SCIENCE EDUCATION SERIES

NO. 22

THE OCEANS IN OUR FUTURE

by

Shanthi Wickremaratne

NATURAL RESOURCES ENERGY & SCIENCE AUTHORITY
47/5 MAITLAND PLACE
COLOMBO 7
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FOREWORD TO THE SERIES

The dissemination of scientific information is one of the main functions of the Natural Resources, Energy & Science Authority. The Journal of the National Science Council published by this Authority provides a medium for the publication of scientific research papers, and "Vidurava", the quarterly science bulletin contains scientific articles of a general nature which is of interest to the public.

There is still a wide gap in the availability of reading material on scientific subjects of local interest. One result of this is that science students confine their reading only to their school notes and to the few available text books which are mostly published abroad. In an attempt to improve this situation, the Working Committee on Science Education Research of the Natural Resources, Energy and Science Authority decided to publish a series of booklets on scientific topics of local interest as supplementary reading material for students and the general public. The authors who have been selected by the Committee to prepare these booklets are experts in their respective fields. The manuscripts that were submitted by the authors were examined by referees before being accepted for publication. The views expressed in these publications are those of the authors and are not necessarily those of the Natural Resources, Energy & Science Authority.

I must thank the Working Committee on Science Education Research of the Natural Resources, Energy & Science Authority, and in particular Prof. V. Basnayake who is the Hony. Director of the Working Committee for the work they have done to make this project a success.

R.P. Jayewardene
Director-General

PREFACE

This is not a text book. A need to write a comprehensive text book on the Oceans in Sri Lanka has not yet come. But it is not too soon to let the young Advanced Level Students and the intelligent public in general know that the oceans present wonderful phenomena and profoundly interesting problems to the observer and the investigator. The science of the oceans having its roots in the remote past has of recent years developed greatly. Today the eyes of all mankind have been turned seaward by the realization that the needs of the expanding world population cannot for much longer be entirely satisfied by the resources available on land.

The idea of writing this book took shape while I was busy following a training programme on the Management and Conservation of Marine Resources conducted by the International Ocean Institute, Malta. This programme made me realize how important the oceans were to mankind and that the better we understand them the easier it will be for us to contribute towards the rational management, development and exploitation of our ocean resources.

I have tried to make the text simple and it has been illustrated where possible. For purposes of understanding unfamiliar words and technical terms a glossary has been provided. The number above the right hand corner of any word corresponds to the order in which it is given in the glossary. For students who are interested in getting to know more about the oceans, a selected reference is given. Some chapters of this book are treated in detail and others only briefly.

However, it is hoped that in balance and emphasis this book will give the reader a layman's understanding of the oceans and make them aware of its great potential.

I should like to express thanks individually to each one of the many specialists who gave generously of their time and knowledge to enable me to understand the growing importance of the oceans to mankind as a whole and developing countries like Sri Lanka in particular, but the list is too long to be included here. However, I should like to thank collectively, the Chairman, Director and Visiting Lecturers of the International Ocean Institute in Malta. I am most grateful to Dr. Hiran Jayewardene, Chairman, National Aquatic Resources Agency (NARA), Colombo, for his valuable contribution towards establishing an Oceanographic Unit at NARA and encouraging oceanographic research in Sri Lanka. Finally, I would like to thank all those who have helped me in preparing this book: to Ms. S.R. Ameratunga, D. Silva and S.P. Wijesinghe, who helped in preparing the illustrations; to Mrs. Shiranee Paul who kindly typed the manuscript and to my family for their love, co-operation and patience.

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CONTENTS

1. INTRODUCTION TO THE OCEANS

1.1 Man and the Oceans:

Contrary to what most people ever realize man has more closely been tied to the sea than to land even though he is land based. It is estimated that two thirds of the world's population live within 80 km of the coast and sixty per cent of the world's largest cities are located within 50 km of the ocean. This heavy concentration of people in only 12 per cent of the total land area comes from the fact that the sea has, from the earliest times served a multitude of human needs. Down through the millennia, coastal dwelling people have harvested bountiful crops of food from the sea often depending almost entirely on fish and marine invertebrates for their dietary protein. In addition, the sea has provided man with an efficient means of travel, making worldwide trade very easy.

The oceans have always held a fascination for mankind and in modern times we sometimes are inclined to forget that ancient man had intimate knowledge of the sea routes of the world. The Phoenicians, were the first great ocean sailors of history, combining navigational skill (possibly derived from a knowledge of Babylonian astronomy) and seamanship. An ancient Egyptian expedition probably manned by Phoenician sailors circumnavigated the continent of Africa over 2,500 years ago. Some anthropologists suggest that they even crossed the Atlantic to Central America, bringing Mediterranean culture and knowledge to the American Indians of Peru and Mexico.

The Vikings built slender craft, showing great economy in materials and successfully conquered the North Sea and North Atlantic. They really began the new era of European expansion and colonization reaching Greenland and North America 500 years before Colombus.

The Polynesians of the Pacific islands were skilled navitors, crossing thousands of miles of stormy seas and settling on islands from New Zealand to Hawaii. They knew their immediate environment and made stick charts indicating the locations of neighbouring islands.

Throughout history, the sea has served man primarily as a source of food, and even though we may be about to witness a great expansion of man's uses of the sea, food production will probably remain the most important. It is not generally realized that the oceans are capable of much greater food production area for area than the land. Whereas on land one hectare could yield 340 kilograms of meat, the same oceanic area can produce 2,500 kilograms of fish.

Seawater has been a physical resource since prehistoric times. The extraction of salt by solar evaporation must have been among the first chemical processes carried out by early man. Most of the world's magnesium and bromine come from the seas, and the harvesting of common sea salt is a fast growing industry in many countries. By the year 2000, at the present rate of population growth, most of the water drunk by the Earth's inhabitants maycome from desalinated sea-water. But it is in the realms of hydrocarbon fossil fuels that the richest commercial rewards are at present being reaped. Today over 40 per cent of the world's oil and gas originate from beneath the ocean bed. Awaiting exploitation in the ever demanding future is a whole range of valuable economic and strategic minerals such as Cobalt, Nickel, Copper, Manganese, Diamonds, Iron Ore, Tin, Ilemenite etc. The resources of the oceans are enormous, but man is fast learning that the oceans are not inexhaustible and also have their limits. Already man has seriously overfished many of the world's fishing grounds and transformed them into underwater Saharas. The great whales — the largest animals ever to live on the earth — have been ruthlessly slaughtered and are at the verge of extinction. Pollution is manifest on a global scale. Even fish and seals in remote Antarctic waters show dangerously high concentrations of man-made toxic wastes and nearer to land, total pollution disasters are commonplace occurrences.

However, the situation is now fast changing, since the signing of the Law of the Sea Convention in December 1982 in Jamaica. It will help man to successfully tackle the problem of exploiting the resources of the oceans on an international and global basis so that individual and nationalistic greeds, which cause overfishing, overexploitation and pollution, may no longer jeopardise its yet unrealized potential.

The oceans have played a major role in Sri Lanka's history and many of the critical issues in its history have been brought by overseas factors. Foreign invaders who colonized Sri Lanka crossed the seas to get to the island. The principal languages and religions and many aspects of the people's culture have come from across the seas. For over two thousand years Sri Lanka's products have found their way across the seas to India, the countries of the South-East Asia and, less frequently to China and even the Mediterranean world. From the sixteenth century onwards, Sri Lanka began to have extensive trade relations with Europe and now these encompass the whole world. In this traffic of people, culture or commodities, the oceans have been the medium of communication.

Another role of the sea was as a repository resource. For millenia, marine products from the Indian Ocean surrounding the Island have been exploited - principally fish, pearls, salt, sea-shells, corals (dead & living) and even sea sand.

1.2 The Shape, Structure and Evolution of the Oceans

Shape of the Oceans: It is known that the surface of the globe comprises 510 Million KM^2 of which 361 Million KM^2 or 70.8 per cent are occupied by oceans. Thus, the area under oceans are incredibly vast being nearly 2.5 times as great as that of the land. The Oceans are divided into four great ocean basins, Pacific, the Atlantic, Indian, Arctic (Table 1) as well as smaller areas such as the North Sea between Britain and Europe, the Mediterranean, the Baltic, the Bering Sea, etc. These oceans and seas concentrate an enormous volume of water, approximately estimated at 1,370,323,000 KM^3.

Table 1

Areas and Depths of Oceans (Marine Atlas, Vol.2)

Ocean	Area million KM^2.	% of the entire area of the world Oceans	Depth in KM Mean	Depth in KM Maximum	Location of Maximum Depth
Pacific	180,	50	4,028	11,022	Marina Trench Philippines
Atlantic	82,	24	3,926	8,385	Puerto-Rico Trench
Indian	75,	21	3,897	7,455	Java Trench Indonesia
Arctic	14,	4	1,205	5.449	Nansen Trench

The waters, in turn, cover a bottom scenery more rugged and grander than anything land can boast.

The average depth of the oceans is 3,795 metres, while the deepest parts of the ocean like the Marina's Trench in the Western Pacific could swallow Mount Everest with several thousand metres to spare.

Structural Features of the Oceans: Some of the Earth's most spectacular scenery lies under the sea. Upthrusting mountain ranges and plunging trenches, awesome canyons[1] and escarpments[2], all are hidden under hundreds and often many thousands of metres of water.If they could be viewed from the deep-sea floor, they would be found in many cases to excel the scenic grandeur of the continents. The most important features of the hidden landscape are designated the continental shelf, the continental slopes, the abyssal plains, the deeps, or trenches and mid-oceanic ridges or mountains beneath the sea. (Fig.1).

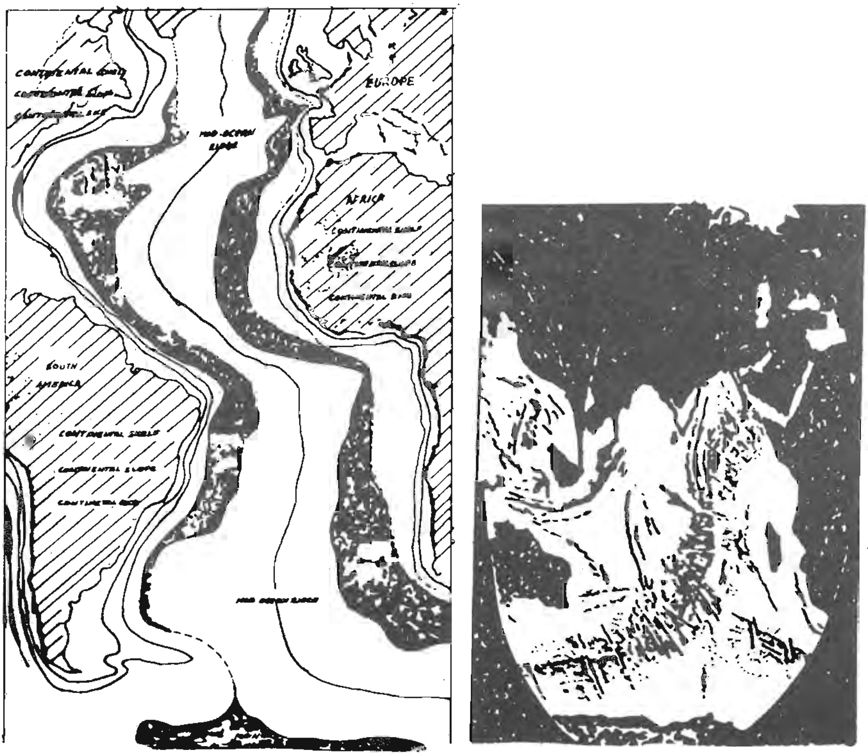


Fig. I The Continental Shelf, slope, rise and abyssal plains

(a) in the Atlantic Ocean (b) in the Indian Ocean (Carlsberg ridge)

The Continental Shelf: The transition from continent to ocean is rarely sudden. Almost everywhere the land is bordered by shallow "Continental Shelves" where land and sea merge into one another. These shallow extensions of the dry continents has in many ways been the most important part of the undersea landscape for practical human purposes. The shelf area has been the first part of the ocean bottom to be studied by man, and its first mention, as a feature, is attributed to Herodotus in about 450 B.C. The shelf is where the great commercial fisheries are found, such as those of the North Sea and of the Grand Banks off Newfoundland or in Sri Lanka off Negombo, Kalpitiya, the Gulf of Mannar and Palk Straits. The shelves also have long been both a hazard and an aid to navigation[3]. Navigators must constantly be on the lookout for shoals[4] and sand bars.[5] At the same time by comparing soundings[6] with those on their charts, they can help guide themselves in their coastwise sailing. Thanks to this practical importance to navigators and fisherman, the shelves are the best surveyed areas under the sea, at least off the coast of major maritime nations.

The shelves underlie only 7.5 per cent of the area occupied by the oceans, but more significantly they equal 18 per cent of the earth's dry land area. By International agreement the continental shelf is considered as the "shallow zone that surround most continents and are terminated seaward by a relatively sharp break in slope, called the shelf edge. If the shelf has more than one break as it often does, then the sharpest break marked the edge of the shelf, provided this break is no deeper than 550 M."

In some places the shelves are wide, as in the North Sea area off Europe or in the Arctic Ocean along the coast of Siberia. On the whole, they have an average width of about 67 Km, a depth range between 54.5 M and 63.6 M, an average slope towards the sea of about 1.6 Metres in a Kilometre ($0^{o}7'$).

Sri Lanka has a fairly consistent 20 KM wide shelf with an average depth of about 65 M and an area of about 28,000 square kilometres. It is narrowest in the south between Matara and Dondra (6 KM) moderately wide off the west coast north of Galle and in the south near Tangalle- Pillinawa Point (20-35 KM), and relatively narrow off most of the east coast, although it exceeds the average width north of Mullaitivu. The shelf widens significantly north of Kalpitiya peninsula on the northwest and in the Palk Strait separating Sri Lanka from India. A prominent feature of the shelf is a wide depression running along it parallelling the South-western and Southern coastline at an average distance of 20 KM from near Colombo to Hambantota (Somerville, 1908).

The shelves are thought to be a gift of the last ice age. At its peak 18,000 years ago, so much water was locked up in the ice that the general sea level fell anywhere from 75 to 130 M. This was an ice age phenomenon that affected all the sea coasts of the world, even those far removed from the glaciers[8] themselves. A change in sea level is known to have happened four times in the four successive ice ages.

Once open to air, the invasion by plant and animal life from dry land began. Then with the rise of the seas as the ice melted, and perhaps aided by the slow sinking that many coastal areas are known to be experiencing the continental shelves were created by submersion. The shelves, often retain marks of their ice-age origin. Off the eastern coast of North America evidence has been salvaged of roaming mammoths, horses, as well as luxuriant forests of pine, oak and other trees.

The shelves have a varied topography.[9] In some places they are hilly or rolling. Occasionally they are very smooth. There are many basins, banks, sand bars, and remains of drowned river valleys with the bottom covered with various sediments.[10]

Continental Slopes: Beyond the outer edge of the shelf the sea bottom begins to drop more steeply into the ocean floor. These more inclined areas are called the "Continental Slopes", and it is here that the deep sea really begins. These great slopes which descend down upto 3000 M are thought to have nothing on land to rival them. Indeed some of them are steeper and more awesome than the famous southern face of the Himalayas.

