FRANKLIN

National Facility
Oceanographic Research Vessel

RESEARCH SUMMARY

CRUISE FR 8/91

Sailed Cairns	0605	Tuesday 24 September 1991
Arrived Townsville	0830	Monday 14 October 1991

PACLARK V - PACMANUS I

GEOPHYSICAL AND GEOLOGICAL INVESTIGATION OF WESTERN WOODLARKAND EASTERN MANUS BASINS, PNG

Principal Investigators

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December 1991

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CRUISE SUMMARY
RV "FRANKLIN": FR 08/91
(PACLARK-V / PACMANUS-I)

Itinerary

Departed Cairns: 0605h Tuesday September 24
Arrived Townsville: 0830h Monday October 14 1991

Scientific Program

Search for hydrothermal vents and associated mineral deposits in the western Woodlark Basin and the eastern Manus Basin, Papua New Guinea

Principal Investigators

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Cruise Objectives Achieved

Cruise FR08/91 was an outstanding success. A completely new occurrence of copper-rich sulfide chimneys, with associated fauna and a plume in overlying seawater to indicate present-day activity, was discovered in the eastern Manus Basin. To be named the PACMANUS deposit, this lies on a neovolcanic zone constructed of very felsic lavas (dacite, with some andesite) and is the closest analogue now known on the modern ocean floor for ancient "volcanogenic massive sulfide" orebodies sought by the land-based mineral exploration industry.

In the western Woodlark Basin, two cored sections were successfully obtained through lower-temperature hydrothermal deposits discovered at Franklin Seamount during previous cruises. In both areas, a wealth of data and samples was acquired for post-cruise laboratory research relevant to developing improved methods for land-based mineral exploration and also to fundamental geoscientific understandings of oceanic rift propagation into continental regimes.

The capabilities of RV "Franklin" for this kind of research were again demonstrated. New on-board procedures tested during FR08/91 were analysis of deep seawater samples for methane (very successful) and manganese (unsuccessful but promising) as real-time indicators of sea-floor hydrothermal activity.

Proposed sites for holes in the Ocean Drilling Program were further surveyed and defined, and as an outcome of the PACMANUS discovery another "Franklin" cruise in 1993 is planned to further explore the eastern Manus Basin and develop targets for manned submersible dives.

Cruise Narrative and Results

After 2 days transitting the Coral Sea and passing through Jomard Entrance, operations commenced on a 24-hour basis in the western Woodlark Basin but were suspended because of unexpected rough weather and "Franklin" then moved north (1 1/2 days transit) to the more protected waters of the eastern Manus Basin for 8 days operations on station. The vessel then returned to the Woodlark Basin where altogether 4 1/2 days were spent working on station before the return voyage to Townsville.

A detailed narrative, listing of stations, and descriptions of results are given in the accompanying Cruise Report. In addition to 12 kHz echosounding, totals of 30 rock dredges, 18 gravity cores, 13 bottom camera-video tows, and 14 CTD-hydrocasts were performed to achieve the cruise objectives. Subsidiary tasks included collection of vent fauna for research at the Australian Museum, and of bottom ooze for sedimentological and ostracod research at Australian National University. Total distance steamed was 2479 nautical miles, of which approximately 2120 miles were transits between ports and areas of operation. Only 10 hours were lost to scientific activities during repairs to ship's equipment. No shore landings were made, but the ship's launch was deployed twice, once for photography during repairs to ship's equipment and once to confirm and survey a purported submarine caldera in Numanuma Bay, Fergusson Island.

