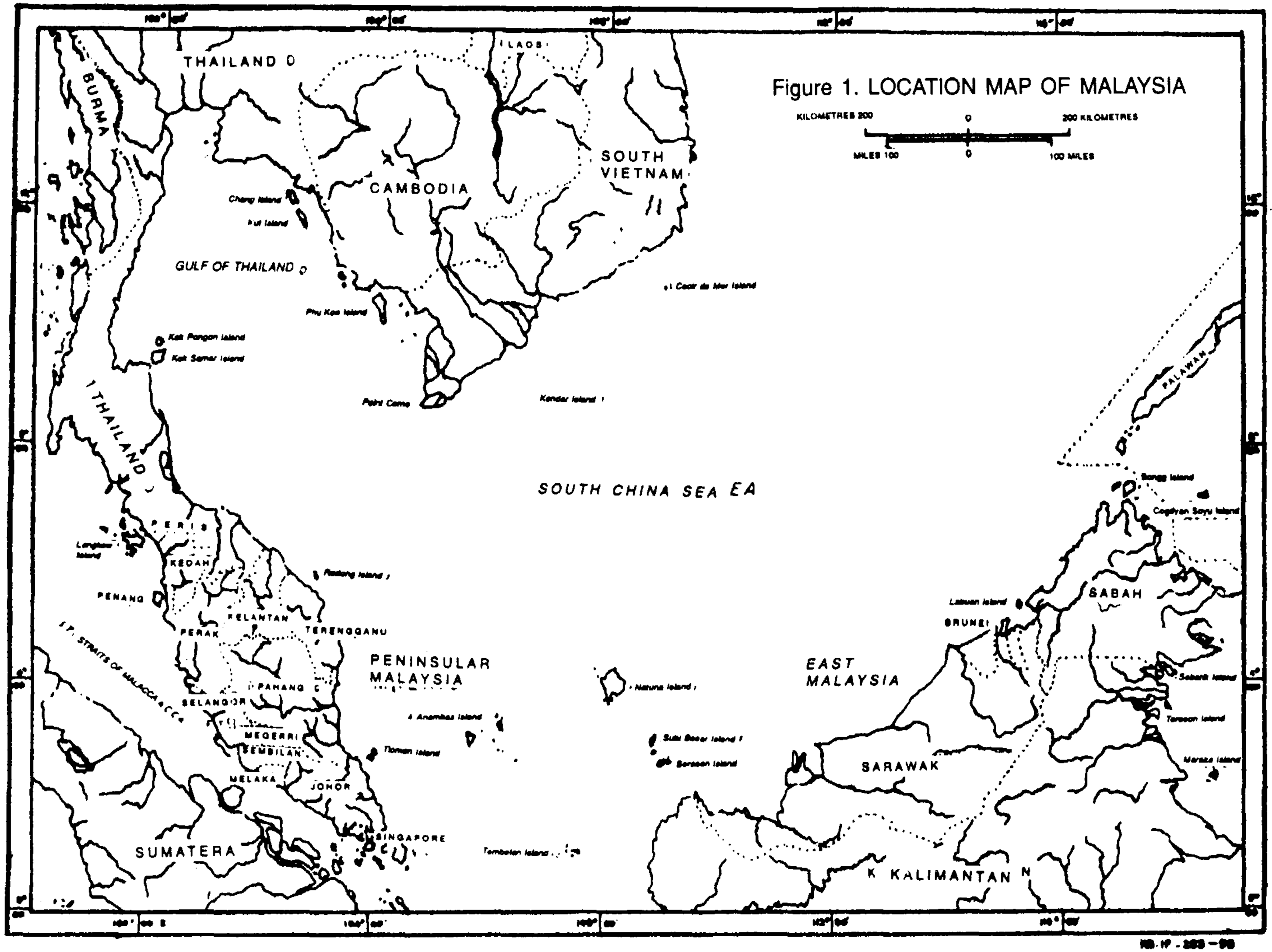

Fig. 1. Location map of Malaysia

small and untapped and Malaysia encourages foreign investment in this area.

Malaysia with its expertise in dredging is also keen to invest overseas. If the conditions are right, Malaysian entrepreneurs and companies will be interested in investing or be involved in the upstream and downstream activities of developing countries and in the areas of common heritage or international seabed.

The Development of Marine Non-Living Resources in Mauritius

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1. Background on Mauritius

Mauritius is by tradition an agricultural (monocrop) island of some 1865 m^2 producing mainly sugar as a major export commodity. For the last two decades emphasis is being laid also on the manufacturing and the tourism sectors which have now become pillars of the Mauritian economy. Development of the manufacturing sector has been marked by the success of its Export Processing Zone Scheme of 1970. The EPZ is now the single largest employer and exporter in Mauritius. The Mauritian EPZ is dominated by the textile sector which has a share of 60% of the total EPZ firms.

GDP by sectors at Current Factor Cost (Rs m)

	1989	1990	1991	1992
1. Agriculture	3370	3880	3887	4380
out of which sugar	(2335)	(2670)	(2540)	(2805)
2. Manufacturing	6365	7375	8205	9045
out of which EPZ	(3450)	(4000)	(4500)	(4800)
3. Wholesale & retail trade restaurants & hotels	4540	5455	6100	6800
Total	26954	31790	35917	39930

As shown in the above table, manufacturing is occupying a more important share of the GDP than agriculture. Even the share of the EPZ is more consequent than agriculture.

The importance of EPZ exports vis a vis the traditional export item, sugar is increasing as shown in the table below.

Sugar and EPZ Exports (Rs m)
1989 – 1991

	1989	1990	1991
Sugar	4946	5212	5221
EPZ	9057	11474	12136
Other	539	633	649
Total	14542	17319	18006

The fact that proceeds from EPZ exports are far more than those from sugar exports are clear indications that the country is diversifying its structure, relying more and more on the non-sugar sectors. For the last 10 years the EPZ has been relying heavily on the Textile Sector which accounts for about 60% of the number of EPZ enterprises. The situation of the EPZ at March 1993 stood as follows:-

Product Group	No. of Enterprises	Employment	Exports (FOB Rs m) (1992)
Food	13	944	295
Flowers	51	616	NA
Textile yarn & fabrics	33	3867	468
Weaving apparel	301	74716	10476
Leather product & footwear	10	1494	NA
Others	146	6170	1842
Total	554	87807	13081

For the last six years the Government has been adopting the two pronged policy of Consolidation of the textile sector and diversification of the industrial base. More vertical integration has been encouraged in the textile sector: weaving, knitting, dyeing have been the main processes that have been brought in. On the other hand to diversify its industrial sector the Government has placed more emphasis on the development of the informatics, the electronics and the agro-industries sectors. The industrial policy has also been geared towards the development of Small Scale Industries and the use at industrial scale of locally available raw materials. The exploitation and development of non-living marine resources will be of great benefit to Mauritius which is also connected to many other islands in the Indian Ocean.

2. Potential for Ocean Energy in Mauritius

Mauritius has been relying mostly on thermal power stations using heavy oil to produce electricity. This is being supplemented by hydro power stations which suffer greatly during the dry season. Bagasse as alternative source of energy is also being used. However, even if the surplus bagasse available in Mauritius is utilised optimally to generate electricity the production will not be more than 400 gwh. The rate at which Mauritius is developing calls for other local sources of energy apart from bagasse and hydro and Mauritius with its vast Exclusive Economic Zone (EEZ) will have no alternative than to turn to the ocean for its energy.

Primary non-petroleum power sources of the sea include mechanical (waves, swells, tides and currents), chemical (salinity gradients and biomass) and thermal (temperature gradients and geothermal). For Mauritius and its other islands (Rodrigues, St. Brandon and Agalega) the future for the exploitation of energy from waves and the Ocean Thermal Energy Conversion (OTEC) looks bright.

3. Wave Energy

Wave energy is one of the solutions to the Mauritian energy problem. Mauritius possesses the following natural conditions:

(a) Unrestricted wave supply

(b) Low tide differential ensuring fair efficiency of wall type wave energy systems at all times.

(c) Coral Reefs which can serve as natural foundation base.

In 1958, Mr. A.N. Batt, ex-manager of the Mauritian Central Electricity Board, mounted a wave energy project. It was based on the over-spilling of waves over an inclined concrete ramp located on the reef and forming the front part of an elongated reservoir parallel to the coast-line. The collected water was to pass through low head turbines to develop power before returning to the sea. However, it was established at that time that the project was not feasible owing to its high cost compared to electricity with diesel generation. At this stage if the project will have to be implemented, the feasibility will have to be established first.

If Mauritius becomes successful in establishing a sea wave plant this will imply less import of oil. Rodrigues and the other islands could also benefit from the experience.

4. Ocean Thermal Energy Conversion (OTEC)

Another exploitable source of energy is through an OTEC plant. A large part of the incoming solar energy is stored in the form of heat in the upper part of the ocean and a thermal gradient exists between the cold deep water (which originated from the sinking of surface cold water of the Antarctic) and the surface water. Around Mauritius and the other islands the temperature difference between the surface and the deep water (around 1000 m) ranges from 20° to 22° C. For an OTEC plant to be economically feasible it is said that a temperature difference of at least 18° C is required. Mauritius and the other islands are thus well endowed with such ocean thermal gradient resources.

However, in Mauritius before such a project is launched preliminary studies should be carried out on its financial and technical aspect. Here also the feasibility will first have to be established and detailed oceanographic and geo-economic surveys have to be carried out first. In this context, expertise from India could be sought to conduct a series of oceanographic surveys to prepare detailed bathymetric charts of the EEZ around Mauritius and its connecting islands.

5. Mineral Resources from the Sea

Salt

The production rate of table salt in Mauritius is rated medium to poor as the yield is about 100 tonnes/hectare/year. Though Mauritius has a big potential in producing table salt, it is still importing a large percentage of its requirement.

The by-products of the table salt industry are also very valuable. For every 1000 tonnes of salt produced from sea brine, 92 tonnes of magnesium sulphate, 145 tonnes of magnesium chloride, 23 tonnes of potassium chloride and sulphate and 2.5 tonnes of bromine are obtained.

Once a project for the production of magnesium oxide using brine as raw material was formulated, the project however did not take off. The technology is therefore available but a fresh start has to be given. Various chemicals could be produced, e.g. caustic soda, sodium chlorate, soda ash, sulphuric acid, several salt derivatives much needed by our industries.

Minerals from the Ocean

Exploratory research to date shows the existence of polymetallic nodules of exploitable (i.e. paramarginal and submarginal) grades around Mauritius, but these may not be worth economic exploitation in the medium term. However, the Central Indian Basin (75°E to 90°E, 0° to 25°S), Area 9 (73° to 80°E and 10° to 16°S) of about 700,000 square kilometers, part of which lies within the EEZ of Chagos Archipelago (Diego Garcia), contains exploitable amounts of nodules rich in nickel and copper (> 0.8%) comparable to the nodules of the world famous Clarion-Clipperton Area in the Central Pacific Ocean. Cobalt has been identified (> 0.4%) to the west of the Mauritius-Seychelles ridge, extending from the Mascarene Basin (25°S) to west of Seychelles (Somali Basin), passing through Tromelin and Agalega islands. Part of that cobalt-rich area is within the EEZ of Mauritius (viz. Tromelin, Agalega, Nazareth Bank).

6. Fresh Water from the Sea

Acute water shortage has become an annual phenomenon in Mauritius during the dry season. This water shortage has a direct bearing on the economic life of the country; particularly the industrial sector.

Mauritius relies for more than 60% of its water requirement from its aquifers and a major share of its water supply comes from Mare-Aux-Vacoas found in a catchment area located on the high plateau. This high reliance on rainfall renders the economy vulnerable and it is unthinkable that a country surrounded by water is being faced with an acute shortage of water.

Fresh water from the sea would have been a proper solution. There have been ideas in the past of getting fresh water from the sea but these have been dropped most probably because of the cost elements.

A fresh start in this field is possible. A preliminary study to determine its financial and technical feasibility should be done first.

7. Facilities offered by Mauritius

The success of Mauritius with its EPZ has rendered it mature and transformed. The proper environment for foreign investment in Mauritius is there: availability of skilled labour, banking and telecommunication facilities and Government's support. However, the institutional support for the exploitation of non-living marine resources is quite inexistent.

8. Co-operation

The development of the projects mentioned above for Mauritius calls for the following elements.

(a) funding

(b) foreign expertise and

(c) appropriate technology

Therefore, co-operation with other countries is vital for Mauritius to be able to exploit its marine non-living resources.

9. Conclusion

Mauritius has always been a receiver of technology but it always make sure that it is the appropriate technology. Foreign ventures have also been welcomed. With the proper facilities available and with foreign technical know-how and findings, development in this sector looks bright.

Development of Marine Non-Living Resources - The Nigerian experience

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Introduction

Ocean mining is a long established industry in many countries around the world. Sand and gravel (aggregates), limestone, tin, gold and hydrocarbons are among non-living minerals that have been mined from shallow coastal waters for several decades worldwide.

Recent global reviews of shore exploration and mining activities for non-fuel minerals by Hill (1980) indicate that some commodities have been commercially extracted from offshore of some twenty-seven countries while exploration has taken place at various other locations around the world. The locations of recent offshore mining activities are shown on Figure 1 which clearly shows that offshore non-fuel mineral exploration is virtually non-existent in Nigeria.

The annual value of offshore non-fuel mineral production from sea floor was estimated to be US$460 million in 1977 (Hill, 1989). Aggregate production lead the list, accounting for 41% of total value of offshore production. This amounted to some 86 million tonnes of aggregates worth about US$ 2.20 per ton. From the foregoing account, it becomes obvious why coastal states are looking to the offshore for revenue generation.

Country Background

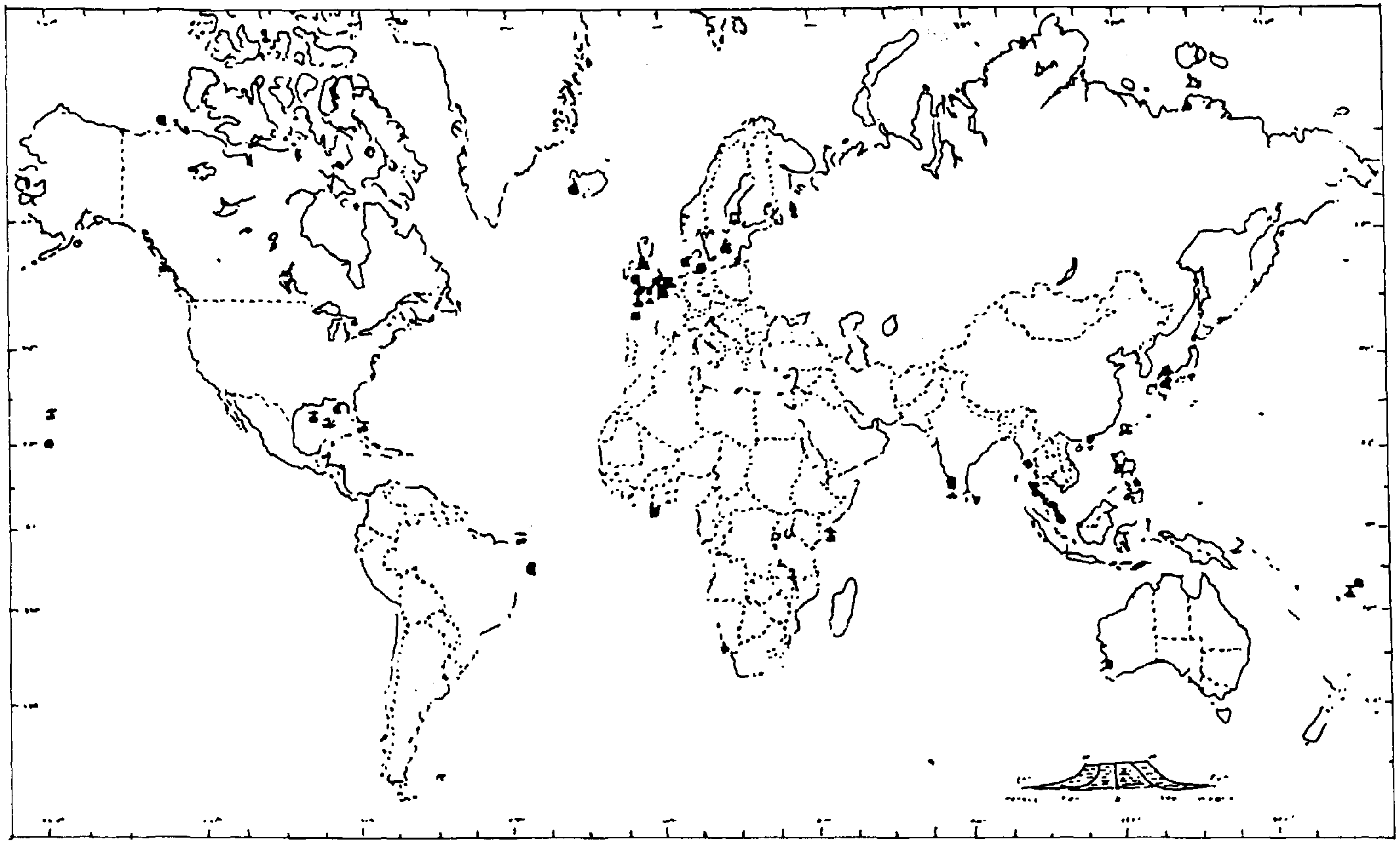
Nigeria occupies between latitude 4°16' - 13°52'N and longitude 2°49 - 14°3'E. It has a coastline of approximately 850 km bordering the East Gulf of Guinea in the Atlantic Ocean. Consequently she is a maritime state and a signatory to the United Nations Law of the Sea Convention. She has an estimated population of about 88.5 million.

In 1978, Nigeria established an Exclusive Economic Zone (EEZ) of 200 nautical miles adjacent to the territorial sea. Ratification and deposition of instrument for declaration was so done on the 14th of August, 1986 (Dublin-Green et al, 1992). The EEZ covers on area of 210,900 km^2 within which she exercise sovereign rights for the purpose of exploration, exploitation, conservation and management of the natural resources of the seabed.

The Nigerian continental shelf is broad and shallow. It is about 20 km wide off Lagos, 56 km off Cape Formosa in the nose of the Niger delta and about 64 km off Calabar in the southeastern corner of Nigeria. The shelf breaks consistently at 120 m.

The major geomorphic features on the Nigerian continental shelf include the Avon, Mahin and Calabar canyons in the coastline. Dead Holocene coral banks running parallel to the coastline also occur in water depths which range between 80 and 100 m. Other features include numerous river mouth sand bars and the deep seated faults of Romanche, Chain and Charcot fracture zones which originate in the Mid-Atlantic ridge.

Geologically crystalline rocks cover approximately 50% of Nigeria and over 90% belong to the Precambrian Basement Complex. The Basement Complex is predominantly gneissic and Granitic but there are also extensive schist belts. Paleozoic sedimentary rocks are not present but the oldest mesozoic sedimentary rocks exposed in Nigeria are cretaceous in Age (Oyawaye 1972, Rahaman 1976). The basement complex acted as important sources of dustic sediment because of uplift in the past. These rocks provided the numeric quantities of sediments which were swept down the drainage basins. The youngest sediments are the Recent Delta Complex deposits which are being laid down at the present day (Whiteman, 1982).



