FRANKLIN

National Facility
Oceanographic Research Vessel

Seafloor Hydrothermal Activity in Arc and Backarc Settings, Vanuatu, SW Pacific.

CRUISE SUMMARY

RV FRANKLIN

FR 08/01

Depart Noumea 0807hrs, Wednesday 5 September 2001
Port of Entry clearance at Tanna Island 1230hrs, Saturday 8 September 2001
Pick up day-visitors Norsup, Malakula Island 0820hrs, Wednesday 19 September 2001
Arrive Brisbane 0830hrs, Tuesday 25 September 2001

Principal Investigators

Dr Timothy F McConachy (Chief Scientist), CSIRO Exploration and Mining
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CRUISE SUMMARY

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VAVE-2001

(Vanuatu and Australia Vents Expedition)

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Principal Investigators

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Scientific Objectives

The major scientific objective was to locate and study seafloor and sub-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.

Specific objectives were:

1. To locate and sample sediment-hosted hydrothermal mineralisation, and gold-copper-zinc-rich massive sulfide deposits associated with submarine volcanic calderas in a back arc setting. Vanuatu has geological settings with excellent potential to host this range of hydrothermal ore systems.

2. To hunt for and locate "natural laboratories", and to collect data and samples that will be 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, comparison with other submarine settings etc., all of which help build up actualistic models of hydrothermal processes and products in relation to their overall geological environment.

3. FR08/2001 will also contribute the definition of future ODP drilling targets to further clarify deep subsurface hydrothermal processes; our Manus Basin ODP Leg 193 in 2000/01 having lead the way.

Special attention was devoted to any locations that appeared during the cruise to have potential for sediment-hosted mineralisation (including within altered epiclastics). A discovery of the latter nature would open up a major new research field highly relevant to land-based mineral exploration.

Cruise Objectives

We aimed to survey selected sites in the Coriolis Troughs and their extensions, centred about 180km SE of Vila, using CTD-transmissometer profiling to detect zones of active venting, followed by bottom camera tows, grab sampling, dredging and sediment coring.

Our strategy was to work from south to north which optimised transit times and made the most efficient use of RV Franklin's time at sea. Decisions on which operations were conducted were made at sea, and depended on results.

The Coriolis Troughs located east of the Erromango, Tanna and Anatom Islands offered scope to investigate a number of volcanic-hosted hydrothermal fields. These troughs or basins had been surveyed by the Metals Mining Agency of Japan in 1994, and good quality seabeam bathymetry, magnetic and side scan sonar data are available over an area of 350 x 120km. We were also fortunate to be given a bathymetric compilation of Vanuatu waters by Dr Bernard Pelletier (Head of Laboratory, Geology/Geophysics Noumea, Institute de Reserche pour le Developpement (IRD)), and Dr Yves Lagabrielle (IFREMER, France). This compilation enabled us to survey more accurately targets outside the Coriolis

Troughs and the area surveyed by the Japanese. We had also planned to survey a chain of seamounts to the east of the Coriolis Troughs. These were named the Lini Chain of Seamounts by our Vanuatu colleagues and ship-board participants, and 3 of the 7 features were surveyed by VAVE.

In addition we surveyed targets within submerged portions of the Vanuatu volcanic arc, including reputed sulfide-bearing altered lava from near the site of an 1453AD massive caldera eruption (Kuwae) near Epi Island in the central part of the arc, where a small post-caldera parasitic cone emerges occasionally.

An extra day was added to the original plan following inclusion of an on going joint research project with CSIRO Petroleum concerning inter relationships between hydrocarbon distribution and hydrothermal activity. The inclusion of a gas chromatograph and ultrasonic gas extraction system on board enabled methane gas levels to be measured in hydrothermal plumes and in sediments. A further 5 sediment coring operations were planned in the South Aoba Basin east of Malakula Island, but only four stations could be accessed safely by the Franklin.

Specific activities included:

- Dredging major features to "ground truth" them and if necessary upgrade their geological interpretation.

- CTD-transmissometer tow-yos and single dips to detect hydrothermal particulate plumes and locate the "eyes" of any plume discovered, to define hydrothermally active edifices and sites. Seawaters from plume "peaks" will be collected by Niskin for subsequent chemical analysis onshore.

- Use of an onboard gas chromatograph to establish methane levels in hydrothermal plumes as part of a research project on the inter-relationships between hydrocarbon distribution and hydrothermal activity.

- Bottom-tow camera-video traverses along promising features, looking for hydrothermal deposits (chimneys, mounds, crusts) and faunal concentrations.

- Precision dredging to sample any deposits found.

- Sediment coring and grabbing (Smith-McIntyre) for subsequent geochemical analysis in order to look for anomalies indicative of hydrothermal activity, and also identify sites to test for indications of subsurface sediment-hosted mineralisation, and possible association with hydrocarbons. The gas chromatograph was also used to establish methane levels in sediments.

Cruise Track

The overall cruise track in shown in Figure 1. Figures 2 and 3 show stations and operations, respectively.

Results

Highlights of VAVE-2001 were:

1. Discovery of a new and potentially large hydrothermal field, Nifonea Ridge, on a neovolcanic basalt ridge in the Vate Basin, SE of Port Vila. The initially detected weak light transmission and subsequent methane gas plume anomaly was mapped and the seabed comprehensively surveyed and sampled over a 48 hour period. At least three separate zones of hydrothermal activity were mapped using deep-tow video within an area measuring 2400m x 600m, with the largest field at around 600m x 400m. Extensive hydrothermal fauna, spire-like structures (some of which may be sulfide chimneys) and yellow-brown oxide crusts were photographed but dredging recovered only fauna and iron oxyhydroxides.

2. The recovery of sulfidic scoria breccia and agglomerate, and quenched native sulfur at Oscostar, an active submarine volcano, 100km south of Anatom.

3. Identifying a submarine dacite to rhyodacite volcano at Cioan volcano near Epi Island, which revealed a hydrothermal plume with high concentrations of methane gas, and recovery of iron rich hydrothermal material.

4. Sampling of the Kuwae caldera and identifying dacite rocks (less SiO_2 than Cioan) with minor basaltic andesite and a hydrothermal plume containing significant concentrations of methane gas.

5. Finding that the supposedly old and sediment-filled Coriolis Troughs (where we hoped to find sediment-hosted hydrothermal activity) were actually floored by very young basaltic lavas. Major revisions of tectonic concepts for the area are required. Our discovery of neovolcanic activity in the Coriolis Troughs is a major achievement of the VAVE cruise. Knowing now of its presence, there are clearly other sites bypassed by VAVE that deserve attention in the future.

6. The recovery of iron rich hydrothermal rocks from Temakons Seamount (formerly numbered 94SO1).

7. The serendipitous discovery of a large volcanic debris field centred about 10km equidistant from Gemini, Gemini North and Oscostar, 100km S of Anatom. Large blocks are strewn randomly over an area of at least 8km^2. Further echosounding is required to complete the picture of this significant debris field.

8. The discovery of a new Seamount, Roimata #B, where a 2000m deep is shown on published nautical charts.

9. Lastly, we confirmed our ability to be able to track down and sample new vent fields in a relatively short time using a variety of equipment and techniques. The exceptional turnaround time of on board methane analyses enabled quick decisions to be made of 'where to next' and was a perfect complement to the real time light transmission readouts from the CTD rosette.

Accordingly, the cruise fulfilled its main scientific objective which was to locate and study seafloor and sub-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.

Other Objectives

VAVE-2001 was not in itself testing major hypotheses. Rather, it represented expeditionary "field work" to hunt for and locate "natural laboratories", and to collect data and samples that will be 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, comparison with other submarine settings, all of which help build up actualistic models of hydrothermal processes and products in relation to their overall geological environment. To this end, VAVE-2001 was hugely successful.

Two secondary objectives of VAVE were to locate and sample (1) sediment-hosted hydrothermal mineralisation, and (2) gold-copper-zinc-rich massive sulfide deposits associated with submarine volcanic calderas in a back arc setting. Unfortunately, neither of these two objectives was achieved. In contrast, a number of unexpected results, particularly with regard to the tectonics of the area, provided surprising highlights (see below).

(1) Sediment-hosted mineralisation

No evidence was found for hydrothermal activity within the sediment cores recovered, although the cores from the Futuna, Erromango and Vate Basins all

have an unexpectedly dark brown massive, silty, hemipelagic clay. In places, we found mm- to cm-thick, very dark grey silty or sandy volcaniclastic layers. None contained any distinctive coloured horizons that were clear candidates for plume-derived metal enrichments. Post cruise research will test for more subtle effects and provide comparisons with hemipelagic sediments from other back arc basins to determine the cause of the dark brown colour, and also confirm or revise the interpretation of a multisource airborne ash origin for the dark grey volcaniclastic layers.

(2) Massive sulfides in caldera settings

We did not recover any massive sulfide associated with submarine volcanic calderas in a back arc setting. A prime candidate for further work to achieve this objective was identified at Cioan volcano, where strong concentrations of methane gas were measured. However, we did photograph possible chimney structures, which resemble massive sulfides, in the new Nifonea hydrothermal vent field.

(3) Tectonics and petrology

We examined two contrasting arc settings, and a number of back arc sites. The arc settings include the felsic Kuwae and Cioan eruptive centres in the north and basaltic Oscostar Seamount in the south.

In the back arc settings, basaltic rocks dominate, with some fractionation toward andesite. Many of the 35 targets studied are relatively old judging from weathering, manganese crusts, and shelly tops. These include the Chain of Lini Seamounts, Sineto and Nan Seamount.

Young, fresh volcanic rocks lacking weathered surfaces and manganese crusts were found at 5 locations within the Coriolis troughs. We have therefore demonstrated that the Coriolis Troughs have developed to the stage of ocean floor spreading. Given their relatively narrow width it is unlikely that spreading has been active for very long. In fact, they are likely among the most youthful of back arc basins, comparable with the Sumisu Rift (Izu-Bonin arc) and Okinawa Trough in Japan. We conclude that the rocks comprising the walls of the Coriolis Troughs are "pre-rift" Vanuatu arc basement, and note that the Nifonea Ridge is oriented normal to the extensional axis of the Troughs.

Other significant tectonic observations include:

- The eroded morphology of the Lini Seamounts and the apparently arc-related (basalt-andesite-dacite) character of their basement rocks is indicative of an important phase of arc volcanism, presumably preceding formation of the

Coriolis Troughs. However, confirmation of the significance of these materials will depend on detailed analytical studies.

- The Masaga Seamount is a horst block composed of the same volcanic and sedimentary strata that form the walls of the Erromango Trough.

- We cannot confirm that the postulated offset of the Western Spreading Ridge exists in the vicinity of 17° 20'S, or that Core Seamount is part of a westward-propogating rift system.