Scientific Personnel

Ray Binns	CSIRO Exploration Geoscience (Chief Scientist 28/9-14/10)
Ian Clark	University of Toronto
Garry Davidson	University of Tasmania
Dave Edwards	CSIRO Oceanography (Cruise Manager)
Melissa Fellows	Australian National University
Bruce Gemmel	University of Tasmania
Kaul Gena	University of Papua New Guinea
Alex Ortega-Osorio	University of Toronto
Don Rigby	CSIRO Exploration Geoscience
Steve Scott	University of Toronto (Chief Scientist 24-28/9)
Chris Taylor	CSIRO Exploration Geoscience
Graeme Wheller	CSIRO Exploration Geoscience

General

A number of minor suggestions concerning future use of "Franklin" for geoscientific research are made in the full cruise report. It is again a pleasure to acknowledge the cooperation and assistance of the Master, officers and crew who contributed greatly to the success of the cruise.

R.A. Binns
Co-Chief Scientist

D.W. Edwards
Cruise Manager

EXTRACT
FROM
CRUISE REPORT

Cruise FR08/91

September 24 - October 14, 1991

PACLARK V

Western Woodlark Basin

and

PACMANUS I

Eastern Manus Basin

Papua New Guinea

RV FRANKLIN

Neil Cheshire Master

Dave Edwards Cruise Manager

Co-Chief Scientists: **Ray Binns**

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SUMMARY

Cruise FR08/91 of RV FRANKLIN (September 24 - October 14, 1991) was an outstanding success and achieved all major objectives, significantly expanding geological knowledge of two key areas of sea floor comparable with the environments of ancient "volcanogenic massive sulfide" (VMS) orebodies. Highlights were the discovery of a new active hydrothermal field ("PACMANUS") forming sulfide deposits associated with dacite in the eastern Manus Basin, and the acquisition of cored sections through low temperature Fe-Mn-Si oxide deposits on Franklin Seamount, a basaltic andesite volcano in the western Woodark Basin.

Initial operations in the Woodlark Basin were suspended when inclement weather was encountered. FRANKLIN moved to the more protected Manus Basin for 8 days on station, then returned to the Woodlark Basin where altogether 4.5 days were spent on station. A total of 30 rock dredges, 18 gravity cores, 13 camera-video tows, and 14 CTD-hydrocasts was conducted in the two areas in addition to 12 kHz echosounding. Transit legs took 7.5 days. The capabilities of RV FRANKLIN for marine geoscientific research of this type were clearly demostrated and fully utilised. New activities relative to previous cruises in the PACLARK program included very successful on-board analysis of methane in water samples as a real-time plume pathfinder, and a less successful attempt at on-board analysis for manganese.

Five sub-areas of the eastern Manus Basin were examined. Three were established as essentially basaltic in character, while two were found to be dominated by more siliceous volcanic rocks. Most attention was devoted to a previously unexplored ridge near 151°41'E (for which the name "Pual Ridge" is proposed), where very young submarine dacite extrusives and lesser andesites are the main rock types. The ridge is part of the complex extensional system of the eastern Manus Basin, but may be related to subsurface intrusive activity in former island arc crust rather than to a form of back-arc sea-floor spreading.

The PACMANUS hydrothermal deposit occurs near 1650-1700 m depth on a bathymetric high composed of dacite flows, in the central sector of Pual Ridge. First discovered using the towed camera-video sysem, it comprises a number of discrete fields of chimneys and mounds in an area extending some 2.5 km along the ridge crest and about 400 m wide. It includes both lightly-sedimented fossil deposits and active deposits associated with conspicuous concentrations of galatheid crabs, molluscs, gastropods, and rarer tubeworms. Individual chimneys range up to 4 m in height. Some are mushroom-shaped, and many have collapsed or have shed red-brown to yellow material. A plume characterised by elevated

turbidity and methane contents was detected in the seawater column up to several miles from the deposit, occurring at depths between 1550 and 1700 m towards the top of a 2.9 °C well-mixed water body below the sill level of the Manus Basin. Seven unsuccessful attempts were made to dredge the deposit with high-precision navigation, but several small fragments were collected by the camera system after collisions with chimneys. These consist of massive, finely crystalline sulfides with some anhydrite, denoting high-temperature formation. Preliminary mineragraphic and microprobe studies show they are very copper-rich.