Energy Mines and Resources, Ocean Mining 1987

Recent Global Offshore Mining Activities

■	Aggregates	◆	Diamond
□	Calcium Carbonate	▭	Gold
⊡	High grade silica sand	♦	Tin
▲	Ilmenite and Magnetite		

Fig. 1. Map showing Recent Global Offshore Mining Activities

National Marine Resources & Policies for development

Nigeria was for a long time one of the world's leading producers of tin but production has steadily continue to decline since the last two decades. Prior to 1964, mining and agriculture sustained the nation's economy. However, in the mid 1970's, Nigeria witnessed an oil boom and with it came a neglect of agriculture and mining. Oil became the main source of foreign exchange for the country. With the recent collapse of the oil market, the Federal Government has been taking measures aimed at widening the nations economic base thus avoiding the dependence on oil (Akpati, 1989). New mining policies have been enacted to stimulate activities in exploration and exploitation of non-fuel mineral resources particularly those located and while virtually nothing has been undertaken offshore.

Such policies include the establishment of measures by the Federal Military Government of Nigeria aimed at reversing dependence on hydrocarbon and increasing activities in the exploration of non-fuel resources in 1989. Through this, the government wants to encourage greater private participation while still wanting to maintain ownership and control of mining corporation and Federal Ministry of Mines, Power and Steel. Such industrial minerals like kaolin, limestone, marble, berets and coking coal are to get government priority attention. Exploration for gold, iron, lead and zinc are to be intensified in the 1990's. For this, mining companies have been granted special exclusive prospecting licensee (BEPL) to search for minerals such as gold, lead, zinc, cassistente and columbite.

Among the non-living mineral resources of Nigeria, oil and gas are presently by far the most important and constitute over 90% of Nigeria foreign exchange earnings. Exploration of hydrocarbon in the Niger delta started in 1950 with the first well by shell D'Arcy (Non shell Petroleum Development Company of Nigeria limited). To date about 980 exploratory wells has been drilled resulting in the discovery of about 173 oil producing fields (Ekweozor et 1992). Hydrocarbon production is from the sandstone reservoirs of Aghada Formation (41 mill.yrs Focene). The following primary non-fuel mineral deposits have/are being developed in Nigeria.

Tin: Production of tin has declined steadily since 1975 from 61175.60 metric tonnes to 1787.70 metric tonnes in 1984 (Kogbe 1989). Decline is attributed to diminishing accessible alluvial deposits and difficulty in exploring the sub-basalt deposits. About 98% of cassistente production comes from Jos Plateau. Smaller quantities are mined in Benue, Ondo and Niger states.

Columbite: Prior to 1965 Nigeria accounted for about 95% of the world output. By 1975 only about half the amount produced in 1965 was produced and amounted to 921.22 metric tonnes. Since then production has declined steadily by about 12% annually (Kogbe 1989).

Wolframite: A tungsten of iron and manganese and ore of wolfram. Won from pegmatites of Younger and Older granites in Jos plateau substantial amount was produced between 1950 and 1957. Since then production has declined and last production was in 1966.

Gold: Traces of gold occur in virtually areas under lain by the Basement Complex in Nigeria. Most are won from the alluvial deposits in small scale in Oyo, Kwara, Niger and Sokoto states. Nigerian Mining Corporation has recently commenced mining the alluvial deposits of Ilesha (Oyo State). Substantial production was recorded between 1965 and 1970 but since then production has declined and production ceased after 1980.

Iron: Iron ore deposits occur in many parts of Nigeria. These include (a) Agbaja Plateau ironstone body near Lokoja. The Ironstone body is about 30.5 million tonnes averaging 50% iron, (b) Itakpe Hill Iron ore: It is a Precambrian deposit located near Okene and reserve is estimated at 182.5 million tonnes (d) Muro Hill Iron ore, plateau state is composed of Hematite and magnetite. Iron content is 40% and estimates show a large ore deposit.

Lead and Zinc: They occur in Nigeria but have been mined on small scale. They occur in narrow belt which extends for about 360 km from the eastern to northeastern states of Nigeria. The Abakaliki reserves is about 711,237 tonnes.

Zircon: It is found in small deposits from Plateau tinfields as a by-product of tin.

Gemstones: Large quantities of gemstones including aquamarine, emerald, sapphire, ruby, topaz and almandine have been mined in Plateau and Kaduna States (Akpati, 1989). Most of the gemstones are mined from pegmatites.

Status of marine industry of non-fuel mineral resources: Assessment Development

Mining of the non-fuel minerals considered in the foregoing paragraphs are land-based. There has been little mining activities offshore except in the petroleum industry where there has been large capital investments.

Nigeria with a coastline of about 850 km has an offshore continental shelf covering about 50,000 sq.km. Despite its large shelf, Nigeria is among those countries that have not seriously evaluated the non-fuel mineral resource potentials of her coastal margin. As mentioned earlier, with the near-collapse of the oil market, the main stay of Nigerian foreign exchange earner, the Federal Government of Nigeria adopted measures aimed at widening the nation's economic base thus avoiding the heavy dependence on oil. Such measures include development of non-fuel mineral resources including those located offshore.

Although the Federal government of Nigeria established the Nigeria Institute for Oceanography and Marine Research in 1976, with among others the mandate to assess the non-living resources of the continental margin, the commencement of this programme did not take off until the late 1980's when actual field work was initiated. Even though Weber (1971) and Adegoke et al (1972) have studied the sedimentology of the Nigerian continental shelf sediments, no systematic study has been made about the economic assessment of the non-living (non-fuel) mineral resources of the country's marine environment. However, Allen (1965) noted the composition of heavy mineral suites of the Niger and Benue Basins. Awosika et al (1988) carried out a comprehensive survey of heavy minerals in rivers and stream sediments throughout Nigeria, partly to determine the sources of detrital minerals to the continental shelf and partly to provide landbased data on source and supply patterns of non-fuel minerals to the shelf.

A study was initiated to evaluate non-fuel mineral abundances and composition (aggregates and heavy minerals) in surface sediments on the entire Nigerian continental shelf. This study aimed at exploring offshore for alternative mineral resources to complement the dwindling land deposit, because from a knowledge of the geology of inland Nigeria, the numerous rivers which flow over the Nigerian landmass supply sediments to beaches and shelf. Submerged beaches may probably contain placer minerals. The study reported here refers to surface samples collected from the shelf between longitudes 2°45' – 3°45' E which was closely sampled (fig. 2). Limitation on the true position of aggregates and heavy mineral contents in this study is placed on the singular fact that only surface samples were evaluated. Only by relatively expensive means boring and

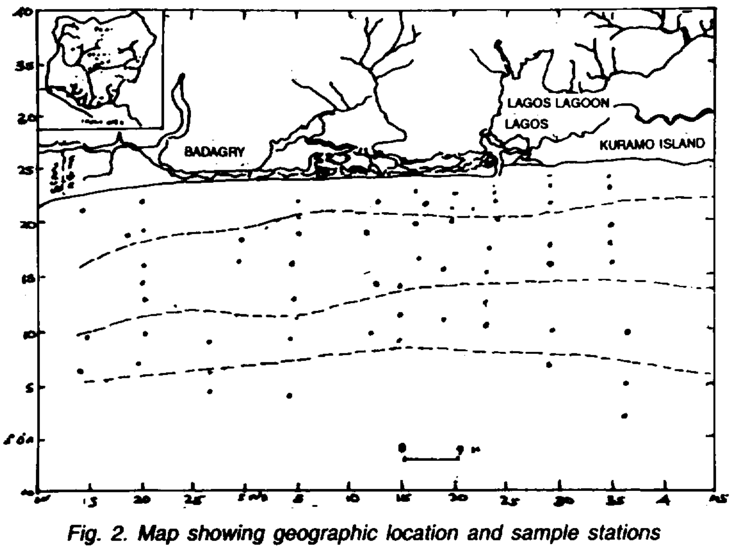


Fig. 2. Map showing geographic location and sample stations

vibratory coring, can one obtain samples below the surface. We do not have these facilities.

Aggregates: Shelf sediments from this study area range from shelly and gravelly sand to mud. Aggregate outcrop extends from the beach to distance of 9 km of Budagry in the west to 7 km off Kurumo Island, Lagos. Nearshore, the deposits is shelly and locally gravelly and is generally coarse to medium sand. Sediments of the eastward limited of the sandbody are medium to very fine sand (Ihenyen, 1991). Viable offshore aggregate industries exist in many parts of the world but as of now there is no offshore aggregate mining industry in Nigeria. However, intermittently and on a small scale, offshore resources have been obtained from dredgings during beach replenish exercises.

Heavy Minerals: Heavy minerals recovered from 5g dried sediments range from, 0.02 – 0.08 g (0.4 – 1.6%). The highest content occurs in two nearshore zones, 2°55' – 3°05' long and immediately east of Logos port (Fig. 3). the lowest heavy mineral contents occur in the shelf below the 40 m isobath. These mineral ranges make it uneconomic in terms of exploitablity. However the possibility of finding them in deeper sediment horizons cannot be ruled out. Unpublished results of fieldwork on the other sections of the Nigerian shelf by the author do point to heavy mineral potentials on the coastal waters. Also United Nations publication ST/ESA/139 on unconsolidated mineral deposits in the Exclusive Economic Zone (EEz) place a higher possibility on the occurrence of favourable offshore mineral deposits in shelf sediments of Western sector and of the Niger delta proper of Nigeria.

Opaque minerals i.e. magnetite, ilmenite, pyrite, hematite constitute between 27.9 and 69.6% of the total minerals point counted. About seven Minerals; amphibole, tourmaline, garnet, zircon, apatite, kyanite and rutile account for 70 – 85% of the total non-opaque mineral assemblage (Fig 4,5.)

Marine Industry and the environment: The environmental effects of marine mining are best documented for aggregates. Shoreline erosion and alteration of seabed morphology are the major concerns. However, since no marine mining of aggregates exists in Nigeria, these effects are not documented.

Pollution of the coastal waters of Nigeria are attributable to a number of sources. Among these are industrial effluents, and wastes from shipping activities. However, the most obvious of the pollutants are oil spills from crude oil exploration and exploitation. This is particularly obvious in the Niger delta. The impact of these pollutants include loss of aquatic fauna and flora, destruction of coastal wetlands and beaches, and loss of drinking water.

Development of marine technology: The potentials for the development of marine technology for non-fuel minerals exist. Policies have been enacted by the federal Government of Nigeria to encourage private participation of individuals and corporate

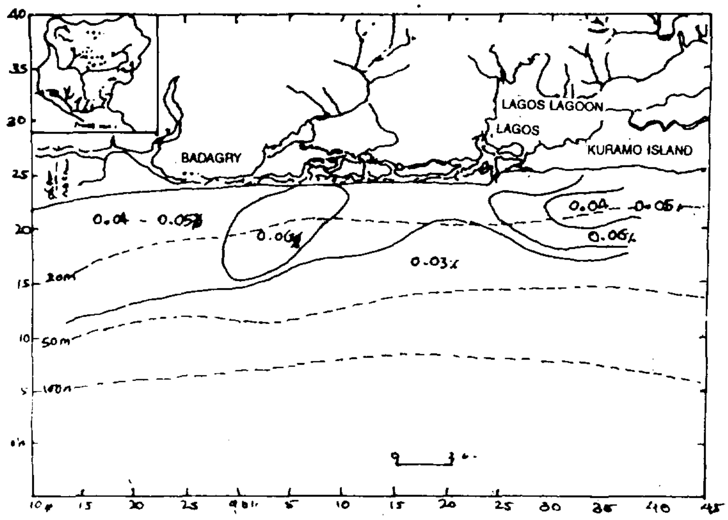


Fig. 3. Isopleth map of heavy mineral contents in 5 g of dried sediments. (20,50 and 100 m isobath shown in broken lines)

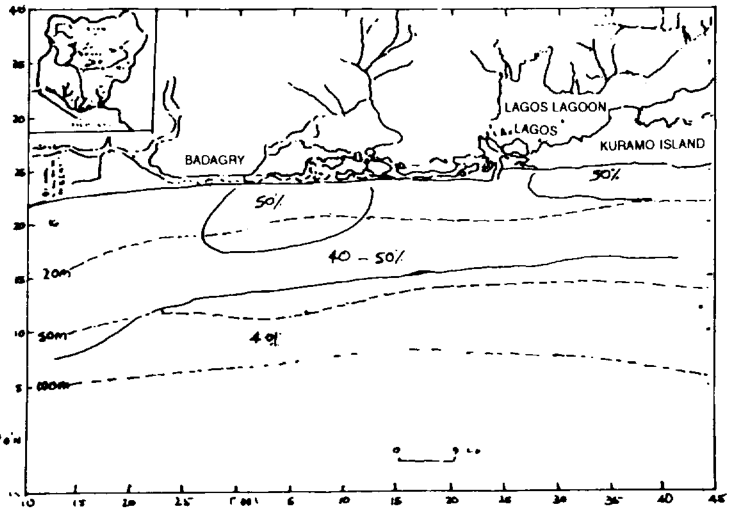


Fig. 4. Isopleth map of opaque minerals as percentage of total heavy mineral contents(20,50, and 100 m shows in broken lines)

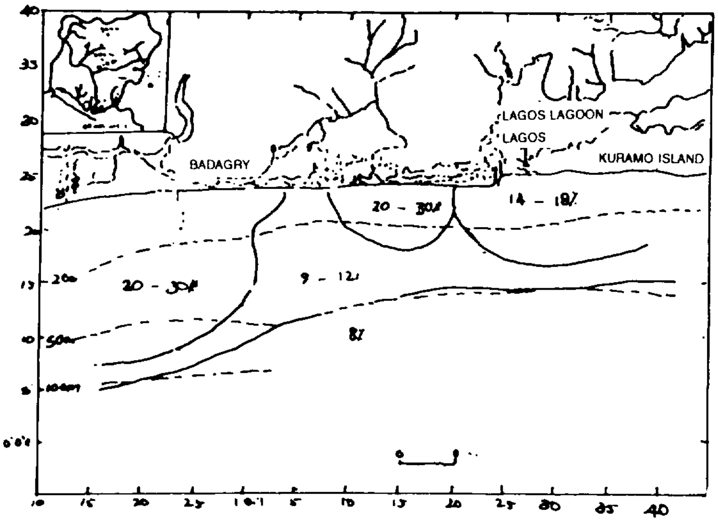


Fig. 5. Isopleth map of amphibole as percentage of total heavy, mineral contents,(20,50 and 100 m isobath shown in broken lines)

bodies. Relevant research institutes e.g. Nigerian Institute for Oceanography and Marine Research, have been established with among others the mandate to research into non-living resources of the continental shelf.

However, one of the problems facing exploration of marine minerals in Nigeria is the lack of accurate bathometric charts of the continental shelf. Currently, the obsolete admiralty charts of 1895, 1862 and 1852 are in use. Efforts are being made to correct this shortcoming.

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Industrialisation Affects Heavy Metals in Recent Sediments from the Continental Shelf off Lagos, Nigeria

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Abstract

The vertical distribution of the elements Pb, Ni, Cr, Cu and Zn in a 37 cm long sediment core off Lagos, Nigeria is investigated in order to find out if civilisational influences from the nearby densely populated city of lagos affect heavy metal levels in the core with time. Results indicate that the vertical variations of these metals are not high especially with regards to the elements Pb. Ni and Cr, although anthropogenic concentrations are recognisable in the uppermost few centimetres of sediment. In contrast, the elements Cu and Zn show higher levels of trace metal concentration particularly in the uppermost few centimetres of sediment in the core analyzed. This development in trace metal pattern is inferred to be associated with recent anthropogenic influences arising from the development of port and city of lagos.

Introduction

Trace elements occur in different forms in aquatic environments and their sources could be either lithogenic or anthrogenic (Forster and Wittman, 1979). In polluted aquatic environment, the usefulness of their study in vertical sediment core lies in the fact that they preserve historical sequences of pollution intensities and enable a reasonable estimation of background levels. The distribution pattern of some enable a reasonable estimation of background levels. The distribution pattern of some heavy metals in nearshore coastal areas particularly of industrialised nations is hence an important geochemical parameter in environmental pollution studies. Studies like this have enabled an objective comparison of heavy metal levels before and after the commecement of industrialisation, especially in polluted Marine coasts and Lacustrine regions (Aston et al, 1972; Erlenkeuser et al, 1974; Forstner and Muller, 1974); Forstner et al,1980 Kitano et al, 1980 and Okon 1982).

In Nigeria, no basic studies on heavy metals have yet been carried out on sediment cores from the continental shelf. However, Kaku et al (1988) studied trace metal concentrations in sediments from the Niger delta. The present study was therefore initiated to investigate the history of environmental pollution as documented in a 37 cm long core obtained from the shallow continental shelf off lagos (lat.6°14'N, long.3°55'E) in 40 meters water depth (Fig. 1). The following trace metals were studied: Pb, Ni, Cr, Cu and Zn.

The coring position was situated about 40 kilometres east of the entrance to Lagos port. The current pattern in this section of the shelf is from west to east, so that any anthropogenic heavy metal input from the port and city of Lagos may be recorded. The base age of the core was estimated by projecting the coring depth against the age-axis using sea-level rise curve of Curray (1975). This gave the base age of about 7,000 yrs Before Present which appears plausible because of the lowa sedimentation rate along this section of the Nigerian shelf.

Method of analyses

The sediment core was collected using R. V Okion of Nigerian Institute for oceanography and Marine Research, Lagos in 1985. The core was frozen pending laboratory studies for the geochemical analyses, the core was sliced into

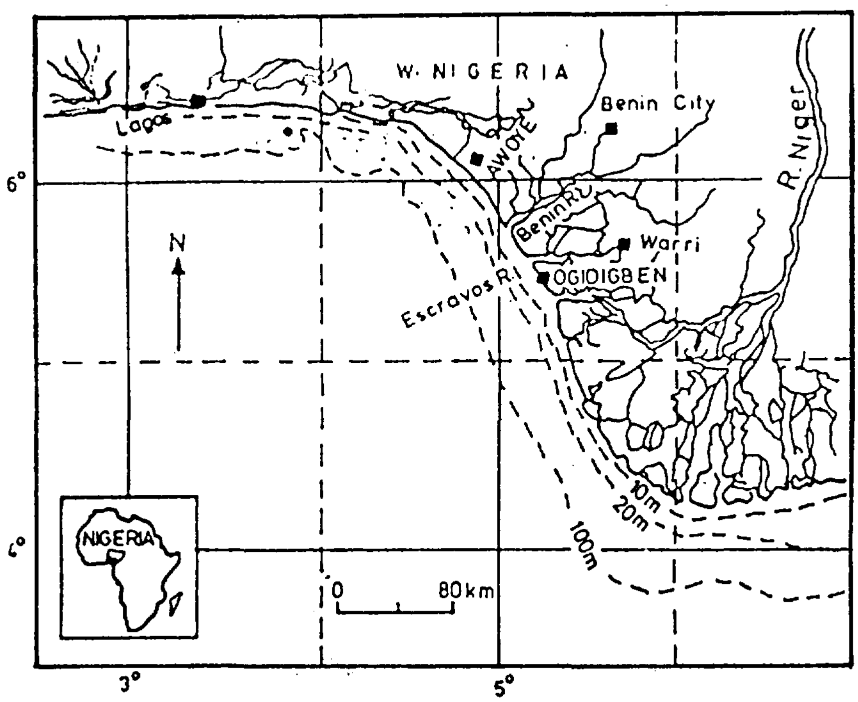

Fig. 1. Map showing sample station (●)

two and from the sliced core, sediment was collected in 5 cm portions and dried. Chemical extractions were carried out on powdered samples less than 63u fractions according to methods of Herman (1976) and Ihenyen, (1984). The trace metal composition was determined by Automic Absorption Spectrophotometry, using Pye Unicam SP 2900.

