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CRUISE REPORT

Ship Name: R/V VEMA Cruise No: 3405

Departure: 28 June 1977 (Date) from Darwin, Australia (Port)

Arrival: 29 July 1977 (Date) at Colombo, Sri Lanka (Port)

Days at Sea: 31 - Days Foreign Port: 3 (No. of days in arrival port)

Area of Operation:

Western Australian margin, Wharton Basin and Ninety East Ridge of the Eastern Indian Ocean

Program Description:

Seismic refraction using TNT and long-range sonobuoys on Exmouth Plateau, Cuvier Abyssal Plain and Ninety East Ridge. Intensive coring on Ninety East Ridge. Sea water sampling for carbonate chemistry, a calcite dissolution rate experiment and Radium-228 measurements. Testing of experimental multicorer.

Participants: (All L-DGO unless otherwise specified)

Larson, Roger	Chief Scientist
Takahashi, Taro	Co-Chief Scientist
Selo, Sam	Coring A.B.
Mossman, Brian	E.T.
O'Neill, Owen (Skip)	E.T.
Paisley-Smith, Van	E.T. (Gravity)
Peterson, Robert	E.T.
Qali, Ropate	Core Bosun
Symonds, Phillip	Australian Observer
Holland, David	Seismic Refraction Technician
Diebold, John	Seismic Refraction Technician
Mutter, John	Australian Observer
Chayes, Dale	Geochemistry Technician
Quay, Paul	Geochemistry Technician
Sundvik, Mike	Core describer

All inquiries regarding cruise should be made to the chief scientist.

CRUISE REPORT

VEMA 3405

Darwin, Australia to Colombo, Sri Lanka

June 28 to July 29, 1977

Vema sailed from Darwin on June 28 and arrived in Colombo on July 29, 1977 after a 31-day cruise in the eastern Indian Ocean to study its seismic and geochemical properties. During this leg, seismic refraction measurements were made on the Exmouth Plateaus, Cuvier Abyssal Plain and Ninety East Ridge. Intensive coring was done on Ninety East Ridge at 6° South latitude. Sea water samples were taken for carbonate chemistry and Radium-228 analyses. The C-14 tagged calcite crystals were exposed to deep water for the measurement of the calcite dissolution rate in sea water.

Seismic Refraction Program

The main objective of the seismic refraction program was to obtain a series of reversed seismic refraction profiles from the base of the Australian continental slope in the Cuvier Abyssal Plain out to magnetic anomaly M-0 in the Wharton Basin just north of the Wallaby Plateau. Larson (1977) recognized Early Cretaceous magnetic lineations in this area of the Wharton Basin and also mapped a sequence of lineated, but unidentified magnetic anomalies in the Cuvier Abyssal Plain. Our seismic refraction profiles are first of all a test of the presumed oceanic nature of the earth's crust beneath the Cuvier Abyssal Plain. Secondly, this transect of profiles should reveal the evolution of the seismic nature of the crust from the base of a Mesozoic rifted margin out to the open, deep sea floor.

In addition to this transect, we also obtained a reversed seismic refraction profile at the crest of the Exmouth Plateau and one on top of Ninety East Ridge. Additional objectives on the Australian western margin were to core presumed Mesozoic outcrops on the south flanks of the Exmouth Plateau, to obtain additional detail about the nature and extent of the unidentified (a,b,c,d) magnetic anomalies in the Cuvier Abyssal Plain, and to make a seismic reflection profile across the outer Wallaby Plateau.

Operations on all seismic refraction profiles were basically the same. The line was first pre-run with normal underway profiling equipment to obtain a reflection profile of the basement topography, and to shoot one or two conventional Navy sonobuoys. The wide-angle reflection information from the Navy sonobuoys was used to calculate sediment velocities, and refractions, if observed, were used as a check on the first refractions made with explosives. At the end of the reflection run, the gear was retrieved and a long range sonobuoy launched. The buoys used were Select International (Aquatronics) sonobuoys model SB76. These buoys work well electronically, but their deployment procedure is hopelessly unreliable. Talk to one of the cruise participants about modified deployment procedures before attempting to use these buoys! Once deployed properly in a moderately calm sea state (≤ 3), the buoys will receive arrivals out to 40-55 km. The buoys were shot using TNT explosives ranging from two to 100 lbs. When primed with a #8 blasting cap, these Australian explosives are extremely reliable. The returns were recorded on an SIE "wiggly line" recorder and the first arrivals picked during the latter part of the cruise. Although the majority of the data requires further analysis, some preliminary results are available now.

