THE ROUTE SURVEY

FOR

MEDAN (INDONESIA) – COLOMBO (SRI LANKA)

SUBMARINE CABLE PROJECT

MARCH 1984

JAPAN INTERNATIONAL COOPERATION AGENCY

PREFACE

It is with great pleasure that I present to the Governments of the Republic of Indonesia and the Democratic Socialist Republic of Sri Lanka a "Report on the Route Survey of Medan (Indonesia) - Colombo (Sri Lanka) Submarine Cable Project".

This report embodies the results of the route survey which was carried out from August 1983 to February 1984 by a team organized by the Japan International Cooperation Agency in response to the request of the Governments of Indonesia and Sri Lanka to the Government of Japan.

The survey team, headed by Mr. Kouichi Uchida, Deputy Director, Tariff Regulation Division, Telecommunications Policy Bureau, Ministry of Posts & Telecommunications, conducted an ocean survey, had a series of discussions with the officials concerned of the Governments of Indonesia and Sri Lanka and has formulated the present report.

I hope that this report will be useful for the development of the Project.

I wish to express my deep appreciation to the officials concerned of the Governments of the Republic of Indonesia and the Democratic Socialist Republic of Sri Lanka for their close cooperation extended to the survey team.

March 1984

Keisuke ARITA
President
Japan International Cooperation Agency

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Summary

Social demands for international telecommunication services are increasing with extension of economic and social activities and development of internationalization of these activities. In order to meet these increasing demands, various countries are constructing international communication transmission lines at the present. The Medan-Colombo Submarine Cable Project forms one segment of the SEA-ME-WE Cable Project which interconnects several countries from Singapore to France. This submarine cable runs across the Indian Ocean for the first time in the world.

International telecommunication services between Indonesia and Sri Lanka are made mainly by the satellite communication system at the present. In this connection it has been required to meet future increasing demands for international communication services, and to improve the quality of communication services by using two main routes; satellite communication system and submarine cable system together.

This submarine cable system will serve as an international communication highway which interconnects Southeast Asia ~ Middle East ~ Western Europe, and it will be extremely useful for improving the quality of international communication services of not only the countries concerned but also surrounding countries.

In response to the request of the Governments of Indonesia and Sri Lanka, the Japanese Government conducted, through JICA, route surveys and financial analysis with respect to this submarine cable project. The summary of results, especially major points, of the surveys conducted by the survey team is as follows:

1. Submarine Cable Route and Cable Length

The submarine cable route, which connects Pantai Cermin (cable landing point in Indonesia) to Colombo (cable landing point in Sri Lanka), has been selected with due consideration to both economic efficiency and high reliability.

The proposed cable route goes up north in the shallow sea area of Malacca Strait, passes through the Great Passage where undulations of the bottom topography are large and the 90°E Ridge, crosses the Bengal Fan, and then reaches Colombo. This route is shown in Fig. 1.

Problems and countermeasures which should be taken into consideration as to the proposed cable route are as follows:

(1) The shallow sea area in the Indonesian side, where the water depth is less than 30 m, spreads over a very wide area and, moreover, an anchorage area is close to the proposed cable route.

As the results of the survey in the Sunda Continental Shelf it was found that fishing activities which may give damage to a cable are not brisk and cable burying is quite difficult due to the stiff seabed. Therefore, it is recommended that a non buried double-armoured cable should be used to a 30 m depth line and a non-buried single-armoured cable in the shelf area.

(2) In the Great Passage, it was observed that undulations of the seabed are severe, the seabed consists of rocks, and tidal currents in the deep sea are fast. Therefore, it is strongly required to prevent a cable trouble resulting from abrasion by using in this area a specially protected cable for deep sea use.

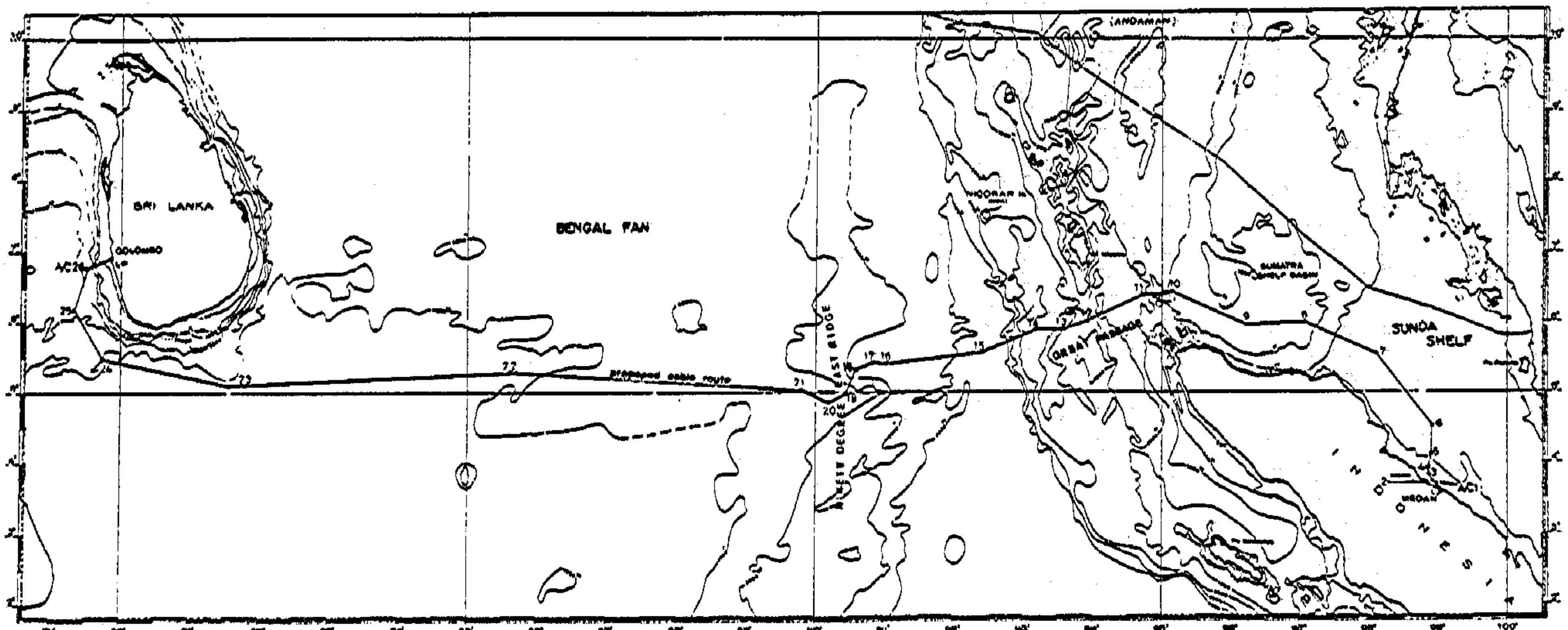


Fig 1 PROPOSED CABLE ROUTE

A/C --- ALTERED COURSE
L.P --- LANDING POINT

(3) The seabed in the colombo shallow sea area is rock covered with a thin layer of sand. Partially,outcrops of rock are found. Taking into consideration the fact that anchorage areas are close to the proposed cable route,it is necessary to use a double-armoured cable in the Colombo shallow sea area,and to protect it by laying in a trench in the reef area close to the beach.

According to the survey results mentioned above, the route length is 1,384.1 nm between two cable landing points. A mean cable slack in this submarine cable section and the total cable length are estimated at about 2% and 1,412.7 nm, respectvely. The cable lengths in this cable section by types of cables are shown in Fig. 2.

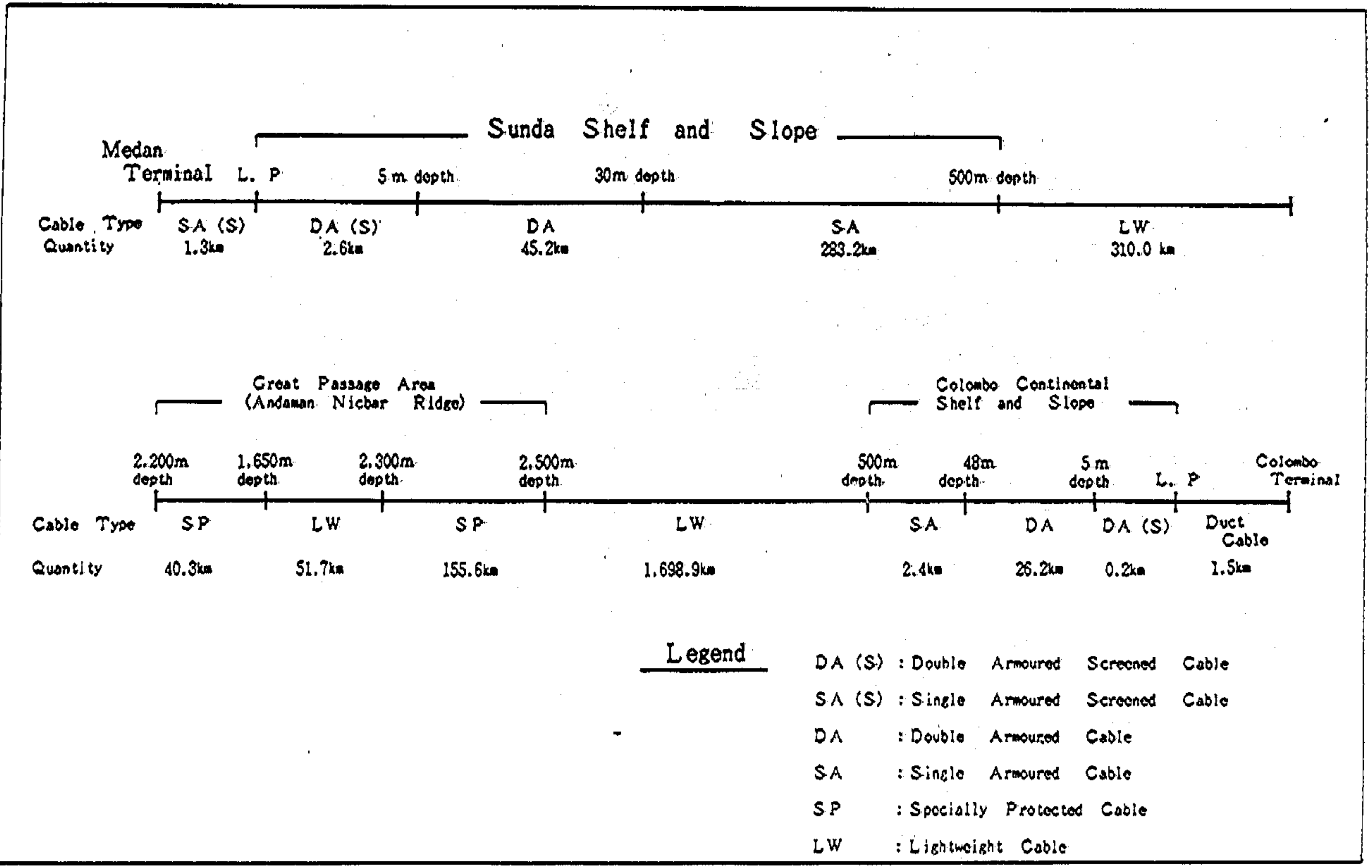


Fig. 2 RECOMMENDED CABLE TYPES AND QUANTITIES

1. Introduction

A submarine cable is being planned to link South East Asia, Middle East, and Western Europe. One of the segments of the cable system is between Medan and Colombo. The Governments of Indonesia and Sri Lanka have requested the Government of Japan to provide assistance to carry out the cable route survey between Medan and Colombo.

In compliance with the request, the Japanese Government arranged to carry out the cable route survey under the auspices of the Japan International Cooperation Agency. In March 1983, the Government of Japan, through JICA, sent a preliminary study team to the two countries, and the Scope of Work (S/W) of the route survey was concluded by the authorities concerned of Indonesia, Sri Lanka and JICA preliminary study team.

Based on the S/W, the JICA survey team started a desk-top study of this project in Japan. The team collected data, such as submarine physiography, seismic activity, weather and currents, fishing activities, and so on. The survey team analized the data, and selected the proposed cable route.

From 30th August to 7th September, the survey team was sent to the two countries, and submitted and explained the Inception Report on the route survey for Medan-Colombo submarine cable project.

After submission of the Inception Report, the team boarded the Japanese survey ship "WAKASHIO MARU" at the Singapore port on 19th September, and carried out the cable route survey from 22nd September to 9th November with full assistance of the Government Authorities of Indonesia and Sri Lanka.

The Indonesia counterpart and French observer together with two officers of the Hydrographic Department of Indonesian Navy joined the survey ship at Belawan. After the survey on the Indonesian territorial area, the two naval officers got off the ship at Kruengraya. The survey ship arrived at Colombo in 16th October after the going-run survey. Colombo approach, inland and inshore survey, as well as the earth resistivity measurement, were carried out from 17th to 22nd October with the full assistance of SLTD, Sri Lanka Survey Department and Colombo Port Authority.

The counterpart of Sri Lanka joined the survey ship at the Colombo port and the returning-run survey was carried out from 23nd October to 9th November.

(1) Names of Participants

The participants in the cable route survey are as follows;

1) Preliminary Study

Mr. Koichi Uchida	MPT	Team Leader
Mr. Ryuichi Kinoshita	MPT	Sub-Leader
Mr. Hajime Tonegawa	MPA	Sub-Leader
Mr. Taisuke Kitamura	KDD	Cable Engineer
Mr. Tokuji Mitsui	KDD	Cable Engineer
Mr. Tadashi Tomizawa	JICA	Coordinator

2) Route Survey

a. Japanese team members

Mr. Koichi Uchida*	MPT	Japanese Survey Team Leader
Mr. Akira Ishii	KDD	Route Survey Team Leader
Mr. Akio Mizukoshi	KDD	Cable Engineer
Mr. Tokuji Mitsui	KDD	Cable Engineer
Mr. Fumitaka Kobayashi*	KDD	Financial Analyst
Mr. Yasuo Nishiyama*	SHS	Hydrographer
Mr. Shigeaki Kubo	SHS	Geologist
Mr. Takeji Otsuka	SHS	Oceanographer
Mr. Masatami Oyama*	JICA	Coordinator

b. Counterparts

Mr. Achmad Lesmana	P.T. Indosat, Indonesia
Mr. Ardhin Ichwan*	P.T. Indosat, Indonesia
Mr. M. B. Rodrigo*	SLTD, Sri Lanka
Mr. U.S.W. Basnayake	SLTD, Sri Lanka

c. Observer

Mr. L. Lemasson	PTT, France

d. Indonesian Navy

Cpt. Mintardjono
Lt. Iswinardi

Reamrks: * Not attended at the actual route survey

MPT: Ministry of Posts and Telecommunications
MFA: Ministry of Foreign Affairs
KDD: Kokusai Denshin Denwa Co., Ltd.
SHS: Sanyo Hydrographic Survey Co., Ltd.

(2) Survey Schedule

The schedule of the survey are as follows;

1) Preliminary study

Preliminary Study Team visited the two countries from 6th to 25th March 1983, and concluded the Scope of Work.

2) Submission of Inception Report

Based on the Scope of Work, the study team prepared the Inception Report for Route Survey, and submitted and explained the report to the two countries from 30th August to 7th September 1983.

3) Route Survey

Going-run survey was conducted from 22nd September to 16th October from Medan to Colombo. The Inland Survey and Earth Resistivity Measurement were conducted at Colombo from 17th to 22nd October.

Returning-run Survey was conducted from 23rd October to 9th November.

4) Submission of Interim Report

After survey, the survey team prepared the Interim Report at Singapore, and submitted and explained to the two countries from 25th November to 2nd December.

5) Submission of Draft Final Report

Through discussion with counterparts from the two countries from 9th to 21th January 1984, the survey team prepared the Draft Final Report, and submitted and explained to the two countries from 24th January to 2nd February 1984.

6) Submission of Fianl Report

The survey tema prepared the Final Report including the comments from the two countries, and forwarded to the two countries at the end of March 1984.

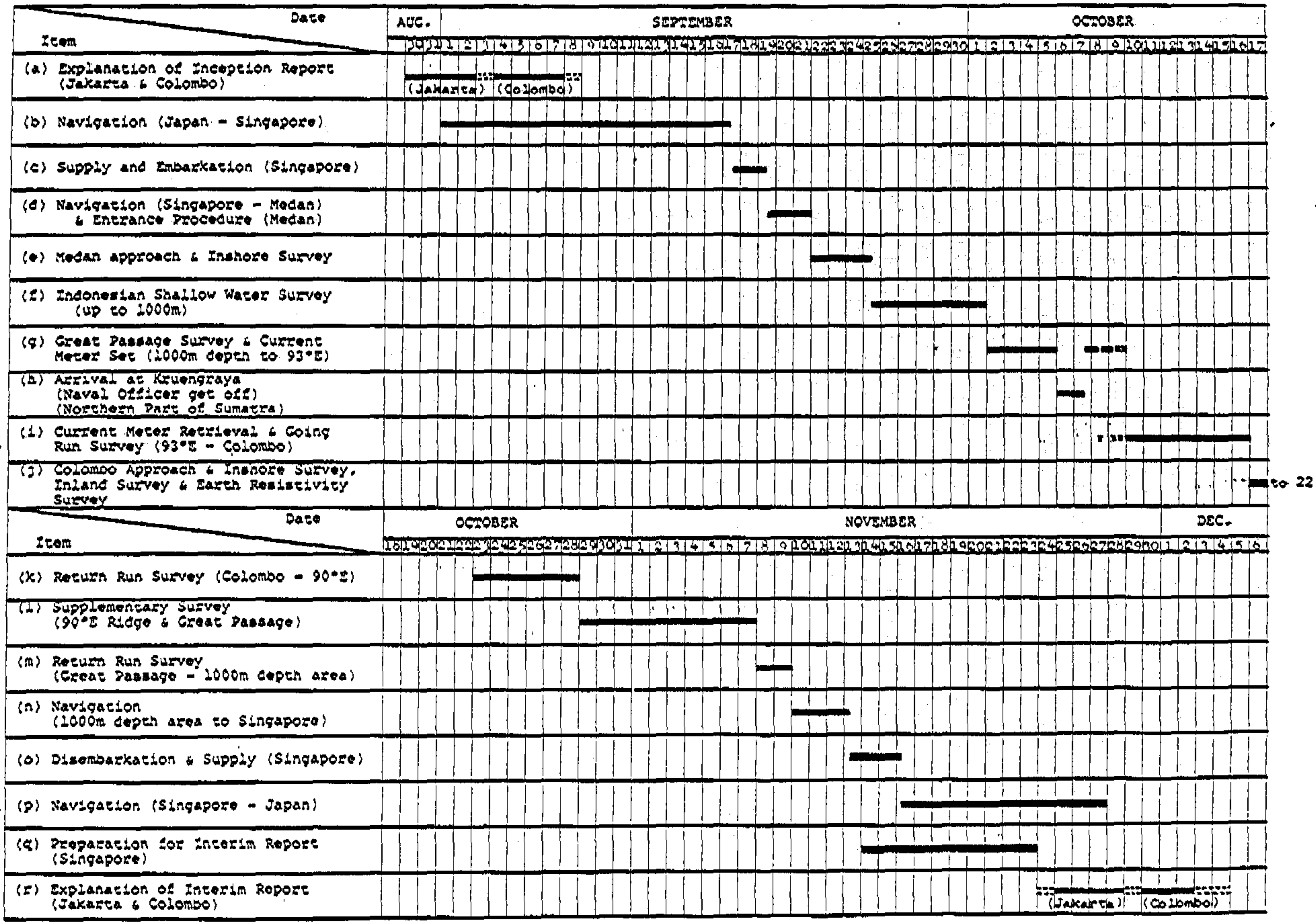


Fig. 1.1 RESUME OF EVENTS ON THE ROUTE SURVEY

2. Desk-Top Study

2.1 General

When collecting data necessary for the cable route survey, it was difficult in Japan to obtain all the information on the coastal areas of Indonesia and Sri Lanka. We, therefore, asked the government authorities of these two countries to furnish us with necessary information.

Data on ammunition dumping areas, offshore oil development activities, etc. were provided by the Government of Indonesia. Various types of information on the Sri Lanka waters and data on underground installations in the urban district of Colombo were provided by the Government of Sri Lanka.

This chapter has been prepared according to these data and additional data collected from several foreign countries.

2.2 Submarine Physiography

The seabeds spreading from Medan (Pantai Cermin) to Sri Lanka can be classified into the following seven areas by topography.

2.2.1 Malacca Strait

2.2.2 Andaman Sea

2.2.3 Great Passage (Andaman-Nicobar Ridge)

2.2.4 Nicobar Fan

2.2.5 90°E Ridge

2.2.6 Bengal Fan

2.2.7 Colombo Continental Slope

2.2.8 Colombo Continental Shelf

Their locations are shown in Fig. 2.2.1 together with the proposed cable route.

2.2.1 Malacca Strait

(1) Sunda Continental Shelf

The Malacca Strait spreads in the direction of northwest-southeast. Its total length is about 800 km, and its width is about 310 km near its north-west opening, but it narrows in the south-east direction, and its width is about 65 km near 2°30'N.

The water depth is as extremely shallow as about 20 m near the south opening, and about 100 m near the north opening.

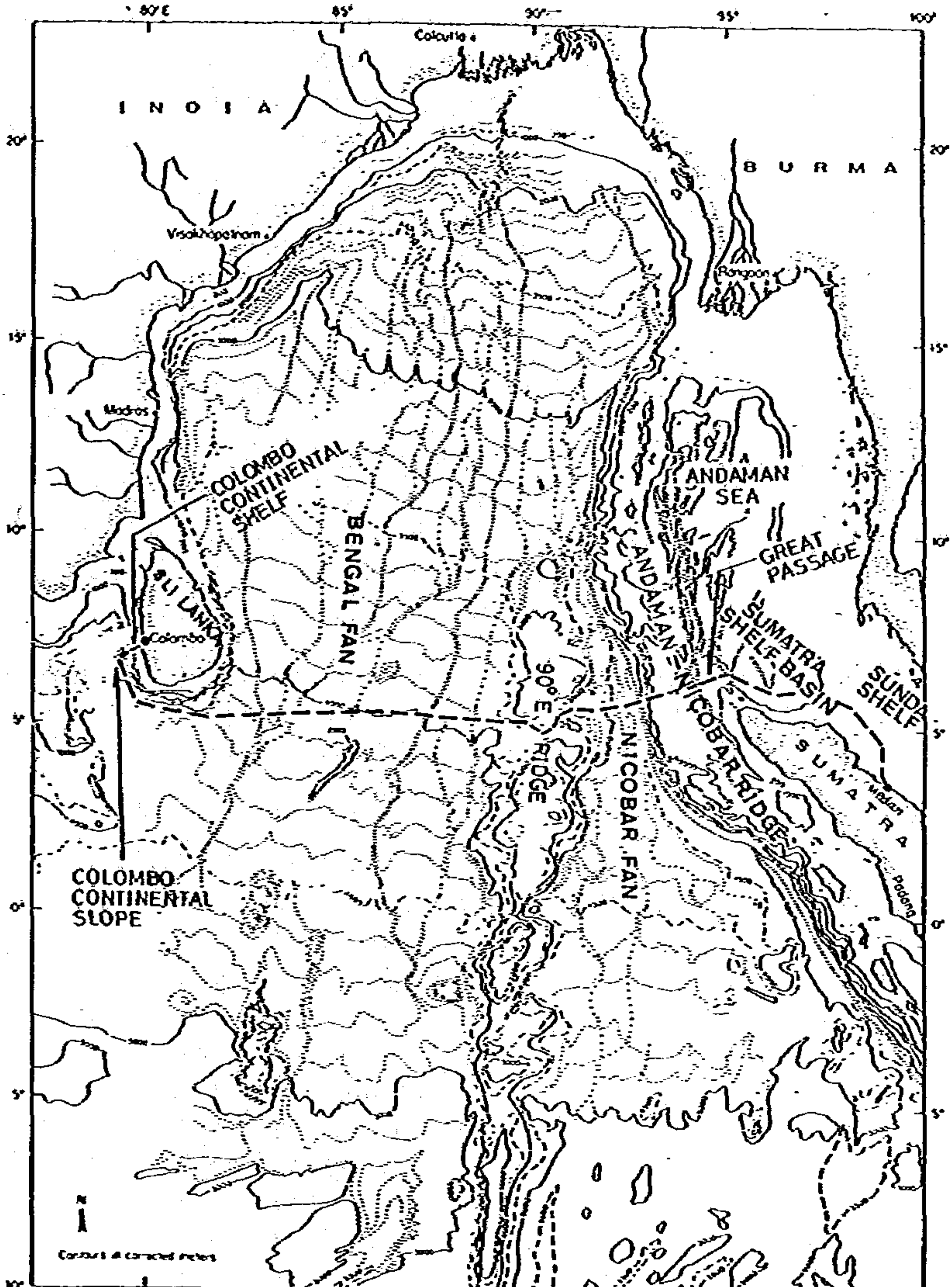


Fig. 2.2.1 GENERAL TOPOGRAPHY OF SURVEY AREA (Modified from Curray et al, 1971)

The Malacca Strait is a part of the Sunda Continental Shelf, and its sea level went down by about 100 m and its greater part became a land in the last final glacial period about 10,000 years ago. At that time the land surface was flattened, or valleys were dug into the land surface due to erosion by rivers. Even after the ice age ended and the sea level was restored to the present one, these erosional valleys remain in the seabed.

The present seabed topography formed in the early Quarternary, i.e., Pleistocene epoch. The seabed consists generally of Pleistocene deposites, and its surface is covered with a thin layer of Holocene sediments. Bottom sediments are mud or sand-mud, but a distribution of sand or pebbles is found at areas where the current is fast.

The proposed cable route runs up north from Medan (Pantai Cermin) and, after having reached to the water depth of 50 m, runs nearly in parallel with the Sumatra Is. about 65 km offshore the Sumatra Is.

(2) Sunda Continental Slope

The Sunda Continental Slope extends from the Sunda Continental Shelf to the Sumatra Shelf Basin floor of the water depth of 1,200 m. Its gradient is steep on the southwest side, i.e., near the Sumatra Is. On the other side, i.e., Ko Pucket side, the gradient is extremely gentle. It is seen that a submarine fan has developed on the Ko Pucket side at the water depth of 300 ~ 400 m. An uneven topography has developed at the lower part of the slope, and it suggests that phenomena of creep and slumping are occurring.

The proposed cable route runs through the lower part of the slope where the topography is stable and undulations are little.

2.2.2 Andaman Sea

The Andaman Sea is a sea area which is enclosed with the Irrawaddy Delta at the north, the Malay-Burma Peninsula at the east, Andaman-Nicobar Is. arc at the west, and the Malacca Strait at the south. On the east side of this sea area, the continental shelf of Malay-Burma Peninsula has developed down to the water depth of 200 m, but the sea abruptly deepens on the west side, and the Narcondam-Barrer Basin is found in the Central Andaman Trough and on the north of the trough, and the Sumatra Shelf Basin is found on the south of the trough. A mean water depth of the former two is 2,000 m, and 4,180 m at the deepest point of the Central Andaman Trough. The proposed cable route passed through the Sumatra Shelf Basin which spreads in the southern part of Andaman Sea. This basin is a basin of incomplete type opening to the west, and the water depth at its deepest point is about 1,300 m.

2.2.3 Great Passage (Andaman-Nicobar Ridge)

The Andaman-Nicobar Ridge extends in the form of arch over a distance of about 900 km from the Middle Andaman to the northern edge of Sumatra. The east side of this ridge stretches to the complicated seabed topography of Andaman Sea. The west side form a steep slope, and stretches to the deep sea area of the Java Trench.

