FRANKLIN

National Facility
Oceanographic Research Vessel

Submarine hydrothermal activity and volcanic petrogenesis associated with the birth of island arcs in the Solomon Islands (SOLAVENTS – 2002).

CRUISE SUMMARY

RV FRANKLIN

FR 03/02

Depart Rabaul 1025 hrs, Tuesday 26 March, 2002
Arrive Sydney 1350 hrs, Sunday 21 April, 2002

Principal Investigators

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Scientific Objectives

1. To study seafloor hydrothermal ore-forming activity in order to develop improved methods of exploring for ancient mineral deposits on land that originally formed by similar processes.

2. To extend our research on seafloor hydrothermal ore systems to additional and different tectonic provinces in the western Pacific, and in particular to nascent volcanic arc environments where there are strong possibilities of finding gold-copper-zinc-rich massive sulfide deposits associated with calderas.

In detail, answers were sought to the following questions:

- What are the distribution and association of rock types (both locally and regionally) in submarine arc volcanoes and what is their relationship to tectonic/structural features?
- What styles of eruption and submarine volcanism characterize the San Cristobal-Santa Cruz volcanic arc? Are they related to volatile content?
- Do nascent arc-related hydrothermal systems fundamentally differ in morphology and composition from mid ocean ridge and back arc systems and if so, why?
- A by-product of the research will be the location and preliminary documentation of the diverse biota that surround seafloor hydrothermal systems which will assist and foster baseline environmental studies and ultimately ensure protection of biological diversity. How common are vent biologic communities in submarine arc volcanoes? How do they compare with mid ocean ridge vent communities? What is the longevity of life-supporting hydrothermal systems in arc environments?

The cruise did not in itself test speculative hypotheses. Rather, it represented expeditionary "field work" where, after hunting for and finding "natural laboratories", we collected data and samples that become the subject of a range of laboratory investigations. These include assessments of tectonic setting, petrological and geochemical studies of volcanic rocks and sediments, examination of mineralisation and alteration phenomena, all of which help build up actualistic models of hydrothermal processes and products in relation to their overall geological environment.

The major hypothesis underlying our overall research program is that magmatic source of hydrothermal fluids and contained metals are vital for the development of "world-class" orebodies in the subvolcanic-epithermal-subhalative-exhalative spectrum. Magmatic-source concepts are now becoming more popular, but it remains important to test them in new seafloor hydrothermal settings such as nascent arcs, particularly in order to develop the best possible geochemical and isotopic criteria and related exploration technologies for use by mineral companies in land-based exploration programs.

The proposed work is also vital for the definition of future ODP drilling targets that will further clarify deep subsurface hydrothermal processes.

Additional Project

In addition to the main research objectives above, an extra two days of ship time was planned to study the abundance, speciation and residence of metals and trace elements in the waters and sediments in the Empress Augusta Bay area, located on the west side of Bougainville Island, PNG. Written permission to proceed with this work was obtained from both the PNG Government and the Marine Research Science committee of PNG. However, less than 24 hours before the start of FR03/2002, Australian Department of Foreign Affairs and Trade senior executives informed the

Chief Scientist that such activity close to the coast was unwise given the current political sensitivity in Bougainville and strongly recommended not to proceed.

The extra two days of ship time were therefore cancelled 24 hours before sailing but one station outside the 12 nautical mile limit was occupied for hydrocast, sediment core and grab operations.

Cruise Objectives

We planned to use CTD-transmissometer profiling to detect zones of active venting, bottom camera tows, dredging and sediment coring to study (1) the San Cristobal-Santa Cruz syn-rift volcanic zone and associated magmatic arcs located between the north dipping San Cristobal Subduction zone and the Vitiaz trench to the north, and (2) the magmatic arc as it swings south towards Vanikoro island, (3) the Kavachi submarine volcano and possibly other features which were studied during FR04/2000 to examine what changes have occurred during a 2 year period.

A planned re-visit to the eastern rift zone at Vella Lavella was not undertaken due to time constraints.

Data Sources

- IFREMER 1997 bathymetric compilations were the main maps used during SOLAVENTS. These were supplied by Bernard Pelletier in Noumea, prior the FR08-2001 VAVE cruise. They proved to be particularly valuable with good accuracy at their scale to arrive at a target and commence more detailed surveying. As anticipated, detailed echousounding revealed shallower points in most instances compared with the broad 200m contour intervals on the IFREMER map.