Deep arrivals recorded at long ranges were prevented on the Exmouth Plateau by a probably mis-deployed hydrophone and generally rough weather. However, the shallow results of these buoys (LRSB's 1 & 2) show that two kilometers of 2.5 km/sec sediments overlies an undetermined amount of four km/sec material. The crust beneath the Exmouth Plateau was not recorded.

Eight successful long-range sonobuoys were shot as four reversed profiles that make a transect from the base of the Australian continental slope out to magnetic anomaly M-0 in the Wharton Basin. Mantle arrivals were recorded on all but one of these buoys. The first of these profiles, comprising LRSB's 3 & 4 have been completely analyzed and the seismic cross-section is shown in Figure 1. This profile is located on the so-called alphabet anomalies in the eastern Cuvier Abyssal Plain near the continental slope. In general, an average oceanic crustal section is observed. Mantle velocity is slightly high, and the Moho dips slightly to the south. The layer 2 and layer 3 velocities and thicknesses are very typical for old oceanic crust. The 1.96 km/sec and 3.17 km/sec sediment layers probably correlate with Pliocene to Recent calcareous turbidites overlying Early Cretaceous ooze, claystone and clay, respectively. This entire section sediment is only 750-800 m thick where it was drilled at DSDP 263, because the overlying turbidites are only 100 m thick at that location (Heirtzler, Veevers, and others, 1974). The 1.96 km/sec and 3.17 km/sec layers also correspond to the layered sediments overlying transparent sediments, respectively, that were observed on the reflection profiling record.

Besides the reflection results, the a,b,c,d lineation pattern was extended nearly to the base of the Exmouth Plateau, and the additional profiles support the hypothesis that these anomalies are the Early Cretaceous sequence M-7 to M-10. This hypothesis implies a spreading center jump at M-7 to M-5 time in the western Cuvier A.P., so the basement age gradient in this area may not be

monotonic.

Three attempts were made to core Mesozoic outcrops on the south flank of the Exmouth Plateau, but all recovered only Tertiary foram ooze. It is unlikely that Mesozoic outcrops exist in that area that can be reached with a piston core or dredge.

One excellent seismic reflection profile was made across the outer Wallaby Plateau. This profile shows a thick cover of presumably carbonate sediments overlying what appears to be a rather smooth volcanic basement surface. Volcanic basement is rather peaked in the center of the plateau, more so than shown by the bathymetric contours, and prominent "shoulders" are present in the basement profile on both flanks.

One reversed seismic refraction profile was shot on the crest of the Ninety East Ridge near 6° south Latitude. Although the basement surface was rather rough compared to the previous profiles, good refraction arrivals were recorded out to about 45 km. This information should shed considerable light on this poorly surveyed structure.

Geochemistry Program

The objectives and accomplishments of the geochemistry program during V-34-05 from Darwin, Australia to Colombo, Sri Lanka, are as follows:

1) To collect a suite of deep sea sediment samples across the Ninety East Ridge at various water depths. The samples will be analyzed in the shore-based laboratories at Lamont for a study of the relationship between the water depths and calcium carbonate content in the surface sediments. The results will be used to test the diffusion-dissolution model of Takahashi and Broecker (in press) for calcium carbonate distributions in deep sediments. During this expedition a total of 15 piston cores (about 5 meters long) plus 13 gravity cores (used as a trigger for the piston core) were collected over the Ninety East Ridge along the 6°S parallel. The water depths for those cores are listed in Table 1. No chemical analysis of the core samples has been conducted on board the research vessel.

2) To collect sea water samples for a carbonate chemistry study in the Wharton Basin (east side of the Ninety East Ridge) and in the Central Indian Basin (west side of the Ninety East Ridge). According to Wyrthki's Oceanographic Atlas of the Internation Indian Ocean Expedition (1971), the Wharton Basin deep water (> 3500 m) has 0.2 to 0.3°C colder temperatures and 0.2 to 0.4 ml/l greater oxygen contents than the Central Indian Ocean deep water. This indicates that the eastern slope of the Ninety East Ridge is bathed with fresh Antarctic Deep Water, whereas the western slope is bathed with an older water mass, which may be less corrosive to the skeletal calcium carbonate than the Antarctic Deep Water. The water samples collected in those basins will be used to obtain $CO_3^{=}$ ion concentrations in deep water, so that the corrosiveness to calcium carbonate in the waters in those basins can be

quantitatively characterized. No high precision carbonate chemistry date for the Indian Ocean deep water are available. A set of the data to be obtained from this expedition will be the first of such data.