The inclination of the slopes vary on the average from 3° up to 6 - 7° and in places reach even 15° and more. The steepest continental slopes are those of the Pacific, which average $5^{\circ}26'$ while the gentlest are those of the Indian Ocean at $2^{\circ}55'$. Almost everywhere, these slopes end in a gentle apron known as the "continental rise" or, over local areas, as a "deep-sea fan".

The continental slopes of Sri Lanka are relatively steep, averaging about 10° and in one place near Trincomalee, a slope of $43^{o}32'$ has been recorded (Stewart et.al.1964) and is the steepest known.

The surface of the continental slopes is dissected by Submarine Canyons. Many of them are 50—60 KM long and 2—5 KM wide (Shepard, 1973), stopping short within range of the slope. But there are also well-known large and deep canyons that stretch over hundred kilometres and descend beyond the confines of the continental slope down to a depth of 3500 and more metres. Some of them can be traced within the range of the shelf and are connected with the mouths of major rivers. To this category belong Hudson, Congo, Indus canyons, associated with rivers of the same name.

On the continental slopes of Sri Lanka too are many of these canyons. The largest occur off the east coast (Shepard and Dill, 1966). In Trincomalee a Submarine Canyon can be traced across much of the continental shelf with its head at a distance of 200 metres from the shore (fig. II). Canyon heads are found in the inner Trincomalee harbour and in Koddiyar Bay.
This steep walled canyon which has walls 1356 M high can be traced seaward for over 60 KM, and down to depths over 3350 M and to 3600 M as a fan valley (Stewart .et.al.1969). The canyon extends into the lower Mahaweli Valley where it is buried beneath its sediments (Zeper, 1960).

The Abyssal Plain: Nearly two-thirds of the ocean floor lies at depths between 3,400 and 5,500 metres representing the gentle undulating features known as the abyss, or abyssal plain.

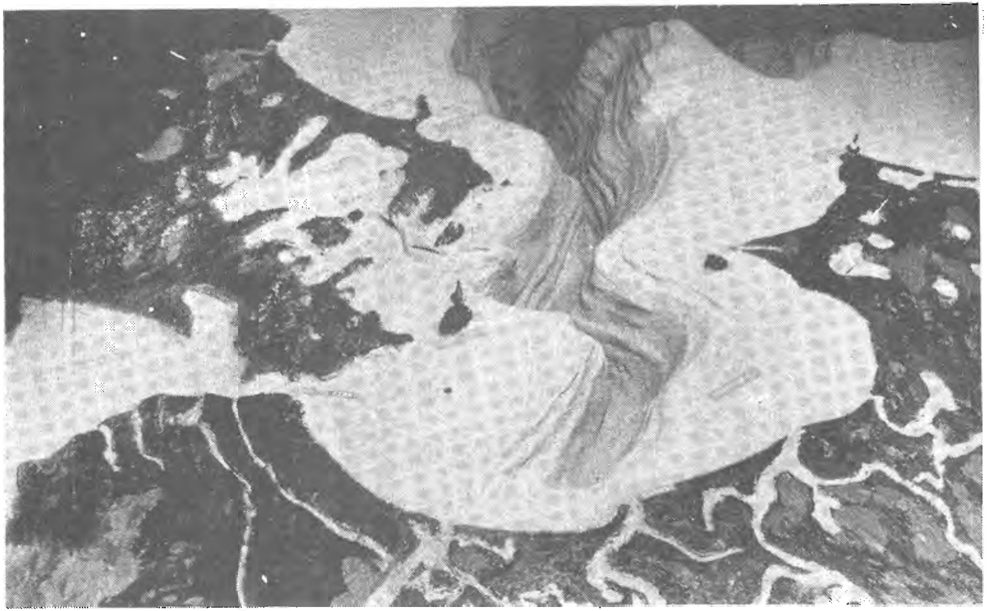


Fig. II   A model of the large Trincomalee Canyon

They have gradients of less than $0^{\circ}03'$ and a change in height of less than 1 metre in one KM. One of the most significant characteristics of the abyss is the winding midoceanic ridges, which extend the length and breadth of the four great oceans (Fig. I). Ocean ridges occupy about 33 per cent of the area of the ocean floor that covers the abyssal plains. The ridges reach heights of 1—4 KM above the floor surrounding ocean basins. The plains also contain minor ridge features and other analogous dry-land features such as escarpments, canyons and fracture zones,[11] and a variety of submerged volcanic peaks known as seamounts. Some of these seamounts have remarkable flat table-tops which stop short of the surface by several hundred metres, and they are sometimes referred to as guyots. Such a seamount exists 132 kilometres Southwest of Galle and rises from about 2800 M from the abyss to a depth of 65 M below sea level. The ocean floor surrounding the island is characterised on the east by the great Bay of Bengal Sea fan (Currey & Moore, 1971) and on the west by the Laccadive-Chagos Ridge and Arabian Abyssal Plains.

The Oceanic Deeps or Trenches: Deep-sea trenches are characterized by their greatest depth (over 6KM) and are largely found close to continental shores or adjacent to chains of volcanic islands forming distinctive arcs. The marginal deep-sea trenches predominate in the Pacific, where some of them attain the greatest depth (Marina's Trench see Tab.1). The deep-sea trenches appear as comparatively narrow depressions with asymmetric cross-section. As a rule, the slopes adjoining the island arcs[12] or continental mountain ridges are steep, while the others are more gentle.

Evolution of the Oceans: Until quite recently many marine geologists[13] believed that the present-day oceans and their basins had changed little since the Earth's crust solidified some 3 to 4 Billion years ago. Although the change of ideas concerning the oceans and continents did not really get underway until early 1960s, Alfred Wegener, a German meteorologist,[14] was the first man in modern times to put forward the revolutionary ideas of continental drift. He put forward the idea that the continents have moved around the surface of the earth, like so many icebergs on a polar sea. Greeted at first with disdain, even ridicule, Wegener's theory has re-emerged, though with considerable modification, as the new theory of plate tectonics. The latest development indicates that the surface of the earth is built of six major plates which are moving relative to each other. When they move apart new oceanic floor is produced at the centres known as mid-ocean ridges; when they come together either montain ranges fold up, or one plate dips below the other, thus forming the ocean trenches.

According to the theory of plate tectonics and sea-floor spreading the continents were once united and called "Pangaea" and later separated to form the six continents of the present. It is thought that about 190 million years ago, a major crack developed between what are now the Americas and Africa and Europe, forming the Atlantic Ocean. Other cracks opened at approximately the same time between East Africa, India, Australia and Antarctica., producing the Indian Ocean. The sub-continent of India was moved northwards by the expanding Indian Ocean until it encountered Asia. Australia had a somewhat similar ride, coming into close contact with South-east Asia. The Atlantic opened gradually to its present width and Greenland separated from North America.

Mid oceanic ridges were supposed to have been formed as the cracks widened and the newly emplaced crusted material moved away on both sides. Near the spreading axis, the crust was hot and therefore stood above the rest of the expanding ocean, which had cooled as it moved away from the centre.

Evidence supporting these ideas have come from the discovery that all mid oceanic ridges contain fossilized[15] tape recordings of changes in the earth's magnetic field impressed in the ocean bed on either side of these ridges. At various times in the Earth's history — at intervals of approximately 12 million years — the direction of the planet's magnetic field has dramatically reversed. North magnetic pole has become south and south pole north. Any new crust that is formed from the mantle[16] carries the fossilized magnetic imprint of the field at that instant. It has been found that on either side of the mid-ocean ridges lie stripes of oppositely magnetized rocks, parallel to the ridge, with increasingly old rock the farther one moves from the ridge — indicating a progressive spreading outwards.

1.3 The Ocean Water Environment: The oceans contain 97 per cent of all water at and near the Earth's surface. Three of the most important properties of ocean water are salinity, temperature and density. Open ocean surface temperatures range from about −33°C in high Arctic and

Antarctic regions to around 30°C in the tropics. And the difference between summer and winter temperatures at any one place is much less than the difference between these geographical extremes. In the depths, temperatures vary with water masses but generally drop off with depth so that all the deep oceans have bottom layers of about 1°C. Salinity likewise varies somewhat with locale. It is higher where evaporation and sluggish or blocked circulation increases the salt concentration of surface waters. It is lower where rivers, heavy rainfall and melting ice dilute these waters. In the Mediterranean sea it reaches 39 parts per thousand (39 ‰) and as much as 40 ‰ in the Red Sea, while in the Baltic it drops to 30 ‰ or less. The average salinity for all the oceans is 34 to 35 ‰ and 90 per cent of the world's sea water falls within a few per cent of that average, as a consequence of the ceaseless mixing of the oceans. In Sri Lanka the average sea surface temperature and salinity are 25°C and 35 ‰ respectively.

Sea water density depends on temperature and salinity. The warmer the water, the lighter it is. The more dissolved salts it contains, the denser it will be and vice versa.

The movements of sea water are variable by their nature. The booming of breakers on an eastern Indian Ocean shore hints of storms that have raged thousands of miles away. Choppy waters in a channel may tell of tidal currents flowing against opposing winds or swell. The varying height of incoming waves along a stretch of shore may reflect the character of the offshore bottom, rising higher where there are ridges and breaking with lower crests where they have passed over a submarine canyon.

Waves: Waves at the sea surface are commonly produced by winds. Waves are not moving masses of water. It is the shape that moves along, while the water stays more or less where it is. As the wave shape passes, individual water particles move up and down with it, describing a circle or an ellipse. There is almost no forward motion due to irregularities in the wind stream.Secondary waves develop on the surface of the big waves. Wave interference occurs, and at each given moment a whole range of different wave forms from big to tiniest develop on the surface of the sea. Waves are described in terms of their height, wave length and period. "Height" is the vertical distance between the high point of a wave crest and the low point of the adjacent trough. "Wave length" is the distance from one crest to the next, and "period" is the time it takes two adjacent crests to pass a fixed point.

Wave size and speed depend on wind speed, wind duration and the distance over which the wind blows (fetch). Theoretically a wave's height cannot exceed 0.14 of its wave length. White caps and breaking waves in strong winds occur when this factor has been exceeded. As waves enter shallow water they slow down and shorten in length because of friction with the sea bed, and the wave crest eventually overtakes the body of the wave, becomes unstable, and breaks into the beach producing surf. During heavy gales and storms waves can be as high as 15-18 metres and more.

According to wave data collected by the U.S. Navy Hydrographic Office around Sri Lanka, waves are propagated mainly from westerly to southerly directions and are of low to medium height with less then tenth of them attaining heights of over 2M. Most waves are of high frequency (less than 3 seconds) and are generated by winds that have not crossed extensive fetch.

Gigantic waves with lengths in order of 160 km between successive crests and with periods of about 15 minutes are called "Tsunami." They travel swiftly, averaging 500-700 km/h, and cover thousands of kilometres without appreciable loss of energy. They are caused by violent submarine earthquakes and intense volcanic-type eruptions.

Tides: The tide is the periodic rise and fall of the sea caused by the attraction of the moon and the sun. When the sea, gradually rising, attains the highest level, this is known as high water. When the sea falls to the lowest level, this is called low water.

The magnitude of high tide is affected by the relative positions of the earth, the moon and the sun. Twice a month at new moon and full moon the earth, the moon and the sun fall along the same straight line, and twice a month at quadratures (The 1st and last quarter) the earth-moon straight line is at right angle to the earth-sun line. The height of the tides at the first instance is called spring tide and have a large amplitude. In the second instance they are called neap tides and have a smaller amplitude. Spring and neap tides occur twice every 28 days. The tidal range normally does not exceed 2-3 metres but in places it can be as much as 15 m. Tides around Sri Lanka are micro tidal by world standards and vary between 6 cms and 75 cm at spring tides and 18 cm and 49 cm at neap tides.

Currents: Unlike waves, the currents move enormous masses of water over great distances. This constant movement of water, this restless stirring which we classify as great current systems, is one of the most characteristic features of the sea. It mixes the oceans so thoroughly that in spite of the local salinity variation that continually develops, the general composition of their disolved salts is everywhere the same. It helps even out the unequal distribution of the sun's heating and regulates the weather. It creates vertical upwelling currents that bring nutrient minerals from the depths. These fertilize rich plant growths in many areas, which in turn are the mainstay of the world's greatest fisheries.

The major ocean currents flow in a roughly circular pattern or gyre, clockwise in the northern hemisphere and anticlockwise in the southern hemisphere. There are six major gyres in operation, one in either hemisphere of the Pacific, Atlantic and Indian Oceans. Separating parts of these gyres are called currents, drifts or streams (fig. III). When surface water becomes cooler and denser than the water below and thus begins to sink, deep ocean currents are set in motion. The cold dense water produced around the polar ice caps, eventually flows under all other oceanic waters and proceeds over the deep sea floor.

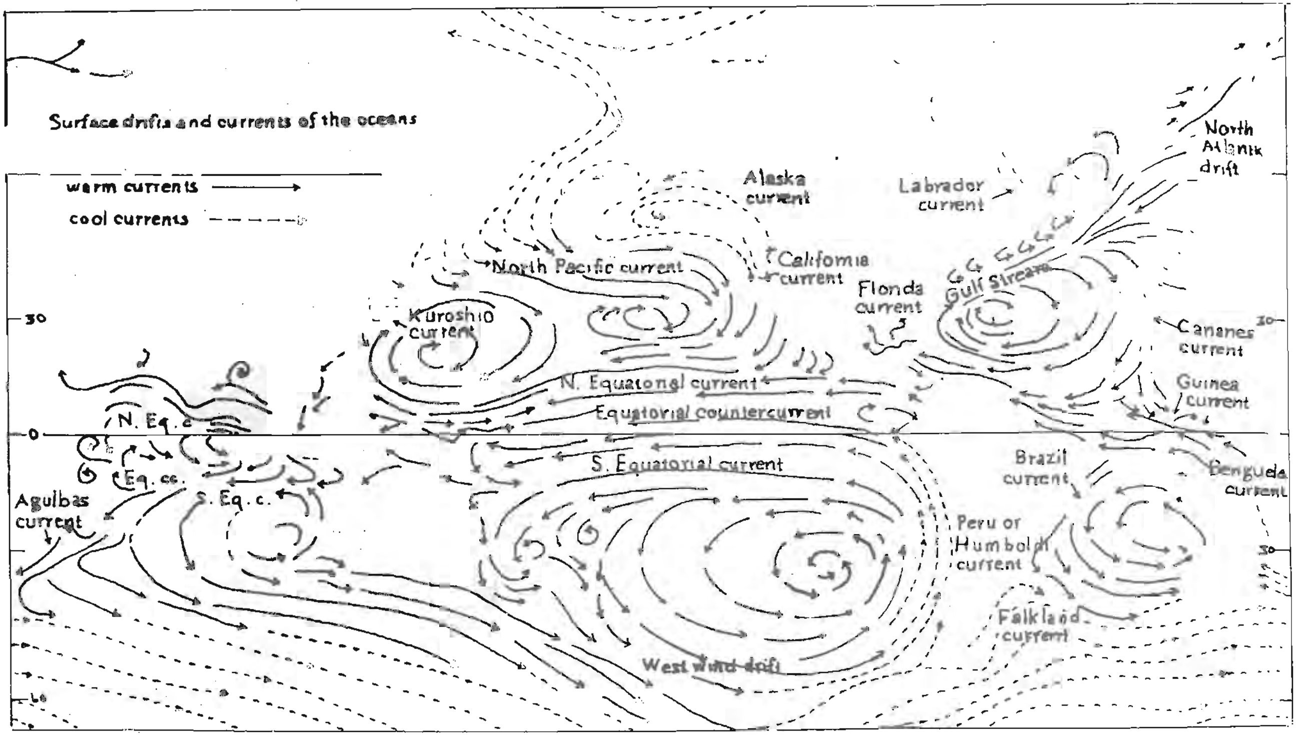


Fig. III Surface drifts and currents of the Oceans

The currents around Sri Lanka are greatly influenced by the monsoons which give rise to the Southwest and Northeast Monsoon Drifts. During the Northeast Monsoon currents flow in a westerly and southwesterly direction. As the Southwest Monsoon begins the Drift appears and flows eastward.