- Detailed interpretations of bathymetric surveys of the eastern Solomons, led by Dr Loren Kroenke (University of Hawaii; on behalf of the South Pacific Applied Geoscience Commission (SOPAC)).

- A full set of nautical charts was purchased and they proved to be particularly accurate around the Santa Cruz, Utupua and Vanikoro islands.

- Mr Donn Tolia (Director of Solomons Geological Survey and SOLAVENTS scientific member) supplied relevant literature and geological maps. Literature included SOPAC reports that are difficult to acquire in Australia.

The original scientific proposal made provision to study a number of recently discovered submarine volcanoes near Malaita. We were unsuccessful in obtaining maps of these occurrences, and therefore no survey was attempted.

The likelihood of hydrothermal activity and deposition of sulfide deposits in the San Cristobal-Santa Cruz synrift volcanic zone and associated magmatic arcs and extensions to Vanikoro Island was considered to be high but to the best of our

knowledge such a topic had not been investigated before. We therefore planned to expand the range of geotectonic settings incorporated in our long-term research program whose outcomes will be improved knowledge of ore forming systems, with applications to land-based mineral exploration strategies and technologies.

Specifically the cruise aimed:

- To collect new marine geoscientific and geotectonic information on a hitherto little explored but significant island-arc region, in the eastern Solomon Islands. Among the island arc-backarc systems of the southwestern Pacific, considerable petrologic and geochemical effort has been expended in the Solomon Islands and Vanuatu. However, there is an apparent gap of fundamental knowledge, between the eastern end of the Solomon arc and the northwestern end of the Vanuatu arc in terms of known subaerial volcanism, with the exception of one known volcano (Vanikoro)
- To document changes over a two year period of the active submarine Kavachi volcano
- To document the state of seabed sediments and water quality in Empress Augusta Bay, 13 years after the cessation of mining on Bougainville.

The principal investigators endeavoured:

- To document numerous aspects of modern, actively-forming mineralised environments, leading to improved interpretation of ancient sequences and orebody settings
- To provide new understandings of hydrothermal mineralising processes at geological settings differing from those so far discovered, thereby adding to the compendium of knowledge about orebody genesis
- To provide resultant strategies for land-based mineral exploration, especially within the sphere of interest of Australian-owned or Australian-based companies

Activities included:

- Identification of targets using available bathymetric and preliminary geological interpretation
- Dredging major features to "ground truth" and if necessary upgrade the geological interpretation
- CTD-transmissometer casts to detect hydrothermal particulate plumes and determine location of the "eyes" indicative of hydrothermally active edifices and sites. Seawater from plume "peaks" were collected by Niskin bottle for on board methane gas analysis using a gas chromatograph and subsequent chemical analysis onshore
- Bottom-tow camera-video traverses along promising features, looking for hydrothermal deposits (chimneys, mounds, crusts) and faunal concentrations or "biological haloes" around vent sites
- Precision dredging to sample any deposits found
- Sediment coring and grabbing (Smith-McIntyre) for subsequent geochemical analysis seeking anomalies indicative of hydrothermal activity, and also at

appropriate sites to test for indications of subsurface sediment-hosted mineralisation.

Equipment

Our plan was to use the same equipment as the previous leg, FR02/2002. Indeed, we considered the previous cruise as the first leg as part of a larger program sharing the same Principal Investigators.

Unfortunately, the FR02/2002 leg lost a dredge and sediment corer, and damaged the video camera. These three items were replaced for SOLAVENTS, the sediment corer and the dredge arriving at 0930, one hour before the Franklin's departure from Rabual.

Cruise Track

The voyage covered 3908 nautical miles. The ship's track is shown in Figures 1 and 2.

We sailed from Rabaul to the Empress Augusta Bay on the western side of Bougainville Island, Papua New Guinea, before entering Solomon Islands' waters, making our way to the Kana Keoki seamount then onto Kavachi submarine volcano on the southern side of the New Georgia Group. We continued into The Slot passing north of Russel Islands before arriving at Honiara, the capital of the Solomons to take on a scientific crew member and to complete customs and immigration procedures. We continued along the northern coasts of Gaudacanal and San Cristobal entering our main area of operations between San Cristobal and Santa Cruz Islands in the far eastern Solomons. A number of days were spent in the vicinity of Vanikoro and Utupua, concluding operations just north of the international border with Vanuatu, west of Tikopia. From there we sailed on a 6-day transit to Sydney, passing north of Torres Island and the northern reefs of New Caledonia.