Results and Discussion

Table 1 summarises the results of the spectrophoto-metric analyses in ppm dry weight. The trace element contents of the various elements in vertical distribution are represented in diagrams in Fig 2 in order to visualise easily the trace element distribution pattern. The core under study was in general homogenous and consisted mainly of fine silty mud. No clay mineral studies were performed in this work.

The trace metal concentrations do not show appreciable variations in the vertical distribution of the individual elements studied except in the uppermost 2 cm in core sediments. The contents of Pb vary between 20.53 and 31.31 ppm. A proportionately high concentration (31.31 ppm) is analyzed in the uppermost 2 cm of sediments, otherwise Pb concentrations range between 20.33 and 24.51 ppm. The high Pb values in the uppermost 2 cm may result from anthropogenic influences from the nearby city of Lagos as a results of recent industrial and communal developments.

Table 1. Results of analyses of HNO_3 decomposition of samples.

Depth Cm	Pb ppm	Ni ppm	Cr ppm	Cu ppm	Zn ppm
0-2	31.31	33.39	124.18	98.61	30.45
2-7	20.87	31.32	113.68	30.71	5.79
7-12	20.87	22.45	116.12	24.84	4.60
12-17	24.51	26.21	113.15	27.77	4.52
17-22	20.83	27.09	114.18	26.87	7.12
22-27	20.83	26.09	113.75	28.24	5.72
27-32	20.83	26.86	113.08	25.77	4.52
32-37	21.30	25.33	113.08	24.84	4.52

The distribution of Cu and Zn are also similar but in contrast to Pb, Ni and Cr, they show a pronounced enrichment in the proportions of trace metal contents in the uppermost 2 cm of sediments. For example, Cu contents range from 24.84 to 30.71 ppm in the vertical depths 2 – 37 cm while the top 2 cm of sediments contain a proportionately high Cu (98.61 ppm). Zn also shows an elevated metal content (30.45 ppm) in the top 2 cm in comparison with low values (4.40 - 7.12 ppm) recorded in the 2 - 37 cm depth. These generally low Zn values cannot be explained but may result from remobilisation due to slightly acidic medium (Okon, 1982).

Ihenyen (1987) reported high Pb. Ni,Cr, Cu and Zn contents in sediments of roadside drain in Lagos metropolis. These road side drains discharge directly into Lagos port and from there flow into the Atlantic ocean. The increased trace metal contents in the upper most 2 cm of core sediments may therefore arise from recent anthropogenic influences.

These surface enrichments in metal in the shallow Atlantic core off Lagos seen to confirm the effect of civilisational influences arising from the development of the city of Lagos in the last few decades. In particular, Cu and Zn show higher trace metal concentrations which may tend to suggest their higher utilisation levels in industries and communities in Lagos.

Results from this study seem to be comparable to those of Kitano et al (1980), Oken, (1982) and Erlenkeuserr et al (1974) who obtained similar surface enrichment in trace metal in sediments from Tokyo Bay, Skangerrak, North sea and Baltic sea respectively ascribed to anthropogenic influences. This study therefore seems to conform with heavy metal distribution pattern usually recorded in environments subjected to anthropogenic influences.

Conclusion

Results of a chemical study on a shallow Atlantic sediment core off Lagos show that anthropogenic concentrations of the trace elements Pb, Ni, Cr, Cu and Zn is recognisable in the upper-most 2 cm of sediments. In particular, Cu and Zn show high degrees of concentration and this is inferred to indicate higher utilisation levels in industries and communities located in nearby densely populated city of Lagos.

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The Development State of Ocean Non-Living Resources in Korea

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1. Introduction

The Ocean represents the largest source of sustainable resources on the earth if properly developed and exploited using the technologies in accordance with the environment conservation.

With the rapid depletion of land-based resources in the past, many kinds of resources in the ocean have been paid great attention to, some of which have been developed and exploited overcoming much difficulty due to required high technology and enormous fund needed. With the technological development, more ocean resources will become detected and exploited in the future. Especially, Korea, a resource scant country has imported most of the resources from abroad to meet the domestic demand, which encourage the exploration and development of ocean resources deposited in the continental shelf or resolved in the water column. Now Korea is endeavoring to find out the potential of ocean resources from the coastal waters towards the deep and distant seas.

In this paper, I will present the potential and development status of ocean non-living resources in Korea.

2. Mineral Resources

Offshore places in Korea are distributed along the west and south coast near the 5 major river mouths where major minerals such as sand, silica sand, monazite, zircon, illmenite(iron sand), etc., are deposited but there have been non exact studies done to estimate overall potential of these resources except some areas.

It is known that gold is deposited along the area between Asan and Chunsu bay, monazite along the Mokpo area also well known for sea sand and Wando island, and titanium along the area between Kyonggi bay and Kangwha island.

There have been some production reports of sand, monazite, zircon, silica sand, placer gold in the west and south coast but exact statistics are not available except sand.

The offshore mining rights are reported as 343 cases, 83,717 ha most of which 95.5% of ocean mining rights, 79,968 ha are located along the west coast while most of the product is sand which is used for construction of apartments and houses, mostly in the metropolitan area - and small portion of the product silica sand is used for manufacturing the bottle glass.

Table 1. Current Status of offshore mining rights

Mineral	Cases	Area (ha)
Sand	267	65,883
Silica Sand	18	3,792
Limestone	17	4,416
Gold, Silver	14	3,812
Others	27	5,814
TOTAL	**343**	**83,717**

In Korea, most of the sand has been produced in inland waters, usually in the delta area of the river mouth. But in the process of economic development, the major rivers related with production of sands have been cleanly developed extracting the sand resources, so sand produced in land have become almost depleted with the completion of the development of major rivers.

A few years ago, the government planned to construct new cities in the metropolitan area including 4 million family apartments to tackle

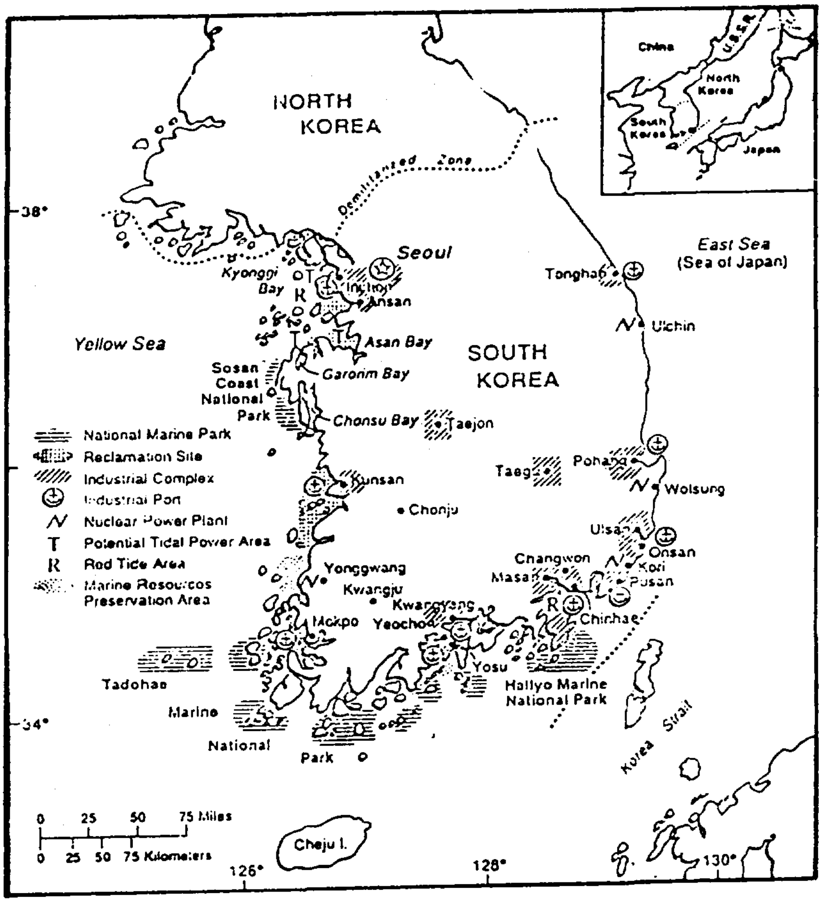

Fig. 1. Coastal Zone Activities in Korea

the shortage of houses, which incurred a large demand for sea sand, so that many private companies began to mine a large amount of sea sand in the west coastal shallow waters. According to some geological survey, the sand resources in the territorial sea is estimated to be about 3.9 billion m^3 in 200 km^2 of waters and gravel resource, about 1 billion m^3 in 200 m^2 of waters. In 1991, over 14 million tonnes of sand and gravel were reported to be transported to the Inchon port by the barges, the main gate for sand consumed in the metropolitan area.

A large quantity of sand supplied from the coastal waters cannot be used immediately because of high salty component which weaken the durability of the building, so that it is necessary to reduce the salt content in the sand to the national standard, through the filtering processes in order to be used for the construction of the apartment or house but it is a difficult problem to be dealt with at a time, because of a large and explosive demand. So in Korea inadequate treatment of salt contained in sand often raised doubts about the reliability of the buildings made by sea sand.

3. Salt production

Sea water contains many kinds of dissolved components such as Bromide, Uranium, Natrium, Kalium, etc. But in Korea, there are no exact data on the production of these materials except salt from sea water.

From the past, salt is one of the major commercialized resources extracted from the sea waters. In Korea, the area of the salt ponds amounts to

9318 ha (1693 places) which is mainly located along the west coastal line. This has continued to become reduced since 1980 because of the reclamation and the comparative degra- dation of profitability in this industry.

The capacity of salt production at salt ponds through the evaporation process by the sunshine amounts to 500 - 550 thousand tons per year while the quantity of salt produced by reverse osmosis process is estimated to be about 230 thousand tons per year.

As the total demand for salt in Korea is estimated as 800 thousand tons per year, 20 - 70 thousand tonnes of salt is imported every year from Mexico or Australia due to insufficient supply.

The salt industry in Korea have much difficulty and is now in danger because of low efficiency compared with salt exporting countries, insufficient labor force in the coastal regions and expected market opening in the near future.

The west coast of Korea also has the great potential of landfill or reclamation for agricultural and industrial use, so that a lot of small salt ponds difficult to survive are expected to be replaced with lands of the various purposes such as industrial and housing complex, agricultural land and airport.

4. Ocean Energy

Now fossil fuel energy has become depleted and occasionally make problems of severe environmental degradation so that the demand for new clean energy will increase and R&D for these energy resources is expected to become more expanded in the future.

Ocean energy is one of the clean and non-depleted energy and this energy has several forms such as tidal energy, wave energy, ocean thermal energy, current energy, ocean bio-mass and so on.

In Korea, several studies have been performed by Korea Ocean Research and Development Institute (hereafter KORDI) to measure the potential of the ocean energy.

The promising area for developing wave energy is Hoopo and Ulroung Island, the southeastern part of the Korean peninsula, which has a total of 5 million KW potential.

It is reported that the current energy can be utilized in the Uldolmok, the south coastal area where this energy was used to defeat the Japanese battle boats by admiral Lee six hundred years ago. But the greatest potential for ocean energy in Korea is the tidal energy of the west sea caused by the largest difference in the world between rise and fall of sea water which made the landing operation in Inchon by U.N. Army Commander MacAthur difficult in 1950 Korean War.

The total potential of tidal energy in the west coast is estimated to amount to 6.6 million kW according to the KORDI report and the promising sites are Asan bay, Inchon bay, Garolim bay, Yong-Hoeung Is., Shin-do Is., etc.

Since 1970, Korea Electric Power Company (KEPCO) have tried to develop the tidal energy in the Garolim bay which have been well-preserved notwithstanding the economic development and several coastal wastal development projects. The government also have had great interest in developing the Garolim bay for several purposes including the tidal power plant. Since 1970, KORDI have performed several scientific studies including the characteristics of tidal energy, living resources in the bay, etc.

The studies done in 1981 and in 1986 by KORDI also include the economic assessment but the economic results of both reports are mutually contradictory reflecting the economic situation in each period, so that the government and KEPCO have reserved the development and decided to wait until a better time comes.

But the recent report issued by KORDI indicated that the comprehensive development of the Garolim bay including tidal power plant, aquaculture and sightseeing is more economically feasible than the sold development of tidal power.

According to a Chinese consulting group which experienced increased aquaculture production in some tidal power plants of China, new high-valued aquaculture is considered to be possible in the Garolim bay after the construction of power plant due to improvement of the fishing grounds and a few other environmental changes as in several Chinese cases, so that this, together with the sightseeing effects could make the B/C of this project rise more, from 0.84 in case of the power development to 1.57 in case of the comprehensive development.

The capacity of the Garolim power plant to be developed is estimated to be 400 - 480 MW and annual output of electricity, to be 800 GWh. Tidal energy is a clean energy with non emission of SO_2, NOx and other wastes contrary to the thermal power plant.

This optimistic report will encourage government to make more rapid decision concerning the comprehensive development of the Garolim bay including tidal power development.

5. Oceanic Oil and Gas

It was not until the late 1960s when a series of geophysical surveys indicated the likelihood of oil under the seabed of Korea's adjacent seas. Since then our government began to become interested in seabed oil development. The UN Economic Commission of Asia and the Far East report (ECAFE; renamed in 1974 ESCAP - Economic and Social Commission for Asia and the Pacific) publicized an optimistic judgement that the sediments beneath the continental shelf in the Yellow Sea were believed to have great potential as oil and gas reserve.

The progress of Korean plans for offshore exploration was initiated by western oil groups in the early stage. Since 1970, oil-development contracts have been signed for seven continental shelf, designated as Block VII by Korea (Fig. 2).

With the promulgation of the Submarine Mineral Resources Development Law(Presidential Decree No.5020, May 30,1970), Korea's exploration has been mainly carried out by some concession contracts with western oil companies. Since 1979, however, the government has initiated efforts towards an independent drilling capability through the establishment of Korea Petroleum Development Corporation (PEDCO), and the government-sponsored corporation intended to manage both downstream and upstream processes of oil development. Results in offshore oil exploration of Korea since 1969 have not yet been appreciable but are not discouraging.

Upto now 26 holes have been drilled by PEDCO and foreign companies, and geophysical surgery have reached 91,000 km. Although offshore drilling has found no commercial deposits of oil or gas, there remains the promising 149 sea beds in the continental shelf.

Despite increased attention by the government, Korea's offshore oil exploration has been hampered by considerable problems, such as a lack of both technical experience and capital availability, and some international disputes concerning the extension of jurisdiction surrounding seabed oil development zones.

Table 2. Economic assessment in each period for Tidal Power Plant in the Garolim bay

Item	1981	1986	1993	Remarks
Capacity Annual Power Generation	480 MW 893 Gwh	400 MW 836 Gwh	480 MW 883 Gwh	
B/C	1.189	0.502	0.84	only for power generation
IRR(%)	11.11	4.47	6.74	
DC rate	9%	10%	8%	
Captial investment	865 (million US$)	862 (million US$)	930 (million US$)	US$,IDC included(93 constant price)

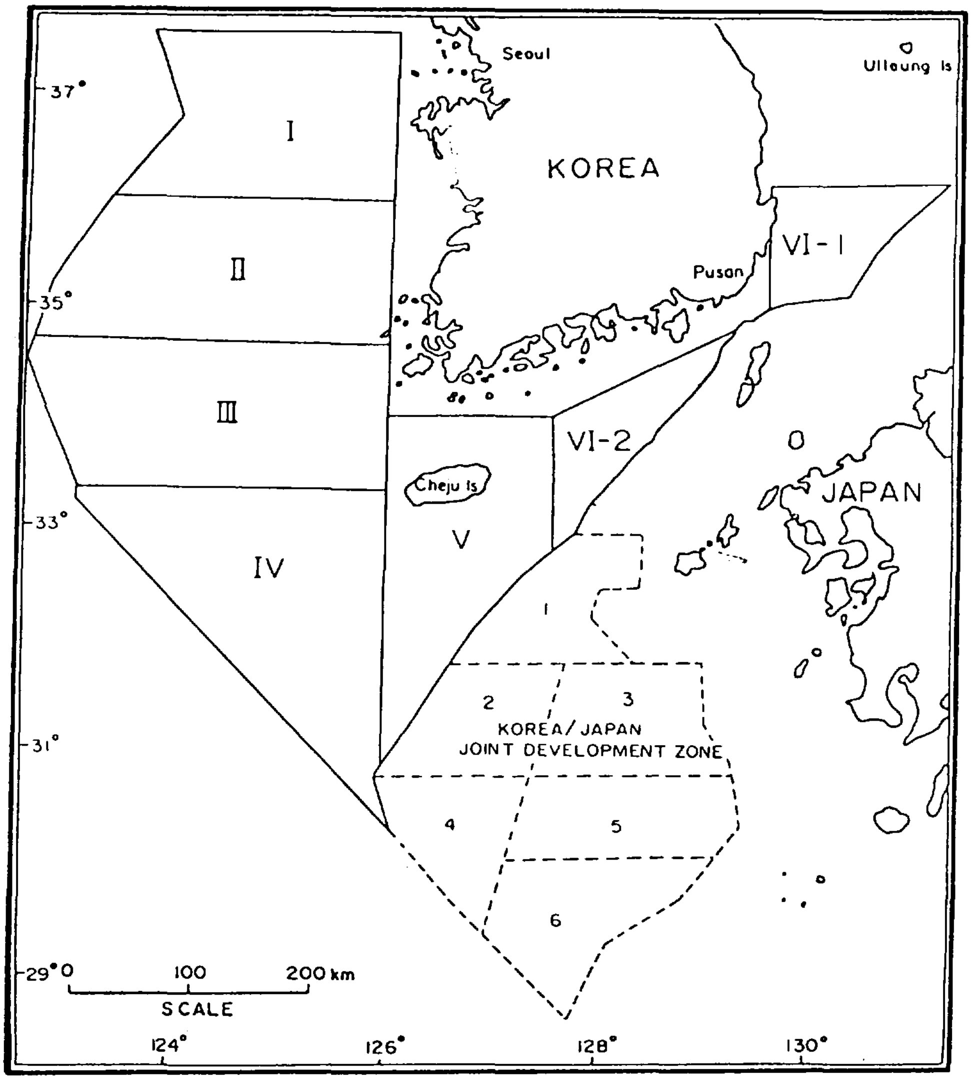

Fig. 2. Unilateral Claims and Concession Areas around the Continental Shelf of Korea.