Elsewhere on Pual Ridge, an isolated chimney was observed at a second site, and deposits of Mn crusts on dacite and ooze at a third also indicate hydrothermal activity in the vicinity. Pual Ridge is highly prospective for further hydrothermal deposits, and a considerable part of the eastern Manus Basin remains to be explored. By virtue of their association with dacitic volcanics, these are closer analogues to ancient VMS ores than all but one previous sea-floor discoveries of modern exhalative sulfide deposit.

Other operations in the eastern Manus Basin included gravity cores in sedimented basins to establish bottom characteristics associated with differing acoustic responses. Four enclosed deeps within grabens adjacent to volcanic ridges were tested as potential traps for dense metalliferous brines but showed no CTD anomalies or unusual bottom sediments. One dredge and a CTD-hydrocast were conducted at the DESMOS hydrothermal site (discovered in 1990 by the Aquarius expedition from Japan) 23 km east of the PACMANUS deposit.

In the western Woodlark Basin, two out of nine deployments of the gravity corer on a knoll near Franklin Seamount recovered complete sections through low-temperature hydrothermal oxide deposits from a 100x200 m target at 2650 m depth defined by previous cruises in this series. No transmissometer plume anomaly was found in a CTD-hydrocast over the crest of Franklin Seamount where active low-temperature venting was discovered during manned submersible dives last year but moderate methane anomalies were detected here and over a subsidiary volcanic knoll 1 km west of Franklin Seamount. Dredges in this area established the presence of older basaltic (oceanic) crust rather than continental crust as the walls of the neovolcanic zone near Franklin Seamount. One dredge, two camera tows, and a CTD-hydrocast investigated a Mn-anomalous zone of seawater detected during the 1990 SUPACLARK cruise. No transmissometer or methane plume anomalies indicative of active black smokers were found, and the presence of an offset segment of the neovolcanic zone southeast of Franklin Seamount was discounted. A previously unexplored ridge north of East Basin was dredged and photographed, proving to be an edifice of young ferrobasaltic pillow lavas and tube flows responsible for a pronounced east-west magnetic dipole extending to Cheshire Seamount.

At the far western end of the Woodlark Basin, near Dawson Strait, previous echo-sounding traverses were extended to define the walls and western extremity of the South Valley rift system. A dredge attempting to characterise the southern wall of this structure recovered only ooze. The ship's boat was used to confirm the presence of a submerged caldera under Numanuma Bay, to collect a bottom ooze sample at 160 m depth, and to survey a safe passage into this structure from the east for future use by large vessels.

Cruise FR8/91 returned with a wealth of material for forthcoming laboratory analysis and interpretation in Australia and Canada. A new target for future manned submersible dives has been defined in the eastern Manus Basin, but proposed surveys with FRANKLIN in 1993 are desirable to further document the PACMANUS site beforehand, and to explore for other potential dive targets.

Total distance steamed was 2479 nautical miles, of which 360 miles was between stations in the 2 areas of operations and the remainder was in transit.

INTRODUCTION AND CRUISE OBJECTIVES

Cruise FR08/91 of RV FRANKLIN was the fifth marine expedition in a research program involving collaboration between Papua New Guinea, Australia, and Canada, the aims of which have been to locate and study a close modern analogue of ancient "volcanogenic massive sulfide" ore deposits associated with submarine felsic volcanism. The emphasis on felsic volcanism, and integration with parallel studies of analogous ancient ore environments to develop improved concepts and techniques for use by the land-based mineral exploration industry, differentiate our program from most other marine research on seafloor hydrothermal activity. Co-Chief Investigators of this program are R.A. Binns (CSIRO Division of Exploration Geoscience, Australia) and S.D. Scott (Department of Geology, University of Toronto, Canada).