Most of the world's weather seems to be run by sources of heating and cooling over land and water. The land heats and cools rapidly. The Ocean with greater heat capacity, can store more of the solar energy for longer periods of time and spread it widely through currents. The ocean is an energy storage system of vast capacity that perhaps helps to keep the atmosphere well controlled for climate and weather.

2. The Study of the Oceans

2.1 Oceanography: Oceanography, the science of the sea, is a subject of recent development, though of ancient origin. It is only in recent years that it has come to be recognised as a distinct branch of science, an organised body of knowledge, including as it does, the study of the sea, and its content in all aspects - physical, chemical, geological and biological. It was not until other sciences were sufficiently advanced to admit these methods and results being applied to the phenomena of the sea that oceanography became a strictly scientific study.

The first scientific ideas about the seas were formulated by the Greeks. The ancient pholosopher-scientist spent hours peering over the side of a boat, studying marine life in relatively shallow depths. Aristotle, for example, was the first and an expert marine biologist. Among others he is credited for being the first to note that dolphins, porpoises and whales are mammals rather than some sort of fish, as was generally believed.

With the advent of open ocean sailing voyages, navigators began to take an interest in the physical side of oceanography. The first chart of the Gulf Streams was published in 1786, by Benjamin Franklin, based on the collected observations of New England Whaling Captains. He also made his own observations of water temperatures on several Atlantic crossings by picking up buckets of surface water and measuring their temperature. The former British Explorer, Captain James Cook, is also credited with collecting scattered oceanographic information during his three celebrated voyages in 1768-79. He is believed to have used the first marine chronometer for navigation, taking soundings as deep as 1350 M. He observed the Salmon and Sardine fisheries of the Red Indians on the Northwest Pacific and logged the tides and currents and all sea phenomena. Joseph Banks, who sailed with Cook made extensive collections of new animals and plants encountered on the voyage while the Forsters, who also sailed with him made temperature observations.

An American naval officer, Matthew Fontaine Maury (1806-73), is regarded by many as one of the pioneers who helped turn men's curosity about the sea into a science. His intensive study of currents helped lay the foundation for the modern science of physical oceanography. In 1853, he was instrumental in holding the first international oceanographic conference, the Brussels Maritime Conference, where uniform methods of making nautical[17] and meteorological observations at sea were agreed upon. In 1855, the world's first text book of physical oceanography — Physical Geography of the Sea — was published by him. The American Navy still pays tribute to this pioneer work in one of their monthly publications that carry the legend: "Founded upon the research made by Matthew Fontaine Maury, while serving as a Lieutenant in the U.S. Navy".

Important contributions to the biology of the sea were made by a British Naturalist Edward Forbes (1815-1854). In a real sense, Forbes was the nineteenth century heir of Aristotle in this field. He was a pioneer of the study of benthos or bottom dwelling plants and animals of sea. He investigated the vertical distribution of life and divided the sea into specific depth zones and pointed out that plant life is limited to the zone near the surface by the concentrations and interactions of nutrients and minerals held in the water and the play of currents - the Chemistry and Physics of the sea.

The Chemistry of seawater was investigated by Danish Professor of Geology, Johann Forchhammer, who could be thought as the founder of the modern science of chemical oceanography. In 1865, he published his findings, which demonstrated that while the total salt content of seawater differs from place to place, the relative amount of the various major salts remain constant.

The beginning of Oceanography as an integrated subject was marked by the first expedition around the world — the historic voyage of H.M.S. Challenger from December 7, 1872 to May 24, 1876. Five scientists under the able guidance of Professor Wyville Thomas one of Forbes' students, made a series of oceanographic observations in the Atlantic, Indian and Pacific Oceans. Deep-sea soundings, a vast collection of animal, plant and mineral samples were among the important results of this great voyage which filled fifty bulky volumes (fig. IV).

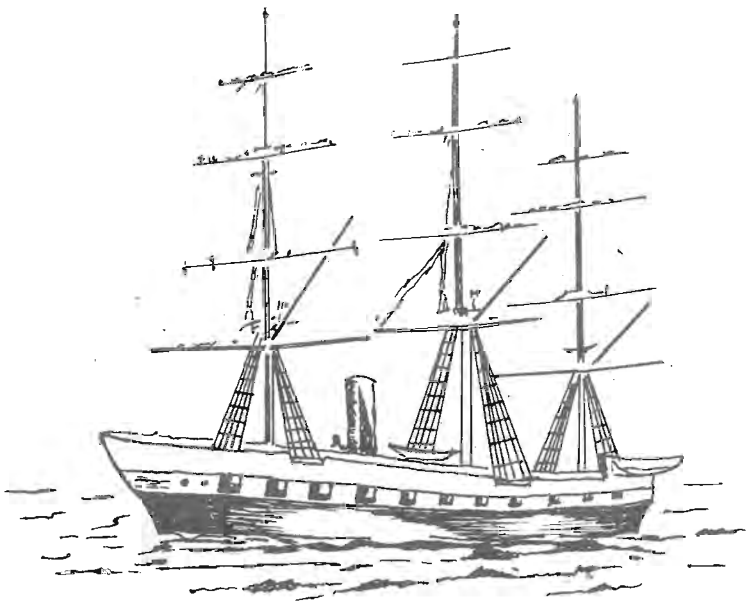


Fig. IV One of the first Oceanographic research vessels — H. M. S. Challenger

The success of the Challenger expedition set off a spate of national oceanographic expeditions from a number of countries through the remaining quarter of the nineteenth century. Among them the expedition made by Prince Albert of Monaco on "Hirondelle" and "Prince Alice" are worthy of mention. He pioneered the large-scale use of floats for plotting the speed and course of ocean currents and also founded the famous Museums of Monaco, and an Oceanographic Institute in Paris in 1906.

The Marine Biological Association of San Diego was founded in 1902 and later, known as the Scripps Institution of Oceanography, became one of the most important centres for oceanographic research in the twentieth century, together with the Woods Hole Oceanographic Institute, founded in 1930 in Massachusetts.

Among many other historic cruises which took place in the twentieth century the Atlantic cruise by the Norwegian research vessel "Michael Sars" in 1910, the Indian Ocean expedition by the Danish ship "Dana" between 1920-1922 and the Swedish Albatross Expedition in 1947-1948 added much to the knowledge on the oceans.

The result of the Atlantic expedition was the beautifully illustrated book "The Depths of the Oceans", which is a classic.

During the Indian Ocean expedition of Dana, the underwater ridge subsequently named the "Carlsberg Ridge" was discovered and named after the famous Danish Beer Company, who contributed funds to the expedition.

The Albatross Expedition contributed to a better understanding of currents, marine life and bottom profiles in the tropic zones. It also made revolutionary advances in bottom coring techniques and pioneered the use of seismic echo methods for finding seabed sediment thickness (see 2.2).

The more recent advances in oceanography date from about the time of the International Geophysical year 1957-58, when scientists of more than twenty five nations joined in a full scale investigation of the Indian Ocean.

More than 50 ships from the U.S.A., U.S.S.R., Great Britain, Germany, India and other countries surveyed the Indian Ocean from 1959 to 1965. Many new oceanographic features were discovered and explored and subsequently many new ideas concerning the problems about the nature and evolution of the great ocean basins emerged from these studies.

Today there are many oceanographic research ships from many countries exploring the deep oceans (fig. V). One of the most useful special experiments was the drilling of holes into the deep ocean floor. In 1968 when the research ship "Glomar Challenger" entered service, it truly heralded a new age in oceanography as the first "Challenger" did in 1872. The long unique cores drilled from the seabed from various parts of the oceans by "Glomar Challenger" helped sceptical scientists to accept the theory of ocean floor spreading.

Fig. V A modern multi-purpose Oceanographic research vessel – SAGAR KANYA of India.

The science of the seas and the oceans has undergone many changes since modern oceanography is truly the blend of many sciences and diverse disciplines. The research ships of today, have aboard biologists, chemists, geologists, physicists, electronics engineers and highly skilled crews working shoulder to shoulder in wresting the secrets from beneath the waves.

The oceanographer's interests are far reaching: He wants to know more about the motion of currents found at the surface and at great depths, about tides, waves and the forces that generate them — the science of Physical Oceanography; the nature of pelagic[18] organisms, primary production in the oceans, vertical migration of zooplankton[19], about plant and animal life in the oceans, marine fishes, fisheries and the exploitation of fish stocks, upwelling fisheries — the science of Biological Oceanography; the study of the chemical composition of seawater, sources, sinks and cycles, some inorganic processes in seawater, chemistry of the air-sea interface – the science of chemical oceanography; the study of the coasts and beaches as far as they are related to marine processes, the study of the continental shelf, slopes, Abyssal plains, deep ocean floor sediments — the science of submarine geology or known lately as marine geology or geological oceanography which also includes exploration of the oceans for mineral resources.

Thus, the exploration of the sea is at a critical juncture in its evolution as a science. Long-standing research limitations are being overcome at a time when governmental interest in the field is increasing worldwide. More and more new, sophisticated oceanographic research vessels are being built and it seems likely that support for oceanographic research will be increased substantially in the next few years. International cooperation in ocean research begun during the International Geophysical Year, is being continued. A special international scientific committee called the Intergovernmental Oceanographic Commission has been set up under the auspices of the United Nations to plan and co-ordinate this work. In Southeast Asia this work is looked after by the Committee for Co-ordination of joint prospecting for Mineral Resources in Asian Offshore Areas (CCOP). A similar body for the Central Indian Ocean called the

Committee for Indian Ocean Exploration — COMINDEX — is likely to become operational in 1985. In 1980 the International Ocean Institute in Malta initiated its programme on the management and conservation of Marine Resources, devoted to the promises and problems of ocean mining.

In Sri Lanka with the establishment in September 1981 of the National Aquatic Resources Agency (NARA), charged with the responsibility of carrying out and co-ordinating research, development and management activities on the subject of Aquatic Resources, the long felt need for a National Oceanographic Institute has been satisfied. Except for NARA none of the other Agencies in the country concern themselves with the totality of resources location, assessment and exploitation in the vast ocean territory coming within the jurisdiction of Sri Lanka. The work of other organisations (except for oil exploration by the Ceylon Petroleum Corporation) is restricted to shallow coastal waters.

NARA with its broad mandate is primarily engaged in Marine and Inland Fisheries, Aquaculture, Oceanography, Ocean Engineering and Technology, Fish Technology and Data Processing. Although Sri Lanka's oceanographic capabilities are at the initial stages every effort is being made by NARA to ensure the future availability of nationals trained and educated suitably to apply marine science and technology. Steps have been taken to obtain assistance and establish co-operative work programmes with local institutions as well as counterpart National Institutions of other states and competent International Organisations.

2.2 Methods and Instrumentation used in Oceanography

Down through the millennia the methods and instruments used in oceanography were a severe handicap to oceanographers. One of the greatest difficulties researchers faced in the open seas was to find where they were. It is much harder to find where you are on the surface of ocean than on land, where you can make reference to fixed points on a map. For centuries mariners used observations of the Sun, Moon, Planets and Stars for navigation. Celestial Navigation — This method was time consuming, laborious, could be used only during certain times of the day and when there is not too much cloud and was not very accurate.

Today Oceanographers use improved methods of navigation which have eliminated much of the difficulties encountered in locating positions in the early days. Radio and Satellite navigation makes it possible to locate positions in all weather and at all times as accurately in the open seas as near land. In radio navigation using fixed stations on the shore and a mobile station on the ship it is possible to fix your position up to several hundred miles with an accuracy of a few meters. By using satellites it is possible for a ship to fix its position anywhere in the ocean to about 300 meters accuracy. In addition to these methods of navigation a new "Global Positioning System" (GPS) will come into effect in 1986. This system will eventually have 17 satellites orbiting the earth compared to 5 for the present satellite navigation systems, facilitating greater accuracy and fixing capability to about 10 meters.

Another source of difficulty Oceanographers face is the fact that water, often kilometers of it, overlies many things that they want to study. How, then, do we know so much about what is hidden by so much of water? In days past the methods of measuring the depth was simply to lower a lead weight on a line and feel the slackening of the pull on the line when the weight hits the bottom. This laborious method was replaced during the 1920s by a quicker and more accurate Echo Sounder that generates a sound wave which bounces off the sea bottom and returns to the ship where it is recorded on paper. The principal of echo sounding is simple. It consists of measuring the time it takes the sound wave to travel down from the ship to the seabed and bounce back (Fig. VI). Since the speed of sound through water is known, the distance to the bottom can be determined. Corrections have to be made for varying temperature conditions which affect the transmission of sound through sea water, but these have been reduced through a simple routine.

Another method used by Oceanographers today is called Side Scan Sonar. Unlike an Echo Sounder which uses a vertical sound wave that reflects from the seabed below the ship, Side Scan Sonar uses an oblique beam of sound which scans an area of sea bottom and produces a kind of "aerial picture". Using this technique, undersea geological mapping[20] can be carried out in a similar way to aerial photography[21] on land.

