Intergovernmental Oceanographic Commission
Training Course Reports **15**

IOC Advanced Training Course on Nearshore Sedimentation and the Evolution of Coastal Environments

Hydrography Directorate
& University Technology Malaysia
Kuala Lumpur, Malaysia, 17-29 February 1992

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IOC Training Course Reports

No.	Title	Language versions
1.	IOC Indian Ocean Region Training Course in Petroleum Monitoring Perth, 18 February-1 March 1980	English
2.	IOC Regional Training Course for Marine Science, Technicians Cape Ferguson, Queensland, 1-28 June 1980	English
3.	ROPME-IOC-UNEP Training Workshop on Oceanographic Sampling Analysis, Data Handling and Care of Equipment, Doha, Qatar, 3-15 December 1983	English
4.	Stage COI d'initiation à la gestion et au traitement de l'information scientifique et technique pour l'océanologie Brest, France, 28 novembre - 9 décembre 1983	French
5.	Curso mixto COI-OMM de formación sobre el Sistema Global Integrado de Servicios Oceánicos (SGISO) Buenos Aires, Argentina, 15 - 26 de octubre de 1984	Spanish
6.	Unesco-IOC-NBO Training Course on Tidal Observations and Data Processing Tianjin, China, 27 August-22 September 1984	English
7.	Stage COI sur la connaissance et la gestion de la zone côtière et du proche plateau continental Talence, France, 18 septembre - 4 octobre 1984	French
8.	IOC Regional Training Course on Marine Living Resources in the Western Indian Ocean Mombasa, Kenya, 27 August-22 September 1984	English
9.	IOC-Unesco Summer School on Oceanographic Data, Collection and Management Erdemli, Icel, Turkey, 21 September-3 October 1987	English
10.	IOC-Unesco Regional Training Workshop on Ocean Engineering and Its Interface with Ocean Sciences in the Indian Ocean Region Madras, India, 17 March-5 April 1986	English
11.	IOC-Unesco Training Course on the Use of Microcomputers for Oceanographic Data Management Bangkok, Thailand, 16 January-3 February 1989	English
12.	IOC Advanced Training Course on Continental Shelf Structures Sediments and Mineral Resources Quezon City, Philippines, 2-13 October 1989	English
13.	IOC/IODE Training Course on GF3 Data Formatting System Obninsk, USSR, 14-24 May 1990	English
14.	IOC Training Course on Microcomputers and Management of Marine Data in Oceanographic Data Centres of Spanish-speaking Countries Bogotá, Colombia, 21-30 October 1991	English Spanish
15.	IOC Advanced Training Course on Nearshore Sedimentation and the Evolution of Coastal Environments Kuala Lumpur, Malaysia, 17-29 February 1992	English

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SUMMARY REPORT

INTRODUCTION

The Course was designed to respond to the urgent needs of the IOC Member States of the central and eastern Indian Ocean (IOCINDIO) and western Pacific (WESTPAC) regions to learn more about the evolution of coastal environments, the influence of sea-level changes, and the non-living resources of nearshore areas. Therefore, the immediate objective of the Course was to provide advanced training to scientists of the region in order to acquaint them with current scientific and technical knowledge on coastal and offshore mapping, shallow seismic profiling, sediment sampling and analysis, and interpretation of related data sets, and to enhance capacities of countries in the region by initiating future cooperative projects.

The two-week course was held in co-operation with the Hydrography Directorate of the Royal Malaysian Navy at the University Technology Malaysia in Kuala Lumpur, and consisted of lectures, exercises and laboratory work to analyze samples and data collected during a one-day research cruise with the Malaysian RV PENYU, and two field trips to the west and east coasts of the Malay Peninsula.

The course was financially assisted by the German Government through a voluntary contribution to the IOC Trust Fund, for TEMA activities. Further assistance was provided by the Government of Malaysia and the IOC Secretariat.

1. OPENING

The Training Course was opened on Monday, 17 February 1992, at 10.00 in the premises of the University Technology Malaysia in Kuala Lumpur, by Capt. Mohd. Rasip Hassan, Director Hydrography Department of the Royal Malaysian Navy, and representative of the host country. His opening statement was followed by a word of welcome by the IOC representative, Dr. Günter Giermann, and by the representative of the University Technology Malaysia, Prof. Dr. Abdul Aziz Ibrahim, Director Coastal and Offshore Engineering Institute. The opening session was attended by four instructors from Germany and one from Australia, and by participants from the following eleven countries of the central and eastern Indian Ocean and western Pacific regions: Maldives, India, Sri Lanka, Bangladesh, Myanmar, Thailand (2), Malaysia (5), Indonesia, Vietnam, China, and Korea (Rep.). Two further trainees selected from Pakistan and Philippines unfortunately could not attend. The scientific course leader was Dr. H.R. Kudrass; Dr. G. Giermann represented IOC and acted as overall course co-ordinator.

The Agenda was presented as in Annex I; participants are listed in Annex III.

The opening session was followed by an introductory lecture given by Dr. Giermann on "Intergovernmental Oceanographic Organizations in the Indian Ocean and in the South and S.W. Pacific, with particular interest in Marine Geology, Geophysics and Non-Living Resources Research, as well as related environmental aspects and hazards".

The afternoon was spent by the instructors to prepare a proper timetable for the Course (cf. Annex II).

2. COURSE PROGRAMME

The training course comprised 13 days including one weekend. Eight days were allocated for lectures, exercises and laboratory work, 4 days for field trips, and one full day for a demonstration cruise on RV PENYU (cf. Annex II). In accordance with the objectives of the Course, lectures included subjects like sea-level changes, coastal sediments and resources, coastal impacts, geo-chemistry and sea water chemistry, as well as mapping and air photo interpretation. Two field trips were arranged, one full day to the Sepang area south of Kuala Lumpur, i.e., the west coast of the Malaysian Peninsula, and another 3 days to the high energy coast north and south of Kuantan, east of the Malaysian Peninsula. Field training included the use of drilling equipment, and studies of coastal morphology, erosion and accumulation processes, sediment sequences in beach, intertidal and supratidal environments, rocky platforms, and Holocene beach ridges.

The cruise started in Kelang harbour and led to the Strait of Malacca. Water was analyzed to determine the state of pollution by semi-quantitative methods, sediment samples were taken with a grab sampler, and side scan sonar and echo sounder profiling as well as trisponder and GPS navigation were explained.

2.1 LECTURES AND EXERCISES

2.1.1 Sea Level Changes

This introductory lecture on sea level changes: causes, rates, and amplitudes given by Dr. H. Streiff, dealt with the components effecting the relative heights and the variations of the sea level. Most of the endogenetic factors, e.g., of processes originating in the Earth, like epirogenetic subsidence or uplift, plate tectonics, and geoidal factors, have long-term influences but minor effects on sea-level variations. Only volcanism can occur with rapid and significant changes in short-time intervals.