- The western rift of the Ambrym Volcano extends offshore.

(4) Hydrothermal plumes

Of the 24 targets tested by the CTD-transmissometer package, 15 or just over 60% returned a positive indication of possible hydrothermal plumes. Three targets (Nifonea, Kuwae and Cioan) yielded light transmission and significant methane anomalies that are unambiguous plume signals. The other 10 targets yielded equivocal plume signals; varying from subtle to strong methane anomalies with no light transmission anomalies, to very weak light transmission anomalies with no methane anomalies.

- The best results come from the Cioan, Kuwae and Nifonea areas. Nifonea is in a back arc position in the centre of the Vate Basin, and the other two are associated with arc volcanism.

- The Erromango Basin appears to be devoid of current hydrothermal activity, except for one possible area.

- The two seamounts the surveyed by the Japanese in 1994 (Temakons, and Sineto) recorded only possible plume signals. The Japanese photographed hydrothermal vents at Temakons but the plume signal from this area is weak, at best. The level of hydrothermal activity is therefore considered to be weak, and this is consistent with other results (e.g. dredging, grab) from this area.

- The anomalously high concentrations of methane measured in the south of Vanutau at Gemini, Oscostar and Mystery Mounds are interesting, even though they are accompanied by no light transmission anomalies. Previous workers have tectonically interpreted this area as the southern extension of the Coriolis Troughs but it could be part of the volcanic arc, a direct extension from Erromango and Anatom. Such concentrations of methane would therefore be consistent with other arc-related volcanoes at Kuwae and Cioan in the north. These appear to be quite gaseous without strong light transmission anomalies.

(5) Hydrocarbons and hydrothermal activity

An extra day was added to the original cruise plan for a 'piggy back' project concerning interrelationships between hydrocarbons and hydrothermal activity. Sediment and water samples from of 4 stations in the South Aoba Basin are subject to on-shore analyses.

(6) *Other Potential Resources*

Echosounding over submarine volcanoes/seamounts at Gemini and Oscostar in southern Vanuatu and Roimata C near Efate identified possible fish schools above the summits. These could represent new fishing grounds for Vanuatu.

Cruise Narrative

A daily narrative is given in Appendix 1 and summary of stations is available from the Chief Scientist.

Summary

The FR08/2001 expedition to Vanuatu was extremely successful.

Not only did the expedition meet most of its scientific objectives but it also surpassed the number of planned operations, enabling collection of a large and comprehensive suite of water, sediment and rock samples, and video coverage for subsequent on shore laboratory research and analysis. We investigated 35 targets, conducted 208 operations and collected 474 rock and sediment samples, 251 water samples, and made 190 on-board methane gas analyses. Some totally unexpected results require significant revision of current interpretations of Vanuatu tectonics and geology. The expedition highlighted a number of areas for follow up research, including possible submersible dives sites and Ocean Drilling Programme 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 21 days. In addition no operational time was lost to weather.

The RV Franklin proved once more to be an excellent vehicle for undertaking this type of work. For most situations, it maintained station to the appropriate degree of accuracy required. Problems were encountered with the SIMRAD EA500 echosounder dropping out every 10 minutes or so during the first half of the cruise. This was not only irritating but also caused loss of data at crucial times during operations. The problem was tracked successfully to not enough

RAM in the current (spare) Master CPU card which was too slow, and it had not been upgraded from a faulty card during a recent replacement (FR07/01). We believe that the manufacturer is aware of this problem but find it unacceptable that they do not provide updates with service bulletins. With one dredge lost on this voyage, the ship is now down to 2 complete sets of weak links. The sheer bolt sets needs re-furbishing, and a third set of weak links is required as a back up for future dredging operations. The computers operated reliably during the voyage, with no major down-time being experienced.

About half a day of operation time was 'lost' as the ship had to visit Tanna for customs port-of-clearance. We learnt of the necessity for customs clearance only hours before sailing. Clearance therefore had to be arranged by the Chief Scientist during the initial stages of the cruise, and was facilitated by the good will of the Vanuatu Government and in particular, the Director, Ministry of Geology, Mines & Water Resources. Future cruises to Vanuatu should take customs port-of-clearances into account, arranged before hand, and incorporated into the cruise plan.

Scientific Personnel

Name	**Affiliation**	**Expertise**
Tim McConachy	CSIRO Exploration & Mining	Economic geology/plumes
Ray Binns*	CSIRO Exploration & Mining	Economic geology /petrology
Chris Yeats*	CSIRO Exploration & Mining	Economic geology/computing
Brent McInnes	CSIRO Exploration & Mining	Economic geology
Stephen Sestak	CSIRO Petroleum	Gas chromatography
Tony Tevi	Ministry of Lands, Energy, Mines & Water Resources, Vanuatu	Geology, tectonics, local expertise and experience
Brooks Rakau	Ministry of Lands, Energy, Mines & Water Resources, Vanuatu	Geology, tectonics, local expertise and experience
Fernando Barriga	Lisbon University	Economic geology
Richard Arculus*	ANU	Petrology /geochemistry
Robina Sharpe	University of Tasmania	Economic geology
Bob Beattie	CSIRO Marine Hobart	Cruise Manager/Computing/CTD
Erik Madsen	CSIRO Marine Hobart	Electronics/CTD

*watch captain

VAVE-2001 Scientific Team

Left to right: *Front Row*: Bob Beattie, Toney Tevi, Richard Arculus, Brent McInnes
Back Row: Fernando Barriga, Stephen Sestak, Robina Sharpe, Chris Yeats, Brooks Rakau, Erik Madsen, Ray Binns, Tim McConachy

RV Franklin Personnel

Name	Title
Neil Cheshire	Master
Arthur Staron	First Officer
John Boyes	Second Officer
Gordon Gore	Chief Engineer
Dave Jonkers	Electrical Engineer
Wayne Hanson	Second Engineer
Dan Davies	Greaser
Mal McDougall	Bosun
Tony Hearn	Able Seaman
Gareth Pratley	Able Seaman
Jason Walker	Able Seaman
Shaun McQuaid	Chief Steward
Marc Sweeney	Chief Cook
Bernie Sorenson	Second Cook

Acknowledgments

The Master and crew of RV Franklin are thanked for their tireless and professional performance throughout the cruise which contributed greatly to the success of VAVE.

Mr Chris Ioan, Director, Ministry of Geology, Mines & Water Resources, Vanuatu is thanked for support of VAVE and for his contributions to logistics and arrangements, especially the port-of-clearance at Tanna and the day-visit near Malakula. Mr Ioan also kindly made available two of his senior officers to participate in the expedition, and contributed project funding from an AusAID grant.

The research on seafloor hydrothermal systems and applications to land-based mineral exploration by CSIRO Exploration and Mining would not be possible without the continuing support of industry sponsors, Normandy Mining Limited, Phelps Dodge Corporation and Rio Tinto Exploration Pty Limited, and the division's management, in particular Professor Neil Phillips and Dr Graham Carr.

Interwest (Vanuatu) LTD and President, Mr Floyd Cardinal are thanked for their support.

A travel grant from Research Centre Creminer and project Dream - Fundação para a Ciencia e Tecnologia - Portugal enabled Professor Fernando Barriga of

Lisbon University to participate on VAVE. Dr Robina Sharpe acknowledges internal Centre for Ore Deposits Exploration SRC travel grant.

The Chief Scientist would like to acknowledge and extend his personal thanks to the scientific team who worked long hours and exceptionally hard to underwrite the success of VAVE. Finally, Dr Joanna Parr, CSIRO Exploration and Mining, Sydney, and VAVE's on-shore participant, is thanked for assistance in pre and post cruise organisation and planning.