The Java Trench is the so-called subduction zone where the Indian Ocean Plate collides with the Indonesia-Sunda Continental shelf, and the former is sinking under the latter. There are several islands in the Andaman-Nicobar Ridge, and they are separated from one another by large and small straits. Among these straits, the Great Passage extending between the Sumatra Is. and Great Nicobar Is. is widest, and the water depth is largest. The width and mean water depth of Great Passage are about 190 km and 1,500 m, respectively.

However, undulations of the seabed of Great Passage are remarkable, and the water depth exceeds 2,500 m at deep points. The proposed cable route determined by the route survey will pass through the Great Passage at a point where undulations are relatively small.

2.2.4 Nicobar Fan

The Nicobar fan was formed with sedimens transported by the turbidity currents from the Ganges-Brahmaputra Delta, and its surface is flat and covered with ooze. The water depth of the bottom of Nicobar Fan is about 4,000 m, and the seabed shows as a whole a very gentle slope toward the Java Trench. The proposed cable route runs on the extremely gentle slope.

2.2.5 90°E Ridge

The 90°E Ridge is a linear ridge which is about 4,800 km in length and about 200 km in width, stretching from near 12°N to 31°S along a longitudinal line of 90°. The water depth at its deepest point is 1,800 ~ 3,000 m, and the seabed is covered with pelagic globigerina ooze. It is judged from the results of seismic survey that the 90°E Ridge was formed rather by upheaval of stratum than the volcanic origin, and its origin is still under study at the present.

In the 90°E Ridge, fractures have developed in parallel with the longer axis direction, and formed a complicated uneven topography. The proposed cable route determined by the route survey is designed to cross the 90°E Ridge at a point where the ridge is narrowest and undulations are small.

2.2.6 Bengal Fan

The Bengal Fan is a sumbarine delta fan which was formed mainly with sediments transported from the Ganges-Brahmaputa Delta and deposited on the seabed. Its length is about 3,000 km southward from the Ganges-Brahmaputa Delta down to the water depth of about 5,000 m, and its maximum width is 1,100 km.

Dips of the seabed are nearly uniform, and about 1.1 m/km. Large and small submarine canyons have developed reticulately on the Bengal Fan as shown in Fig. 2.2.1.

These canyons are passages through which sediments are transported, and their profiles are varied comprising V-shaped profiles like those of land rivers, profiles of a developed natural levee, river terrace, etc.

It is said that sediments are still actively transported through some of these submarine canyons at the present. The proposed cable route crosses the Bengal Fan nearly along a line of 5°N, and since this line is about 1,600 km distant from the head of delta, it is considered that there is not such a strong current as to give damage to a cable.

2.2.7 Colombo Continental Slope

The slope of the continental shelf of Sri Lanka is relatively steep (about 10° on an average), and especially on the south side of the island, the slope is as steep as 45° at some points.

The proposed cable route extends to a deep area with the shortest possible way.

2.2.8 Colombo Continental Shelf

The continental shelf is narrow, and its width is about 20 km. The water depth at the continental margin is about 65 m on an average. Sediments on the continental shelf are sand, fragments of coral reef, etc.

The proposed cable route extends from the Colombo landing point to the direction of WSW on the relatively flat continental shelf, keeping clear of a reef or large-sized ship anchorage areas.

2.3 Seismic Activities

Earthquakes occurred in the last twenty years (1960 ~ 1980) in an area including the survey route show a distribution plotted in Fig. 2.3.1. These earthquakes convergently occurred in a limited area, and their details are shown in Fig. 2.3.2. The Sunda Shelf and Slope are stable crustal blocks on the Indonesia-Sunda Continental Block, and a weak earthquake was recorded in this area 1959, but an earthquake has scarcely occurred since 1959.

Near the Great Passage, occurrence of earthquakes of a magnitude of less than 7 was recorded in the past, but an earthquake occurrent frequency is low. It is said that these earthquakes occur at a boundary between the Indian Ocean Plate and the Indonesia-Sunda Continental Block when the former is sinking under the latter, and most earthquakes concentrated to a belt zone within 200 km of the Java Trench.

In the 90°E Ridge, earthquakes concentrated to an area between 3°N and 10°S, and the past records show that earthquakes of a magnitude of more than 7 occurred in this area. The survey route passes near 5°N, and the bottom topography is relatively gentle in slope and, accordingly, there is almost no fear that a turbidity current caused by occurrence of an earthquake gives damage to a cable. The sea area spreading from the Bengal Fan to Sri Lanka is on a stable crutal block, and seismic activities in this area were scarcely recorded.

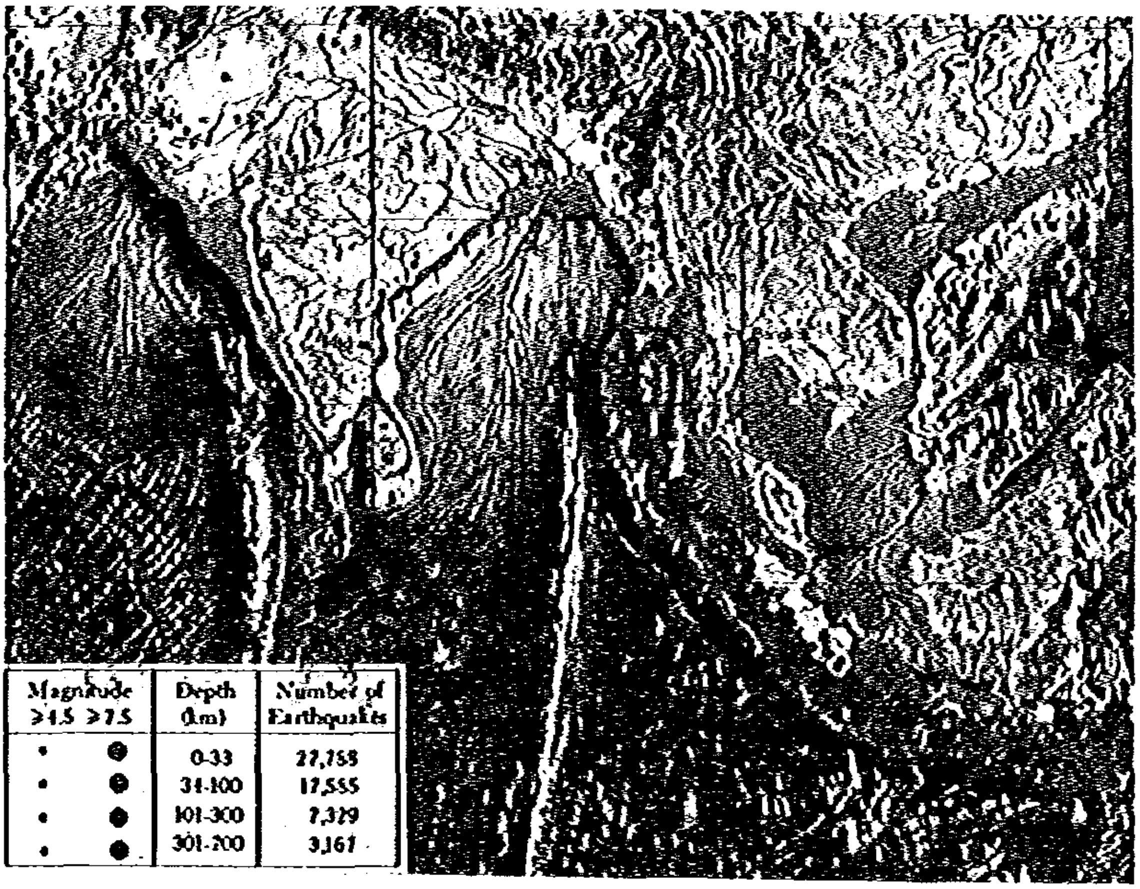


Fig. 2.3.1 SEISMICITY AROUND THE SURVEY AREA, 1960-1980
(A.F.Espinosa, W.Rinehart and M.Tharp, 1981)

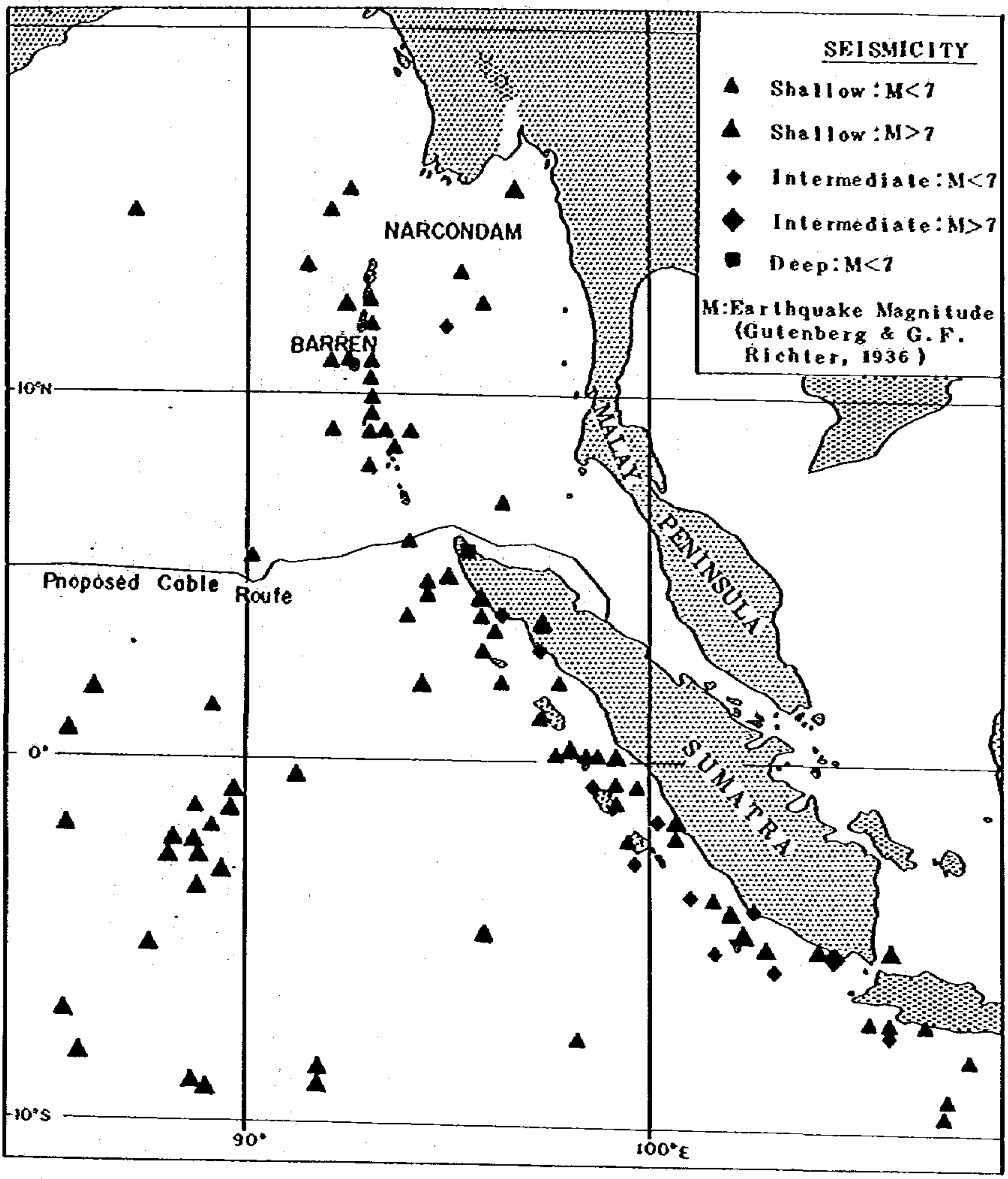


Fig 2.3.2 SEISMICITY IN THE VICINITY OF SUMATRA AND 90°E RIDGE
(Modified from Rodolfo, 1969)

2.4 Weather, Currents and Wave Height/Wave Direction

2.4.1 Weather

The monsoon of the Indian Ocean is dominant over the sea area where the survey was conducted. That is, the southwestern monsoon from May to September and the northeastern monsoon from November to February are dominant over the whole survey sea area. The southwestern monsoon prevails from May to September, while the northeastern monsoon prevails from November to February.

The wind force of the southwestern monsoon is generally 4 (Beaufort scale), but is sometimes reaches 5 or 6.

In this period of time, it is very sultry, a cloudy weather continues, and it often rains. Both the wind velocity and wind force of the north-eastern monsoon are somewhat apt to change, but the wind force is generally about 4 - 5, and the wind direction in north or northeast. In the period of northeastern monsoon, it is fine, cool and air is dry.

A monsoon alternating period is from April to May, and in this period it is hot, weather is apt to change, and there is also a lot of thunderstorm in this sea area.

A monsoon alternating period in the autumn is from October to November, and the climate and weather are both nearly the same as in the monsoon alternating period. A tropical cyclone forms in the Bay of Bengal throughout the year. It forms mostly from May to the first decade of December, and reaches to peak in October. It generally cruises to the northwest from December to March, to the northeast in April and May, and cruises up north through the Bay of Bengal from May to July. It shows also tendency that it cruises to NNW in August and September, and to the north-west, north or NNE in October and November. (Fig. 2.4.1.1 - 2.4.1.2)

2.4.2 Current

The climate and weather are nearly the same in the whole survey area, but ocean current survey areas are divided roughly into the Malacca Strait, Bay of Bengal and an area near Colombo, and ocean currents in these three areas are separately described here-under.

(1) Malacca Strait

The water depth in the Malacca Strait is relatively small, about 73 m or less in the greater part of the Malacca Strait. Therefore, the current direction is this strait is greatly influenced by tide. It is, nevertheless, said that the current toward the northwest is predominant in this strait throughout the year. The reason is that a southernly current in the South China Sea passes along the head of the Malay Peninsula, then flows into the Malacca Strait in the northeastern monsoon period, and in the southwestern monsoon, period, a part of the current, which flows from the Karimata Strait to the South China Sea enters the Malacca Strait and flows to the northwest. In the monsoon alternating periods the current weakens, and its direction is also somewhat unstable. At the zenith of the northeastern monsoon period, a counterclockwise mixed current is sometimes observed at the northern part of the Malacca Strait.

(2) Bay of Bengal

In the Bay of Bengal, a current pattern is observed throughout the year. That is, at the opening of the Bay of Bengal which is south of 10°N, there is an apparent current corresponding to the monsoon. It flows generally to the west from December to March, and to the east or east-northeast from May to September.

(3) Colombo Approach

Current of the Indian Ocean, Arabian Sea and Bay of Bengal meet one another at the Sri Lanka approach. The current of Sri Lanka approach is often strong and, moreover, abruptly changes in both short time and short distance. Especially at the southeastern coast of Sri Lanka, these phenomena are frequently observed. In the offing of the southern coast of Sri Lanka, there is a strong and prevailing current, and it is apparently closely related to the northeastern and southwestern monsoons. This current flows to the west or southwest from November to March, and this current changes to an eastern current from June to September. It was recorded that these two currents flow 100 miles a day. These two currents variously change in the monsoon alternating periods, but it is said that they flow generally about 24 miles a day.

2.4.3 Wave Height/Wave Direction

Wave conditions in the Bay of Bengal are as follows according to a report of the Naval Physical and Oceanographic Laboratory, Cochin (April, 1964).

The waves in the Bay of Bengal are most gentle in March, and most rough in June according to the records of 1960 - 1964. The mean wave height in June is 1.75 m. A tropical storm and cyclone form most frequently in October, but the mean wave height in this period is only 0.97 m. Wave conditions in the monsoon period are as follows.

Monsoon Alternating Period (March - April):

Wave directions are varied over the Bay of Bengal. The waves are most gentle in this period, and the mean wave height is 0.84 m.

Southwestern Monsoon Period (May - September):

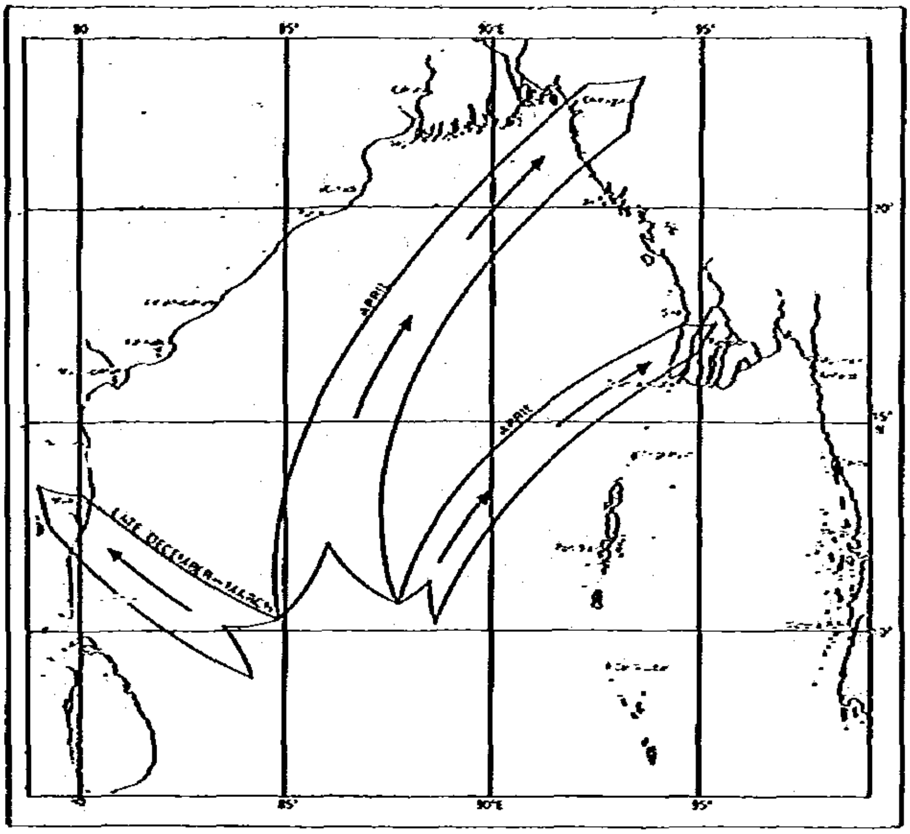
The wave direction is West or Southwest, and the wave height is maximum in this period. The sea grows most violent in June, and the mean wave height is 1.75 m.

Monsoon Alternating Period (October):

Wave directions are varied, and the mean wave height is 0.97 m.

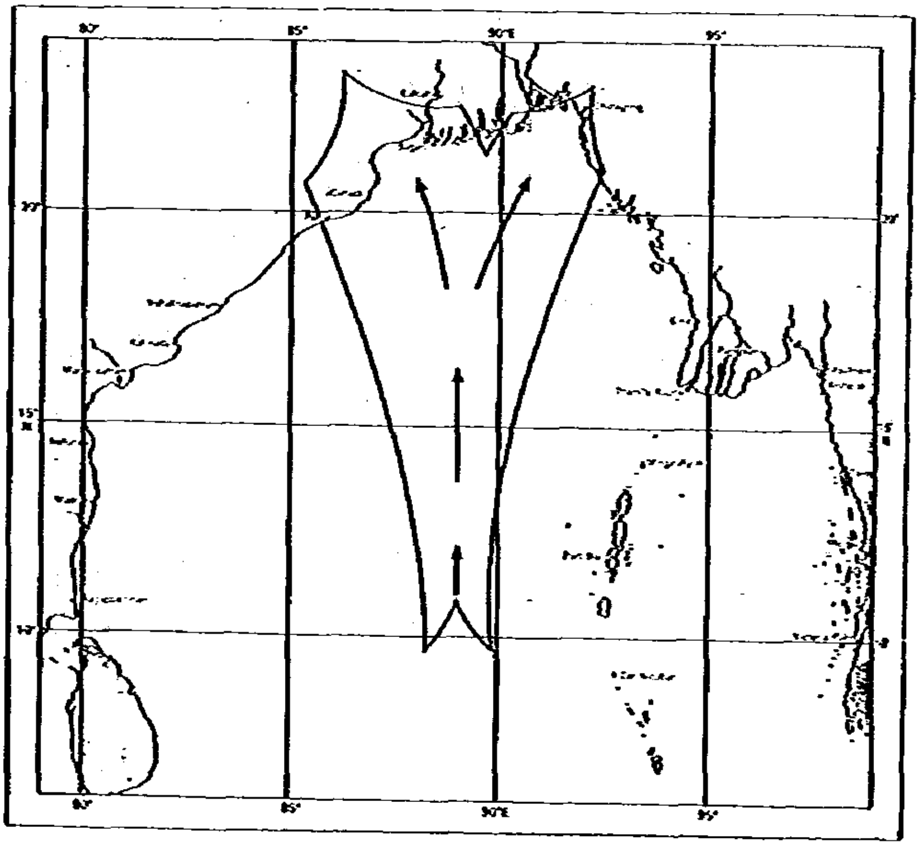
Northeastern Monsoon Period (November - February):

Waves correspond to the northeastern wind. Near the Nicobar Islands. However, the wind direction is apt to change in January and November. The wave height in this period is generally lower than that in the south western monsoon period.



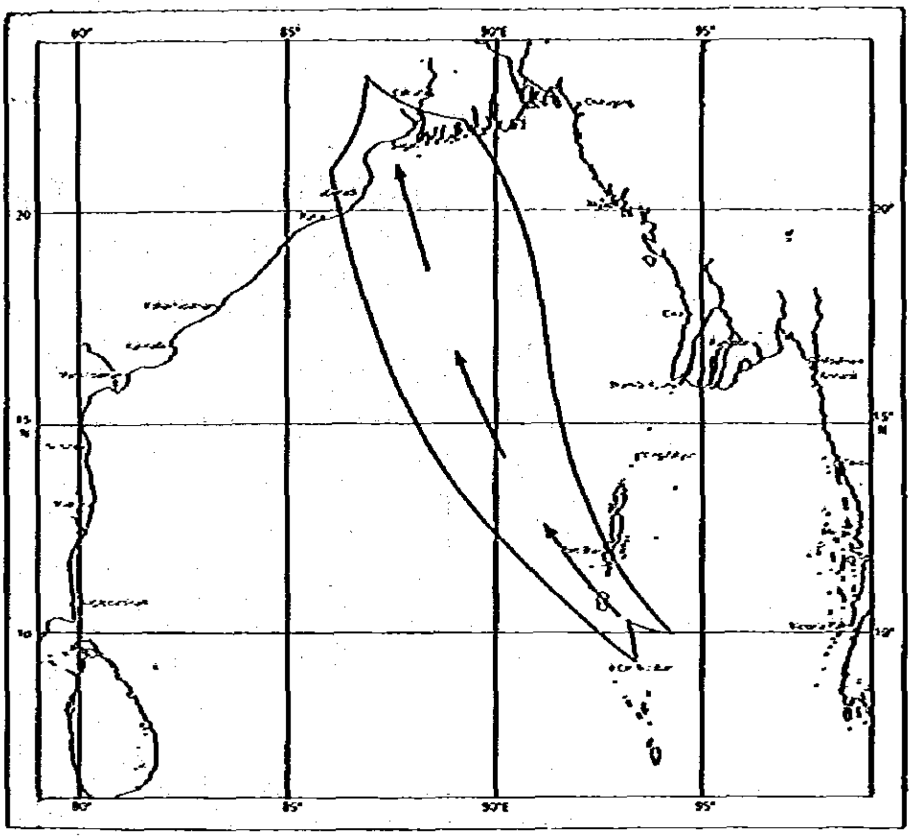
December to April

Fig 2.4.1 GENERAL DIRECTION OF CYCLONE



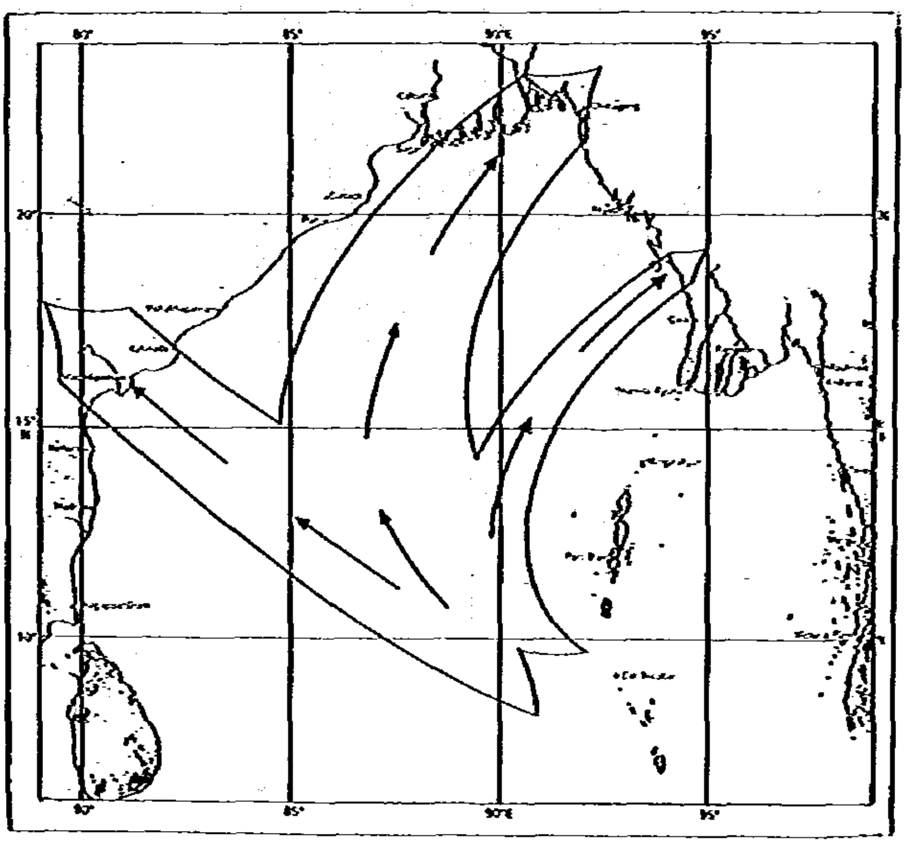
May to July

Fig 2.4.2 GENERAL DIRECTION OF CYCLONE



August to September

Fig 2.4.3 GENERAL DIRECTION OF CYCLONE



October to November

Fig 2.4.4 GENERAL DIRECTION OF CYCLONE

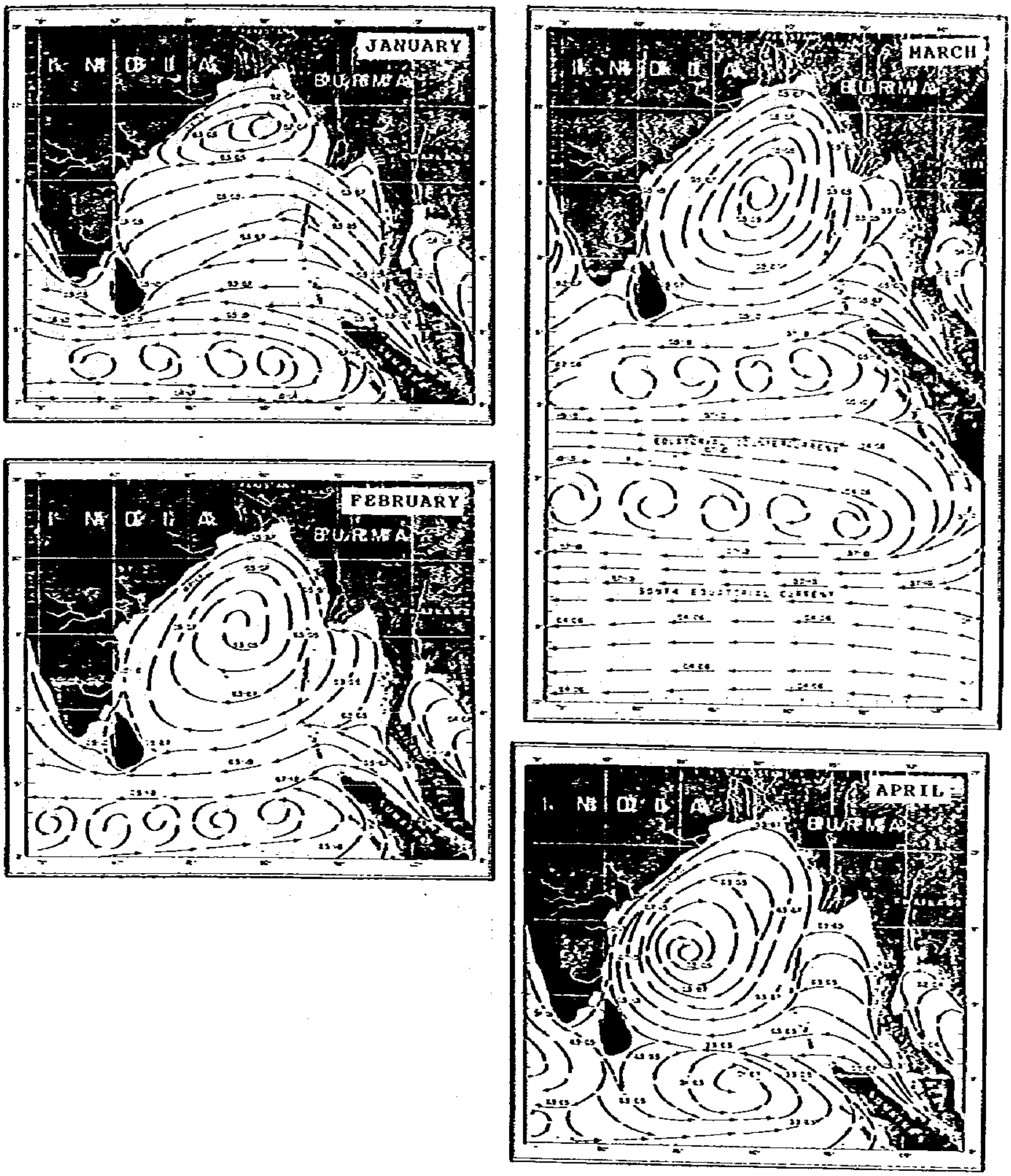


Fig 2. 4. 5 GENERAL SURFACE CURRENTS AVERAGE
Speed in knots.