6. Deep seabed Mining

KORDI, sponsored by the Ministry of Science and Technology (MOST) and the Ministry of Trade, Industry and Energy (MOTIE) has conducted deep seabed mineral resource exploration since 1983. KORDI had a joint exploration program with USGS from 1989 to 1991, aiming to evaluate the potential of manganese nodules in the Clarion-Clipperton (C-C) zone as well as that of manganese crusts in the Western Pacific. Since 1992, the Korean government accelerated its program by the reconfirmation through the economic ministers' meeting and the commission of newly-built research vessel, Onnuri-Ho. The R/V Onnuri-Ho is about 1,400 G/T, facilitated with various advanced instruments including GPS, multi-beam echosounder (Seabeam 2000), multi-channel seismic system and MDM system.

The Korean deep seabed mining program aims at concentrated exploration activities for manganese nodules in the C-C zone of the Pacific Ocean spending about US$ 40 million up to 1994. During this period, the exploration target area each year is approximately 500,000 km^2 and 4 or 5 cruises are being carried out for 4 - 5 months each year.

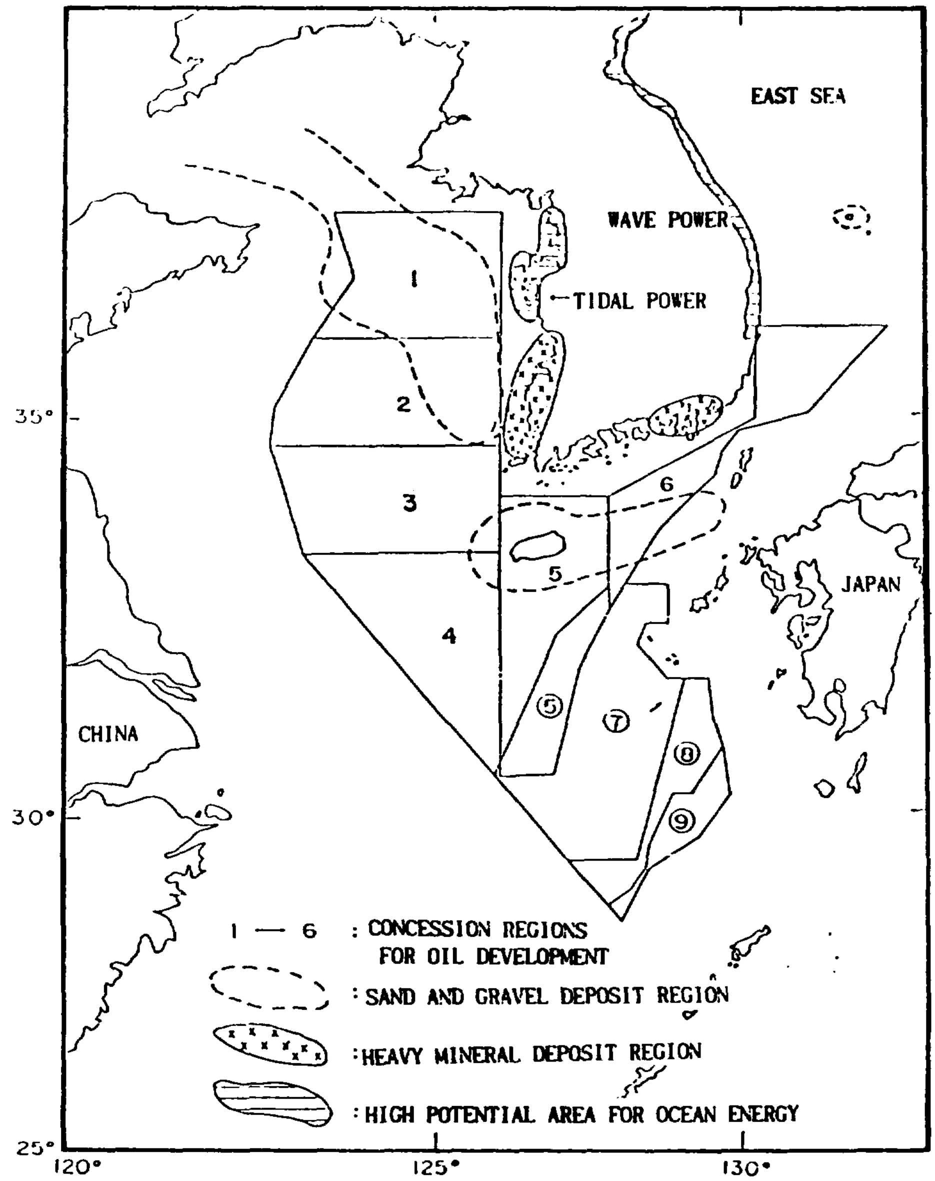

Fig. 3. Potential Area for Ocean Energy and Mineral

Having prepared the prerequisite legal requirements to become a pioneer investor, Korea will disclose its desire to become a pioneer investor before the Law of the Sea Convention enters into force.

Korean participation in deep sea bed mining ventures offers both opportunities and risks. Effective investment decisions, especially with significant government involvement, require inter-disciplinary considerations. The most important benefits of many opportunities would be to maintain stable long-term procurement of strategic metals, and to enhance the level of marine science and technology.

7. Conclusion

In the process of economic development, Korea has imported many kinds of natural resources such as oil, minerals, metals, coal, etc., because she does not have enough resources within the national boundary. So many efforts have been made to explore and exploit these resources within the land area and so was in the coastal waters. First of all, oceanic oil and gas was the major concern of the government because Korean economy has been heavily dependant upon the import of these resources. Although there has been no definite evidence of oil in the continental shelf until now, Korea will continue to endeavor to find out the commercializable oil well.

Recently demand for sea sand increased rapidly because of the construction of large apartment complexes in the metropolitan area and of the depletion of inland sand resource. Plenty of sand resource is mainly deposited in the shallow waters of the west coast, so that it can be easily extracted and transported to the neighboring cities where it is demanded, after filtering out the salty component.

The quantity of salt produced in the salt pond located in the west and south coast has been decreasing due to the various coastal development plans, the loss of competitiveness of this industry and so on. This trend is expected to continue in the future and salt pond would be replaced by spaces of more productive purposes.

The west coast has great potential for tidal power plant due to the large difference of tidal range and other natural conditions. Several locations of great potentials of tidal energy were found out by the research of KORDI, of which the Garolim bay is considered most feasible for the comprehensive development including tidal power development. It is thought that in the near future the detailed development plan will be specified by the government and related power company.

Deep-sea bed mining program is a national project carried out by KORDI with a hope of self-sufficiency of major metals from the Pacific Ocean floor. Korea is now trying to and almost meets the requirements for a pioneer investor as a developing country, so that the registration as a pioneer investor with the continuous exploration of the Pacific by the newly constructed scientific research vessel is being prepared by the government with the help from KORDI.

Marine Industrial Technology for the Development of Marine Non-Living Resources

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1. Country Background

1.1. Geography and Climate :

Sri Lanka is situated in the Indian Ocean 20 km to the South of India between latitudes of 6-10 degrees North and longitudes 80-82 degrees East.

The island has a land area of approximately 66,000 Sq.km and a coast line of 1560 km. It has sovereign rights of over 233,000 sq. km of the ocean, result of the declaration of Exclusive Economic Zone in 1978.

The continental shelf which is rather narrow specially in the South coast and in the East, rarely exceeds 40 km. and averages 22 km. In the North, it is wide and merges with the continental shelf of India. The total area of the shelf is about 26,000 Sq.km, which is around 11% of the total area covered by the Exclusive Economic Zone (EEZ).

Sri Lanka lies in the monsoon region of South Asia, and has a humid tropical climate, the average rainfall varies from 125 cm. in the dry North West to 500 cm. in the wet South West region of the Central hills. The mean rainfall for the island is 200 cm. The temperature varies between 33^0 in dry zone to 11^0 in regions above 2300 meters.

1.2 Economic Profile :

Sri Lanka is a densely populated island, the estimated population in 1992 was 17.6 m and its growth is 1.3% per year and is one of the slow growing populations in the region. Economic growth of Sri Lanka has been moderate, her average growth in the decade 1980-1990 was 4% per year. During 1990-92 the growth was 5.0%. The modest growth is the result of low level of savings and investment, sluggish growth of agriculture and external trade.

1.3 Industrial Profile and the Priorities :

The performance of the Country's industrial sector was 25 percent of the gross domestic production. It grew at 4.6% per year during 1980-1990 period. In 1991 it rose to 6.8% and in 1992 to 9.0%. The country's economic growth would have been lower had it not been for the better performance of the industrial sector. Sri Lanka has matured in the 1st stage of industrialisation, involving labour intensive industries such as garments. This stage provided employment to large numbers and the Country's entrepreneurs were able to get experiences and management skills, they also gathered techniques, and learned the markets outside the country. In passing to the next stage of industrialisation with more complex and technologically advanced methods the country needs large inflow of foreign capital and high skills. The priority of the state at present is the task of upgrading the skills of the work force through education, research and development.

2. Policy, the Agency Responsible and its Work

According to the maritime zone law No. 22 of 1976 passed by the National State Assembly. "All the natural resources both living and non-living within exclusive economic zone on and under sea bed and in the sub soil and on the water surface and within the water column was vested in the republic".

The Principal National Institution charged with the responsibility of carrying out and co-ordinating research, development and management activities on the subject of aquatic resources both living and non-living is the National Aquatic Resources Research and Development Agency (NARA).

This agency has 07 divisions namely :

1) Oceanographic Division
2) Marine Biological Resources Division
3) Inland Aquatic Resources Division
4) Institute of Post Harvest Technology; Division
5) Engineering and Technology Division
6) Environment Study Division
7) National Hydrographic Division

2.1 Oceanographic Division

Oceanographic Division which is responsible for the exploration of the non-living aquatic resources in the vast area which is several times the land territory of Sri Lanka was obtained as a result of the declaration of the EEZ. The Division is manned by 10 scientific Research Officers. It is equipped with a small research vessel (25 m length) with modern laboratory; equipment for data collection. The Agency presently carries out surveys not only on the continental shelf region but also on the coastal zone and on the beds of rivers.

Due to high cost involved in the deep sea marine research, the agency encourages research in collaboration with other countries. Already one such project with Germany is underway.

2.2 Studies on the continental shelf around Sri lanka

Substantial amount of information have been gathered in the continental shelf around Sri Lanka using the locally available resources. This has resulted in locating aggregates, placer deposits and phosphorites on the continental shelf region.

2.2.1 Aggregates

Substantial amount of non metallic deposits consisting of sand, gravels, shells or coral debris deposits were identified on the western continental shelf of Sri Lanka. Pilot mining carried out successfully by the agency shows that considerable amount of sand deposit exists closer to the shelf region. This sand can be easily made available for sand based industry which require it in large amounts.

2.2.2 Placer Deposits

Placer deposits are metallic minerals which have been transported to their sites of depositions in the form of solid particles. They have been made available on breakdown of their parent rock.

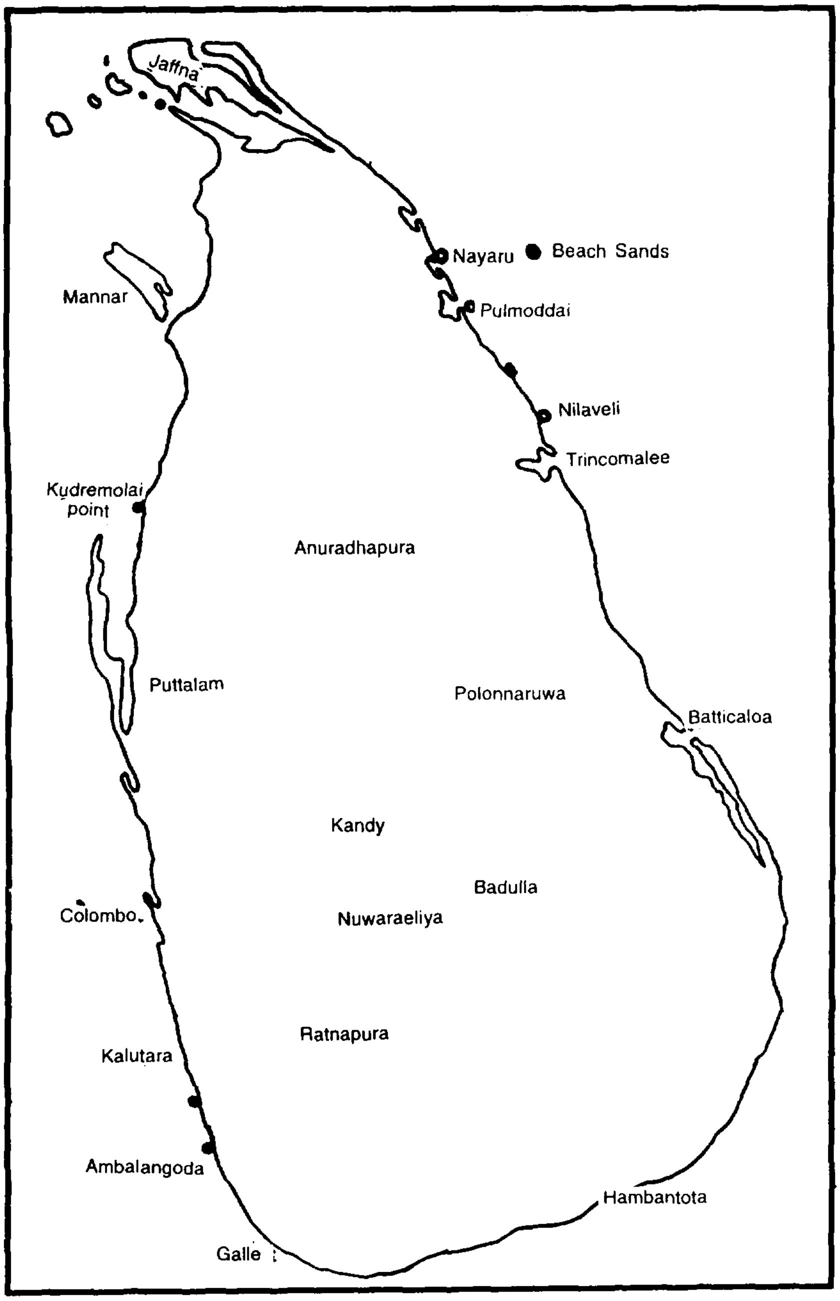
The presence of localized patchy monazite bearing placer deposit was identified on the continental shelf in the area lying South of Colombo from Kalu Ganga mouth to the South of Babnungala points. Initial studies have shown that the concentrations of upto 2.5% monazite are found in these deposits. Detailed studies on this deposit will be started by the end of this year with the assistance from United Nations Revolving Fund. The area mentioned is served by two major and several minor rivers with a large sediment discharge containing heavy minerals. The fact that the river discharges are seasonal led to the assumption that there could be considerable monazite bearing heavy sand.

2.2.3. Phosphorites

In the upper continental slope of the western coast of Sri Lanka fine grain sediments were found which have a higher percentage of phosphorus (P) than the surrounding area. Studies are underway to estimate the quantity and quality of phosphorites deposits.

2.2.4. Ocean Wave Energy

The energy of waves around Sri Lanka's shores is relatively low when compared with regions in higher latitudes. Even then wave energy as an alternate source to Coal, Petroleum and natural gases was explored by NARA. Studies on the ocean wave energy were carried out by NARA, in an attempt to establish a suitable site and a suitable method to generate power using ocean waves. The studies said to have given promising results and are in the initial stages.



Non - Ferrous Mineral Group - Sri Lanka

3. Minerals Investigations in the Exclusive Economic Zone

3.1 Black Sand

Natural concentrates of ilmenite, monazite and zircon with some garnet and Secondary minerals get deposited by wave action on sea beaches along the coast of Sri Lanka. But extensive deposits are found at the river mouths of east and west coast. The largest such deposit is located at Pullmoddai in the east coast of Sri Lanka.

At Pullmoddai, the sand is processed for the recovery of ilmenite, rutile, zircon and other minerals, using 3 different types of processing. Pullmoddai deposit was estimated to contain 4 million tons of "Black Sand" with the following compositions:

Composition of Black Sand at Pullmoddai

Material	% of material in the sand
1. Ilmenite	70-72
2. Zircon	8-10
3. Rutile	8
4. Monozite	0.3
5. Sillimanite	1

Nearly 500 persons are employed in this project. Yearly 80-100 thousand tons of black sand are process and exported.

Work is in progress for the establishment of an integrated mineral sand project by the Ministry of Industries. It is also planning to establish a factory to recover the other two minerals and to establish local industry based on separated minerals.

As mentioned earlier ilmenite containing a higher percentage of monozite is found in an area between head-lands, Kalutara and Beruwala and at Devinuwara in the south. The chemical composition of the monozite from the above places is as follows :

Chemical Analysis of Monazite from
Beruwala and Dondra
(Mineral Resources of Sri Lanka - J.W. Hearth)

Constituents		Beruwala	Dondra
Thoria	ThO_2	8.65	9.51
Ceria	C_2O_3	27.35	28.70
Lantheunum	La_2O_3	31.08	28.56
Yttrium	Y_2O_3	0.95	1.05
Ferric Oxide	Fe_2O_3	0.15	0.10
Aluminia	Al_2O_3	0.78	1.31
Lime	CaO	0.20	0.89
Silica	SiO_2	1.60	-
Phosphorus Pentoxide	P_2O_5	27.50	28.91
Titania	TiO_2	0.15	0.05

3.2 Petroleum and other marine energy resources :

It is estimated that a primitive man used only 2000 calories of energy and the "technological" man of today uses 100 times what primitive man used, showing energy is a prerequisite for the advancement of man.

In Sri Lanka energy consumption in different sectors is as follows:

i) Industry 18.5%

ii) Transport 11.7%

iii) Domestic 66.8%

iv) Commercial 31.0%

The domestic sector which consumes nearly 2/3rd of the total energy is provided by fuel wood(70%), oil (20%), Hydro electricity and coal (10%).

For Sri Lankans wood will be the main source of energy till the turn of this century, but the pressure it exerts on the dwindling forest resources is such that before we reach the year 2000 we may reduce the forest cover to less than 20%. Hydro power the other major supplier of energy was exploited during the last two decades to such an extent that before long it will be utilised to the maximum capacity.

In the absence of Coal, Petroleum and Natural Gases, Sri Lanka has to depend on imported fuel for future energy requirements. To reduce the dependency on imported energy requirements, the Petroleum Corporation in early seventies carried out explorations with Russia's assistance in the Mannar island, after getting positive results from surveys conducted in the land and the sea area off Jaffna and Mannar islands. The other marine resources which are considered for development are the wave energy and thermal energy resources. NARA too in a small way is attempting to design a small scale device to generate electricity from wave energy. We in Sri Lanka can learn from the attempts made in India specially in Vizhinjam near Trivandrum, Kerala to generate power from the sea waves. Another study under way is to generate thermal power from the deep sea bottom near

Trincomalee, where the bottom temperatures are near freezing point.