Dr Timothy F McConachy
Chief Scientist

Figures

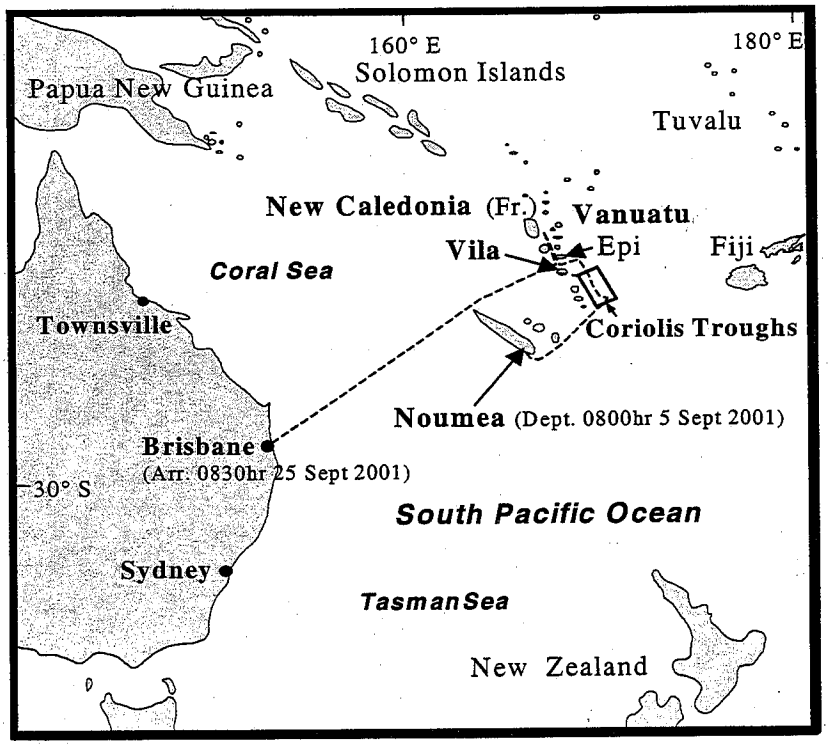

Fig. 1 Cruise Track of VAVE-2001

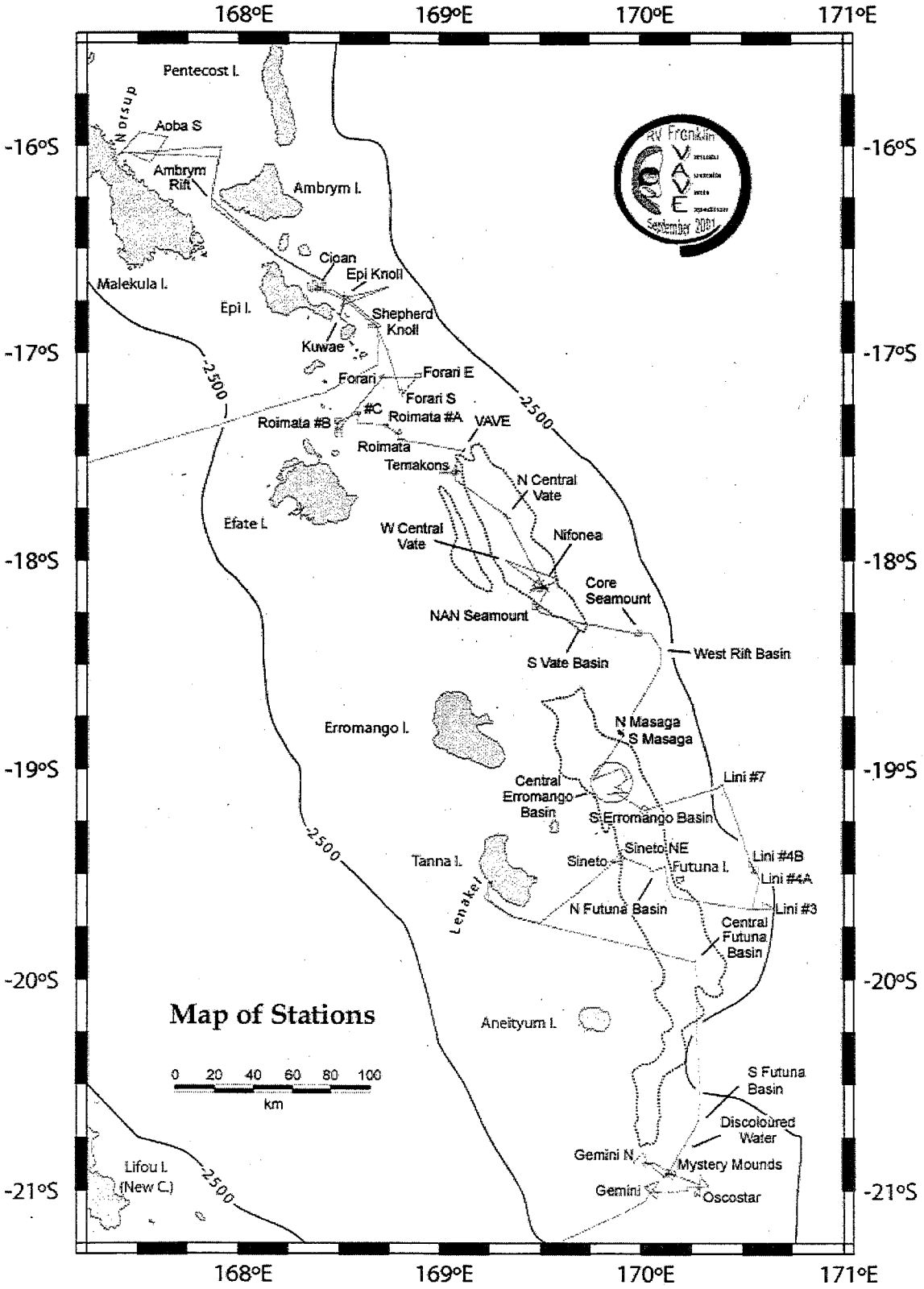

Figure 2: Location of stations investigated during VAVE-2001.

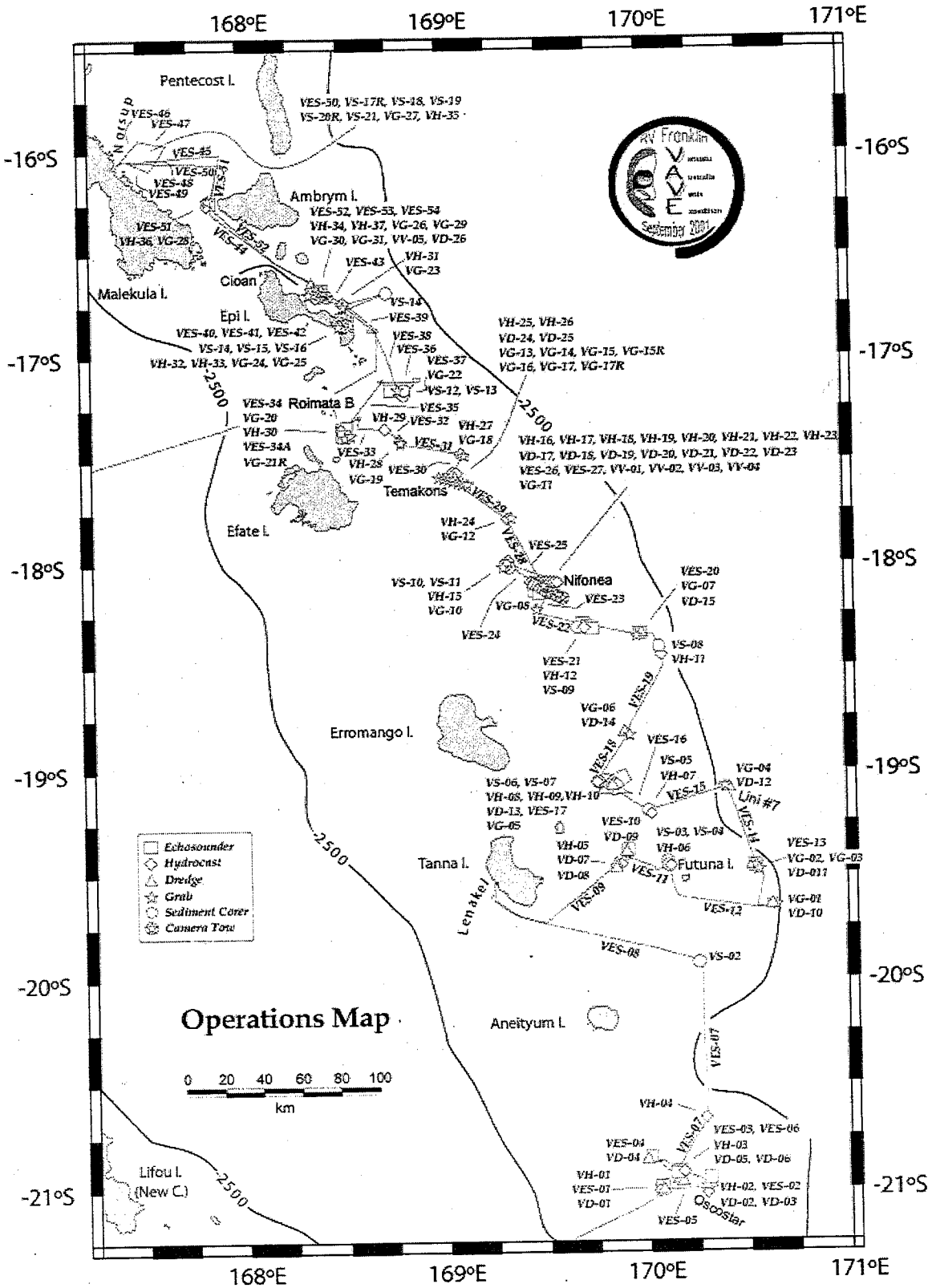

Figure 3: Location of all operations carried out during VAVE-2001.

Appendix – Daily Narrative

Tuesday 4 September 2001

Franklin docked at Baie de la Moselle in downtown Noumea, New Caledonia at 1000hours.

Lunch on board the Franklin was a special "French" style of assorted seafood which was relished by all except for two of the scientific party who were travelling from Sydney. The afternoon was spent unloading equipment and gear from the hold, and organising the various laboratories.

Visit by Dr Bernard Pelletier (Head of Laboratory, Geology/Geophysics Noumea, Institute de Reserche pour le Developpement (IRD)), and Dr Yves Lagabrielle (IFREMER, France) brought new bathymetric maps and literature.

All the scientific crew had dinner at local restaurant in Noumea before sleeping aboard.

Day 1
Wednesday 5 September 2001

Calm and cloudy as we cast off from Noumea at 0807hr and sailed around the southern tip of New Caledonia. Morning spent arranging equipment. Held a science meeting at 1300hr where scientific objectives, strategy and house keeping matters were discussed. The meeting was preceded by the Master's welcome and general comments on safety and other procedures.

At 1615hr a fire drilled was held.

Formal watches commenced at 1600hr, and team members were shown the intricacies of the navigation plotting system. The ship was continuing to sail towards the first waypoint, 3nmi SW of the submarine Gemini volcano. The Simrad echo sounder is not working properly despite efforts by the technical staff to fix it. Apparently it was like this on the previous cruise.

Day 2
Thursday 6 September 2001

At first light in calm seas and overcast skies we arrived at first waypoint for VAVE and proceeded to deploy the CTD rosette for the first operation of the cruise, **VH-01**. The location is about 60 nautical miles south of Anatom Island. VH-01 was positioned 3 miles SW of a reputed 1999 eruption site of the Gemini submarine volcano, as described to us by French geologists who visited the Franklin in Noumea, the day before yesterday. The CTD package was deployed to 1325m (~50 meters above bottom). Light transmission decreased by ~1% below 950m but it was a gradual decline and not characteristic of a hydrothermal plume. Small blips in dissolved oxygen were noted. Eleven bottles were fired on the upcast at regular

intervals, including the blips in dissolved oxygen. When surfaced at 0650hr, only five bottles had triggered. These were sampled for methane analyses, and samples were collected for geochemical analysis on shore. Results indicate higher than expected background levels of methane.

An echo sounding run (**VES-01**) was done over the estimated summit of Gemini submarine volcano, and created a new bathymetric sketch map to assist with follow up dredging operations. The summit is at 78m, 40m higher than shown on charts.

We then dredged the summit with **VD-01** and retrieved a quarter full bag of ferruginous limestone and cemented gravel. When cut, the rocks showed limonitic spheroids of altered volcanics, and pumiceous glass. One small piece of altered glass was also collected.

We then sailed east to Oscostar seamount, a site we named after the Australian vessel MT Osco Star, which recorded an eruption there in 1996. By a remarkable coincidence, a crewmember on our cruise had been a crewmember on the Osco Star at the time of the eruption and was able to describe the event. His version matched with the documented description in the pilot's book of *"eruptions, consisting of steam and occasional bursts of muddy water shooting vertically into the air"*. A single dip CTD/hydrocast **VH-02** was conducted to 1019m depth to the WSW of Oscostar but found no transmission anomaly. There was a hysteresis problem with the transmission readout, with a gradual drift of transmission with depth. Seven bottles were fired for background samples. One bottle was not sealed and was not useful for gas analysis.

A science meeting was held at 1300hr where various operational issues were discussed.

An extensive single channel echosounding survey (**VES-02**) over the summit and surrounding slopes was completed to produce a preliminary map of the area, followed by dredge **VD-02** over the NW slope and summit at 90m. A small percentage of the haul contained reddish oxidation and grey-whiter clay alteration but no obvious visible sulfide. One person noted a slight smell of hydrogen sulfide, but others did not notice this. On the basis of the investment of time already put into Oscostar, the promising hydrothermal alteration and the fact that there appeared to be a flatter section and possible fault controlled structure it was decided to do a follow up dredge.