It has been found that by increasing the power generated in the sound waves it is possible to get reflection not only

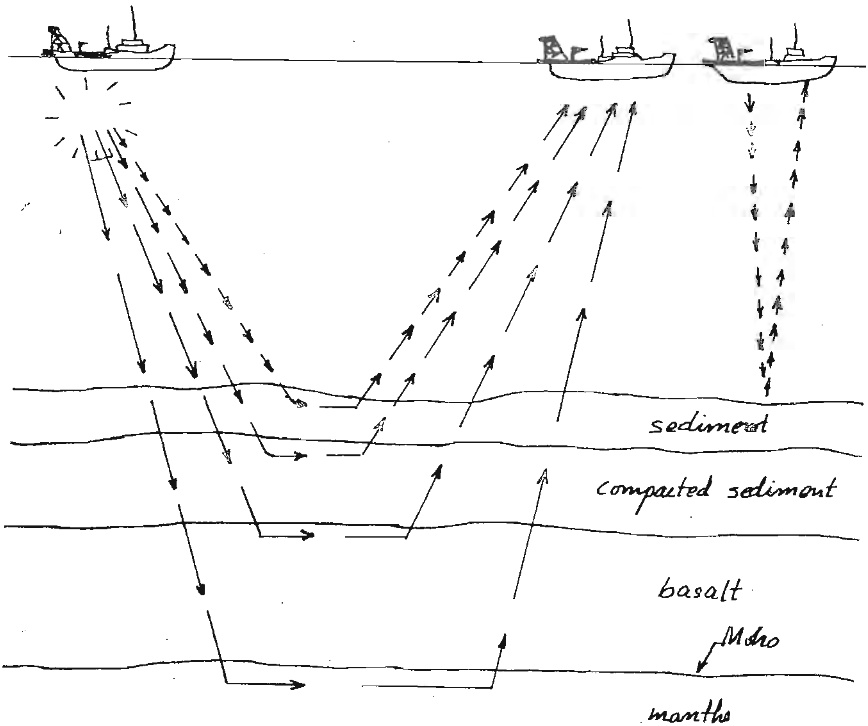


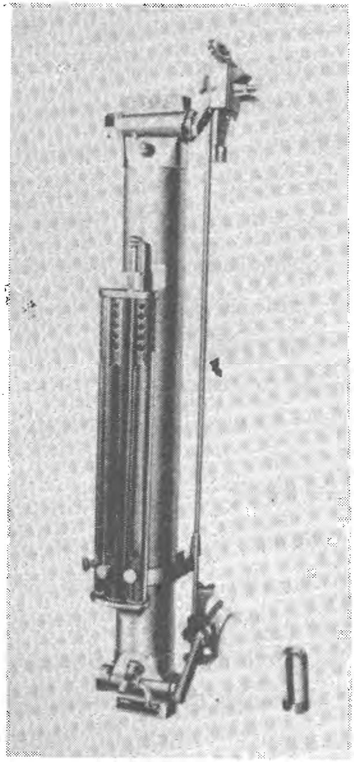
Fig. VI : Probing the depth with sounds. On the left, sound waves from underwater explosion are refracted by the different layers of sediment and crust. Right, pulses from an echo sounder give depth to top of sediments.

from the seabed, but also from harder rocks underlying the soft sediments on top. This method is called "Seismic Profiling" by Oceanographers. Another sound technique that has enabled marine geologists to probe deep into the crust of the earth is deep-sea seismics. It is necessary to use explosion of dynamite or TNT[22] in the ocean to generate sound waves that penetrate deeply into the crust[23] of the earth. The speed of sound varies in layers of different density. This causes sound waves to be refracted[24] and to arrive back at the surface at different times and places. By studying the arrival times and patterns of these returning sound waves, Oceanographers can determine something of the nature of the crustal layers through which sound waves have passed. This technique has long been used on land for oil prospecting.

In the early days of oceanographic exploration most bottom samples were taken by a dredge — a coarse netting bag on a rectangular frame that is dragged along the sea bottom for picking up marine life. Today a similar technique is used. A heavy bag made of chain mail fitted with a strong steel mouth, is dragged very slowly behind the ship by a strong cable. Another widely used bottom sampler is the Grab Sampler. In the past, the Grab sampling device, consisted of steel jaws held open during descent of the heavy sampler and then upon striking the bottom the jaws are closed by a spring or other type of release.

Another way of obtaining sediment samples is by using a gravity corer. The corer weighted down by heavy lead weight is forced into the sea floor by gravity or the use of an explosive, and the sediment enters the hollow tube at the bottom. Today most of the cores are collected with the gravity corer, a long steel tube about five cm. in diameter with a 250 kg lead weight attached to the top (Fig. VII). The corer is lowered by a wire from a Winch on board the ship. To make the corer fall quickly so it will go deep into the sediment a large weight is hung about 30 metres below the device. When the weight touches bottom it trips a switch that lets the corer fall freely. The corer is still connected by a spare loop of wire, so it can be pulled back to the surface with its sediment sample. An improved version of the corer is the piston corer, which sucks the sediment core up into the tube, enabling oceanographers to bring up corers of 20-30 metres from the deep oceans.

The device, originally invented by the Great Danish Explorer Fridtjof Nansen is used even today to take water samples. This device, is a cylinder fitted at each end with a valve (Fig. VII). The bottle is attached to the wire in an open position, with a clamp at the bottom and a catch at the top. When a cylindrical weight, called the "Messenger" is dropped along the wire and hits the catch, the top of the Nansen bottle is released and it flips over, closing the valves and sealing off the water sample. At the same time, the bottle releases another messenger to flip the bottle beneath it. Using the Nansen bottle water samples could be taken at any depth and brought back without contaminating it with other water.



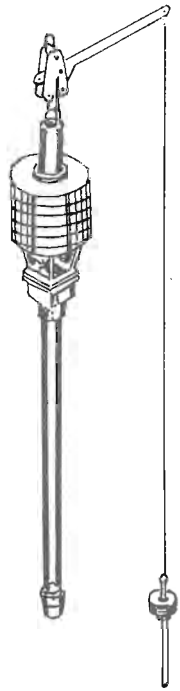


Fig. VII : Nansen bottle for taking water samples

Piston corer for taking a column of sediments

Hauling up of water samples for analysis has today given way to instruments that can measure such things as pressure, temperature, salinity and oxygen content directly at any depth and relay the information to the surface by electric cable. We cannot see very far into the oceans, but underwater cameras and television have made it possible. Biologists now can study many of their subjects in the natural environment. Geologists can see for themselves what the shallow bottom looks like. Deep water cameras have already brought back pictures from depths of 10,000 metres. Today, even a tantalising glimpse of the abyssal scenery is possible by direct observation from a bathyscaphe (from the Greek, meaning "deep boat").

The bathyscaphe which was invented by Professor Auguste Piccard, is essentially a pressure resisting steel chamber with observation ports that is supported by a float filled with gasoline. It is a kind of undersea balloon whose descent and ascent are regulated by siphoning off small amounts of gasoline and dropping ballast. On 23rd January 1960 a bathyscaphe, named Trieste descended to the bottom of Challenger Deep in the Marinas Trench to a record depth of 11,040 metres with Piccard's son, Jacques, and Donald Walsh of the United States Navy.

More and more scientists feel the need to explore the ocean by diving and seeing for themselves. But alongside these developments has come a new sophistication in oceanographic instruments and measurement with remote-controlled sensors on the ocean bottom, ocean surface and at depths in between. With additional information now available from surface and satellite monitors of ocean conditions all over the world, it is possible to make accurate predictions of the state of the sea. The importance of such systems for utilization of ocean resources is immeasurable. Let us now examine the vast resources of the oceans.

3. The Wealth of the Oceans

In the oceans are enormous amounts of valuable metals, food and even drugs enough to supply all mankind for years, even centuries to come. Estimated resources of copper in the ocean are more than hundred times that of the known resources on land. Vast quantities of oil and natural gas are now being pumped from the North Sea and Gulf of Mexico. Valuable deposits[25] of Manganese and Phosphates are known to exist on the ocean bottom, but are not yet being exploited. Down through the Millennia people have harvested bountiful crops of food from the sea and even today more than three quarter of the world's population depends on fish for the greater part of its animal protein. Marine organisms with novel chemical constitutents are excellent sources of new drugs. One hope of oceanography is that it may increase man's scientific knowledge of the oceans and help man to systematically and effectively exploit these resources.

3.1 Beach deposits:

All the time that the oceans are being stirred by the currents, tides and waves, they are being fed with minerals[26] and other materials washed down from land by rivers and streams. On reaching the sea these minerals may be moved alongshore or seawards by the action of waves, forming beach deposits. A variety of minerals are presently being extracted from such beach deposits. Considerable quantities of minerals such as gold, chromite (yielding the metal chromium), diamonds, magnetitite (yielding iron), Monazite (yielding thorium), Platinum, Cassiterite (yielding tin), Ilmenite (yielding titanium), Zircon (yielding zirconium), are found in beaches all over the world (Fig. VIII).

In addition to the beaches that we now find above present sea level and those presently at sea level, we can expect to find a number of submerged beaches formed during the Ice Ages when sea level was much below its present level. These submerged beaches have been found to contain the same minerals such as those found on present beaches. A study of the present beaches in any area, thus, should provide valuable information concerning what can be expected to be found offshore.

Beach deposits have been mined[27] in South Africa for diamonds, for Platinum and Gold in Alaska, Iron in Japan. The beaches of India, Australia and Brazil, have been worked for many years for their Titanium, Thorium and Zirconium.

In Sri Lanka the Northeastern and Southwestern beaches have been worked for over 80 years. The beach sands in these areas contain Ilmenite, Rutile, Zircon and Monazite. The mining of these beaches is seasonal and storms generally replenish the valuable mineral content

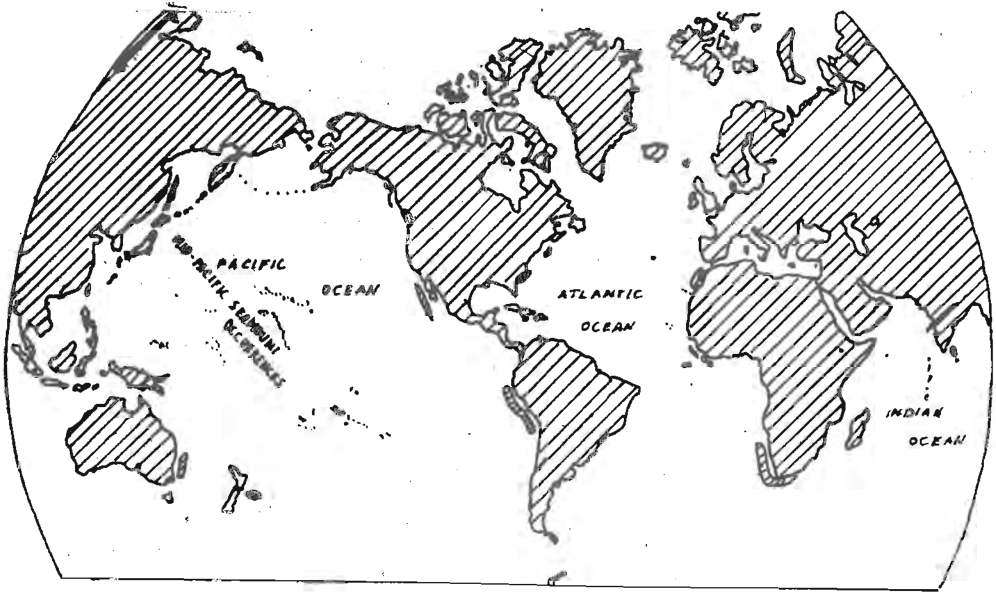


Fig. IX : Known Phophorite occurrences on the Ocean Floor.

of mined areas with minerals from the offshore area (Cruickshank, 1962). Large deposits of beach sands commonly known as 'black sands', for their blackish appearance, are found abundantly in many parts of the coastline.

3.2 Ocean Water:

Salt is the first mineral to be taken from the ocean. Sea salt is known to have been used by primitive man thousands of years ago. It was extracted, even as it is in many places today, through solar evaporation of sea water.

It is quite surprising how much solid matter exists in a dissolved state in ocean water. Perhaps it is easier to understand the wealth of ocean water if we consider the amount of various minerals that are dissolved in one cubic kilometre of sea water. One cubic kilometre of sea water holds 100 billion kilograms of salts altogether and contains 62 billion kilograms of Sodium Chloride (table salt), 5 billion kilograms of Magnesium Sulphate (epsom salt), 155 million kilograms of Bromine and the rest is made up of calcium sulphate and potasium sulphate. In addition, there are small amounts of aluminium compounds together with compounds of Iron, Manganese, Copper, Lead and even small traces of Radium. In fact, all metals are found in the sea including gold and silver.

In Sri Lanka salt is extracted from seawater by solar evaporation. Salt producing areas are located in the Northern, Western and Southern regions. The State owned National Salt Corporation produces annually around One Hundred and Fifty Million kilograms of salt and small amounts of epsom, iodised salt and gypsum.

One other very important use of ocean water is helping to solve the problems of fresh water needs in several countries like Malta or Saudi Arabia. This can be done by towing icebergs[28] or by desalination.

Ninety per cent of the world's ice (the largest source of fresh water) is in Antarctica. Antarctica is full of icebergs. If a large iceberg could be towed to a country in need of fresh water, it would provide a large volume of it. A square kilometer by 250 metres iceberg would provide 35 million cubic meters of fresh water. There are many desalination plants in the world. The biggest of them all in Malta uses sea water to produce 100,000 cubic meters of fresh water.

3.3 Mineral wealth of the Continental Margin

The shelves of the world contain deposits of several materials such as sand and gravel, shells, phosphorites, gluconite (a mineral rich in potassium), coal, sulphur, petroleum and gas and the already mentioned submerged beach deposits of gold, diamonds, ilmenite, zircon, etc. The continental slope has phosphorite, iron-containing minerals.

Most probably the most important mineral commodity, from a standpoint of tonnage mined, is sand and gravel. They represent important reserves of aggregate for concrete in these days of decreasing land sources. In 1972 for example, about 12 per cent of 112 Million tonnes of sand and gravel used in Britain came from the continental shelf. In Sri Lanka too with decreasing land sources of sand and the environmental hazards involved with the removal of sand offshore sand deposits found abundantly in the Northeast and Northwest could be a future source of this valuable material.

In warm tropical waters large deposits of coral and shells are found abundantly in the shelf region. Coral and shell which are mined for the manufacture of cement and lime from offshore areas in many countries have however contributed to severe coastal erosional problems. In Sri Lanka too the extensive mining of coral from coastal and nearshore areas have contributed towards damage caused to the coastline from Ambalangoda to near Matara.

An important mineral for the fertilizer industry phosphorite is found in the continental shelves as well as on the slopes in many parts of the world (Fig. IX). This mineral is generally found in the shape of crusts, nodules and pellets. Such deposits have been found off Japan, South Africa, Argentina, east coast of U.S.A. and along the west coast of North and South America and off New Zealand. Large deposits of phosphate are found on land and therefore it is not yet economical to make use of it, although one estimate puts economically workable phosphate on continental shelves at 3×10^{10} tons - enough for 100 years at the present rate of consumption.

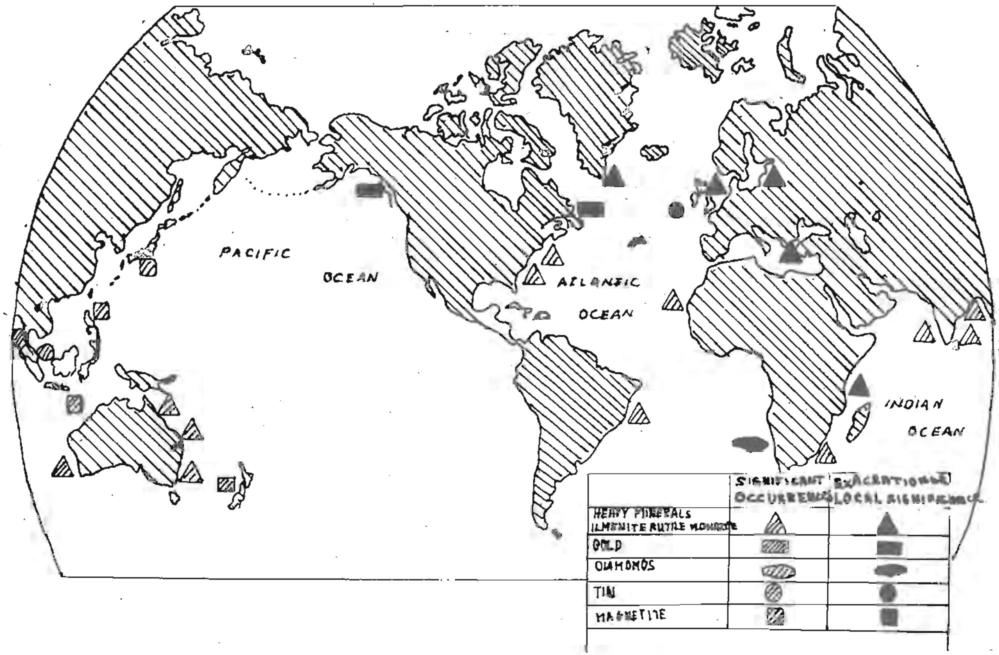


Fig. VIII : Mining of Heavy Minerals from Beach Sands and Submerged Beaches

Phosphorites are thought to have formed from decomposing phosphate matter on the bottom of the shelf. When large numbers of marine organisms are killed by rapid changes in temperature they settle down on the ocean floor and then are transformed into phosphorites by chemical and physical processes.