In the course of the 2.5 million years of the Quaternary period, however, sea-level changes were dominated by exogenetic processes originating at or near the Earth's surface, or from outside. The most important factor was and is the changing climate which considerably influenced the ice/water balance of the Earth. This resulted in a lowering of the sea-level in periods of cold climate. Vice versa, a sea-level rise and high stands of sea-level occurred at periods of warm interglacial climate. With an amplitude of about 100 meters these sea-level changes generated shoreline displacements of some hundred kilometers in lowland areas. In addition, the processes coincided with considerable isostatic movements. The formation of so called isostatic forebulges effected uplift in regions adjacent to the glaciated areas. In contrast, the forebulges collapsed when the inland ice melted, and strong uplifts occurred in former depocenters of the ice sheets. Comparative studies of the course of events of the last 3 periods of interglacial warm climate can be used for the verification of models dealing with future developments of coastal lowland areas.

Dr. Burne lectured on sea-level variation and coastal evolution. Sea-level is the most important reference surface on earth, though satellite measurements have now demonstrated considerable variation in the water level of present day oceans. It was once thought that worldwide sea-level (eustatic sea-level) was a fixed reference surface when the Earth was in an ice-free state. There are two first order topographic components of the surface of the lithosphere which result from isostatic equilibrium between crustal materials of different densities - the granitic continents (mean elevation of 0.8 km relative to present sea-level) and the basaltic ocean basins (mean depression of -3.8 km relative to present sea-level).

The boundary between continental and oceanic crust does not occur at the coastline. There is sufficient water in the world's oceans to overtop the ocean basins and flood onto the margins of the continents such that 25% of the surface of the area of continental crust is currently beneath the sea. This area forms the continental shelves that total 8% of the area of the seas. The extensive shallow seas thus formed bring much of the sea floor within the photic zone which enables photosynthetic primary production in benthic ecosystems. The edge of the continental shelf is therefore a critical depth which fortunately varies between about 100 and 130 metres. The process of overwhelming importance in the consideration of coastal processes over a long time scale is variation in eustatic sea-level.

During the Quaternary, changes in sea-level have largely been associated with fluctuating continental ice sheets. Sea-level would rise an additional 70 metres if all remaining ice-caps in the Antarctica and Greenland were to melt. Conversely the maximum fall of sea-level during the last glaciation was 130 metres. This depth corresponds the abrupt break in slope at the shelf edge suggesting that the morphology of the continental shelves may have been created by fluctuating sea-level. Analysis of seismic profiles of the sediments of the continental margins has shown that sea-level has fluctuated through geological time. Sea-level probably attained its highest level in the Cretaceous (≈350 metres higher than present) and its lowest level in the Oligocene (≈250 metres lower than present). However, these variations are in slow, long-term cycles of 1 million to 10 million or even 40 million years duration with rates of sea-level change of the order of 1 cm/1000 years. They are probably the result of tectonically driven changes in the volume of the ocean basins caused by events such as changes in the volume of the mid-ocean ridge system. In contrast the rate of change in sea-level caused by glacial melting during the post glacial transgression attained 2 cm/year or more.

However, what is observed as Holocene sea-level change around the coastlines of the world is not simply a result of volumetric changes in the oceans caused by melting of the ice sheets - it is the result of relative change in sea-level resulting from the combination of these effects, local tectonic movements affecting the coastal area, and both direct and flexural responses in the crust to the re-distribution of loading caused either by the melting of ice-caps, or the increased loading by the weight of transgressing and deepening shelf seas. Severe cooling and glaciation began in the northern hemisphere during the late Miocene, but the development of ice-sheets in North America and Scandinavia did not begin until the late Pliocene ($\approx$3 million years ago). A critical climatic threshold was passed at that time, since when the Earth has exhibited glacial oscillations. During the last 1.6 million years the Earth has experienced 30 glacial episodes accompanied by repeated large scale latitudinal displacements of climatic zones and sea-level oscillations of the order of 100 metres. From the frequency of the glacial cycles the Earth is due for another ice-age, but the effect of humans on the atmosphere, especially since the industrial revolution, is giving rise instead to global warming and what is known as the "Greenhouse Effect".

World sea-level may rise by as much as 70 cm $\pm$25% over the next century as a result of the thermal expansion of the oceans coupled with the melting of the Alpine and Greenland glaciers and the possible disintegration of the west Antarctic ice sheet. Such a rise would have significant implications for coastal communities and coastal structures, but coastlines would not all respond in the same way. Sandy coastlines would recede unless this was offset by an influx of sediment. On coastlines colonized by mangroves or coral reefs biological growth may be able to keep pace with rising sea levels. Rising sea levels will also have an effect on the distribution of coastal wetlands and the dynamics of tidal inlets. On cliffed coastlines, unconsolidated cliffs would retreat while indurated cliffs will be more stable. Faced with the possibility of rising sea- level coastal communities have 3 options - Hard Options (the construction of engineered structures such as dykes and sea walls), Soft Options (Beach Nourishment, Mangrove Plantations) or Retreat (with the establishment of set-back lines for construction, halt the artificial stabilization of the shore, and removing coastal stabilization devices that threaten coastal safety).

The best protective measure for a coast threatened with rising sea-level is the retention of natural environments and ecosystems to allow the natural resilience of the environment to find its own adaptation. Artificial structures are expensive to build and upkeep, and may only serve to increase the long-term problem by reducing environmental resilience. In order to understand the stability and history of a coastal sequence, modern rates of sedimentation and shoreline change are assessed from changes shown on sequential records in aerial photographs, charts, maps and historical records. The rates can be assumed to continue into the near future. This morpho-dynamic approach can be linked to direct measurement of active sediment transport and deposition and used as a basis for theoretical calculations of sediment transport for which sedimentary processes are predicted. A more powerful approach to the analysis of coastal complexes is to combine an analysis of morpho-dynamics, morpho-stratigraphy and ecological zonation with respect to inundation. Precise tidal records, surveyed levels along ecological transects and age dating of sea-level indicators will enable the construction of a sea-level curve for the area.

A lecture on sea-level changes and related shifts of coastal depositional environments was given by Dr. Kudrass. Sea-level changes can be caused by tectonic subsidence or uplift, climate change, and local effects as compaction or change in wind stress. During a regression rivers erode into their former beds and the deltaic-coastal depositional system moves across the shelf. During a transgression the mouth is drowned and sand is trapped in the river channels. Peat or mangroves develop in the flooded low-lands of the former coastal plain. During stable positions of the sea level, fluviatile input and dispersal of sediments by long-shore currents can reach a semi-equilibrium state.

2.1.2 Coastal Sediments and Resources

Dr. Burne lectured on carbonate sediment budgets in the coastal zone. The evolution and stability of carbonate coastal systems have quite different characteristics to coastal systems dominated by terrigenous sediments. However, most coastal engineering practice has evolved from experience gained on the terrigenous systems of north west Europe and north America.