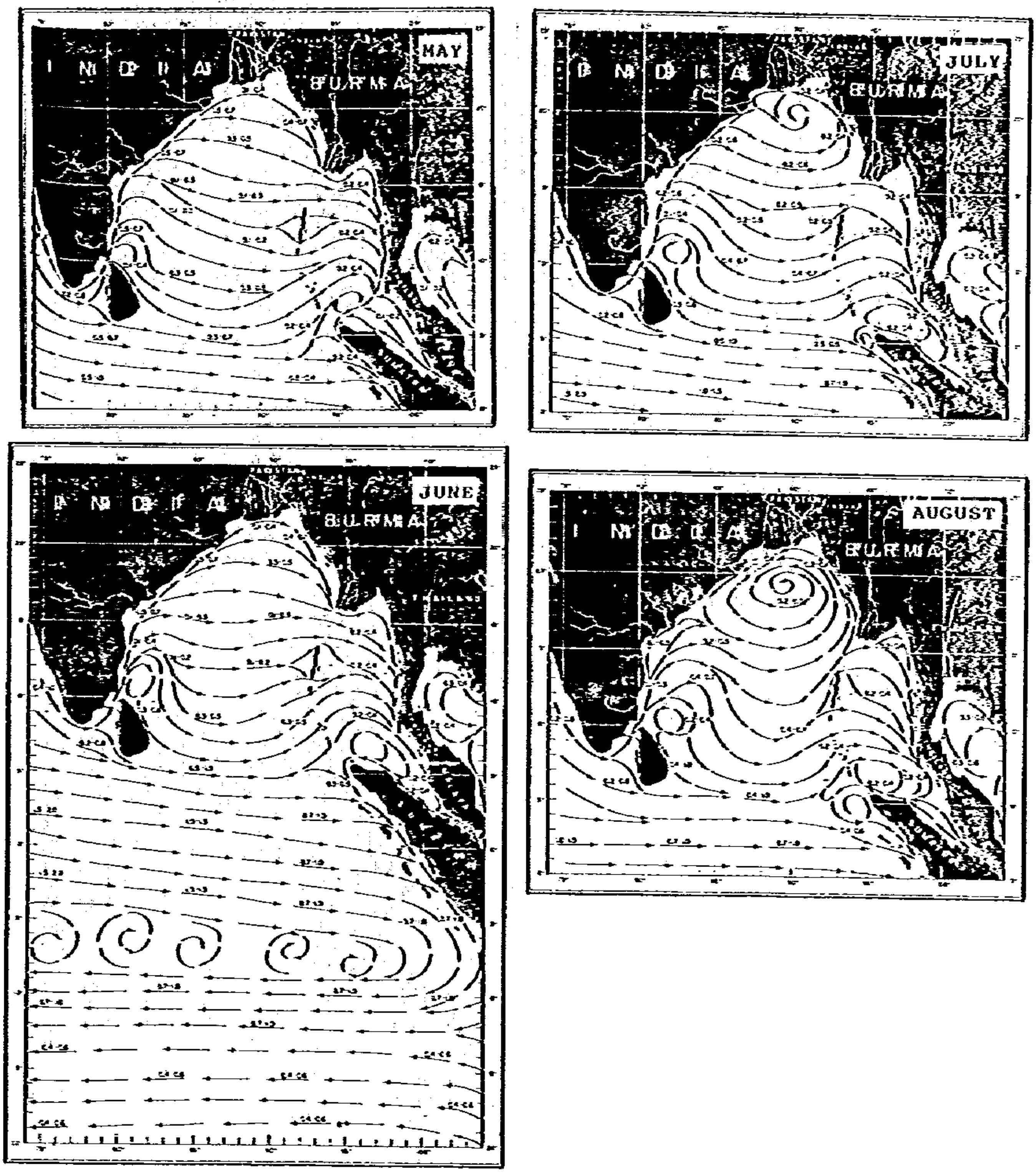


Fig 2.4.6 GENERAL SURFACE CURRENTS AVERAGE

Speed in knots.

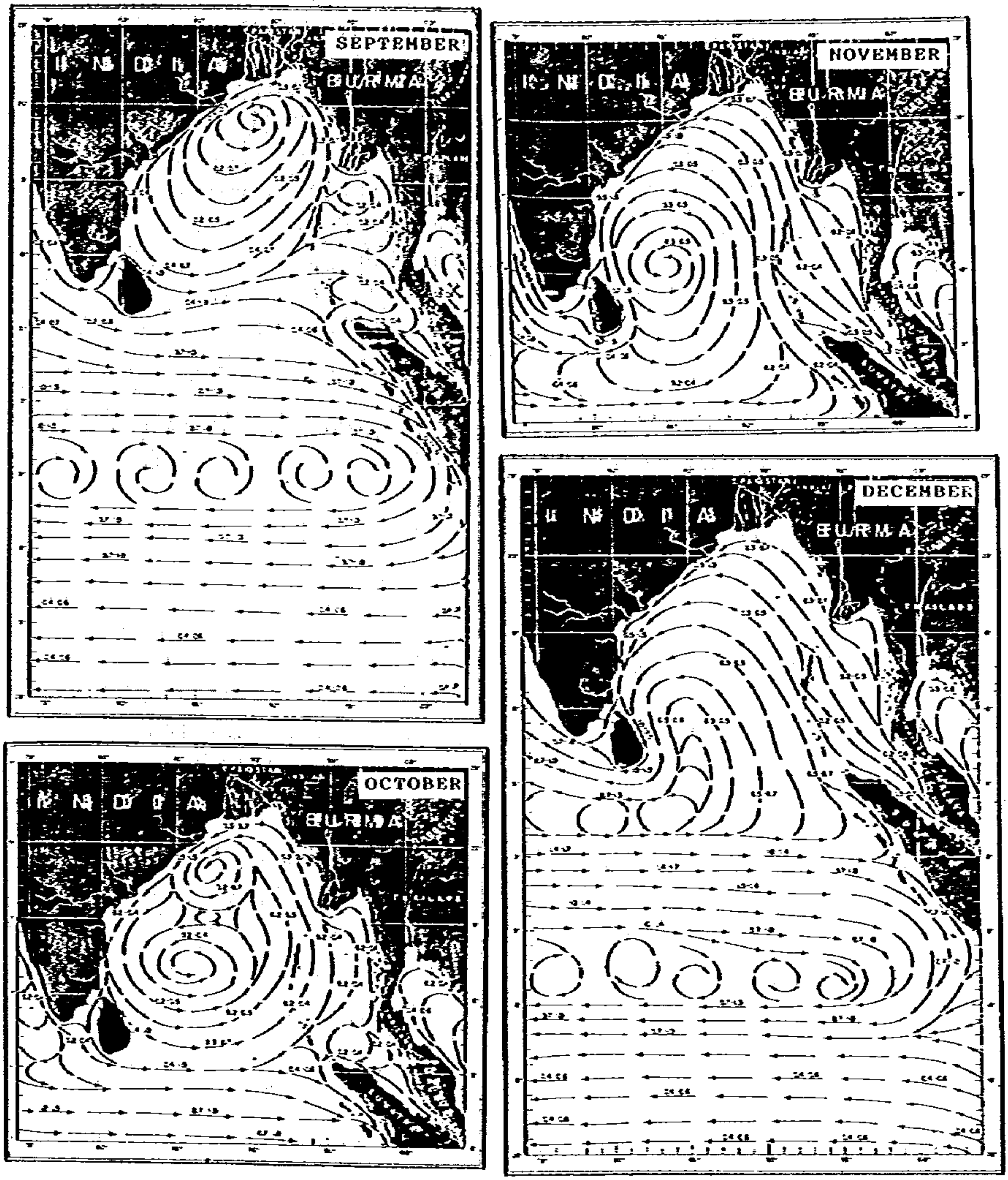


Fig 2.4.7 GENERAL SURFACE CURRENTS AVERAGE

Speed in knots.

2.5 Fishing Activities

2.5.1 Indonesian Waters

Small fishing boats of 1 ~ 2 tons are in operation near Pantai Cermin, and their fishing methods are gill net and hand line fisheries. In addition to these fisheries, a small-scaled fishery called "runpon" (fish lure) is also in operation. Near the Medan LP, five systems of net fisheries using nets attached to a wooden underwater structure called "jermal" (tidal trap) are in operation over a sea area spreading 3 ~ 3.8 km offshore the Medan LP. (Fig. 2.5.1)

Among these fishing activities, the jermal is located on the originally established cable route and, accordingly, a course of the cable route was forced to be changed. The jermal, however, does not directly give damage to a cable as a gill net and hand line do not.

In the course of carrying out the survey work, we did not meet with the trawl fishery which is possible to gives damage to a cable. Moreover, the trawl fishery was prohibited since January 1, 1983 over the whole Indonesian waters by the order issued by the President of Indonesia in January, 1982.

We understand, therefore, that the trawl fishery is not approved along the coast of Sumatra which is related to the survey route. From the above-mentioned, damage of a cable by the trawl fishery is nearly negligible.

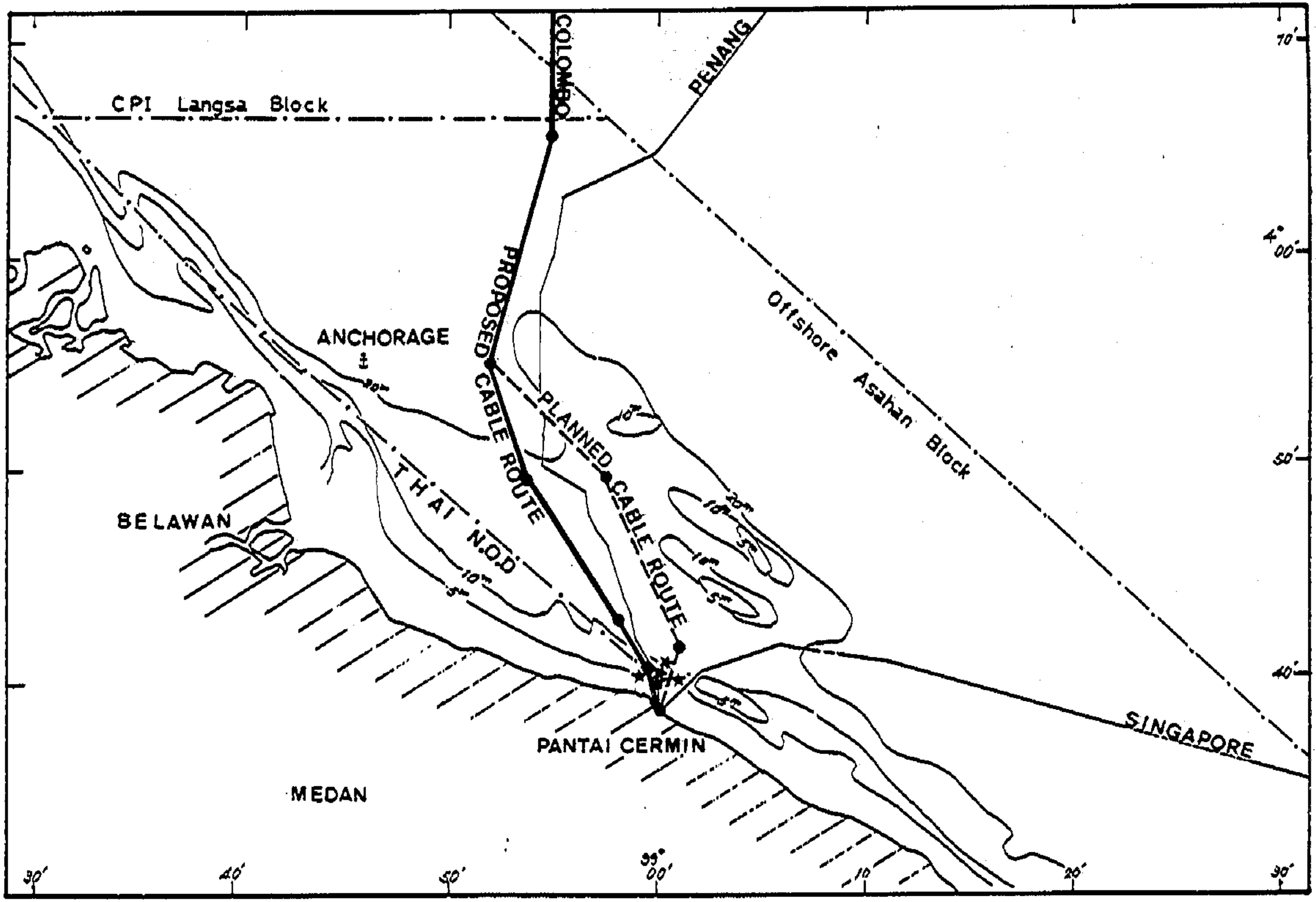


Fig.2.5.1 CABLE ROUTE OFF PANTAI CERMIN

2.5.2 Colombo Waters

Near the coast of Colombo, around 80 fishing boats are catching fish by the gill net or trawl fishery. The size of fishing boats is 10 tons or less, and that of the greater part of fishing boats is about 3.5 tons. The season of fishery is September. Among these fisheries, what may give damage to a cable is the trawl fishery, but its scale is small, and it seems that damage or trouble of a cable by the trawl fishery is nearly negligible.

2.6 Shipping Activities

2.6.1 Main Shipping Routes

Main shipping routes, which are classified into large and small ships, in the sea area spreading from the offing of Singapore to that of Colombo are roughly as follows.

(1) Large-sized Ship

1) From the Singapore Strait to One-Fathom Bank

The traffic separation scheme authorized by IMCO. (Inter-Government Maritime Consultative Organization) has been established in this area, and its course has been set on a line which is nearly at the center of the strait but a little close to Malaysia, where the water depth is large.

2) From One-Fathom Bank to Northwestern End of Sumatra Is.

In this area a shipping route extends from the One-Fathom Bank to a point which is about 10 nm offshore Diamond Pt.(about 140 nm to the northwest of Medan) and, beyond this point, it runs toward a point which is about 5 ~ 15 nm to the north of Wé Is. This course crosses the cable route near A/C 6 of the route survey.

3) Offing of Northwestern End of Sumatra Is. (Near 95°E Line)

In this area, ships sail on the north or south side of the small island Pu Rondo, which is located at the northernmost of Sumatra, nearly in the east-west direction. This course is about 10 ~ 15 nm distant from the proposed cable route.

4) From Northwestern End of Sumatra to South of Sri Lanka

In this area, ships sail in a straight line from Pu. Rondo to a point, which is about 10 nm to the south of Dondra Head, on a course of 269° over a distance of about 850 nm. This course crosses the proposed cable route in the Great Passage.

5) From South of Sri Lanka to Southern Offing of India

After passing through Dondra Head, ships double the southwestern end of Sri Lanka, and sail to a point which is 15 nm to the southwest of Cape Comorine which lies at the southern end of India.

This course crosses the proposed cable route at a point which is about 40 nm to the southwest of Colombo.

(2) Small-sized Ship

Sea areas where small-sized ship sail are the northwest of Sumatra Is. and the coast of the southwest of Sri Lanka. The number of ships sailing in this area is generally small, but it is a little large near the Medan or Colombo Port. Since their course passes within close range from the coast, the course does not cross the proposed cable route excepting near the Medan or Colombo Port mentioned above.

2.6.2 Number and Type of Shipping

The number and types of ships which sail through the Singapore Strait, the Malacca Strait and Indian Ocean (the Bay of Bengal), and ships which passed through near the survey vessel in the course of conducting the cable route survey are as follows.

(1) Singapore Strait

The results of investigation of ships, which sail through the Singapore Strait, conducted by the Singapore Government are given in Table 2.6.1.

However, the numerical values given in the above table include those of small ships of less than 75 gross tons, and it is conjectured that small inshore sailing ships to Indonesia and Malaysia are included in the observed ships.

(2) Malacca Strait

Statistics of checking the total number of ships sailing through the Malacca Strait are unavailable, but the number of ships sailing through the Malacca Strait is estimated as follows from other data.

1) Supposing from the numerical values given in the above Table 2.6.1 that 1/5 of ships smaller than 5,000 gross tons and all ships larger than 5,000 gross tons sail through the Malacca Strait, the mean number of ships which sail through the Malacca Strait is estimated at 89.7.

2) According to data issued by Japan Shipowners' Association, the number of Japanese ships which sailed through the Malacca Strait throughout 1968 is 3,474. On the other hand, the number of Japanese ships checked by the Singapore Government ammounts to 14.2% in the component ratio by nationality of ships which sailed through the Singapore Strait. Calculating the number of ships which sails through the Malacca Strait according to these values, the mean number of ships which sail through this strait is 67.0/day.

Since the statistics in 1) were collected in 1973 and 2) were 1968, it is estimated that the number of ships sailing through the Malacca Strait exceeds the number given in 1) and is around 100/day.

3) Bay of Bengal

Data issued by Japan Hydrographic Association in 1983 are available as data for estimating that how many ships sail from the northern end of Sumatra Is. toward Dondra Head of Sri Lanka out of ships which sail through the Malacca Strait. According to this data, 4% of ships which pass through the Malacca Strait sail to Rangoon, Calcutta and Madras, 39% sail to the east coast of Africa and double the southern end of Africa, and the remaining 57% double Dodra Head and sail to the Persian Gulf or the Suez Canal.

Table 2.6.1 Ships Sailing Through Singapore Strait

	Oct. 1969 (28 Days)			Feb. - Mar. 1973 (28 Days)		
	Q'ty of Ships	Mean Q'ty of Ships/ Day	Component Ratio (%)	Q'ty of Ships	Mean Q'ty of Ships/ Day	Component Ratio (%)
1) Q'ty of Ships observed at Mount Faber	3,623	129.4		4,019	143.5	
2) Component Ratio by Applications Tanker, bulk carrier	1,231	44.0	34.0	1,115	39.8	27.8
Cargo boat	1,961	70.0	54.1	2,595	42.7	64.6
Passenger boat	27	0.9	0.7	38	1.4	0.9
Others	404	14.4	11.2	271	9.7	6.7
Total	3,623		100.0	4,019		100.0
3) Component Ratio by Tonnage 30,000 gross tons or more	162	5.8	4.5	276	9.9	6.9
5,000-30,000 gross tons	2,344	83.7	64.7	1,857	66.3	46.2
75-5,000 gross tons	940	33.6	25.9	1,882	67.2	46.9
75 gross tons or less	177	6.3	4.9	4	0.1	-
Total	3,623		100.0	4,019		100.0

Note: The above table is quoted from "Investigation on Economical Effect of Dredging Malacca and Singapore Stratis" (1973)

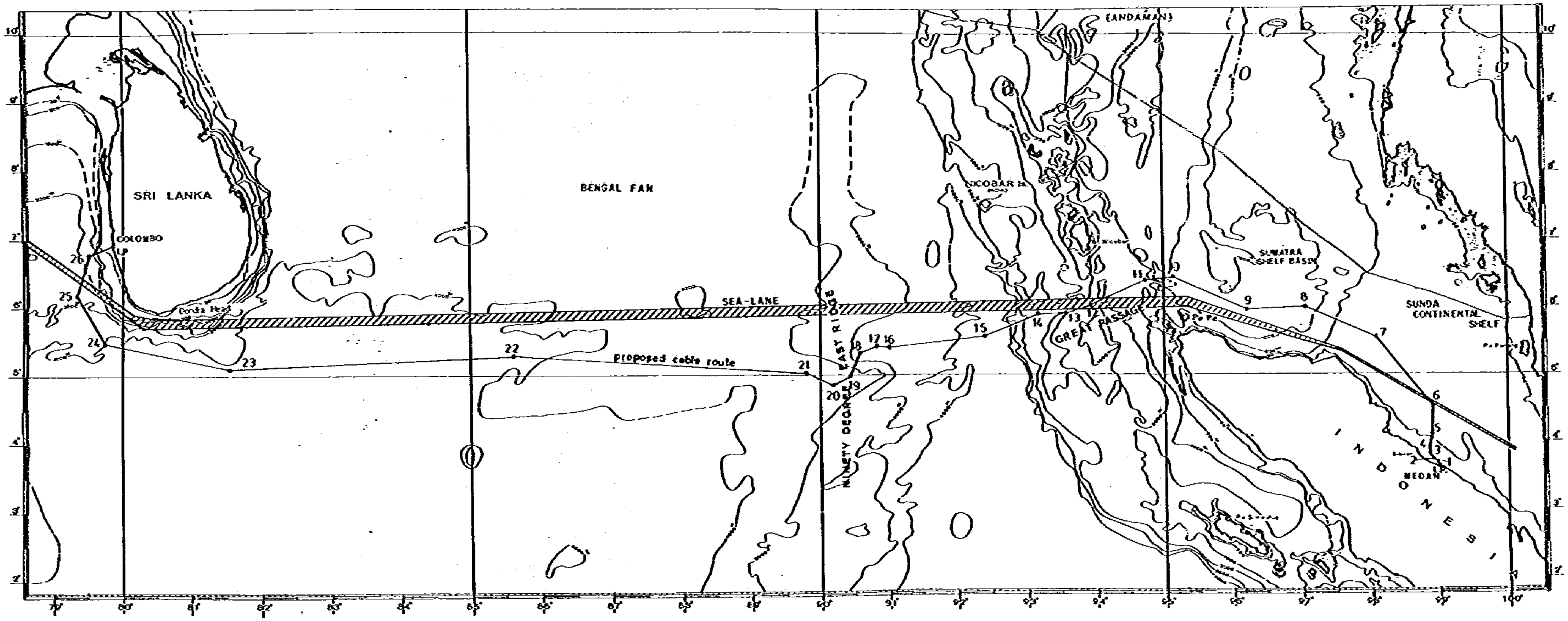


Fig. 2. 6. 1 SEA-LANE AND PROPOSED CABLE ROUTE

The number of ships which sail on this course is, therefore, 57/day, but since ships which sail to the north of the east coast of Africa also sail near this course in the sea area close to Sumatra Is., the number of ships which sail on this course increases by a few %, and is estimated at more than 60 on an average.

2.6.3 Number of Ships which Passed Near Survey Ship During Route Survey Work

The number of ships which passed near the survey ship during the route survey work conducted from October 7 to November 8, 1983 is given in Table 2.6.2. The number of some ships detected by a radar is included in the values given in Table 2.6.2.

In this Table a sea area spreading over the proposed cable route is divided into sections at intervals of 10° Longitude, but since the cable route runs in the north-south direction in an area between 79°E and 80°E spreading on the southwest of Sri Lanka, this area is divided into two assuming that the north and south sides of 6°N. in latitude are (N) and (S), respectively. Also when the number of workdays in one section is less than one day, it is counted as one day.

Fig. 2.6.1 shows a course of large-sized ships and the proposed cable route. A point where the course and cable route cross each other is near A/C 6, A/C 11- A/C 13 and between A/C 25 and A/C 26. The number of ships visually checked near this crossing point and the Colombo and Medan Ports was large, but the number of ships observed in other areas is small, because these areas are 10 ~ 30 nm distant from the average shipping route.

Table 2.6.2 Number of Ships Observed During Survey Work

Section (East Long.)	Q'ty of Observed Ships	Number of Workdays	Q'ty of Ships/Day
79° ~ 80° (N)	21	3	7
79° ~ 80° (S)	21	2	10.5
80° ~ 81°	1	1	1
81° ~ 82°	10	2	5
82° ~ 83°	2	1	2
83° ~ 84°	4	1	4
84° ~ 85°	1	1	1
85° ~ 86°	0	1	0
86° ~ 87°	2	1	2
87° ~ 88°	0	1	0
88° ~ 89°	1	1	1
89° ~ 90°	0	1	0
90° ~ 91°	4	2	2
91° ~ 92°	5	1	5
92° ~ 93°	17	2	8.5
93° ~ 94°	100	6	16.6
94° ~ 95°	48	4	12
95° ~ 96°	0	1	0
96° ~ 97°	5	1	5
97° ~ 98°	0	1	0
98° ~ 99°	10	1	10

2.7 Offshore Oil Activities

According to the data given by Indosat (Table 2.7.1) and the Oil Drilling Planning Drawings (Petroconsultant, S.A. Geneva, 1983) of Figs. 2.7.1 and 2.7.2, the oil mining claim through which the proposed cable route passes is as follows.

2.7.1 Indonesian Water Area

The proposed cable route passes through the mining claim of ASAHAN block by about 80 km in the sections of A/C 1 ~ A/C 6, about 180 km in the sections of A/C 6 ~ A/C 8 of the NSO block, and about 190 km in the sections of A/C 8 ~ A/C 9 ~A/C 10 of the NSO extension block. The title to these mining claims is as follows.

ASAHAN Block	:	Offshore Oil, OXOCC International
NSO Block	:	Mobile Oil Indonesia
NSO Extension Block	:	Indonesia PTE Ltd.

In the planning drawings mentioned above, abandoned oil wells/platforms/rigs are shown at six points in the ASAHAN block on the both side of the proposed cable route, and abandoned oil wells/gas wells/platforms/rigs are shown at twenty points in the northern part of the NSO block. However, no abandoned or existing oil well/platforms/rigs is shown in the NSO extension block excepting only one platform or rig at near the coast in the northern part of Sumatra.

We inquired of Indonesia PTE Ltd. (joint corporation of Pertamina and Japanese company) about an oil development plan in this sea area, but no comment was obtained.