In Sri Lanka phosphorite nodules have been reported off Kirinde in an area of upwelling. Although we have presently land based deposits of phosphates we still import a considerable amount of phosphate from abroad. The National Aquatic Resources Agency (NARA) is reported to be organising an oceanographic cruise to evaluate the potential of these phosphorite nodules in 1986.

Another interesting potasium rich mineral called glauconite is also found abundantly on the shelf and slopes of the ocean. This mineral gives sea sand taken from the bottom of the oceans a green colour. Off the coast of California some dredge samples have shown nearly 80 per cent of this greenish material. At present this material is not used for any industry but in the future it could be used as a source of potash for use in agriculture or as a source of potassium or potassium compounds. This material is characteristically a constituent of green muds and sands found in the offshore areas of Sri Lanka.

Underground deposits on land have been found to extend beneath continental shelves. In Britain for example, the coal deposits of north-eastern England and eastern Scotland, are presently being mined under the North Sea shelf. Another material which is mined from under the shelf is sulphur.

Many valuable minerals on the continental shelf are represented by submerged beach and river deposits which were formed at times when the sea-level was much lower than it is now. These submerged accumulations of valuable minerals were concentrated in rivers and were partly drowned by the rising sea-level. The tin deposits along the coast of Thailand, Malaysia and Indonesia come from such submerged areas. Off South Africa, diamonds are being mined from old drowned stream deposits. In Sri Lanka such submerged areas are found off the south-west coast. Presently the National Aquatic Resources Agency is carrying out investigations to find out whether these areas have accumulations of valuable minerals.

3.4 Offshore Oil and Gas

The oil and gas industries were the pioneer industries in utilizing the wealth that lay beneath the seas and oceans. Offshore oil prospecting is known to have originated from the shallow waters of Southern California in 1899 (Thomasson, 1958). Widespread activity began in 1930 and by the 1940s, wells were being drilled in the shallow waters of the Gulf of Mexico.

Today, there is worldwide activity on many continental shelves. The largest oil deposits are found in the North Sea. During the last decade 70 countries have drilled in the sea and over twenty are producing. The United Kingdom, Norway and Nigeria have become major producers. Oil and gas are trapped in hardened sediments that were deposited in prehistoric seas. The continental shelves are estimated to contain 50 per cent or more of the earth's oil and gas reserves.

Oil deposits usually can be found in offshore areas where the continental shelf is covered with sediments a few kilometers thick and where there are such places where the oil could be trapped in the sediment. Most oil and gas is formed by the decay of marine animals and plants in shallow water. This process needs suitable time, place and conditions.

In the Gulf of Mexico oil has been found on the continental slope. It is believed that oil may be found along the lower reaches of the continental slopes and on the deep ocean floor itself.

The continental shelf of Sri Lanka is covered with thick sediment layers in certain areas such as the Gulf of Mannar and Palk Bay Strait. The Ceylon Petroleum Corporation which is responsible for all exploration work has leased the offshore areas to foreign companies on a profit sharing basis. Four offshore wells[29] have been drilled upto date and no oil has been discovered.

3.5 Mineral Wealth of the Ocean Deep

There is a fortune in valuable metals liberally lying about the ocean bottom. The metals in question are manganese, cobalt, nickel and copper. All of these have strategic and commercial importance. Material containing these metals are lying about many areas of the sea floor in lumps called "nodules". Scattered over the seabed, these nodules were first discovered by the 'Challenger' expedition of the last century.

The peculiar lumps of valuable minerals are somewhat built up layer by layer rather like an onion. Usually there is an inside hard centre (core) consisting of a shark tooth or a piece of volcanic rock. It looks as if these hard cores have acted as seeds, rather like seeds that are used to make oysters form pearls in the Japanese cultured pearl industry. Millions of square kilometers of the Atlantic, Pacific and Indian Ocean floors are carpeted with nodules (Fig. X). On the average the nodules contain something like 20 per cent manganese, 15 per cent iron (not considered of importance here), 0.5 per cent of nickel cobalt and copper, and 64.5 per cent silica.

The nodules are roughly potato-shaped and usually run from about 1 cm to 25 cm with occasional large ones in deep dredge hauls.

The manganese may come from several sources. Some of if is leached out of the land and carried to the sea by rivers. Some of it thrown up by undersea eruptions that pour out volcanic material into the oceans. Some of it is leached out directly out of undersea rocks. Once in the water, the manganese quickly reacts with dissolved oxygen and, as part of the endless activity of the sea, precipitates out as manganese dioxide on anything handy. This can be found deposited all over the ocean bottom. It turns up as small grains in deep sea muds and clays.

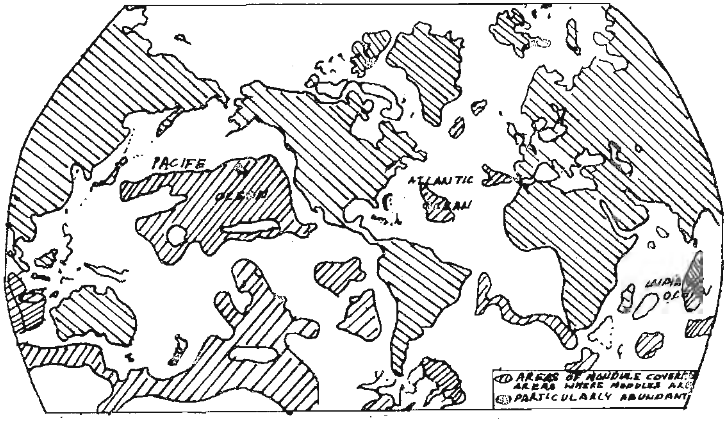


Fig. X a): Distribution of Manganese Nodules in the Ocean

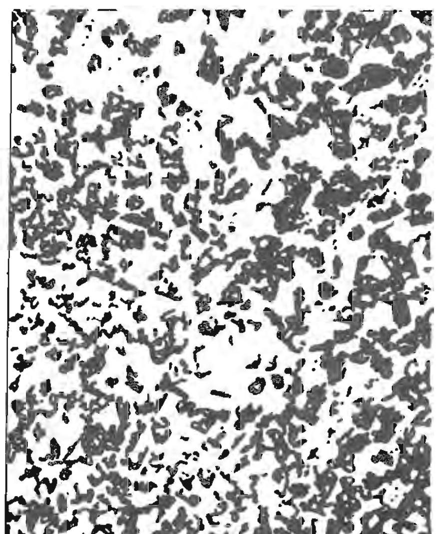


Fig. X b) : Underwater photograph of Manganese Nodules lying on the sea bed.

If there is any small object lying about, such as an old shark's tooth, a whale's ear bone, or just a lump of clay, it will precipitate around that and form a nodule. As the manganese dioxide forms itself into nodules, it carries bits of cobalt, nickel and copper along with it. In this way the nodules get their mixed cargo of valuable metals.

Another promising area for seabed exploitation lies on the bed of the Red Sea basins where a 90 meter thick deposit, rich in copper, zinc, lead, silver and gold, has been discovered. The estimated value of the minerals present in the Red Sea basins exceeds several billion dollars. The Red Sea basins' waters contain water much hotter than normal and with salinities almost eight times higher than normal and are therefore called the Red Sea brines.

3.6 The Oceans as a Source of Food

Men have relied on the sea for food from time immemorial. Oysters and lobsters, considered a luxury today, were probably a staple and monotonous diet for many coastal people in ancient times. Today the range of sea food avaialble to us is much wider than it was in ancient times, simply because over the years improved techniques of fishing have been developed.

The problem today is not that of catching enough fish, but the possibility of catching too many and temporarily reducing the numbers of a particular species, to a dangerously low level. As recently as 1937, the various species of whales yielded as much as 16 per cent of the world's total marine catch. By 1970 the cruel depletion of these slowly reproducing creatures had reduced the catch to two per cent. It is likely that even this low percentage corresponding to one million metric tons of whale a year, will disappear over the next decades. Another example of this dangerous tendency is the fall of the Peruvian fishery, which from a 1970 production of 12 million tons, went down to 2 million tons in 1973.

It is expected that the world population will double by the year 2000. Mankind faces the bleak outlook of continuing chronic hunger for a majority of the earth's people, unless food supplies can be multiplied. Seen in this light, the ocean presents an opportunity and a challenge that man must face up to with courage and understanding.

Taking food from the oceans today is largely a matter of hunting. With research and capital investments, there have been tremendous changes in the fishing industry. But however productive it may be in its own terms, hunting is the most inefficient way to exploit a food resource.

The whole basic system of harvesting the fruits of the sea must be changed — is in fact changing.Today aquaculture, the farming of the sea, is in progress, and when fully developed it will be as revolutionary an advance over fishing as agriculture has been over hunting on the land and one might call it the "Blue Revolution".

Sea farming has historical precedence much deeper in the past than is generally assumed. Oysters were cultured in the orient long before the Christian era. Primitive forms of aquaculture both in seawater and brackish water have been part of the traditional economy of Southeast Asia for many centuries. Farm ponds are constructed by clearing mangrove swamps and diking them with mud slabs. The ponds are then stocked with fry[30] of various kinds, most commonly milkfish, mullet and shrimp. Initially they are fed in a "nursery pond" while a community of algae, bacteria, worms and other plankton is raised in the adjoining ponds. When the fry attain fingerling size, they are transferred to these production ponds where they mature within a few months, or at most, a year. The average yield of such a pond is about 540 kilograms per hectare, which compares well with protein production.

It has been calculated that if 40 million hectares of wetlands were set aside for aquaculture development, the potential yield, using improved methods of production, would be 100 million tons a year — the equivalent of the potential yield from the world's commercial fisheries.

Some success has been already recorded. The French who began oyster farming in the 19th century, produce 500 million oysters every year for the European market. The Japanese have been able to raise the productivity of oysters from 675 kilograms per hectare under natural conditions up to 80,000 Kilograms per hectare under culture — a hundred fold increase. In the Caribbean, Green turtles are farmed. Kelp and seaweed are being cultivated for human consumption. Carp, mullet and milkfish, plaice and whitefish, trout and salmon, shrimp and squid are already being farmed.

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With the population of the world increasing, certainly it would seem that mankind has no choice but to make the effort that will enable it to increase substantially its production of food from the oceans.

In Sri Lanka aquaculture projects are run by the Ministry of Fisheries and NARA. A considerable extent of sea, brackish and fresh water areas have the potential of being developed for the culture of economically valuable aquatic forms. Work on mussel culture at Trincomalee, (Fig. XI), cage, pen and pond culture of carps, Tilapia and prawns, and the utilization of brine shrimp cysts[31] from salterns is in progress. A pearl oyster culture project was set up with Japanese collaboration in 1985 in Trincomalee and a prawn culture project has been set up in Batticaloa. We are only at the beginning of this development, but we could look to a future of increased activity in this field.

3.7 Drugs from the Sea

Ancient maritime peoples, notably the Chinese and Japanese, ate a variety of iodine-rich seaweed that undoubtedly accounted for their low incidence of goiter[32]. They also used certain seaweeds as medicines.

The search for drugs from the sea is a recent undertaking. Workers in many disciplines have become involved, including chemists, marine biologists, pharmacologists, microbiologists.

Some marine organisms, are venomous or poisonous. Because toxicity is indicative of potent physiological

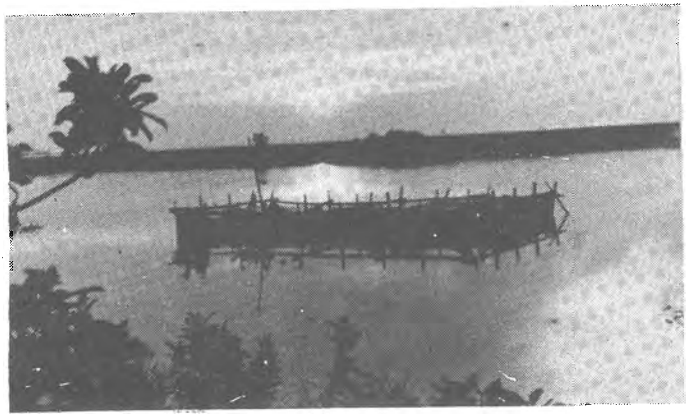


Fig. XI a) : Cage culture of Tilapias at NARA

Fig. XI b) : Harvest of Tilapias

activity, it is likely that some of the toxins from marine organisms will yield new compounds having marked pharmacological activities. Many other compounds from marine organisms have inhibitory effects on a variety of micro-organisms that cause disease in man. Such natural products may enter directly the realm of medicine or they may serve as models for the synthesis of new and effective drugs.

Cod liver oil from fresh livers of a variety of fish called Gadidae is effective in treating deficiency in Vitamin A and D in humans, and is incorporated into ointments for the treatment of wounds, burns and abscesses of animals. Liver oil from the fish Halibut is also used in Vitamin A and D therapy. Fish glue obtained from the inner membrane of the swim bladder of various species of sturgeon and hake is sometimes used as nutrient and food instead of gelatine and as a protective colloid in the manufacture of various chemicals (Rahwa , 1968). Alginates from brown seaweeds and agar and carrageenan extracts from Red seaweeds, are used extensively in the food, cosmetic, pharmaceutical and other industries. An extract from a red seaweed soothed throat irritation of soldiers who had been gassed during World War I (Chapman, 1950). Carrageenan denatured with Whisky was highly recommended for coughs in a number of bars in New York and had predictably good results. Extracts of seaweeds are also beneficial in cancer therapy. Tetro dotoxin, one of the most toxic of low melecular weight poisons, is found in certain ocean sun fishes and porcupine fishes (Brown and Mosher, 1963). These are just but a few of the numerous marine organisms with novel constituents that are excellent sources of new drugs.

New developments in methods of extraction, physiological evaluation, structural determination and chemical synthesis should in the future provide mankind with a bonanza of new cheap and effective drugs to fight various sicknesses and diseases.

We have examined the great wealth of the oceans. Its vast mineral food and drug potential. The ocean is the last great frontier remaining on this planet. Its vast store of wealth in the form of minerals, food and drugs has hardly begun to be tapped.

4. Ocean Mining Methods

The minerals of the oceans pose many problems for the future. The most important among them is the seemingly simple one of devising methods of collecting in bulk (mining) the riches of the oceans. While hundreds of methods exist for the mining of land deposits, we find for the ocean relatively few methods.

People mining minerals on land have always found it a difficult task to overcome nature. At sea, we are faced with nature at her most capricious level. The phenomena of waves, tides, taunamii and the constant movement of the waters are but a few of the difficulties one has to overcome in designing effective ocean mining methods. Another problem of recovering wealth found in ocean waters is mainly those of scale. Work in hundreds of meters of water are involved and huge installations would be required.