As mentioned earlier Sri Lanka will face energy crisis before the turn of the century. The Ceylon Electricity Board which is responsible for the supply of electricity to the country is considering establishment of coal and thermal power plants to meet this crisis. The consumers have to pay a higher price for the energy produced by these projects if they come into operation.

Foreign Investors with capital and technology can make use of the present foreign investment opportunities in Sri Lanka to start industries for producing energy based on non-living resources of the sea.

The United Republic of Tanzania

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1. Introduction

The United Republic of Tanzania (URT) is located on the southeastern coast of Africa. It lies between latitudes 1 and 12 degrees South and longitudes 22^0 and 40^0 East. It is comprised of a mainland (formerly Tanganyika) and the islands of Zanzibar and Pemba. The country is bounded on the East by the Indian Ocean, Kenya to the Northeast, Uganda to the Northwest, Zambia to the Southwest and Malawi and Mozambique to the South. It was former British colony for protectorates, gaining independence in 1961. The URT has good access to seaboard shipping and has a fairly extensive road and railway network.

Back Ground

Basic Geography, Economic and Ecological features:

While having quite a diversified economy, it is dominated by the agriculture sector, which generates over one-half of the Country's Gross National Product (GNP). Industry (manufacturing) adds just under 10%; trade, banking and business around 17% followea by infrastructure and public administration, which contribute some 10 and 11% respectively. Agriculture also dominates trade, contributing more than 80% by value. However, Tanzania has a negative balance of trade, caused mostly by imports of industrial inputs, which account for over two-thirds of the total. Fuels add an additional 22%, with food and agriculture imports making up the balance (about 2 and 8% respectively).

Tanzania also has an internal budget deficit (expenditures exceeding revenues) requiring continual deficit financing by foreign aid, commercial lending and domestic financing. While total government revenues have increased over the past five years, from 17.8 to 20.5% of GDP, so have government expenditures, the latter having grown from 23.1% of GDP in 1985 to 24.6% in 1989 - 90.

In terms of development expenditure, domestic contributions (in % of GDP) have remained fairly stable at about 5%, while recurrent-cost expenditures have increased slightly, reaching 21.6% in 1989-90. Debt and debt-servicing makes up a large portion of this increase, with current expenditures on this item rising from 19.6% of total expenditures in 1985-86 to 30.8% in 1989-90. Thus, Tanzania is, and will remain very much dependent upon foreign assistance to finance development efforts necessary to achieve economic growth over the rest of the decade.

Administratively, the mainland is divided into 20 regions, each further divided into districts; these, in turn, comprise of divisions which are made up of villages; the latter being the smallest of the country's administrative units. Regions have considerable autonomy with respect to planning and carrying out development efforts. Budgetarily, however, they are very depen- dent upon the Central Government for funding support, most of which comes from external assistance, which has been averaging around US $ 8000,000 annually.

At the various levels of government (central, regional and local) various public institutions are involved in administration. Concerns of marine affairs are by and large being pursued on a sectoral basis with separate authorities existing in Zanzibar and on the mainland. These institutions include the Ministry of Foreign Affairs, the Attorney General's chambers, the Ministry of Communications and Works, the Ministry of Water, Energy and Minerals, the Fisheries Department under the Ministry of Lands, Natural Resources and Tourism, The National Environmental Management Council, The Tanzania Fisheries Research Institute, The Tanzania Commission for Science and Technology, the University of Dar es Salaam, the Tanzania Harbours Authority on the Mainland.

In Zanzibar, institutions dealing with marine affairs include the Ministry of Marine, Tourism and Forestry, the Ministry of Communications, and the Institute of Marine Sciences under the University of Dar es Saalam. The existence of the Union between the mainland and Zanzibar was identified as creating unique political situation in the establishment of an integrated marine policy, because the Revolutionary government in Zanzibar retains a wide range of autonomy in most areas of the government and in the management of the economy. More often than not activities in one part of the union are conducted with very limited collaboration with the other part.

Size and population statistics

By international standards, Tanzania is a large country, having an area of approximately 950,000 km of which above 580,000 km^2 are inland water bodies. The coastline with only 23 million people ranks in the middle range in terms of population, giving it a low population density of 25 people per square mile or 40 ha per person. Moreover, the population is very unevenly distributed, with almost two-thirds of the people living in areas of Indian Ocean, comprising little more than 10% of the total land area, mostly around the periphery, with a central interior that is sparsely populated. This is due partly to prevalence of tsetse fly in continental shelf regions, as well as lack of water and poor soils.

Thus, in terms of demographic pressure on its land resources, Tanzania would appear to be well off, with less than 20% (some 7 million ha) of its estimated 40 million ha or about 30,000 km^2 cultivable land presently being cropped. However, this is decieving, as much of this land lies in regions with limited, seasonal rainfall, resulting in low productivity. Soils are also an Economic problem in a number of regions, with almost 20 million ha classified marginal for crop production.

Consequently, despite its outward appearance, the potential for lateral agriculture expansion, to meet the food security needs of a population growing at 3.0% annually year, is more constrained than might at first be thought and, for this reason, self-reliance in meeting its food requirements is one of the Government's highest development priorities and goals. This concern stems from both a basic philosophic perspective and a very practical one. Food production in many parts of the country are uncertain from year to year, due to erratic and unreliable rainfall.

Main Physical Features

Altitudes within the country also vary considerably, from the lowlands along a narrow 900 km coastal strip in the East to the highlands in the North and South, which reach to over 800 m at the tip of Kilimanjaro, Africa's highest peak. In fact, most of the country lies at altitudes in excess of 300 m, with a central plateau averaging 1000 - 1500 metres overall.

The Rift Valley with its two great arms, stretches across the entire country, from Kenya in the North to Lake Nyasa in the South. The Valley contains vast plains used by livestock herdsman and is inhabited by one of the last remaining wildlife spectacles on earth, which is being preserved in Tanzania's National Parks. The western branch of the Rift Valley contains lakes Nyasa and Tanganyika, which together with Lake Victoria form part of the country's national boundaries. Fig.1.

Climate

While receiving an average precipitation of over 1000 mm per year, only a little more than one-half of the country receives rain more than 750 mm, and this is quite seasonal. The coastal areas have a more tropical climate, with high temperatures; an average annual rainfall of 1000 - 2000 mm and high humidity, with rains coming in two distinct periods - the "short rains" from October through December and the "long rains" from March through May.

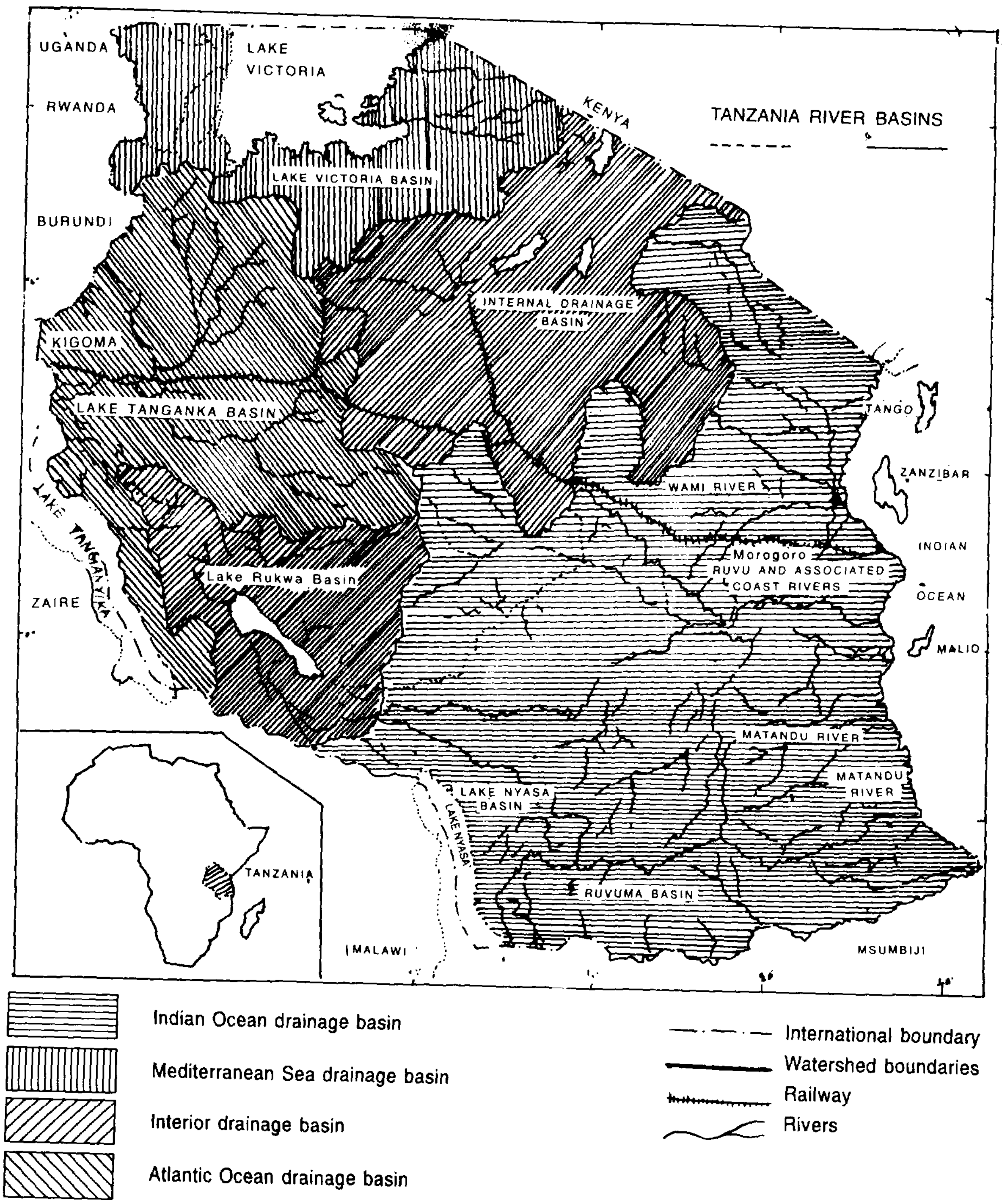

Fig. 1

The central plateau has diurnal seasonal variations in temperature and relative humidity, with a much lower average rainfall (500 - 700 mm annually) precipitation coming in one short rain-fall period from March to May, with the remainder of the year being dry. The semi-termperate highlands, where variations in altitude produce a wide range of climatic regimes, from tropical to temperate, is both more productive as well as conducive to greater crop diversification. The average rainfall is plentiful (800- 2000 mm annually) and reliable in most years.

These climatic conditions (overall) result in annual, potential evapotranspiration levels of between 1600- 1200 mm, falling to less than 1000 mm in some isolated locations. In all regions, these generally exceed annual rainfall, with nearly one-third of the country having potential evapo-transpiration exceeding precipitation during nine months of the year. Thus, while appearing sufficient at first glance, adequate moisture for reliable crop production and year-around grazing is extremely tenuous in many regions, making water a critically vital resource and one needing to be effectively developed and efficiently managed and utilized.

Social structure

Soon after independence, Tanzania began moving progressively toward a socialist style of Government. With the Arusha Declaration in 1967 as the real turning point, the government began making a number of fundamental changes in both development strategies and policies that affected both agriculture and industry, as well as the social sectors. In the latter, this included universal education, an assault on the eradication of illiteracy, the improvement in health care services and the wide spread availability of adequate and safe water of everyone, including remote rural areas. While these social efforts greatly benefitted the people, they were also quite costly and absorbed a high and growing share of government expenditures.

At the same time, government gradually assumed more and more control over economy, nationalizing most private enterprises and becoming increasingly involved in the management of a wide variety of economic activities, particularly in industry and agriculture. They included the creation of large state farms and parastatals, government controlled cooperatives and unions, which tightly controlled trade, as well as being involved in production. However, despite these efforts and substantial success, the system came under increasing stress during the latter part of the 1970s and early 1980s, as the costs of this social change became greater and revenues to support them declined.

However, beginning in the mid-1980s, a reversal in some of the above areas began to be made by government, most notably in the area of macro-economic policy. This has led to an extensive liberalization of trade, gradual decontrol of many parts of the economy and a growth in private economic activities. The form of government is still very much socialistic but much less repressive with respect to both political involvement by the people as well as the stimulation of private initiative.

2. Marine Resources: Policy and Management Issues

Having a coastline of over 800 kilometres bordering the Indian Ocean. Tanzania has a direct interest in whatever goes on in the Indian Ocean. Tanzania is a signatory to the UN Convention on the Law of the Sea (UNCLOS) adopted at Kingston, Jamaica, on the 10th December, 1982 and is also amongst the very first countries to ratify that convention, having done so on the 30th September, 1985.

As part of the measures to give practical effect to the provisions of UNCLOS, Tanzania promulgated an act on the Territorial Sea and Exclusive Economic Zone (Act No.3 of 1989) which identifies amongst its objectives, as being to provide for the implementation of the Law of the Sea convention, to establish provisions for the exploration, exploitation, conser- vation and management of the resources of the ocean and other related matters in the exercise of the sovereign rights of the United Republic of Tanzania.

Though the adoption of UNCLOS and the enactment of Act No.3 of 1989 enable Tanzania to extend her jurisdiction over the living and non living resources of the ocean to a limit of 200 nautical miles off the coast, this right unfortunately for most developing states does not translate into immediate tangible benefits. Most developing countries find themselves lacking the necessary expertise, methods, as well as the political and economic infrastructure needed to fully exercise this right and properly manage these areas. The challenge for a developing coastal state in managing its marine resources also involves the attainment of long term benefits for the people of the nation.

Management in this context is used in a broad sense, to include the entire range of activities designed to develop and conserve the marine and coastal resources for present as well as future generations. It includes both development and conservation because sustained development is not possible without rational conservation and it involves varying and multifaceted activities including inter-alia, fisheries, exploitation of mineral resources, such as oil and gas, maritime transport, tourism, the development of aquaculture, marine scientific research and the protection and preservation of the marine environment.

The existing infrastructure, comprising of separate mechanism governing different marine sectors and activities is not conducive to the goal of attaining the ideal situation encompassing total integration and comprehensive planning as it results in duplication of effort and more often than not over - lapping of responsibilities and conflicts between ministries of institutions engaged in marine activities as discussed earlier.

3. Living Resources

Marine fish output constitute a greater part of the Tanzanian Marine living resources. It contributes about 15% of the total fish catch in the country: and the fishery concentrates in inshore waters and around the numerous islands off the coast. Efforts are underway to develop the fisheries resources in the EEZ by allowing foreign participation through licensees.

The coastline stretches for about 800 km with an estimated area of about 30,000 km^2 (excluding the EEZ). The continental shelf is narrow, falling sharply after the depth of 60 metres and covers an estimated area of 17,500 km^2 of which only 12,000 km^2 are available for trawling.

4. Non-Living Resources

The development of marine non-living resources in Tanzania has concentrated on exploration of petroleum and hydrocarbons. Foreign multinational oil companies in collaboration with a parastatal Tanzania Petroleum Development Corporation (TPDC) have been undertaking and continue to carry out oil exploration both on and offshore.

4.1 History of Petroleum Exploration :

The history of petroleum exploration in Tanzania may be dividing into three phases, with the initial phase commencing in 1952 when British Petroleum and SHELL were awarded a concession covering the On-shore Coastal Basin on the Islands of Zanzibar, Pemba and Mafia located in the Indian Ocean. These Companies carried out extensive geological and geophysical surveys including the drilling of about 40 stratigraphic boreholes, gravity, aeromagnetic, refraction and single fold reflection surveys. Four wildcat wells were drilled, one each on Zanzibar, Pemba and Mafia islands and one on the Mainland in the Mandawa Basin.

Each of these deep tests found potential reservoirs containing minor hydrocarbon deposits and oil-proven sources rock potention at several locations. However none of these wells encountered hydrocarbons in sufficient quantities to justify further drilling at a time when companies were making major discoveries in the Middle East and Nigeria: and the entire concession was relinquished by BP and SHELL in 1964.

The beginning of the second phase of exploration with the establishment of Tanzania Petroleum Development Corporation (TPDC) in 1969; when during the same year, the first production Sharing Agreement was concluded with AGIP based on terms and conditions obtained under the Tanganyika Minerals oil Ordinance, 1958. AGIP were awarded a concession covering the entire coastal basin of Tanzania including the Indian Continental Shelf to a water depth of 200 meters. In 1973 they were joined on 50:50 basis by AMOCO. These companies carried out geological gravity aeromagnetic and regional seismic reflection surveys in bcth the on-shore and off-shore areas. The same time several marine seiemic surveys were made to delineate structures on the continental shelf.

From 1973 to 1982 AGIP drilled 3 off-shore wells in the Indian Ocean in Tanzania. The first wildcat drilled by AGIP was at RAs Machuisi and is located in the odd-shore area north of Dar Es Salaam. The second well was drilled N.W. of Songo Songo Island in the Indian Ocean and discovered a gas field in the lower cretaceous sandstones which at the time AGIP considered uncommercial but which is subsequently being developed by TPDC.

AGIP carried out a 1500 km. marine reflection seismic survey and drilled a well in 1982 at Mnazi

Bay in Mtwara Region which found significant quantities of gas in sediments of Oligocene-Miocene age.

Since its formation in 1969 Tanzania Petroleum Development Corporation has conducted an active exploration and drilling programme aided by a number of international agencies and foreign national oil companies. This was initiated by support for the regional evaluation of Tanzanians hydrocarbon potential and the development of Songo gas field came from UNDP/UNIDO/ONGO and the NPD.

During the 1970's when companies became interested in exploration of the outer continental shelf, seismic survey were carried out from 1975 - 1977 by OCEANIC and the SEAGAP Consortium consisting of Phillips as the operator with Getty AGIP and Hispanoil Oceanic acquired 1250 km of 24-fold reflection seismic and seagap group acquired 2.605 km of 24-fold of data. These surveys were located on the continental slope and reached about 200 east of the shelf.

Following the major relinquishment made by AGIP in 1976, a Government decision was taken to accelerate exploration and encourage private participation. TPDC carried out off-shore seismic surveys in the Maifa channel in 1980; on Mafia island and Zanzibar channel in 1981 and 1983. TPDC'S main drilling effort was the appraisal of the Songo gas field in which significant gas reserves were proved; well SS-2-3 and 4 in 1978/79 with cooperation from ONGC of India; wells SS-5 and 6 in 1980/81; followed by wells SS-7,8 and 9 in 1982/83 under IDA credits co-financed with EBB and the OPEC Fund for international Development. Further another off-shore well TAN-CAN 1 located at Kimbiji area is also dealt with by TPDC.

The third phase in the exploration history in Tanzania was initiated by enactment of petroleum Act (Exploration and Production) 1980 and the increased international exploration activity as a result of high oil prices during the early eighties.

The exploration license covering the northern part of the Ruvu Basin and its off-shore extension was granted to IEDC in November 1981. At this time all prior seismic data in the permit area, both on-shore and off-shore were obtained and interpreted.

The off-shore data comprised a broad (approximately 6 x 6 km) grid of 1969 vintages reflection seismic survey shot and processed by GSI and AGIP, together with a number of shallow water extension lines dating from 1971 to 1972, shot processed by OGG.

