FRANKLIN

National Facility
Oceanographic Research Vessel

RESEARCH SUMMARY

Cruise FR 5/93

PACMANUS-II

SEARCH FOR SUBMARINE HYDROTHERMAL VENTS EASTERN MANUS BASIN, PAPUA NEW GUINEA

Sailed	Cairns	0118	Friday	4 June 1993
Arrived	Cairns	0754	Wednesday	23 June 1993

Principal Investigators

Dr. Ray Binns
CSIRO Division of Exploration Geoscience

Professor Steve Scott
Department of Geology, University of Toronto, Canada

August 1993

For further information contact:

ORV Operations Manager
CSIRO Division of Oceanography
GPO Box 1538, Hobart, Tasmania 7001

Phone (002) 206 222
Fax (002) 240 530
Telex AA 57182

AUSTRALIA

FRANKLIN is owned and operated by CSIRO

RESEARCH SUMMARY

Cruise FR 5/93

PACMANUS-II

SEARCH FOR SUBMARINE HYDROTHERMAL VENTS EASTERN MANUS BASIN, PAPUA NEW GUINEA

Itinerary

Sailed	Cairns	0118 Friday	4 June 1993
Arrived	Cairns	0754 Wednesday	23 June 1993

Principal Investigators

Dr. Ray Binns — CSIRO Division of Exploration Geoscience
Prof. Steve Scott — Department of Geology, University of Toronto, Canada

Cruise Objectives

To survey recent and current hydrothermal vent sites on the seafloor of the eastern Manus Basin spreading zone, and to collect samples of vent plumes, mineral deposits, and associated rocks and sediments. During outward passage, examine a recently-identified volcanic ridge in Goodenough Bay for hydrothermal activity.

Cruise Narrative

Scientists commenced attending RV *Franklin* on Monday May 31 after she moved from NQEA to Trinity Wharf. The ship was in a very untidy condition having just come out of drydock. The computers were down because of a failure of the un-interruptible power supply (UPS). After cleaning out the laboratories, and delivery of our gear aboard (5 of the 6 pallets were damaged on lifting), installation and testing of our equipment proceeded through the next few days. On Wednesday June 2 we received from Hawaii a side-scan image of Goodenough Bay just completed by Brian Taylor on RV *Moana Wave*. This indicated that "Goodridge", a seismic structure inferred to be volcanic when found by John Mutter on RV *Maurice Ewing* in 1992, was an insignificant feature. Our original plan had been to examine this on the way to the Manus Basin, but it was decided instead to proceed directly to the Manus Basin and consider visiting Goodenough Bay on the return passage.

All scientists boarded the ship on Thursday evening June 3 in readiness for departure.

Day 1 - Friday, June 4 1993

Planned departure at 2200h the previous night was delayed because of continuing problems with reconstruction of the UPS transformer. This threatened both the computing systems and the engine room monitors.

To clear our berth, *Franklin* cast off at 0118h from Trinity Wharf, Cairns, and proceeded to an anchorage outside the marked navigation channel, where work continued on the UPS. It was finally decided to bypass the UPS and continue the cruise despite the risk this posed. Raised anchor at 1238h and sailed for Grafton Passage where we turned northeast to cross the Coral Sea. A Boat Stations drill at 1630h was followed at 1745h by a safety lecture from the Master and a tour of the ship for scientists new to *Franklin* . A total eclipse of the moon, peaking at 2215h, was observed through scattered cloud.

Day 2 - Saturday, June 5

Continued our transit across the Coral Sea, experiencing slight seas on a slight swell, considerably more comfortable than during previous cruises. Weather varied from fine and sunny to overcast. Wind and swell from the southeast. Fire Drill conducted at 1030h. Ship's engineers worked on repairs to the brake of the towing winch.

Day 3 - Sunday, June 6

After encountering a calmer but confused sea, passed through Jomard Entrance at 0640h. Continued through the Louisade Archipelago, passing east of East Island into the Woodlark Basin where there was a slight chop but little swell. Weather was overcast most of the day. Repairs to the winch brake were not completed until we were east of Egum Atoll, and we then turned back south to deeper water to pay out and re-spool the towing cable, the final 1500 m of which was spliced-on new wire which had not been able to be properly tensioned in port. Passed through the Marshall Bennett Islands and entered the Solomon Sea at about 2100h. With calmer conditions, further preparations of equipment and planning of activities were carried out during the day.

Day 4 - Monday, June 7

Continued passage across the Solomon Sea in rainy weather and a slight to moderate swell, with scientists again engaged in preparations and planning. Hove to at 0927h for a pressure test of the camera-video housings and the YeoKal submersible data logger (SDL), which were lowered in stages to 2500 m. This revealed several problems. A small amount of water entered the video housing, but this was assumed to be from the seal rather than a failure at depth. After initia'ly functioning well, the pinger signal was lost on the new Simrad EA500 echosounder. At first this was thought to be a problem with the backwards-looking receiver or operation of the Simrad, but when the cage was returned to the surface it was noted that the pinger was not operating, although it resumed pinging after an accidental knock against the stern. The pinger was dissembled and five faults corrected including a broken solder joint. The SDL survived the pressure test, but conductivity readings appeared spurious and the pressure (depth) readings exceeded the wire-out so that recalibration was planned.

Several attempts were made during the day to contact Rabaul Volcano Observatory to discuss operation of the GPS base station set up there to attempt differential measurements. They eventually phoned us the next day in response to a telex, and were clearly devoting considerable effort to the task.

A management meeting with ship's officers discussed operational matters, and it was decided that either Dave Vaudrey or Dave Edwards would oversee future afterdeck operations to avoid coordination problems that were evident in the recovery of the camera-video cage. A meeting of scientists discussed the objectives of the cruise and watch-keeping operations.

The first watch stood to at 2000h as Rabaul was approached. **Echo-sounder traverse MES-6** was conducted at 9.5 kt in a northwesterly direction to profile Tavui Caldera offshore Crater Peninsula, Rabaul. The southeastern crater rim was crossed at 355 m. The floor is very flat, but with several levels (1084, 1090 m particularly) separated by apparent collapse faults. After a very steep wall, the northwestern rim was crossed at 270 m. Variable tidal effects were observed at the rim, causing speed over ground to rise then fall distinctly. The sub-bottom profiling facility of the SIMRAD was used during the run, showing some differences in structure apparently related to bottom type (unlithified ooze thickness?) but greatly influenced by steep slopes.

Day 5 - Tuesday, June 8

We returned over Tavui Caldera and conducted a successful test of the repaired pinger, which was deployed close to the flat bottom as though for a camera tow. The colour display of the new SIMRAD appears ideal for maintaining camera height above bottom. However it was found to be impractical to switch the SIMRAD occasionally to measure bottom depth. Although this could be recorded from the Bridge echosounder during a camera tow, the readings are less accurate.

CTD-Hydrocast MH-12 was conducted in an easterly direction, commencing above the caldera floor and ending near the crest of the eastern rim, with southwesterly wind at 6 kt. Confused currents near the rim caused some problems with wire angle while maintaining course, and at one stage the cable touched the A-frame. A current of 1 kt setting east was estimated overall. No transmissometer anomaly was observed over the floor or the eastern rim. Three Niskin bottles were fired within the caldera: very close to bottom (1090 m), and at 795 and 600 m depth. Subsequent methane analyses gave only background values of 23-35 nl CH_4 /litre seawater (henceforth nl/l). It is concluded that no hydrothermal venting occurs in the portion studied of Tavui Caldera.

At 0540h, we commenced the transit to the PACMANUS site in Eastern Manus Basin, entering almost perfectly calm waters with a 1 kt north-northeasterly breeze. Arrived at the PACMANUS site at 0900h, with calm but squally conditions.

Dredge MD-24 was carefully targeted on the PACMANUS field on a southwesterly heading. Very calm conditions allowed a near-perfect operation, and the dredge was placed on bottom close to the main zone photographed in 1991, and hauled for an estimated 50-100 m. Although only minor bites were recorded by the tensiometer, a large haul was returned, which included **two substantial and one small chimney samples** with patches of purple-coloured bladed crystals (bornite coating anhydrite?), a variety of pale grey altered dacites and red-brown ferruginous deposits, and some Mn-encrusted samples. The dredge bag was stratified, with relatively fine (cm-sized) and fresh dacite hyaloclastite in the bottom, and the altered material and chimneys in the top. Some samples with possible malachite staining will need further study to check this did not come from the green-painted shovel used to sift through the load for large specimens. Fauna included a number of *galatheid* crabs, several mussels, and several broken tube worm casings. A small snail attached to bluish-green bacterial mat was on the larger chimney sample. No ooze was found in the sediment traps, or within the load except for one pocket of about a cubic cm. Since the Master had ruled for safety reasons that no afterdeck activities were permissible while the equipment was lowered on the towing cable, the ship maintained position for almost 2 hours while the haul was examined and sampled. Excess material, mostly fine-grained, was shovelled and hosed overboard.

Subsequent study of the 3 chimney samples showed that they all fitted together as a mushroom-shaped structure 25 cm high and 20 cm across. The purple bornite-coated bladed crystals line the main orifice of the stem and the hat, and some underlie the top surface of the hat where it had been chipped. The high specific gravity of the chimney suggests it is constructed mainly of barite. A Sepik dialect word for mushroom, **Talenga**, will be used as the name for this chimney.

Camera-Video Tow MCV-12 was flown in calm conditions and light rain (wind 2 kts from the northeast) in a southwesterly direction along the PACMANUS field, commencing on the southern slope of the northern crestal knoll and then traversing the full length of the southern knoll and descending the southern stem of Pual Ridge to about 1850m depth. The course was ideally navigated in silent running mode. A complete blackout of the ship's power supply occurred while hauling the CV system to the surface after the tow. On return to deck, it was found that the video had not operated, but a full roll of 35 mm film was taken. The video fault was traced to a fuse which blew when the

video turned on, thought to have been caused by a leaky splice in the video lamp cable but subsequently proving to be a fuse overload when the 2 floodlights switched on.

Dredge MD-25 at the PACMANUS field was set up with the weak link behind rather than in front of the lead weight (as was the case for MD-24). It was deployed under calm conditions with a similar track to MD-24 on a chimney field observed at the intersection of MCV-5 and MCV-9 (1991). The final portion of the run-up drifted slightly off course, and because the GPS readout at the winch station terminated rather than rounded off distance from waypoint, the dredge was placed on bottom 1-2 cables east of the intended point. It anchored on volcanic outcrop, and the weak link and first safety chain shackle broke on recovery. The dredge returned upside down but with a good haul of dacite in the lower portion of the damaged chain bag. This was sorted and sampled in very heavy rain. Besides dominant black glassy dacite, there were some fragments with distinct red-brown and white alteration deposits or stains. No ooze occurred in the sediment traps. One very squashed mollusc was recovered.

Day 6 - Wednesday, June 9

Strong southerly winds, to 20 kt, became associated with the heavy rain squalls overnight. By morning, the winds had swung to the southeast and a moderate swell developed. Attempts to estimate the current were made, but were confused by GPS degradation. They appeared to be about 1 kt to the northeast, swinging to northwest later in the day. After dawn the rain ceased, and the day became overcast with brief sunny spells and with consistent 20 kt east to southeast winds. The wind and swell abated slightly after midday. The changeable and inclement conditions required numerous alterations to the operations plan, and reduced productivity considerably.

Sediment Core MS-9 was taken at 2125 m towards the southern end of the valley east of the stem of Pual Ridge, as the first in a sequence to examine settling of plume particulates from PACMANUS. 55 cm of brown clay and silt was recovered, with chips of dark glass in the nose cone indicating that a lava surface was hit. Three finer hyaloclastite or layers occurred higher in the core, at 30.0-30.5 cm, 31.5-32.5 cm and 40-43 cm.. This core (and subsequent MS-10) indicates that much of this flattish-bottomed valley, which shows high reflectivity on the *Moana Wave* sidescan image, is underlain by lightly-sedimented lavas.