4.1 The Mining of Marine Beaches and Offshore Minerals

Beaches where accumulation of minerals occur, have been mined for over hundred years. In the early days almost any practical method of picking up material off the ground was used. For example, until recently, the mineral sands at the Pulmoddai deposit in Sri Lanka was collected by hand. Today the sand is heaped up by a bulldozer and then an excavator scoops it up. It is then loaded into lorries or wagons and transported to the processing plant where the valuable minerals are separated from the other materials. In some countries large bucket wheel excavators with capacities of 11,000 cubic meters are being put into service. In a bucket wheel excavator instead of the traditional one bucket, several buckets are built around a wheel, which rotates and scoops up material filling up all buckets in one rotation of the wheel (Fig. XII). Such an excavator's daily capacity corresponds to the work done by 2000 men with pick and shovel.

Offshore submerged beach minerals have been mined from the beginning of this century. The most important offshore mining activities take place in Thailand and Malaysia for the metal Tin, in Australia and Brazil for Titanium rich minerals. The basic principle used in collecting soil from shallow water is dredging or scooping up material using an apparatus called a dredge.

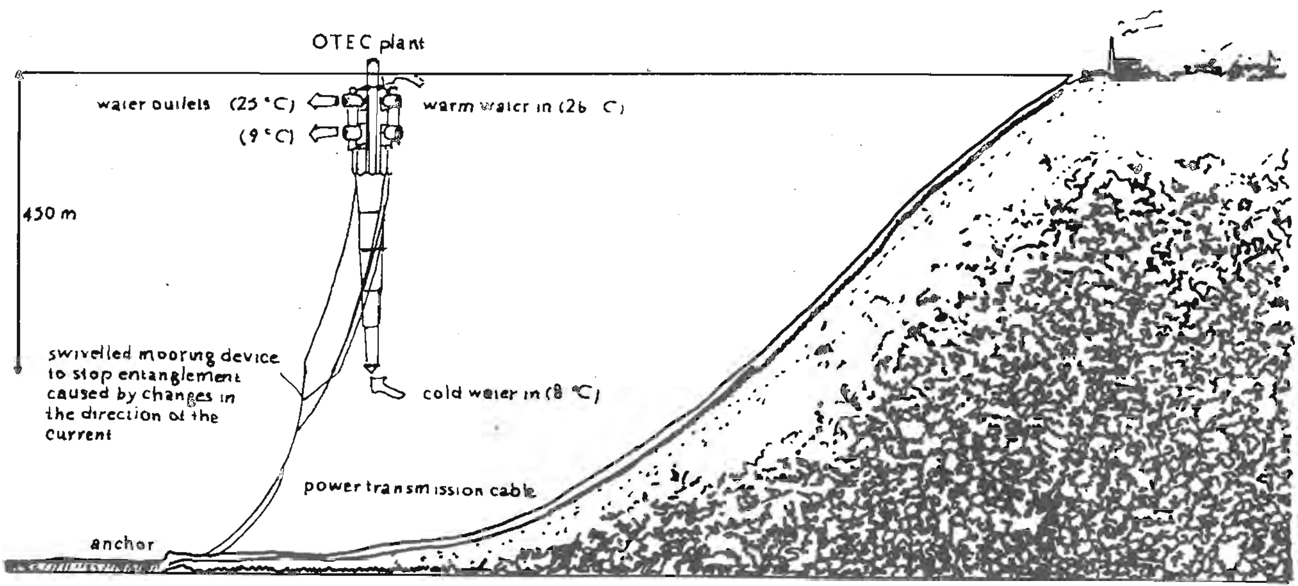


Fig. XII : Artist impression of the proposed 'Ocean Thermal Energy Conversion' (OTEC) plant which would use the difference in temperature between the surface of the ocean and deep waters to obtain electric energy. (Source: G. Harber 1977 Solar power from the oceans in New Scientist)

The first dredge in offshore areas was introduced in 1908 off Phuket Island in Thailand. In this dredge called the bucket-line dredge, digging tools or buckets were attached to an endless chain mounted on a ladder and is drawn over the edge of the ladder. The heavy ladder over which the chain and buckets are drawn is rested on the bottom and dredging operations begin. The dredged material is drawn up the ladder, and as the buckets ride over the rear teeth of the wheel rim, arranged to fit the links of the chain, they dump their load into a container from which the dredged material is emptied slowly into devices to separate the valuable minerals.

In the last 70 years, many changes have taken place in the design of the bucket dredge. Modern dredges have 150 buckets compared with 35 buckets and are operated by diesel engines instead of the steam engines used on the old dredges. The buckets bring up material at a speed of 36 buckets per minute compared with 11 buckets per minute and could be used in water depths of 60 M compared with 15 M of the old dredge and they have a bigger volume (Fig. XIII).

Another very commonly used method which has been in use for about a century is the Grab dredge. Grab buckets called clamshells consist of a dredging device which when lowered to the bottom of the sea, on hitting the bottom, bites into the bottom material and contains it inside the closed shell. The bucket and load are then hoisted to the surface where the shell is opened to dump the load. This dredge is capable of digging and hauling up about 1500 – 2000 tons per hour of dredged material (Fig. XIV).

Fig. XIII Giant Bucket-wheel Excavator.

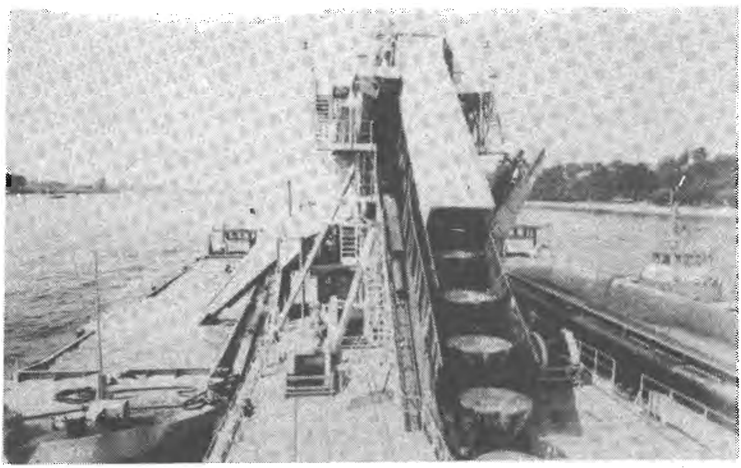


Fig. XIV Bucket dredge for mining offshore minerals.

Because of its simplicity, the Grab bucket could be used effectively in even deep waters.

Since recently another type of dredge has come into operation using the principles of Hydraulics to suck the bottom material. The cutter suction dredge consists of a hull on which is mounted a suction pipe and support, with motors and controls, and a discharge line. A cutter head or sharp toothed device is mounted on the lower end of the suction pipe to cut and soften up the soil. These dredges are also used in dredging canals and harbours and in providing filling material for the creation of land in near-shore or low lying areas. For example, Crow Island on which the National Aquatic Resources Agency has been built was filled up by using a cutter suction dredge which pumped up sand from the Kelani river to fill up the marshy land.

The cost of building these dredges are very high and they could operate only in calm seas with waves of not more than 1.5 meters. Therefore, mankind is faced with the challenge of developing cheaper more efficient dredges to harvest the enormous wealth that has accumulated in submerged beach deposits.

4.2 Extraction of Oil and Gas from the Continental Shelf

The oil and gas industries were the pioneer industries in exploiting the mineral wealth that lay beneath the oceans. When man realized that oil fields on land could extend into the sea, he built bridges into the sea and drilled from them. When the oil fields became further away from the shore, artificial islands, Platforms were built for oil well drilling. To find oil and gas holes were drilled up to 3000 to 4500 meters from platforms or traditional ships modified for the purpose. When an oil deposit is found and has enough oil to be extracted, the drilling ship or platform is replaced by a fixed platform.

In most instances, production takes place via steel or concrete platforms built with supporting legs resting on the seafloor. A platform rig[35] is essentially a land rig that drills wells from a position atop the platform. It is then moved off by barge or other vessel when the drilling is finished. If oil is found the platform then houses all production equipment.

In waters that are sought for a fixed platform wells are drilled with mobile offshore rigs on the floating jack-up platforms. In this type of platform, a few legs (three to a dozen) which can be moved up and down vertically stick through sleeves on a 'float' and when under two they are moved up and carried clear of the water (Fig. XV). This enables the platform to be assembled in even very shallow water. A big advantage over the fixed type platforms, which could only be constructed in deep water environments and have to be towed long distances and therefore are more costly. On location, the legs are pushed down to the bottom and can be adjusted to raise the platform clear of the waves. The first jack-up platform made its appearance in the Gulf of Mexico in 1950. The Jack-up Platforms are now designed to operate in sea depths up to 90 meters and they are stable in waves of over 20 meters. Fixed platforms are constructed of large table like frameworks pinned to the seafloor with piles, and can operate in depth upto 120 meters (Fig. XVI).

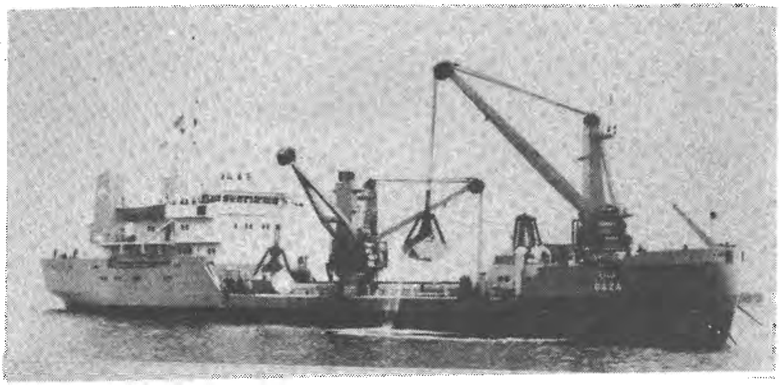


Fig. XV Grab dredge.

Fig. XVI A giant fixed oil-drilling platform. This 3000 ton platform can drill up to 2500 metres deep.

More recent mobile drilling platform rigs are semi-submersive vessels. Here the 'float' is submerged in water and the drilling platform is made to be above the sea level (Fig. XVII). It provides greater stability for drilling in heavy weather and in deep water. Most semi-submersibles can be anchored at the site and are self propelled. One such semi-submersible vessel built in Japan and named the Ocean Prospector, measures 103 x 79 metres and can travel up to 10 kilometers per hour forward and 5 kilometers per hour in reverse.

From a single platform ten to twelve wells are usually drilled, slanting outwards to tap the largest possible area of the field in which they are working. Pipelines connecting each platform gather the oil which is pumped to a central point for transmission through a major pipeline to the shore. The most modern system in use is called the sub-sea method. Here the wells are completed with all the openings of the wells (well heads) connected through a 'Christmas tree' (valve assembly) to a storage tank. The connecting pipes and the storage tank are submerged, and the valves controlled automatically. The central storage tank is connected direct to the shore or to a floating tanker.

Some platforms operating now in the Gulf of Mexico stand 385 meters high, which is taller than New York's Empire State Building (381 meters) and require 40,000 tons of steel to build and cost 40 - 50 Million Dollars.

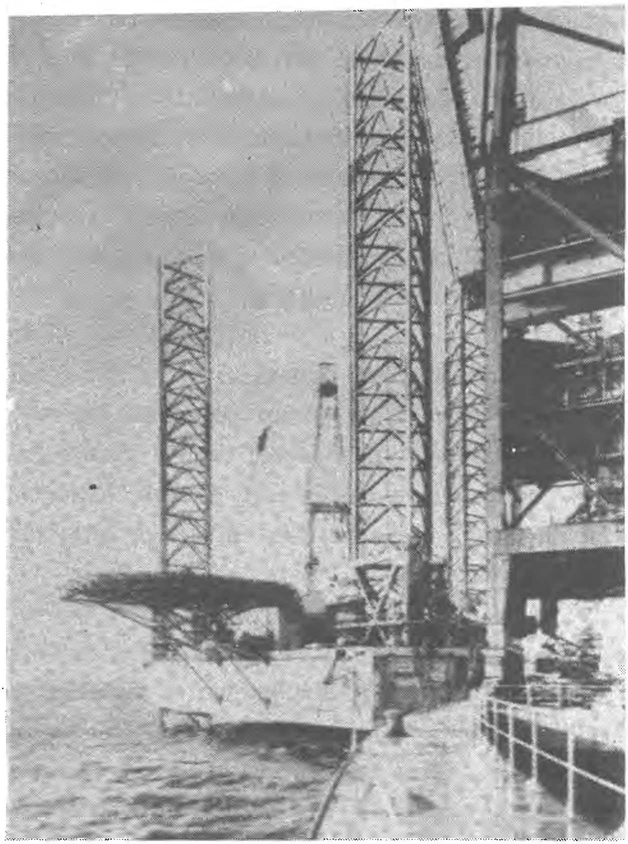


Fig. XVII   A jack-up oil-drilling platform "with adjustable legs".

4.3 Mining the Wealth of the Ocean Deep

Although the sea bottom is thought to be very rich in minerals the deposits have hardly been exploited at all so far, except for petroleum, because of the difficulties of prospecting on the ocean bottom. The problem which has been confronting technicians for several decades is how to harvest these deep-water nodules. Effective technology for extracting non-petroleum minerals from the sea bottom is now becoming available.

The manganese nodules, locked in a remote, forbidding environment, were only of an academic interest until 1959. In that year, John Mero, then a young graduate student in mining engineering at the University of California, published the first effective argument for deep-sea mining.

Today the simplest of the systems being developed is John Mero's continuous line bucket, a series of one-ton buckets on 15,000 meters of 10 centimeter thick rope. The line which hangs between two ships, is towed slowly so that each bucket drags along the bottom and scoops up the nodules (Fig. XVIII).

Another system which has been developed — perhaps more effective than the line and bucket system, is the suction-lift system. Suction dredges winnow nodules from the seafloor and then suck them up a pipeline by means of hydraulic pumps or compressed air just like a vacuum cleaner.

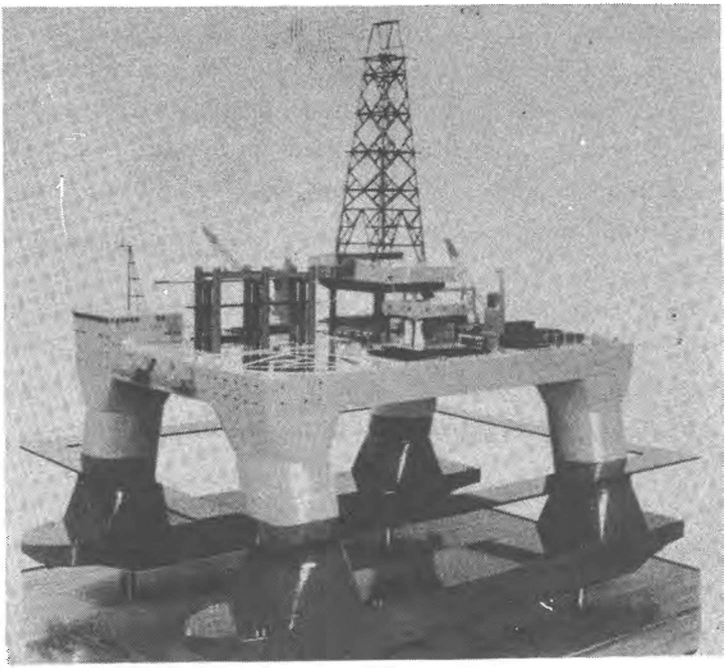


Fig. XVIII A model of a modern semi-submersible oil-drilling platform.