Table 2.7.1 POSITION OF OIL PLATFORM/RIGS IN SUMATRA (Given by INDOSAT)

OIL COMPANY	POSITION	
	Latitude (N)	Longitude (E)
M.E.I.I.	05-43-00.8	97-45-35.3
M.E.I.I.	05-40-34.8	97-45-32.9
Mobil Expl. IND. INC.	05-39-33.2	97-45.43.3
Mobil Expl. IND. INC.	05-43-51	97-45-37
Mobil Expl. IND. INC.	05-19-04	98-04-20
Mobil Expl. IND. INC.	05-23-20.8	98-05-28.4
Mobil Expl. IND. INC.	05-27-38.6	98-04-49.2
Mobil Expl. IND. INC.	05-18-18.4	98-02-34.3
Mobil Expl. IND. INC.	05-17-57.4	98-02-16
Mobil Expl. IND. INC.	05-41-28.6	97-45-31.7
Mobil Expl. IND. INC.	05-44-26.9	97-48-2.4
Mobil Expl. IND. INC.	05-45-20.3	97-51-54.2
Mobil Expl. IND. INC.	05-45-35	97-49-55
Mobil Expl. IND. INC.	05-43-18.3	98-06-03
Mobil Expl. IND. INC.	06-14-31.8	97-50-21.1
Mobil Expl. IND. INC.	05-19-37.03	98-04-30.441
Mobil Oil IND. INC.	05-20-10	96-05-33
Mobil Oil IND. INC.	04-33-24	99-02-41
Aquitaine INC. IND.	04-07-09	98-37-38
NORTH SUMATERA Oil INC.	03-52-13	98-51-42
NORTH SUMATERA Oil INC.	04-01-39	98-59-26

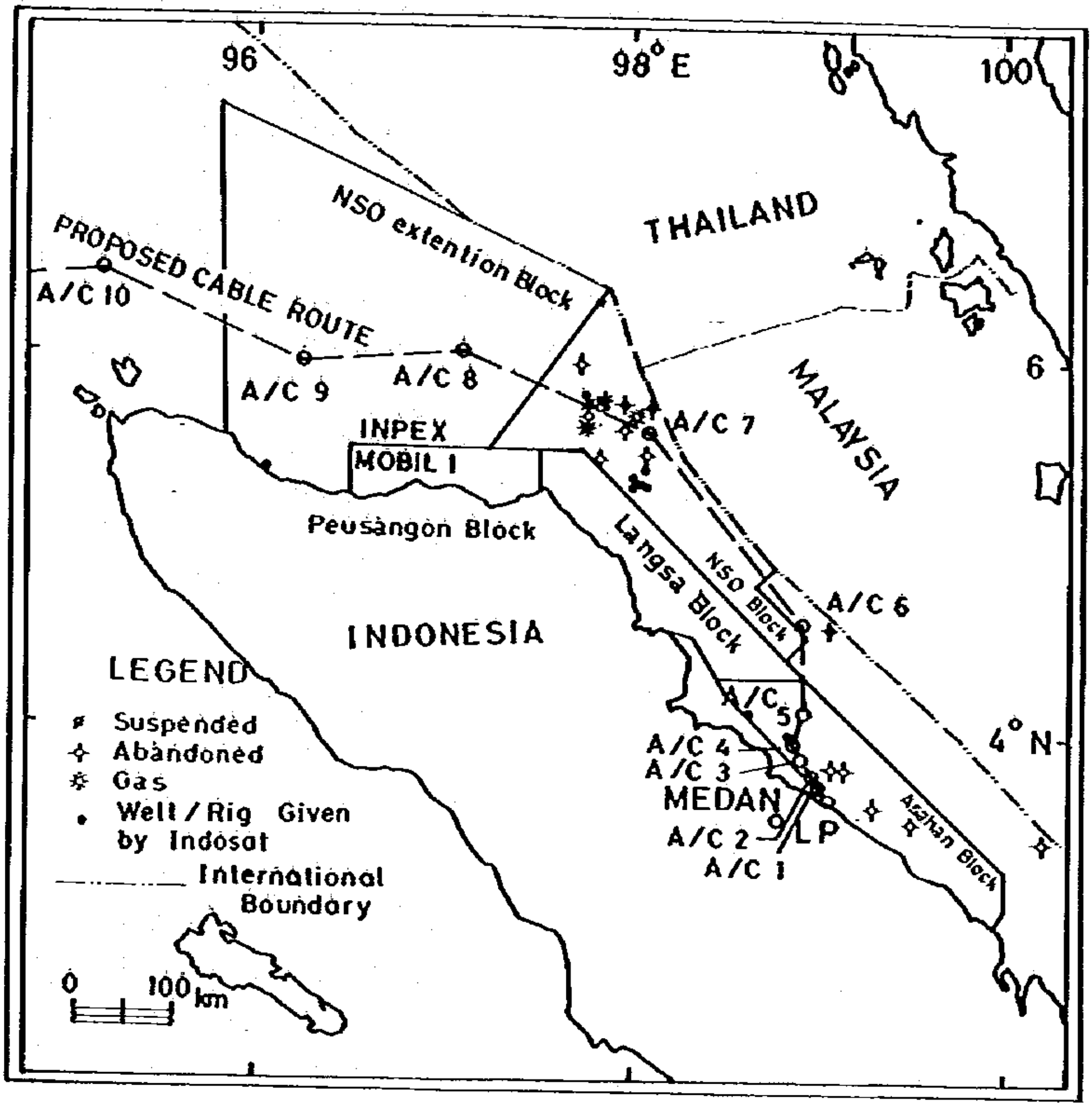


Fig 2. 7. 1 OFFSHORE OIL ACTIVITIES IN INDONESIAN WATER
(Data by Indosat and Oil Drilling Planning Drawings)

However, according to the opinion of persons concerned with Indonesia PTE Ltd., a company which starts a work or development preceding others has a priority even in a mining claim of oil development. If a sumbarine cable has been laid in advance, an oil drilling point or oil drilling facilities should keep clear of the submarine cable route. In case, however, oil or gas development is a pressing need, an oil development company must make proportional compensation for cable relocation.

During the route survey, any wells/platforms/rigs were not observed near the proposed cable route.

2.7.2 Sri Lanka Water Area

The proposed cable route passes through the block No. 8 over about 4 km between A/C 25 and A/C 26, and about 37 km of the block No. 9 between A/C 26 and L.P. The title to each block is as follows.

Block No. 8: R.J. Walker Oil Co.

Block No. 9: Phoenix, OFF PET.

As a result of inquiry made by SLTD to the government agencies related to oil development, it was found that an oil mining claim extends over the whole continental shelf of Sri Lanka, but an area where oil activities are being actually made is limited to the northern part of Sri Lanka for the time being. As for a water area near Colombo, it was found that there is no concrete plan of oil development at the present, and a cable can be laid without trouble.

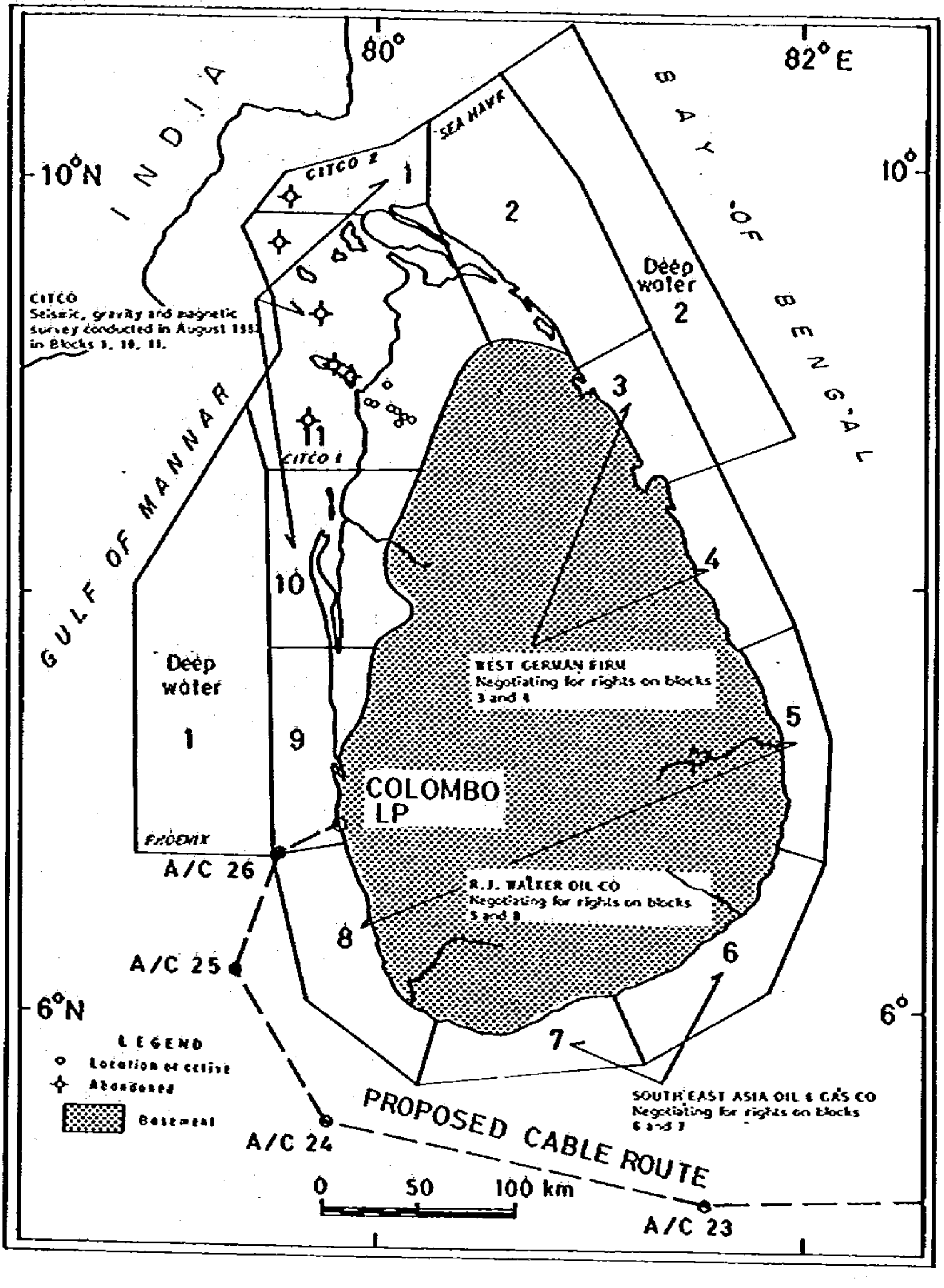


Fig 2. 7. 2 OFFSHORE OIL ACTIVITIES IN SRI LANKA WATER
(Data by Oil Drilling Planning Drawings)

2.8 Previous Cable Fault Histories

Telegraph cables previously laid and related to the sea area where the survey was conducted are as follows. By using the data of cable fault histories -regarding 5), 6), 7), 8) - obstained from PTT of France, their locations and fault causes are plotted in Fig. 2.8.1 and Fig. 2.8.2.

1)	Madras	- Penang No. 1	1871	- 1927
2)	Madras	- Penang No. 2	1891	- 1962
3)	Madras	- Penang No. 3	1921/2	- 1973
4)	Colombo	- Penang No. 1	1913	- 1973
5)	Colombo	- Penang No. 2	1923	- 1973
6)	Medan	- Penang	1891	- 1950
7)	Aden	- Colombo	1913	- 1966
8)	Colombo	- Seychelles	1922	- 1954

With respect to the Medan - Penang cable, most of cable faults resulted from corrosion, but in the sea area near the coast of Medan, faults due to an unknown cause and such artificial faults that a cable is hitched by a dredger or crane are found. As for the Colombo - Penang No. 2 cable, cable faults took place on the Sunda Shelf and its Slope near the Penang Island, Great Passage and Colombo Shelf and Slope. The cable faults on the Sunda Shelf and its Slope resulted from corrosion as in the Medan - Penang cable.

Most of cable faults in the Great Passage resulted from chafe, at Colombo side, two cable faults were reported; one resulted from a cable kink on the shelf slope, and the other resulted from chafe and corrosion near the beach.

It can be seen from the above that cable faults took place on the Sunda Continental Shelf, Sunda Continental Slope, Great Passage and near the beach of Colombo, but cable faults in the deep sea such as 90°E Ridge, Bengal Fan, Nicobar Fan, etc. were not reported.

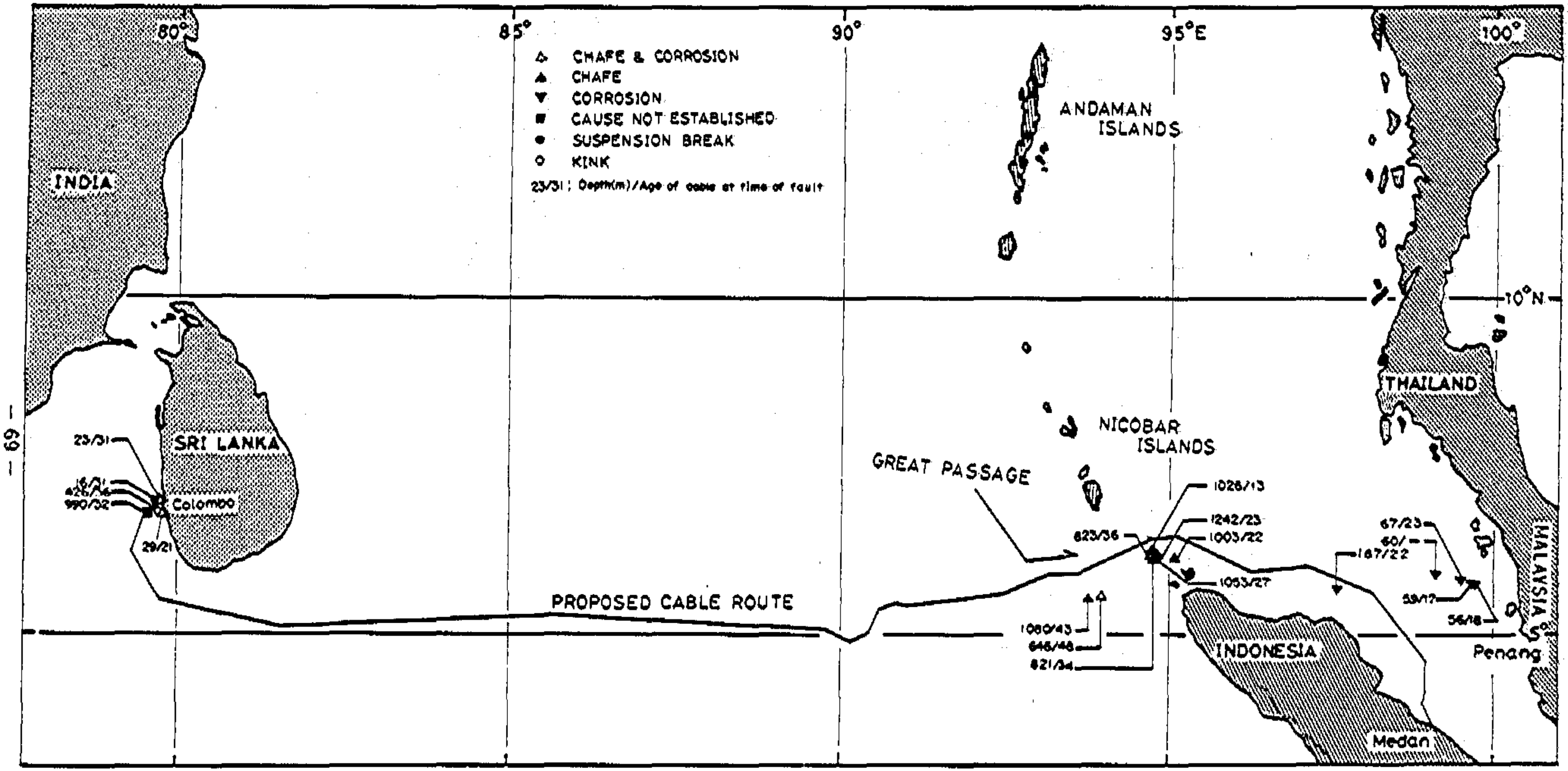


Fig 2.8.1 CABLE FAULT HISTORIES AROUND THE PROPOSED CABLE ROUTE

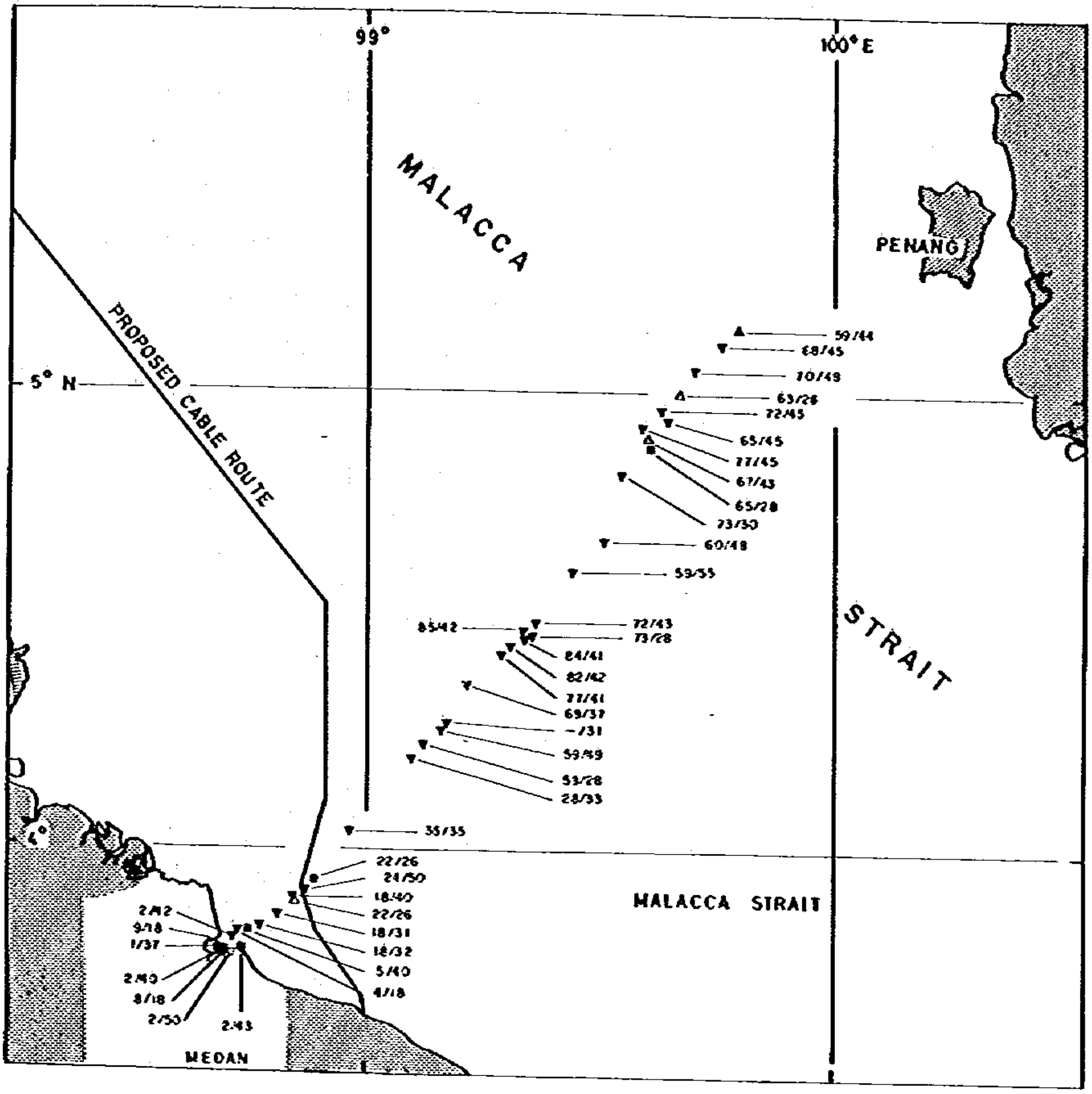


Fig 2.8.2 CABLE FAULT HISTORIES AROUND MEDAN

2.9 Existing and Abandoned Submarine Cables

Submarine cables which are in use at the present and were abandoned in the Bay of Bengal and Malacca Strait are as follows. (Fig. 2.9.1)

The proposed cable route crosses some abandoned telegraph cables among undermentioned cables near the both landing points.

1) Submarine Cables in Use at Present

Medan-Penang Cable ..... laid in 1983.

Penang-Madras Cable ..... laid in 1981.

2) Abandoned Cables (Telegraph Cables)

Medan-Penang Cable .... abandoned in 1950.

Penang-Madras Cable (three lines) ... abandoned in 1927 - 1973.

Penang-Colombo Cable (two lines) .... abandoned in 1973.

Colombo-Aden Cable .... abandoned in 1966.

Colombo-Seychelles Cable .... abandoned in 1954.

3) Submarine Cable under Contemplation

The laying of a submarine cable between Medan and Singapore is on foot.

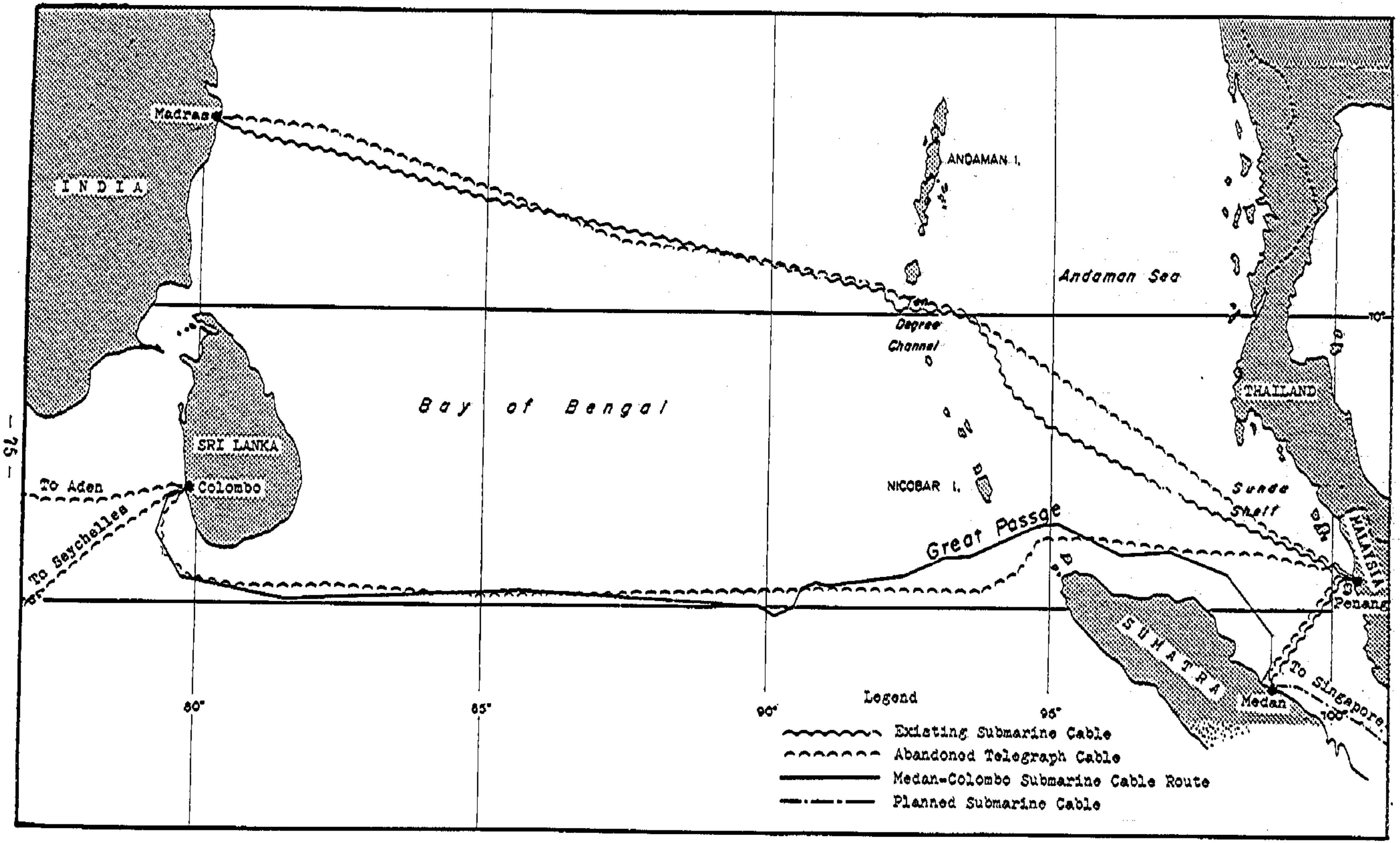


Fig 2.9.1 EXISTING AND ABANDONED SUBMARINE CABLES

2.10 Existing and Abandoned Pipelines

2.10.1 Indonesian Waters

In the Indonesian waters, oil or gas wells, those were abandoned for such reasons that the boring results show no indication of presence of oil or gas, or that oil or gas reserves are not so much as to be worthy of development, are found near the proposed cable route as mentioned in 2.7.1. These gas or oil wells were, however, abandoned or their development plans were stopped at the initial stage, and no submarine pipelines for them were not laid.

2.10.2 Sri Lanka Waters

In the Sri Lanka waters, no oil or gas development was made near the proposed cable route up to the present as mentioned in 2.7.2 and, accordingly, there is no fear that a pipeline for an oil or gas well gives damage to a cable.

2.11 Ammunition Dumping Area and Others

2.11.1 Indonesian Waters

There are the following ammunition dumping areas and others in the Indonesian waters (see Fig. 2.11.1).

The positions of Ammunition Dumping Area and Bomb Positions, etc., are shown on the Indonesian Naval Charts No. 6,9 and 10.

(1) Prohibited and Ammunition Dumping Area

1) Near Belhara Island

The area enclosed with longitudinal and latitudinal lines of 99°27'10"E, 3°50'07"N, 99°30'10"E and 3°43'30"N near Belhara Island is ammunition dumping area where unauthorized entry is prohibited. This area is located about 26 nm to the east of A/C 1 of the proposed cable route.

2) Near Wé Island

On the northwest of Wé Island, the area enclosed with lines interconnecting the following four points is an ammunition dumping area where unauthorized entry is prohibited.

a. 05°58'10"N, 95°07'50"E

b. 05°58'20"N, 95°07'30"E

c. 05°57'10"N, 95°05'10"E

d. 05°57'00"N, 95°05'50"E

This area is located about 30 nm to the south of A/C 10 of the proposed cable route.

(2) Bomb Dumping Point

Bombs are dumped at two points indicated by the following longitudes and latitudes. These two points are located respectively about 14 nm and 50 nm to the east of A/C 5 of the proposed cable route.

a. 04°02'30"N, 99°09'30"E

b. 03°58'00"N, 99°44'30"E

(3) Locations of Obstacles

There are obstacles on the seabed of two points indicated by the following longitudes and latitudes. The point "a" is located about 3 nm to the west of A/C 4 of the proposed cable route, and the point "b" is located about 37 nm to the southwest of A/C 7.

a. 04°01'10"N, 98°50'35"E

b. 05°09'50"N, 97°38'00"E

(4) Mine Area

The area which is within one nm of the northern coast of Wé Island and enclosed with the following longitudinal and latitudinal lines is mine area.

a. 05°52'30"N, 95°15'00"E

b. 05°52'50"N, 95°15'20"E

2.11.2 Sri Lanka Waters

There are no ammunition dumping area, etc. near the proposed cable route in the Sri Lanka Waters.