CTD-Hydrocast MH-13 was a northwesterly traverse across the 1991 site of the PACMANUS plume to confirm its presence and location, and to select sites for further plume studies. The planned track was followed closely but at higher speed than intended because of following winds and current, which caused high wire-out angles and prevented close approaches to bottom. The 1991 character of the PACMANUS plume, with distinct but relatively weak transmissometer anomalies, was confirmed. An increased anomaly was also noted on the final upcast (#6), which possibly belongs to a separate plume. Also, a 0.02°C temperature anomaly (relative to a shallower depth in the previous cast) was noted on upcast 5. Assessments of the CTD position considering depth (decibars) and altimeter readings relative to bathymetry suggested this anomaly was associated with a small knoll at 3°42.5'S 151°40'E, north of the PACMANUS field. Methane results were essentially background (between 30 and 37 nl/l) except for one slightly anomalous value at 1676m of 43 nl/l.

Echo-Sounder Traverse MES-7 was close to a reciprocal track of MH-13, located to pass directly over the centre of the PACMANUS field. It was sailed in a southeasterly direction at 6 kt. The profile clearly showed two breaks in slope, at different levels, either side of Pual Ridge, and a steep scarp directly east of PACMANUS.

Sediment Core MS-10 was taken at 2125 m from the valley east of Pual Ridge, south of PACMANUS. Only about 100g of sediment with some glass shards in the nose cone

and core catcher were recovered. The wind at this stage was 15-20 kt from the east, and the estimated current 0.5 kt to the northwest.

Dredge MD-26 was deployed in an easterly direction up the small knoll (north of PACMANUS) thought to be the site of the temperature anomaly encountered in MH-13. The "white" dredge was used for the first time. Several small bites were made before raising. The dredge returned almost empty, but with several large chips of fresh ?dacitic glass, one prawn, and one sediment tube full of ooze.

Sediment Core MS-11 was attempted at 2389 m in a shallow depression south of the Marmin Knolls area west of PACMANUS, which was apparently thickly filled (non-reflective) on the *Moana Wave* sonar image. No pinger was attached (unlike previous core operations during this cruise) and the corer was not held at 100 m above bottom before dropping. The tensiometer indication of bottom impact was not definitive, and the corer returned empty. The operation was then repeated as **Sediment Core MS-12,** which returned with only a few grams of mud and a several small rock chips in the nose cone. Four hours were then spent on tests of the pinger/echo-sounder combination to improve the operation of camera tows, especially in rougher weather. On the first attempt, with only the YeoKal SDL (also being tested) as extra weight, the pinger kited far behind the ship. A half tonne weight was then added, and the tests repeated with the ship in both silent running and TAC modes. Although a southwesterly course was made with both wind and current from astern, speeds were in excess of 1 kt in silent running mode which made flying difficult. It was established that successful separation of direct and bottom-reflected pinger signals could be made with the thrusters operating in TAC mode, under which conditions speeds were maintained at about 0.5 kt. This will allow future scheduling of camera tows in weather conditions similar to those experienced during Day 6. The YeoKal submersible data logger, intended to detect temperature anomalies during camera tows, proved faulty and was not used again.

CTD-Hydrocast MH-14 was a south to north traverse across the Marmin Knolls west of Pual Ridge, between the broadly spaced 1991 tacks of MH-1 and MH-2, testing for hydrothermal plumes in this area and checking the Mn-transmissometer anomaly recorded at Station 2242 of the *Keldysh* 21st Cruise of 1990. Despite a wind change to a 10 kt southwesterly halfway through, the planned course was followed well. A weak transmissometer anomaly at the usual depth of 1650m was encountered, which would appear to be separated from the plume at PACMANUS. Subsequent analysis of the 11 water samples taken revealed background methane contents of 29-36 nl/l, except for one near-bottom sample at 44 nl/l.

Day 7 - Thursday, June 10

The wind change allowed **CTD-Hydrocast MH-15** to be sailed from north to south, 1.5 miles east of MH-14. This tow-yo showed only modest transmissometer anomalies (0.2-0.3% reduction at 1750 m, rising to 1650 m southwards) in the northern half of the track. Methane results were between 20-34 nl/l except for one slightly anomalous result at 1650m of 45 nl/l.

Camera-Video Tow MCV-13 was sailed with the wind again changed to an easterly breeze and only a slight swell, in a northeasterly direction along the western side of Pual Ridge at the PACMANUS site. Once again, no video was obtained: the main fuse had blown seconds after the recorder turned on. The second floodlight fitted for this and the previous tow probably overloaded the circuit. A full 35 mm film roll was taken. One major grounding, probably on sediment or a flat hyaloclastite bank occurred when winch instructions were misinterpreted. The shield of the camera cage was dented and smeared with ooze, some black deposit and some red-brown ferruginous deposit. A **small sample of massive sulfides** was wedged against the window of the video housing, which was damaged and replaced. Several small rock chips were also recovered from the base of the tail fin.

Dredge MD-27 was deployed in a northeasterly direction onto the PACMANUS site, aimed at the intersection of previous camera tows MCV-5 and MCV-9. Although a zig-zag run-up occurred, the dredge was placed on bottom close to target. Only small nibbles were recorded by tensiometer before the dredge left bottom. A <5 kg haul of small fragments, including fresh black dacite, "fibrous" bronze-coloured dacite glass, and grey altered dacite was returned. Some dacites had red stains. Also present were numerous flat shells on the rocks and one tube worm. The dredge evidently hauled across a hyaloclastite bank. Some ooze with dacite fragments was recovered from the sediment traps. A fragment of lead, presumably from the dredge depressor weight, was also recovered.

With calm conditions and the return of a 2 kt southwesterly, **Dredge MD-28** was deployed on the same target in a southwesterly direction. Again with a sinuous run-up, the dredge dropped close to target. After several good bites, a 1 tonne haul mainly of fresh glassy black dacite was recovered. One sample (15x4x2 cm) of **chimney wall**, probably barite with a chalcopyrite-lined orifice, occurred in the middle of the bag. Three small molluscs, a 20 cm tube worm, a smashed large snail, and several of the flat limpet-like shells were also present. The sediment traps were empty. Several bad kinks were developed in the main cable, which needed repair before further dredge or camera operations.

CTD-Hydrocast MH-16 was a northwesterly tow-yo (with an increasing easterly wind and rising swell) across northern Pual Ridge, crossing just north of the "isolated chimney" site (MCV-8) 2 km northeast of PACMANUS. A substantial transmissometer anomaly (0.6%) was encountered between the 2 arms of Pual Ridge, possibly with coincident temperature anomalies. Half way through the tow, while changing computer files, the ship was successfully moved astern then brought back on track. All 11 Niskin bottles were fired, mainly within the plume at 1650 m. Methane analyses were nevertheless at background level, 26-35 nl/l.

Day 8 - Friday, June 11

CTD-Hydrocast MH-17 was conducted in the same direction as MH-16, placed 1 mile to the south, to further define this plume. A zone of weaker and thinner transmissometer anomalies (relative to MH-16) near 1650 m was defined. This may be the same plume as found in 1991, but shifted some 2 miles north, or a separate plume arising either from the "isolated chimney field" on the northeast arm of Pual Ridge or from an undetected field in unexplored territory north of PACMANUS. All 11 Niskin bottles were fired, at various depths, again yielding background methane contents (23-32 nl/l).

Sediment Core MS-13 was taken at about 1910 m on a flattish area underlying the plume of MH-16 over northern Pual Ridge, reverting to use of the pinger (attached 100m above the corer) to hold above bottom before the final descent. Only a small sample of hyaloclastite was recovered. A kink worsened in the main cable 10 m from its end. The ship hove to for 90 minutes while the last 130 m of the main cable was removed and a new eye spliced on. A successful pressure test to 2200 m depth of the repaired video housing and cabling was conducted to the south of this site.

With a light easterly breeze (2-3 kt) and weak swell, **Camera-Video Tow MCV-14** was flown in a northeasterly direction from the northern end of the crestal knoll of Pual Ridge (just northeast of PACMANUS), across the twin knolls that are possible sources of the plume detected on MH-16 and MH-17, and into the deeper zone between the arms of Pual Ridge underneath this plume. The video shut off after 2h31m, just before ascending the first of the twin knolls and after crossing hackly dacite with increasing sediment. However a **group of inactive chimneys** was recorded near 3°42.1'

151°41.8, on the northern slope of the main crestal knoll. A full 35 mm film was taken. The problem with the video was assessed as being caused by a drop in battery voltage, caused by using two floodlights. Rather than alter the wiring, it was decided future tows will be planned to last 2 hours instead of 4 on bottom, and also that flying height should be reduced from 5 to 3 metres. Continuing problems experienced in logging the Toronto Magellan GPS unit were overcome during the day by mounting it on a broomstick in a plastic bag above the roof of the bridge, thus using the unit's internal antenna.

Sediment Core MS-14 was taken at about 2150 m, towards the northeastern end of the valley east of Pual Ridge. Muddy water drained from the corer as it was recovered, but a 22 cm core of colour-banded silty mud without hyaloclastite ("ash") layers was obtained. Changeable winds caused difficulties planning operations during the night, and a dredge was twice deferred. **Sediment Core MS-15** was taken at about 2080 m from the depression north of the andesites between the two arms of Pual Ridge. A plug of mud was lost from the nose cone on recovery, but a 55 cm core of layered silty mud and fine sand with two "ash" layers (30.5-34.5 and 47.5-49.5 cm) was obtained.

Day 9 - Saturday, June 12

With variable but light winds, **CTD-Hydrocast MH-18** was a southeasterly tow-yo placed about one mile northeast of MH-16 to test for continuity of the transmissometer anomaly detected in the latter. A strong anomaly was again detected over the last two-thirds of the course. One collision with bottom occurred when the altimeter failed to respond. All 11 Niskin bottles were fired, mostly around 1700 m near the peak anomaly positions. Methane analyses were again in the background range, 27-35 nl/l.

Dredge MD-29 was deployed on the western flank of the twin knolls which appear to be an extension of northern end of the PACMANUS stem of Pual Ridge, under a 10-15 kt southeasterly wind and low swell. Half a bag of rubbly volcanic rock, possibly andesite, mixed with ooze was recovered, plus two traps full of sediment. No signs of hydrothermal material were noted, but a shrimp and one tubeworm were present in the haul.

Using the Smith-McIntyre grab for the first time, **Grab MG-1** was deployed on the PACMANUS site. Although placed on bottom the grab did not close. A small amount of black sand, possibly the slag used for sand-blasting the ship's deck prior to our cruise (and which despite repeated washing is everywhere a potential contaminant), was recovered from within the grab. **Grab MG-2** was a successful repeat of this operation at the same site. It returned a full sample, with Mn-encrusted rocks, Mn-cemented hyaloclastite, and platelets of Fe-Mn crust (some on semi-lithified ooze) at the surface which, however, had been slightly disturbed by oscillations of the grab during ascent. Most of the grab was filled with fragments of unaltered dacite and a dark ooze. The grab apparently descended on a hyaloclastite bank with dark encrustations of the type photographed at PACMANUS in 1991.

After aborting a northeasterly attack because of difficulties with variable currents (wind was 2 kt from the east), **Dredge MD-30** was deployed in a southeasterly direction onto the PACMANUS site, again aiming at the main zone of MCV-5 between the sites of MD-28 and MD-25. A moderate load of glassy dacite, some with frothy khaki rinds, was recovered, with no ooze and no biota. The fishnet liner was badly damaged and subsequently replaced.

Camera-Video Tow MCV-15 was a 2-hour tow in an easterly direction, placed to cross two areas of isolated chimneys seen on MCV-14 and MCV-6. Video shut off just as the system climbed a very steep slope to the small "chimney" knoll of MCV-6. A full 35 mm film was taken. No hydrothermal deposits were noted on the video at either site.

The tow intersected many jagged outcrops of dacite, interspersed with a platy lava type, possibly andesite. The lavas are lightly sedimented. No rock samples were recovered.