There are several different coastal settings where carbonates dominate. **Coral Reefs**: most important in coral island situations. The framework is a cor-algal construction. The reef is generally well zoned, and carbonate sediment is exported from the active area of reef growth. Important carbonate production also takes place in the lagoons of the back-reef. **Sea Grass Banks**: carbonate production does not create a rigid framework. Instead epiphytic growth and colonization of the protected benthic environment produce a well-bound skeletal carbonate sand. **Tidal Shoals**: tidal activity may increase alkalinity in the disturbed water and encourage the precipitation of carbonate to form extensive ooid shoals. **Skeletal Deposits**: shelly deposits build up in areas of very slow sedimentation. **Lagoons**: the nature of the lagoonal sediments depends very much on the hydrological regime. Lagoonal sediments range from evaporites similar to salt lake sediments, e.g., the Gypsum Deposits of Malden Island, through to Brackish water carbonates such as those of Rangiroa Atoll.

The overall requirement for the formation of carbonate sediment is the presence of the necessary ions in solution. There are 3 ways in which carbonate may be precipitated. **Skeletal Mineralization**: this is a genetically directed process that forms calcified hard parts within an organism as a result of normal metabolic processes. The organisms involved include molluscs, corals, Foraminifera and coralline algae. **Biologically Mediated Calcification** : in this process the precipitation of carbonate occurs in close association with an organism, but is not intimately associated with the metabolism of the organism. In the case of some algae it is associated with photosynthesis, which alters the pH in the immediate environment of the plant, thus promoting calcification. In the case of Cyanobacteria, the chemical nature of the decaying sheath material acts as a site for the nucleation of carbonate crystals. This latter process of microbially associated calcification may be an important factor in the formation of ooids and in early cementation of reef Framework. **Inorganic precipitation, cementation & diagenesis**: inorganic precipitation of carbonate is often lined with evaporation. This may occur in some lagoonal situations, but is more often related to high alkalinity waters. These develop frequently in an interstitial pore water environment, and are major factors in carbonate cementation.

Once formed, carbonate sediment becomes vulnerable to erosion in a number of ways. **Mechanical erosion** is an important factor in the breakdown of reef framework and in the comminution of carbonate grains. Dissolution of carbonates is important in the sub-aerial and inter-tidal environments. It plays an important role in producing pore waters of elevated alkalinity. **Biological erosion**, both mechanical and chemical, are extremely important factors in the breakdown of reef framework. **Microbial erosion** is important in the comminution of sand-sized carbonate grains. Once croded the carbonate sediment becomes available for transportation. Because of their porous nature and irregular shape, many carbonate grains have a hydraulic equivalent size much less than their actual size. Halimeda grains represent an extreme example of this. Hence relatively gentle currents or waves may give rise to apparently high-energy structures. Although carbonate sediments are a renewable resource, in that they are constantly being created, the situation is most often one of balance, and may be best regarded as a fixed pool of sediment being dispersed by conventional processes of onshore-offshore transport and long-shore drift. The coast may provide a storage place for considerable quantities of carbonate sediment. This is available to be re-introduced into the offshore system providing it is not isolated by coastal development. It is important to recognize the unstable nature of the coastal zone. The following table contrasts carbonate coastal sediment budgets with those of terrigenous sediments.

Comparison of the relative importance of items in littoral sediment budgets of terrigenous and carbonate systems.

BUDGET ITEM	TERRIGENOUS	CARBONATE
CREDITS:		
River sediment supply	+ + + + +	+ to x
See-Cliff erosion	+ + + +	+ to x
Wind supply	+	x
Wave transport:		
long-shore	+ + + + +	+ + to x
onshore	+	+ + + + +
Biogenous supply	+ to x	+ + + + +
Hydrogenous supply	x	+ + to + + + +
Beach nourishment	few side effects	numerous side effects

DEBITS: [1]

Wind transport out	+ + + to x	+ to x
Wave transport out:		
long-shore	+ + + + +	+ + to x
offshore	+ +	+ + to +
Submarine slope transport	+ to x	+ to x
Solution and abrasion	x	+ + +
Mining	numerous side effects	numerous side effects

In many areas the morphology of the coast is determined by the Quaternary sea-level history and its preserved record in carbonate sediments. In many carbonate settings, onshore-offshore transport is of much greater significance than long-shore movement. Grains are often inappropriately used to protect beaches in carbonate areas dominated by onshore movement. They increase erosion between grains, and attract sand to themselves, which is then easily removed offshore at times of storm. Sea walls increase erosion of the foot of the wall by refraction, and may result in the total loss of the beach. Loose boulder ramparts also focus erosion around their bases. Offshore nodal structures are preferred for protecting many carbonate beaches. They attract sand by the Tombolo effect. Several activities may have a deleterious effect on areas of carbonate production. Once the shallow area of active carbonate production has been destroyed it takes time to become re-established. Dredging and mining areas remove the surface ecosystem that is producing carbonate. The major part of the material removed is fossil deposit and is not readily replaced by re-colonizing calcifying ecosystems. This influx of nutrients can destroy the carbonate producing ecosystems which often require low-nutrient environments.

Dr. Kudrass lectured on composition of sand in marine sediments. The analysis of sand (grain size, grain surfaces, grain composition) yields a wealth of information on its provenance, depositional environment, age, and early diagenetic history. Especially the biogenous components as foraminifera, mollusc shells, radiolaria, and diatoms allow a very detailed specification.

In an exercise, samples from different water depths were analyzed in using a binocular microscope.

2.1.3 Coastal Impacts

Dr. Giermann introduced 3 case studies based on research work conducted under the guidance of the South Pacific Applied Geoscience Commission (SOPAC) - formerly Committee for Co-ordination of Joint Prospecting for Mineral Resources in South Pacific Offshore Areas (CCOP/SOPAC), with headquarters in Suva, Fiji, and one case study carried out in Sri Lanka under his supervision.

Case Study I: Sand and Gravel Deposits in the Lagoon outside Nuku'alofa, Tonga: Environmental effects of the proposed dredging

Tongatapu, the largest island of the Tongan group (35 x 20 km), is formed of uplifted coral limestone of mainly Quaternary age. Reefs are fringing the island except outside Nuku'alofa, where the central part of the lagoon is open to the north and reefs are not present. However, between Fafa and Atata Islands, a sill (-10/-12 m) is baring the deep basin (-25 m), which exists right in front of Nuku'alofa, from the open sea.

On the island, supplies of sand for construction of concrete buildings and roads are predominantly taken from beaches on the southeast and west coasts (with some small amount being obtained from the crushing of quarry rock). It has become evident now that the rate of extraction of sand from beaches has reached a level far greater than the rate of natural replenishment, leading to potential damage to tourist industry, and risking erosion of back beach areas. It is a matter of urgency therefore to find alternative sources of construction material.