VD-03 was hauled along the same SE direction but this time closer to the summit. Positioning the ship at the first waypoint showed that the summit was shallower to 50m causing some concern initially with the bridge as we were not sure what lay ahead. The dredge was dropped in 59m of water, and the dredge effectively sampled this site and down a slight slope for a distance of 300m. Deployment was near perfect again and the result was half a load of a spectacular mixture of semi-consolidated, friable scoriaceous boulders (up to 30cm), cobbles and gravel with yellow native sulfur along fractures, clasts of fine grained pyrite. In places the native sulfur looked to have quenched from a melt and had a "wormy" appearance, so temperatures must have been as high as 108°C. A 25cm-long worm and a red shrimp were also recovered. The result was excellent and very exciting, and a big fillip for

the cruise at such an early stage. The find is the first such hydrothermal deposits found at this location.

During the day, problems with the echosounder sporadically and irritatingly cutting out were being addressed. All scientists were becoming more familiar with TrackPlot.

Day 3
Friday 7 September 2001

Following the successful dredge at the Oscostar submarine volcano, we transited and proceeded to conduct a sediment core **(VS-01)** in the centre of an interpreted large caldera about half way between Oscostar and Gemini North. Just before we reached the waypoint for this operation, a number of peculiar looking "cones" and "hills" were evident on the echosounding trace whose tops looked to be made of softer material than the surrounding sediment. We retraced our path a mile to the south east on flat seabed at 1383m and completed **VS-01,** using the mini corer with a pinger attached 100m up above it, as the winch wire out meter was not accurate. The use of the mini corer it was considered a lower risk to use since the much larger AGSO gravity corer would have been used for the first time at night. A 65mm-long core was recovered comprising semiconsolidated brown-khaki mud, with minor silt and with possible volcaniclastic layers. The top of the core was dark brown watery mud.

An echosounding traverse **(VES-03)** was undertaken to the north of the first sightings the **"Mystery Mounds"** (as we termed them) on route to survey the Gemini North summit with **VES-04**. A map of the summit and surrounding slopes was compiled from the echosounding data and a dredge (**VD-04**) was completed over the NW slope and summit area. **VD-04** recovered one boulder of fairly fresh plagioclase –phyric basalt with a light tan hydrothermal (?) oxide coating. This was enough material for laboratory analyses.

It was decided to follow up the Mystery Mounds with more systematic echosounding traverses (**VES-05**) in order to map their size and distribution. Our working hypotheses included possible mud volcanoes, an avalanche debris field from nearby Gemini Seamount (similar to Lihir Island), resurgent volcanic domes and older volcanic edifices. Contouring the bathymetric data proved to be difficult since the distribution of the hills seemed 'haphazard'. This observation lends credence to the debris field idea.

The scheduled science meeting at 1300hr was postponed and later cancelled, and will now be held on Saturday 8 September.

After a 3 hour delay with continuing problems with the echosounder (the reset button had shattered, a replacement board was faulty and, when fixed, the echosounder was found to ping faster), a CTD/hydrocast tow-yo (**VH-03**) was completed along a 2 mile west to east section in the middle of the Mystery Mounds. Only three of the five bottles that were triggered during the final up cast closed and these were sampled for methane and geochemical analysis. Neither an obvious transmission nor a dissolved oxygen anomaly was seen in any of the tow-yo casts.

We are still experiencing unwanted hysteresis effects with the transmission readout (the up profile is considerably different from the down profile) and it is planned to pair transmissometers for the next hydrocast.

A hill located in the NW of the Mystery Mounds area was selected as a potential dredge target in order to find out its composition. Further echosounding was carried out (**VES-06**) to define the summit at 1092m and dredge **VD-05** was hauled from NW to SE. Only two pieces of coral and a thumb nail-size volcanic rock were recovered. Two weak links were broken. Brown to light tan smears on the dredge collar suggested that the dredge was dragged over oxidised or possibly hydrothermally altered rock. The dredge was therefore repeated but further upslope, using less wire out (200m vs 300m) and **VD-06** returned a 20kg haul of basalt and mud. The basalt was olivine-feldspar phyric and moderately weathered on the outer surface. Two sediment traps were full of mud.

On balance, our work has shown that the Mystery Mounds are most likely an avalanche debris field from the Gemini North volcano.

The final operation for the day was **VES-07**, an echosounding run over a site marked on nautical charts "discoloured water 1998", around 10 miles NE of the Mystery Mounds. The seabed descended to a 1585m deep valley then over a broad rise with numerous asymmetric peaks (highest point 953m). For the final 1.5 miles approaching the 'discoloured water ' site, the floor is featureless but sloping gently north. Therefore no Seamount was detected below the discoloured water. We continued onto the southern Futuna Basin to start a new day, and conduct a single dip CTD/hydrocast **VH-04**.

Day 4
Saturday 8 September 2001

A single dip CTD/hydrocast **VH-04** was deployed to 3355m in the south of the Futuna Basin to test for hydrothermal activity. The Futuna Basin is the southern most of the three basins, which comprise the Coriolis troughs. It is around 80km long and 30km across at its widest point. A second transmissometer from CSIRO North Ryde was placed on the rosette (in bottle #3 position) to investigate by comparison the hysteresis problem (profile on down cast different from profile on upcast) on the other transmissometer. No transmission anomaly was evident. A similar hysterysis problem was found to exist in the second transmissometer but was only half as severe. The deployment and recovery of the rosette went faster than planned which allowed just enough time to collect a sediment core (using the mini corer) in the same location, before we had to depart for Tanna for port clearance for Vanuatu customs. As daylight broke, we saw nearby Futuna Island (the birthplace of one our Vanuatu geologists) and its distinctive limestone flat top. Sediment core, **VS-02** successfully recovered 55cm of yellowish mud with a number of thin, dark volcanic ash layers. 10cm of core from the bottom of the hole was lost on retrieval when the corer had to be placed back into the water to prevent excessive swaying.

A SE wind was picking up to 16 knots at nearly 0600hr when we started our transit (**VES-08**) to Lenakel, Tanna, and the rougher conditions were affecting a small number of the scientific team. We arrived at Lenakel (SW side of Tanna) at 1150hr.

We also heard the sound of an aircraft, which was probably the plane that carried two officials from Port Vila (the National Customs man and Maurice Cliff from the Department of Geology and Mines). A small outboard boat containing 2 customs officials and Maurice Cliff came along the lee side and boarded the Franklin at around 1230hr. The boat returned to shore while all paper work (and lunch) was completed and then it returned at 1400hr to take the officials back to shore. The Director of the Department of Geology and Mines will deliver the final clearance papers when he visits the Franklin on 19 September near Norsup off Malakula.

We departed Tanna for **94S02 Seamount** (renamed **Sineto Seamount** – see Day 5) at 1405hr in rougher seas and wind gusting to 18 knots from the SE. At 1845hr arrived at Sineto Seamount and concluded an echosounding traverse (**VES-09**) to check the MMAJ bathymetry map; and this proved to be accurate. A Tow-yo (**VH-05**) was conducted from west to east over the summit of Sineto. The track was sailed perfectly in 15 kt SE winds, with current to south of 0.8 kt, managing 6 casts, using lag calculations and the detailed bathymetric map to accurately determine position of CTD. The North Ryde transmissometer failed abruptly on the first up cast. On the west side of the crest, a conspicuous anomaly at 850-900m was seen where temperature, salinity and dissolved oxygen were relatively constant. Unfortunately, these went off scale of monitor mid tow so the data will have to be replotted. No light transmission anomaly was seen on the west side, but on the eastern side of the crest a small anomaly was detected at around 900m but limited in extent. The final up cast was sampled (6 bottles all fired successfully) in the positions of the anomalies, though they did not appear on this cast. Our results show that there is weak hydrothermal activity at Sineto.

Dredge **VD-07** was completed over the "oxidation zone" at the summit caldera in Sineto and yielded around 2kg of only moderately fresh to weathered olivine-plagioclase phyric basalt with oxidised crust and fragments of brown iron-oxide material of hydrothermal origin. The weak link on the dredge broke and the second weak link was deformed.

Day 5
Sunday 9 September 2001

A second dredge (**VD-08**) was done on the NW slope of **Sineto Seamount** to obtain some "fresh rock" and returned 20kg of olivine-plagioclase phyric basalt, very similar to the material dredged from the crest, but without the hydrothermal iron oxides. The sediment traps were also full of biogenic and basaltic sand and gravel. The wire out meter on the main winch is still not accurate and various correction factors have been used. The best one to apply is 1.12. (true wire out x 1.12 = metered wire out)

A planned camera tow over the southern caldera rim of Sineto was cancelled because of adverse weather conditions and continuing problems with the echosounder. The camera tow was planned for only 1 hour duration but with the time required to reset the echosounder (it was cutting out about every 10-20min) while having the camera a safe distance off bottom and then getting it back to bottom at working distance meant that the operation would have been significantly compromised.

We departed for the nearby Sineto NE Seamount and undertook an echosounding survey (**VES-10**) over the summit area which proved to be around 400m NW of where we had plotted. This 'error' was due to the large scale of original map. Because the Seamount did not have a caldera (it was conical shaped), the watch decided not to do a planned CTD/hydrocast and opted for the second part of the operation plan, a dredge on the NW slope of NE Seamount (**VD-09**). A large haul of around ten 15kg boulders of fresh, black partly vesicular plagioclase-clinopyroxene phyric basalt was recovered just before breakfast. The weak link had broken. No material was in the sediment traps. This dredge contains the first clinopyroxene we have seen as phenocrysts - it is more primitive.

At 0810hr, a decision was made not to conduct a CTD/hydrocast over NE Seamount, but instead sail to the north end of Futuna Basin to carry out a sediment core using the AGSO gravity corer. This would be done in daylight and be the first deployment for all but two of the scientific team.

Deployment of **VS-03** was delayed by 1.5 hours due problems with the tensiometer. It was deployed in 3317m of water at around 1030h and returned gushing water with cm-size fragments of an indurated dark olive mudstone and volcanic sand and grit. It clearly had not penetrated sediments.

It was decided to retry 1 mile to the south of **VS-03** in 3301m water depth with **VS-04**.

During deployment of **VS-04**, a science meeting was held at 1300hr and the previous day's operations and results were reviewed along with the plan for the next 24 hours. Sampling protocols were discussed.

VS-04 was recovered at 1418h and contained around 10 pea size fragments of fresh, black volcanic glass chips. The nose cone was damaged and it had obviously hit a seafloor of hard fresh rock, indicating very recent magmatism. This result was totally unexpected (we had anticipated a sedimented bottom) and calls for a revision of the volcanic history of the Futuna Basin.