Societe Nationale Elf Aquitaine (SNEA) were awared a seismic option in 1983 on a shelf area extending from the TPDC Songo Songo block up to and including the Mafia Channel and Island. However only 403 km of off-shore seismic data was acquired under this license before Elf reliquished the acreage.

During December 1989 the SHELL were awarded a licence covering the Mafia Channel and the Mafia Island. A 1.700 km seismic survey acquired processed and interpreted. In October 1991 a well was drilled in the Mafia Channel. Results were disappointing as a consequence SHELL had to wind up its operation and closed its office in Tanzania.

In fall 1989 TPDC and ENH of Mozambique conducted a joint seismic programme in the off-shore Ruvuma Basin. About 800 line km. of seismic data acquired, processed and interpreted jointly.

In addition to multinational ventures in oil exploration, the Univeristy of Dar Es Salaam through its Zanzibar based marine institute, is carrying out physical and applied sciences research in the following areas :

(i) The study of coastal currents and surface fronts off Zanzibar Town in relation to dispersion of domestic wastes. In this project it is intended to study the coastal currents and surface fronts off the Zanzibar town with the view of predicting the dispersion and eventual transporation of wastes.

(ii) Environmental impact assessment of the dredging activities in the expansion of the Zanzibar harbour. This study is intended to determine the impact of the dredging of the harbour and disposal of dredging spoils on the reefs around the Bawe Islands.

(iii) Ocean Wave energy: an alternative energy resources in Tanzania. The objective is to explore possibilities of exploring ocean wave power for electrification of coastal areas and Islands of Unguja, Pemba and Mafia. The purpose is to identify suitable locations of Tanzania's coastline and Islands by making wave measurements and analysis. The study will also assess the economic viability of wave power plants in Tanzania.

(iv) Sediment distribution in the western coast of Zanzibar. This project aims at making a systematic sedimentology study of the area in order to produce a map of sediment distribution on the coast. The data so

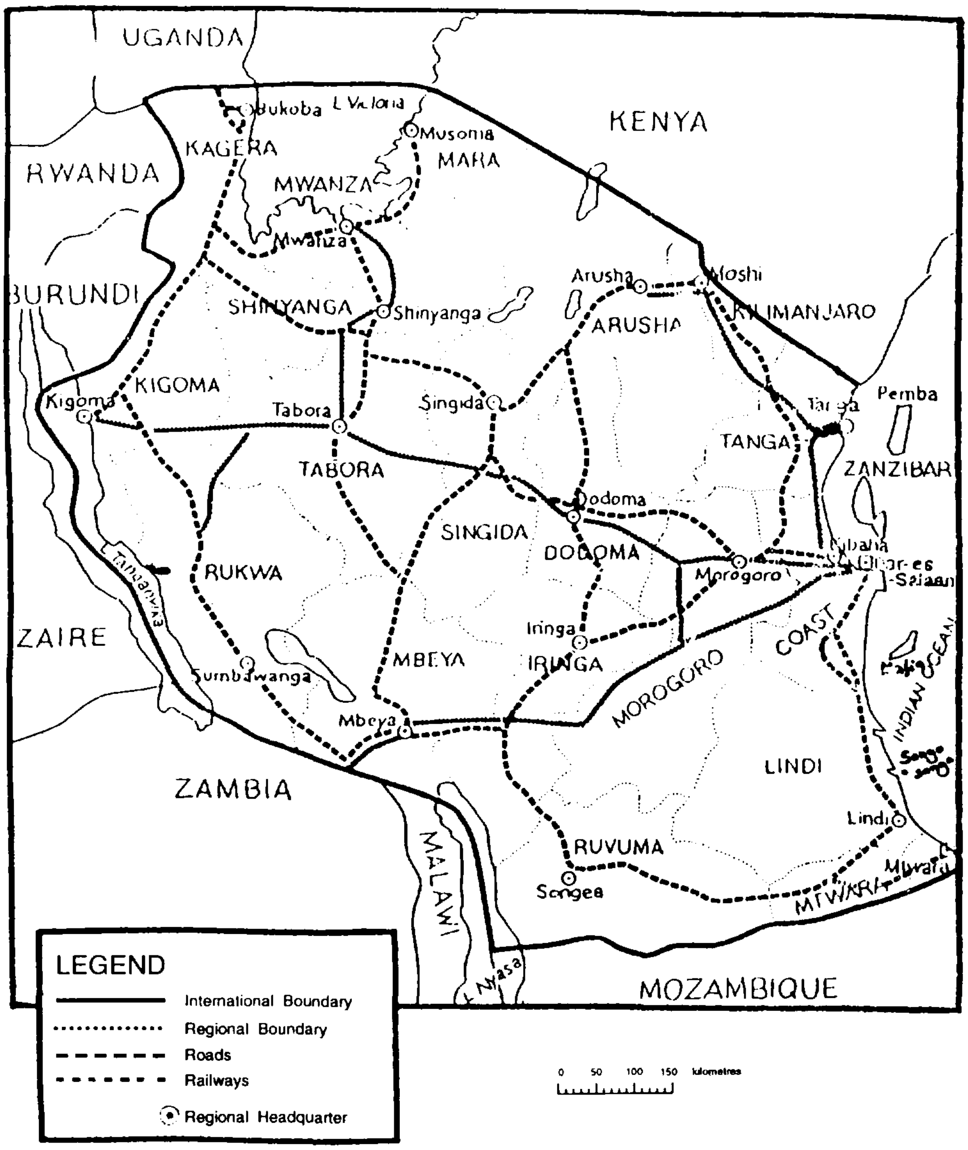

Fig. 2. Tanzania

obtained will be to interpret transport the depositional process in the westem coast of Unguja Island.

4.2 Exploitation of Natural Gas

The natural gas exist at two places; Songosongo Island and Mnazi bay. Although the capacity of Mnazi bay has yet to be estimated; the Songosongo gas field is estimated at 29.02 billion cubic meters recoverable high quality natural gas.

The Songosongo gas field was discovered in 1974 by AGIP (Africa). The gas was not utilised because it was considered not commercially viable. In the late seventies the Oil and Natural Gas Company (ONGC) of India discovered a well ss-4 with significant gas reserves, however, the well caught fire and was abandoned.

By 1983 five out of seven wells drilled, were found to have abundant natural gas estimated at 750 billion cubic feet (2902 billion cubic meters) of high quality gas.

Initially the government intended to use the gas for the production of fertilizers. The Kilwa Ammonian Company (KILAMCO) was to be constructed at Kilwa Masoko on the mainland. The pipeline was to be constructed from Songosongo Island to Kilwa Masoko and Funding was expected from the donor community. The estimated project cost was USD 4325 million. The project was to be owned jointly between the government and the prospective investor. The government contribution was to be USD 54 million. No funds were made available from the govemment and International funding agencies i.e. IMF thought that the project was not worthy pursuing given prevailing political and economic climate by then. The government is now considering the use of Songosongo gas in producing electricity.

Songosongo gas field has enough gas to supply 200 mega-watts for 25 years at a cost which is slightly more economical than hydoelectric power. This proposition will also ensure diversification of the country's energy sources and reduce extemal dependence on fuel oil.

The new project is expected to generate electricity to be sold to industries most of them located in Dar es Salaam and the surplus will be exported to the neighbouring Kenya.

The proposal includes the construction of the generator in Dar es Salaam; and the pipeline from Songosongo Island.

No funds have been secured so far; the govemment has however, open door to private investors (both local and foreigners) to consider investing in the project.

5. Conclusion

Although it is widely recognised that the Indian Ocean has great potential for minerals and hydrocarbons, Tanzania has not made a well planned concerted effort to realise the benefits of our heritage particularly the non-living resources. This is partly due to lack of national capabilities in marine science and technology as well as financial constraints.

Development of Coastal Non-Living Resources in Yemen

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Introduction

Coasts and oceanic seafloors are known to be of important living and non-living resources, especially, to coastal countries. Moreover, coastlines in most countries, such as Yemen, are frequently to be ideal locations for industrial setting based on convenient access to both oceanic shipping and land-based transportation systems. Although, marine industrial technology is still a new concept in Yemen, but it worth a careful and real attention by the government and local sectors.

Regarding non-living resources in Yemen, little is known about them due to the scarcity of publications. The mining is only involved in salts, for exploration and local uses, and gypsum for cement and building materials. This shows that the economic development for these resources are not clearly realized by the government. This is also obviously indicated by the lack of adopted mineral exploration policy in Yemen.

This report is devoted to industrial materials with emphasis to coastal non-living resources. Consequently, the relevant literature has been searched and personal communication has also been conducted to summarize:

- The present and existing knowledge regarding coastal non-living resources,
- the present economic framework of the country
- the exploration policy adopted by the country
- recommendations for both economic development and exploration policy for the country

Background

The Republic of Yemen (ROY), informally named Yemen, is an islamic state. The capital is Sana'a. The country is governed by a Presidency Council headed by the President, assisted by a Cabinet and by recently elected Parliament. The administrative division of ROY is a result of a long historical evolution. The country consist of governorates, which are more-or-less homogeneous areas. The dimensions of the provinces range from 20,310 sq.km^2 to 2,170 sq.km^2. Each province is managed by a Governor (Mayor) who is appointed by the Prime Minister. The Governor is assisted by a Regional Council. Each province is divided into districts of various number and size. Each province is managed by a Governer (Mayor) who is appointed by the Prime Minister. The Governor is assited by a Regional Council.

Location

Yemen is located in the southwestern Arabian Peninsula, bounded in the north by Saudi Arabia and east by the Sultanate of Oman. It is extensively open to the Red Sea, Gulf of Aden and Arabian Sea and owns quite numbers of islands namely the Soccotra, Kamaran, Zugur and Hanish Islands.

Climate

The climate is affected by the latitudinal position of Yemen and the distribution of altitude. The southwest monsoon brings about the rains whereas the masses of warm and dry air are brought by the northeastern winds from central Asia (Edwards, 1987). A warm and very damp tropical climate, which is more endurable in winter, prevails in the coastal plain.

Annual rainfalls averages less than 100 mm and eastward, may rise to 400 mm in some places. At Al-Hudyadah the average annual temperature is 28°C. A narrow fringe, which corresponds to western slopes of the mountainous area, has a subtropical climate with average annual rainfalls ranging from 400 to 1,000 mm. The average annual temperature is around 22°. Within the mountains, the moderate climate shows some nuances. Annual rainfalls reach 330 mm at Sana'a and 1000 mm at most at Ibb. The distribution of rain is seasonal with maximum rainfalls in April-May and July - September. The eastern plateau passes from a moderate climate in the valley to a subtropical climate on the slopes and a desert climate eastward. Rains are rare and less than 80 mm. Rivers are mainly, found along three basins that of the Red Sea, the Gulf of Aden and Rub Al-Khali. Practically, they are of no perennial rivers. Rivers may be torrential especially in the western escarpment (DHV, 1990).

Population

The total population of Yemen in 1990 was about 11.3 million and reached 12.5 million in 1991. This obvious increase is mainly the result of the return of about 800,000- 1,000,000 yemeni emigrants following the Gulf crisis and the annual growth rate in Yemen, which is reported to be of 3.1% (Mutahar, 1993).

Economy

Economy in Yemen is traditional. Agriculture, for example accounts for 62.9% of employment, construction 4%, manufacturing 3.9% and public and private sector 12.9% (Mutahar, 1993).

Low economic growth has prevailed since 1985 and up to present. Agriculture share in GDP decreased from 28.2% in 1985 to 23.8% in 1989. Manufacture and services with shares of 13.7% and 56.6% respectively remained almost without change. The only increase was in mining and quarrying in the former Yemen Arab Republic (YAR), which increased from 0.7% to 5.8% as a result of oil production. (Mutahar, 1993).

Industrial Minerals

Rock Salt (Halite)

Generally, the salt domes extend along the Red Sea Coast from southeast of Hodiedah to Al-lehia. As Salif is the most important location for salt mining (Al-Enbaawi, et al. 1992). Other localities of rock salts are Iyadh, Ayadim, Lai'adim, Bayhan, Milh Kharwah, Milh Mag'ah, Al-Mintag, Shabwah (Greenwood and Bleackley, 1967). The estimated reserves at As Salif is between 30 million tons (Habashi and Bassyouni, 1982) and 72 million tons (El-Shatoury; and El-Eryani, 1979). The Salt alternates with gypsum and clay or carbonate mud (Al-Enbaawi et al, 1992). Much of the salt is exported. The salt domes at Safir are mined by artesinal methods for their local purposes. It has been reported that salt is obtained from seawater by; evaporation at Khourmaksar, north of Aden, (Habashi and Bassyouni, 1982).

Gypsum :

Gypsum is generally known to occur in considerable amount in the northern and eastern parts of Yemen, but not yet been exploited. According to El-Shatoury and El-Eryani, (1979),m the following localities are reported to contain gypsum: Al Ahjar, Al Gheras, Al Harra, Al-Mahabsha, Al-Magazar, Al-Rawnah, Al-Urayashi, Azzaroggash II, Baihan, Salif and Thula, as well as Al-Musila basin along the Gulf of Aden.

The most accessible deposit occur between Mayfa'ah and Rudhum on the western side of Wadi Mayfa'ah(Lewis, 1982), where the gypsum associates with an hydrite and interbedded with limestones and shales.

There is still a lack of markets, which restricts developmental activities.

Sulphur :

Hot springs at Hammam Ali, Al-Lispi, Ispiel, Damt, Al-Ahjar and Keshr are reported to be the main resources of sulphur (El-Sharoury and El-Eryani, 1979). There is a high possibility of finding sulphur associated with salt domes and gypsiferous sabkhas.

Coal and Bituminous Shale :

Bituminous shales are known at Safir, Bajil, Rejam and Bani Hammad. They usually, alternate with sandstones and clays (Habashi and Bassyouni, 1982).

Coal samples from Al-Razy near Nagd Halkan yield 48.6% carbon, 43.3% ash, 2.7% sulphur, 8% volatile and 1.3% moisture (Habashi and Bassyouni, 1982). Lignite with carbon content greater than 20% has been reported in Wadi Arf almost 30 km WNW of Ash Shihr village (lewis,1982).

Black Sand :

Recent sediment along the Red Sea Coasts in Tihama Coastal plain, especially north of Al-Hodyadah linecontain an important heavy minerals such as zircon, monozite, magnetite and castertite (Al-Sannabani, in preparation).

Glass Sand :

Cretaceous Tawilah sandstone is thought to be a suitable ore for glass making area (Alawi, 1977, el-Shatoury and Al-Eryanir, 1979).

Marble and Carbonate :

Various localities are reported as marble deposits area. They are Hajda, Al-Harra, Shiban Village, Al-Gerass, hajja, Waqdi Suirdud, Wadi Maqsab, Wadi Akwam, and Al-Mahazer.(El-Shatoury and al-Eryani, 1979). The wadi Aqwam deposit occurs as a metamorphosed Jurassic limestone and is locally mineralised with ilmenite at contact with gabbro intrusion(Genkens, 1966).

Carbonate rocks occur at Haddah, al-Audain, Safir, Damt, Shara'ab, Khanfar, Al-Mukalla and SSE of Denjaj (Greenwood and Bleackley, 1967).

Fluorite :

Fluorite occurrence in an area about 45 km NE of aden. Another fluorite locality at Hachd Esmani (Lewis, 1982).

Barite :

Barite is believed to occur at Jabali, Wadi Sayl, Wadi Jari and Shib Madu. Further studies are required to elucidate these occurrences.

Mica, Graphite, Talc and Asbestos :

Muscovite is known to occur to the east of al-Bayda. Mica localities are at Wadi Abdan, Al-Khabt, Al-Souda, Arhab, Azzarogah, Kharef, Jabal Nehm, Shara'ab, Wadi Hasn, Mudia area and Wesab Al-Safil (Greenwood and Bleackley, 1967). Graphite occurs mainly near Saadah and east of Taiz (El-Anbaawy, 1985), however talc and asbestos are found close to Al-Baydah (field observation).

Pumica and Basalt :

Pumica is usually know to occur east of Dhamar (Alawi, 1977). Coastal balast would be investigated as a source of artificial rock-wood.

Ilmenite-zircon placers :

Beach placer deposits consisting ilmenaite, rutile, leucoxene, zircon and monozite have been found at Bir Raddah, mayfa, hajr, Riyanm Qusay'ir, Raydat, at Abd-al-Wadud, Sayhut and Al-Ghaydah (according to Hunting and Geophysics, 1976- 77).

A re-evaluation of these deposits in the light of present economic circumstances is warranted.

From the various information in different literature (e.g. El-Shatoury and Al-Eryani, 1979, Habashi and Bassyouny 1977 etc.) it is apparent that there is a diverse of minerals worth studies, investigation and explorations in Yemen. It remains for further exploration to decide whether a larger or small will be found.

Petroleum :

The future hydrocarbon potential of Yemen is encouraging. The south of the country still remains under exploration. Commercial discoveries have been made in the Shabwa Basin. A significant find has been made in the Sayhut Basin and oil and gas shows reported in the Rub Al Khali basin.

The interior basin of Marib and Al-Jawf in the north, has been of successful major discoveries. Exploration in coastal and offshore areas of the Red Sea has not been successful so far, but it has been very sparse and promising.

Economic Framework

Although the cultivate land only represents 8-10% of the total surface area of the country, agriculture occupies about 47% of the active population.

The mining sector is in its infancy. The poorly structured extraction industry is only involved in salt, limestone for cement and building materials.

The board outlines of the economic development are fixed by the five-year plan. The terms of the 1992 - 1996 fourth plan are not yet clearly known. In the second and third plan of 1982 - 1986 and 1987 - 1991, the main objectives in mining are to:

1. intensify exploration land prospecting in areas where oil and minerals, such as copper and iron ore may exists.
2. increase the production of quarries and other construction materials, and improving extraction methods.

The economic framework in Yemen has been reconsidered after the discovery of oil and gas. The government has decided to reduce its dependency on foreign aid. Consequently the government gave priority to industrial development and encouraged the private sector activities. For instance gypsum, cement and salt production has enormously increased according to data on Table 1. The import of natural fertilizers have noticeably increased as well as the manufacture paper products, whereas manufactured fertilizers shows a trend of decrease. This is also indicated by the increase in chemical raw materials importation (from 60 to 238 million YR from 1981 to 1987) as shown in Table 2. Local paper products could be set up fair rapidly, using locally-produced fillers (e.g. Kaolin, carbonates or talc).

Exploration Policy

The exploration policy for non-living resources in Yemen is not well defined. It is generally, worked out as a part of the national policy.

Generally Yemen promotes mineral industry activity, because the government know it is one of the major factor for the development of the national production of goods and services. It also contributes to diversify the basic element of economy. Therefore, a mineral industry must be integrated to the general framework of the national policy.

It is very important that mining policy be based on immediate requirements and future perspectives as much as possible. This is because the average time between discovery and mining development phase may; range between 6 to 10 years and the consumption of mineral substances varies according to economic, technological and sociological constraints.

The mineral exploration policy should include :

- comprehensive assessment of underground potential resources. That is the inventory of the mineral potential which is indispensable for renewing the mining patrimony. and
- immediate mining of the deposits for economic reasons.