Previous cruises in the series worked in the western Woodlark Basin, where sea-floor spreading is propagating into continental crust. These were:

PACLARK-I	April 1986	RV FRANKLIN
PACLARK-II	January 1988	RV FRANKLIN
PACLARK-III	February 1988	HMAS COOK
SUPACLARK	April 1990	RV AKADEMIK MSTISLAV KELDYSH and MIR submersibles

Cruise FR08/91 operated in two areas, the plan being first to complete the research program in the western Woodlark Basin (PACLARK-V), and then to conduct a reconnaissance in the eastern Manus Basin (PACMANUS-I) where recent cruises by other parties indicated a high potential for finding hydrothermal activity associated with felsic volcanic rocks.

Specific objectives of PACLARK-V in the western Woodlark Basin were as follows:

1. Obtain cored sections through a large but inactive deposit (ca. 200x100 m) of Fe-Mn-Si oxide ("Beaujolais") discovered by SUPACLARK on a small volcanic edifice northwest of Franklin Seamount, with the particular aim of testing whether massive sulfides or auriferous barite underlie this deposit, and also in this same area to check the previous failure to detect a plume above actively-venting Fe-Mn-Si deposits on Franklin Seamount. A small gravity corer, designed to withstand the harsh treatment expected, had been built at CSIRO for the coring exercise.

2. Investigate the area southeast of Franklin Seamount, where a manganese anomaly in deep seawater had been detected by SUPACLARK hydrocasts without determining its source, and where there were prospects for hydrothermal activity associated either with an offset neovolcanic zone or with rifted continental crust adjacent to the oceanic spreading zone.

3. Define the nature of ridges constituting the northern and southern walls of the neovolcanic zone near Franklin Seamount. Magnetic surveys by PACLARK-III and SUPACLARK had not resolved whether these were older oceanic crust, or continental crust belonging to the Woodlark and Pocklington Rises as defined by exposures on islands flanking the Woodlark Spreading Zone.

4. Similarly define the nature of previously-unexplored ridges north and south of East Basin, to clarify the structure of the very propagating tip of the Woodlark Spreading Axis.

5. Acquire more information on the walls of South Valley, a rift structure within continental crust some 50-80 km ahead of the propagating sea-floor spreading. It was hoped to clarify relationships to exposures on Normanby and Fergusson Islands flanking this rift, and also the relationships between subsidence and the submarine andesite-rhyolite volcanism at and near Dobu Seamount discovered by earlier PACLARK cruises.

6. Use the ship's boat to confirm a presumed submerged caldera structure in Numanuma Bay near Dobu Island in Dawson Strait. This appeared central to a ring of subaerial pumiceous rhyolite volcanoes with hot-spring activity, and was a potential target for shallow submarine hydrothermal deposits associated with extensional rifting of continental crust ahead of the Woodlark spreading axis. An attempt to sample bottom was planned, and a safe passage for larger vessels through surrounding reefs was to be surveyed.

7. Further develop a proposal for ODP drilling in the western Woodlark Basin, and obtain more survey data on candidate sites.

All these objectives were successfully achieved, except that task (5) and task (4) in part were inconclusive since the dredges returned with bottom ooze only, and time did not allow further attempts to sample rock.

The PACMANUS-I leg in the eastern Manus Basin had the advantage of an excellent SeaBeam chart (1:100,000 scale) provided together with other cruise results by Professor H. Sakai, Chief Scientist of the 1990 Aquarius Expedition of RV HAKURO MARU, a published SeaMarc-II side-scan image (1:250,000 scale) from the 1985-86 cruise of RV MOANA