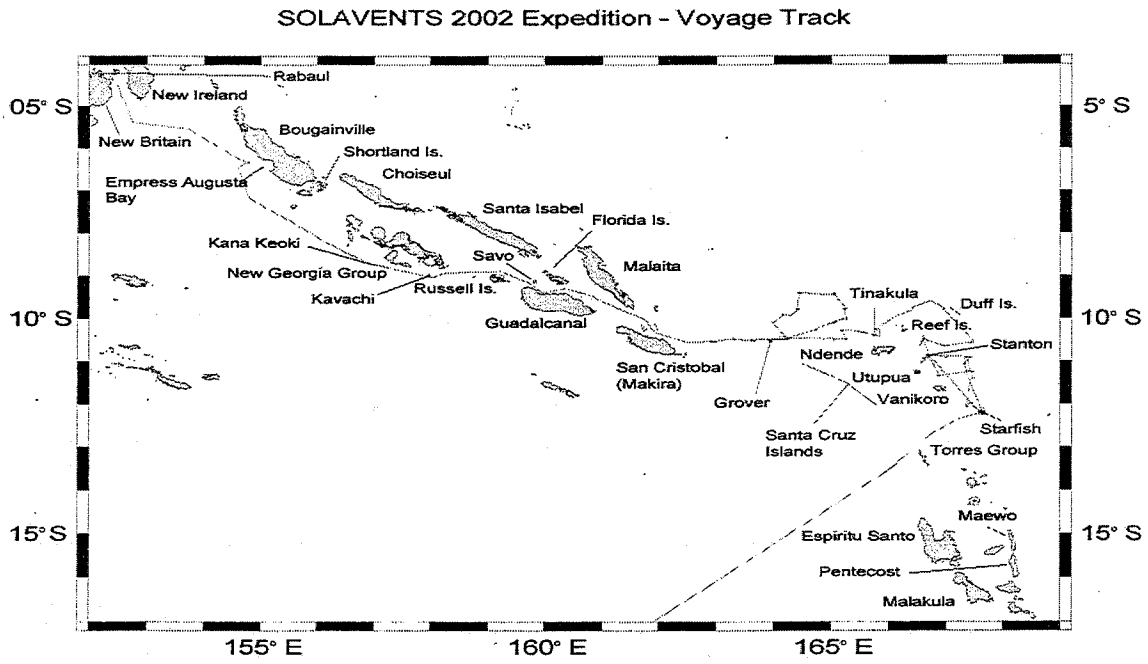

Figure 1 FR03/2002 (SOLAVENTS) Voyage Track

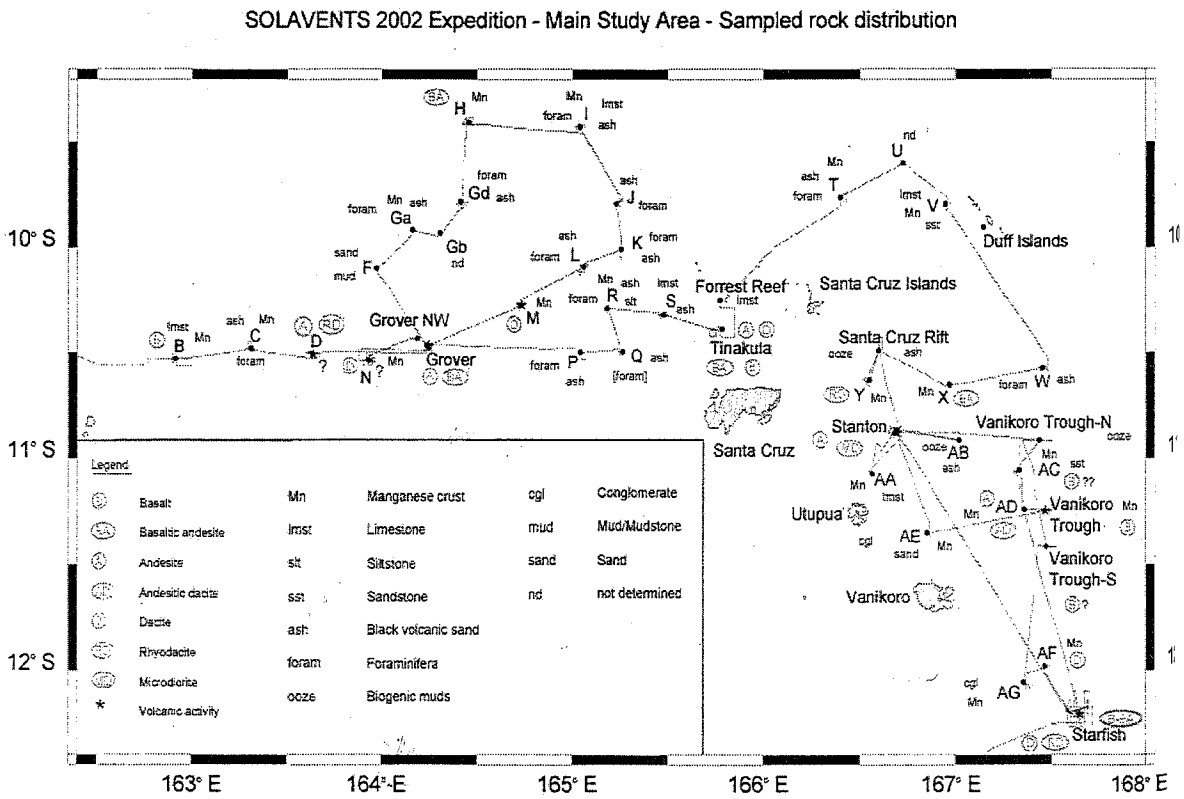

Figure 2. FR03/2002 (SOLAVENTS) Main area of operations showing ship's track, targets investigated and summary of result

Results

The main results of sampling are summarised in Figure 2.

1. We confirmed that the chain of seamounts at ~ 10 ° 30'S in the San Cristobal Arc includes a number of recently magmatically active (and currently hydrothermally active) volcanoes (Targets C, D, N, Grover, and M) that vary in composition from basaltic andesite through to rhyodacite.

   This is a discovery of first-order significance, given the current San Cristobal Trench-parallel Australian Plate motion vector, and the global lack of arc-type volcanoes in such "transform-adjacent" settings.

2. There is no evidence of new crust creation in a "neovolcanic zone" or spreading ridge system at 9° 30'S; rather, the zone is dominated by subdued topography, and the slightly elevated parts of the topography appear to be uplifted basement blocks, comprising old volcanic rocks and volcaniclastic- and carbonate-rich lithologies (Targets F, Ga, Gb, Gd, J, K), equivalent to those recognised in the "Western Belt" of the Vanuatu segment of the New Hebrides Arc, and also exposed in the Duff Islands.

3. Manganese-coated and carbonate-rich lithologies recovered from the summits of seamounts (Targets H and I) in the "Rejuvenated Vitiaz Magmatic Zone" at ~ 9° 15'S do not appear to be young (i.e., less than 2 Ma). Dating of these samples will be critical but at this juncture, these structures appear to be part of the (old) Vitiaz arc. In themselves, however, the morphology of these seamounts, if they represent original volcanic centres, is of interest in that evidence of former Vitiaz activity in much of the Western Belt of Vanuatu is preserved as volcaniclastic-rich sediments rather than as volcanic edifices.