  Also one should put in mind that the development of mining activities must :
- be focussed on current/future domestic needs
- take the greatest care when investing in products which are strongly dependent of foreign markets

The mineral exploration policy should also, accompanied elaboration and implementation of development plan and completed by the proclamation of mining laws.

Mining Legislation

The mining legislation still needs to be defined. A well-defined legal and statutory framework, including taxation and custom regulation and techniques to be applied should accompanied the mining activities.

Mining legislation should define the ownership of the soil which could include:

- ownership of the mineral substances to differentiate between the subsoil, deep deposits, deposits spread over several properties.

- the scheme of soil rights and the rights on mineral resources

This is because the detailed rules for granting of mining rights vary according to the system of ownership. Therefore, any legislation must endeavour to preserve a balance between the interest of the community and the mining company.

General Recommendation

Considerable investigation has been done in Yemen in the field of geological and mineral exploration. However, all these works did not come up with the concrete results. This was mainly because the work has not always well proposed and the technical quality was not considerably high. Therefore, the following recommendations are very essential:

- The mining policy must be carefully brought out and clearly defined because it is a part of the general policy of the country.
- Regarding documentation it is relatively abundant but not always available and easy to consult. Therefore, some important information may get lost if it is too dispersed. The lack of consulting reference works and scientific journals reduced the ability of personnel to maintain high level of qualifications and hence, the lost of the staff from the main sectors. Hence, establishment of data and information centre is very important
- A search for industrial non-living resources must be tied to market requirements, either locally to supply centers of population or internationally to outside markets.
- Support the Geological Survey Department and provide it with qualified personnel, equipment and machinery.
- Strengthen cooperation with international multilateral and bilateral institutions in studies and exploration.
- Encourage join investments to exploit mineral resources.

Coastal setting for industrial purposes has a number of definable economic advantage. But there is also a great potential for disturbance of coastal ecosystems unless through consideration is given to site selection, design and operational requirements. Consequently, institutional framework should be carefully considered.

Table 1. Industrial and rock production of Yemen from 1982 to 1986 (thousand short tonnes).

Product	1982	1983	1984	1985	1986
Hydraulic cement	242.6	623.4	708.5	698.2	708.1
Gypsum	4.5	23	59	90	68
Salt	70.4	151.4	167	169	133

Source : CPO

Table 2. Value of main imports from 1981 to 1987 (thousand of Y rails)

Product	1981	1982	1983	1985	1987
Natural Fertilisers	6424	17317	5411	1873	32500
Mfd Fertilisers	4537	21223	11792	46248	14600
Plastic Materials	60105	88830	86032	150368	238100
Rubber Manufacture	70444	129708	98526	111029	90700
Paper Manufacture	63101	78929	102992	165557	285900

Workshop on Marine Industrial Technology for the Development of Marine Non-Living Resources and its Industrial Applications

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Bangladesh is a riverain country. River transport play a vital role in the communication system of the country. Many small and medium industries are established in the country to make river crafts and sea-going small vessels. Government has policies to establish bigger industry in the ship building sector in future for which foreign assistance is expected to develop new technology in the ship-building industry.

Hydro Electric Power

River water flow is used to produce in the country. At present 230 MW electricity is being generated from water flow of the river Karnafully which is 09.785 of the total electricity generation in the country which is 2352 MW. First Hydro electric Power was developed in the country in 1962. The life of the water reservoir is being used to produce the Hydro electricity is 270-300 yrs.

Mini Hydro electricity plant may be set-up in some places of the main rivers. But those will be seasonal, those can be operative only in the rainy seasons i.e. 3-4 months in a year. In the other seasons those cannot be operational due to insufficient flow of water.

Natural Gas :

Bangladesh is situated at the North of Bay of Bengal i.e. at the south of Bangladesh there is vast sea-bed from where we can explore the Marine Resources for the development of the country. Till today 17 Nos of Natural Gas field has been discovered in the country among which only 1 (one) is offshore and the others are at different places in the country. Total Gas reserve in those 17 gas fields is 12.4 TCF. Among those 17 fields, gas is being produced from 7 Nos of field and the average daily production is 650 MMCF. The only offshore field which is discovered till not developed due to financial constrain.

Main users of the gas in the country are as follows :

Power	-	43%
Fertilizer	-	34%
Others	-	23%

Gases using in the sector are utilised in the industrial development of the country and the gases during the Fertilizer sector help the Agriculture in the country.

We hope that if the investigation and exploration are carried out in the seabed, gas field may be discovered. At present the exploration work of gases in the country is going on by the only Government Organisation "Petrobangla". For the exploration work foreign participation is expected.

Oil

Till today only one oil field is discovered in the country and the production of oil is 150 barrel/ day. If the exploration is carried out more oil field may be discovered.

Conclusion

Bangladesh has a vast seabed adjacent to its south shore. Gas and oil field can be discovered if exploration work is carried out. But due to financial constrains it can not be done. For which Foreign and International assistance and participation is expected for exploration work in the sea-bed.

Offshore Oil Exploration and Exploitation in China Sea

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1. Introduction

There has been about 100 years history on offshore oil and gas exploration and exploitation around the world. From 60's and 70's, drilling on the continental shelf and seabed has been developed rapidly and the technical level on offshore oil exploration and exploitation has been raised quickly.

In the middle of 60's China began the offshore oil exploration and exploitation. From 1979, when we began to co-operate with foreign countries, we have got a very fast development on offshore oil exploitation.

2. Offshore Oil Resources in China

China has about 2600,000 sq.km ocean area and about 1300,000 sq.km continental shelf area. They are components of oil and gas belt along western Pacific brink. How much offshore oil is there in the China Seas? Depending on the geological status and relevant investigation, Major Half(Sound American) estimated that there are about 4 billion tonnes oil in China Seas, in which, 1.7 billion tonnes in East China Sea, 1.1 billion tonnes in South China Sea and 0.75 billion tonnes separately in Yellow Sea and Bohai Sea. In March of 1980, In a workshop in estimative methods on undeveloped oil resources, which was held by CCOP in Kuola Lumpur, Mr. J.O. Williams from Norway estimated that there are about 16.43 billion tonnes oil in China Seas, include 7.14 billion tonnes in East China Sea, 2.86 billion tonnes in South China Sea, 2 billion tonnes in Bohai Bay, 2.43 billion tonnes in Yellow sea and 2.0 billion tons in Taiwan Straits. American expert M.T. Halbouty estimated that there are about 6.84 11.6 billion tons oil in China seas. So, from the information above mentioned, there are about 4.0-16.4 billion tons oil recoverable reserves in China Seas. This number is similar to the number estimated by Chinese experts.

3. The Present status of Offshore Oil Exploration and Exploitation in China

1) Relevant Laws and Regulations

Regulations of the Peoples's Republic of China on the Exploitation of Offshore Petroleum Resources in Cooperation with Foreign Enterprises was promulgated by the State Council on January 30, 1982. It made the exploitation on offshore oil developing rapidly these years. Meanwhile, we have made some relevant law and regulations in order to protect the marine environment. For instance,

- Regulations of the People's Republic of China Concerning Environmental Protection in Offshore Oil Exploration and Exploitation. (Promulgated by the State Council of the People's Republic of China on December 29, 1983).
- Measures for Implementation of the Regulation of the People's Republic of China Concerning Environmental Protection in Offshore Oil Exploration and Exploitation. (Issued by the State Oceanic Administration of the People's Republic of China on September 20, 1990).
- The Marine Environmental Protection Law of the People's Republic of China. Adopted at the 24th Meeting of the Standing Committee

of the National People's Congress and promulgated by order No. 9 of the Standing Committee of the 5th National People's Congress of the People's Republic of China on August 23, 1982.

These law and regulations efficiently control the environmental impact coming from the processing of oil exploitation and protect the marine bio- system environment.

2) Relevant Organization

In order to the Regulations of the People's Republic of China on the Exploitation of Offshore Petroleum Resources in Cooperation with Foreign Enterprises, the China National Offshore Oil Corporation(CNOOC) was established on February 15, 1982. From then on, the offshore petroleum exploration and exploitation in China have jumped on to a new developing step.

CNOOC is a state (national) corporation with; the qualifications of a juridical person and has the exclusive rights to explore for, develop, produce and market the petroleum within the zones of cooperation with foreign enterprises. Up to now, the CNOOC has 4 regional corporations, 4 speciality companies and some sub-organisations. They are:

At meantime, CNOOC has offices of the charge 'd' Affairs in foreign countries and areas, such as Hustun, Tokyo and Singapore and Hongkong.

3) Undertaking Service in the Offshore Oil Operation

At present, there are many kinds of undertaking services in the offshore oil operation. In China, these service include: service on ocean earth physical exploration, service on ocean orientation, service on drilling operation in the sea and their complete set, service on logging operation, service on marine engineering geological investigation, service on operating vessels, services on building marine engineering, service on settled marine engineering, service on operation of laying oil pipeline, service on supply from the bases on land, and common special services, and so on.

These special services, with their particular functions, have made very important roles in the development of offshore petroleum and promoted the qualities and efficiencies of themself.

- China Offshore Oil - Bohai Corp.
- China Offshore Oil - Nanhai West Corp.
- China Offshore Oil - Nanhai East Corp.
- China Offshore Oil - Donghai Corp.
- China Offshore Oil - Development and Engineering Corp.
- China Offshore Oil - Gas Utilisation Corp.
- China Offshore Oil - Exploration & Development Research Corp.
- China Offshore Oil - Logging Company
- China Offshore Oil - Marketing Company
- China Offshore Oil - Accounting and Audit Company
- China Offshore Oil - Financing Company
- China Offshore Oil - International Engineering Company

CNOOC Directory

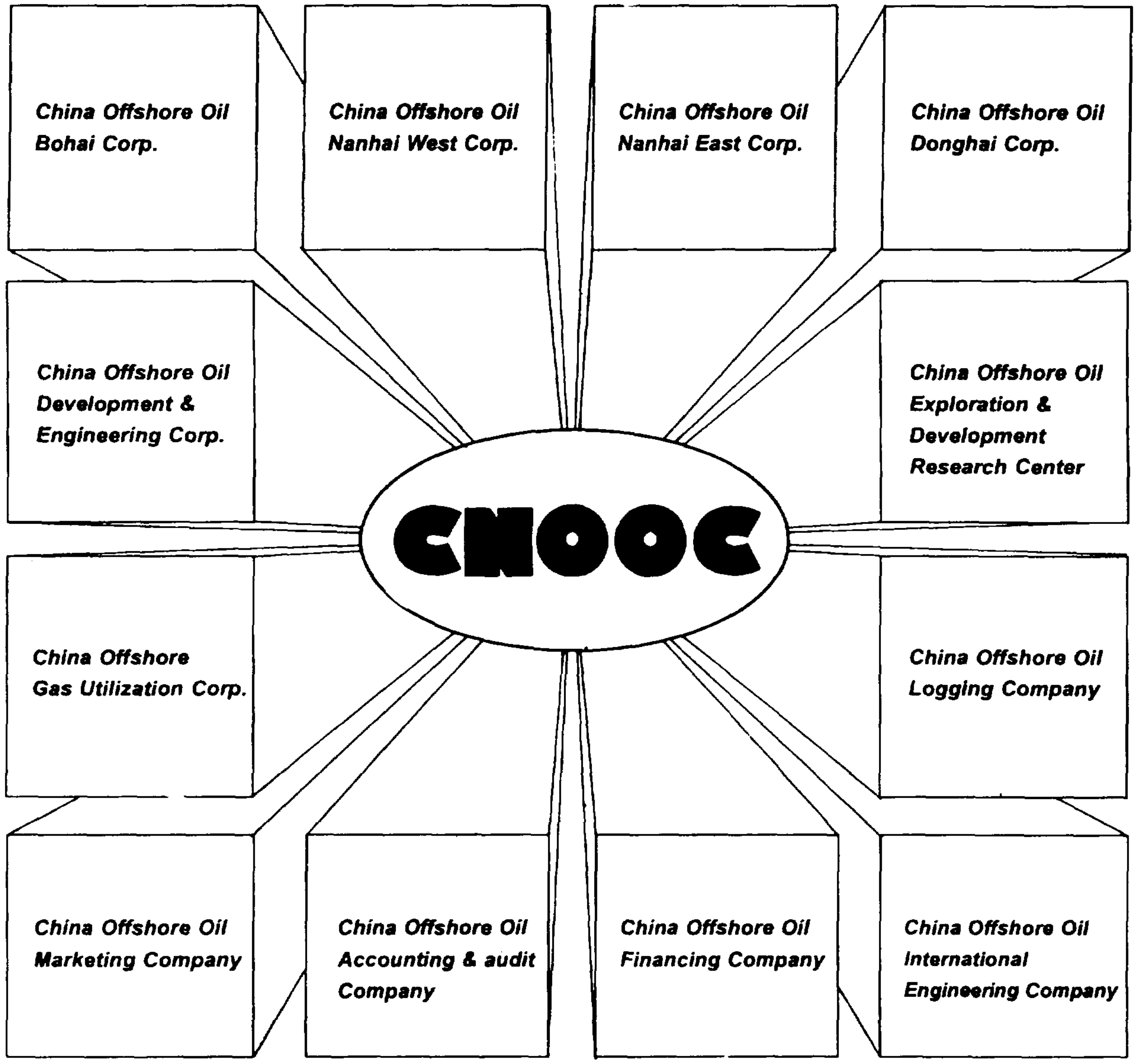

Fig. 1. CNOOC Directory

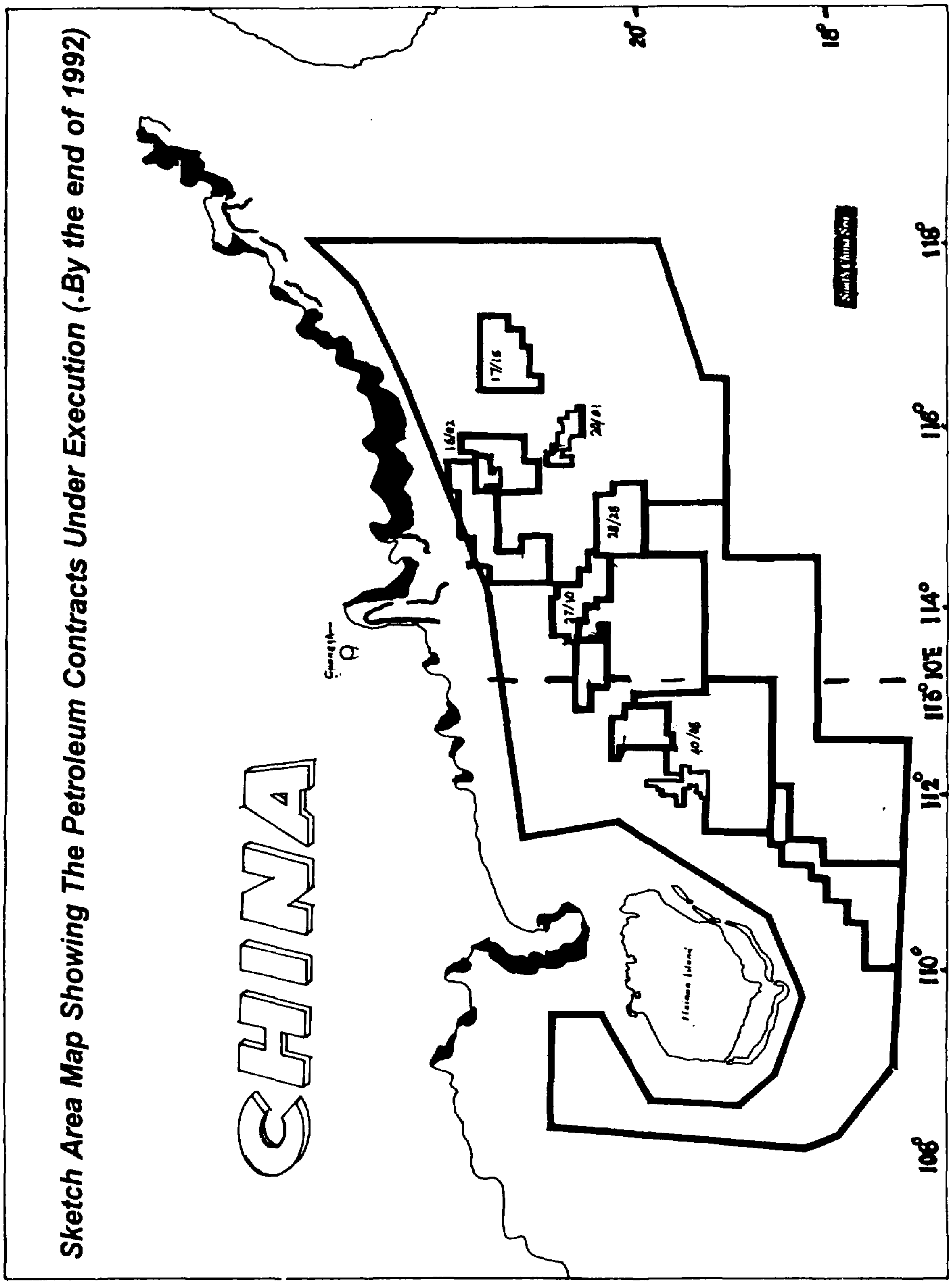

Fig. 2. Sketch area map showing the petroleum contracts under Execution (By the end of 1992)

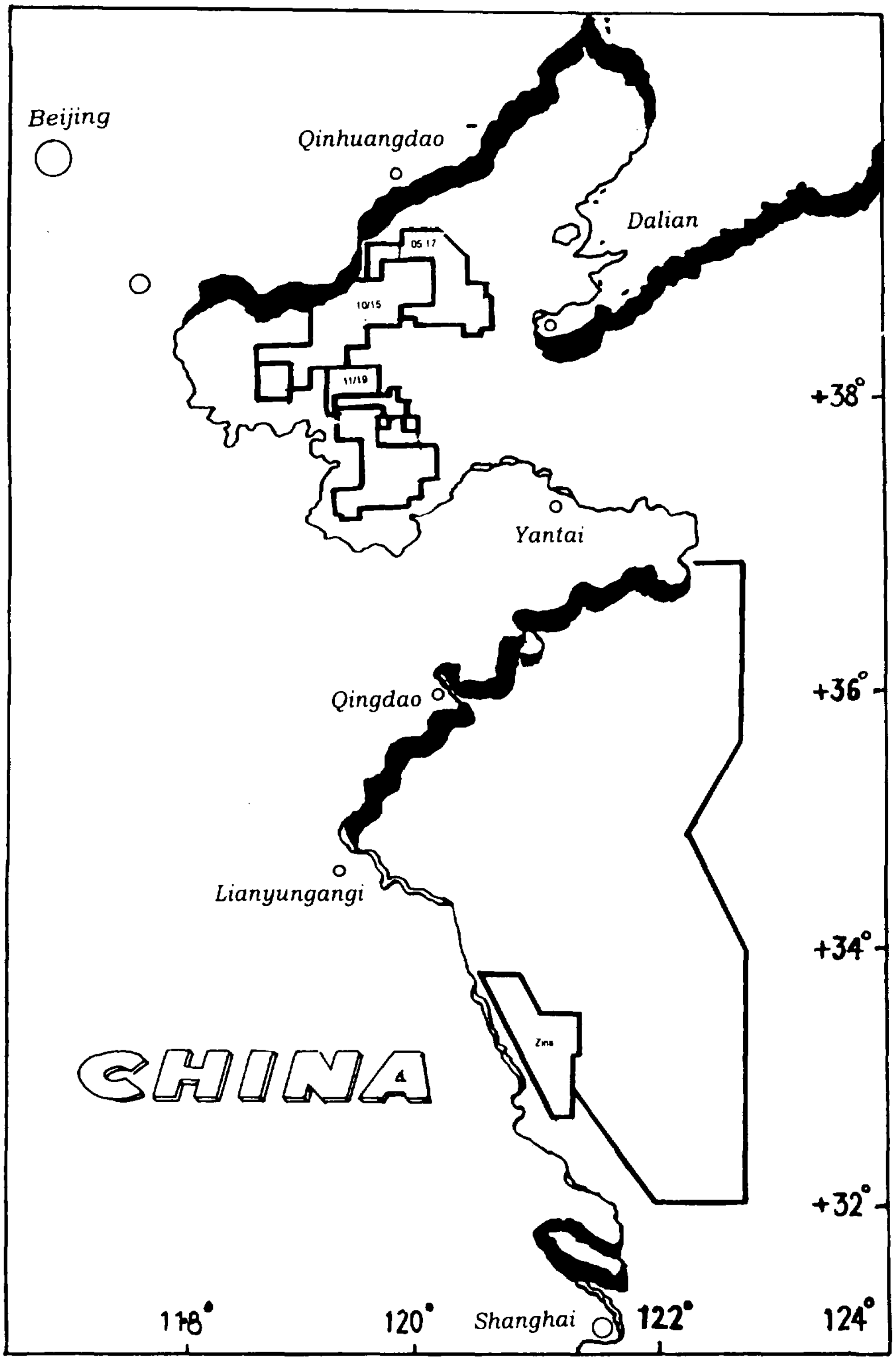

Fig. 3. Sketch area map showing the petroleum contracts under Execution (By the end of 1992)

4) Cooperation with Foreign Countries.