Among the many sophisticated devices built to extract nodules, the system based on the simple idea of transforming a two-dimensional deposit into a three-dimensional one has been tried out successfully in the Pacific Ocean. This is done by collecting the nodules by using various mechanical methods, heaping them up or, in other words, concentrating them in a ridge (Fig. XIX). This ridge is later removed by means of suction pumps connected to the surface.

The French are developing a fleet of remote controlled self propelled vehicles (bugs) that could dive down, scooping up nodules and return to the surface where the nodules could be transferred into a nodule carrier.

There are several problems facing nodule mining. The great depths at which they are found, makes recovery very costly. The uneven ocean floor poses another problem in nodule mining, in particular when towing nodule collectors over the sea floor. Weather condition, mining rate are some of the other problems which will have to be given consideration in designing mining machines.

Today, it is possible to build deep sea mining machines, but considerable funds and research work will be needed if mankind is to reap the harvest of nodules rich in metals from the seafloor in the near future.

Another promising area for seabed exploitation is the Red Sea brines rich in Copper, Zinc, Lead, Silver and Gold.

A method to mine these brines has already been developed by the Germans. Here long steel pipes are lowered through the centre of a specially equipped ship into the mud at a depth of 2000 meteres. At the bottom of the pipe a vibrating specially designed mining head and pump which pumps water under pressure breaks up the mud. The mud is then sucked up through the pipe to the ship and the valuable metals concentrated. And then the refuse or tailings ejected through a 400 meter long vertical pipe below the ship.

A full scale pilot project to mine the Red Sea brines will come into operation in 1985. Thus, mankind is one the verge of taking his first steps in the long journey of mining the vast store of wealth in the oceans.

5. Energy Sources of the Oceans

With oil and gas deposits being used up rapidly, mankind is faced with finding alternative sources of energy, some of which exist in the oceans. The oceans, with their enormous volumes of water always in motion, represent a promising renewable source of energy.

5.1 Tidal energy

Tidal motions have been used to provide mechanical power for hundreds of years. The first attempt to use tides to produce electricity was made in the thirties on the coast of Maine (U.S.A.). Like in hydro-electric power generation, a head of water is used to drive turbines for electricity generation.

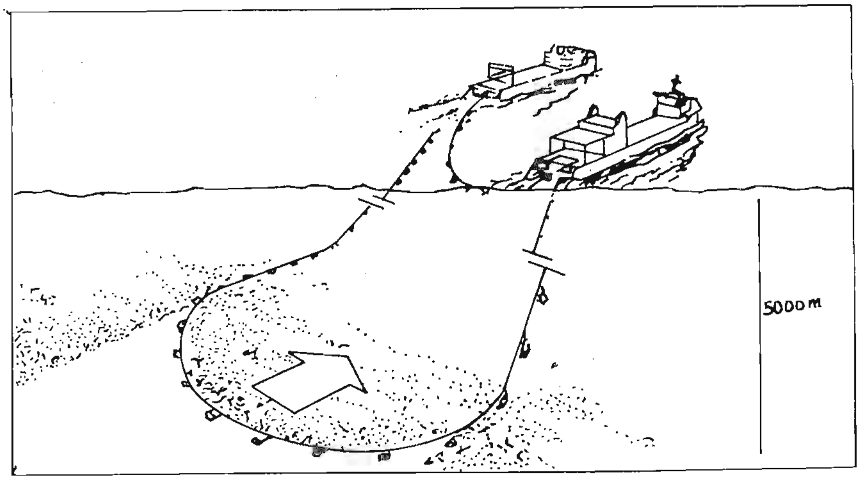


Fig. XIX Two ship continuous line bucket system of collecting manganese nodules.

Tidal waters entering a lagoon during high water and flowing back to the ocean during low water can be used to turn turbines to generate electricity. For economic generation of electricity a tidal range of at least 5 M is necessary. There are only a few places in the world where the rise and fall of the tide is that great enough to make this method of generating electricity worthwhile.

Today there are a few operational tidal power stations in the world. The biggest of these all is the tidal power station built by the French on the Rance estuary[33] at St. Male on the English Channel.

This tidal power station has a dam extending across the estuary of the river Rance, which traps the large tides of 10 meters or more. Two-way turbines built within the dam are operated first by incoming tide and then by outgoing tide. Because the turbines need a certain amount of water to operate them efficiently, they also serve as pumps to adjust the water level in the estuary that may be required in order to resume power generation between tides. A reserve head of water has also been built up for times when peak power loads occur. This station which came into operation in the late 1960s produces about 240 MW annually.

In Sri Lanka due to the very small tidal range, there are no possibilities of developing this type of energy.

5.2 Wave Energy

Another oceanic energy source under consideration today is waves. Wave power is provided by the onslaught of a breaking wave which can be captured in a reservoir, accessible by way of a converging ramp and connected with a return channel at the exit of a low-pressure turbine. However, the power can also be generated by means of devices set directly in motion by the wave itself. Experiments have been conducted in Japan, France, United States and the United Kingdom. The Japanese have tried out an electrical plant by constructing a barge and anchoring it offshore. Although hundreds of patents have been taken out, actual use is limited today only to buoys[34], ship's devices and small schemes as electricity from waves is costly.

5.3 Ocean Thermal Energy Conversion (OTEC)

Possibly the most promising of the many potential sources of energy of the oceans is Ocean Thermal Energy Conversion (OTEC). This potential source takes advantage of the temperature difference existing between water on the ocean's surface and water at great depths, often as much as 30 degrees centigrade. That difference in temperature is put to use in a way similar to the steam in a steamship. In a steamship the ship's boiler heats water to produce steam, which turns turbines and then is condensed by cool sea water for use once again. Likewise, in ocean thermal energy conversion, the difference in the temperature between water at the surface of the sea and the water some distance below would be used to boil and recondense a low-boiling liquid (ammonia, for example) in a closed system (Fig. XX).

To obtain this power from the sea, large floating power generating plants would be moored in warm seas such as

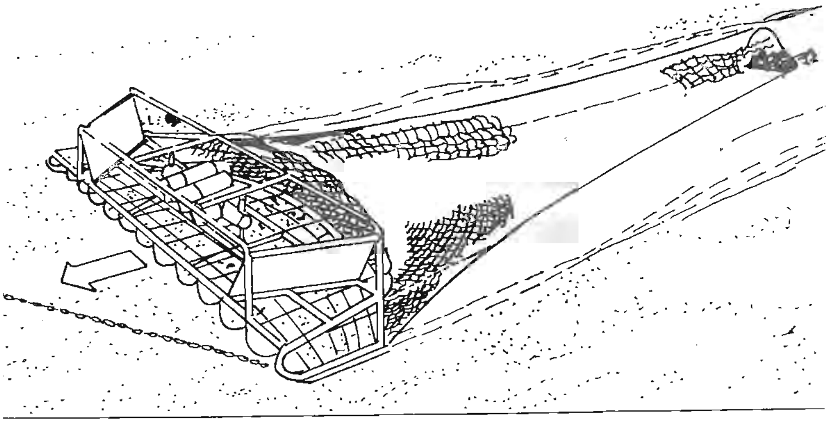
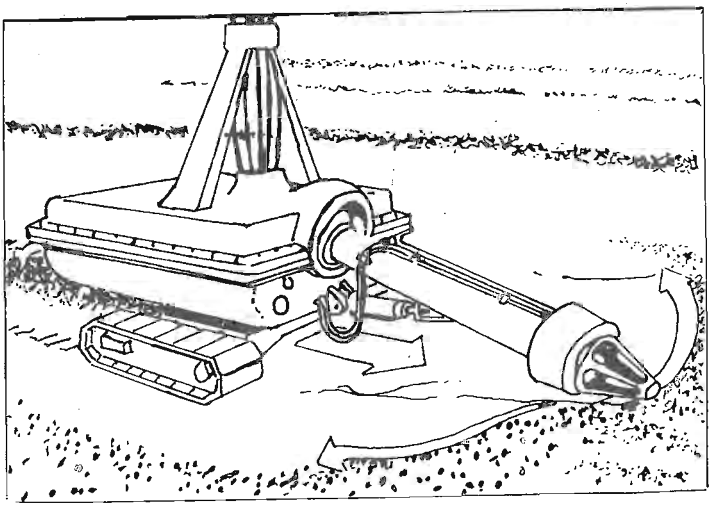


Fig. XX Collection and concentration of manganese nodules.

(a) with a drag net.



(b) employing a tank like device.

the Bay of Bengal or Gulf of Mexico. The electricity generated by OTEC, could be economically transmitted via submarine cable to land that is within 150 KM. Beyond this the power could be put to more efficient use at the generating site, manufacturing such energy—intensive products as ammonia (used in fertilizer) or aluminium metal.

Several countries are now working on designs for prototype OTEC plants. In August 1979 the United States successfully demonstrated a Mini OTEC plant off Hawaii. The plant produced 10 kilowatts of power. In 1980 a large scale One Megawatt OTEC plant was tried out in Hawaiian waters. The French proposed to build the first pilot OTEC plant in Tahiti in 1988. This land based plant would produce 5 MWe.

Capital construction costs for the first OTEC plants are expected to be around 2000 dollars per kilowatt generated in 1990 but for later models may be reduced to as little as 1100 dollars per kilowatt, making it very competitive with oil-fired generating plants.

Adverse effects on the environment in OTEC power generation would be reasonably low. It could even enhance the growth of desirable sea life by enrichment of the surface waters with mineral nutrients which are brought up from the depths in the cold waters.

The many submarine canyons found around Sri Lanka could be potential OTEC sites. The large submarine canyon in Trincomalee is one such place. In areas very close to the coast temperature differences of about 22 degrees centigrade have been reported and could be utilized for an OTEC plant based on land in the future.

5.4 Other types of Ocean Energy

Ocean currents, salinity gradient and biomass offer other sources of energy that could be harnessed from the oceans.

The principle of tapping current energy from the oceans is similar to tapping wind energy as in windmills, but currents have velocities an order of magnitude less than those of winds. The energy output is directly proportional to the diameter of the propeller and therefore proposed structures to tap energy even from the Karo-Shio or the Florida current are too expensive under their present form.

When fresh water and ocean (saline) water are brought next to each other at a semi-permeable membrane, there is a salinity gradient set up and osmosis starts. It is this osmotic pressure that could be used to derive energy. Theoretically, by mixing at the rate of 1 cubic meter of fresh water per second with ocean water 24 MWe can be tapped. Though research is actually in progress, improvement of membranes is necessary and technology at present needs refinement. The potential is great.

During Photosynthesis, plants convert light energy into chemical energy. During combustion, this is reversed to release energy. Certain kelps grow 30 cm a day and adults reach heights of 60-80 M. If kelp can be grown on the ocean bottom, they may constitute a good energy resource.

A 1000 square metre area can produce about 75 to 120 tons of biomass capable of yielding 25,000 Kilowatt energy annually. Because large expanses of the ocean are needed, it is possible that bioconversion plants will be limited to regional and thus smaller facilities.

6. Pollution of the Oceans

Pollution has become a worldwide problem. A typical dictionary entry defines pollution as "to destroy the purity, make foul or filthy". In oceanic pollution, due to the fact that the 'foulness' or 'filth' is often invisible to our eyes, we are not aware of its potential dangers.

6.1 Pollution: A growing problem

As the population of the world increases its harmful waste-products have created a world-wide disposal problem. The oceans are treated as the planetary dustbin on an ever-increasing scale. Sewage, pesticides, petroleum products, detergents, chemical wastes from factories are but a few of the pollutants that are being dumped into the sea. In early days, the discharge into the sea of human, animal and industrial wastes were relatively so small that the oceans could purify them. Even so, however, there were local problems, where raw sewage was deposited on beaches. Domestic sewage also contains detergents. The nitrates and phosphates in detergents over-stimulate micro-life of closed water ways.

Eventually the water becomes turbid, dead and rotting plants use up all available oxygen, especially in deep water, and fish can no longer survive. Many areas of the deeper parts of the Baltic Sea are now devoid of oxygen. One way this could be avoided is to discharge the waste far out at sea and away from the shallow coastal waters. In fact, if discharged into barren areas of the oceans, they might indirectly increase the world's supply of food.

An ever increasing and serious danger comes from new and powerful pesticides, chlorinated hydro-carbons as they are called, but better known as DDT. DDT was developed and put in widespread use as an insecticide some 40 years ago. Soon the runoffs from agricultural lands dispersed this relatively indestructible compound along coastal waters where traces began to be found in fish. The stately pelican became a victim, because female pelicans that ate fish contaminated with DDT laid eggs with shells so thin and fragile that most broke, killing the embryos and preventing the bird reproducing. The telling evidence of widespread pollution came some years later when even Antarctic penguins, also fish eaters were found with traces of DDT in their bodies. Due to such discoveries the use of DDT has declined, but other substances just as lethal are now being used.

The modern world is highly dependent on oil and vast quantities are transported across the oceans. Crude oil is now found in every part of every ocean, killing marine life more extensively than most people realize. It has been estimated that 2.5 million tonnes of crude oil and its products are released into the oceans every year. A common source of oil pollution is the deliberate discharge of small quantities of oil in the course of tank cleaning operations. The dangers of accidental spillage resulting from collisions at sea are however growing with the ever-increasing size of individual oil tankers. The "Torrey Canyon" disaster was only one of the well-publicised examples. In March 1967, the SS. 'Torrey Canyon' ran aground near the Scilly Isles, spilling 10.8 million kilograms of crude oil into the English Channel to wash ashore at Brittany, France and Cornwall, England. The results included miles of fouled shore line thousands of dead birds and many irate citizens (Potter and Jeffrey, 1973). When oil spills occur, a serious nuisance is created. Some marine life, especially birds, are harmed directly and great harm is done to sandy beaches when the oil drifts ashore. Underwater oil drilling poses another growing problem. The Santa Barbara disaster when an oil well on a platform in California blew out, released eight to nine million kilograms of crude oil. Oil pollution in the oceans is often noticed by the accumulation of lumps of tar or 'tar balls', Such tar balls have been noticed in the Southwestern beaches of Sri Lanka. They are thought to be caused by deliberate dumping as giant tankers wash out their tanks, en route to the Middle East.

Industrial wastes including the heavy metals copper, zinc, chromium, cadmium, nickel, lead, mercury and iron, find their way into the sea via estuarine waters, as the run-off from mine workings, extraction and smelting plants and other industrial processes. The heavy metals are lethal to land and ocean life alike, but the threat to the microscopic floating plants — phytoplankton is particularly grave, because they produce much atmospheric oxygen. In 1970 it was found that some canned fish was polluted with dangerously high levels of Mercury.

Radioactivity is possibly the most worrying of all lethal by-products of human ingenuity. Canisters of radioactive wastes are usually dumped in the deep ocean and are hoped to last the lethal lifetime of their contents. The consequences if they do not are unthinkable. Other dangerous material dumped to the sea is cylinders of nerve gas and other chemical warfare wastes. In August 18, 1970, the United States Army in spite of international protest and court action dumped canisters containing 67 tons of nerve gas in the Atlantic.