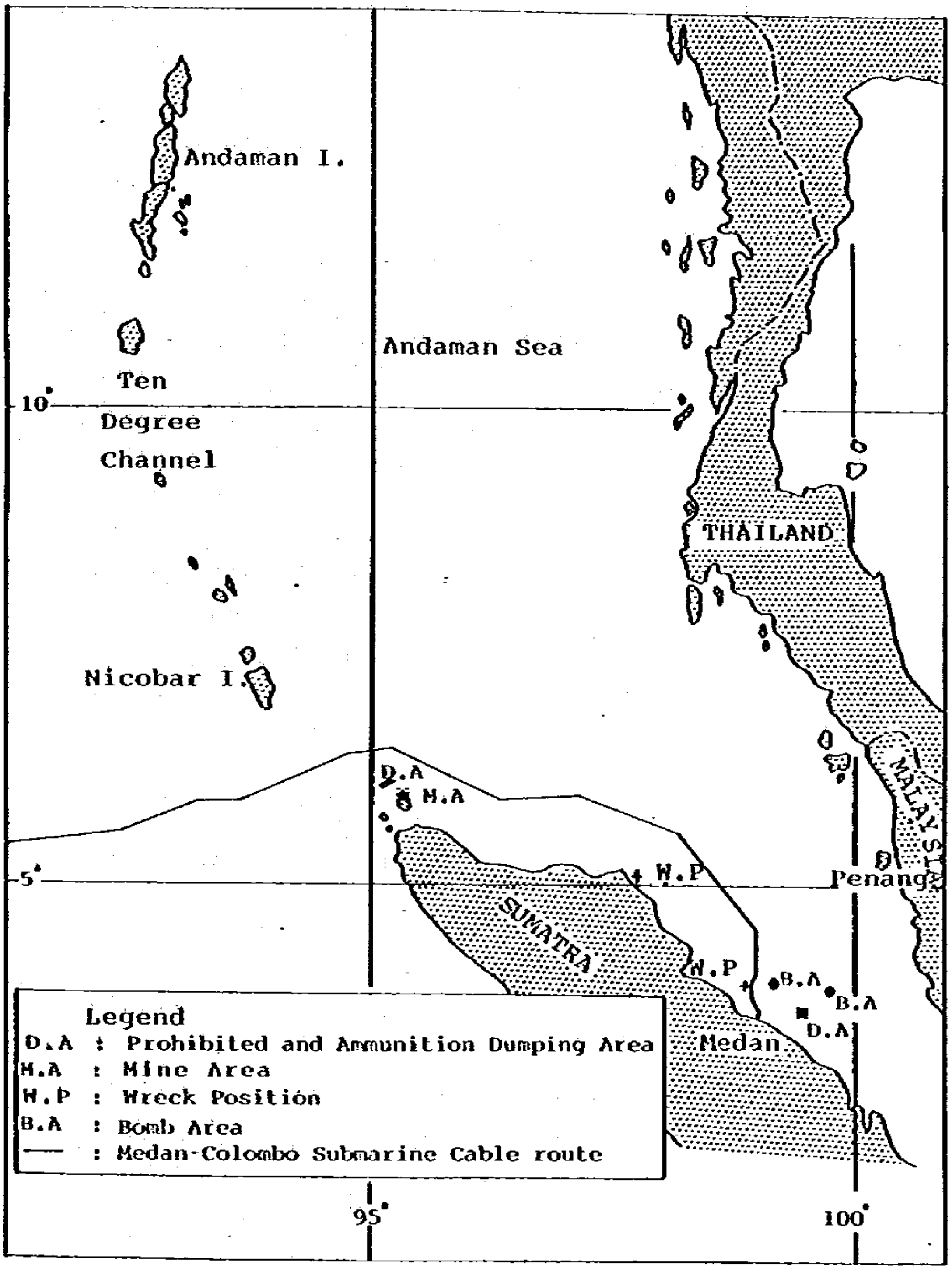


Fig. 2.11.1 AMMUNITION DUMPING AREA AND OTHERS

3. Inland Survey

3.1 Medan (Pantai Cermin)

3.1.1 Beach and Landing Site Survey

The Medan (Pantai Cermin) cable landing point had been decided by INDOSAT for the Medan-Colombo Submarine Cable Project using a cable terminal station in common with the Medan-Penang and the Medan-Singapore submarine cable systems. Because all the necessary inland survey for the project has already been done by INDOSAT, the field survey was limited to identify the landing point, the coordinates of which are given in the SCOPE OF WORK.

The survey of the beach of Pantai Cermin was conducted on September 22, and the datum point survey of Medan-Colombo Landing Point (MCLP) was conducted on September 23. The MCLP was determined by the traverse according to given control point by INDOSAT (CLP), etc. The survey results are shown in Fig. 3.1.1. The latitude and longitude of MCLP are as follows.

Latitude : 3°38'46.269"N

Longitude: 99°00'03.012"E

As shown in Fig. 3.1.2, the land cable route runs almost in a straight line from the beach landing point to the cable terminal station (B2 Point) through a marsh area crossing a creak and two ancient sand bars spreading over a distance of 1,196.78 m. Although a path along the land cable route had been constructed by cutting a mangrove jungle to a width of about 50 m, most of the land cable route was in a marsh area.

From the landing point, the well sorted sandy beach goes down, at a slope of around 1 in 10 or 6°, to a flat shelf. This flat shelf consists of muddy sand, extending to the offing at an extremely gentle slope of around 0.1°. At the lowest tide, the surfline recedes about 500 m seawards from the landing point, while at a high tide, this drying flat is under the water being several meters apart from the beach.

Bottom sediments of the flat were found to be very soft from the fact that an iron-bar easily penetrated the seabed to a depth of more than 1.5 m. The penetration check was carried out at intervals of 100 m along the proposed cable route.

	LATITUDE (N)	LONGITUDE (E)
CLP	3°38'46".156	99°00'03".190
MCLP	3 38 46.269	99 00 03.012
A/C 1	3 40 44.400	98 59 40.200
A/C 1 (planned)	3 40 30.000	99 01 00.000

Note : Coordinates of CLP are given by INDOSAT

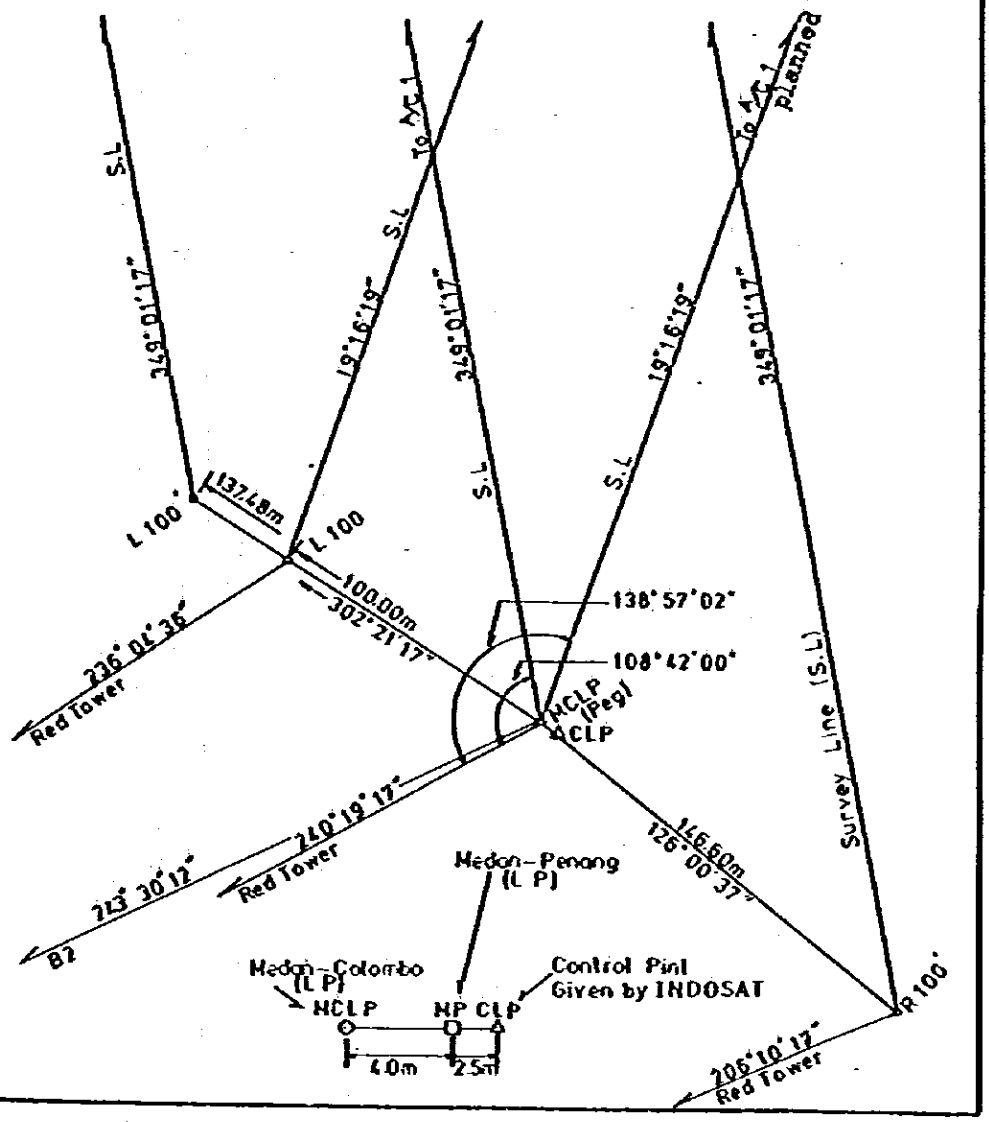


Fig. 3.1.1 NAVIGATIONAL SHORE STATIONS FOR MEDAN APPROACH

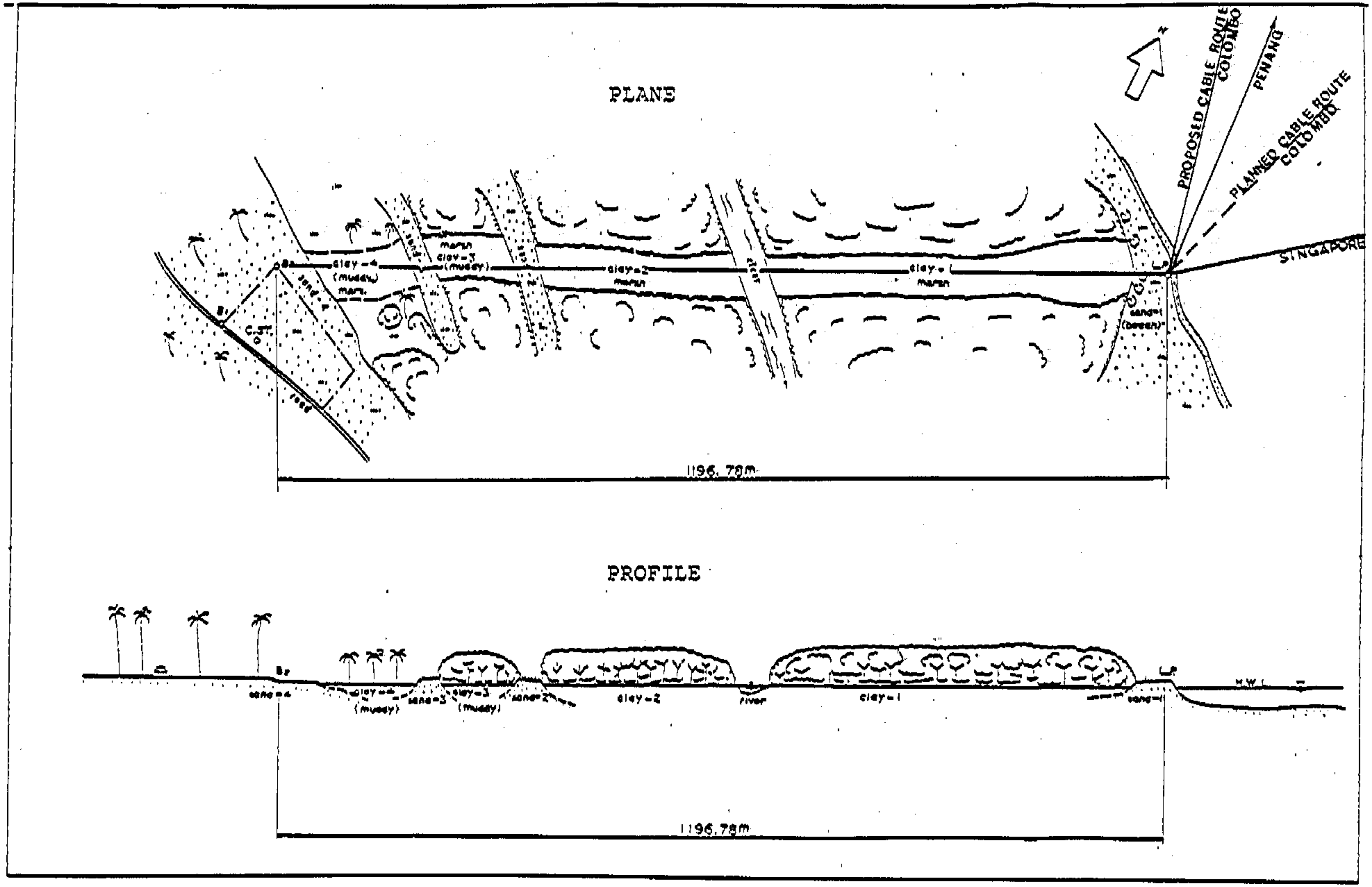


Fig. 3.1.2 CABLE LANDING SITE IN PANTAI CERMIN

3.2 Colombo

3.2.1 Beach and landing Site Survey

The potential cable landing site was at a wide tract of rocky beach, with a shoreline of some 1 km. It stretches just in front of Galle Face Green and is bounded by the stone sea-wall of about 4 m in height. A thin sand layer covers the beach at a depth of about 1 m within 10 ~ 15 m of the wall. This rocky beach consists of gneiss, a kind of metamorphic rocks.

As it was impossible to select the landing point avoiding extremely rocky areas, the landing point was selected with emphasis placed mainly on the following points:

- to find the optimum cable route to avoid the existing anchorage areas, information on which was obtained from the Colombo Port Authority.

- to get a shorter land cable route.

- to provide an enough space with a thicker sand layer for the earth bed and cable landing operation.

The proposed landing point was selected to be about 650 m on the north of Galle Face Hotel.
The survey of the landing point (LP) was conducted on October 18.
The location of LP was found from the results of the survey, Points A and B, conducted by the Survey Department of Sri Lanka in response to our request. It was determined by the traverse survey using datum points A and B. The survey results are shown in Fig. 3.2.1, and the latitude and longitude of LP are as follows.

Latitude : 6°55'32.750"N

Longitude: 79°50'29.668"E

	LATITUDE (N)	LONGITUDE (E)
A	6° 55' 13".4419	79° 50' 35".9776
B	6 55 25.8797	79 50 32.0036
LP	6 55 32.750	79 50 29.668
FP	6 56 01.946	79 50 37.899

Note : Coordinates of A and B are given by Survey Department of Sri Lanka

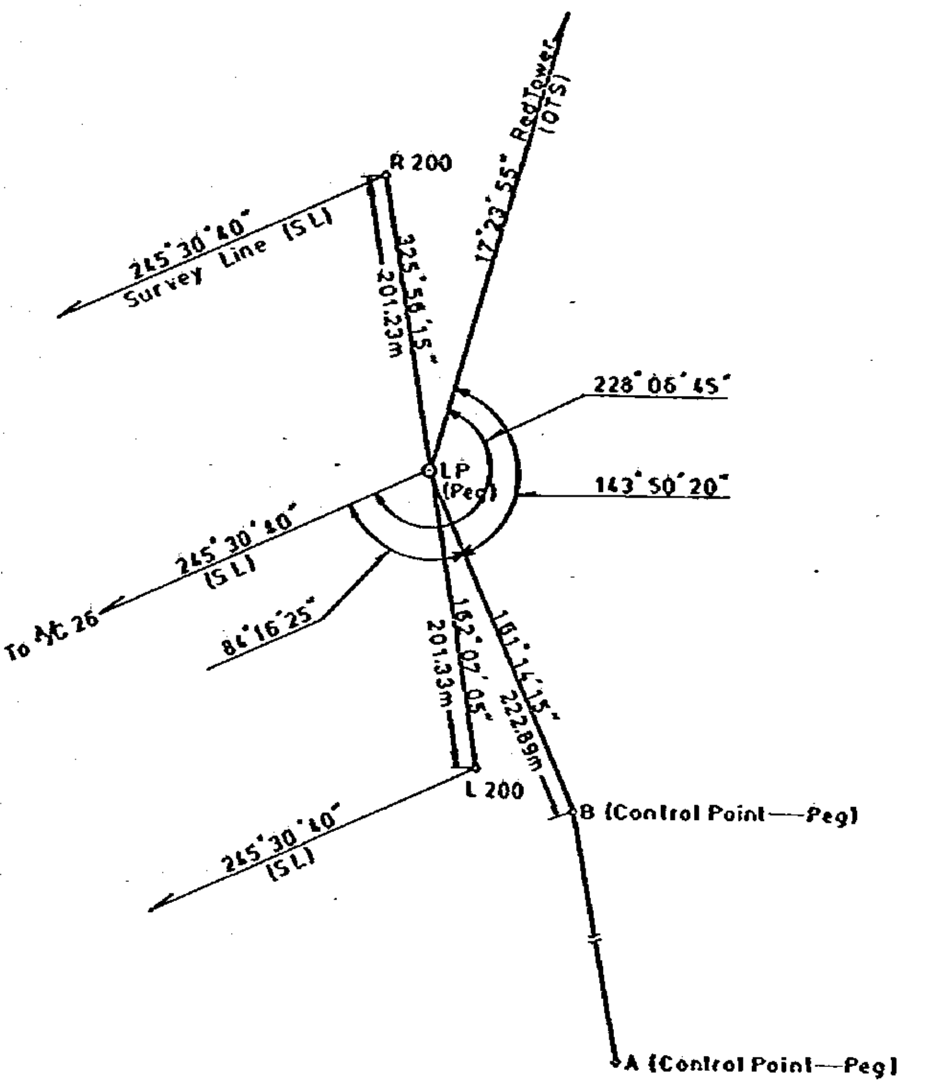


Fig 3.2.1 NAVIGATIONAL SHORE STATIONS FOR COLOMBO APPROCH

3.2.2 Inland Survey

The land cable route was selected along the urban streets, including new road under construction, to the OTS building through close consultation with SLTD. The survey work was carried out through the congested areas with the assistance of SLTD and Sri Lanka Survey Department.

The survey was conducted on October 19. When conducting the route survey, datum points A and B were used between the landing point (LP) and the OTS building (FP), and undulations and distance were found by the traverse survey and levelling. The survey results are given in Table 3.2.1. Relations between the cable route and building, etc. standing along the cable route were checked. The check results are shown in Fig. 3.2.2. Small pegs were embedded at some important points along the proposed land cable route as shown in Fig. 3.2.2.

The total distance by cumulating distances among all transverse points from the landing point to the OTS building along the proposed land cable route was 1,361.12 m.

A thorough survey shall be made before starting an actual construction to check underground obstacles such as power cable, communication cable, water supply pipe, sewage, gas pipe, etc.

According to data provided by the agencies concerned, existing underground installations and those under consideration are as shown in Appendix 14.

Table 3.2.1 RESULT OF LANDING SITE SURVEY

CONTROL POINT	LATITUDE (N)	LONGITUDE (E)	HEIGHT ABOVE D.L	DISTANCE
A	6° 55′ 13″.4419	79° 50′ 35″.9776	4.^{m}08	401.^{m}03
B	6 55 25.8797	79 50 32.0036	4.18	201.23
L.P	6 55 32.750	79 50 29.668	4.28	14.45
T 1	6 55 32.902	79 50 30.114	4.67	239.78
T 2	6 55 40.357	79 50 27.799	5.58	23.66
T 3	6 55 40.859	79 50 28.384	5.08	36.48
T 3′	6 55 41.826	79 50 27.693	4.60	127.87
T 4	6 55 45.772	79 50 26.368	4.29	150.31
T 5	6 55 50.410	79 50 24.806	4.77	51.29
T 6	6 55 52.075	79 50 24.929	5.03	38.83
T 7	6 55 53.245	79 50 24.448	5.31	132.10
T 8	6 55 57.451	79 50 25.343	7.60	230.27
T 9	6 55 57.393	79 50 32.845	7.06	143.70
T 10	6 56 02.065	79 50 33.105	8.37	146.38
T 11	6 56 01.108	79 50 37.777	5.27	26.00
F.P	6 56 01.946	79 50 37.899	5.41	
			Total (L.P~F.P)	1361.^{m}12

HEIGHT ABOVE D.L = M.S.L - 0.38 m
M S L = Mean Sea Level
D L = Datum Level

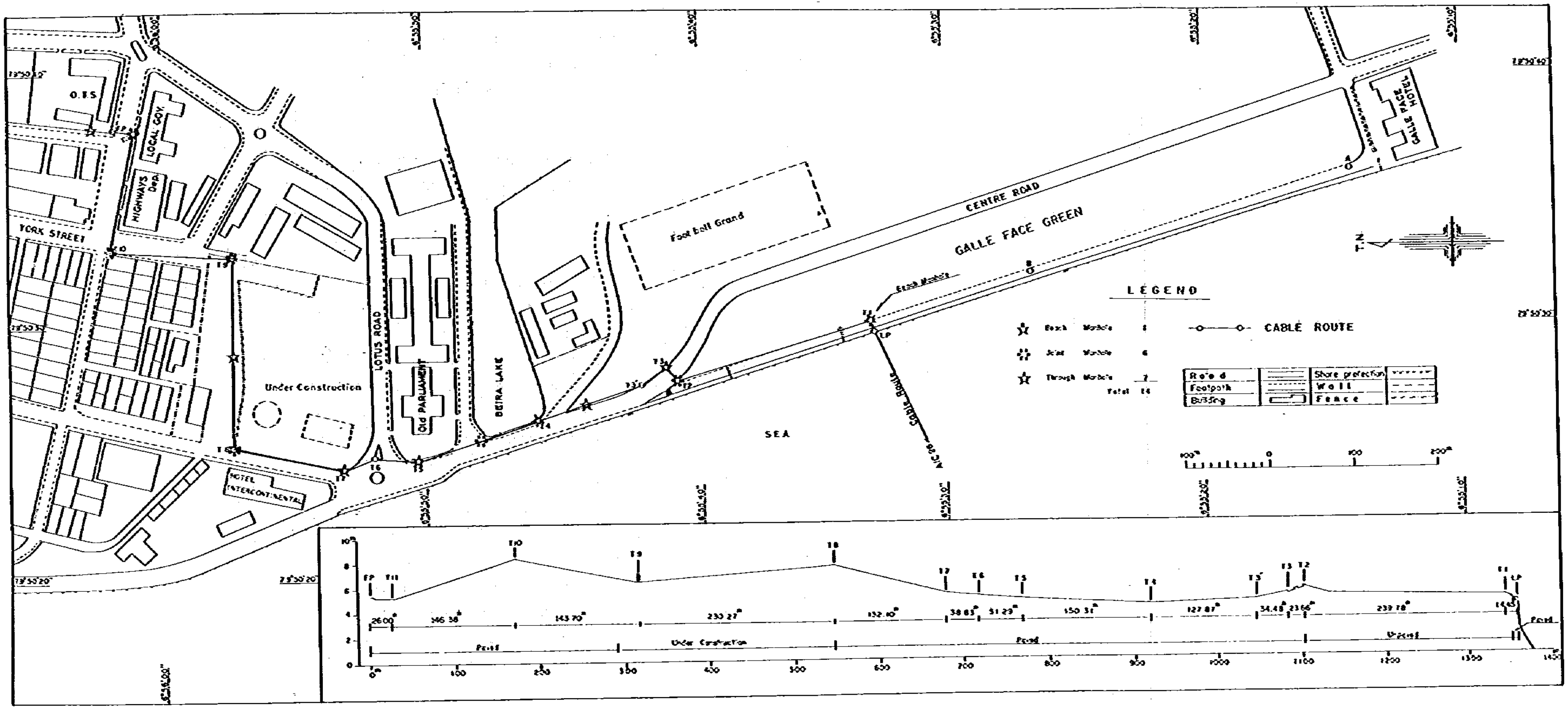


Fig. 3.2.2 PROPOSED LAND CABLE ROUTE IN COLOMBO

3.2.3 Earth Resistivity Measurement

At the Colombo side, an earth resistivity measurement was made near the beach landing point to locate the most suitable beach earth site and to determine the most favourable earth electrode system for the chosen site.

On October 19 and 20, the specific earth resistivity was measured in the Wenner's four-electrode method at six points to cover the proposed earth bed area. A detailed method is shown in Appendix 4.

Although the measurement was started expecting to find an enough depth of a sand layer - more than 5 m - with a low resistivity to spike earth electrodes, the results showed unfavorable conditions.

On the basis of the interpretation, it is estimated that a sandy-looking beach consists of a thin sand layer of less than 1.5 m overlaying a few-meter weathered rock with the sea water and rock extending beneath it. The average specific earth resistivity of this rock is estimated roughly at around 180 ohm·m; less than 10 ohm·m that in the sand layer. Further details are illustrated in Table 3.2.2 and Fig. 3.2.3.

At the Medan side, the PFE earth system for the Medan-Penang Cable System had been installed in the Medan terminal property and it had been decided by INDOSAT that the Medan-Colombo and Medan-Singapore Cable Systems would use the same earth in common with the existing one for Medan-Penang System. Therefore, an earth resistivity measurement at the Medan side was not made.