WAVE, and unpublished data for rocks dredged during these two cruises provided by Dr T. Ishii (University of Tokyo) and Prof J. Sinton (University of Hawaii) respectively. We were attracted to this tectonically complex area, where extensional volcanism is associated with eastwards propagation of the Manus back-arc spreading axis into island arc crust, by the previous discoveries of some submarine dacites (among predominantly more mafic volcanics) and by the chances of finding hydrothermal activity associated with these arising from the Aquarius Expedition's discovery of active low-temperature venting at the basalt-hosted DESMOS Cauldron, and also from extensive turbidity, Mn and methane anomalies in seawater detected by Aquarius and during the 1986 PAPATUA expedition and the 1990 cruise of RV AKADEMIK MSTISLAV KELDYSH. The 1990 discovery of active "black smokers" on the Central Manus Spreading Ridge, some 180 km further west, by KELDYSH and RV SONNE was a further factor in guiding us to the eastern Manus Basin.

On the Australian side of this international research program, the PACMANUS leg has initiated a new collaboration between CSIRO and the Department of Geology, Australian National University, while participation of two scientists from the University of Tasmania represents a developing cooperation between CSIRO and the Centre for Ore Deposit and Exploration Studies in practical applications of the marine research to mineral exploration in Australia.

The aims of the PACMANUS-I leg of FR08/91 were to explore essentially-unsurveyed portions of the eastern Manus Basin to the west of the DESMOS field, specifically:

1. To seek evidence for hydrothermal activity directly associated with felsic volcanic rocks. To aid this, apparatus and methods to measure methane and dissolved manganese in seawater as a means of detecting hydrothermal plumes were assembled and developed at short notice.

2. To locate and sample massive sulfide deposits associated with felsic volcanic rocks or failing that with more mafic rocks.

3. Thereby to develop potential targets for future manned submersible dives.

4. To test a number of enclosed depressions evident from the SeaBeam chart as potential sites for trapping dense brines and thus for formation of hydrothermal deposits with Red Sea rather than ocean-ridge affinities.

Subsidiary tasks included identifying the causes of various acoustic bottom characteristics defined from previous cruise data by M. Fellows (ANU), and the collection of ostacods from bottom ooze and of fauna near vents for research projects at ANU and the

Australian Museum respectively. The cruise plan was developed at CSIRO (North Ryde) during May-September 1991.

Our discovery of the dacite-hosted PACMANUS hydrothermal site and confirmation of its present activity and formation of massive sulfides represents exceptional achievement of the major objectives. Together with the DESMOS site, two potential submersible targets are now defined in the eastern Manus Basin, but it is clear that the area has great potential for finding further hydrothermal sites. A second PACMANUS cruise to explore the area with RV FRANKLIN is proposed for 1993, and opportunities for an expanded international collaboration leading to manned submersible dives in the near future are being actively pursued.

CONCLUSIONS AND RECOMMENDATIONS

Western Woodlark Basin

1. The area southeast of Franklin Seamount now appears discounted as a locus for black smokers. The Mn anomaly detected in seawater by SUPACLARK is not accompanied by transmissometer or methane anomalies so probably does not represent a hydrothermal plume, and no evidence of hydrothermal deposits was found by dredge or camera on the underlying sea floor. West of 152°E, all likely sites for hydrothermal activity have now been effectively tested, significant discoveries being the active low-temperature vents forming Fe-Mn-Si oxide spires and mounds, and the inactive auriferous barite-silica chimneys near and at Franklin Seamount. Both were explored by MIR submersibles during the SUPACLARK cruise. No other obvious targets for submersible dives remain.

2. From 9 attempts, 2 gravity-cored sections were obtained through thin "Beaujolais" Fe-Mn-Si deposits from the extensive inactive development on a volcanic knoll northwest of Franklin Seamount. These show no obvious signs of underlying massive sulfides or barite concentrations. To further test for the latter, for example under thicker mounds, an alternative method of drilling with much better positional control would be needed. A nascent technology exists overseas to do this, but the considerable effort and expense involved could not be justified by the scientific significance of the results.

3. In the vicinity of Franklin Seamount, older oceanic crust extends at least 10 km south (=450,000 years at the SUPACLARK-estimated half-spreading rate of 2.2 cm/1000yrs) and at least 4 km north of the current neo-volcanic zone. The boundaries of the Woodlark spreading zone with its continental walls are not yet accurately located.