Pollution of the oceans is an international problem and it has been taken up at the Law of the Sea Convention (see Chapter 8). International agreement on pollution control is not a romantic, idealistic dream, but the only hope for a living oceanic future. If the sea is to be saved from serious pollution an agreement restraining all nations will have to be worked out.

6.2 The importance of Pollution Studies

The major oil spills due to collision, blow up of oil platform wells and today more recent episodes of the collision, of ships loaded with radioactive material have increased public awareness and sensitivity towards the threat of serious pollution of the oceans. In Britain, Torry Canyon sparked off an interest in oil pollution and by extension other environmental troubles which had previously been aired only rarely in the mass communications media.

Biologists and workers in various technologies were stimulated to carry out a wide variety of investigations both in the field and laboratory. Many scientific studies were taken up and data on acute toxicities or long term effects of oil spills, waste disposal technologies have been accumulated. These studies have helped in creating a more lively public awareness of the variety of undesirable materials which now reach the sea in some quantity, and increasing consciousness in us of the sensitivity of marine ecology[36] to such additions. Pollution studies have helped us build new equipment and organise teams ready for dealing promptly with oil spills. The oil slicks may be sprayed with dispersants, which break them up into small droplets which are more quickly attacked by bacteria and will often sink. Pollution studies have shown that some detergents when used to disperse oil-slicks at sea, may be more harmful to marine life than the oil itself. Removing spilt oil from the sea or shore is at all times preferable to dispersing or sinking it. This is done by various mechanical methods.

Mankind is preparing to penetrate into the deep sea to exploit the vast mineral resources found on the ocean floor and it has done so during recent years. All such industrial activity will exert a certain impact on the marine environment. Modern human life cannot exist without environmental impact, but it is essential to minimize all impacts. We must learn how to study (evaluate) the possible risk and we have to establish a balance between natural conditions and our civilization.

The impact on the deep sea is introduced by waste dumping, including radioactive waste products, mining for manganese nodules and mining for metalliferous sediments.

While dumping of waste products will have a rather local effect on a short term basis, the question will occupy us for long periods of time whether hazardous substances may be set free from containers and may enter food chains[37A] with negative effects on all kinds of organisms including ourselves.

Mining and the disposal of waste material from the mining ship will have an immediate and far reaching influence on the biological system due to its fragility. Mining will disturb the bottom, the sedimentation rate will increase, the food supply will be diminished, metals will be leached and will contaminate the water. All these environmental alterations will disturb many species and destroy the food chain within this highly diverse community. Unlike in shallow water, where it may take no more than 5-10 years, the lifetime of several generations, to reestablish the original type of community, it may take hundreds of years for the recolonization of the longliving and seldom reproducing animals in the deep sea.

As pointed out above, our knowledge on deep sea ecology is rather limited and we are not timely prepared for risk assessment. However, oceanographers have to try risk estimation as early as possible and it has to be accepted that later corrections may have to be introduced. The earlier such studies are initiated, and the better the knowledge on deep-sea ecology, the better will be the environmental predictions. Thus, all agencies penetrating into the deep sea for ocean mining, i.e. endangering the ocean environment by their activities, must contribute to a joint effort for improved pollution studies, the indisputable aim of which must be the protection of the oceans for mankind.

7. The New Convention on the Law of the Sea

The use of land on earth is governed by certain laws. Likewise the use of the sea is also regulated by law. In the very early stages in the use of the sea, whoever wanted to use the sea could do so without hindrance. The use of the sea was not regulated. However, because of the low level of overall development sea use was not as extensive as it is today.

With the increase in sea use there was a need for its regulation. The first recorded attempt in history to regulate the use of the sea dates back to 1493. Pope Alexander VI divided the world's sea between Spain and Portugal. Whoever wanted to use the sea was required to seek permission of either state depending on which part of the sea was intended for use.

This division was heatedly contested and criticised by emerging maritime powers. These included the British and the Dutch. They wanted the sea to be open to all nations. Their views were articulately presented by Hugo Grotius in 1609, the Dutch Diplomat, Jurist and

Businessman, who published a small book on freedom of the seas. Contrary to this, an Englishman, John Selden, in 1634 expressed his view that the seas are not common to all, but in their original state belong to no one and are thus available for national appropriation. However, the debate did not end there, but continued into eighteenth and nineteenth and even to the twentieth centuries.

The landmarks in the development of the Law of the Sea are 1930, 1958, 1960 and 1973-1980. It is in these years that four major conferences have been held on the Law of the Sea. The first among these was the Hague Codifications Conference (1930) held under the auspices of the League of Nations. The second Conference followed twenty eight years later in 1958 in Geneva. This was under the United Nations and is also known as 1st United Nations Conference on the Law of the Sea (UNCLOS 1). The third Conference followed two years later in 1960 in the same city Geneva. This was the second to be organised by the United Nations and it is thus known as UNCLOS II. The last Conference is the source of current Convention on the Law of the Sea. It began in 1973 and also under the aegis of the United Nations and ended in 1982 having been the longest conference ever with eleven sessions, some going on for months. The Convention on the Law of the Sea was signed at MontegoBay, Jamaica, on 6th December 1982. The Convention will come into force when 60 of the 119 countries who signed it ratifies it, i.e. it is passed by their respective Parliaments or such bodies.

The Third Conference on the Law of the Sea can be said to be the result of a proposal made by the then Maltese

Ambassador to the United Nations, Arvin Pardo, on 1st November 1967. In his proposal he introduced the concept of "the common heritage of mankind".

7.1 The concept of "the common heritage of mankind":

The origin of the concept of "the common heritage of mankind" is disputable, but it cannot be denied that it was first introduced to the General Assembly of the United Nations by Malta's delegate, Arvin Pardo, in 1967.

In his address to the United Nations General Assembly Pardo spoke on the global problems of the use and misuse of the oceans. Detailing the vast wealth blanketing the sea bed, he reminded nations of the loopholes in existing International Law on the sea. The law in the Geneva Convention of 1958 he said says that whatever is on the floor of the sea belongs to whoever can get it. If the vast resources of the seabed and ocean floor were left open to free and uncontrolled enterprise of nations possessing the technology and capital resources for their exploitation, these would only be the developed nations of the world. Yet another source of wealth would have been thrown open to developed nations and the plight of the poor developing countries would be rendered infinitely wrose. Like the scramble for land in Africa in the last century when Colonial powers with power and capabilities (the equivalent of technology and capital resources in seabed mining) colonised Africa and exploited the vast resources on this continent, there would be a scramble for colonizing and exploiting patches of the seabed by the developed nations.

He suggested that the seabed and the ocean floor underlying the seas beyond the limits of national jurisdiction (high seas) should become the "common heritage of mankind" and should be used for the exclusive benefit of mankind as a whole. The resolution which was put forward by Pardo was passed by the United Nations in 1970 with all nations supporting this concept. Based on this principle the new Law of the Sea Convention was drafted and was signed in Jamaica in 1982.

In the concept of the "common heritage of mankind" the high seas will be the common property of all peoples and nations. The vast wealth found on the seafloor when exploited will be used for the benefit of all mankind and distributed on an equitable basis where the poorer nations will receive a larger proportion and the richer nations will receive a smaller proportion of the wealth.

7.2 Salient Features and Problems of the Convention on the Law of the Sea:

Generally, the Convention on the Law of the Sea is the codification of the well established rules of the International Law governing maritime activities including scientific activity.

According to the Convention the ocean is divided into various areas seaward from the coast. These areas include the territorial sea, the contiguous zone, the exclusive economic zone, the continental shelf and the high seas. The territorial sea of the coastal state is 12 nautical miles (21.6 kilometers). In this area, the coastal state has total jurisdiction and has complete sovereignty over the water, air space and the seabed. However, foreign ships are allowed to enjoy the right of "innocent passage" in the territorial sea without any hindrance. The contiguous zone is the area contiguous to the territorial sea not beyond 24 nautical miles (43.2 kilometers). In this area the coastal state can exercise its power and enforce its customs, immigration, health and such related regulations while allowing other states to continue exercising the freedom of the high seas save for the freedom of fishing. The continental shelf of a coastal state (different from oceanographic definition) comprises the seabed and the subsoil[37] of the submarine area that extends beyond the territorial sea through the natural prolongation of its land territory to the outer edge of the continental margin, or to a distance of 200 nautical miles (360 kilometers)where the outer edge of the continental margin does not extend up to the distance. The coastal state has exclusive rights over the resources of its shelf. The Exclusive Economic Zone (EEZ) of the coastal state is the area beyond and adjacent to the territorial sea. This area extends to 200 nautical miles from the baselines[38]. In this area the coastal state has sovereign rights for the purpose of exploring and exploiting, conserving and managing the natural resources, whether living or non-living of the waters near the seabed and of the seabed and its subsoil, with regard to other activities for the economic exploitation and exploration of the zone, such as the production of energy from currents, waves and tides. Under terms of the Law of the Sea Convention Sri Lanka has control of an off-shore territory twenty times as big as the total land area of the country. This is in addition to the 360 kilometers Exclusive Economic Zone that is provided in the Convention.

The area beyond the national jurisdiction is known as the high seas. In this area all states have the right to enjoy the freedom of the seas. These include the freedom of over-flight, fishing, navigation, laying of submarine cables and pipelines, construction of artificial islands and other installations and freedom of scientific research. The Convention emphasises the fact that this area should be used for peaceful purposes.

According to the Convention all investigation and exploitation activities in the high seas will be organised and controlled by a single body called the Seabed Authority. All countries will be members of the Authority where membership is based on "one member one vote".

Given their difference in development, developed and developing countries look at the Law of the Sea Convention differently. Their specific values and interests definitely lead to different philosophical outlooks.

The developed western countries are rich and have both finances and technology to enable them to go into the oceans and mine its mineral wealth. Philosophically they therefore feel that "might is right". This means that whoever has capabilities can mine the resources of the deep seabed. The developing countries are poor and lack both finance and 'know-how'. The developed states have substantially contributed to their plight. This is a known historical fact. These developing states thus strive for a global and united way of approaching seabed mining. One of these ways is through the United Nations Convention on the Law of the Sea which provides for the formation of the International Seabed Authority.

The Law of the Sea Convention provides an avenue for the International community to peacefully and equitably deal with the resources of the deep-seabed. The developing states are therefore in favour of this law and support its ratification. The developed states in general and their big mining companies in particular feel that the Law of the Sea Convention is inadequate. They think that it is not fair for them to invest most of the money for exploiting the resources of the deep seabed and for the developing countries to get the bigger shares of the wealth! They have forgotten history, where they plundered the developing countries and took everything and gave nothing. They are, therefore, not for the signing and ratifying of the Convention, notwithstanding the fact that they took an active part in the nine years of the Conference.

For the developing states the minerals in the deep seabed, if exploited and shared on equitable basis, provided a way towards their economic independence. This is very important to them and will contribute substantially to the achievement of their demand for the equitable distribution of resources.

The demand for equitable distribution of resources of the International area (high seas) of the seabed is a legitimate one which must be made in the strongest terms possible. The struggle, therefore, continues with the hope that as more and more states ratify the Law of the Sea Convention "those against it will see light" and join mankind in the efforts to make this world a better place to live in.

GLOSSARY

1. Canyon — A deep valley with vertical sides excavated by a river. A submarine canyon is a V-shaped valley found on some continental slopes.
2. Escarpment — The abrupt face or cliff of a ridge or hill range.
3. Navigation — The art or science of directing the movement of ships on the sea, including more especially, the methods of determining a ship's position and course by the principles of geometry and nautical astronomy.
4. Shoal — A place where the water is of little depth; a shallow sand bank or bar.
5. Sand bar — A bank of sand formed at the mouth of a river or harbour by the action of the water.
6. Sounding — The action of sounding or ascertaining the depth of water by some means; in the past by lowering a lead weight attached to a wire or rope; presently by means of an echo sounder.
7. Ice age — A period of time during which glacial ice spreads over regions which are not normally ice-covered. The emphasis is on a large scale regional spread, not merely a local advance of valley glaciers due to minor climatic fluctuations. The last time this happened was about 18,000 years ago.
8. Glacier —An immense mass or river of ice in a

high mountain valley formed by the descent and consolidation of the snow that falls on the higher ground.

9. Topography — The accurate and detailed delineation and description of any locality.

10. Sediment — Earthy or detrital matter deposited by aqueous agency.

11. Fracture zone — A zone in which faulting has taken place. Fault is a fracture in rock along which there has been an observable amount of displacement.

12. Island arc — An arcuate chain of islands, e.g. Japan, Aleutian island. They are found around the margins of the Pacific, Malaya and Indonesia and in the Caribean. They are associated with areas of strong seismic activity and earthquakes; deep oceanic trenches occur on the convex sides and deep basins on the concave side. They are regions of intensive gravitational and magnetic anomalies.

13. Marine geologist — One who studies the geology of the ocean and its floor (see 20 for geology)

14. Meteorologist — One who studies the motions and phenomena of the atmosphere especially with a view to forecasting the weather.

15. Fossilize — To turn into a fossil. A fossil is the remains of animals and plants, belonging to past ages and found embedded in the strata of the earth.

16. Mantle — The portion of the earth lying

between the depth of 35KM to 2900 KM which is supposed to be made of molten material.

17. Nautical — Pertaining to seamen or to the art of navigation.

18. Pelagic — Living on or near the surface of the open sea or ocean, distinguished from its depths.

19. Zooplankton — Floating and drifting animal life.

20. Geological mapping — An examination of the geology of an area to prepare a geological map. Geology is the study of the earth as a whole, its origin, structure, composition and history and the nature of the processes which have given rise to its present state.

21. Aerial photography — The art of taking photographs from the air by using an aircraft.

22. TNT — An explosive — Trinitrotoluene.

23. Crust — The outer portion of the earth or the upper or surface layer of the ground (in reference to a supposed matter interior of the earth). The crust as a whole is thickest beneath the mountains (35 km) and thinnest under the oceans (11 km).

24. Refraction — The bending of a wave of sound or light as it passes from one medium into another.

25. Deposit — An accumulation of valuable minerals which could be extracted economically with available technology.

26. Mineral — Any natural substance which is neither

animal nor vegetable. A structurally homogeneous solid of definite chemical composition, formed by the inorganic processes of nature.

27. Mining — Work connected with making excavation in the earth for the purpose of digging out valuable minerals, coal, precious stones, etc.

28. Iceberg — A huge floating mass of ice, often rising to a great height above the water.

29. Well — A pit drilled in the ground to obtain oil and gas.

30. Fry — Young fishes just produced from the spawn.

31. Cyst — A thin-walled hollow organ or cavity in an animal body (or plant) containing a liquid secretion.

32. Goiter — An enormous enlargement of the thyroid gland of the neck.

33. Estuary — An inlet of the sea at the mouth of a river.

34. Buoy — A floating object fastened in a particular place to point out the position of things under water.

35. Rig — A well-boring plant; eg. for oil.

36. Ecology — The scientific study of the distribution and abundance (i.e. exactly where they occur and precisely how many there are), and any regular or irregular variations in distribution and abundance, followed by explanation of these phenomena in terms of the physical and biotic factors of the

environment.

37. Subsoil — The soil beneath the bottom of the sea.

37A. Food chain — A cyclic occurrence through which newly formed plant materials are eaten by small creatures and these by larger ones, until we come to the largest fish and whales.

38. Baseline — Generally is the low-water line along the coast.

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