Sediment Core MS-16 was taken from a small enclosed basin in the valley east of Pual Ridge, at about 2200 m. A 123 cm core of layered brown mud overlying a greenish dacitic "ash" bed (63.5-86 cm) and mud was recovered. Severe changes in wind and current directions led to numerous changes of plan throughout the night. **CTD-Hydrocast MH-19** was a southeasterly tow-yo commenced in a 3 kt southerly breeze, extending the line of MH-16 further southeast across Yuam Ridge ("Area D" of 1991) and offset slightly south. Area D, which has three subparallel ridges on its crest in a pattern resembling fingers, was re-named **Yuam Ridge** after the Sepik dialect word for fingers. A moderate transmissometer anomaly at 1650 m was observed early in the tow, and again towards the end as Yuam Ridge was approached. This suggested that further work should be undertaken on the western "finger" of Yuam Ridge. Seven Niskin bottles were fired to obtain a profile through the earlier anomalous zone, again however yielding only background methane levels (28-33 nl/l).

Day 10 - Sunday, June 13

After concluding MH-19, **Sediment Core MS-17** was taken at about 2170 m from the main basin southeast of Yuam Ridge and the Eastern Manus Volcanic Zone. An 83 cm core of layered silty mud, with a pale "ash" layer at 64-66.5 cm, was recovered. Two dredges were then scheduled to sample southeast-facing scarps interpreted as basement exposures from *Moana Wave* (1985-86) sidescan and single channel seismic data.

With the wind at 6 kt from 160°, **Dredge MD-31** was hauled north up the lower of two scarps southeast of Yuam Ridge. With only one small bite, it returned empty apart from a piece of pumice and a shred of wood, but with sediment tubes filled with ooze. **Dredge MD-32** was hauled up the higher scarp in a northwesterly direction. It also returned empty apart from several pieces of pumice, indurated dark sediment from animal burrows, and traps full of ooze. Retrospective assessment of these dredges indicated they were placed on bottom early, before climbing the target slopes. They probably filled with ooze, which washed out on the haul to surface. The wire-out readings from the tensiometer tricycle were noted to be constant while hauling MD-32, and the dredge returned on deck at a reading of 95 m. This required suspension of main winch operations while the problem was investigated and repairs initiated.

Grab MG-3 at the PACMANUS site was targeted on the chimneys photographed by MCV-11 in 1991. It apparently hit rock and returned with a small haul of black glassy dacite chips, significantly with no ooze which confirms that the light sediment cover recorded by video and camera on PACMANUS outcrops is of negligible thickness. **Grab MG-4** was then deployed with the same waypoint. It hit bottom very close to target, but also returned with a small haul of dacite fragments, many with frothy khaki glass rinds, and again no ooze.

CTD-Hydrocast MD-20 was an unsuccessful drift test across the apparent peak transmissometer anomaly position of MH-16, designed to choose the target for a single-dip CTD deployment carrying a set of titanium water samples (preset to fire at various depths) sent by Dave Norman, New Mexico Tech. The transmissometer readings were higher (less anomalous) than MH-16, and the drift was oblique to the track of MH-16. Either the plume had shifted, or the CTD did not reach the same spot. It was decided to repeat this later as a tow-yo operation. No Niskin bottles were fired. Repairs to the main winch tricycle were completed during this operation. An apparently faulty reed relay was replaced with another from a spare set of tricycle electronics.

To provide time for a barbeque supper on the afterdeck, a relatively long transit was scheduled at this point to a steep ridge northwest of the Eastern Manus Volcanic Zone.

Dredge MD-33 was deployed on the northwest face of this ridge, attempting to sample basement rocks. With a 3 kt easterly wind and slight swell, this first attempt was made at about 1 kt, dropping the dredge to bottom on arriving a the predetermined waypoint. Further problems were encountered with the wire-out meter, and on raising the dredge the lead weight almost hit the sheave when the reading was 530 m. Apart from a few fragments of pumice, the dredge returned with an empty bag (but collapsed netting liner) and filled sediment tubes. Reconstruction of the operation suggested that the dredge dropped and lifted before the target slope. **Dredge MD-34** was re-deployed on the same target, this time at 0.5-0.7 kt and holding the wire-out at 2600 m until the dredge drove into the slope. 500 m extra wire was then paid out as the ship continued ahead. A flag was attached 100 m above the dredge to avoid a repetition of the previous near-disaster. The operation was very successful, although the weak link broke soon after hauling and the dredge returned upside down held by its safety chain. The haul included numerous large pillow segments of vesicular basalt (which looked relatively old), small to large fragments of moderately lithified mudstone, ooze in the sediment traps, and a large fragment of pumice. The fishnet liner was effectively destroyed, and the cable was also severely damaged. It was decided that only sediment cores could be conducted with it in this state, so other dredges scheduled to sample basement ridges were cancelled pending termination and resplicing.

Day 11 - Monday, June 14

Returning towards PACMANUS, **Sediment Cores MS-18** and **MS-19** were taken at the northeastern end of Kumul Trough and its extension north of the Marmin Knolls, west of Pual Ridge. A pinger was attached 100m above the corer, and the cable was flagged to overcome difficulties posed by the misbehaving tensiometer and wire-out meter. Both deployments returned good cores, 86 and 82 cm long respectively. MS-18 contained two pale (felsic) "ash" silt layers, at 39.5-40.5 and 55.5-57 cm, and a 22.5 cm greenish dacitic "ash" bed (mainly silt) at 63.5-86 cm. MS-19 also contained two felsic "ash" silt layers at 38-41 and 56-59.5 cm.

After a drift test, **CTD-Hydrocast MH-21** was a tow-yo conducted with the ship moving slowly in a 12 kt easterly wind, placed to intersect the peak transmissometer anomaly position of MH-16 and more accurately locate the "eye of the plume" for the planned vertical profile deployment of Dave Norman's bottles. Although covering the desired position, only relatively low transmissometer anomalies were recorded. The CTD was accidentally placed on bottom during one cast. No Niskin bottles were fired. The results suggested that the plume is patchy.

After a delay while a new reed relay was installed in the tensiometer tricycle, **Camera-Video Tow MCV-16** was flown in a northeasterly direction along the crest of the northwestern arm of Pual Ridge, above that part of the eastern foot where MD-14 and MCV-8 recorded evidence of hydrothermal activity in 1991. Heave caused by an increasing swell caused some problems in flying towards the end of the tow. A good-quality 2-hour videotape confirmed that this ridge crest is heavily sedimented and thus probably old. No hydrothermal deposits were recorded. A full 35 mm film was taken. On recovering the camera, both wire-out and winding rate meters for the main winch failed, and pinger crossovers were used to control the haul. A planned back-to-back camera-video deployment was deferred because of these problems.

While further repairs were carried out to the tricycle, including the fitting of braces manufactured by the Chief Engineer to prevent lateral movement of the top wheel from the electronic sensor box, **CTD-Hydrocast MH-22** was conducted in a light southerly breeze and decreased swell. This was a short deployment in the valley east of PACMANUS, undertaken to test the CTD after the previous collision with the sea floor had clogged the conductivity cell with mud. The test was successful. No Niskin bottles were fired. A very weak transmissometer anomaly at 1670m was present. **Camera-Video Tow MCV-17** was a northeasterly traverse of the PACMANUS deposit which

commenced under relatively still conditions but was soon affected by increasing southeasterly winds (to 20 kt) and northeast-setting current. Markers were fitted to the cable in case further problems were experienced with the wire-out meter. Wind forced the initial portion of the track to divert over the western slope of the ridge, where very rugged topography and poor pinger signals caused very difficult flying. The camera was raised until the ship returned to the planned track. A 2-hour video and full 35 mm film were taken. The tricycle behaved well, with wire-out reading -9 m when the camera returned to deck. The video showed two segments of hydrothermal mounds and chimneys, both with very abundant fauna indicating present-day activity. Careful assessment of wire angle and wire-out versus depth measurements allowed reconstruction of the camera locations, which lagged 600-700 m behind the ship. These indicated that the hydrothermal deposits were at the same location as the main field recorded by MCV-5 and MCV-10 in 1991.

Day 12 - Tuesday, June 15

Smith-McIntyre **Grab MG-5** was aimed at the main PACMANUS hydrothermal field, but was forced 400m to the northwest of its target by 12 kt easterly to northeasterly winds during rain squalls. A 2 kg load of dacite fragments was returned. The grab probably landed on a rock outcrop. **Grab MG-6** was then deployed on the same target. Although the ship was exactly on position when the grab hit bottom, an excessive wire-out caused by approaching too fast (1 kt) from the south implied an impact 200-300 meters south of the target. The grab returned 2/3 full, with 5-10 cm of gritty ooze overlying fragments of frothy dacite glass, some with ropy surfaces. No Mn crusts, hydrothermal deposit or altered dacite were present. Two small pieces of abraded pumice, a squashed mollusc shell with black to dark brown chitinous skin, an (?)echinoid spine, a sediment-coated worm, and numerous large foraminifera were also present in washed material. Apparently the grab landed on a lightly sedimented hyaloclastite bank. At the central Manus spreading ridge, RV *Keldysh* in 1990 measured a sedimentation rate of 15.5 cm per 1000 years. Presumably the value is higher in the Eastern Manus Basin, so (neglecting the possibility of reworking) an age between 200 and 500 years is indicated for the hyaloclastite.

With a 10-18 kt south-southeast wind and mild swell, **CTD-Hydrocast MH-23** was sailed initially in a northwest direction directly across the PACMANUS field. Shortly after crossing the ridge crest, the wind altered to a 8 kt southwesterly, forcing the track to the north. A pronounced transmissometer anomaly, reaching 1.5% depression, was observed when the CTD was just northwest of PACMANUS. Methane contents of 43 nl/l were determined at 2 points in the plume. These results and a reassessment of earlier data, taking into account lag of the CTD behind the ship, were used to determine a new target for the proposed vertical profile in the eye of the PACMANUS plume.

After several plan changes as the wind swung from south to northeast while a cloud front passed, **Camera-Video Tow MCV-18** was another northeasterly traverse across the PACMANUS field, flown under relatively calm conditions with a 3 kt northeasterly breeze. The planned track was maintained well. When the cage returned to deck, the video floodlights turned on and the camera commenced recording again. On playing the tape, an inexplicable gap occurred for 19 minutes, unfortunately when the camera was over the expected position of the PACMANUS deposit. High quality video was taken of jagged dacite outcrops, becoming more sedimented on the knoll northeast of PACMANUS, but no hydrothermal deposits were recorded. A full 35 mm film was taken. Examination of the video camera indicated that a major fault had developed, which could only be traced by dismantling the camera. The second camera was substituted instead.

Grab MG-7 was deployed on the PACMANUS deposits recorded by MCV-17 but landed about 100 m south of its target. A small haul of dacite glass chips with some coarse flocculent sediment was recovered. **Dredge MD-35** was deployed southwesterly

onto the assessed position of the hydrothermal deposits recorded by MCV-17, with a calm sea returned and a 1 kt southwesterly breeze. A near-perfect track was sailed by the First Mate, returned to the Bridge after a period of illness. Allowing for ship's speed and estimated dredge lag, the targeted position was very closely attained after holding the final lowering until past the on-bottom waypoint. Two very sharp bites were noted by tensiometer. The dredge returned with a half-full chainbag, dominated by black glassy dacite at the bottom and with a **1 metre-long massive sulfide chimney plus numerous smaller chimneys and sulfide fragments** wedged in the upper half. Two large gastropods but no other fauna were present in the haul. The sediment traps were clogged with dacite chips and sulfide fragments. Unfortunately, CSIRO regulations prevented appropriate celebration of this major success, and the First Mate returned to his sickbed. Heavy rain commenced as the haul was sorted, and the samples were bagged for later cataloguing.