During the current expedition, a total of 26 samples each for pCO_2 and total CO_2 has been collected. The analyses will be performed in the shore-based laboratories at Lamont. The oxygen titration for those water samples have been performed on board the ship by Dr. Paul Quay. The oxygen data will be used to identify the water mass and to obtain a mass balance of the $CO_2 - O_2$ system.

3) To collect samples of Radium-228 in the deep water regime of the Wharton Basin. Radium-228 is a 6.7-yr half-life radioactive nuclide species, and is a daughter product of 1.4×10^{10} yr half-life Thorium-232. Since Radium-228 diffuses out of the sediments into the deep water, its spacial distribution may be used to estimate the vertical as well as the horizontal mixing rates (i.e., the eddy diffusivity) of the deep water, Because of the topographic prominence of the Ninety East Ridge and the flat abyssal plain of the Wharton Basin, the area is suited for measurements of the vertical and horizontal gradients of Radium-228. During the present expedition, 4 Radium stations were occupied in the Wharton Basin, and a total of 32 samples were collected. Those samples will be analyzed by W.S. Broecker at Lamont. The data will be the first Radium-228 data in the Indian Ocean.

4) To determine the ionic exchange rate of carbon atoms between the calcite surface and seawater, and to measure the rate of calcite in deep water using the C-14 tagged calcite crystals. Dissolution of calcite in deep ocean water is an important feed-back mechanism in the geochemical cycle of calcium and carbon in the oceans. However, the rate of the dissolution of calcite,

the major mineralogical constituent of foraminiferal tests, is not well known. A new technique which employs calcite crystals, of which the surface (∿ 200 atomic layers) is tagged with radioactive C-14 is being developed at Lamont for the measurement of the in situ dissolution rate of calcite in deep ocean water. Four sets of C-14 tagged calcite crystals were exposed to the deep ocean water at 3000, 4000, 5000, 5500 m deep for 8 hours concurrently with the Radium-228 sampling. The loss of C-14 activities will be determined in the shore-based laboratories at Lamont. Such a loss of C-14 activities comprises of a) net dissolution of calcite and b) ion exchange between calcite and sea water. Thus in order to determine the ion exchange rate for carbon atoms, several additional sets of the C-14 tagged crystals were exposed to a seawater sample slightly super-saturated with respect to calcite (hence no net loss of $CaCO_3$). Such an ion exchange rate experiment was conducted on board the Vema using a deep water sample from the Wharton Basin at two temperatures, i.e., 10°C and 26°C. These samples will be analyzed for C-14 at Lamont. If successful, the experiment which has taken a 6-month exposure of calcite samples on a deep sea mooring by a conventional method can be reduced to 8 hours or less and can be made at an ordinary hydrographic station.

5) To test the performance of a multiple corer in the deep ocean. A coring unit, which is capable of taking several sediment cores during a single lowering, is being developed by Takahashi, Broecker and Biscaye at Lamont. Such a unit should be highly useful for taking a number of short cores of sediments in a close spacing to study local horizontal gradients and variability of sediments. The first prototype model has been tested three times during the current leg at water depths of 1200 fms to 2500 fms.

No sediment cores were obtained. The failure appears to be due to a weakness in the coring tube (made of plastic tubing 2" in diameter), which appears to shear off during the coring process. Valuable information has been obtained for the launching and recovering procedures of the multiple corer unit, and for oscilloscope display of the pinger signals from the corer in order to detect the elevation of the unit above the sea floor.

Table 1

Summary of the Piston Cores taken over the Ninety East Ridge, ∿6°S.

EAST SLOPE		WEST SLOPE	
Core No.	Water Depths* (fms)	Core No.	Water Depths* (fms)
56	1514	57	1198
55	1636		
54	1779	58	1773
48	1999		
53	2084	59	2010
52	2178		
49	2235		
51	2396	61	2405
50	2468		
47	2835	60	2741

*) Corrected for the mean sound velocity using Matthew's table (1939).

Delete

Equipment Operation

PDR's — Both the 12 KHZ and 3.5 KHz and PDR's are in good repair and give excellent records.

Gravity — The gravimeter is working well, but one gyro and the portable Worden meter are being returned to Lamont for repairs.

Magnetometer — The magnetometer is working well, but both tow cables must be towed short because partial shorts or open circuits have developed at the original water line tow points.

Sonobuoys — The sonobuoy receiver is working well and the antenna has been remounted slightly higher up the mast.

SIE Seismic Records — This recorder is working very well, although there is slippage of the drive wheels that pull the paper out of the machine causing non-linear paper advance.

Airgun and Eels — The airgun system is working well at this writing, although we had some trouble maintaining a constant pressure in the low pressure system early in the leg. Three eels are onboard, and only one was used. It gives very good records.