4. The northwards-offset magnetic dipole extending westwards from Cheshire Seamount passes through a ridge north of East Basin now known to be composed of young ferro-basalt pillow lavas and lobate flows. The central knolls (explored by SUPACLARK Dive 6) on the floor of East Basin have similar compositions. A model treating these knolls and the northern ridge as surface manifestations of dyke-like structures cutting continental crust ahead of propagating oceanic accretion remains feasible, and needs testing by deep seismic surveys and ODP drilling. The nature of the ridge between East Basin and Southeast Basin remains unknown, and in view of its importance to tectonic assessments another attempt to dredge it should be made en route during the proposed PACMANUS-II cruise.

5. The presence of a submerged caldera under Numanuma Bay on Fergusson Island is confirmed. This is relatively flat-bottomed and probably heavilly-sedimented. The small bottom mud sample recovered shows no obvious evidence of hydrothermal activity. Large vessels could access the structure from the east by careful passage north of Waiope Island.

6. The structure of the far western end of the South Valley rift has now been defined bathymetrically.

7. The PACLARK research program in the western Woodlark Basin is now effectively completed. A great deal of fundamental data has been acquired relevant to the tectonics of oceanic-rift propagation into continental crust. Further advances can be expected shortly with two cruises proposed for 1992, deep seismic sounding (J. Mutter, RV MAURICE EWING), and SeaMarc-II imaging and re-appraisal of magnetic profiles east of 152°E (B. Taylor, RV MOANA WAVE). Four high-priority ODP drill hole sites testing aspects of rift propagation have been defined, one of which (East Basin) would be a "bare-rock" site.

Eastern Manus Basin

1. Active hydrothermal venting, forming copper-rich sulfide-rich chimneys and mounds, has been discovered associated with submarine dacite eruptives on Pual Ridge (the PACMANUS field). Andesites and possibly rhyolites are subordinate components of the volcanic package of this ridge, which bears strong similarities to many ancient volcanogenic massive sulfide ore environments. The PACMANUS site may be the best modern analogy so far found in the oceans for ancient VMS settings, and further research will unquestionably provide new data of considerable relevance to the mineral exploration industry. Except perhaps for real-time TV-guided grab-sampling (e.g. RV SONNE), the capabilities of surface-vessel exploration have been extensively exploited, and the next requirement is for manned or robot submersible dives to collect larger chimney samples and examine their geological and tectonic context, to sample vent fluids, to survey the peripheries of vent fields for lower-temperature exhalites and other potential pathfinder characteristics of the setting. Sufficient data are now available to target dives on the PACMANUS site.

2. Besides PACMANUS, and the DESMOS field found by the AQUARIUS Expedition, the eastern Manus Basin has high potential for futher discoveries of active and fossil vent fields. Two additional highly-prospective localities were defined by our cruise on the Pual Ridge, but this feature and other portions of the basin remain only slightly explored and further reconnaiscance is highly desirable. Recognising that plumes in the Manus

Basin spread at the interface between two water bodies (one well-mixed and below sill level), the value has been demonstrated of CTD hydrocasts and on-board methane analysis of seawater as effectively real-time exploration techniques using plume pathfinders. On-board Mn analysis would be a most useful supplement, and further work on this is planned before the proposed 1993 PACMANUS-II cruise.

3. Four depressions in grabens beside volcanic ridges were tested by CTD and gravity corer with no indications of entrapped dense brines or (pending checks by chemical analysis) metalliferous sediments. Phase separation of high-temperature hydrothermal fluids is feasible on elevated volcanic structures in the eastern Manus Basin, but we found no evidence that brines generated thereby were vented to descend and concentrate in enclosed basins.