CTD-Hydrocast MH-24 was the carefully planned and sited vertical profile study of the "eye" of the PACMANUS plume. The rosette was fitted with the usual 11 Niskin bottles (10 litre), and with Dave Norman's 6 evacuated titanium water samplers with valves pre-set to open at 1575, 1600, 1625, 1650, 1675 and 1700 m depth. Variable winds and current caused slow progress towards the waypoint, and at one stage the Master carried out a pirouette of the ship with the CTD deployed just above the plume. Measurements of wire-out, wire angle, pinger signals of depth from bottom, and depth from the SeaBeam map were used to assess position of the CTD relative to the ship. On reaching the waypoint, the rosette was rapidly deployed to 1774 m (corrected) or 49 metres above bottom, to fire the Dave Norman samplers. The maximum transmissometer anomaly (0.7%) was observed at the usual depth of 1650 m. The upcast was commenced immediately. Niskin bottles were fired at similar depths to the Norman samplers with an additional two samples below and 3 above this range. The transmissometer anomaly observed on this upcast was slightly weaker (0.4%). Surprisingly, methane results gave only background values 25-33 nl/l. The CTD is estimated to have moved no more than 3 cables NNE during the entire sampling exercise.

With repairs to the video system still in progress, a planned camera traverse of Yuam Ridge was again deferred. **Dredge MD-36** aimed to sample a small volcanic edifice in the valley between Pual and Yuam Ridges. It commenced under a moderate easterly wind which soon increased to 20 kt, raising a strong swell. On the run-up, the dredge (or more probably just the weight) briefly hit bottom on the eastern slope of Pual Ridge, and with some navigational difficulties it was finally anchored along the southwestern flank of the target edifice. After swinging the ship, it was hauled off from a southwesterly direction. The dredge returned with no weak links broken and about 150 kg of large fragments of black vesicular basalt or andesite with glassy rinds. No ooze was present in the bag or traps.

Day 13 - Wednesday, June 16

With deteriorating conditions, **Sediment Core MS-20** was taken at about 2170 m depth in the valley just northeast of the MD-36 knoll. The recovery was 32 cm of silty mud. With wind increasing to 20-25 kt and varying from northeast to southeast, and with the swell becoming stronger, and with the video camera still not replaced, two dredges were planned on inferred basement scarps north of Pual Ridge.

Dredge MD-37 was deployed into the strong southeasterly on a higher northwest-facing scarp (1900-1650 m). Despite good tensiometer indications it returned with no load in the bag. Ooze was recovered from the sediment traps. The scarp is evidently thickly sedimented with material which washed readily out of the bag. **Dredge MD-38** was then deployed in stormy southeasterly wind and swell on a lower scarp of the same ridge (2200-1900 m). It returned a good load which included large vesicular basalt blocks and lumps of deepish green indurated sediment, thought to represent basement

and cover sequence respectively on which the EMVZ formed. Brown ooze was recovered from one sediment trap -the others were empty.

With improving seas but occasional heavy rain, **CTD-Hydrocast MH-25** was a southeasterly tow-yo located a mile north of previous tracks, intended to close off the PACMANUS plume. Only weak transmissometer anomalies were observed. Four Niskin bottles were fired. Methane analyses were at background levels (29-32 nl/l).

Camera-Video Tow MCV-19 was a southwesterly traverse along the crest of the western "finger" of Yuam Ridge, conducted with 6 kt southeasterly wind and rain squalls but a moderate swell. The aim was to explore for a possible source of the isolated transmissometer anomaly recorded at the eastern end of MH-18. Heave of the ship caused flying problems, and the col between the two knolls of this ridge was only just attained. A good video and full 35 mm film were taken. The northern knoll is heavily sedimented relative to the PACMANUS site, but jagged outcrops occur in the col. No hydrothermal deposits were noted.

A program for PC logging of positions from the NAVTRACK GPS unit on the Bridge, which read more continuously than the Trimble unit in the Operations Room, was written and installed.

Dredge MD-39 was deployed in rainy conditions with the southeasterly wind rising to 13 kt, but the swell subsiding. It aimed to sample the largest knoll at the far northeastern end of the eastern arm of Pual Ridge. The wind conditions necessitated an unconventional attack up the gentler western slope. The dredge was placed on bottom close to the waypoint and anchored almost immediately when hauling commenced. The ship was turned south into the wind but actually moved north and screwed around its anchor until eventually hauling off in a northerly direction. The dredge returned unharmed, with a large load of an unfamiliar, very fresh volcanic rock with pale splintery glass. Later refractive index measurements revealed this to be the most siliceous rhyodacite so far recovered on Pual Ridge. All sediment traps were filled with ooze, plus some volcanic glass in one. The towing cable was severely kinked, preventing further afterdeck operations until once again re-terminated. This was unfortunate as the sea was falling quite calm.

Day 14 - Thursday, June 17

A series of Smith-McIntyre grabs was scheduled for the remainder of the night, aimed at sampling bottom sediments under the PACMANUS plume. **Grab MG-8** was placed in a flat-floored re-entrant on the eastern arm of Pual Ridge. It returned with a 4 cm fragment of dacite wedged between the grabs, and evidently hit outcrop. The operation was repeated at the same site as **Grab MG-9**, which returned closed but entirely empty having apparently again hit rock.

Grab MG-10 was deployed into a shallow depression east of the knoll sampled by MD-26 and recovered a half load of gritty ooze and dacite chips. On its first deployment, **Grab MG-11** near the crest of the knoll immediately northeast of PACMANUS failed to close. A repeat attempt given the same number returned a few chips of dacite and minor sediment.

In very calm seas (4 kt easterly), **Grab MG-12** sampled a shallow re-entrant west of the MD-29 knolls between the arms of Pual Ridge. It returned a good load of mud, with a vertical indurated worm burrow, bivalve fragments, and a small fan ?coral. While conducting a 1.5-hour transit to the next site, 200 metres more cable was cut from the main winch and a new eye spliced in the end.

At the end of the transit, the terminal velocity of a half-brick in water was measured as close to 1 metre/second. Much effort had been devoted over recent days and the night just

passed to complete the construction of 50 sediment traps intended for deployment at PACMANUS to collect settled plume particulates for collection by future submersible dives. These were made from plastic bags glued to rings cut from plastic plates strengthened by nylon rope, with half-brick weights and aluminium foil-wrapped, freshwater-filled balloons as floats and sonar targets.

Dredge MD-40 was deployed on the steep southwestern flank of a narrow ridge extending northeast from the Djaul transform fault, which offered an opportunity to collect basement to the Eastern Manus Volcanic Zone, here on the southern plate boundary. The dredge was placed successfully on the lower part of the slope and made several good bites before anchoring. It released after a sharp drop in tension suggested a broken weak link, and returned upside down with the weak link and first safety shackle broken. A small but important load including several fragments to 5 cm size of old-looking basalt was retained by the bunched fishnet. Numerous pieces of abraded pumice (apparently washed from what must have been a considerable load of mud in the chainbag base) were also present. Some mud adhered to the broken safety shackle and was wedged at the apex of the yoke. One sediment pipe was full of mud but the others were empty.

After a return transit to Pual Ridge in calm seas but a rising westerly wind, **Camera-Video Tow MCV-20** was made as a dogleg traverse starting northeasterly on the crest of a small knoll 2 km north of PACMANUS where a possible chimney was videoed by MCV-8 in 1991, and where MCV-15 terminated earlier in this cruise. It then turned north-northwest to pass under the apparently isolated transmissometer anomaly recorded by MH-16. Very rugged topography was encountered on the initial knoll. A good video tape and full 35 mm film were taken. Much of the traverse appears to be andesite tubeflows and sheets rather than jagged da ;ite. No further indications of hydrothermal deposits were seen.

Taking advantage of a still relatively calm sea, though with rain squalls and a southwesterly wind rising to 15 kt, **Dredge MD-41** was targeted and placed about 40 metres from the very successful MD-35 on the PACMANUS site, with similar results. A large load of glassy dacite, with prominent reddish staining of fracture surfaces, filled the bag. Many blocks had chips of spongy glass stuck to them. One 50 cm and two smaller samples of chalcopyrite-rich **massive sulfide chimney** were present at the top of the load. A flat 15 cm **sulfide-bearing fragment** of different character, possibly barite with disseminated pyrite, was found deeply buried in dacite towards the bottom of the load.

After much planning for the deployment of our sediment traps to bracket the PACMANUS deposit, and considerable effort preparing them, the Master ruled out this operation with advice from the Cruise Manager that our traps would be considered as garbage by others, on the basis they fell under MARPOL regulations forbidding disposal of operational wastes made of plastic. Arguments advanced that they were not garbage but carefully-designed scientific equipment, manufactured from relatively cheap materials, were to no avail, and the first stage of a potential benchmark experiment that would have helped resolve major problems interpreting the geochemistry of ancient exhalites in mineral exploration was thus not conducted.

With near-continuous rain, **Camera-Video Tow MCV-21** continued the traverse along the western finger of Yuam Ridge, commenced by MCV-19. A wind change from an unusual northerly to the more typical 10-15 kt southeasterly with frequent rain required this to be rescheduled as a northeasterly track. This was sailed more slowly than anticipated, and the end-point did not quite reach that of MCV-19. A 2-hour video and full 35 mm film were taken. The video showed mainly bioturbated sediment with occasional outcrops of hackly dacite, with no sign of hydrothermal deposits.

An overnight assessment of priorities for the remainder of the cruise concluded that some time still remained for operations in the vicinity of PACMANUS before proceeding to DESMOS and Bugave Ridge further east. The question of visiting Goodenough Bay on the return passage to Cairns was again examined, and it was decided this had low priority relative to Manus operations and was accordingly abandoned.

Day 15 - Friday, June 18

After a 1-hour transit in rain storms and a light northeasterly wind, **Dredge MD-42** was deployed in a southeasterly direction on the far southwestern end of Pual Ridge where the ridge crest is 2000 m deep. About 100 kg of fresh volcanic rocks of two types were recovered, typical vesicular dacite, and towards the bottom of the bag a platy brownish sheeted type which is possibly andesite. The sediment tubes were clogged with dacite chips lacking ooze. Fauna included a 15 cm worm and a jellyfish.

CTD-Hydrocast MH-26 was conducted in heavy rain as a short leg of 2 casts at this southern site, designed to ensure no hydrothermal plumes were missed here. Weak transmissometer depressions (0.1%) occurred near 1650 m, but are probably not anomalous. Two "background" water samples were collected at 1650 m. Methane results for the two samples collected were 37 nl/l.

Sediment Core MS-21, again in heavy rain with 10 kt winds from many directions, was intended to sample the narrow valley west of Pual Ridge near PACMANUS. The ship drifted back over the ridge during deployment, so the corer was hauled back to re-position. The pinger, clamped 100 m above the corer as usual, was accidentally hauled to the main sheave and the cable sheared. Both the corer and pinger were lost. No injuries occurred, but incident reports were filed by all concerned. A delay occurred while the cable was reterminated and the main block lowered to check for damage, of which there appeared to be none.

Advice was received during the morning from both CSIRO Hobart and the ship's operating company, Howard Smith, that deployment of our sediment traps was permissible under the MARPOL convention. However inspection of the traps, which had been set out in readiness the previous afternoon, revealed that heavy rain overnight had caused them to be severely contaminated both with oil and blasting slag from the deck. Cleaning them was considered impossible, so we did not proceed with this operation.

Grab MG-13 was deployed higher up the valley where MS-21 was lost, and returned a good load of mud with some sand and rare glassy volcanic fragments.

Camera-Video Tow MCV-22, the last at Pual Ridge for this cruise, was aimed to commence on a low rise where dark exposures that were possibly hydrothermal mounds had been photographed in 1991, and to extend northwards under the northern plume anomaly of MH-16. Conducted in mild southwesterly wind and a relatively smooth sea, the bottom signals were not strong for the first 3/4 of the tow. A 2-hour video and full 35 mm film were taken. Most of the track covered bioturbated ooze, except for heavily sedimented sheetflows and spire outcrops near the end. Numerous burials of the camera in mud and crashes against rock occurred. The sled returned with many rock chips on the batteries (probably derived from the near-end outcrops), and some clots of mud. The reflector of the Benthos strobe was damaged, but the strobe evidently operated to the end.