[1] KEY: Relative level of significance shown by number of plus signs (+ to + + + + +)
Item insignificant or non-existent shown by cross (x)

Between 1978 and 1989, several surveys were conducted by CCOP/SOPAC, and 5 morphological provinces were defined off Nuku'alofa. The most notable feature is the *sill area* covering at least several square kilometers west and northwest of Fafa. The coarseness, low mud content of the sediment and proximity to Nuku'alofa harbour (7 km) speak in favour of this deposit, a drawback may be water depths of more than 10 m. Medium coarse shelly sands were found suitable for use in construction industry, others for landfill. Another exploitable area of coarse sand in shallower water (1-9 m deep) occurs on the reef platform and its northern margin, between Motu Tapu - Fukave - Ata. Negative are the greater distance to Nuku'alofa (15 km) and the proximity to an active reef that might be damaged. In assuming that 8,000 tons/year are required, one body west of Fafa could supply sands for 850 years, i.e., that a 1 m thick layer of 70 x 70 m will have to be removed every year (1.7 tons/m^3, approx. 4,700 m^3/y). Extraction might imply the use of a large mounted crane with clamshell buckets, and a tugboat.

Scientists warned that consideration should be given to environmental effects of the proposed dredging, however, these would probably be minimal and extremely localized in this area. They further noted that exploitation west of Fafa shall take place in the area where no reef exists to protect Nuku'alofa from storm swells. The sill between Fafa and Atata (at -10/-12 m), which presently has a protective function, could be damaged by dredging, and a breach might open letting deep-going swell enter into the enclosed basin (-25 m) between the sill and Nuku'alofa, thus endangering the town's sea front. Violent northerly squalls and hurricanes producing such swells often occur in this region.

Case Study II: Coastal Changes at Rarotonga, Cook Islands (South Pacific)

Rarotonga is a tropical island. The central area is mountainous with peaks up to 653 m. A 32 km long and 750 m wide coastal terrace of 3 to 50 m in elevation surrounds the island. Offshore a continuous reef protects the island against destructive seas and swell. When large seas or swell break upon the reef, secondary reef waves originate which tend to transport sand to the beach, but do not transport much sand along it. Water introduced over the reef rim can raise the water level in the lagoon above that of the water outside of the reef. This can cause a current to develop from the lagoon back to the ocean. In narrow channels, speed can become significant. As rainfall is important, one can also expect sediment discharge into the lagoon along the small rivers (streams) of the island.

Two areas are considered: (i) Ngatangiia Harbour and Muri Bay in the east; and (ii) the Rarotongan Hotel area in the southwest of the island, where either sedimentation or erosion affect the coast. Ngatangiia Habour is protected by two small islands, Motutapu and Oneroa. In the last century schooners anchored in the harbour, however, in more recent times the sediments of two streams have filled most of it. Sediment input through streams increased when about 1970 significant grading for a banana plantation occurred. Also trees had been cut lining the Avana Stream, and plowing started up and down the grade which increased land erosion. As for Muri Bay located one km south of Ngatangiia Harbour, the beach along the west shore of the lagoon has experienced a significant amount of sand erosion during the past few years.

After a detailed field survey the CCOP/SOPAC team came to the conclusion that the primary cause of the two problems - sedimentation here and erosion there - appears to be the development in the watershed area tributary to the lagoon. The filling of the harbour probably has contributed to a reduction in the hydraulic flow through Muri Bay, and a slight increase in the water level in the lagoon. This in turn appears to have contributed to a more aggressive wave action on the beach areas near the Sailing Club, and may be cause for the erosion there.

Action was recommended for amelioration of the two problems: (i) the harbour should be dredged to remove the terrestrial sediments; (ii) the channel that formerly drained Muri Bay (now a fish trap) should be re-established; (iii) some type of erosion control and sediment traps (mangroves) should be employed in the watershed area.

Restoring the old drainage channel and lowering the water level in the bay will increase the flow of ocean water pumped over the reef by wave action. The passage of high quality water through the harbour on its way back to the ocean will increase the reef-forming organisms and consequently attract more fish.

The Rarotongan Hotel is located on a small sand projection. It opened in 1977, one year later, beach erosion problems were reported. In 1979, a coconut log groyne was built to control a long-shore sand drift. After some storm damage, a rock seawall was constructed in 1982. But beach erosion continued at an average rate of approximately two meters per year. In 1984, the coastline was within 5 meters of the eastern block of rooms.

After careful study the CCOP/SOPAC team concluded that diversion channels should be cut immediately into storm bars to release some of the nearshore hydraulic gradient and reduce the velocity of the nearshore reef current, being a major factor causing the erosion of the shoreline at the hotel. It was also noted that large quantities of sand were mined from the nearshore area to fill the hotel place during construction - this had certainly created instability. It seemed advisable to restore at least part of the sand removed. It was finally recommended to construct a sea wall or point structure and a diffraction mound, and that a sand reserve be distributed along the beach.

Case Study III: Rabaul Caldera (Papua New Guinea): A natural hazard

Rabaul Caldera dominates the lowland of northeast Gazelle Peninsula, New Britain Island. The caldera, breached by a 5 km gap on the southeast side, forms Blanche Bay, the harbour of Rabaul (population about 15,000; within 15 km of the center of the caldera, total population about 70,000). Rabaul Volcano is a shield volcano of probably Quaternary age. The caldera is elliptical in shape measuring 14 km N-S and 9 km E-W, with walls are up to 450 m high. Several satellite cones exist outside (2) and inside (6) the caldera, with more of them under water (at least 3). The most recent catastrophic event happened in 1937, when 505 people died. An estimated 0.3 km^3 of material was ejected in the 4-day eruption.

Seismicity of the Caldera between 1967 and 1971 was quite low and stable, and the earthquake rates varied from about 20 to 100 events per month. Since late 1971, distinctly higher rates have been noted. In January 1982 1,170 events were recorded. The highest magnitudes were 5.2 and 5.1 in 1980 and 1982 events. The most dramatic caldera unrest occurred from late 1983 to mid 1984, during which time, hundreds of earthquakes were recorded daily, with rapid local uplift (sea bottom rise) and lateral expansion within the caldera. The pattern of recent seismicity follows the elliptical shape of the caldera, and lies inside. Interpretation of reflexion seismics shows that generally structure within Rabaul Caldera is simple, except for an area just south of Matupit Island and Harbor. Here the sea floor is upbowed and hummocky, and a prominent *bulge* can be identified composed of two distinct, in echelon, dome-like ridges that exhibit anticlinally folded strata, trending generally in a N-S direction, and being separated by a series of active, stepped faults. The feature appears directly responsible for the increase in elevation taking place near Matupit Island. The comparison of 1983 and 1984 surveys suggests an uplift of over one meter, centered 1 km SE of Matupit Island. In its neighbourhood submarine slumping takes place.