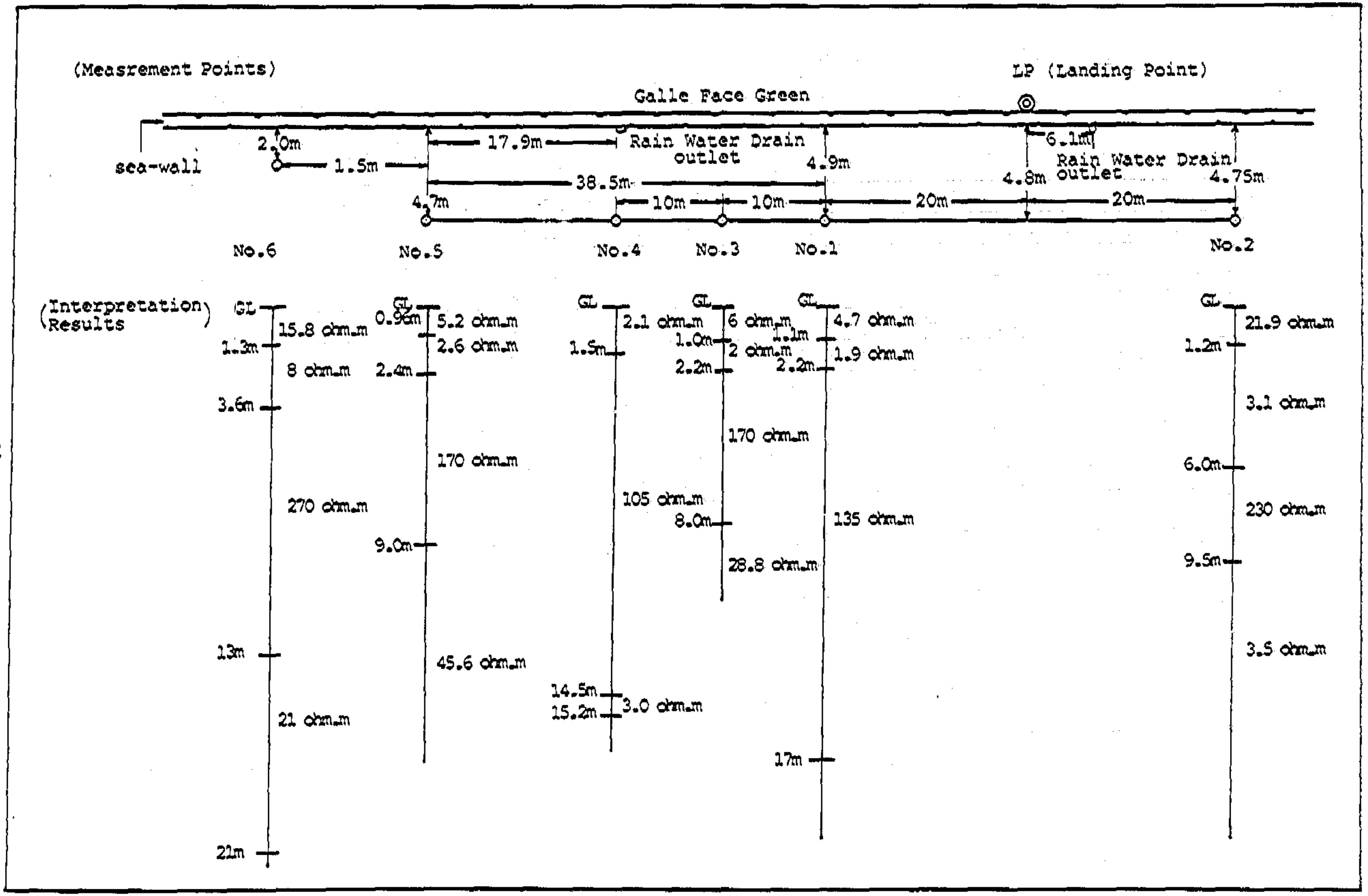


Fig.3.2.3 MEASUREMENT POINTS AND INTERPRETATION RESULTS

Table 3.2.2 EARTH RESISTIVITY MEASUREMENT IN COLOMBO

1. Measurement Results

a (m)	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
	R (ohm.m)	R (ohm.m)	R (ohm.m)	R (ohm.m)	R (ohm.m)	R (ohm.m)
1	6.7 x 0.1	3.5 x 1	9.5 x 0.1	3.4 x 0.1	8.0 x 0.1	27.5 x 0.1
2	28 x 0.01	9.75 x 0.1	2.8 x 0.1	3.0 x 0.1	3.0 x 0.1	8.8 x 0.1
3	26.6 x 0.01	3.5 x 0.1	2.8 x 0.1	2.9 x 0.1	29.6 x 0.01	5.2 x 0.1
5	27.9 x 0.01	17.5 x 0.01	24.4 x 0.01	2.9 x 0.1	29.0 x 0.01	3.4 x 0.1
7	24.4 x 0.01	16.5 x 0.01	25.4 x 0.01	27.2 x 0.01	27.5 x 0.01	27.8 x 0.01
10	25.5 x 0.01	12.5 x 0.01	19.4 x 0.01	25.2 x 0.01	22.0 x 0.01	23.8 x 0.01
12	23.0 x 0.01	10.5 x 0.01	16.0 x 0.01	20.0 x 0.01	20.0 x 0.01	23.6 x 0.01
15	17.5 x 0.01	9.5 x 0.01	19.7 x 0.01	19.0 x 0.01	19.5 x 0.01	20.4 x 0.01
20			10.0 x 0.01	14.2 x 0.01		14.0 x 0.01

a (m)	$2\pi Ra$ (ohm.m)	$2\pi Ra$ (ohm.m)	$2\pi Ra$ (ohm.m)	$2\pi Ra$ (ohm.m)	$2\pi Ra$ (ohm.m)	$2\pi Ra$ (ohm.m)
1	4.21	21.98	5.97	2.14	5.03	17.29
2	3.52	12.25	3.52	3.77	3.77	11.06
3	5.01	6.59	5.28	5.47	5.58	9.80
5	8.76	5.50	7.67	9.11	9.11	10.68
7	10.73	7.25	11.17	11.96	12.10	12.23
10	16.01	7.85	12.19	15.83	13.82	14.95
12	17.30	7.91	12.06	15.08	15.08	17.79
15	16.49	8.95	18.57	17.91	18.38	19.23
20			12.57	17.84		17.59

4. Shipboard Survey

4.1 General

The survey route was selected according to existing charts and data on topography and geology of the seabed so as to keep clear of sea areas dangerous to a cable and to minimize the cable length. It starts from Medan (Pantai Cermin), and crosses the shallow sea area of Indonesia, Great Passage and the Bay of Bengal and extends to Colombo over a distance of about 2,500 km (see Fig. 5.2.1). The total sailing distance for the survey amounts to about 6500 km.

In the survey sea area, the Penang-Medan cable has been laid, and the Singapore-Medan cable is to be laid. In addition, a mining claim for oil development has been set inshore Indonesia, and an anchorage area has been designated offshore Colombo. It was, therefore, confirmed that some of survey routes planned at the initial stage cross an existing cable or anchorage and, accordingly, a part of the survey route was changed. Survey works were carried out separately in the offing which is 4 - 5 nm distant from the coast, and an inshore area which is distant from the coast by less than 4 - 5 nm. The works carried out are described below.

The offshore survey was conducted separately in the going run and return run sailings using the Wakashio-maru. The survey in the going run sailing was carried out from September 22 to October 15, and that in the return run sailing from October 23 to November 9. For a survey line, two routes; a main survey line and a subsurvey line which is in parallel with and 2 nm south of the main survey line were planned. The survey was carried out along the main survey line in the going run sailing, and along the subsurvey line in the return run sailing.

In the going run sailing, the survey was conducted up to the shallow sea area (Water depth 1,000 m) of Indonesia along the subsurvey line besides the main one. The survey was conducted on the following items.

(i) Echo Sounding

(ii) Bottom Scanning

(iii) Seismic Prospecting

(iv) Bottom Sampling

(v) Water Temperature Measurement

(vi) Bottom Current Observation

In the return run sailing, an auxiliary survey line was set in both areas of the 90°E Ridge and Great Passage of complicated topography according to data obtained in the survey conducted along the subsurvey line and in the going run survey, and a detailed bottom topography survey was conducted to determine the optimum route (Appendix 19, 20). The survey items are as follows:

(i) Echo Sounding

(ii) Bottom Sampling

(iii) Water Temperature Measurement

(iv) Seabed Photographing

Among the survey works conducted in the going run and return run sailings, the bottom current observation was conducted with a current meter installed near the seabed in the Great Passage area. The water temperature measurement, bottom sediments sampling and seabed photographing were conducted according to the results of analyzing data obtained in the survey works, those had been conducted in advance, with the survey ship stopped at an observation station on the main survey line.

The inshore survey was conducted on the following items along the coast of Pantai Cermin (Sep. 22~25) and Colombo (Oct. 17~22) using boats (Golden Seahorse and Mahawell Nadee) hired at the site and the workboat of the Wakashio-maru.

(i) Echo Sounding

(ii) Bottom Scanning

(iii) Seismic Prospecting

(iv) Bottom Sampling

(v) Water Temperature Measurement

(vi) Bottom Current Observation

(vii) Seabed Photographing

The surveys were conducted along the main survey line and two parallel lines, which are 200 m distant from the main survey line on both sides, up to 4 - 5 nm from the coastal line.

Details of the sea floor, current and water temperature, and positioning are described in the following sections.

4.2 Sea Floor

4.2.1 Sunda Continental Shelf

(1) Inshore

The original main cable route survey track had been chosen to go to a deeper area with the shortest possible way crossing the Medan - Penang Submarine Cable at two points. However, at the INCEPTION REPORT meeting held in Jakarta, an alternative route going slantways along the coast was indicated by INDOSAT to avoid these crossings. Therefore, the survey was undertaken along the two main different tracks to find the best route. As the results showed no distinctive difference in bottom features between them, the route suggested by INDOSAT was selected as a proposed cable route.

An inshore survey was carried out from the landing point to the offing of 8.8 km (4.75 nm) at a depth of around 15 m by using a local boat "Golden Seahorse" (about 20 tons) and a vessel's launch. The sea bottom falls gradually keeping a slope of around 0.2° from the landing point to the 4 km offshore where the water depth reaches 10 m. In the area, 4.0 ~ 8.8 km seawards, six ups and downs of 2 ~ 5 m with a length of 200 ~ 500 m were observed in the form of unsymmetrical sand waves. Bottom sediments are soft sandy mud or muddy sand and their thickness is estimated at more than 2 m.

These results are illustrated in Appendices 7, 8 and 9.

(2) Offshore

The proposed cable route runs through the Sunda Continental Shelf over a distance of about 315 km from the landing point and reaches the shelf edge at a depth of about 140 m.

Sunda Continental Shelf is a shallow flat region. Bottom core samples indicate 20 ~ 40 cm surface sediment, mainly muddy fine sand, overlaying a harder basement of viscous clay. (Appendix 17) Topographically remarkable points are that there exist sand bars, paleo river, dimples which are conjectured to be traces of gass sprouting and sand ripples.

Sand waves, which appear frequently at a location of 5 ~ 20 km distant from the landing point, rising 2 ~ 5 m from the floor and spreading 200 ~ 500 m in length, form mainly unsymmetrical topography as shown in Appendix 18.

The trench, conjectured as a paleo-river, is located at 251 km distant from the landing point in a depth of 100 m. It's scale is about 1km in width and 10m in depth. Survey records indicate that the soft sediment is deposited on the river bed. (Appendix-18)

Side scan sonar records show many dimples in the area between 44 km and 295 km from the landing point. These dimples mainly 30 ~ 40 m in diameter and 1 ~ 2 m in depth, are considered as traces of gass sprouting. Many sand ripple marks appear at the area of 110 ~ 200 m in water depth adjacent to the shelf edge, about 425 km to 440 km from the landing point.

In the shelf edge area, seismic profiling/side scan records sometimes indicate rock outcrops with sand ripple marks between them along the proposed cable route over 2 km at a depth of 138 ~ 160 m. Sandstones and mudstones were collected from the bottom by a bottom sampler, and the samples proves that the above outcrops consist of sandstones and/or mudstones.

4.2.2 Sumatra Shelf Basin

The proposed cable route extends to the flat bottom of Sumatra Shelf Basin, descending on the continental slope which contiued to Sunda Shelf. This basin is imperfect in its shape, opening WNW ward. The cable route passes through this flat basin and extends to Great Passage (Andaman - Nicobar Ridge) through the basin opening.

The continental slope which forms the basin is a gentle slope decreasing the depths from 140 m to 1,330 m. It's gradient is 2.6° between the shelf edge and the 540 m depth line - approx. 330 km from the landing point -, and is 0.5° in an average at a deeper area. The surface of the slope is generally smooth down to a 540 m depth line, however, many undulations (150 ~ 700 m long, 2 ~ 10 m high) appear as the slope descends further.

On the slope, the sediment consists of soft mud with a thickness of 5 m or more at most areas. A sand or gravel stratum is expected to be underlying the soft sediment. This bottom of basin is very flat and smooth, and is covered with mud sediments with a thickness of 20 m or more.

4.2.3 Great Passage (Andaman - Nicobar Ridge)

This area shows the most complicated topographical features in the whole survey areas. Therefore, the survey was conducted elaborately by setting many survey tracks. Although the distance between A/C 10 and A/C 15 along the cable route is only 315 km, the survey distance amounted to 1,553 km, more than 5 times longer than the route distance.

A sounding run was proceeded in fixing survey vessel's position elaborately by NNSS, sometimes stopping the survey waiting for the better NNSS signals. At the final stage of the survey, an additional sounding run was carried out at around the A/C 12 area,and the results showed more complicated features than those observed, in the preceding run. Therefore, sounding lines were set at a 1 nm spacing between segments, keeping a precise radar fixing in reference to the deployed two position buoys. In comparison with the topography obtained by the preceding NNSS fixing run, the results of survey using position buoys showed no distinctive difference. Consequently, it was confirmed that the elaborate position fixing using NNSS has an enough accuracy.

As shown in Appendices 19 and 20, this area is characterized by the following five features:

(i) Valley between A/C 10 and A/C 11.

(ii) Gentle slope extending 10 - 65 km to the west of A/C 11.

(iii) Valley formed between the above slope and A/C 12.

(iv) Many sea mountains and/or valleys extending westward of A/C 12.

(v) Western slope of the ridge descending towards the ocean floor.

The valley mentioned in item (i) is a big valley with a maximum water depth of 3,425 m, formed between an eastern mountain with a slope of 12° and a western mountain with a slope of 12.4°. The valley bottom which is 14 km in width inclines gently westward and is covered with muddy soft sediment of 20 ~ 40 m thickness.

The slope mentioned in item (ii) goes down gently westward. The surface is smooth and consists of muddy sediments with a depth of more than 2 m.

The valley mentioned in item (iii) is located on the west of the above mentioned slope with a maximum water depth of 2,686 m. The bottom spreading 4 km width is flat and smooth, and its surface is covered with mud at a depth of more than 5 m. The gradient is 11.3° on the east slope and 10.3° on the west one.

In the area mentioned in item (iv), some high and low mountains, at a water depth of 1,200 ~ 2,000 m, continue westward over a distance of some 140 km from A/C 12. However, even the steepest slope never exceeds 10°. Sediment was scarcely found on the mountains. The muddy sediment was partly observed on the bottom of some valleys. The largest valley has a flat bottom of 2 km.

In the area mentioned in item (v), the western side of the Great Passage (Andaman - Nicobar Ridge) slopes directly from a depth of 1,551 m down to 4,350 m in the Nicobar Fan. The maximum gradient is 17° in the area of 3,000 ~ 3,900 m depth lines.
Bottom sediments are scarcely found in this area.

4.2.4 Nicobar Fan

The Nicobar Fan is located in the area between the Great Passage (Andaman - Nicobar Ridge) and the 90°E Ridge about 890 km to 1,070 km distant from the Pantai Cermin landing point.

The sea bed extends at the depth of 3,570m to 4,350m and has gentle rising slope toward the 90°E Ridge. The bottom sediment of this area as well as that of the Bengal Fan had reportedly been transported from the Ganges - Brahmaputra River Delta by turbidity current though submarine canyon. Bottom sampling was carried out at two stations by using a piston corer, and soft mud was obtained at both stations. (Appendix 17)

4.2.5 90°E Ridge

The main survey route was chosen to cross the 90°E Ridge with the possible shortest distance through little undulating part. As the main route encountered with a rather rugged area, several sounding lines were arranged to select a better cable route.

The distance of the cable route in this area is about 310 km. The ridge is divided into four mountainous regions as shown in Fig. 5.2.2. The first mountainous region, adjacent to the Nicobar Fan, is a rather small area represented by a mountain with a relative height of 140 m and a slope of 5°. The second region shows a relatively complex topography, therefore, several sounding lines were set to cover this area as well as a part of the third region. The results indicate existence of five undulations with a relative height of approx. 50 ~ 170 m and a slope of max. 5°.

The third and fourth regions consist of gentle undulations of 20 ~ 80 m in height except for the southern slope of 5° in the fourth mountainous region.

The greater part of the surveyed 90°E Ridge areas are covered with soft mud. (Appendix 17)
Thickness of the sediment at the bottom of valleys is approx. 5 m to 20 m.

4.2.6 Bengal Fan

The survey in this area was carried out along the main survey route nearly in parallel with the line of 5°N latitude crossing the Bengal Fan to the Colombo Continental Slope over a distance of about 940 km from 90°E Ridge.

The Bengal Fan is characterized by many submarine canyons incised into the monotonous plain, which is considered to have been formed by sediments transported by turbidity currens from the Ganges - Brahmaputra delta through these canyons. Some reports say that turbidity currents still flow through some of these canyons. (Appendix 6)

During the survey, profiles of 10 sumbarine canyons, other parts were extremely monotonous plains, were recorded on the survey route, which had a width of 700 ~ 3,500 m and depth of 10 ~ 140 m.

Bottom sampling and sea-bed photographing were conducted at the canyon bed, and the results showed a high possibility of existence of turbidity currents. Judging from the fact that photographs indicated no ripple mark and the sampled material was soft yellowish grey clay containing no coarse/grain sediments, it is considered that no high-velocity turbidity currents which give damage to a cable exist.

4.2.7 Colombo Continental Slope

The Colombo Continental Slope is one of the steepest slopes encountered during the shipboard survey between the Bengal Fan, and the Colombo Continental Shelf edge.

As shown in Fig. 5.2.2, the slope becomes steeper in some distinctive steps as it approaches the coast. The shapes of these steps are transformed by varied sea-mountains. The average slope in each segment is 1° for 4,040 m (near A/C 24) to 1,750 m (about 60 km off L.P) in depth, 9.2°for 1,440 m to 650 m in depth, 21° for 510 m to 115 m in depth - steepest area among the segments, and 5.4° for 115 m to 40 m in depth, respectively. Seismic profiling data show scarce bottom sediments over the rock basement.

4.2.8 Colombo Continental Shelf

(1) Inshore

The inshore survey was undertaken by using a local boat "MAHAWELI NADEE" (about 20 tons) of Colombo Port Authority from the beach landing point to a 30 m depth line, some 6.8 km (3.7 nm) seaward. The results are illustrated in Appendices 10, 11, 12 and 13.

From the beach surfline, the sea-bottom consisting of fine sand falls to some 300m seaward at a slope of 2 ~ 3°. The offshore area of 0.3 ~ 1.0 km is covered with coarse sand excluding two rock outcrops of gneiss. A gentle slope (0.2°) with less undulation continues in the area 1 ~ 6.8 km seaward. A thin surface bed of coarse sand, 1.5 ~ 2.0 m in thickness, covers the lower undulating rock and gravel/sand strata. The cable route was selected avoiding outcroppings 4.5 km seaward from the beach and offshore anchorage areas, as shown in Fig. 4.2.1.

(2) Offshore

The Colombo Continental Shelf extends to the continental edge of 50m in depth over a distance of 26.5 km from the beach.

This continental shelf has a very gentle slope and is covered mainly with sand on its surface except for rock exposed part. Bottom sediments change to muddy sand only near the continental slope. Judging from seismic profiling records (refer to Appendix-23), the bottom is covered with thick sediments of 5 ~ 10 m.

A core sample obtained by the Vibro-corer revealed that the bottom sediments include gravels formed by shell fragments/coral fragment and becomes rather solid at about 2.5 m or more. (Appendix 17) Rock outcropping area lies at 8.2 km off the landing point as if forming a natural dam to keep off the sediments. This natural dam forms a cliff of 5 ~ 6 m in height seaward.

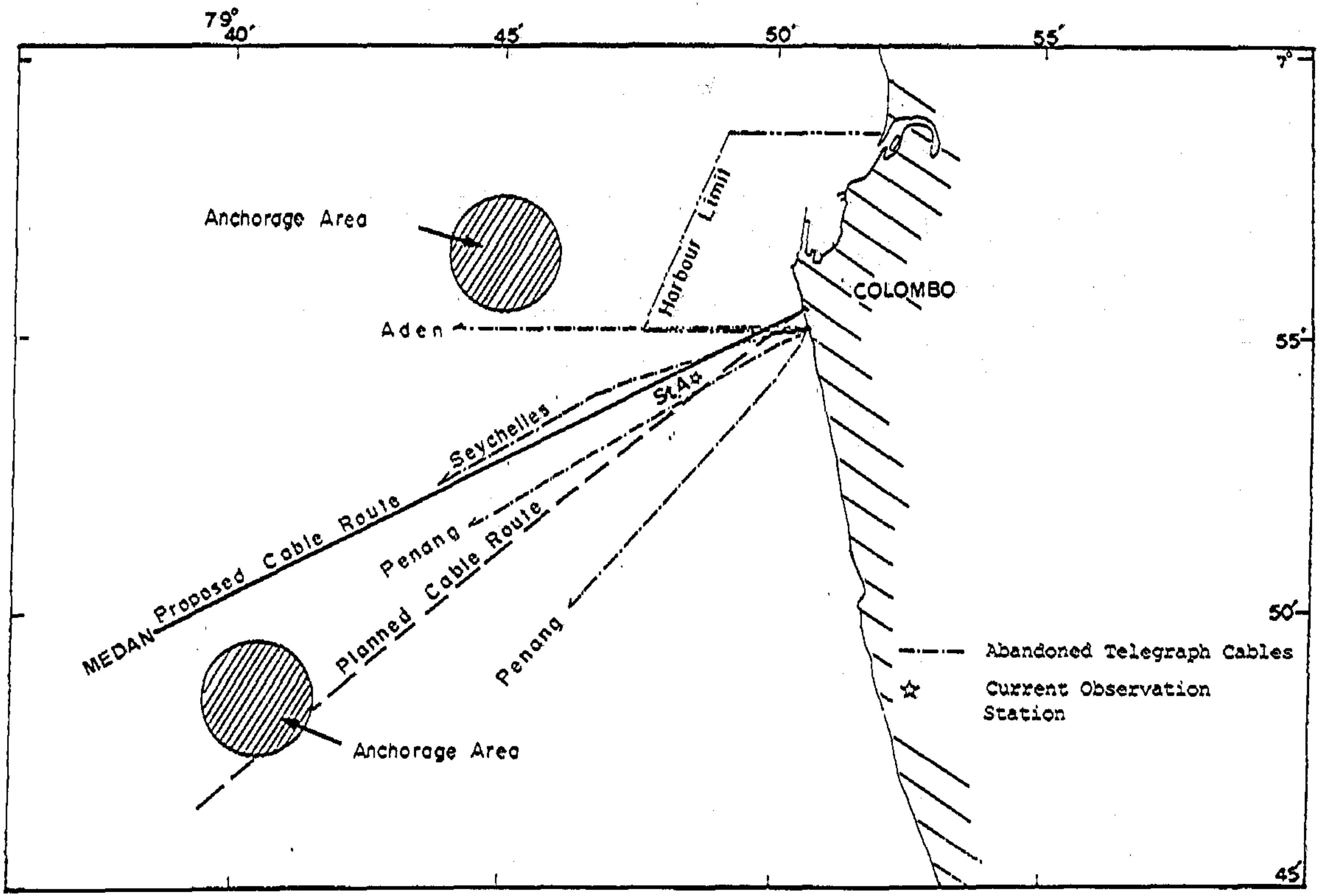


Fig 4. 2. 1 CABLE ROUTE OFF COLOMBO

4.3 Current and Water Temperature

4.3.1 Current and Tide

(1) Medan (Pantai Cermin) Inshore

Currents of both the upper (5 m under surface) and lower layers (5 m above seabed) vary similarly, and currents appear at a very high frequency in the directions of the northwest and southeast along the coast of Malacca Strait. These currents reciprocate in the northwest-southeast direction, and their variations are systematic. (Fig. 4.3.1)

The maximum velocity value measured during the survey period is 69.0 cm/sec (1.3 kt) at the upper layer, and 58.9 cm/sec (1.1 kt) at the lower layer. A scalar mean velocity is 40.6 cm/sec (0.8 kt) at the upper layer, and 37.7 cm/sec (0.7 kt) at the lower layer. Although the current velocity of the upper layer is slightly higher than that of the lower layer, the difference between them is little. Mean currents observed during the survey period are that the current direction is 2° and velocity is 2.6 cm/sec at the upper layer, 187° and 1.4 cm/sec at the lower layer, and the current direction in the upper and lower layers are reverse to each other. (Fig. 4.3.1)

Currents of a high appearance frequency amount to 60 - 70% of the whole in two directions of the northwest and southwest at both of the upper and lower layers. (Fig. 4.3.1) A current velocity of a specially high appearance frequency was not observed, and a weak current of a current velocity of less than 10 cm/sec was also scarcely observed.

(2) Great Passage (Andaman - Nicobar Ridge)

The results of current measurement show that there is a current, which is stronger than conjectured in the bottom layer of the water depth of 1,500 ~ 1,600 m, a current of mean velocity of about 20 cm/sec is seen at all the survey points, and some periodicity is seen in its variations. (Fig. 4.3.2)

The maximum current velocity measured during the survey period is 41.1 cm/sec (0.8 kt) at St. 1 (10 m above the seabed), 37.2 cm/sec (0.7 kt) (15 m above the seabed) and 37.5 cm/sec (0.7 kt) (10 m above the seabed) at St. 2, and 49.3 cm/sec (1.0 kt) (15 m above the seabed) and 47.7 cm/sec (0.9 kt) at St. 3 (10 m above the seabed). Thus, though the measurement was carried out in the bottom layer of a deep sea, a current of velocity of approximately 1.0 kt was observed.

A scalar mean velocity is 20.0 cm/sec (0.4 kt) at St. 1 (10 m above the seabed), 18.5 cm/sec (0.4 kt) (15 m above the seabed) and 18.0 cm/sec (0.4 kt) (10 m above the seabed) at St. 2, and 20.1 cm/sec (0.4 kt) (15 m above the seabed) and 19.7 cm/sec (0.4 kt) (10 m above the seabed) at St. 3. The scalar mean current velocity was about 20 cm/sec (0.4 kt) at every survey point.

Mean currents observed during the survey period are that the current direction is 164° and current velocity is 12.8 cm/sec at St. 1 (10 m above the seabed), 24° and 4.3 cm/sec (15 m above the seabed) and 33° and 4.8 cm/sec (10 m above the seabed) at St. 2, and 250° and 9.5 cm/sec (15 m above the seabed) and 253° and 8.7 cm/sec (10 m above the seabed) at St. 3.

The directions of currents observed were SSW'ly at St. 1, NNE'ly at St. 2 and WSW'ly at St. 3, respectively. Current directions of a high appearance frequency are SSW (26.9%) at St. 1 (10 m above the seabed), NE (18.9%) at St. 2 (10 m above the seabed), and WSW (20.1%) at St. 3 (10 m above the seabed). The current direction varies with survey points. As a whole, a current is a southernly current at St. 1, and reciprocating current flowing in the direction of the northeast-southwest at Sts. 2 and 3.

The current velocity of a high appearance frequency is within a range of 10 - 20 cm/sec at every survey point, and its appearance frequency is 46.3% at St. 1 (10 m above the seabed), 47.3 % at St. 2 (10 m above the seabed), and 59.2% at St. 3 (10 m above the seabed), amounting to about 50 % of the whole. (Fig. 4.3.2)

Through examination of a trajectory at 10 m above the seabed of each survey point according to progressive vectors in a period of from 0 o'clock of October 6 to 0 o'clock of October 8, during which data were obtained at all of three survey points, it was found that the current flows in the direction of SSE as a whole, while repeating southeastern and southwestern currents, since a permanent current component is large at St. 1.

The current is a gentle current to the north as a whole at St. 2, while repeating a reciprocating current. At St. 3, the current repeats a reciprocating current as at St. 2, but since a permanent current component is large at St. 3, the current flows in the direction of WSW, and its flow distance is large. Current velocity variations show some periodicity at each survey point. (Fig. 4.3.2)

(3) Colombo Inshore

Since the coast of Colombo directly faces the ocean, an influence of tidal current is small, but currents are complicated. In general, currents flowing in the north-south direction along the coast are most frequently observed, there is not a correspondence between currents of the upper (5 m under surface) and lower (5 m above seabed) layers, and currents of the upper and lower layers sometimes flow in reverse directions. (Fig. 4.3.3)

The maximum current velocity observed during the survey period is 25.9 cm/sec (0.5 kt) in the upper layer and 25.6 cm/sec (0.5 kt) in the lower layer.

A mean scalar current velocity is 18.4 cm/sec (0.4 kt) in the upper layer, 13.4 cm/sec (0.3 kt) in the lower layer, and there is a tendency that the current velocity of the upper layer is higher than that of the lower layer, but a significant difference is not seen between them.

Mean currents observed during the survey period are that the current direction is 197° and current velocity is 7.2 cm/sec in the upper layer, 130° and 5.2 cm/sec in the lower layer, and they are southerly currents in both the upper and lower layers.

Current velocity variations do not show a clear periodicity, but it is seen that current velocity of the upper layer variations contain a variation approximate to that in a diurnal period.