4. Volcaniclastic-rich sedimentary lithologies recovered from the crests of WNW-trending ridges in the region between 10° - 10° 30'S and 165 ° – 166 °E (targets P, Q, R, and S), are similar to lithologies described from the early Miocene of Santa Cruz, and are evidence that the equivalents of the Western Belt, Vitiaz arc-generated lithologies are preserved in the forearc of the San Cristobal Arc.

5. Prominent, conical-shaped seamounts in the northern New Hebrides Arc (Targets AA, AE, AG) are variously capped by "old" limestones and voclaniclastic-carbonate-rich lithologies similar to the early Miocene of Santa Cruz. While paleontological dating is required of the numerous benthic foraminifera preserved in these lithologies, these seamounts would appear to be old structures related to the Vitiaz arc

6. Recovery of sediments from the floors of the Santa Cruz Rift and Utupua Trough, indicate that these rift basins are not magmatically active.

7. Recent pristine basaltic lavas were recovered from the summits of gentle peaks in the floor of the central and southern portion of the Vanikoro Trough. These peaks,

crossed in transects across the Trough, may well be linked (N-S) to form a nascent spreading system. As with the case of the Coriolis Troughs discovered to be spreading during VAVE FR08-2001 in the southern New Hebrides Arc, the SOLAVENTS cruise has demonstrated unequivocally that the Jean Charcot Troughs, at least in part, are magmatically active and form a nascent spreading system.