A 1-hour transit was then made to the DESMOS Cauldron, where **CTD-Hydrocast MH-27** was deployed as a single-dip operation just north of the caldera, to sample plume particulates and cross-check methane analyses against 1991 data. A single 3% transmissometer anomaly was observed at 1620 m. All 11 bottles were fired, profiling the plume between 1800 and 1000m. Methane results were at background levels 28-35 nl/l except for two samples taken at 1500 and 1550m which were anomalous giving 41 and 50 nl/l respectively

Dredge MD-43 was conducted in a westerly direction in a light 5 kt easterly wind and mild sea, to sample the unexplored edifice now named **Umbo Knolls** southeast of DESMOS. A scarp 400 m high on the east side of the feature was the target. The dredge anchored and was released by turning the ship. A full load of mud and rocks was recovered. Large samples of black, highly vesicular basalt appeared to dominate the front part of the bag, while deeper in the bag were vesicular basalt blocks with patchy pale grey alteration, commonly below glass rinds where the latter were present. It will be necessary to check by petrology and geochemistry whether two lineages are present, one perhaps being basement to the volcano. One sample of more weathered appearance also occurred, plus small fragments of abraded pumice. There were three types of mud: soft sloppy brown, sticky greenish grey mud, and stiff pale grey sandy mud. A sheet of fine gravelly basalt hyaloclastite (resembling scoria?), several litres in volume, was folded into the mud near the front of the bag. Unlike the rest of the load, this itself lacked a mud matrix. The sediment tubes were full of ooze. The dredge apparently hauled up a talus slope with sheets of very young mass wasting debris from higher on the edifice. The edifice sampled within Umbo Knolls would appear similar in character to the Marmin Knolls west of Pual Ridge, and may be relatively old judging from the abundance of ooze.

Day 16 - Saturday, June 19

After another 1-hour transit, **Dredge MD-44** was deployed in similar mild sea conditions but a 6 kt southerly wind onto the northwestern scarp of another unexplored edifice west of Bugave Ridge (at the northwest of what was later named Tumai Ridge). It returned with a quarter load, mostly of mud. One fist-sized block and several smaller fragments of black vesicular basalt, plus a fragment and an abraded pebble of pumice, were recovered by sifting through the mud. The sediment tubes were filled with mud also, one with a few mm-scale volcanic chips.

CTD-Hydrocast MH-28 was an easterly tow-yo 1.5 miles long located between Bugave Ridge and a dacite knoll dredged by the Aquarius cruise to the south, intended to test the area for presence of a hydrothermal plume. A significant transmissometer (0.7%) anomaly was detected at 1450-1475 m in early casts, declining eastwards. Three Niskin bottles were fired. **CTD-Hydrocast MH-29** was then conducted, in still conditions and a very calm sea, to the west of MH-28 as a southeasterly cross track to further examine this indication of a plume. The transmissometer anomaly rose successively to 1.9% towards the centre of the tow-yo then declined. Six Niskins were fired. Prompt methane analyses of samples from the anomalous depths gave extraordinary methane contents from 100 to 400 nl/l, with ethane and butane also detectable. These exciting results pointed to the possibility that the source was a small knoll on the northwest-trending ridge south of Bugave Ridge (for which the name **Tumai Ridge** was chosen, after a native New Guinean implement like a hammer -Bugave Ridge being the handle).

Two short echosounder runs, **MES-8** and **MES-9**, were made to locate the crest of this ridge exactly for the following camera tow. They revealed that the southern flank was steeper and more abrupt than the northern flank, and the highest point crossed was at 1550 m, 30 m higher than indicated by the SeaBeam chart.

Camera -Video Tow MCV-23 was perfectly navigated, under ideal calm conditions but with a noticeable northerly set, as a short traverse along the crest of this ridge. To enable the final operation of the cruise, the camera was hauled early after starting a steep descent down the eastern spine of the knoll. Later inspection of the video showed an almost completely sedimented ridge, with only few rubbly rock outcrops, possibly of dacite. Some strange protuberances from the ooze, of unfamiliar appearance, were seen near the crest. No faunal concentrations were evident. A full 35 mm film was taken, half of which was in mid water following the departure from bottom. The video provided a rare record of surfacing through the photic zone.

Dredge MD-45 was commenced before the video results were available, hauling up the western slope almost to the crest of this same knoll again under ideal conditions. The liner bag contained only small fragments of abraded pumice, and one very white angular pumice fragment that conceivably came from an outcrop. Many pieces of woody matter were also present. The bag probably contained a lot of mud, which washed out during the rapid (80m/min) haul-up. All sediment traps were full of sloppy brown to greenish ooze.

The transit back to Cairns was commenced at 1505h, five minutes after the Master's deadline. After cleaning out the dredge, watches were stood down at 1515h, although tasks were assigned for the completion of the cruise. A group photograph session was held on the foredeck at 1630h. The volcanoes at Rabaul were passed around 1730h, with increasing cloud developing in the failing light. After passing through St Georges Channel, we encountered 20 kt headwinds and parallel swell, creating uncomfortable conditions on board and slowing the ship to 9 kt.

Day 17 - Sunday, June 20

Crossing the Solomon Sea beating into a 20 kt southerly headwind, with a 2 m southerly swell. The ship was pitching considerably overnight, but with little roll. Conditions improved slightly as we moved further south. Packing of gear and report writing continued. The measurement of refractive indices on glass samples to characterise our hauls of volcanic rock was completed.

Day 18 - Monday, June 21

Passed through the Marshall Bennett Islands and entered the Woodlark Basin soon after midnight, with a 22 kt southeasterly and the swell again increasing. Passed Jomard Entrance at 0730h and entered the Coral Sea. At 1605h, we stopped briefly to collect a 20 litre sample of surface seawater to be used as a Sr isotope standard by Dave Whitford of CSIRO at 13°31'S 155°31'E in 4502 m of water. The swell in the Coral Sea was fortunately less than predicted, though 20 kt southwesterly winds buffeted the ship. Report writing and packing up equipment occupied much of the day for scientists.

Day 19 - Tuesday, June 22

Conditions improved overnight, and the ship made 13 knots in relative comfort. Diverted slightly from the course to pass close by Bougainville Reef around 1630h, after which the ship was slowed to allow an 8 am ETA at Cairns. The ship's HIAB crane was damaged overnight while removing the tricycle from the main cable.

Day 20 - Wednesday, June 23

Collected the Pilot at 0648h, and berthed at Trinity Wharf, Cairns, at 0754h after a most successful cruise. Gear was packed and unloaded speedily in readiness for an early departure of *Franklin* on the following leg next day.

Summary of Work Completed

Scientific Achievements:

Specific objectives of PACMANUS-II were as follows:

Main tasks

1 Survey the PACMANUS hydrothermal field, and define targets for ROV and submersible deployments
2. Sample the PACMANUS field; particularly sulfides, oxides, altered volcanics, and metalliferous bottom sediments
3. Map the PACMANUS plume, and collect particulates within it derived from the seafloor hydrothermal activity
4. Collect bottom sediments from the general vicinity, to define the settling pattern of plume particulates
5. Explore northeast arm and southern stem of Pual Ridge: characterise volcanics and look for other hydrothermal sites
6. Survey other potential hydrothermal sites in East Manus Volcanic Zone
7. Characterise "unexplored" edifices in EMVZ
8. Clarify regional geological and tectonic setting of EMVZ: basement etc
9. Place a grid of near-bottom sediment traps at PACMANUS for subsequent collection by submersible, to collect settled plume particulates.

Other tasks

10. Collect vent fauna for Australian Museum
11. Collect plume water samples for Dave Norman (methane etc)
12. Test Tavui Caldera (north of Rabaul) for hydrothermal activity
13. Test Goodridge (Goodenough Bay) for hydrothermal activity

Tasks 9 and 13 were not accomplished, the first because the sediment traps became contaminated while prepared on deck for deployment during an unfortunate delay as approval was sought for the operation (omitted by oversight from the cruise plan), and the second because sidescan data from the April-May cruise of RV *Moana Wave* received the day before this cruise showed that the Goodridge seismic site was not sufficiently attractive to warrant priority over Manus operations.

Apart from these, the cruise was an outstanding success as indicated in the cruise narrative, with all the above tasks successfully tackled. Highlights were the recovery in 4 dredge hauls of numerous sulfide chimney samples, and the recovery of altered volcanic rocks and low-temperature hydrothermal crusts in one dredge and one grab. These, and the extensive collections of volcanic rocks and bottom sediments have provided material for a major program of laboratory research at Sydney, Hobart, Toronto, Honolulu and Port Moresby during the coming year and beyond. The full collection of volcanic rocks from Pual Ridge, on which PACMANUS lies, is very compehensive.

The PACMANUS hydrothermal deposit is now very well surveyed, and the data most certainly justify manned submersible dives and ROV deployments proposed for the near future. The hydrothermal plume above PACMANUS has been mapped and sampled in detail.

Another small and inactive occurrence of hydrothermal chimneys was found to the north of PACMANUS. The discovery close to Rabaul (Tumai Ridge) of an intense transmissometer anomaly accompanied by very high contents of methane in seawater on the final day in the eastern Manus Basin represents another exciting outcome of the cruise, which demands further investigation in future.

Finally, the dredging program completed the characterisation of all major unexplored volcanic edifices in the eastern Manus Basin, and also successfully sampled (at 3 of the 6 sites tested) the presumed basement below the East Manus Volcanic Zone.

The results of this cruise will lead to many publications in international journals, and PACMANUS will be widely recognised as one of the best, if not *the* best, modern analogues for ancient "volcanogenic massive sulfide" orebodies on land, and a source of knowledge to help land-based exploration for the latter.

Suitability of the Ship and Equipment

Franklin has once again demonstrated her suitability for work of this nature. All vital systems worked well and efficiently, and very little time was lost during the cruise as is indicated by the impresive total of 79 operations conducted in the 10.5 days on station (22 dredges, 14 sediment cores, 13 grabs, 12 camera-video tows, 18 CTD-hydrocasts, and 4 precision echo-sounder runs). The cooperation and expertise of the ship's crew and ORV support staff was a key factor in our success.

Among changes from previous cruises, the new SIMRAD EA500 depth sounder and broad-beam transducer was a marked improvement over the previous system used for maintaining camera-video tows 3m above bottom. The Hobart-manufactured Smith-McIntyre grab proved very useful for sampling bottom sediments and even the occasional rock, and was successfully deployed off the hydro wire at depths up to 2200m. The program which provided printouts every minute of ship's position, depth and wire out was a boon, relieving watches from much record-keeping effort.

Some of the problems experienced were due to delays caused by bad weather during port maintenance before the cruise. The amount of blasting sand, presumed to be Mount Isa copper slag, left in every nook and cranny of the topsides was a continual worry in relation to sample contamination, and it was responsible for the ultimate abandonment of what would have been a benchmark experiment -deployment of sediment traps at PACMANUS for subsequent collection by manned submersible. The container was a new one to us, lacking drawers and shelves, and we needed to buy a variety of plastic baskets in Cairns to equip it effectively for its intended purpose - sample handling and maintenance of the camera-video system.

The 1500m of new towing cable fitted in Cairns was decidedly inferior. About half of it was lost through kinking during operations, far more than on our previous cruises.The tricycle system to measure wire-out and tension on the towing cable sufferered some breakdowns, and its design and construction warrants further attention. The YeoKal submersible data logger once again did not function. This instrument, for which we paid half the cost in 1986, was intended principally to record near-bottom temperature anomalies indicative of active hydrothermal venting during camera tows. More effort to rectify and depth-test this instrument during other cruises would have been far preferable to discovering fatal flaws too late on our own.

One of the requests in our cruise plan, automated plotting of ship's track in real time to save manual effort, could not be introduced with the present computer system, and it is to be hoped it will be possible with the new system to be installed shortly. For our type of work, there are several recommendations worth considering regarding navigation and position recording.