A single dip CTD/hydrocast, **VH-06**, was also completed in the north of the Futuna Basin in the same location as **VS-04**. Apart from an unusual light transmission anomaly at 320m on the up cast, the 2975m profile looked unremarkable and showed no anomalies. Hysteresis problems were still affecting the transmissometer and in particular the interpretations of the printouts. All 11 bottles were fired to provide a background profile. Our first-time-at-sea colleague from CSIRO Petroleum had recovered sufficiently from two days of particularly bad seasickness to perform methane analysis of the samples.

At around 1700hr we commenced an echo sounding traverse SE (**VES-11**) towards the third seamount in the Chain of Lini Seamounts, Lini 3. The swell was increasing with wind from the SE at 18-20 kt. As the sun set, we had an excellent view of Futuna Island which is capped by Pleistocene coral reefs that rise 700m above sea level. Brooks Rakau's parents were born on this island which has no roads and no cars, and has an air service about twice week from Port Vila.

This chain of Seamounts was named by our team's two Vanuatu representatives, Toney Tevi and Brooks Rakau, after Dr Fr. Walter Lini, the Father of Vanuatu's independence. The heart-felt words of Toney and Brooks are given below:

The Chain of LINI Seamounts

LINI SEAMOUNTS

The name originates from the father of our independence the Late Dr. Fr. Walter Hayde Lini who died on February 21st 1999. Fr. Lini was originally from the island of Pentecost.

In 1980 after a decade of struggle, the Late Hon. Dr. Fr. Lini, through his vision, wisdom and faith (with the assistance of his colleagues), brought us out from the condominium era to an Independent state of which to day is known as Vanuatu.

In a speech after Independence he made the following opening remarks *" To day we have achieved independence and independence means freedom. Freedom from the French and British colonial masters. We are now masters of our own ship. Independence of this country is for us, for those who have died and* ***for our future generation to come".***

To commemorate the 1000th day of the nations mourning of this great leader which will end November 16th 2001, I Toney Tevi , Brooks Rakau and the people of Vanuatu would like to pay our last respect by honoring his name to these chain of Seamounts(islands one day) *"The chain of Lini Seamounts."*

For, the future generation to come, will one day, be masters of these chain of Lini Islands.

As we traversed the first crossing of Lini 3, it was apparent that it has a very flat top. On the basis that it could be a coral reef, similar to what we had seen at Futuna Island only hours before, it was decided to discontinue the echosounding run and take a sample from the summit using the Smith McIntyre Grab. At around 2300h and from 385m, **VG-01** successfully recovered a good load of pale brown calcareous sand and grit, therefore confirming our suspicions, and showing that the structure was not a recent volcano.

A dredge (**VD-10**) was successfully deployed on the western flank of Lini 3, recovering about 400g of assorted fragments of black volcanic rock, coral, shell and pebbles of pumice. The weak link broke and echosounding problems continued. Around 100m of cable was ruined during the dredging operation and had to be cut off and respliced.

Based on the results of the grab and dredge, which suggested that the potential for hydrothermal activity at Lini 3 was virtually zero, a planned 6.5mile CDT/hydrocast tow-yo was cancelled.

Day 6
Monday 10 September 2001

In the early hours of Monday morning, we headed for Lini Seamount 4A (south) and 4B (north), on echosounding traverse **VES-13**. Wind and sea conditions had abated and we enjoyed a comfortable ride. The traverse went along the NW axis of the two aligned seamounts, and then returned south to do W-E and E-W traverses across the individual seamounts to determine more accurate locations for further operations. The results of VES-13 show that the northern seamount, Lini 4B, is flat topped with strong reflectors, suggesting a foundered atoll. By contrast, the southern feature, Lini 4A is deeper (820m vs 725m) and does not appear to be capped by a strong reflector.

A Smith-McIntyre grab (**VG-02**) over the summit of Lini 4A landed on the side of the crest (882m) but recovered about 100g of black branched coral and bioclastic sand and grit. Another Smith-McIntyre grab (**VG-03**) was also completed over the summit of Lini 4B and recovered a full load of carbonate sand. At just after 0500hr, a dredge (**VD-11**) was deployed to recover rocks on the west flank of Lini 4A in 1070m water depth. The dredge got stuck and experienced persistent pulls over 3 tonnes manoeuvring the ship back and around to free the dredge. The dredge was back on deck at 0640h with a 5kg load of carbonate coated grey to black volcanic rock. Under the microscope the rock is a clinopyroxene-olivine phyric basalt in fragments about 5cm across. Giant sponge spicules, up to 0.5m long, were also recovered, as well as <1cm solitary corals.

During yesterday our Vanuatu colleagues had named the 94S02 Seamount "Sineto Seamount" and their story is given below.

SINETO seamount (formerly 94S02)

SINETO Seamount is named after a famous god that reigns what is known to-day as the TAFEA Province (Tanna, Aniwa, Futuna, Erromango and Aneityum) and spiritually, Sineto still exists and is feared throughout the province.

An explanation of how the geological location of the islands of TAFEA Province today came to existence would be best explained by a local storyteller. *"Sineto did it. One day the Tongans came ashore to "Feiava", today known as Herold Bay Futuna, on a normal regular visitation and on their return back to Tonga, took with them Sineto's only daughter, Sina Feniriki.Upon realizing that his daughter was missing, Sineto was furious. He wanted her daughter back so badly. So he got a rope and tried pulling all the islands closer to Futuna. On all the Islands he pulled, he searched for Sina Feniriki (his daughter). Upon pulling Fiji Islands the rope snapped and broke off. Thus his final mission to pull up Tonga failed. These islands use to be very far away but it was Sineto who pull them closer".* Says the storyteller.

Among the islands Sineto pulled, were Seamounts and it would only be an honor that the Seamount is name after him so that the legend lives on.

Long live the legend of Sineto! Long live the Sineto Seamount

At 0700h we sailed to Lini 7, the northern most seamount in the Lini Chain, doing echosounding run **VES-14.** The waypoint for the next operation, a grab (**VG-04**) was virtually at the summit of Lini 3 (1400m) so little traversing was required to define this location. The grab returned a good load of light to pale brown carbonate sand and grit with around 5% by volume of dark black volcanic glass and volcanic minerals of olivine and clinopyroxene. A conundrum exists why the carbonate sand contains so much fresh volcaniclastic material. The source is most likely local but from where? A dredge on the western flank of Lini 7 recovered only fawn coloured carbonate ooze. Unfortunately, no actual rocks were recovered but there is probably sufficient material in the fines to characterise rock types.

During our echosounding transit (**VES-15**) to the southern part of Erromango Basin, a science meeting was held at 1300h to review the last 24 hours and to discuss the next 24 hours. The echosounding transit showed a number of prominent normal faults on the west side of the basin as we approached its centre.

Because of the surprise result we got from the northern part of Futuna Basin (recovered fresh basalt from around 3300m depth on a flat seabed where there should have been sediment) there was some discussion about how best to tackle the southern part of Erromango Basin. It is only about 10 miles to the north, and it was considered best to deploy the small corer. A sediment core using the small corer **VS-05** was successfully deployed and recovered. A superb 1.43m-long core contained mainly a dark to medium mottled brown silty ooze, separated from brown increasingly compacted brown silty clay by a volcaniclastic sandy layer at 31cm. the mottling is due to bioturbation. Worm burrows show the remnants of this ash in the worm's trail.

A single dip CTD/hydrocast (**VH-07**) was also completed at the same station. By 1900hr, this operation was completed, with no signs of a hydrothermal plume. We commenced a new echosounding traverse (**VES-16**) to the central Erromango Basin. This showed a series of normal block faults going up slope to the shallower part of the central Erromango Basin.

A sediment core using the large AGSO corer was delayed (again) due to problems with the tensiometer on the Port GO block. For a number of logistical reasons, it was decided to forego the AGSO corer and use the small corer. The operation was designed to test a position 0.2 miles to the east of a previous site where a Japanese cruise had cored 24cm of 'black mud'. **VS-06** successfully recovered 65cm of bioturbated dark brown mud that contained darker zones. Analyses will determine the presence or absence of input from hydrothermal sources, as there was no macroscopic sulfides.

In late evening of the sixth day, a revised plan saw a single dip CTD/hydrocast become a 6 hour long tow-yo (**VH-08**) over a 6 mile-long west to east traverse across the central ridge-basin-ridge structure which was interpreted to be part of a spreading axis. No anomalies were detected in any of the casts. Unfortunately due to a mistake, all 11 bottles were fired at the bottom of the final cast, and so a geochemical profile at this location was missed. This operation also saw the start of a new watch and a new day.

Day 7
Tuesday 11 September 2001

The CTD/hydrocast **VH-08** came on deck around 0600h in good sea conditions and a 9kt wind from 100°. One sample was collected for methane and geochemical analysis.

We then dredged (**VD-13**) a 25kg haul of khaki coloured mud/siltstone, variously manganese-stained with evidence of fossil worm burrows, from the top of the main central ridge at 2500m, in the same location as 'oxidization zone' on the Japanese MMAJ- SOPAC maps. Although we failed to recover manganese rich crusts as they had done, we did recover a number of pea-size fragments of volcanic rock from the sediment traps amongst the light brown gritty ooze. There was also a strange looking black cigar shaped but highly delicate piece that turned out be silica rich under the microscope and is a type of coral. This dredge gave important geologic information. First, the horst-graben block-faulted structures are indurated sediments (or basement) and are not especially prospective for the sort of hydrothermal activity we are seeking. Secondly, the black volcanic glass and fragment recovered in the sediment trap are not locally derived and probably come from the volcanic arcs to the west. The fragments are possibly the same as we recovered from the tops of the Lini seamounts to the SE and reflect a widespread distribution of fresh volcanic rock fragments. Geochemical analyses of the chips will test this hypothesis.

Following the dredging operation **VD-13**, we sailed to the middle of a sub basin in the west of the Erromango basin where a single dip CTD/hydrocast (**VH-09**) was completed in 2800m water, again with no indication of hydrothermal activity. Seven

bottles were successfully fired and sampled for on board methane analysis and on shore geochemistry. The ship moved NW to a grab operation (**VG-05**) to sample an 'oxidised zone' identified in an earlier Japanese cruise. The grab recovered dark brown mud but no evidence of oxidised rocks. The fines in the mud consisted of black glassy fragments, again suggesting that these are spread far and wide in the Erromango Basin and to the east in the Chain of Lini Seamounts. Indeed, black glassy fines were seen on the surface of the mud. This suggests quite recent volcanic activity, but not necessarily local derivation.

At 1300h, a science meeting was held during transit to the western part of the Erromango Basin to test another sub basin (6x4-mile) using large gravity corer and CTD/hydrocast. The meeting reviewed the results of the past 24hr and their implications and discussed the plan for the following 24hr. Sampling protocols were fined tuned.