Computer — Despite considerable repairs made in Darwin, the computer was inoperable for the majority of the leg. Nick Leiser the long-term computer operator got off Vema in Darwin and was not replaced, so this may be due to inexperience on the part of the present E.T.'s. The file on WEBDISK was inaccessible to the operators and a radio exchange of symptoms and possible solutions plus a lot of manual

studying was required to unlock the file. The machine is operational at this writing both for FIXPIT processing and plotting, but numerous items prevent on-line data acquisition. The AD01-D and TC-11 problems were not fixed in Darwin and the disks need a lot of preventative maintenance.

Coring

The coring gear and winch are in good shape although a broken bolt badly damaged the wire at 2590 fm requiring that it be spliced. This is the third splice in the present wire.

Explosives

6 1/4 tons of Australian TNT are still onboard for use in upcoming legs. This consists of 21b charges, 3350 each, 71b charges, 276 each, 151b charges, 252 each. It is fresh and extremely reliable. 15,600, #8 blasting caps, 12,000 feet of fuse, and 11,000 fuse lighters make up the rest of the explosive inventory.

Ship Operation

The ship is in good repair, and, as usual, well maintained. Repairs to the evaporator have made a great improvement in available fresh water. The hull is very dirty and slow speed results. About 8.8 - 9/0 kts can be expected from full ahead at 230-240 rpm.

References

Heirtzler, J.R., Veevers, J.J. and others, Site 263, Initial reports of the Deep Sea Drilling Project, 27, 279-308, 1974.

Larson, R.L., Early Cretaceous breakup of Gondwanaland off western Australia, Geology, 5, 57-60, 1977.

Takahashi, T., and Broecker, W.S., in press, Mechanisms of calcite dissolution on the sea floor, ONR Symposium on the fate of fossil fuel CO_2, N. Anderson and A. Malahoff, editors.

Wyztky, K. Oceanographic Atlas of the International Indian Ocean Expedition, National Science Foundation, Washington, D.C., 1971.