Given the current small width (~ 2 km or less) of the base of the central Vanikoro Trough, it is clear that this must be one of the most juvenile magmatically-active backarc basins in the world.

8. A survey of the Kavachi submarine volcano showed that it has changed significantly since surveys done in May 2000 by FR04-2000 (SHAARC). The summit is now clearly well below sea level, compared with 3 m below in 2000, and there was no evidence of wave action near the summit. Some lower parts of the volcano appear to be at shallower depths, perhaps due to mass wasting downslope. The most shallow point we surveyed at 85m was approximately 170m east of the 34m-summit defined by a local diver using a hand held GPS 12 days before our arrival (but emailed to us 21 days after our visit). Therefore in the space of 2 years, the summit has sunk around 30m and "moved" eastwards by 315m. An unusual rise in the surface seawater temperature was recorded NW of the summit area. Scum resembling oil slicks was noted on the surface in places. CTD-hydrocasts failed to show any light transmission anomalies.

The first methane determinations at Kavachi indicate hydrothermal sources on the flanks of Kavachi at depths between 200 and 500m or deeper, with the highest methane concentration of 31nl/l at 522m or 10mab, but interestingly are not accompanied by light transmission anomalies.

A sample of gravel taken at 95m depth east of the summit returned a pungent hydrogen sulfide odour which permeated the back deck and the operations lab. The black volcanic sand contained small specks of up to pea size yellow native sulfide and traces of pyrite. Hydrothermally altered grey to cream-coloured basalt was also recovered.

Hydrothermal Activity

1. We discovered four new hydrothermally active submarine seamounts varying from andesite to rhyodacite in composition. The first two, Grover and Target M, occur in the central portion of the San Cristobal magmatic arc and the other two, Stanton and Starfish are located in the northern New Hebrides volcanic arc near Vanikoro.

2. Grover, Stanton and Starfish are associated with hydrothermal activity, locally focussed methane-rich and carbon dioxide-rich (from pH measurement) hydrothermal plumes and weak to strong sericitic-clay-pyrite-silica hydrothermal alteration. Grover and Stanton have abundant iron oxide hydrothermal precipitates and shimmering water, with abundant vent biota. Massive sulfide in the form of pyrite-marcasite and native sulfur was dredged from Stanton. Stanton is particularly interesting since cobbles of quartz diorite porphyry-like rock were

recovered from near the rim of a resurgent dome-crater complex, and near a dredged sample of inactive massive sulfide. These cobbles are interpreted to represent a possible intrusive diorite with similarities to island arc porphyry copper-gold environments. How cobbles came to the seabed is not known at this stage.

3. Target M located in the central San Cristobal volcanic arc is recognised by a methane anomaly 600mab, and recovered slightly manganese stained, grey, blocky dacite.

4. A possible fifth hydrothermally active seamount, Target N, is also located in the central San Cristobal Arc, around 15 miles west of Grover Seamount where hydrothermal manganese-oxide cemented dacite breccia was recovered. Surprisingly, none of the discoveries have significant hydrothermal particulate plumes, and indeed, a possible characteristic of arc- related volcanoes.

5. Our results indicate that the volcanic arcs of San Cristobal and the northern New Hebrides represent a potential extensive source of relatively shallow ventfields emitting gas rich fluids from heterogeneous source rocks.

Other

Reconnaissance off the remote volcano-island Tinakula was completed in the ship's zodiac Franklin. A vent high up on the western flank is actively expelling gas/steam, which can be heard as a low roar 50m from shore. Small avalanches down the steep western side are common, and one larger eruption was observed from the bridge lasting about 5 minutes. Small transmission anomalies were detected in the water column and are probably turbidity induced-particulate plumes. A weak methane anomaly was also recorded 1.75 miles off the NW coast of Tinakula.

Cruise Narrative

Forty-three sites were surveyed, of which 4 were completed in significant detail. 254 operations were conducted, including 135 over-the-side deployments of the CTD, dredge, grab, corer and bottom-tow video system. This work resulted in the collection of 486 rocks and sediment samples totalling around 2.7 tonne, 323 water samples, from which 222 on-board methane gas and 218 pH, conductivity and free iron analyses were made. Forty-four biological samples were recovered serendipitously during dredging operations. Seventy operational plans were issued, with 350 waypoints.