During retrieval of the last Grab (**VG-05**), the CTD wire was damaged and had to re-terminated. This is an engineering problem and should be avoidable with a proper deployment and retrieval protocol. Avoidance relies on safe and careful deployment of the grab while ensuring that the CTD cable has just enough play not to become kinked.

The Port GO block and tensiometer for the AGSO gravity corer on the main aft A frame was being fixed, prior to the next waypoint. This posed a conundrum, as our one technician, Erik Madsen, could not do two things at the same time. It was decided to once again cancel the use of the large corer, and deploy the small corer so to give time for the hard working technical staff to mend the CTD cable; and have this equipment ready for deployment immediately after the coring operation. To Erik's credit this was done expertly, in good humour despite lack of sleep. **VS-07** was successfully deployed, with a pinger 100m above the mini corer, to a depth of 3019m. It recovered 32cm of dark brown clay, partly laminated with several bands of coarse-grained volcanic ash. A single dip CTD/hydrocast (**VH-10**) was deployed at the same location, but failed to record any indications of hydrothermal activity.

At around 1800hr we set a NE course across the northern part of the Erromango Basin to investigate Masaga Seamount that, based on the published seabeam bathymetry, has two peaks. We called this Masaga, a Futuna dialect for 'twin', as explained by Brooks Rakau. The 'g' is pronounced as 'ng'. The echosounding traverse continued to confirm the block faulted, horst and graben architecture of the northern Erromango Basin, and we mapped the two peaks at Masaga.

A grab (**VG-06**) was deployed to sample the summit of the southern higher peak and returned with coral, shells, grit, sharks teeth and one tiny fragment of manganese rich crust. A dredge (**VD-14**) was then expertly executed up the western slope of the southern peak of Masaga and returned about 20kg of subrounded blocks/cobbles of olive brown, coarse grained poorly sorted sandstone with 5mm manganese crusts. A large 70x45x15cm slab of manganese encrusted brown mudstone contained a fossil leaf. This was a surprising result as we thought we would dredge volcanic rock but none was recovered. Based on these results and the absence of any indications of hydrothermal activity, a planned CTD/hydrocast was not done.

By 2300hr, we had completed planned operations in the Erromango Basin and proceeded to conduct an echosounding traverse (**VES-19**) from Masaga Seamount to a suspected rift valley, 25 miles NNE.

Day 8
Wednesday 12 September

The south side of the suspected rift zone was extremely steep, without the series of faulted steps that characterises the Erromango Basin. A sediment core using the small corer (**VS-08**) in the deepest part of the valley at around 2600m recovered 1.7m of olive brown clay. There were no macroscopic signs of hydrothermal input. A single dip CTD/hydrocast (**VH-11**) at the same position also failed to indicate hydrothermal activity. Eleven bottles were fired at staged depths in the water column. Every second sample was analysed for methane on board while all bottles were sampled for later on shore geochemical studies. Our work in this suspected rift valley showed that it is probably old and inactive.

At about 0600hr we heard the first news reports of the mind-numbing terrorist attacks in New York and Washington on Tuesday morning their time. This was to dominate everyone's' thoughts and conversations for the rest of the day and beyond.

A course was set to the NW out of the suspected rift valley to survey a prominent topographic feature, which could be part of a core complex (**VES-20**). We mapped the feature during the echosounding run and sampled its summit at around 800m with a grab, **VG-07**. Abundant black coral pieces and a small quantity of manganese-rich fragments of sandstone and basalt were recovered. Dredge **VD-15**, sampled the north west slope of this 'core complex' and returned a good haul (50kg) of cobbles of brown manganese encrusted, highly bioturbated, poorly sorted sandstone and grit (90%) and cobbles and pebbles of manganese encrusted olivine phyric basalt. The centres of the basalt cobbles are fresh and suitable for chemical analysis. The results showed that this was not a core complex (we are about 10Ma too early) but they do raise many questions about the tectonic history of the region. In terms of hydrothermal activity, there was insufficient encouragement to warrant a CTD/hydrocast at this location.

An echosounding traverse (**VES-21**) commenced just before lunch to the south of Vate Basin. During this time 100m was cut from a damaged (from dredging operations) main winch cable and respliced. A science meeting was held after lunch at 1300h where the previous 24hr were reviewed, and plans for the next 24hr discussed. Not all scientists attended.

A single dip CTD/hydrocast (**VH-12**) was deployed to just above bottom at 2610m in the south Vate Basin but failed to detect any signs of hydrothermal activity in the water column. It drifted 200m north of the waypoint during the operation. Eleven bottles were fired successfully and sampled for later geochemical analysis. At the same location the small corer (**VS-09**) recovered an 82cm-long core of mostly brown mud with one 5cm-wide soupy sandy layer and one prominent black layer.

Echosounding traverse **VES-22** commenced around 1630h on a NW course of around 8 miles to a prominent hill (called here Nan Hill=Need Another Name) which forms part of a broad linear trend of topographic highs that frame the western side of the Vate Basin. To the best of our knowledge, this feature had not been sampled previously It is in a similar position to Sineto Seamount near Erromango Basin and thought to be possibly hydrothermally active. Two operations were planned at 'Nan Hill'. The first, a grab (**VG-08**) from the 950m deep summit recovered a good piece of pillow lava plus a few cubic centimetres of foraminifera-scaphopod and shelly sand with sharks teeth. Evidently, the grab hit an outcrop of relatively old pillow lava. The second planned operation was a dredge along the NW side of Nan Hill, but this was cancelled due to the success of the grab.

At 2130hr we moved into the central part of the Vate Basin where side scan sonar showed a strong reflector, and a 'hooked' shaped easterly ridge rising to around 1850m. This seemed to offer good potential to host hydrothermal activity as it has analogies with Pual Ridge (host of the PACMANUS field) in the Manus Basin and may be the centre of a pull-part or opening within an opening. Success! A weak ~90m-thick plume transmission signal of around 0.2% was located between 1730m and 1820m, close to the bottom. Later methane analyses showed a pronounced spike of close 30nl/l at 1755m compared with a background of around 11-17nl/l. A dredge, **VD-16** , was positioned along the ridge but it on recovery it was found to be empty except for three sediment traps containing brown silty mud. The fishnet liner in the dredge was extended outside the chainbag, which suggests the bag was full of sediment that washed out when hauled through the water. Following the success of **VH-13**, and further single dip CTD/hydrocast (**VH-14**) was done around 3 miles to the NE of the ridge. This failed to record a transmission anomaly. Eleven bottles were fired and sampled for geochemistry but none were sampled for methane as the GC operator desperately needed some sleep. The depth was much shallower than expected from seabeam bathymetry (2135m vs 2450m).

Day 9
Thursday 13 September

A 16 mile transit (**VES-24**) was made NW to a sub basin in the west of the Vate Basin. It is the deepest part of the Vate Basin at 2800m, and was considered to have potential for sediment-hosted mineralisation. The AGSO gravity corer was deployed (**VS-10**) but got zero recovery. Its nose cone was damaged and it must have hit hard rock. The Chief Engineer again reamed the nose cone for reuse. The side scan sonar image of this area indicates sediment cover but it could be thin. A single dip CTD/hydrocast (**VH-15**) to 2000m failed to detect any anomalies that could be hydrothermal. Eleven bottles were fired and sampled for geochemistry but none were sampled for methane. It was decided to collect a grab sample at this station and **VG-10** returned a good haul of brown mud. (Note that operation number **VG-09** was skipped by mistake) Push cores revealed no layering but the mud got stiffer with depth at around 10cm. Fines revealed mainly foraminifera and a small volume of fine black grains. Fines were also observed on top of the sample. The AGSO corer was deployed 0.1mile to the SE to try to obtain a longer core. **VS-11** returned with a damaged nose cone, later reamed for reuse, around 400g of black shiny volcanic glass fragments (clearly tops of recent flows) and a couple of pumice pebbles. This was a remarkable result for it demonstrates that there is active recent

volcanism in the basin. Here it seems that a thin (10cm) layer of sediment overlying fresh volcanic rocks covers the basin. This was the third piece of evidence of recent volcanism in the Coriolis Troughs collected to date during VAVE.

At lunchtime, we commenced a transit (**VES-25**) SE, back to the area we now call '**Nifonea**' ridge, a local dialect word for "hook" (the shape of the ridge), to follow up the hydrothermal plume detected in VH-13. A science meeting was held at 1300hr during the transit, and various housekeeping issues were attended (e.g. sorting out weak links and shackles). A camera system test to 500m was successful prior to a single dip CTD/hydrocast **VH-16** being done around 3 miles west of VH-13. VH-16 recorded a stronger (0.7% reduction in light transmission) and more complex-structured anomaly, suggesting that it is closer to the source. This was a very exciting development. Samples were collected from below, within and above the plume both for methane and geochemical analysis.

A dredge (**VD-17**) was deployed with the aim of sampling the northern scarp of Nifonea ridge. A large haul of pillow basalt was recovered. Weathering of rinds suggests that it not recent.

A single dip CTD/hydrocast (**VH-17**) was done 3 miles south of VH-16, on the north south trending section of Nifonea ridge. The aim was to pin the direction of the plume and zero in on the source of the plume with further CTD dips and camera tows. A 0.7% transmission anomaly was detected, slightly lower than the transmission anomaly in VH-16, but is still significant.

Two further single dip CTD/hydrocasts were completed on Day 9 of VAVE 2001. The first was **VH-18**, 2 miles W of **VH-16**, and the second, **VH-19**, 2 miles to the N. **VH-18** recorded a 0.4% transmission anomaly, while **VH-19** failed to detect the plume. These results indicated that the eye of the plume lay south of VH-16. CTD/hydrocasts were being done quickly and the efficiency of the bridge, crew and scientists to handle the volume was exemplary.

Day 10
Friday 14 September 2001

At the start of Day 10, an echosounding traverse (**VES-26**) was run over Nifonea ridge in preparation for our first camera tow (**VV-01**) of the expedition. Both were completed successfully. The camera tow was positioned between two anomalous hydrocasts, **VH-16** and **VH-17**. At least four zones of hydrothermal material were photographed, with the biggest and the best field being near the end of the tow. Lava morphologies such as sheet flows and ropy lava suggest high lava fluidity, close to source. Some fresh, black basalt was recovered by the camera during one of its hits on the bottom.

All bathymetric data from the various operations completed in the Nifonea ridge to date were meticulously compiled onto a 1:50, 000 scale map in order to provide a suitable scale map for planning and recording.