1. There is an urgent need for an accurate digital clock in the Operations Laboratory to replace that which disappeared with the old sounder (being unable to display this on the Trimble GPS while the emphasis was on position, we had to rely on the analogue wall clock which did not lend itself to logging tasks requiring seconds of accuracy).
2. The JRC position display unit installed for this cruise on the Bridge is potentially very useful, but for our purposes it would have been better located at the winch control station rather than chart table, and a repeater is also desirable in the Ops Lab. Another problem is that this display relies on the NavTrac GPS unit which continually changes satellite constellations (unlike the Trimble in the Ops Lab.) -with degraded signals causing major apparent jumps in ship's position, making estimates of current prior to positioning the ship for operations very difficult, for example. It would have been beneficial to have had the ADCP along also for this purpose.

3. The Echo-Excel navigational repeater at the winch station terminates GPS positions to 0.1nm, rather than rounding them off. This means the bridge officers become uncertain of position relative to waypoints at critical stages of dredging and camera operations. They need a 0.01nm readout, preferably introduced also to the Echo-Excel software.

4. The Trimble GPS in the Ops Lab is now obselete. It failed to log on many occasions when the Bridge NavTrac and our own Magellan GPS units were functioning. When replacement occurs, it would be prudent to ensure that all navigation and logging systems work off the one GPS receiver, with facility to substitute a back-up unit when required.

The sediment corer and 12 kHz Benthos pinger lost as a result of unfortunate human error during MS-21 will need replacing.

Personnel

Ship's Crew

Paddy Lorraine	Master
Dick Dougal	First Mate
Bryce Bathe	Second Mate
Max Cameron	Chief Engineer
Ian Hayward-Bryant	Second Engineer
Don Roberts	Electrical Engineer
Norm Marsh	Bosun
Chris Hallen	Able Seaman
Paul Sanhueza	Able Seaman
Bluey Hughes	Able Seaman
Reg Purcell	Chief Steward
Garry Hall	Chief Cook
Bob Clayton	Second Cook

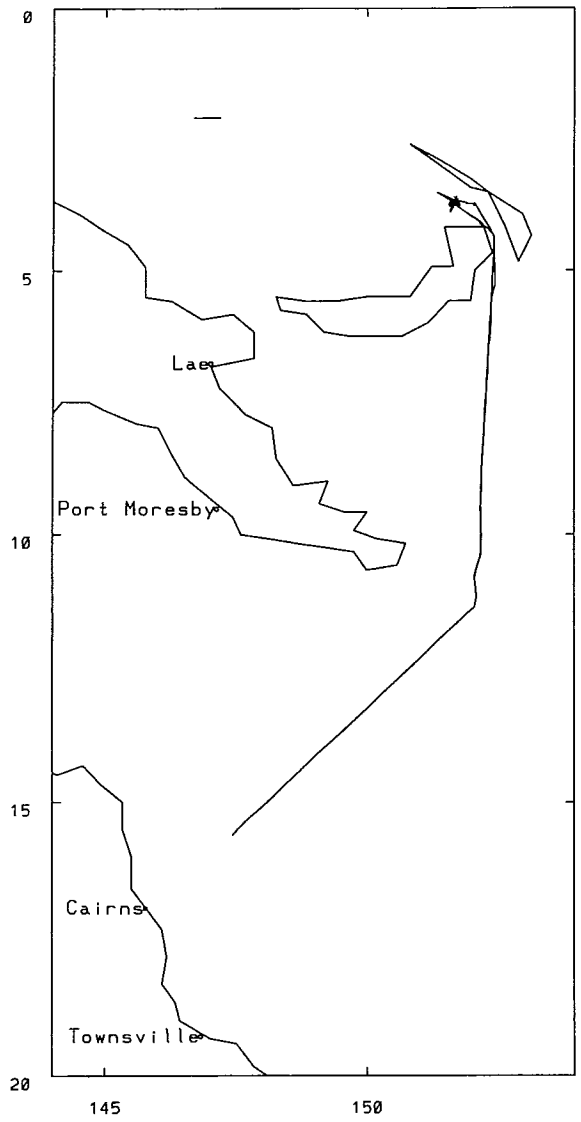
Scientific Party

Ray Binns *	CSIRO Division of Exploration Geoscience, Sydney
Keith Crook +	HURL, University of Hawaii, USA
John Eames	CSIRO Division of Exploration Geoscience, Sydney
Dave Edwards #	CSIRO Division of Oceanography, Hobart
Bruce Gemmell+	CODES, University of Tasmania, Hobart
Benny Kruman	Dept of Geology, University of Papua New Guinea
Roger Moss	Dept of Geology, University of Toronto, Canada
Alex Ortega-Osorio	Dept of Geology, University of Toronto, Canada
Joanna Parr	CSIRO Division of Exploration Geoscience, Sydney
Larry Petrie	Dept of Geology, University of Toronto, Canada
Steve Scott * +	Dept of Geology, University of Toronto, Canada
Dave Vaudrey	CSIRO Division of Oceanography, Hobart

* Co-Chief Scientists # Cruise Manager + Watch Captain

Appendix: ***Station List***

Franklin Cruise 5/93



STATION LIST PACMANUS-II

Numbers assigned to operations follow on from those of the PACMANUS-I cruise (FR 09/91). All positions given are those of the ship, mainly from the Trimble Global Positioning System located in the OP's room and supplemented with data from the bridge. They are uncorrected for lag of dredge or camera. Unless otherwise specified, depths are those under the ship from the SIMRAD 12 kHz precision depth recorder. Times shown are local (UT+10 hours).
nd = no data

Dredge Hauls

Operation	Date	Event	Time	Latitude (S)	Longitude (E)	Depth (m)	Wire out (m)
MD-24	08/06	in water	0920	3°43.60'	151°40.38'	0	
		on bottom	0946	3°43.72'	151°40.17'	1664	1660
		off bottom	1010	3°43.88'	151°39.94'	1750	1750

MD-24 was designed to sample the hydrothermal deposits and altered dacites of the PACMANUS site. The dredge was half full when recovered, and contained glassy dacite, hyaloclastite, altered dacite and a mushroom-shaped sulphide-rich chimney fragment as well as various fauna.

MD-25	08/06	in water	1955	nd	nd	nd	0
		on bottom	2022	3°43.64'	151°40.33'	1740	1701
		off bottom	2106	3°43.74'	151°40.12'	1657	1717

Another attempt to sample PACMANUS sulfide chimneys (at intersection of 1991's MCV-5 and MCV-9). Dredge returned half full and contained only dacite, 10 -20 % of which was stained or altered.

MD-26	09/06	in water	0930	03°42.46'	151°39.38'	2120	0
		on bottom	1012	03°42.47'	151°39.93'	1860	2105
		off bottom	10.45	03°42.22'	151°40.33'	1917	
	1956						

A further attempt to sample the northwest margin of the PACMANUS deposit. The dredge returned andesite chips, fauna and one tube of sediment.

MD-27	10/06	in water	1441	03°43.83'	151°40.03'	1670	0
		on bottom	1515	03°43.60'	151°40.30'	1692	1665
		off bottom	1533	03°43.45'	151°40.50'	1700	1642

Another unsuccessful attempt to sample the PACMANUS deposits essentially repeating the MD-25 attempt. About 5 kg of dacite glass, hyaloclastite, minor altered dacite, numerous shell fragments and a tube worm were recovered.

MD-28	10/06	in water	1701	03°43.50'	151°40.38'	1689	0
		on bottom	1727	03°43.65'	151°40.25'	1650	1700
		off bottom	1757	03°43.91'	151°40.05'	1666	1655

A south westerly traverse designed to sample the PACMANUS deposits recovered a full bag of black vesicular dacite, some fauna and a piece of a sulphide chimney.

Operation	Date	Event	Time	Latitude (S)	Longitude (E)	Depth (m)	
MD-29	12/06	in water	0703	03°41.43'	151°42.22'	1827	0
		on bottom	0727	03°41.46'	151°42.38'	1786	1869
		off bottom	0757	03°41.47'	151°42.60	1783	1810

The aim of this dredge was to sample the small knolls under the strong transmissometer anomaly recorded during MH-17. The dredge returned approximately half full, with samples of dacite/andesite(?), dacite glass, and rusty brown mud.

MD-30	12/06	in water	1330	03°43.23'	151°40.74'	1702	0
		on bottom	1409	03°43.62'	151°40.23'	1654	1727
		off bottom	1437	03°43.90'	151°39.89'	1660	1695

Approximately 20 kg of glassy, vesicular dacite, some with hackly or frothy glass rinds, were recovered in this attempt to sample the elusive massive sulphides of PACMANUS.

MD-31	13/06	in water	0602	03°46.76'	151°45.44'	2171	0
		on bottom	0637	03°46.30'	151°45.47'	2086	2203
		off bottom	0713	03°45.74'	151°45.43'	nd	1906

Designed to sample the basement to the Eastern Manus Volcanic Zone (EMVZ), possibly exposed on an east-west trending fault scarp, south of Yuam Ridge. Dredge returned only a piece of wood and some pumice fragments in the net, but all four sediment traps were full of mud.

MD-32	13/06	in water	0906	03°45.08'	151°46.78'	2065	0
		on bottom	0936	03°44.82'	151°46.41'	2050	2056
		off bottom	0955	03°44.56'	151°46.16'	1922	1797

MD-32 was deployed on a higher scarp to MD-31 in a second attempt to sample basement. Similar results were obtained, with the addition of 4 black burrows.

MD-33	13/06	in water	2004	03°30.42'	151°21.18'	2572	0
		on bottom	2055	03°30.02'	151°21.02'	2308	2803
		off bottom	~ 2150	03°31.39'	151°22.99'	2204	2073

A further attempt to sample basement, this time on a prominent ridge in the far north west of the study area. Only pumice and mud were obtained.

MD-34	13/06	in water	2325	03°30.72'	151°21.64'	2569	0
	14/06	on bottom	0008	03°31.05'	151°22.00'	2354	2625
		off bottom	0132	03°31.32'	151°22.99'	2148	2433

Essentially a repeat of MD-33, slightly further to the south west. This time the attempt was successful, returning approximately 15 kg of basaltic pillow lava fragments (basement?), pumice and lumps of semi-consolidated mud as well as two sediment traps of brown ooze.

MD-35	15/06	in water	1620	03°43.40'	151°40.53'	1700	0
		on bottom	1655	03°43.67'	151°40.26'	1660	1706
		off bottom	1725	03°43.83'	151°40.23'	1665	1753

An extremely successful dredge, designed to sample chimneys observed during MCV-16, returned half full. A large chimney piece together with numerous smaller chimney pieces were recovered. Many chimney orifices were sealed, suggesting that they were inactive. Black glassy dacite with some Fe-staining constituted the remainder of the haul.

MD-36	15/06	in water	2253	03°42.61'	151°42.50'	1811	0
		on bottom	2352	03°43.09'	151°42.89'	1949	2091
	16/06	off bottom	0036	03°43.05'	151°42.72'	2011	1977

Designed to sample a small volcanic edifice within the valley between Pual and Yuam Ridges, a possible source of the transmissometer anomaly east of MH-18. Dredge returned one third full, and contained volcanic glass, some with Fe-staining.

Operation	Date	Event	Time	Latitude (S)	Longitude (E)	Depth (m)	
MD-37	16/06	in water	0456	03°35.11'	151°43.43'	1981	0
		on bottom	0533	03°35.39'	151°43.65'	1911	2064
		off bottom	0625	03°35.61'	151°43.70'	1740	1674

Only mud, sampled by the sediment tubes, was recovered during this attempt to sample basement on a fault scarp to the north of Pual Ridge.

MD-38	16/06	in water	0740	03°35.56'	151°40.55'	2265	0
		on bottom	0849	03°36.10'	151°41.13'	1968	2254
		off bottom	0940	03°36.54'	151°41.48'	1868	1959

A successful attempt to dredge basement and cover sequence rocks. Older-looking pillowed and glassy basalt (basement?) and a dark grey-green cohesive mud (cover sequence?) were recovered.

MD-39	16/06	in water	2130	03°40.27'	151°44.53'	1878	0
		on bottom	2222	03°40.75'	151°44.96'	1709	1873
		off bottom	2340	03°40.39'	151°44.79'	1841	1927

A dredge over the northeast stem of Pual Ridge. A large haul was recovered, consisting predominantly of black to pale green- brown volcanic (possibly rhyolite?).