In 1989, Dr. de Saint Ours, of the Rabaul Volcanological Observatory, reported that Rabaul has been very quiet since the end of the 1983-1985 seismo-deformational crisis, even though our monitoring indicated a slow, on-going inflation of the shallow magma reservoir, 2 km below the centre of the caldera floor.

Continuation of this activity will almost certainly culminate in an eruption, possibly with the construction of a new volcano. It therefore became necessary to identify possible hazard zones (including areas effected by tsunamis) and start with eruption contingency planning.

Case Study IV: Placer deposits on the shelf off SW Sri Lanka

In 1986, Dr. Giermann supervised a UNDP Project on Strengthening of the National Aquatic Resources Agency (NARA) in Colombo. Three of the field projects were aimed at studying the insular shelf for mineral occurrences.

Implementation started under the efficient leadership of Dr. Shanti Wickremeratne on board RV SAMUDRA-MARU with bathymetric charting, reflection seismics (3.5 KHz sparker), and sediment sampling along the west and southwest coasts of Sri Lanka. One of the results was the discovery of a submarine terrace off Panadura (just south of Colombo) at a depth between -45 and -50 meters, which is virtually horizontal and covered with the well-known reef (or dunes) and lagoon landscape. Into it the steep walls of the Panadura Canyon are cut. The terrace is up to 9 km large, ending at the shelf break at approximately -50 meters, followed first by a narrow gentle and then, from -100 meters onwards, steeper slope leading to the abyssal plain below -2000 meters.

In July 1988, Dr. Wickremeratne reported that during a more recent survey he had found the same terrace much deeper further south, and that probably tectonical movements were the reason for its deplacement. It is now of great importance to try to date this terrace. We assume that it is of late Würmian age.

It is interesting to see a developing country like Sri Lanka making great efforts in exploring its offshore resources. NARA surveyed with RV SAMUDRA-MARU large areas off the western and southwestern coast of the island, accompanied by land surveys along the beaches. This led to the discovery of several economically important mineral deposits. Surveys after 1986 have indicated the presence of buried river valleys on the shelf belonging to the major rivers that debouch into the sea. For example, off the Maha Oya and the Panadura Ganga, gem quality minerals like spinel, corundum and garnet have been identified in heavy mineral concentrations sampled from buried river valleys. Also off Panadura, a mid-shelf deposit containing up to 30 percent of glauconite with calculated reserves of 39,000 tons has been found.

Furthermore, large amounts of calcarous sands have been discovered on the western shelf, estimated at 2 billion tons in the upper first meter of the seabed. Another area of approximately 15 square kilometers is enriched in sediments containing in average 8.6 percent of heavy minerals, 1.4 percent being monazite. The mineral rich layer is 2 to 5 m thick. The economical value is estimated to be high.

In more general terms, the western shelf of Sri Lanka is predominantly covered with sand-sized particles of lithogenic quartz and biogenic carbonates. In a nearshore zone down to -30 meters, coarse grained quartz beds are actively formed along the entire coast. Prevailing winds and currents transport these mainly fluvial sands northward. The nearshore zone is then followed by the terrace and shelf break described above.

It still has to be determined how much of the mineral accumulation can be related to buried river channels, and how much to wave action along drowned strandlines.

2.1.4 Geochemistry and Sea Water Chemistry

Dr. H.J. Brumsack lectured on instrumental methods used in geochemistry . The major fields of geochemical research were briefly introduced. It was mentioned that besides the common chemical characterization of igneous rocks and sediments, process orientated interdisciplinary research becomes increasingly more important. Furthermore, environmental geochemistry will play a major role in the near future.

The basic principle as well as the advantages and disadvantages of the different analytical methods (XRF, AAS, ICP-AES, stable and radiogenic isotopes) were presented.

Whereas XRF seems to be the appropriate method for the routine determination of major elements and several trace metals in solid samples, AAS and ICP methods require digestion procedures by strong mineral acids, which are very time consuming. Furthermore, samples are diluted by factors between 100 to 1,000 during the digestion procedure. This fact has to be considered when detection limits of AAS and ICP methods are related to sample concentrations.

Acid extracts (e.g., *aqua regia*) allow the determination of several trace elements of environmental concern by AAS and ICP methods, but caution must be taken since only few elements are completely dissolved in these extracts. Only the parallel analysis of international reference materials allows controlling the accuracy of the applied analytical methods.

Seawater chemistry and estuarine processes was introduced by Dr. Brumsack. The question: "why is the seawater salty"? was answered by comparing the major ion composition of seawater with that of river water. It was mentioned that the anions of seawater originate from degassing of the interior of the Earth, whereas the cations are released during weathering of the crustal rocks.

In contrast to the conservative behavior of many major ions, the minor and nutrient elements often exhibit non-conservative concentration - depth distributions. These elements are frequently incorporated into biogenic particles which are easily regenerated (biologically controlled), or they are scavenged by particulate matter with large surface area (geochemically controlled). These regeneration and scavenging processes should also influence the chemical composition of the underlaying sediments. For this reason e.g., high Cd concentrations are not expected in deep water setting. Processes of metal fixation/mobilization in estuaries were briefly discussed. Element mobility depends upon changes in redox conditions and salinity. Whereas for many elements estuarine behavior is still under debate, the importance of human activities for the trace metal content of nearshore sediments was demonstrated. Trace metals anomalies, particularly of Pb, Zn, and Cd, are in most cases related to industrialization processes at the beginning of this century. These anomalies are even recognized in remote areas, resulting from the rapid and hemisphere-wide distribution of pollutants through the atmosphere.

Dr. Kudrass briefly introduced hydrothermal mineralization along an active back-arc spreading center. A video of white and black smokers of the hydrothermal field discovered by the German RV SONNE in the Lau Basin (SW Pacific) and filmed by the French Submersible **NAUTILE**, was shown to confront the participants with a totally different environment. The processes resulting in the built-up of sulfide chimneys were explained.

2.1.5 Mapping and Air Photo Interpretation

Dr. Streif lectured on field techniques, field data capture, evaluation of field data, and their presentation in sequence maps of the coastal Holocene. A great variety of drilling equipment is available for mapping in coastal lowland areas. With regard to sea-level changes, palaeogeographic development and geotechnical purposes, it is recommended that most of the boreholes should penetrate the entire sequence of coastal deposits. Great advantages can be taken by using a symbol notation for the field data capture, like the "*Symbolschlüssel Geologie*" published by the Geological Survey of Lower Saxony and the Federal Institute for Geosciences and Natural Resources, Hanover, Germany. This offers the full use of computer-assisted evaluations of the field data in form of profiles of individual boreholes or cross sections and maps.

For a graphical presentation of geological data obtained from coastal lowland areas, sequence maps have been developed by Hageman (1963), Barckhausen et al. (1977), and Streif (1978). They offer possibilities to depict all essential litho-stratigraphical, petrographical and genetical units of the coastal Holocene in one geological map. Combined with a documentation system of the field data and the techniques of automatic data processing, this type of map offers new aspects which by far exceed the possibilities of conventional geological mapping.