Two further single dip CTD/hydrocasts, **VH-20** and **VH-21**, were completed 1 mile SE of **VH-16**, and 1.5 miles SW of **VH-16**, respectively. **VH-20** recorded a 1.2%

reduction in light transmission, an anomaly of higher intensity and as complex as the one seen in **VH-16**, but **VH-21** recorded a weaker light transmission anomaly of around 0.7%. We had planned for a further CTD/hydrocast and dredge but at 1000h problems with the bow thruster postponed the start of these operations. Instead we conducted a 3kt echosounding traverse (**VES-27**) to fill in gaps in the bathymetric coverage between VH-20 and the newly discovered hydrothermal deposits. Fortunately, the problems with the bow thruster were fixed and at lunchtime we deployed a single dip CTD/hydrocast (**VH-22**) 1 mile E of **VH-20**. This hydrocast recorded a similar good result to **VH-20** and returned a very high methane concentration within the light transmission anomaly of around 77nl/l compared with a background of 20nl/l. This good result enabled a narrowing down of possibilities to locate the source of the plume. A dredge (**VD-18**) planned to collect samples from the biggest of the hydrothermal fields photographed in **VV-01**. The dredge was expertly deployed. It recovered black, fresh, 'frothy' highly vesicular, sheeted basaltic lava but no hydrothermal chimney material. The basalt surfaces were covered in part by a tan coloured precipitate, possibly hydrothermal in origin.

Problems with the bow thruster delayed a start of a second camera-video tow (**VV-02**) around 0.15 miles to the north of the first tow. The aim of this operation was to get a better fix on the position and extent of the hydrothermal deposits.

The camera tow was off bottom at 2000hr, and was followed by a dredge (**VD-19**) and CTD hydrocast (**VH-23**). Unfortunately the camera had focus problems and the footage was blurry (the cause of which was traced to a technical issue of turning the camera off before disconnecting power). It did, however, record vent fauna over a 16 minute period, coinciding with temperature (1.2°C above background) and salinity anomalies (negative) measured by the CTD mounted on the camera frame. This result gave us much encouragement, and there were smiles all around. When the camera track was plotted, it appears that the vent field photographed during **VV-02** could connect with the inactive site pictured in **VV-01**.

Dredge **VD-19** was designed to collect samples from the hydrothermal deposits we photographed in **VV-01**. It recovered only about 20g of black volcanic glass, which will be sufficient for on shore analyses.

Day 11
Saturday 15 September 2001

CTD/hydrocast **VH-23** was aimed at closing off the Nifonea hydrothermal plume to the SE. To this end, it was successful, recording a relatively low peak reduction in light transmission of around 0.4%. The four Niskin bottles fired during the operation had their vent valves open a small amount. Methane analyses appeared to give reasonable numbers in spite of this. The hydrothermal plume has been constrained in space and its source is in a graben within Nifonea ridge.

A third video camera run (**VV-03**) was done around 0.12 mile NE of **VV-02** in order to see if the vent fields extended in this direction. Unfortunately the camera light blew 36 minutes into the tow over lightly sedimented ropy lavas and lava rubble with the occasional anenome and rat tail fish. Later in the tow, the camera mounted CTD showed coincident and significant temperature (+1.2°C) and salinity anomalies

(negative) clearly reflecting active hydrothermal venting. The results indicate that the hydrothermal activity does extend another 0.12 mile to the NE. Some fragments of black glassy basalt were found on the top of the sea battery in the camera cage but it was uncertain whether they were collected during **VV-03** or an earlier tow.

The weather thus far has been fairly constant and predictable, with a SE wind at 10-20kt and pleasantly warm days. The swell is variable 1-2m. Today the wind is more from the east and it is cloudy and overcast, and more humid.

A dredge (**VD-20**) was aimed at the vent field defined by camera tow **VV-02**. It returned a 1/8 bag of Mn-coated vesicular black basalt, mainly wrinkle flow surfaces but no hydrothermal material. A grab (**VG-11**) was launched in the same position but it came up with no sample. Given our lack of success in dredging hydrothermal material it was decided to change the direction of the next dredge to go NW along the perceived strike of the vent field. This was not an optimum operational direction as the wind was from the SE, which meant it was abeam to the ship. The Master was willing to give it a try. **VD-21** achieved its aim and returned around 70kg of black, fresh highly vesicular basalt with significant light tan hydrothermal staining and precipitates, on fractures and in vesicules. Around 20 small pieces of light tan material were collected for on shore studies. In addition, a mussel and pieces of mussel shell, two small shrimp (possible galatheid crab?) and one scale worm were also recovered, indicating that we had successfully sampled the fringe of a hydrothermal vent field. Another dredge (**VD-22**) was deployed east of **VD-21**, with the aim of getting closer to the main vent field and deposits. The haul was around a 1/8 bag full of black, glassy, ultra fresh and very young basalt, including several fragments of crusts of a tube flow with drain back features on under surface and glassy rims. No fauna was present, and there was no staining of iron oxides.

The regular 1300hr science meeting was postponed to 1400hr because of preparations for a fourth camera tow, **VV-04**. Because of time constraints, it was decided to complete one last dredge following the camera tow before departing Nifonea. **VV-04** was designed to traverse west to east between **VV-02** and **VV-03**. A problem with the bow thruster during deployment caused the ship to drift west of the first waypoint. Consequently, it was not possible to complete the entire length of the 1 mile tow as planned. Additionally the lag of the camera behind the ship was greater than normal. The light on the camera was been knocked side ways during the tow but still provided usable illumination throughout.

The final dredge at Nifonea, **VD-23**, was to sample the vent field close to the most successful previous dredge, **VD-21**. It returned a 50kg load of light tan stained fresh, highly vesicular, glassy sheet flows and tube flows. Nontronite was noted in one sample. Several small pieces of shell were also recovered. No sulfides were recovered.

Overall our work at Nifonea was highly successful. From the beginnings of a 0.2% light transmission anomaly in a hydrocast we mapped a plume, and traced its source, leading to the discovery of a new hydrothermal vent field in a back arc basin, and recovered hydrothermal materials, all in two days! In addition we gained considerable insight into the lava morphologies and the style of hydrothermal

activity in a very young environment. To the best of our knowledge, this is the first field of its kind found in Vanuatu waters.

Later analysis of the light transmission anomalies, methane results and camera tows showed the following:

- The plume is elongate in a NW-SE direction, mimicking the direction of the graben on Nifonea Ridge and possibly a weak NW current.

- The plumes defined by light transmission and by methane gas analysis are virtually coincident and therefore most likely sourced from the same vent field.

- Areal extent of the plume is 10 x 6 km or around 60 square kilometres.

- The plume is thickest (150m) between 1600 and 1750m (about 150mab) and most complex around **VH-20** and **VH-22**. Both these hydrocasts recorded maximum drops in light transmission of around 1.2-1.3% and methane gas concentrations in the 50-77 nl/l range. A smaller plume is also evident at around 1820m, closer to bottom in this area, which is further evidence of proximity to the source.

- Distal from the main area, the plume is diluted with respect to particulate matter and methane gas and is thinner (50-60m). Light transmission generally drops by around 0.2-0.4%, and methane gas concentrations are around 30nl/l.

- Evidence of hydrothermal activity by way of deposits on the sea floor, biological activity and temperature and salinity anomalies was recorded on all four camera tows at Nifonea.

- At least three separate zones of activity were mapped within an area measuring 2400m -across and 600m-long (approximately 1.4km^2). Assuming continuity of hydrothermal activity between camera tows the biggest of the three fields is around 600m x 400m, and is open to the NE and SW.

At around 1900hr, we sailed for the start of **VES-28** to survey a ridge slightly north of the central Vate Basin. The crest was surveyed and found to be shallower than shown on published maps. A CTD/hydrocast (**VH-24**) failed to find any sign of hydrothermal activity, and a grab (**VG-12**) returned fresh basalt indicating young, recent volcanism.

We then sailed to the Temakons Seamount. This had been numbered by the Japanese as **94S01**, but we named it after the former and highly respected Director of the Republic of Vanuatu Department of Geology, Mines and Water, Mr Stanley Temakon.

Day 12
Sunday 16 September 2001

A large part of Day 12 was spent surveying Temakons Seamount. The wind was coming in gusts up to 20kt from the east, and the sky was overcast. Several rain squalls punctuated the day, and after lunch saw the postponement of a camera tow and further dredging as conditions for these operations were deemed unsafe. Day 12 will also be remembered as the day we lost the red dredge.

The day commenced as the 12-4 watch completed an echosounding run over the Temakons Seamount, and especially to discern possible fault structures not apparent on the bathymetric charts. No faults were seen within the caldera on the north-south line but 2 significant faults were mapped on the east inner wall, corresponding to changes in slope on the bathymetric maps.

A single dip CTD/hydrocast (**VH-26**) was completed in the NE part of the caldera, where earlier work had reported active venting. No transmission anomalies were recorded although there was severe hysteresis (temperature equilibration of the transmissometer) giving an apparent anomaly 20mab. Three bottles were fired in the "anomaly". There was an unusual dissolved oxygen profile near the thermocline base 450-600m, and also a step in the temperature around 500m. The methane analyses showed a 31.1nl/l anomaly at around 750m but not in the transmission anomaly 20mab.

A dredge (**VD-24**) was designed to sample an area of hyrothermal activity in the NE of Temakons Seamount. Because of wind from the NE, the direction of the haul was changed from the original SE plan to NE. The dredge did not make it back to the surface, as all weak links broke. The lead weight and the safety chain came back. A reconstruction and post mortem showed that the change of the dredge direction had placed the dredge on the down side inner fault scarp defined by the echo sounding traverse, but the watch had not recalled this result, communicated to them by the earlier watch. The dredge was anchored on the cliff of the inner caldera wall when it was being raised. Lessons learnt included always do an echosounding run over the dredge path prior to deployment. This would have alerted the watch to the fault scarp and the implications of the sudden depth change. A single dip CTD/hydrocast (**VH-25**) in the throat of the caldera failed to record a transmission anomaly. Four bottles were fired for methane and geochemistry but 6 hours later it was discovered (too late) that the bottles had not been sampled for geochemistry. The transmissometer continued to show serious hysterisis effects on the up cast. A grab (**VG-13**) sampled the centre of the Temakons caldera and returned a small stratified load containing 2cm of deep brown ooze overlying 2cm of pepple to sand sized basalt cinders with minor orange flecks, possibly hydrothermal in origin. The site would not have been suitable for the AGSO corer.

The white dredge was prepared for its first duty of the cruise, and **VD-25** aimed at the NE hydrothermal field where the red dredge had found its resting place. It returned promising looking black glassy basalt that was strongly vesicular with well developed glassy rinds and tube structures, variously coated with a red-brown iron

oxyhydroxide along fractures. No sulfides were recovered. Just after lunch a video tow was planned over the northern caldera rim.