CUVIER ABYSSAL PLAIN
"ALPHABET" ANOMALIES

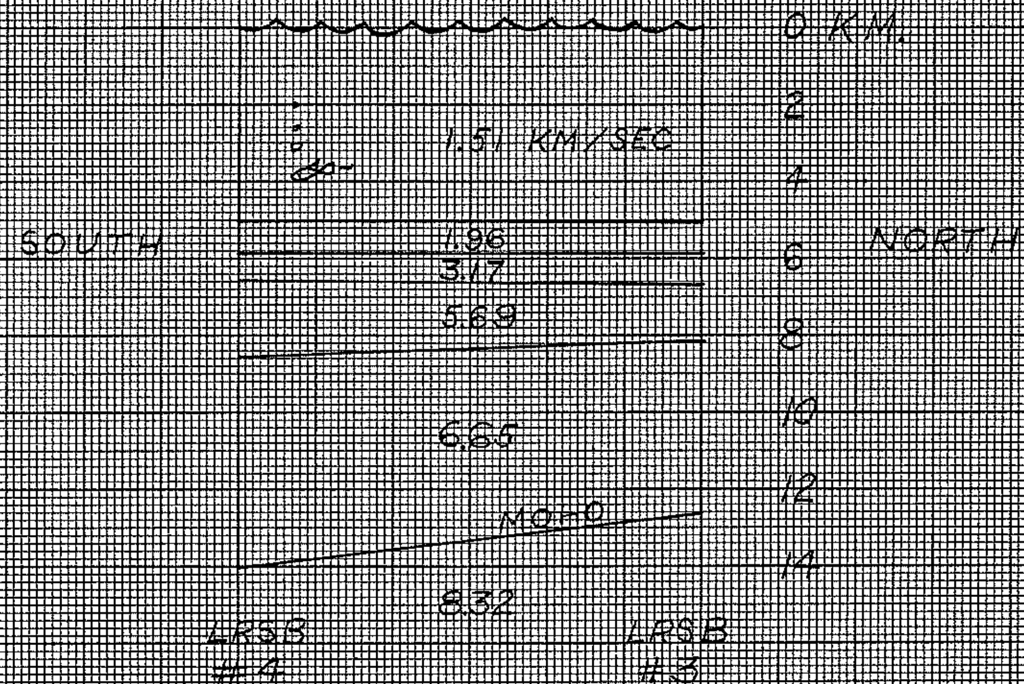
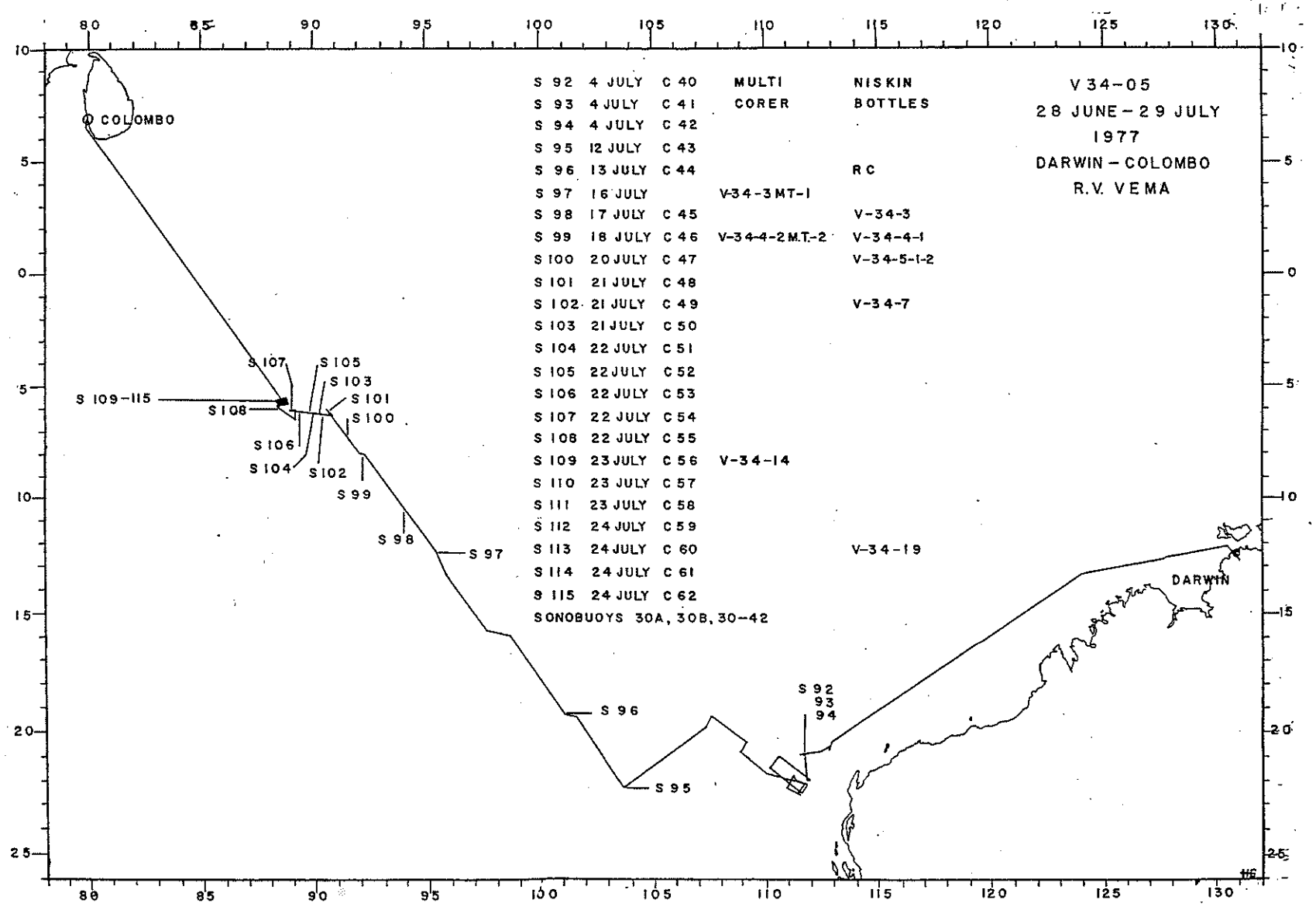


FIGURE 1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COLOMBO
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DARWIN
S 92 4 JULY C 40 MULTI NISKIN
S 93 4 JULY C 41 CORER BOTTLES
S 94 4 JULY C 42
S 95 12 JULY C 43
S 96 13 JULY C 44 RC
S 97 16 JULY V-34-3MT-1
S 98 17 JULY C 45 V-34-3
S 99 18 JULY C 46 V-34-4-2M.T.-2 V-34-4-1
S 100 20 JULY C 47 V-34-5-1-2
S 101 21 JULY C 48
S 102 21 JULY C 49 V-34-7
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S 109 23 JULY C 56 V-34-14
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S 113 24 JULY C 60 V-34-19
S 114 24 JULY C 61
S 115 24 JULY C 62
SONOBUOYS 30A, 30B, 30–42
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28 JUNE – 29 JULY
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DARWIN – COLOMBO
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