Sea-floor mapping: principles and instruments was introduced by Dr. Kudrass. Bathymetry, fine-scale morphology and sub-bottom structures of nearshore areas can be mapped by various sonar systems. An exact determination of water depth is possible, when sound velocity, which varies with temperature, salinity, and pressure, is measured or calculated. Long-range echosounders use low frequencies (6-12 kHz), as the attenuation of the sonar signal decreases with lower frequencies. Records of single-beam echosounder are not to scale and hyperbolic reflections are caused by small high-reflectivity objects as for instance pipelines or small elevations. The reflectivity of the sea floor increases from muddy, sandy, gravelly to rocky bottom, and allows a first estimation of the type of bottom sediments. Swath-mapping systems, for instance Hydrosweep, determine water depth in a strip to both sides of the ship's track (up to 6 times the water depth). The strips can be easily combined to a bathymetric map. Side-scan sonar systems produce an acoustic map of the sea floor showing combined effects of reflectivity and micro-topography.

The penetration of sonar signals into the sediment increases with decreasing frequency. Sub-bottom profilers, for instance, parasound with a high vertical resolution operate at 1-3.5 KHz, and are able to penetrate up to 100-150 meters of unconsolidated sediments. Records of the different systems with typical examples were presented and discussed. Some of the instruments were presented during the cruise on RV PENYU (see 2.3 below).

Dr. Burne lectured on remote sensing and coastal zone mapping. This presentation deals with air-borne and space-borne systems that utilize electromagnetic energy for mapping the coastal zone (elsewhere in this training course the properties of sound and its use in ship-borne systems for mapping sea-floor characteristics are described). The natural forms of electromagnetic energy exploited by remote-sensing are visible, light and near, and middle infra-red radiation from the sun that is reflected from the Earth's surface, and middle and thermal infra-red radiation which are both emitted from the Earth's surface. In addition, imaging radar systems measure the two-way travel time and backscatter of artificially generated radiation of microwave wavelengths.

A knowledge of how electromagnetic radiation interacts differently with the various materials that cover the Earth's surface forms the basis of remote sensing analysis. The pigmentation, physiological structure and water content of vegetation all have an effect on the reflectance, absorbance and transmittance of electromagnetic energy. The reflectance properties of soils, sediments and rocks are moisture content, organic content, texture, structure and mineralogical composition. The majority of electromagnetic energy incident on water is either absorbed or transmitted and not reflected. Water strongly absorbs near and middle infra-red wave-lengths which enables a sharp boundary between water and land to be defined from infra-red film or spectral data. Water transmits visible light to varying degrees, with maximum transmission by clear ocean water of the 0.45 - 0.5 μm wave-lengths of blue light. In shallow water transmitted light may also be reflected from the materials at the bottom of the water body.

The various remote-sensing systems were described. They vary in resolution, with higher resolutions being obtained from aircraft systems (<1m-10m) and lower resolutions (10 m - global) from satellite systems. They have varying spectral characteristics, with film camera systems utilizing films and filters of varying spectral characteristics and multi-spectral scanners utilizing various detectors sensitive to specific electromagnetic wave-lengths. They vary in aspect from vertical to oblique. Three applications of remote-sensing to coastal mapping have been developed by the Coastal Geoscience Project of BMR Australia (with the co-operation of P. Bierwirth and E. Bleys). (i) Aerial photographs have been available for the past 50 years or more. Current technology allows the digitizing of aerial photographs. Sequential aerial photographs can be digitally compared to provide a record of change that can be used to monitor coastal processes or assess the impacts of development on coastal systems; (ii) Landsat TM is the only satellite multi-spectral scanner that samples the bandwidth of maximum light transmission by water (0.45 - 0.52 μm). TM bands 1 (0.45 - 0.52 μm), 2 (0.52 - 0.6 μm) and 3 (0.63 - 0.69 μm) are processed using an algorithm that separates effects due to water depth from those due to reflectance from the sea bottom. As a result it is possible to map sea-floor features such as the distribution of coral reef zones, sea-grass meadows, and sand bodies, as well as to derive a relative chart of shallow bathymetry; (iii) Landsat TM imagery of onshore coastal areas are analyzed to provide information on the distribution of different materials such as clay, Fe-oxide, silica, green vegetation, and dry vegetation.

Since the pixel reflectance is a simple linear mix of component reflectances, the composition of each pixel with respect to these materials is determined by using an algorithm that analyses each pixel spectrum over all bands by comparison with a set of known reflectance curves for the materials to be investigated. The method is not yet perfect. It lies somewhere between an enhancement and an expert system.

Coastal zone aerial photo exercises was arranged by Dr. Burne.

(i) Stereo interpretation of vertical aerial photography.

(ii) Interpretation of sea-surface and submarine features on vertical aerial photographs.

(iii) Morpho-stratigraphic and morpho-dynamic interpretation of coastal complexes using vertical aerial photographs.

(iv) Mapping of morphological units on overlays.

(v) Workshop on the interpretation of the coastal evolution and dynamics of area south of Kuatan based on field observations and combined results of the group's aerial photo interpretations.

Exercises on the evaluation of aerial photographs from the coastal zone around Kuantan were conducted by Drs. Streif, Burne and Kudrass. With reference to the field exercises in the Kuantan area (see 2.2 below) an evaluation of aerial photographs was carried out on the coastal evolution north and south of Kuantan in the course of the last 5,000 years. Series of beach ridge systems differing in shape and orientation indicate repeated migrations of the mouth of tidal inlets and river deltas. The lateral migrations of these sources of sediment supply resulted in phases of local coastal progradation and erosion. Based on this kind of information, predictions can be made as to future coastal developments in the area.

2.2 FIELD STUDIES

Drs. Streif and Kudrass, with the assistance of the Geological Survey staff, conducted the field excursion with exercises on drilling techniques, sedimentary sequences, coastal environments and morpho-dynamics in the Sepang area, west coast of Peninsular Malaysia. In the Sepang low-land area, the Geological Survey of Malaysia demonstrated drilling techniques (bangka drilling and automatical bangka drilling) as well as geotechnical investigation methods applicable for the classification of unconsolidated sediments. With the hand auger Guts, continuous sedimentary cores were taken from coastal deposits down to a depth of 5.6 m below land surface. By aid of this very efficient tool, drilling can be carried out by two persons in clay-silty deposits and peat, to a depth of about 15 meters. The borehole in the Sepang area demonstrated a sequence from peat at the surface, through deposits of a Nippa swamp into typical mangrove sediments. Comparisons were made between the cored sedimentary units and the present day environments along the low energy west coast of Peninsular Malaysia. Beach profiles were described and sampled by 3 working groups, covering a transect from a small tidal creek through the intertidal zone to the top of a sub-recent beach ridge system.