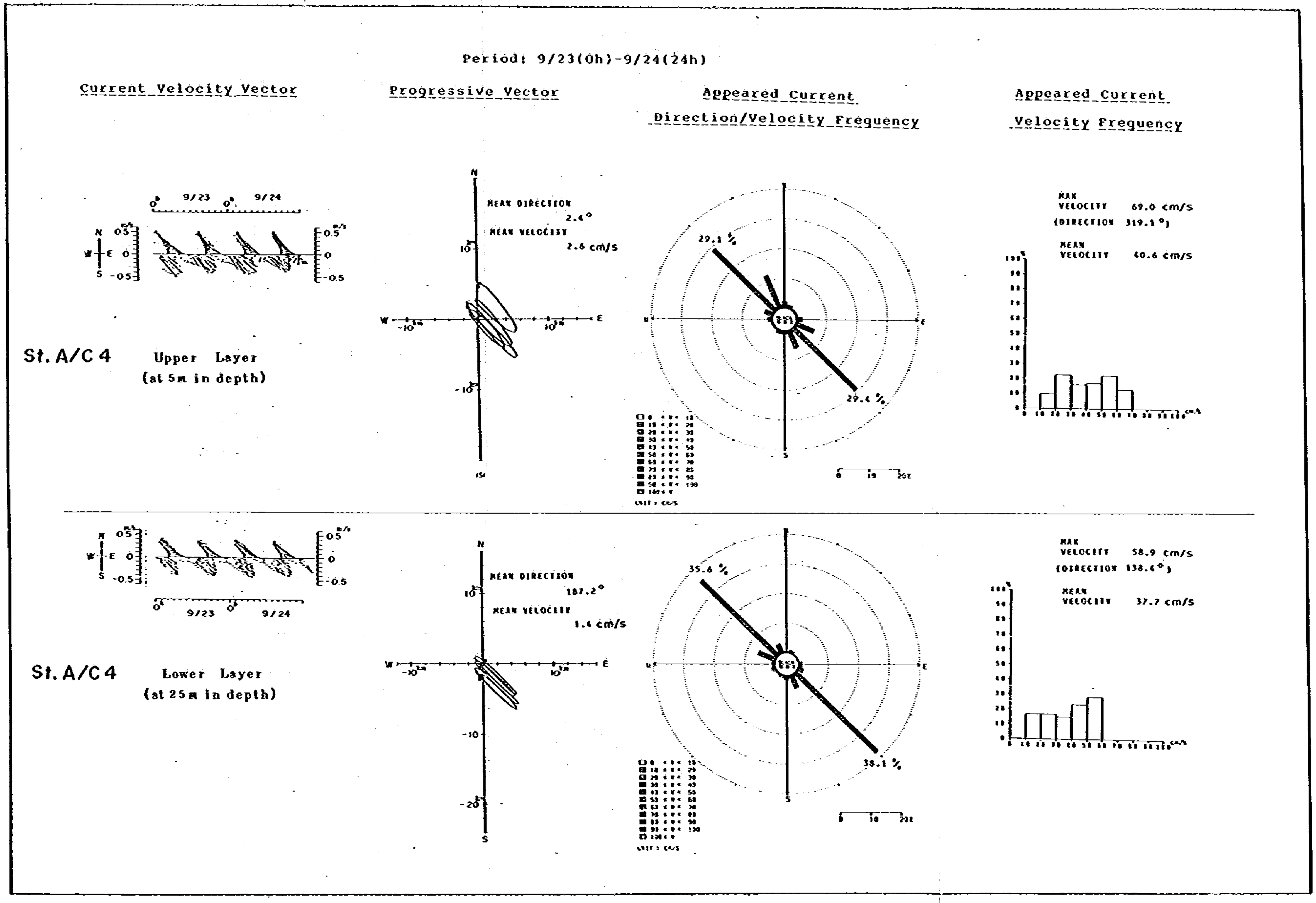


Fig 4. 3. 1 CURRENT AT A/C 4 MEDAN INSHORE (Pantai Cemin)

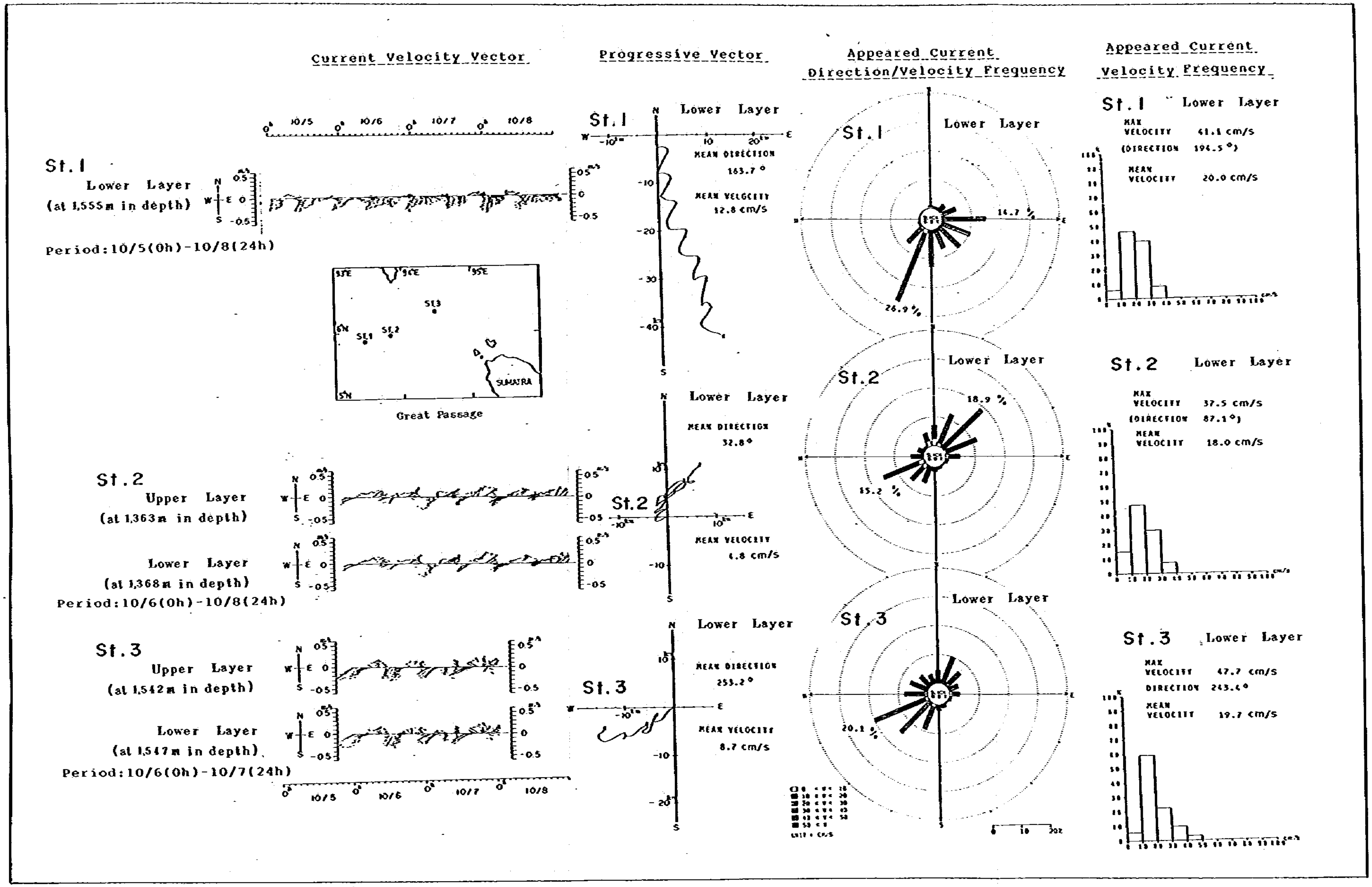


Fig 4. 3. 2 CURRENT IN GREAT PASSAGE (St. 1, 2, 3)

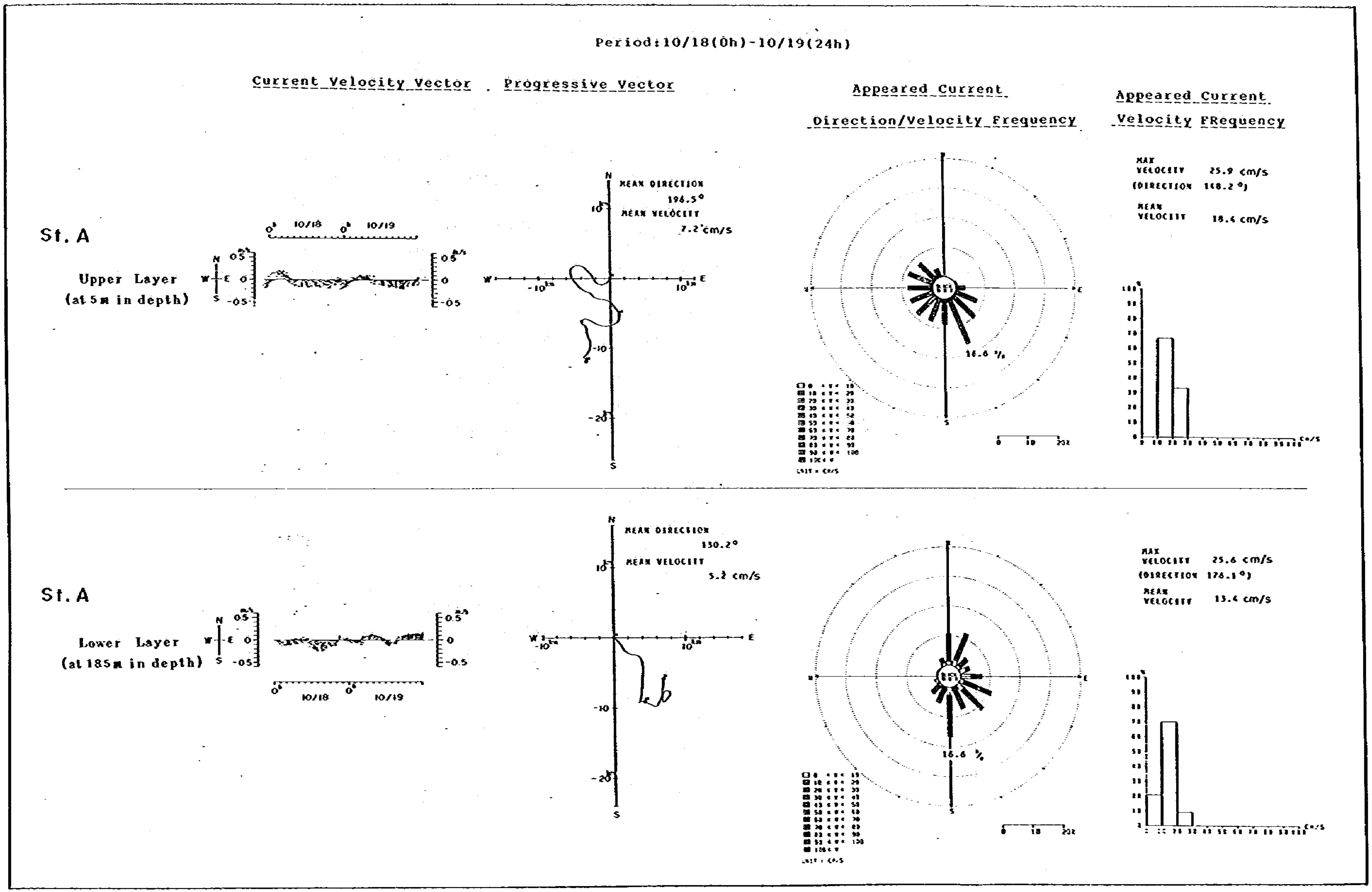


Fig 4.3.3 CURRENT AT St. A IN COLOMBO INSHORE

4.3.2 Water Temperature

(1) Medan (Pantai Cermin) Inshore - Malacca Strait

At Medan (Pantai Cermin) Inshore, the water temperature is vertically uniform, approximately 29°C, ranging from the surface layer to the bottom in about 50 m depth. The water temperature of the bottom layer falls about 10°C from 29°C to 19°C, as the water depth increases from 50 m to 100 m. A remarkable thermocline is formed at the water depth of 50 ~ 90 m, and a vertical slope of the water temperature distribution is about 0.2°C/m. (Fig. 4.3.4)

According to a continuous record of water temperature measured at Medan Inshore (St. A/C 4), the water temperature of the upper layer is 29.1°C ~ 29.7°C, and that of the lower layer is 29.7°C ~ 29.8°C. As can be seen from these values, the water temperature of the surface layer slightly changes due to an influence of a weather disturbance, but that of the lower layer scarcely changes and is nearly constant. (Fig. 4.3.6)

The reason why the difference between the water temperatures of the upper and lower layers is small, and the water temperature is uniform down to the water depth of 50 m is that the waters are vertically well mixed with one another in the Malacca Strait by a strong tidal current.

(2) Great Passage and Bay of Bengal

The water temperature distribution in Southern part of the Bay of Bengal extending from Indonesia to Sri Lanka shows that a remarkable thermocline is present at the water depth of 100 ~ 500 m in a sea area extending from the Sumatra Shelf to the Great Passage, but a water temperature slope is gentle below the water depth of 500 m.

The water temperature of the bottom layer is constantly 4°C ~ 5°C, but a distribution of isotherm of 5°C shows an influence of the seabed topography. In the oceanic area, the water temperature is as nearly constant as 2.7 ~ 2.9°C at the water depth of 2,000 m, and 1.1 ~ 1.6°C at the bottom layer. (Fig. 4.3.5)

In a vertical distribution of the water temperature, the water temperature of the surface layer is about 28 ~ 29°C, and the water temperature gradually falls up to the water depth of 50 m. A remarkable thermocline is observed at the water depth of 50 ~ 300 m, and at the depth of 300 m the water temperature is 11 ~ 12°C, about 15°C lower than that of the surface layer. The water temperature gradually falls down to about 3°C up to the water depth of 2,000 m, and its fall is extremely gentle in the deep sea below the water depth of 2,000 m. Below the water depth 3,000 m, the water temperature is within a range of 1.1 ~ 1.6°C, and nearly constant in every part of the sea area.

Grobally considering, places where a water mass forms in a deep sea exceeding the water depth of 4,000 m are only two places; offing of Greenland and the Weddell Sea of the South Pole, and water which has sunk at these places spreads in the deep sea area of every ocean.

In other words, the water temperature in the deep sea must be considered on the global basis, and its variations are extremely gentle on a large time scale.

Data collected in the route survey are nearly the same as those of MARSDEN, showing that the water temperature in the deep sea scarcely changes. (Fig. 4.3.9)

The continuous water temperature record obtained with a current meter installed at the water depth of about 1,500 m in the Great Passage shows that the water temperature is 5.0 ~ 5.4°C at St. 1 (10 m above the seabed), 5.0 ~ 5.7°C (15 m above the seabed) and 5.1 ~ 5.7°C (10 m above the seabed) at St. 2, 5.0 ~ 5.1°C (15 m above the seabed) and 4.8 ~ 4.9°C (10 m above the seabed) at St. 3, and 4.8 ~ 4.9°C (10 m above the seabed). A slight variation of the water temperature is observed at St. 1 and St. 2 also at the bottom layer. (Fig. 4.3.6)

At St. 2 where the water temperature variation is relatively large, northerly components of a current well correspond to temperature variations of the current, and a tendency that the water temperature falls when a southerly current appears is seen. A similar tendency is seen also at St. 1 where the water temperature variation is small, and there is a tendency that the water temperature falls when a westerly current appears. (Fig. 4.3.10)

From the results of observing a vertical minute configuration of water temperature at ST. 1, 2 and 3 using the XBT (Expendable Bathythermograph), it can be seen that a thermocline observed at the water depth of 50 ~ 200 m is undulating. (Fig. 4.3.7) Also when conducting a visual observation, a place where the sea is abnormally choppy, slick, etc. were observed in several lines in the North-South direction. (Pl. 4.3.1)

The phenomena described above offer suggestions as to presence of internal waves in this sea area. Richard B. Perry and Gerald R. Schimke also reported (1965) internal waves in this sea area. In a sea area where internal waves are present, current directions of the upper and lower layers are reverse to each other above and below a thermocline layer. (Fig. 4.3.8)

(3) Colombo Inshore

Data of the water temperature measurement conducted at Colombo Inshore show that the water temperature is within a range of 28.1 ~ 28.6°C at the surface layer, and it is scarcely different from the water temperature at the water depth of 3 ~ 4 m. A thermocline is present at the water depth of about 5 m.

Up to 2.5 km from the coast, the water temperature of the bottom layer is 26.2 ~ 26.7°C, but the water temperature is slightly lower 25.6 ~ 25.9°C in the offing beyond 2.5 km. The results of continuously measuring the water temperature at Colombo Inshore (St. A) show that the water temperature of the surface layer is 28.7 ~ 29.2°C, that of the lower layer is 26.0 ~ 28.2°C, and it can be seen from these data that the water temperature variation is extremely large at the lower layer.

Currents exert a wide influence upon this variation, and with respect to correlations between velocity components of currents and the water temperature, a northern velocity component (correlation coefficient: -0.50) and eastern velocity component (correlation coefficient: 0.70) are observed at the surface layer.

A northern velocity component (correlation coefficient: -0.73) and eastern velocity component (correlation coefficient: 0.34) are observed at the lower layer, and it seems that the water temperature is closely related to the values of both of the northern and eastern velocity components at the upper layer, and to the value of the northern velocity component at the lower layer. In other words, the water temperature of the upper layer shows a tendency of falling when a northwestern current appears, and rising when a southeastern current appears. On the other hand, the water temperature of the lower layer shows a tendency of falling when a northern current appears, and rising when a southern current appears.