MD-40	17/06	in water	1035	03°51.60'	151°35.96'	2067	0
		on bottom	1120	03°52.07'	151°36.31'	1848	2056
		off bottom	1227	03°52.07'	151°36.61'	1879	1893

Designed to sample basement, the dredge successfully recovered several pieces of old-looking basalt, despite breaking two links and returning upside down. Several small pieces of abraded pumice were also recovered, along with mud from one of the sediment tubes.

MD-41	17/06	in water	1839	03°43.46'	151°40.51'	1696	0
		on bottom	1906	03°43.71'	151°40.34'	1652	1715
		off bottom	1934	03°43.87'	151°39.95'	1661	1637

The third successful attempt to dredge massive sulphides from the PACMANUS deposit. The dredge returned two thirds full and consisted of black glassy dacite (approximately 25% of which was Fe-stained), four chimney pieces and various fauna. Three chimney pieces are chalcopyrite-rich, while the fourth shows disseminated pyrite and is suspected to be barite-rich.

MD-42	18/06	in water	0243	03°45.26'	151°35.00'	2381	0
		on bottom	0337	03°45.99'	151°35.27'	2112	2324
		off bottom	0420	03°46.45'	151°35.17'	2131	2080

A dredge up the northwest side of southern Pual Ridge. The haul contained two rock types, black dacite and another volcanic (possibly andesite). A jellyfish (probably from near surface) and a worm were also retrieved.

MD-43	18/06	in water	1937	03°43.27'	151°56.20'	2160	0
		on bottom	2051	03°43.23'	151°55.45'	1600	2050
		off bottom	2215	03°43.18'	151°55.73'	1835	1854

Investigation and sampling of an unexplored edifice south east of Desmos Cauldron. A half full dredge returned a mixture of mud, sandy mud, blocky and vesicular basalt, and minor pumice.

MD-44	19/06	in water	0005	03°43.43'	152°01.87'	2085	0
		on bottom	0057	03°43.78'	152°02.60'	1837	2104
		off bottom	0215	03°43.92'	152°03.52'	1800	1605

Designed to sample and characterise an unexplored edifice west of Bugave Ridge. The dredge returned about a quarter full, and contained predominantly dark brown mud, with a few pieces of black volcanic rock (basalt?) and rounded pumice fragments.

Operation	Date	Event	Time	Latitude (S)	Longitude (E)	Depth (m)	
MD-45	19/06	in water	1259	03°46.23'	152°03.60'	1692	0
		on bottom	1403	03°46.34'	152°04.73'	1581	1870
		off bottom	1435	03°46.23'	152°05.33'	1672	1697

Following up on the exciting results of MH-28&29, the dredge was designed to sample the north west end of Tumai Ridge in the hope of finding a clue to the source of the plume. Pumice was the only rock recovered, but all four sediment tubes were full of brown-greenish mud.

Sediment Grabs

MG-1 12/06 on bottom 0956 03°43.65' 151°40.21' nd 1658
The first Smith-McIntyre sediment grab deployment was an attempt to sample the PACMANUS deposit. The grab failed to close and hence no samples were obtained. A few milligrams of sand in the bottom of the grab were bottled.

MG-2 12/06 on bottom 1057 03°43.58' 151°40.24' 1668 1652
A second more successful attempt to sample PACMANUS resulted in a haul of rock fragments with manganese crusts, ooze balls with thin Mn crusts, fibrous glass and mud.

MG-3 13/06 on bottom 1218 03°43.25' 151°40.35' 1687 1668
Designed to obtain samples of a hydrothermal deposit from a chimney field at the north end of PACMANUS, the grab returned about 2 handfuls of black glassy dacite chips.

MG-4 13/06 on bottom 1420 03°43.31' 151°40.38' 1680 1680
A repeat of MG-3, with similar results, yielding vesicular dacite fragments with glassy rinds and minor mud.

MG-5 15/06 on bottom 0131 03°43.52' 151°40.10' 1658 1768
Designed to sample another part of the PACMANUS deposit. Grab returned black glassy dacite fragments.

MG-6 15/06 on bottom 0244 03°43.71' 151°40.16' 1646 1731
A repeat of MG-5. Grab hit bottom on target, and returned lava crusts, hyaloclastite, pumice and gritty ooze.

MG-7 15/06/ on bottom 1519 03°43.73' 151°40.26' 1660 1749
An unsuccessful attempt to sample the part of PACMANUS deposit seen on MCV-17, recovered only a very poor sample of black dacite chips and brown mud.

MG-8 17/06 on bottom 0136 03°42.16' 151°42.51' 1865 1870
Designed to collect sediment for an investigation of plume particulate content, the grab was placed on bottom close to the south arm of Pual Ridge approximately 2 miles north of PACMANUS. A piece of black dacite, caught in the jaws of the grab, was the only sample retrieved from this site.

MG-9 17/06 on bottom 0243 03°42.20' 151°42.55' 1868 1876
A repeat of MG-8, resulted in a closed grab, but no samples-not even ooze.

MG-10 17/06 on bottom 0409 03°42.03' 151°40.50' 1948 1981
Another attempt to sample sediment for plume particulate study. Located north of PACMANUS, this attempt was more successful, returning about half full of ooze with minor grit and dacite chips.

Operation	Date	Event	Time	Latitude (S)	Longitude (E)	Depth (m)	
MG-11	17/06	on bottom	0639	03°42.94'	151°41.15'	1660	1685
The second of two attempts to collect a sediment sample at this site. The first returned empty with open jaws. Only minor sediment and dacite chips were recovered on the second attempt.							
MG-12	17/06	on bottom	0754	03°41.21'	151°41.83'	1872	1868
Further collection of sediment for particulate study. The grab returned approximately one third full and contained mud and some fauna.							
MG-13	18/06	on bottom	1059	03°42.74'	150°39.29'	2203	2251
Intended to collect sediment for the plume fallout study, the grab returned sticky-stiff colour banded mud with rare burrows(?) and protozoans, minor sand, and rare pebbles.							

Sediment Cores

MS-9	09/06	on bottom	0010	03°43.57'	151°42.58'	2125	2186
First of a series of cores to sample sediments surrounding PACMANUS and test for settled plume particulates. 55 cm of core was recovered, mostly consisting of silty mud.							
MS-10	09/06	on bottom	0726	03°44.98'	151°40.93'	2110	2125
Second of PACMANUS sediment samples to test for plume fallout. Less than 3 cm of collapsed core was obtained, consisting of silty mud and sand.							
MS-11	09/06	on bottom	1257	03°43.75'	151°35.99'	2389	2431
An unsuccessful attempt to sample sediment well west of the PACMANUS site. No sediment or ooze was found in the corer when it was recovered.							
MS-12	09/06	on bottom	1436	03°43.82'	151°36.00'	2386	2485
A repeat of MS-11. Once again no core was recovered, only a small amount of mud and some small chips of volcanic glass.							
MS-13	11/06	on bottom	0736	03°40.80'	151°43.68'	1904	1940
Located to the north east of MH-16 to test for plume particles settled from the newly discovered plume. 8 cm of hyaloclastite gravel and some mud was recovered.							
MS-14	11/06	on bottom	2028	03°40.60'	151°45.87'	2150	2150
Sediment was sampled in the valley between Pual and Yuam ridges. 22 cm of colour-banded mud was recovered.							
MS-15	11/06	on bottom	2215	03°38.06'	151°45.17'	nd	2010
56 cm of predominantly silty mud was recovered. Two layers of felsic volcanic ash were also present in the core.							
MS-16	12/06	on bottom	2045	03°41.45'	151°45.36'	2200	2210
Sampled sediment in valley between Pual and Yuam Ridges to assess their relative contributions. A good yield of 125 cm was obtained consisting mainly of silty mud.							
MS-17	13/06	on bottom	0450	03°46.23'	151°46.92'	2170	2185
83 cm of core was recovered from a heavily sedimented area to the south of Yuam Ridge. Sediment consisted predominantly of silty mud, with graded sand beds and an ash layer.							

Operation	Date	Event	Time	Latitude (S)	Longitude (E)	Depth (m)	
MS-18	14/06	on bottom	0426	03°37.93'	151°33.49'	2600	nd
Sample taken at the north east end of Kumul Trough to check for contribution from surrounding ridges and knolls. 86 cm of mainly mud with minor ash and sand was recovered.							
MS-19	14/06	on bottom	0634	03°38.65'	151°39.00'	2485	nd
Sampled sediment to the west of the north arm of Pual Ridge. 82 cm of mainly silty mud with minor ash layers, one containing pumice, was recovered.							
MS-20	16/06	on bottom	0327	03°42.57'	151°43.80'		2245
Investigation of sediments to the southeast of Pual Ridge in the vicinity of a small volcano.							
MS-21	18/06						
Designed to assess the timing/history of basaltic and dacitic volcanism, no core was recovered as the sediment corer and pinger were lost during retrieval.							

Camera/Video Tows

MCV-12	08/06	on bottom	1348	03°43.30'	151°40.73'	nd	1661
		off bottom	1740	03°44.84'	151°38.59'	nd	1844
Designed to photograph the PACMANUS deposits along the crest of Pual Ridge. The video camera failed to operate due to a suspected short in the electrical wiring causing a fuse to blow. All 35 mm film passed through the Benthos camera.							
MCV-13	10/06	on bottom	0930	03°44.28'	151°39.32'	1669	1704
		off bottom	1330	03°42.80'	151°40.92'	1675	1702
A second attempt to photograph the PACMANUS deposits along the crest of Pual Ridge. The video camera once again failed to operate due to a blown main fuse.							
MCV-14	11/06	on bottom	1423	03°42.32'	151°41.40'	1697	1690
		off bottom	1831	03°40.72'	151°43.48'	1895	1942
The objective was to photograph two knolls to the north east of the PACMANUS site, that may be the source of the plume found during MH-16. The video camera recorded 2 hours and 31 minutes before shutting off due to low battery voltage. The track covered mostly hackly dacite with variable amounts of sediment. Chimneys were observed at 3 hours 11 minutes, corresponding to a position of 03o42.05'S 151o41.80'E.							
MCV-15	12/06	on bottom	1641	03°41.95'	151°41.77'	nd	1798
		off bottom	1849	03°42.14'	151°43.28'	nd	1844
A two hour tow across two chimney sites (seen on MCV-14 and 1991's MCV-6) to the north east of the fork in Pual Ridge. Platey lavas (andesite?) and jagged outcrops (dacite?) were observed in an otherwise light to moderately sedimented environment. No signs of hydrothermal activity were evident.							
MCV-16	14/06	on bottom	1516	03°39.27'	151°42.76'	1787	1961
		off bottom	1650	03°38.20'	151°43.55'	1722	2029
Designed to photograph the crest of the western arm of Pual Ridge, below which evidence of hydrothermal activity was found in 1991. Only a few outcrops of unidentified volcanics were seen, with most of the traverse covering areas of bioturbated sediment.							

Operation	Date	Event	Time	Latitude (S)	Longitude (E)	Depth (m)	
MCV-17	14/06	on bottom	2200	03°43.86'	151°39.82'	nd	1701
		off bottom	2352	03°42.98'	151°41.18'	1675	1783

A tow across the PACMANUS deposit returned good footage of part of the deposit including lots of vent fauna, a large mound field, and another active mound with large chimneys. The host rock appears to be variably sedimented dacite.

MCV-18	15/06	on bottom	1045	03°44.03'	151°39.81'	1650	1720
		off bottom	1255	03°42.08'	151°41.37'	nd	2006

Another traverse of the PACMANUS deposit including the unexplored southeast side of the slope. The ridge traversed is characterised by moderate to heavy sediment cover, with some jagged and sheet volcanics (probably dacite).

MCV-19	16/06	on bottom	1757	03°41.66'	151°46.17'	nd	1835
		off bottom	1958	03°42.31'	151°45.10'	nd	1847

A camera survey of the southeast finger of Yuam Ridge and the possible transmissometer anomaly at the east end of MH-18. Survey shows the ridge to be heavily sedimented, with only minor volcanics. No vent fauna or other signs of hydrothermal activity were seen.