Field training in the area south of Kuantan on coastal morphology and sediment sequences of beach, intertidal, and supratidal environments was guided by Drs. Streif, Burne and Kudrass. A full day training course dealt with the accumulation and erosion processes, the geomorphology and sedimentary sequences along the high energy east coast of Peninsular Malaysia. Characteristics of the surface morphology and the vegetation on beach ridge systems and in the deep-seated swampy inter-ridge areas were one subject of the excursion. Special attention was paid to sedimentary environments and depositional as well as erosional processes. Sedimentation and bio-turbation structures of sandy shoals and intertidal gully deposits were studied by the aid of lacquer peels, including heavy mineral enrichments in these zones. Depositional features of the supratidal zone-like sand spits, washover fans, and primary dunes were investigated together with fossil soil and vegetation horizons. As a whole, these kind of studies is a basis for the interpretation of sea-level indicators. In addition, they are a necessary tool of ground checks which have to be carried out for the evaluation of aerial photographs.

Field training in the coastal zone to the north of Kuantan was given by Drs. Streif, Burne and Kudrass. Sedimentary structures of a beach environment were investigated in the area south of Pantai Batu Hitam (Black Rock Beach). In a continuous trench extending from the low water line to the supratidal zone, phases of "normal" beach sedimentation were distinguished from layers which were deposited in the course of storm surge events. As promontories of granitic rocks occur in the south of this zone, whereas a small outcrop of basaltic rock exists in its north, advantage was taken to determine the influence of the different source rocks on the sand budget of this beach section. In basing on investigations of Fitch (1952), geomorphological studies were carried out on different generations of beach ridge systems in the region south of Chukai. A 15 meter high beach ridge system of Stage I occurs in the innermost part of the bay, probably belonging to the last interglacial period. Ridges of Stage II are about 5 m high and belong to the mid-Holocene transgression. The youngest ridge system, classified in Stage III, reaches heights of about 3 m and was formed in sub-recent times.

2.3 DEMONSTRATION CRUISE

Dr. Brumsack lectured on water analysis by semi-quantitative methods including exercises on board and later in the laboratory.

Surface water samples were collected during the RV PENYU cruise from Kelang harbour to the open Strait of Malacca. Four different parameters were semi-quantitatively determined on board ship by coulometric methods, including ammonia, phosphate, iron, and pH. Whereas the Kelang harbour samples were characterized by elevated ammonia and iron concentrations indicating anthropogenic input (waste water) and potential oxygen depletion, values rapidly decreased towards normal when approaching the Strait of Malacca. Tidal mixing seemed to be restricted to a small zone (front) in the Kelang river. Samples were stored in plastic bottles for further chemical analysis in the laboratory. The determination of ammonia by semi-quantitative methods seemed to be a sensitive tracer of anthropogenic menure input into the river water.

2.4 LABORATORY WORK

Dr. Brumsack introduced analytical geochemistry with laboratory exercise. A very simple method to obtain geochemical data by flame AAS was demonstrated. Several samples which have been collected by the participants during the field trips were dried in an oven for 24 h and then homogenized in a mortar. Sample splits of 5 g were carefully transferred into Kjeldahl glass reaction tubes and treated with hot *aqua regia* for approximately 2 h. The extracts were filtered and made up to a volume of 100 ml in glass volumetrics. The assumed Fe-concentration of the sample and the optimum concentration range for the Fe flame AAS method was given to the participants, who then had to calculate the dilution factor.

The Fe absorption signals of 5 calibration solutions and the diluted sample solutions were determined by flame AAS at the UTM Environmental Laboratory. Calibration curves were constructed by the participants and the unknown Fe-content of the samples was calculated. Advantages and problems of AAS determinations were discussed.

Analyses in the chemical laboratory of material collected during cruise were carried out under the guidance of Dr. Brumsack (see above under 2.3).

Training by Dr. Streif was carried out in the sediment laboratory of the University Technology Malaysia. Grain size analyses were carried out in 3 working groups. Basing on sorting images, grain shape and roundness images, and visual estimation of percentage composition, comparisons were undertaken between different samples of beach sand from marine-intertidal to supratidal environments, and a sample of fluvial-terrestrial sand from the borehole.

3. SEMINAR

A special Seminar was held to allow trainees to present their own personal research work, the research activities of their respective countries or institutes, and to discuss co-operation with the instructors (Kudrass, Streif, Burne, Brumsack) and among themselves. The seminar met 4 times. Trainees presented brief lectures as follows:

18 February 1992:	H.L. Among: Coastal plain of Sarawak, Malaysia P. Suthanaruk: Coastal erosion at Phuket, Thailand S. Kengkoom: Placer deposits in the Gulf of Thailand M. Hoque: Hydrodynamic problems of the Ganges-Brahmaputra delta, Bangladesh
20 February 1992:	Li Yan: Sedimentation in the tidal area off Hangzhou, China T. Surat: Coastal geology of Sabah, Malaysia V. Krishakumar: Wave-induced long-shore transport along the west coast of India T. Dharmaratne: Sedimentation at the shelf north of Colombo, Sri Lanka
25 February 1992:	H.K. Bahng: Mineral provinces at the western shelf of Korea A. Naseer: Coastal management of reefs and atolls in the Maldives Myattar: The coastal areas of Myanmar
27 February 1992:	Suyarso: Coastal and marine research activities in Indonesia Van Hung Tran: Coastal and nearshore sediments in Vietnam

Dr. Giermann informed trainees in which way co-operation can be arranged through IOC and other international multilateral or bilateral funding agencies. Dr. Kudrass provided some information on German agencies providing funding to foreign scientists, such as DAAD, GTZ, Humboldt Foundation, and others.

4. CONCLUSIONS

The closure day started with a one and a half hour final discussion and summary of the Course, in which all instructors and trainees participated.

The contents of lectures, exercises, and excursions were briefly summarized and the most important results repeated. In addition, open questions concentrating on the time-frequency domain (transgression-regression, season, tides) were discussed. In a general statement, the responsibilities of marine geologists were deduced, who must use their scientific time-oriented knowledge to recognize natural long-term developments in erosional or accretionary processes along the coast.

There was general agreement on the usefulness of such training courses which do not only give an insight into advanced knowledge, but also provide a possibility to meet and to discuss co-operation amongst instructors and trainees, and the trainees themselves. The trainees evaluated that the course contents were useful to advance their work at their home institute and that lectures, laboratory exercises and field training were well-balanced, especially field training which was practical and useful. They expressed their wishes that if a similar course could be organized on a regular basis, i.e., every two/three years, young scientists in the region would have more opportunity to keep up their knowledge and techniques. They also stressed that practical lessons through laboratory exercises and demonstration cruises are very important elements of the course and hoped more time could be used for this purpose.

IOC was also requested to stay in contact with the trainees, and to provide information to them on matters of interest, so to keep them aware of IOC's on-going programme on Ocean Sciences in Relation to Non-Living Resources (OSNLR) and TEMA activities.