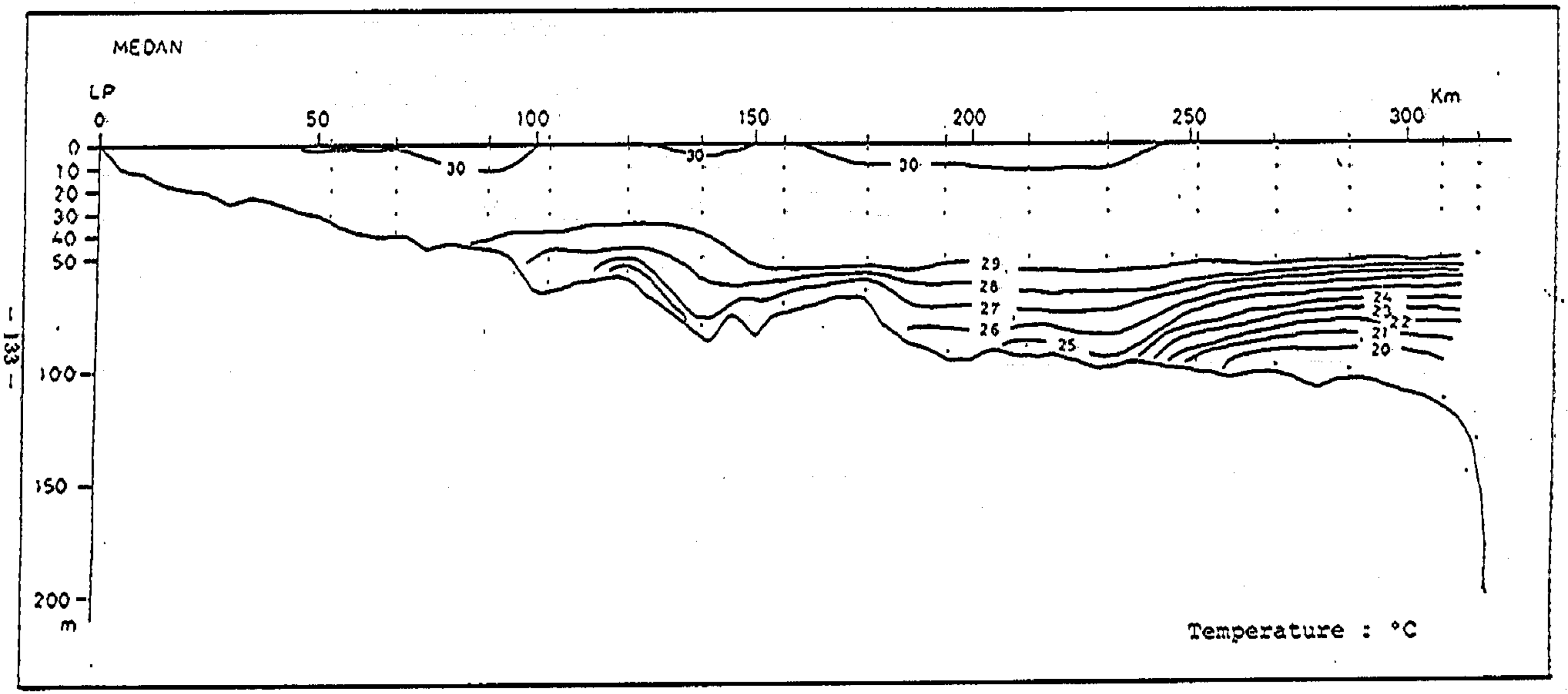


Fig.4.3.4 WATER TEMPERATURE ON THE SUNDA CONTINENTAL SHELF

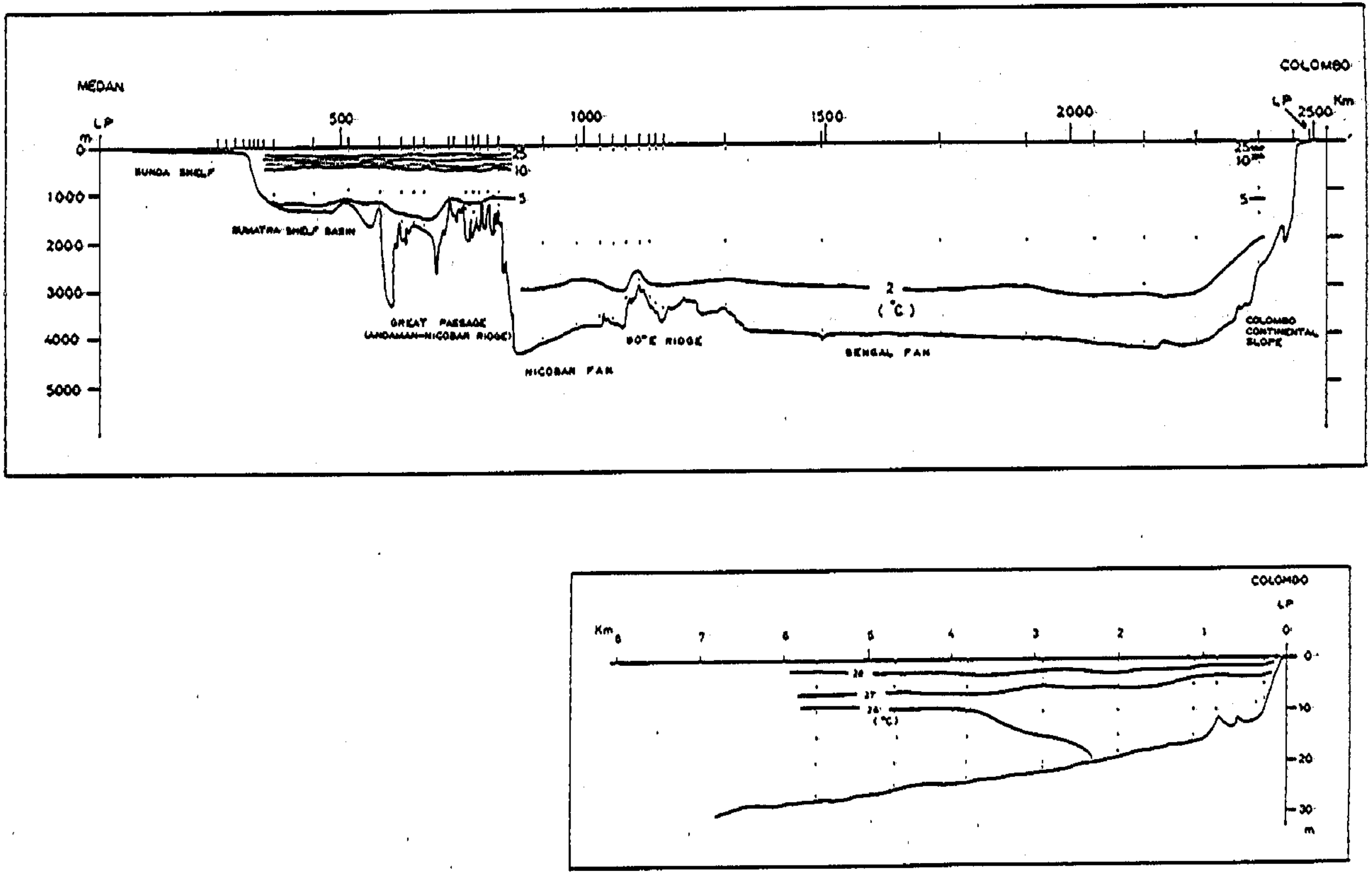


Fig. 4.3.5 WATER TEMPERATURE IN BAY OF BENGAL AND COLOMBO INSHORE

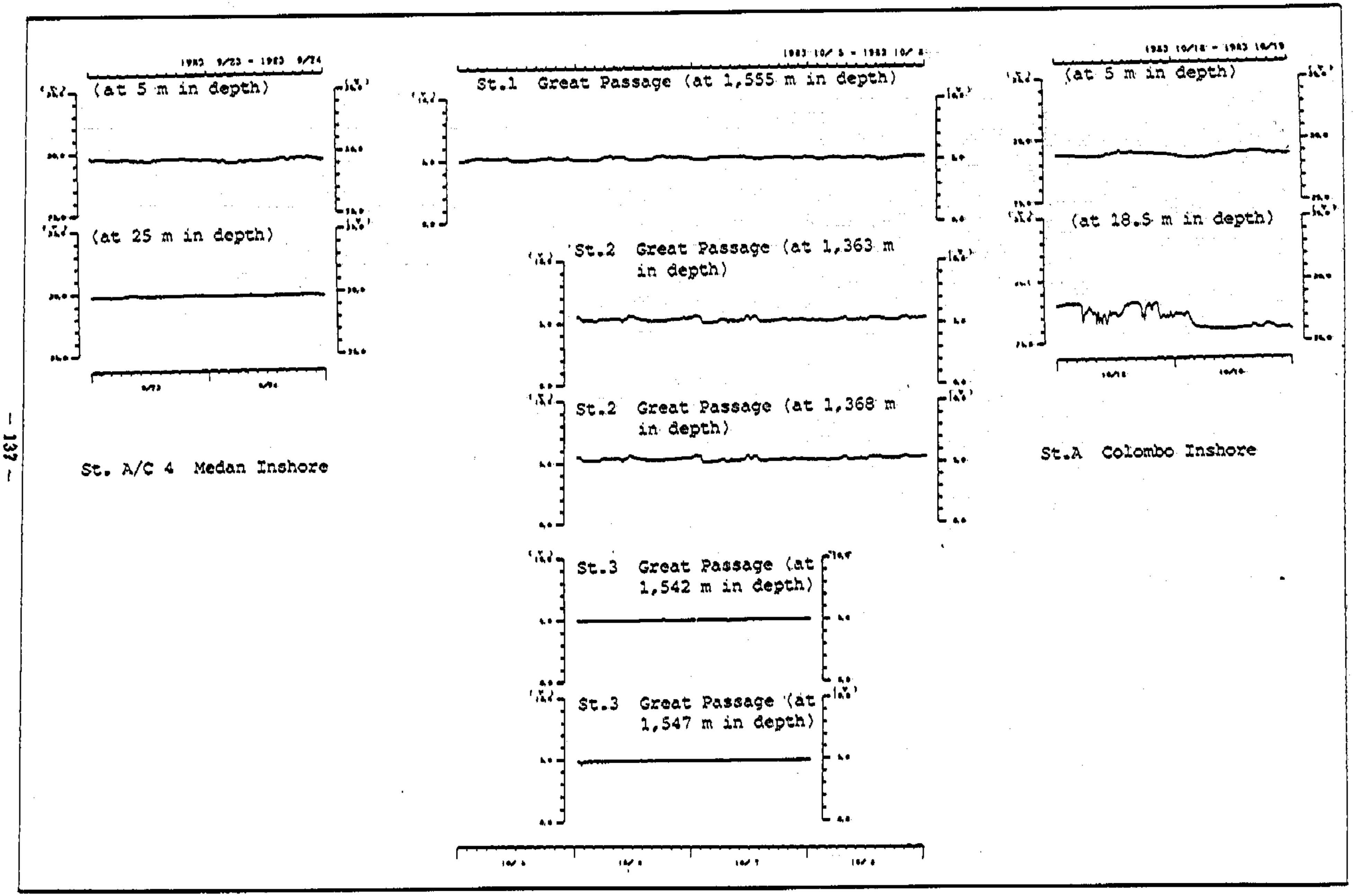
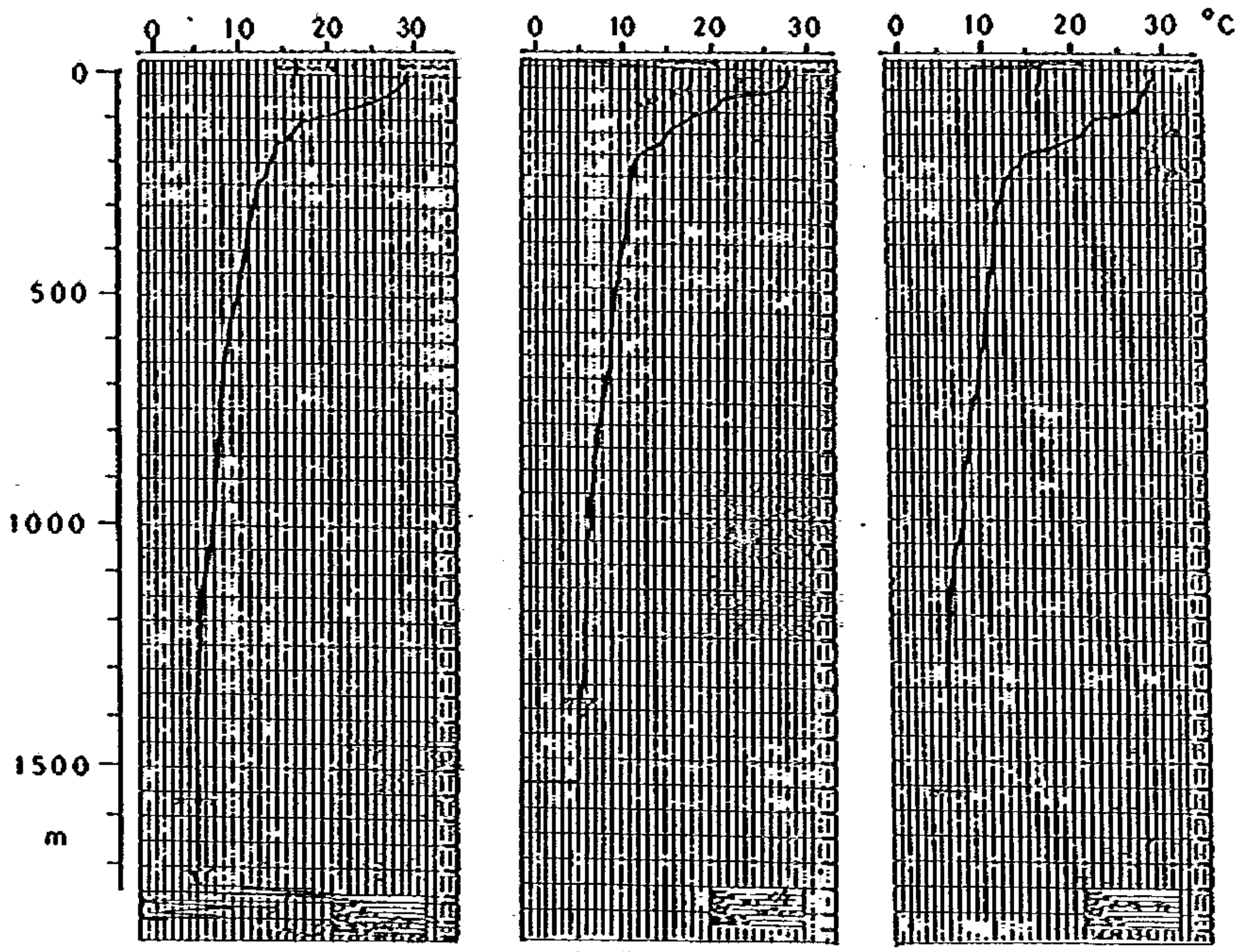


Fig. 4.3.6 CONTINUOUS RECORD OF WATER TEMPERATURE

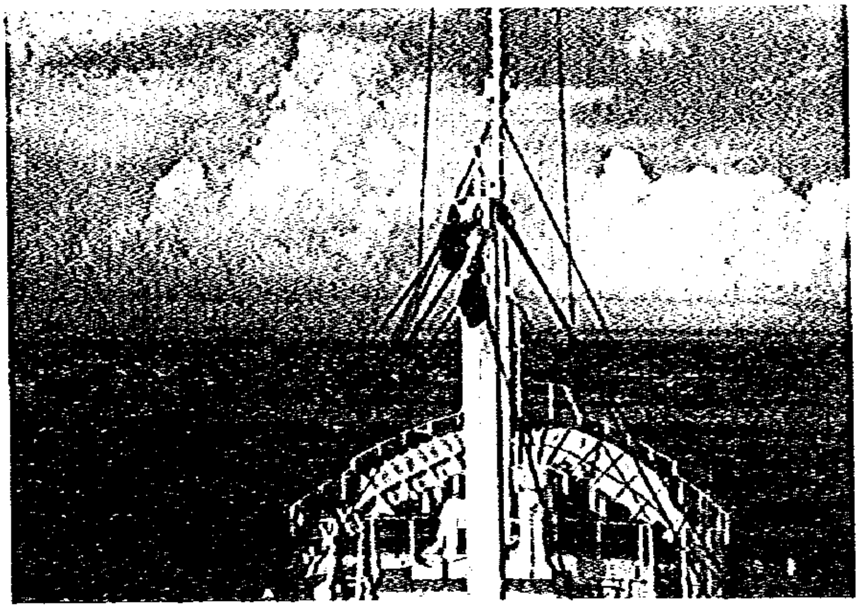


STATION	St.1
DATE TIME	9th Oct. 13 - 20
DEPTH(m)	1,565
LAYER(m)	WATER TEMP. (°C)
0	29.1
10	29.0
20	28.4
30	27.9
50	26.3
75	22.2
100	18.3
150	15.2
200	13.3
300	11.6
500	9.8
600	8.7
800	7.7
1000	6.8
1200	5.5
1500	5.2
B +10	5.1

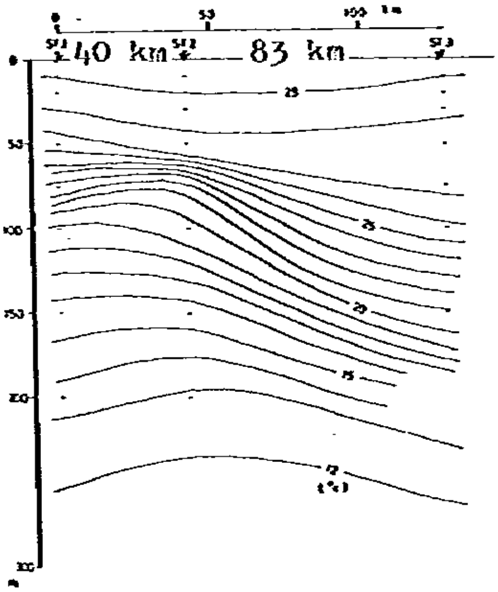
STATION	St.2
DATE TIME	9th Oct. 08 - 15
DEPTH(m)	1,378
LAYER(m)	WATER TEMP. (°C)
0	29.0
10	29.0
20	29.0
30	28.8
50	27.5
75	21.3
100	19.3
150	15.3
200	12.2
300	11.1
500	9.6
600	9.1
800	7.6
1000	6.5
1200	6.1
B +10	5.4

STATION	St.3
DATE TIME	8th Oct. 15 - 32
DEPTH(m)	1,557
LAYER(m)	WATER TEMP. (°C)
0	29.0
10	29.0
20	28.7
30	28.2
50	27.6
75	27.1
100	25.9
150	20.9
200	14.4
300	11.5
500	10.2
600	9.6
800	7.7
1000	7.0
1200	5.4
1500	5.1
B +10	5.0

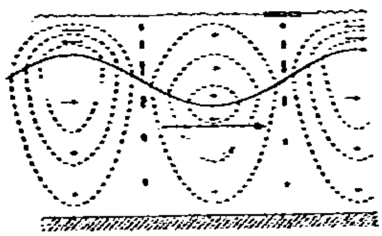
Fig. 4.3.7 WATER TEMPERATURE MEASURED BY XBT IN GREAT PASSAGE



Pl. 4.3.1 CHOPPY AND SLICK ON SEA SURFACE IN GREAT PASSAGE



Thermocline in Great Passage



Internal Wave (by LaFond,1969)
Internal wave appears at thermocline progressive direction of internal wave reversed with surface wave.

Fig. 4.3.8 EXPLANATION FOR SLICK/CHOPPY PHENOMENA WITH THERMOCLINE AND INTERNAL WAVE

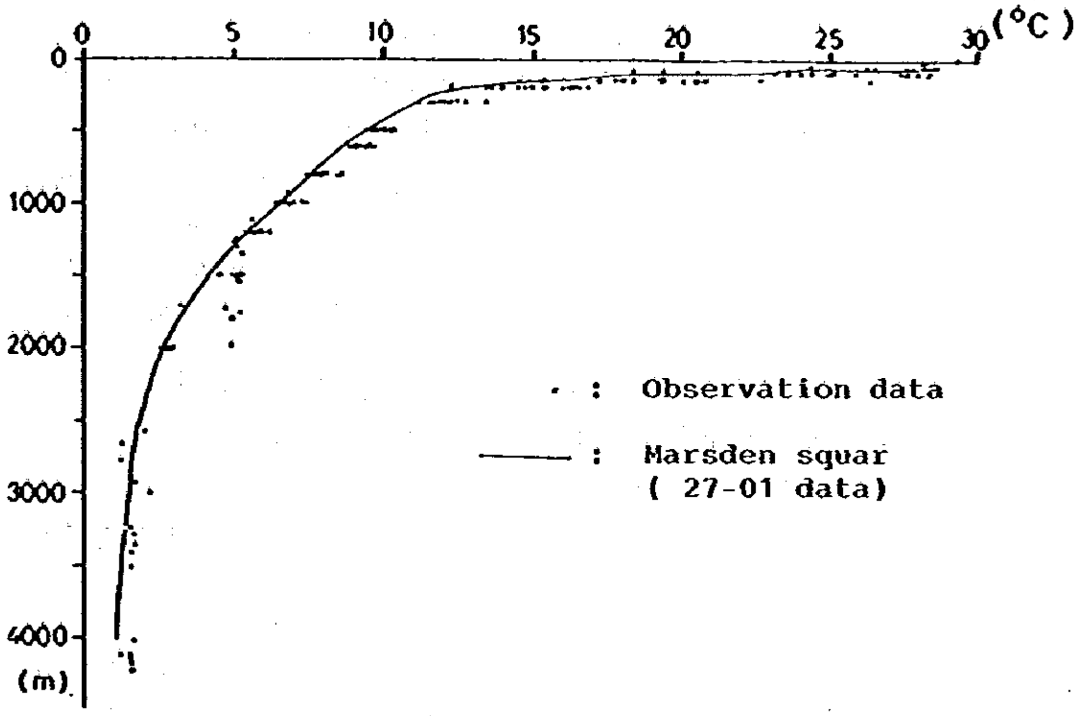


Fig. 4.3.9 WATER TEMPERATURES DATA (Marsden square 27-01) AND OBSERVATION WATER TEMPERATURE DATA

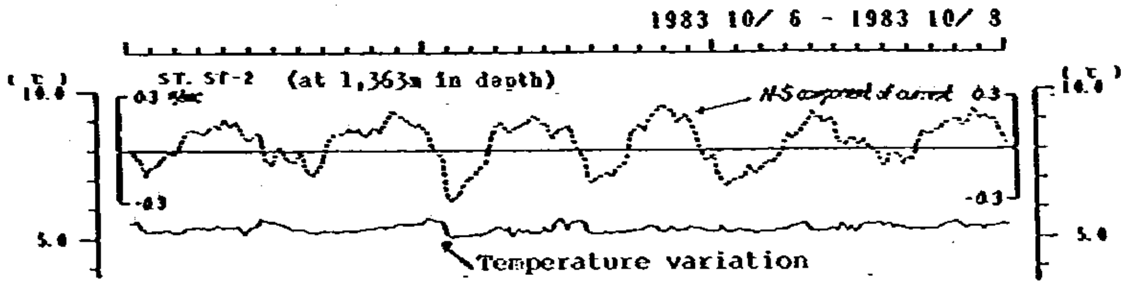


Fig. 4.3.10 RELATION OF WATER TEMPERATURE AND CURRENT AT St.2 IN GREAT PASSAGE
(Northernly components of a current well corresponds to temperature variation, and tendency that temperature falls when southernly current appears is seen.)

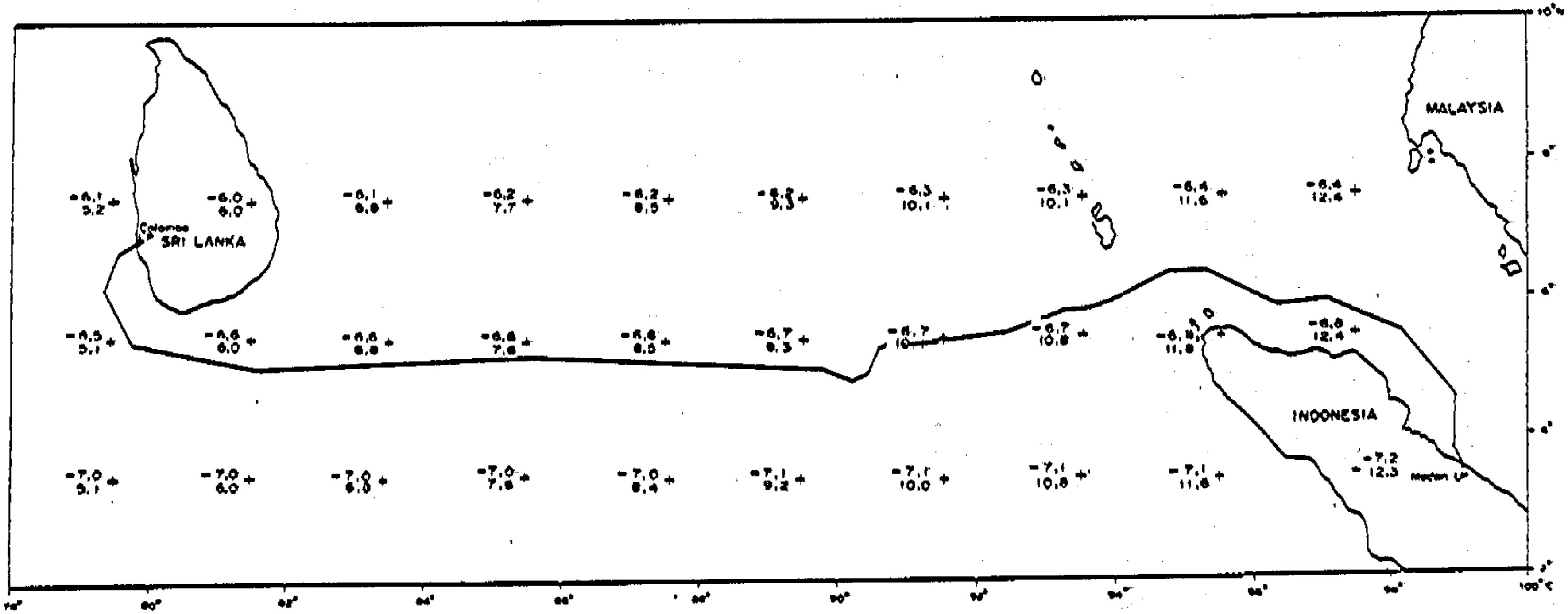
4.4 Position Fixing

4.4.1 Geodetic system and Projection Used for Survey

The survey sea area is a wide area spreading from Medan to Colombo, and the chart INT No. 706 was issued by India in 1973. When conducting the survey, this chart was used to check outlines of the water depth and bottom topography, and to examine the survey results. When prepearing a track chart which is used for actual survey works, shore lines, islands, conspicuous targets, etc. necessary for finding a ship's position were adopted from this chart.

Since the geodetic system of this chart is the Indian system (Everest), a track chart for survey was also similarly prepared, and values of Everest (1830) were used for geodetic constants. Since, however, positioning data provided by the NNSS and OMEGA navigation system are based on the world geodetic system (WGS-72), they should be converted into those of the local geodetic system (Indian system). When making this conversion, longitudes and latitudes were divided into 1° meshes, data were calculated in each section, and corrected values were obtained. It was found as a result of the calculation that points which are 250 ~ 450 m deviating toward southeast from the world geodetic system in the survey sea area correspond to the longitude and latitude of the local geodetic system (Indian system). Geodetic constants used for the calculations are as follows.

Everest	Equatorial radius:	6377276.345 m
	Flattening :	1/300.8017
WGS-72	Equatorial radius:	6378135 m
	Flattening :	1/298.26



Numeral of upper row ---- Difference of latitude
Numeral of lower row ---- Difference of longitude
(in sec)

Fig. 4.4.1   COORDINATES CONVERSION DIAGRAM FROM WGS 72 TO INDIAN SYSTEM

Corrected values thus obtained are shown in Fig. 4.4.1. The track chart for survey was prepared in the Mercator's projection method, taking 5°N as a reference, and ship's positions were plotted in it.

4.4.2 Position Fixing for survey Vessel and Boat

The inshore survey work was carried out by use of the microwave ranging system mounted aboard a small local boat chartered at the site. The survey ship's position was determined from the distance and bearing by fixing a transit at a guide point, which had been set on the beach in advance, guiding the survey ship to a survey line, and using the microwave ranging system.

The accuracy of this system is as extremely high as about ±3 m even though a displacement of the survey ship resulting from the transit guidance is taken into consideration. In the offshore areas accounting for a large part of the survey route, only NNSS and OMEGA are able to receive signals, and these areas are out of service areas of other ranging systems. It was, therefore, planned to adopt a hybrid navigation system using both of NNSS and OMEGA for determining the survey ship's position.

Since an orbit of satellites passes just above the north and south poles, the number of times of receiving signals from satellites is small in a low-latitude area near the equator, and it is larger at a higher latitude. It is said that the position fixing using a satellite is possible about 20 ~ 24 times/day in the sea area where the survey was conducted.

It is, therefore, necessary to find the ship's position by other ranging system during a period from the position fixing using one satellite and that using a next satellite and, accordingly, the position fixing was made mainly by use of OMEGA.

Since the propagation of OMEGA is always influenced by variations with movement of the ionosphere in the daytime and those with sea areas, season and time, the deviation of propagation characteristics of OMEGA should be corrected. The hybrid navigation system using NNSS and OMEGA was therefore adopted.

The position fixing value of OMEGA contains a larger error than that of NNSS, but it is immediately forced to be corrected to the position fixing value determined by receiving signals from NNSS. At this point, the accuracy of the position fixing value of OMEGA coincides with that of NNSS. The position fixing accuracy of NNSS is 0.1 nm when a ship is at anchor, and 0.2 - 0.5 nm when a ship is sailing.

Receiving conditions of OMEGA, which was used as an auxiliary system to the NNSS navigation, sometimes deteriorated and became unstable depending upon areas and time. In such cases, the position fixing was continued by the dead reckoning navigation based on a gyrocompass and ship speed until a next receiving point based on the NNSS navigation. In order to improve the position fixing accuracy, the survey ship was often stopped and made to stand by for receiving signals from NNSS until satisfactory position fixing data are obtained.

At a part of the Great Passage area where the bottom topography is complicated, positioning buoys were installed, and a survey of high accuracy was conducted using a radar. This navigation system continuously tracks the position of a radar reflector attached to the head of a buoy installed on the sea surface.

A precise position of the reflectors had been beforehand determined by NNSS, and a position of the survey ship was continuously found from the distances and the bearing between the reflectors and the ship.

A positioning error caused by an unavoidable downstream excursion was corrected by using an acoustic range/bearing device in combination with calculating relations between a surface current and excursion. The position of the positioning buoy was corrected at each time when a new positioning information was provided from NNSS.

In comparison with the topography obtained by the preceding NNSS position fixing run, the results of positioning using position buoys showed no distinctive difference. Consequently, it was confirmed that the elaborate position fixing by NNSS has a high accuracy. In inshore areas, a position fixing method of finding the ship's position by measuring the distance to a conspicuous target using a radar was used in combination with the position fixing system using NNSS, but a large difference was not found between positions determined by the radar and NNSS, and the ship's position could be determined at a satisfactorily high accuracy.

The survey was conducted on the going run and return run sailings in a zone of 3°N ~ 7°N. The results of checking satellites which flied over this zone in the survey period (38 days) are given in the following Table 4.4.1, and paths and flying frequency of satellites are shown in Appendix 24, respectively.

Table 4.4.1 Flying Frequency of Satellites in Survey Period (38 days)

	Usable	Unusable	Total
Flying frequency	416 times	300 times	716 times
Frequency/day	11 times	8 times	19 times
%	58%	42%	

The above results show that the number of times the survey ship receives signals from satellites is 19 times a day on an average, and satellites, excepting unfavorable ones, from which satisfactory positioning data can be obtained appear 11 times a day on an average, and a mean appearance interval is about two hours.

The shortest time interval between the signal reception from one favorable satellite and that from a next favorable one is a few minutes, and the longest time interval is about six hours (refer to Appendix 24). Judging from the above circumstances, it seems advisable to secure a high positioning accuracy by installing a positioning buoy in a part of the Great Passage area, where the bottom topography is complicated, when laying a cable.

5. Discussion and Conclusion

5.1 Inland

5.1.1 Medan (Pantai Cermin)

(1) Land Cable Route

The Pantai Cermin Beach was decided early as a suitable landing point for the Medan-Penang cable, and is to be selected for the Medan-Singapore and Medan-Colombo cable projects.

Construction works in the terminal building have been finished, and the site area at present consists of marsh with low lying scrub.

Although a path along the land cable route had been made by cutting a mangrove jungle in 50 m width, the greater part of the land cable route was in a marsh area.

The landing point for the Medan-Colombo cable was selected 4 meters northwestward from that for the Medan-Penang cable.

The land cable route runs almost in a straight line, keeping 4 meters apart from the Medan-Penang cable, from the beach through a marsh area crossing a creak, and its length is 1,196.78 m. (Fig. 3.1.2)

The land cable could be trenched directly into the ground.

(2) Earth System and Route

The PPB Earth System for the Medan-Penang cable system has been installed in the terminal building property, and is to be used in common with the Medan-Singapore and Medan-Colombo cable systems.

5.1.2 Colombo

(1) Land Cable Route

The land cable route was selected through close consultation with SLTD. The route runs over a distance of 240 m along the footpath of Galle Face Green, merging into Center Road. Then it goes to the OTS building along the paved congested streets, including new road under construction over a distance of 250 m. The total distance from the landing point to the OTS building is 1,361.12 m. The maximum level difference along the route is 4 m.

To keep cables free from man-made hazards and radio interference, a duct line with a depth of more than 1 m is recommended. For the Medan - Clombo - Djibouti Submarine Cables, four tubes with 100 mm dia. - two for submarine cables, and one for earth cable, and one for spare - are recommended. However, the number of tubes depends on future plans. A beach manhole is recommended to splice the seaward cables with land cables in it. For laying the land section cables, it is recomended to arrange 14 manholes as shown in Fig. 3.2.2

As the land cable runs through a congested urban area, it is impossible to select the route in such way as to keep clear of all the underground obstacles such as a power cable, communication cable, water supply pipe, sewage, gas pipe, etc. These locations are illustrated in Appendix 14. It is, therefore, recommended to carry out a thorough survey to clarify the existing underground obstacles before the actual civil work.

(2) Earth System and Route

It is recommended from the economical and safety viewpoints that the land earth cable route uses same duct line in common with communication land cables.

As shown in the results of earth resistivity measurement (Fig. 3.2.3, Table 3.2.2), a rocky beach extends unavoidably near the landing site. Therefore, some countermeasures shall be taken to get low resistance of less than 10 ohm.

As the PPE earth system, the following beach earth system (a) and sea earth system (b) are recommended;

(a) To install multiple long electrodes in a rock strata near the landing point and cover them with low resistivity materials such as carbon or bentonite.

(b) To install a sea earth around 1.0 km offshore (15 m in water depth) to protect it from wave motion and to lay an earth cable in a underwater trench.

Although both earth systems have difficulties in construction, the beach earth system (a) would be preferable as it is more economical, stable and safer than the sea earth system (b). However, it would be impossible to disclose every detail of the interior of the ground from the surface in the electrical prospecting method especially in the rock ground in question. Therefore, the final decision shall be made according to boring survey results. If geological survey based on boring shows bad results, then the sea earth system have to be considered. In this connection, a boring survey is highly recommendable at the early stage of actual construction planning.

5.2 Proposed Cable Route and Route Condition

5.2.1 Proposed Cable Route

It can be concluded from the result of the survey that the cable route shown in Fig. 5.2.1 can be proposed as the most suitable route for the Medan-Colombo Submarine Cable System. The total distance between the landing points is 2,563.34 km. The course alternation points and distance between them are shown in Table 5.3.1. The bottom profile along the proposed cable route is also illustrated in Fig. 5.2.2.

5.2.2 Route Condition

To keep the cable route free from influences of development and dredging activities of Belawan, it should run to the northeast from Pantai Cermin, having obtained a required depth as quickly as possible.

However, the Medan-Panang cable has already been laid and the route for the Medan-Singapore cable has been decided to run along the coast of Pantai Cermin. A sufficient space in the northwest direction has been left for the Medan-Colombo cable. The proposed cable route extends without crossing other cables.

At the inshore area of Pantai Cermin, the seabed has a regular topography except for various partial steep irregularities.

However, the irregularities of sand bank are supposed to be moved seasonally.

Offshore the Belawan Port, the cable route keeps out of an anchorage area, although it runs along the coastal line.

Beyond the coast of Pantai Cermin, the Sunda Shelf has a regular topography with no adverse ground or steep slopes. This good ground permits a straight line route along the coastal line throughout these areas.

Fishing activities are generally made in the continental shelf. This was verified by the operation of fishing boats during the survey, and from fishing data and references on these areas.

However, no trace ascribable to the trawling was found by the side scan sonar. Unfavorable viscous clay of bottom sediments makes the cable burying hard.

Beyond the Sunda Shelf, the slope is less steep, with a gradient of 2.6 degrees, deepening from 140 m to 1,330 m before the Sumatra Shelf Basin. Subbottom profile records indicate several meters of sediments, mainly mud, overlying a harder basement.

The proposed cable route decends this slope running westward for 120 nm, then reaches the Great Passage to facilitate a suitable approach to the ridge, which extends southeastward from the Nicobar Island.

It was found as a result of the survey that the Great Passage (Andaman-Nicobar Ridge) comprises a series of interlocking ridges and troughs. The topography often rises up to 1,200 m and falls down to 3,400 m, creating a relief over some 500 m.

From A/C-10 to A/C-11, a big valley with a width of 14 km and maximum depth of 3,425 m, having a maximum gradient of 12.4 degrees, was found. Bottom samples obtained from the area all indicated a muddy seabed.