MCV-20	17/06	on bottom	1457	03°42.17'	151°42.94'	1775	2003
		off bottom	1710	03°40.55'	151°43.08'	nd	1968

Designed to photograph a small knoll where a possible chimney was seen in 1991 (MCV-8), and to pass under the transmissometer anomaly recorded during MH-16. Outcrops of sheet (andesite?) and jagged (dacite) volcanics were seen, but no sign of hydrothermal activity was observed.

MCV-21	17/06	on bottom	2250	03°43.38'	151°44.09'	1850	2085
	18/06	off bottom	0045	03°42.40'	151°45.13'	1900	2022

Traverse designed as an extension of MCV-19, with the aim of locating the source of the plume observed during MH-16 and 17. The area is heavily sedimented with minor dacite outcrops.

MCV-22	18/06	on bottom	1340	03°41.00'	151°42.40'	1750	1905
		off bottom	1541	03°40.01'	151°43.45'	1950	2086

A traverse below a hydrothermal plume near possible mound photographed in 1991. No evidence of hydrothermal activity was found.

MCV-23	19/06	on bottom	1100	03°46.38'	152°04.51'	1593	1770
		off bottom	1205	03°46.24	152°05.22'	1643	1687

An attempt to find the source of the plume observed during MH-28&29, this traverse was conducted over a knoll lying between the two hydrocasts on Tumai Ridge. No evidence of hydrothermal activity was found. The knoll appears to be well sedimented with rare talus/rubble.

CTD-Hydrocasts

Operation	**Date** (S)	**Event** (E)	**Time** (m)	**Latitude**	**Longitude**	**Depth**
MH-12	08/06	CTD in	0255	04°07.68'	152°12.72'	1089
		Bottles 1-3	0338-0348	04°07.64-07.63'	152°12.64-12.77'	1088
		CTD up	0520	04°07.50'	152°14.60'	519

A "Tow-yo" traverse planned to investigate the possibility of hydrothermal activity in Tavui Caldera, near Rabaul. No obvious transmissometer, temperature or conductivity anomalies were found on an ENE traverse from the caldera floor to the upper rim.

Operation	Date	Event	Time	Latitude (S)	Longitude (E)	Depth (m)
MH-13	09/06°	CTD in	0130	03°44.17'	151°42.21	2100
		Bottles 1-3	0213-0250	03°43.37-42.67'	151°41.38-40.72'	1766-1702
		Bottles 4-6	0312-0410	03°42.45-41.30'	151°40.44-39.40'	1894-1802
		CTD up	0415	03°41.30'	151°39.40'	1802
MH-13 was designed to map and sample a SE-NW profile through the PACMANUS particulate plume. Good transmission anomalies were observed along the profile.						
MH-14	09/06	CTD in	20.25	03°43.01'	151°35.88'	2177
		Bottles 1-5	2111-2257	03°42.30-40.51'	151°35.97-36.04'	1872-1831
		Bottles 6-11	2301-2345	03°40.41-39.70'	151°36.04-35.90'	1809-1943
		CTD up	0000	03°39.58'	151°35.85'	2050
Designed to test Pual Ridge for hydrothermal plumes. Good transmissometer anomalies observed, suggesting the existence of a new plume to the east of PACMANUS.						
MH-15	10/06	CTD in	0205	03°44.12'	151°37.38'	2344
		Bottles 1-6	0245-0450	03°43.73-42.04'	151°37.47-37.44'	2057-1926
		Bottles 7-11	0516-0636	03°41.60-40.39'	151°37.42-37.46'	1871-2113
		CTD up	0713	03°37.84'	151°37.49'	2000
Situated between MH-14 and the PACMANUS site, the aim of this run was to test for continuity between the plume detected during MH-14 and that detected during 1991 hydrocasts. Only modest transmissometer anomalies were observed at the start of the traverse.						
MH-16	10/06	CTD in	1940	03°42.38'	151°44.94	1920
		Bottles 1-7	2025-2130	03°41.71-41.00	151°44.18-43.47'	2187-1880
		Bottles 8-11	2145-2200	03°40.80-40.62	151°43.32-43.17'	1872-1906
	11/06	CTD out	0000	03°39.71'	151o41.92'	nd
MH-16 was designed to map the PACMANUS plume and to check for activity near a chimney observed during 1991 and suspected to be active. A large transmissometer anomaly was observed at about 1650 m depth in the valley between the arms of Pual Ridge.						
MH-17	11/06	CTD in	0101	03°42.97'	151°44.31	1856
		Bottles 1-6	0319-0425	03°41.95-41.40	151°43.37-42.90'	1971-1830
		Bottles 7-10	0439-0454	03°41.26-41.09	151°42.85-42.68'	1829-1853
		CTD out	0609	03°40.50'	151°41.83'	1860
A traverse parallel to MH-16, approximately 0.75 miles to the south west, designed to follow up transmissometer anomalies observed during hydrocast MH-16. Transmissometer anomalies observed were weaker and thinner than those observed during MH-16.						
MH-18	12/06	CTD in	1140	03°39.17'	151°42.89'	1749
	13/06	Bottles 1-6	0120-0200	03°40.08-40.58'	151°44.11-44.54'	1873-1820
		Bottles 7-11	0235-0358	03°40.69-41.53'	151°44.69-45.56'	1823-2057
		CTD out	0534	03°42.34'	151°46.33'	1640
A "tow-yo" to the north east of MH-16 to check for continuity of the transmissometer anomaly observed during MH-16. Strong transmissometer anomalies were again observed, especially in the later part of the traverse.						
MH-19	12/06	CTD in	2206	03°41.09'	151°44.45'	1845
		Bottles 1-3	2333-0026	03°41.90-42.55'	151°45.46-46.04'	1732-1681
	13/06	Bottles 4-7	0151-0304	03°43.11-43.69'	151°46.62-47.26'	1951-1935
		CTD out	0331	03°43.39'	151°47.11'	1960
Another "tow-yo" situated between MH-16 & 18 to further define the plume detected by these hydrocasts. The traverse began on the south arm of Pual Ridge and extended south of Yuam Ridge. Transmissometer anomalies were detected in the first and last third of the traverse, and Niskin bottles were fired at anomaly peaks.						

Operation	Date	Event	Time	Latitude (S)	Longitude (E)	Depth (m)
MH-20	13/06	CTD in	1555	03°43.53'	151°42.83'	1860
		CTD out	1647	03°40.71'	151°43.16'	1900

An unsuccessful attempt to locate the "eye of the plume" as a prelude to sampling a profile through the plume using preset titanium bottles. Only weak transmissometer anomalies were found during the traverse.

MH-21	14/06	CTD in	1010	03°41.45'	151°43.51'	1869
		CTD out	1211	03°40.58'	151°43.09'	1910

A "tow-yo" through the eye of the plume on MH-16 to locate the best position for the profile sampling of the plume. Weak transmissometer anomalies were found all along the traverse at 1650-1700 M depth.

MH-22	14/06	CTD in	1845	03°43.45'	151°42.60'	nd
		CTD out	1907	03°43.33'	151°42.79'	nd
		CTD in	1909	03°43.33'	151°42.82'	nd
		CTD out	1945	03°43.04'	151°42.98'	nd

Successful test of proper CTD operation after a collision with bottom during MH-21.

MH-23	15/06	CTD in	0350	03°44.77'	151°41.87'	2060
		Bottles 1-6	0613-0738	03°43.65-43.23'	151°40.68-40.13	nd
		Bottles 7-11	0750-0839	03°43.14-42.15'	151°40.15-40.42	nd
		CTD out	0933	03°42.14	151°39.88'	nd

A traverse across the PACMANUS field in an attempt to close off the plume, or to see what lies directly above PACMANUS. Moderate to strong transmissometer anomalies were recorded especially during the second half of the traverse - above and to the north of PACMANUS. Niskin bottles were fired close to anomaly peaks.

MH-24	15/06	CTD in	1938	03°43.33'	151°39.97'	NA 0
		Bottles 1-11	2126-2141	03°42.70-42.43	151°40.29-40.21'	1866
		CTD out	2142	03°42.43'	151°40.21'	1866

A single upcast designed to sample a profile through the plume. Eleven samples were taken using 10 litre Niskin bottles, as well as six samples taken using titanium sample bottles (several decilitres capacity) preset to sample at specific depths.

MH-25	16/06	CTD in	1110	03°37.81'	151°43.53'	nd
		Bottles 1-4	1249-1446	03°38.82-39.97'	151°44.39-45.46'	2056
		CTD out	1519	03°40.06'	151°o45.56'	2000

A traverse designed to close off the PACMANUS plume. Weak to moderate anomalies were observed during the later two thirds of the traverse, in the valley between the north and south arms of Pual Ridge.

MH-26	18/06	CTD in	0519	03°46.05'	151°37.47'	nd
		Bottles 1&20559,	0618	03°46.21-46.04'	151°37.24-37.01'	nd
		CTD out	0646	03°46.11	151°36.79'	nd

A "single dip" test for signs of a plume at the south western end of Pual Ridge. Although no transmissometer anomalies were detected, good background values were obtained. The two 10 litre samples taken will be used to determine background water chemistry.

MH-27	18/06	CTD in	1723	03°41.46'	151°52.16'	nd
		Bottles 1-11	1801-1822	03°41.34-41.27'	151°52.08-52.05'	nd
		CTD out	1847	03°41.18'	151°51.89'	nd

A successful attempt to sample a profile through the hydrothermal plume at Desmos Cauldron. A very strong (about 3%) transmissometer anomaly was observed between 1530-1690 meters, with a peak at 1620 meters. Eleven 10 litre Niskin bottles were fired to profile the plume.

Operation	Date	Event	Time	Latitude (S)	Longitude (E)	Depth (m)
MH-28	19/06	CTD in	0320	03°45.71'	152°03.96'	1825
		Bottles 1-3	0356-0432	03°45.77-45.71'	152°04.48-04.98'	nd
		CTD out	0535	03°45.46'	152°05.54'	nd

A successful search for hydrothermal plume activity, possibly originating from the dacite ridge to the south. Strong, narrow transmissometer anomalies observed near the start of the "tow-yow", dropped off towards the east, suggesting a position at the edge of the plume. Three samples were collected at the peak of the anomalies on separate upcasts using 10 litre Niskin bottles. All three samples showed anomalous methane values of 100-400 nl/l CH_4.

MH-29	19/06	CTD in	0606	03°45.16'	152°03.30'	nd
		Bottles 1-6	0644-0809	03°45.49-46.61'	152°03.74-04.47'	nd
		CTD out	0837	03°46.93	152°04.78'	nd

A further investigation of the transmissometer anomaly observed during MH-28. This "tow-yow" was conducted in a southeasterly direction to the east of Tumai Ridge. Transmissometer anomalies were observed throughout the traverse with a maximum of 1.9%. Six samples were collected near peaks of anomalies on separate upcasts. Onboard methane analysis returned anomalous values up to 350 nl/l CH_4.

Echo-Sounding Runs

MES-6	07/06	start	2310	04°10 99'	152°18 00'	nd
	08/06	end	0033	04°03 76'	152°06 42'	1064.0

Designed to provide a bathymetric profile across Tavui Caldera near Rabaul, a recently re-discovered submarine arc volcano (dormant ?).

MES-7	09/06	start	0526	03°41.91'	151°38.13'	
	end	0621		03°45.24'	151°42.00'	

A north west to southeast traverse designed to pass over the PACMANUS field and provide a detailed profile across Pual Ridge.

MES-8	19/06	start	0858	03°46.60'	152°04.00'	1500
		end	0905	03°45.40'	152°03.85'	1763

An echosounding traverse to locate the crest of a ridge in the vicinity of the plume found during MH-28 & 29 in preparation for a camera tow.

MES-9	19/06	start	0949	03°45.90'	152°04.60'	1675
		end	0955	03°46.80'	152°04.61'	1746

A reciprocal traverse to MES-8 (heading south), approximately 0.6 miles east, to further investigate the topography in preparation for MCV-23.