From 1979, we began to cooperation on the offshore oil and gas exploration and exploitation with foreign countries. And from then on, we have got a great achievement.

The first round inviting bids was begun in 1982, and 19 contracts was signed. The second round bids was held in November of 1984 and 8 contracts were signed. The third round bids began in 1988 and another 5 contracts and agreements were signed. In June 1992, CNOOC made announcement on the 4th Round of Bidding for part of the East China Sea area with a total acreage of 72,800 sq.km. This bidding has been responded commonly and warmly in the international circle. By the end of 1992, a total of 68 companies from 19 countries expressed in a written form their interests in this bidding round and over 40 companies among them came to China for reviewing the geological data packages and discussed with CNOOC in relevant issues. (According to the Rules of Bidding, the deadline for receiving bid proposals from foreign oil companies is June 30, 1993)

Up to the end of 1992, CNOOC had signed a total of 72 petroleum contracts and agreements with 50 companies from 13 countries and regions of which 28 are under execution.

4. Achievements in 1992

In the year of 1992, new achievements have been made in all aspects of petroleum exploration, development and production by the enterprises of the offshore petroleum sector.

- A new breakthrough made in the hydrocarbon exploration. A new situation was created for the exploration in the southwestern part of Bohai Gulf by the highly productive discovery on Qikou 18-1 prospect the good potential of a large gas province in the western part of the South China Sea is indicated by the new discoveries of gas bearing prospects in Ying-Qiong region; and the reserve of several oil fields have been further improved during the process of appraisal and development.
- The development of oil and gas fields unfolded to full scale. The very first Chinese offshore gas field under CNOOC financed programmes - Jinzhou 20 - 2 condensate gas field came on - stream partially, showing a new level of standard reached in the construction of offshore fields. All of the ongoing oil field development projects are proceeding well with the quality, schedules and budgets under a good control.
- The crude oil production stepped up further. A total of 3.87 million tons of crude oil was produced during the year, 1.46 million tons, i.e., 60% increase compared with that of the previous year, being a year with the largest production increment.
- The East China Sea opened for foreign bidding, with the consent of the State Council and the approval of the Ministry of Energy Resources, the offshore bidding for Sino-foreign cooperation in part of the East China Sea, i.e., the 4th round of bidding, was announced on June 30. Many foreign companies have applied and purchased data packages, contract negotiations will be initiated in 1993.
- The construction of Ya 13 - 1 gas field started up. Whining 8 months following the signed of the principal agreement to supply gas to Hongkong, and the Overall Development Plan have been signed of approved.

5. The Future of CNOOC (i.e., The Future Strategy of Offshore Oil and Gas in China)

CNOOC is going to continuously implement the five strategies for the development of Chinese offshore petroleum industry, i.e., insist on and develop the co-operation with foreign countries, insist on and develop the financed exploration and exploitation, insist on developing large gas fields in the west part of the South China Sea, expansion of the open policy in the East China Sea, and reclaim new field of oil refining and petrochemical.

Development of Marine Non-Living Resources - The Indian experience

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"Whoever controls the Indian Ocean dominates Asia. This Ocean is the key to the 7 seas. In the 21st Century, the destiny of the world will be decided on its waters."

- Alfred Mahan

Ladies and Gentlemen, this seemingly starting pronouncement may just well come true, if climate ie. the economic, political and industrial conditions and increasing realisation of the potential of the countries on its shores are any indication.

Indian Ocean

Consider this : Indian ocean that lies south of Asia between Africa and Australia with Antartica in South covers an area of 28,400,000 sq. miles (73,600,000 sq kms), accounts for 80.7% of world extraction of Gold, 56.6% of Tin, 28.5% of Nickel, 18.5% of Bauxite, 12.5% of Zinc, 77.3% of Natural Rubber. Its importance has further been enhanced due to availability of largest seams of oil bearing rocks on its coast. Initial Survey also indicates that Indian Coastline & continental shelf contains polymetallic nodules, the source of commercially imported metals such as manganese, nickel, cobalt and to a lesser extent metals like Molybdium, Vanadium, Zinc, Lead and Cadmium scattered on the ocean floor at depths ranging from 3500 to 6000 metres.

India has been granted exclusive Sea Bed Mining rights and earmarked successfully on the production of oil from the Off-Shore regions of Arabian Sea like Bombay High and Bay of Bengal, Cauvery Basin. India could hope to mine 3 million tonnes of these nodules a year within next decade. These polymetallic nodules contain 15000 tonnes of Nickel, 1200 tonnes of Copper, 60000 tonnes of Manganese, 1500 tonnes of Cobalt and undefined quantity of Gold. The Indian Ocean in total has an estimated 150 million tonnes of the polymetallic nodules.

Indian Marine Potential

After very intensive survey, India has identified two sites of nodule deposits suitable for mining. Further detailed surveys in these areas are in progress. As a result of a massive effort put in by India involving a very sizeable expenditure, our country has been accorded the status of 'Pioneer Investor' by the 3rd UN Conference on the law of the sea as far back as 1982, making India the only developing country to acquire such a status. It shares this privilege with 3 developed countries - France, Japan, Erstwhile USSR and 4 multinational consortia.

As we are all aware that subsequent to a new regime that came into being in December 1982, at Jamaica, with 100 countries signing the new convention there is an immense promise of develop ment particularly for developing nations, with respect to protection of rights and sharing of ocean wealth.

In such an important situation, India has a new role responsibility to explore and exploit the vast ocean located at its door step.

Being one of the leading maritime countries, India has a deep interest that has acquired new dimension with the knowledge of the influence that ocean has on the landmass and its potential for providing rich resources for the benefit of the mankind.

Ladies and Gentlemen, indeed this workshop is being held at an opportune moment when India is on the threshold of globalisation and integration with the rest of the world.

India — U Turn

India - the uncaged tiger, though is a catchy slogan but she is more like an Elephant, slow and steady. And India is surely making a U-turn with its Economic reform policies of De-regulation,liberalisation and achieving macro-economic stability.

We at CII believe that India can be a major economic nation and economic power and the U-turn by the Elephant is slowly, but surely heading India in that direction.

India's Plus Points

- 6th largest economy in the world.
- A strategic geographical location.
- Abundant supply of managerial and technical skills.
- Increasing purchasing power.
- US $70 billion capital market.
- Good Service Infrastructre :
  - Well established and growing Capital Market
  - Sophisticated Financial Institutions.
  - Highly developed marketing and advertising services.

The Market :

200 million upper and middle class consumers large number of rural consumers. Emerging mega-market.

The Industrial Base :

Mature industrial sector manufacturing steel and steel items, petroleum and petrochemicals, electronics, telecom, pharmaceuticals, fertilizers, power generation, automotive products, software, etc.

Science, R&D base :

Large pool of sceintists and technological manpower as well as R & D infrastructure.

Resources :

Produces oil satisfying 2/3 of own petroleum consumption, large iron ore and coal deposits, rich in many other minerals.

Manpower :

Trained manpower in engineering science and management, supported by technical institutes and skilled personnel at competitive wages.

Enterprises :

Strong and experienced entrepreneurial talent and experience.

From Red Tape to Red Carpet

Freedom given to entrepreneurs from regulations, controls, clearances, approvals and licences for investment, production and growth. For instance,

- Nearly all industries de-licenced.
- No permission is needed for new projects of expansion of existing ones
- Foreign brand names/trade marks can be used freely. Although India is not yet a member of the Paris Convention, there is express provision in the Indian law to enable the Government to fulfill the requirements of any treaty, convention or arrangement between India and any other country.
- Foreign companies can acquire and sell immovable property.
- Foreign companies can borrow and accept deposits from the public.

- ❑ Foreign companies can open branches and liaison offices trading houses.

Investors Welcome

- ❑ Majority foreign share-holding permitted.
- ❑ Foreign investment strongly encouraged in critical infrastructure sectors - power, petroleum, ports, telecommunications etc.
- ❑ Free repatriation of earnings.
- ❑ Bilateral treaties to gaurantee investment.
- ❑ A single empowered body - Foreign Investment Promotion Board to negotiate and clear major foreign investment proposals.
- ❑ A cut from 65% to 30% in the short term capital gains tax on portfolio investments.

Trade Liberalised

- ❑ Exports and imports can be done freely.
- ❑ Full convertibility of rupee on trade account.

Fiscal Reforms

- ❑ Total tax holiday for five years for new projects in power sector.
- ❑ Tax holidays for units in soft and hardware Technology Parks.
- ❑ Tax holidays for new industrial investments in nine states of India.

Capital Market Open

- ❑ Dividend and interest incomes will be taxed at a flat concessional rate.
- ❑ Foreign Institutional Investors (FIIs) are free to invest in all securities, including equity and other instruments of listed companies.
- ❑ No lock-in period for such investments.
- ❑ FIIs can open foreign currency denominated accounts and transfer sums from foreign currency accounts to rupee account and vice versa, at market rates.

Friends, here I would like to draw your attention to the recent events in West Asia that have exposed India's critical dependence on oil imports. Such dependence has shown how vulnerable the country's economy is to pressure beyond control. Yet, India has proven oil resources to the extent of 0.73 billion tonnes. Funds allocated from fiscal 1990 to 1995 to the Offshore efforts are to the tune of US $9000 million, earmarked for oil field equipment and services.

Coupled with the call for increasing Private Sector involvement the market is lucrative enough for MNCs. For Indian Companies such massive investment offers endless opportunities in manufacturing, contracting, Joint Ventures and third country collaborations.

Some of the areas one could look at for such ventures could be as follows:

- ❑ Seismic and Sea bed surveys (Devices and services)
- ❑ Well exploration structures / equipment / consumables / Services.
- ❑ Horizontal / vertical drilling technology / equipment/consumables / services.
- ❑ Oil well cement and oilfield chemicals including well-head fire suppressors.
- ❑ Control and Instrumentation systems.
- ❑ Pumps and compressors.
- ❑ Pipeline equipment services, insulation and jacketting devices.
- ❑ Offshore support and maintenance equipment—Diving bells and suits, underwater equipment and services, speciality lubricants and greases, hoists and winches, underwater paints and coatings.
- ❑ Communication equipment (Walkie talkies, paging systems, etc.)
- ❑ Tank farms and storage terminals.
- ❑ Transportation and supply (Offshore supply vessels, Ocean tugs, towage equipment, crane barges, VTOL aircraft, antiroll landing decks).

- Rig positioning equipment, installation and maintenance.
- Special vessels, jack-up piers.
- Fabricated structures including production platforms.
- Marine salvage equipment.
- Navigation aids and signalling equipment.
- Mooring and marker buoys - Installation and maintenance.
- Deep water technologies and structures.
- Special equipment to explore/drill in strata such as shale, tar sands and in polar regions.
- Enhanced Oil Recovery Technology and Equipment.

May I, here to put things in perspective briefly touch upon the categorisation of marine non-living resources with special reference to India :

[1] Resources from beach and sea bed in shallow waters

[2] Resources buried in deep sediments

[3] Resources found in underlying rock

[4] Resources obtained from sea water

1. Resources from Beach and Sea Bed in Shallow Waters

Many high value minerals such as Gold, Diamond, etc are commercially exploited in various such parts of the world. Deposits on our own West Coast are largely concentrated as high grade beach and low grade dune deposits, extending from Kanyakumari to the Maharashtra Coast containing ilmenite, rutile, Zircon and Monazite (which incidentally are also some of the few economically exploitable deposits of the world) with varying proportions of magnetite and garnet.

Coal, Tin, Bauxite, Phosphorite are some other minerals which get dislodged from metamorphic and igneous rocks under normal geological processes and find place on beaches and littoral zones as black or coloured sand.

2. Resources Buried in Deep Sediments

These sediments have generally high content of organic material because of life processes in the overlying water during their deposition favouring oil and gas accumulation. Sand and gravel are other valuable minerals extracted from buried deep sediments.

Exploration of oil is presently under way on continental shelves of 75 countries and more than a third of them are producing sub sea oil and gas. In fact, Off-shore reserve of oil amount to 21% of the total reserve of 60 billion tonnes.

The Indian continental shelf covering about 320,000 sq. Km can be broadly sub-divided into 10 sedimentary basins. Of these preliminary geophysical investigations on the Kutch, the Bengal, the Cauvery, the Mahanadi, the Godavary basins and a few others have already been undertaken. The areas in the West Coast near Ratnagiri and Bassein have been proved to be economical and production in Bombay High is a success story.

In Bay of Bengal, 8.5 Km south west of Annalpuram in Andra Pradesh, the Krishna-Godavari Basin, the Andaman Nicobar Island should hold good hydrocarbon deposits estimated as 1400 million tonnes.

Polymetallic Modules

The floor of Indian Ocean is spread with polymetallic modules with concentration of valuable metals such as Manganese, Tin, Zinc, Nickel, Cobalt, Copper, Iron, Lead, Cadmium, Gold, Silver etc in an area of 15 million sq. km. of the total 46 million sq. km. in the world.

3. Resources found in Underlying Rock

Principally materials extracted from the Off-shore Bed Rock are Coal, Iron, Tin, Bauxite and Salt and there is lots to be done in exploiting the Sea Bed Rock along the Indian Coast. Countries like Japan, Australia, Turkey, U.K., Canada are extracting appreciable amount of coal and other minerals from under the sea.

4. Resources obtained from Sea Water

Salt, Magnesium and fresh water are some other important resources obtained from the Sea Water.

Indian Initiative

This brings us to the critical issue of whether enough or sufficient is being done to exploit and explore the marine non-living resources. Well, to know more about the deeper parts of the ocean for countries man has been devising better and better methods. Submersibles diving systems sophisticated instrumented devices have been developed for exploring and studying the Sea Bed and the deeper layers of water mass.

India proposes to acquire knowhow and technology needed to design, build and operate such Underwater Vehicles. Manned submersibles is proposed to be built.

Till not too long ago all Oceanographic work was carried out by one vessel - R.V. Gaveshani. With the arrival of ORV Sagar kenya (which participants here are eagerly waiting to visit) work has been accelerated.

Remote Sensing Technology - Maritime activities such as Shipping, Off-Shore Mining and Oil Drilling require effective short term and long term forecasting systems. Remote sensing makes it possible to collect high density and high frequency data on a Synoptic and Global Scale.

Enough not being Done

But that is not enough. India has to revise its planning for harnessing the Off-Shore riches as by the turn of the century she will have 1/6 th of the world population to sustain on 150th part of World's surface and since she is fortunate to have 6000 Km long coastline and UN conference on "Law of the Sea" has extended the economic jurisdiction of the coastal states to an area ranging from 200 to 300 nautical miles from the low water line giving her exclusive rights to operate in an area upto 150,000 sq. Km. in high seas, which is equivalent to 60% of total country's land mass.

Areas to be Pursued

Very little work has been done by marine

- Science engineers, Scientists, Geologists and Oceanographers of under-developed and developed countries. There are manifold fields of ocean ie. physical and chemical oceanography, marine biology, marine geology, marine geophysics, ocean engineering, marine ecology, marine instrumentation, meteorology which need scientific exploration and exploitation of minerals in the nearfuture.
- The process of exploitation of minerals and resources in the oceans is an expensive project. Seeing the growing requirement of minerals for rapid industrial development of India, more funds be earmarked for further exploitation and researches.
- An important component of the development programme should be acquisition of technology. Technologies related to instrumenta tion, diving systems, position fixing and position maintenance, ocean data collecting devices should be priority.
- Infrastructural support forms an essential prerequisite for Ocean development. Basic support facilities like safety and rescue at sea, navigation chains, communication network, development of appropriate maps and charts etc. Provision of adequate parts and harbour ship building and ship repair facilities be augmented in addition to skilled manpower in various sectors of development.
- We also need to have a database to coordinate efforts made by different agencies because of rapid growth of information in ocean science and technology.
- There is a greater need for exploitation of oil and natural gas as the entire continental shelf and high seas of Arabian Sea and Bay of Bengal hold large reserves under oceanic seams and bed. Very little effort has been made in this direction.
- Opportunity also lies in the strategic location of India at a position where from almost all nations of the world can be united through Indian Sea routes.

- For extraction of ocean resources an expert advise from Americans, Japanese, Canadians and British Scientists should be welcome.

To this end, it is essential that we do our utmost to cultivate and develop the Science and Technology for exploiting the various marine resources. Much of this knowledge can only be acquired through R&D in Oceanography.

This would also mean close cooperation with both developing and developed countries in a spirit of understanding of the concept that the oceans are a common heritage of humankind.

The effective utilisation of marine non living resources is one of the major challenges still facing mankind. To say that development and betterment of the livelihood of mankind hinges on it probably not overstating the case.

It is of extreme significance that we are gathered here, transcending race, religion and nationality, to discuss the issue of development of marine non living resources as a heritage of mankind to be handed down from generation to generation. That scientists and engineers and members of the world society that are gathered here from many countries will contribute to world's prosperity through the exploitation of oceanic wealth.

Therefore I look forward to this workshop on Development of Marine non living resources to be an occasion not only for presenting scientific papers but also for setting the future course of mankind through the effective exploitation and utilisation of marine wealth.