No equipment was lost and no equipment was damaged apart from the normal wear and tear during operations (e.g. light globes in video system). We experienced some difficulties with the termination of the hydro wire into the CTD but these were fixed. There were two minor delays caused by problems with the main winch and a pump. The inability of the bow-thruster to deliver full power meant that dredging and video-tow operations were conducted on the optimal track for wind and current directions.

Generally, however, we learnt to cope with this limitation and devised sampling and surveying strategies accordingly.

A feature of our echosounding traversing was the development during the cruise by the cruise manager of an efficient and timely use of contouring package in Matlab. We were able to generate up to date contour maps to guide operations and waypoints. This ability to produce quick accurate contour maps played an extremely important role in our operations and discovery rate, and underscored significantly the success of the cruise.

Overall the weather and sea conditions were good to excellent and a relatively small amount of operational time was lost because of bad weather and unsafe conditions for over-the-side deployment of equipment. One sediment core operations was abandoned due to proximity of a fishing vessel and long-lines.

Summary of operations:

Operation	**Number**
echosounding traverse	115
CTD-hydrocasts*	40
dredge	37
sediment core	9
grab	49
CTD-Transmissometer	1
video yow	12
Total	**254**

*no tow-yos were done

Summary of Samples:

Sample Type	**Number**
Unfiltered water	284
Filtered water	39
Particulates on filter	39
pH, conductivity, free iron	218
Methane	222
Rock and sediment	486
Biota	44
Total	**1332**

Summary

The cruise was highly productive, and a great success, meeting nearly all of our scientific objectives. The one and only disappointment was not being able to complete the 2 extra days sampling in Empress Augusta Bay, PNG, in spite of careful and long term planning involving considerable expense.

A number of unexpected results require significant revision of current interpretations of Solomon Island tectonics and geology. The expedition highlighted a number of areas for follow up research, including possible submersible dives sites and Ocean Drilling Program targets, to clarify deep subsurface hydrothermal processes.

The success and high productivity of the cruise was a function of both the ship's crew and scientific team who all worked well together, in a safe, professional, and diligent manner throughout the 27 days.

The considerable amount of material collected will form the basis of ongoing studies at CSIRO, Australian National University, University of New South Wales, Macquarie University, University of Tasmania, the Korean Ocean Research and Development Institute and the Solomon's Ministry of Mines and Energy.

Scientific Personnel

Tim McConachy	CSIRO, Exploration and Mining	Chief Scientist
Richard Arculus*	Australian National University	Petrology/Tectonics
Chris Yeats*	CSIRO, Exploration and Mining	Computing
Stephan Sestak	CSIRO, Exploration and Mining	Hydrology
Donna Tolia**	Mines and Energy, Solomon Islands	Geology
Jayne Holden	University of NSW	Engineering/Environment
Barney Stevens	CSIRO Visitor	Economic Geol/Petrology
Christian Schardt	CODES, University of Tasmania	Economic Geology
Jong-Uk Kim	Korean Ocean R&D Institute	Geology/Geochemistry
Susan Belford	Phelps Dodge Exploration	Economic Geology
Bob Beattie	CSIRO Marine Research	Cruise Manager
Lindsay MacDonald	CSIRO Marine Research	Electronics/CTD

*watch captain
** boarded 29/04/2002 in Honiara

Ship Personnel

Neil Cheshire	Master
Arthur Staron	First Mate
John Boyes	Second Mate
John Morton	Chief Engineer
Dave Jonker	First Engineer
Paul Dickson	Second Engineer
Dan Davies	Greaser
Mal McDougall	Bosun
Tony Hearne	IR
Lou Jacomis	IR
Graham McDougall	IR
Frank Soutter	Chief Steward
Peter Williams	Chief Cook
Angie Zott	Second Cook

Acknowledgements

There was a good deal of justifiable nostalgia surrounding the Franklin's last voyage, having fulfilled a distinguished 17-year role in marine research. The Master, Neil Cheshire and crew are thanked for their tireless and patient efforts in operations, and for the professional and safe way they go about the business of running the ship and ensuring that the scientific objectives are met.

The members of the scientific team are thanked for the long hours and hard work put in to achieve the results.

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The government and people of the Solomons Islands are thanked for allowing us to survey their waters.

Tim McConachy
Chief Scientist-FR03-2002
(SOLAVENTS-2002)

14 June 2002