Logistic Aspects

1. The weak links for dredging mandated by CSIRO Hobart appear excessively conservative. On two occasions they broke while the dredge and weight were being hoisted off the deck! We recommend that the design be re-examined, and the shear strength of the material used for pins be tested. More replacement pins should be taken so that new ones can be used for each operation. A slightly tapered pin and matching hole would enable easier replacement.

2. We did not make full use of the ship's VAX computer (lack of expertise and plotting hardware). Immediate printout of GPS coordinates and SIMRAD depths would have released one watchkeeper from manually logging these data (knowing they could be recovered later is not sufficient). A large-bed plotter and software to create charts in real time would save further manual effort. This should be located in the "map room" adjacent to the Operations Room for easy consultation during operations.

3. As CTD operator, electronics technician, weak-link replacer, and Cruise Manager, Dave Edwards was often over-worked to the point of near-exhaustion. If as anticipated the next cruise involves a high proportion of CTD-hydrocast work, an extra operator is desirable (combine with computer specialist?). Also, we should devise ways of avoiding tying up the rosette during filtration (e.g. use 2 sets of Niskin bottles?).

4. Displays (and ideally automated recording) of wire-out and cable tension are needed in the Operations Room during dredging, camera, and coring operations.

5. Unless the ship is re-equipped with a better photocopier, we should take one capable of enlargement/reduction of maps etc., and with a fixed rather than sliding top (latter prevented copying logbooks, sounder chart, etc. on board).

6. The extra room made available next to the Operations Room by relocating the VAX to the GP Laboratory was a great improvement. Permanent fluorescent lighting is needed above the benches for map preparation etc. A temporary arrangement rigged by the Electrical Engineer worked well. With the increased use of portable computers, desk lamps are needed in cabins.

7. Ship's Milli-Q water supply may be contaminated.

8. The deep-tow video and still cameras are due for extensive overhaul or replacement.

9. The following items of equipment unfortunately did not operate successfully during cruise FR08/91. Attempts should be made to rectify problems before the proposed 1993 cruise.

   (i) 3.5 kHz sub-bottom profiler

   (ii) broad beam transducer to receive pinger signals during camera tows

   (iii) digital oscilloscope attached to SIMRAD to display and store direct and reflected signals from pinger during camera tows

   (iv) Yeo-Kal SDL, particularly needed to record bottom water temperatures during camera tows.

10. Supply deficiences to be rectified next time include:- a shovel to clear excess dredge hauls from the after-deck; insufficient particulate filters (brought 100, need 150 for 12 hydrocasts) and methane-Mn sample bottles; insufficient sample vials, medium-sized (30x40 cm) plastic bags and small buckets; insufficient soft drinks (the can-per-day ration was insufficient for the tropics).

ACKNOWLEDGEMENTS

We thank the National Facility Steering Committee ORV for the opportunity to undertake this cruise, and the Master, officers and crew of RV FRANKLIN for unstinting support and assistance during shipboard operations.

Special appreciation is extended to Professor H. Sakai (Yamagata University, Japan) and colleagues for generously providing data from the 1990 AQUARIUS Cruise to guide planning for the PACMANUS leg, to Professor John Sinton (University of Hawaii, USA) for unpublished data on rocks collected on the 1985-86 cruise of RV MOANA WAVE, and to Dr Keith Crook (ANU, Canberra) for advice on the tectonic and sedimentological setting of the eastern Manus Basin. Activities in the western Woodlark Basin benefited from unpublished research by previous PACLARK participants.

Travel and logistic expenses of PACLARK-V / PACMANUS-I were supported by the following. Papua New Guinea; South Pacific Applied Geoscience Commission (SOPAC); Australia; CSIRO, sponsors of the CSIRO project "Geochemistry of Exhalite Horizons" (notably Newcrest Mining Limited), ANU Faculties Research Grant, CODES University of Tasmania: Canada; Natural Sciences and Engineering Research Council, Bank of Nova Scotia, University of Toronto.