5. CLOSURE OF THE TRAINING COURSE

A formal closure of the Session was held on Saturday, 29 February 1992, in the Hall of the Electrical Science Museum of the Technical University Malaysia, to which some guests and the press were invited. It included the official closing session in the Hall (Electrical Science Museum) chaired by the IOC representative, with brief allocations by Capt. RMN Mohd. Rasip Hassan, Director of the Hydrography Directorate, official host of the Course, Professor Ir. Dr. Abdul Aziz Ibrahim Director, Coastal and Offshore Engineering Institute, University Technology Malaysia, Dr. Günter Giermann, representative of the Intergovernmental Oceanographic Commission of UNESCO, organizer of the Course, Dr. H.R. Kudrass, Federal Institute for Geosciences and Natural Resources, Hanover, Scientific Course Leader, speaking on behalf of the instructors, and Mr. Sunoj Kengkoom, Dept. of Mineral Resources, Bangkok, speaking on behalf of the trainees.

A farewell reception was given by the host country and the course was closed on 29 February 1992 at 1200 hours.

After the course Captain RMN Mohd. Rasip Hassan and Dr. Gunter Giermann had a press conference (see text in Annex IV).

ANNEX I

AGENDA

1. **OPENING**

2. **COURSE PROGRAMME**

    2.1 LECTURES AND EXERCISES

    - 2.1.1 Sea Level Changes
    - 2.1.2 Coastal Sediments and Resources
    - 2.1.3 Coastal Impacts
    - 2.1.4 Geochemistry and Sea Water Chemistry
    - 2.1.5 Mapping and Air Photo Interpretation

    2.2 FIELD STUDIES
    2.3 DEMONSTRATION CRUISE
    2.4 LABORATORY WORK

3. **SEMINAR**

4. **CONCLUSION**

5. **CLOSURE OF THE TRAINING COURSE**

ANNEX II

TIMETABLE

17 February 1992	a.m.	Opening
	p.m.	Organizational Matters (instructors only)
18 February 1992	a.m.	Sea-level changes: causes, rates, and amplitudes (Streif) Sea-level changes and related shifts of coastal depositional environments (Kudrass)
	p.m.	Seminar (Among, Suthanaruk, Kengkoom, Hoque)
19 February 1992	a.m. p.m.	Field training in Sepang area (south of KL) with exercises on drilling techniques, coastal sedimentary sequences, coastal environments, and morpho-dynamics (Streif, Kudrass, Geol. Survey staff)
20 February 1992	a.m.	Sea-level variation and coastal evolution (Burne) Instrumental methods used in geochemistry (Brumsack)
	p.m.	Seminar (Li Yan, Surat, Krishnakumar, Dharmaratne)
21 February 1992	a.m.	Grain size analyses & sample comparisons in laboratory (Streif) Introduction to analytical geochemistry in laboratory (Brumsack)
	p.m.	(Streif cont.) Composition of sand in marine sediments (Kudrass)
22 February 1992	a.m.	Bus transfer
	p.m.	Field trip to prepare exercises (Kudrass, Streif, Burne, Geol. Survey staff)
23 February 1992	a.m. p.m.	Field training in Kuantan area (east coast) on coastal morphology, sediment sequences of different environments (Kudrass, Streif, Burne, Geol. Survey staff)
24 February 1992	a.m.	Field training in the coastal zone north of Kuantan (Kudrass, Streif, Burne, Geol. Survey staff)
	p.m.	(bus transfer)
25 February 1992	a.m.	Case studies on environmental impact through dredging in a lagoon (Tongatapu), and an active submarine caldera as a natural hazard (Rabaul, PNG) (Giermann) Sea-floor mapping: principles and instruments (Kudrass)
	p.m.	Hydrothermal mineralization along an active spreading ridge (with video) (Kudrass) Seminar (Bahng, Naseer, Myattar)
26 February 1992	a.m. p.m.	Demonstration cruise on RV PENYU in the Strait of Malacca outside Kelang, with water analyses, sediment sampling, sidescan sonar and echosounder profiling, trisponder and GPS navigation (Brumsack, Streif, Kudrass)

27 February 1992	a.m.	Seminar (Suyarso, Van Hung) Seawater chemistry and estuarine processes (Brumsack) Remote sensing and coastal mapping (Burne)
	p.m.	Case studies on coastal changes through man-made impacts (Rarotonga), and placer deposits on a shelf (Sri Lanka) (Giermann) Water analyses in laboratory (Brumsack) Exercise on remote-sensing and coastal mapping (Burne) Followed by a reception given by the German Embassy (Mr. Berger)
28 February 1992	a.m.	Early diagenetic processes (Brumsack) Exercise on Holocene sea-level change in the Strait of Malacca (Kudrass)
	p.m.	Exercise on evaluation of aerial photographs from Kuantan coastal plain (Kudrass, Streif, Burne)
29 February 1992	a.m.	Panel discussion and formal closure session

ANNEX III

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ANNEX IV

PRESS RELEASE

From 17 to 29 February, the Intergovernmental Oceanographic Commission (IOC) of Unesco, Paris, conducted an advanced training course on Nearshore Sedimentation and Evolution of Coastal Environments in the premises of the University Technology Malaysia in Kuala Lumpur. The Official host was the Hydrography Directorate of the Royal Malaysian Navy. The Course was co-hosted by the University Technology Malaysia. It was funded by the Government of Germany, with contributions from the host country and IOC. The Course was designed to respond to the urgent needs of the countries of the central and eastern Indian Ocean and western Pacific to learn more about the evolution and structures of their coastal environments, the mineral resources of their nearshore areas, and the influences of a changing sea level. The two-week course was divided into lectures, exercises and laboratory analyses, and included 4 days of geological field work with sediment sampling along the western and the eastern coasts of Malaysia in the Sepang and the Kuantan areas, as well as a one-day cruise on board a Royal Malaysian navy vessel starting in Port Kelang. The Course was led by 4 instructors from Germany and one from Australia, namely Dr. H.R. Kudrass from the German Geological Survey in Hanover, serving as Scientific Course leader, Dr. G. Giermann from the Alfred Wegener Institute in Bremerhaven also officially representing IOC, Dr. H. Streif from the Lower Saxony Geological Survey in Hanover, Dr. H. Brumsack from Göttingen University, and Dr. R. Burne from the Bureau of Mineral Resources in Canberra.

The course was attended by sixteen trainees coming from the following countries: Bangladesh, China, India, Indonesia, Republic of Korea, Malaysia, Maldives, Myanmar, Sri Lanka, Thailand (two of which were ladies), and Vietnam. The local secretariat was in the competent hands of Lt. Cdr. Mohd. Fairuz bin Abdullah of the Hydrography Directorate assisted by staff of the University Technology Malaysia. The Course is one out of a number of training activities which the German Government offered and will offer to developing countries through financial contributions to the IOC Trust Fund.