The weather was heaving the stern of the ship 2-4m, and the wind was gusting 20kt from the ENE. It was decided to postpone the tow and cease all further dredging operations until conditions improved. What followed were 4 successful grab operations: **VD-14**, **VG-15R** (a repeat of **VG-15**, which failed to trigger), **VG-16** and **VG-17R** (a repeat of **VG-17**) around the caldera rim.

The highlight of this work was the recovery in **VG-15R** of a full load of red-brown hydrothermal material with fumerole like structures from the SE of the caldera. The red brown material formed a cap over nontronite rich material and watery to stiff black sandy grit. One galetheid crab was found in the mud. It was an undisturbed sample and much photographed by the scientific team, and clearly an excellent example of an active, low temperature hydrothermal deposit. The other grab samples returned very fresh and vesicular volcanic tube flows (and sand size equivalents) with variable amounts of red brown staining on fractures and the underside of flow tubes.

On that positive note, we departed the Temakons Seamount for Stanley Seamount at around 1900h completing echosounding traverse **VES-30.** The Stanley Seamount (subsequently renamed VAVE Seamount late in the cruise at the behest of our Vanuatu colleagues) was encountered earlier and is more elongate in an east-west direction than expected. There is probably another pimple about 0.5 mile to the east. A single dip CTD/hydrocast and a grab operation were completed over the summit of the Seamount. **VH-27** did not record any significant anomalies and the irritating transmission hysteresis continued on the up cast. The grab (**VG-18**) returned about 10cm of undisturbed unlaminated, sandy sediment, a mixture of black sand, foraminfera and ooze. Two rocks were included in the sample and two blackened corals were sticking up, one deeply rooted in sand.

We set forth toward Roimata Seamount, named after a famous local chief (see below as told by Brooks Rakau).

Roimata Seamount.

"Roimata", the name well known to all present inhabitants of Efate. He was famous then during his reigning era. Chief Roimata died centuries ago, but his name prevails as one of the inspiring leaders of his time, and one that all indigenous Efateans talk about when it comes to leadership issues.

Chief Roimata was one of the highly respected chiefs on the island of Efate, the island where the capital of Vanuatu is situated. He was known throughout Efate, and the neighboring Sherpards islands. He was known as a peacemaker. His intention was for every village's around Efate to live peacefully, in harmony, and not hatred. This was not an easy thing to do during those days of cannibalism and tribal wars.

Chief Roimata was the first Chief known to the people of Efate to stop two tribal communities from tribal war. These communities were however miles away from his area of reign.

During his death, the whole population of Efate and the Neighboring islands moaned. Chief Roimatas wives and some of his followers were buried alive with him. This was to show their allegiance for him and believed that they would serve him in the "next World".

Roimata seamount is named after this great chief who was a great leader during his time, and will be an example for all chiefs around Vanuatu.

The 17 mile WNW transit to Roimata Seamount included **VES-31.** The Seamount is around 3 miles NNW of its estimated position, from the regional map supplied by the French. It is also considerably shallower at 486m (vs 700m).

Day 13
Monday 17 September 2001

A single dip hydrocast (**VH-28**) was completed over the summit of Roimata Seamount. No transmission anomalies were observed, but there was a curious temperature and salinity drop at the bottom of the cast. Samples were not collected for methane analysis, but all three bottles fired were sampled for geochemical studies.

A grab (**VG-19**) on the top of Roimata Seamount recovered around 20g of old-looking basalt and some coral pieces.

A transit (**VES-32**) was then done towards Roimata #A, a distance of about 8 miles NW. The echosounding work showed that the Seamount is conical with a maximum height of 400m. Because of strong winds gusting to 24 kts and opposing strong current the Franklin was unable to remain on station and so single dip CTD/hydrocast, **VH-29** was aborted at around 160m depth. For the same reasons a planned grab was cancelled.

A further echosounding traverse (**VES-33**) was done to Roimata #B but it was interrupted by a change of course towards Roimata #C as the nautical chart showed a 2010m deep-hole at #B, rather than a topographic high. Suveying around Roimata #C identified a summit knoll at around 360m, and a shoal of fish over the summit. Sea conditions and wind made accurate deployment of both the CTD and grab very difficult and it was decided not to do them.

Discussions followed and it was thought that the hole at Roimata #B, if real, could represent the caldera of a very large volcano, so the ship headed toward Roimata #B just as breakfast started, on an echosounding run, **VES-34.** A very detailed and new bathymetric map was subsequently made of Roimata #B , which looked completely different from the published nautical chart 1570. Instead of a 2103m-deep, the survey showed two high features at approximately 400m depth and an ENE trending saddle around 750m in between them. Two grabs, **VG-20** and **VG-21**, were taken over the north and south hills, repectively and a single dip CTD/hydrocast (**VH-30**) was completed over the saddle between them. A short east west echosounding run, **VES-34A**, was done prior to doing VG-21 to obtain better accuracy. This showed the southern knoll to be simple cone with a crest at 404m. The first grab, **VG-20**,

returned around 20g of volcanic sand, shell, coral and reddish brown carbonate cement breccia, and a small pebble of pumice. The second grab, **VG-21**, did not fire (probably 'kited' and did not hit bottom), and so it was repeated as **VG-21R**. This grab also kited but recovered about 300g of rubble of black manganese oxides with colloform banding. The largest piece was a kernel of vesicular basalt overgrown by a thick 4cm crust of Mn oxides. Shell fragments are embedded in the crust, and coral was growing on one piece. The thickness of Mn crust is impressive, and indicates that this feature is most likely an old volcano. The Mn crust will be analysed on shore. The single dip CTD/ hydrocast at Roimata #B failed to register any transmission anomaly. The lowest sample, however, was anomalous at around 28nl/l methane which suggests that some very low temperature venting may be present in the saddle or rift between the two 'old' knolls.

A science meeting was held at 1315hr and a review of the past 24 hours was done and the plan for the next 24 hours was discussed.

A new transit and echosounding run, **VES-35**, was done between Roimata #B Seamount and Forari Seamount (named after defunct manganese mine on Efate), 17.5 miles to the NE. This survey showed the Forari seamount to be box-shaped feature, like a 'table top mountain'. A planned CTD was not done, and a grab (**VG-22**) returned a good load of sand comprising about half pumice and the rest volcaniclastic mixed muddy material with foraminifera and shells. No manganese oxide or other evidence for hydrothermal activity was evident.

A traverse was made to the east to investigate a large area with a small hill, Forari #A. The echosounding survey downgraded the prospectivity of this feature and it was decided to do no further work.

A further transit S reached a flat plain where the small corer was deployed for sediment core operation **VS-12**. A short 12-cm core was recovered containing two ash layers and foraminifera. On this basis, the large gravity corer was planned for deployment 0.5 miles south of **VS-12**. Since the ship was having difficulty in maintaining station due to wind and current it was calculated that the ship would drift into the position of **VS-12**. *A fault in the tensiometer block caused a cancellation of the operation, which nevertheless was given a number* (**VS-13**). This was very frustrating as we thought the problem had been fixed. We need to get this AGSO corer working efficiently!!!

A 2 hour transit followed to Shepherd Knoll, 5 miles off the east coast of Shepherd Islands.

Day 14
Tuesday 18 September 2001

Our echosounding survey, **VES-38**, around Shepherd Knoll showed a series of irregular fault blocks (or possibly debris flow blocks), and downgraded it as a volcanic feature worthy of detailed study. Accordingly, the planned CTD and grab were cancelled and the ship sailed NW onto Epi Knoll, off Epi Island, recording bathymetric data (**VES-39**) on the way.

Operations at Epi Knoll included the continuation of the echosounding run over the feature, a single dip CTD/hydrocast (**VH-31**) down to 789m (about 15mab) and a grab (**VG-23**). No light transmission anomalies were seen, and the large hysteresis problems continue to plague the instrument. Four samples were collected for geochemistry and methane. The transmissometer failed on the upcast and may have taken some moisture. This problem was fixed by the technicial staff. **VG-23** recovered a good load of sediment which included two

very distinct layers of black volcanic ash/sand covered and separated by units of brown mud. The sequence is similar to the one recovered in core **VS-12**, south of Forari, except that **VS-12** did not have brown mud on the top.

At 0615hr, close to the entrance of Kuwae caldera, the weather conditions were poor. We faced low cloud, poor visibility, wind gusts up to 32kt and a rain cell centred over the area. The Master was not prepared to sail into the area under these conditions. It was therefore decided to sail 16 miles NE and conduct a sediment corer (**VS-14**) on a break in slope at 2233m using the AGSO gravity corer. In day light, the problem with the tensiometer which prevented deployment of **VS-13** the night before, was found to be with an oversize shackle connected to the A frame, putting unnecessary tension on the block. The point of contact between the shackle and the A frame was greased and this seemed to fix the problem. Smiles all around. Also by the time the corer was well on its way to bottom the sun had come out momentarily, and it had stopped raining. Even the seas seemed to be less bumpy. **VS-14**, to the amazement of all aboard failed to recover sediment. Instead, it recovered around 20-30g of rounded pumice pebbles and black fine grained volcanic sand. The nose cone returned in re-useable order and the barrel with a very slight bend but was also re-useable. The deployment and recovery went exceptionally well in moderate seas.

At 1000hr we sailed west towards Kuwae caldera between Epi and Tongoa Islands. This was the scene of the second largest volcanic explosion in recorded human history, after Tambora in Indonesia, and is thought to be about 3.5 times larger than Krakatoa. Eruption is timed at around 1453 AD and there is circumstantial evidence that it caused cold summers in the northern hemisphere, and was a factor in the siege of Constantinople and eventual fall of this city to the Ottoman Turks. Ice cores in the Antarctic record a volcanic ash layer at this time, also attributed to the Kuwae eruption.

An echosounding run (**VES-40**) was conducted to Kuwae. The highlight was passing over the caldera rim and measuring a vertical drop of around 150m. We had excellent views of the islands and especially Fatu Miala rock. We could see the small rock the l'Atalante had hit in 1996 between Laika and Tongoa, called Somerville Bank (perhaps after the Master of L'Atalante?). The story behind the L'Atalante's hitting the rock was that it was doing multibeam swath mapping, and the rock was not evident on two previous swaths. Locals on the nearby island were flashing the ship with mirrors, attempting to warn of the impending danger. Outcrop is shown on the 1:100,000 scale geological map. The wind was gusting to 25kt from 125° and the white caps with current up to 1.5kt to SW made for difficult working conditions and the ship struggled to maintain position.

In the 5 hours in Kuwae caldera, we completed 9 operations: 3 echosounding traverses (**VES-41, 42 and 43**), 2 single dip CTD/hydrocasts (**VH-32** and **VH-33**), 2 grabs (**VG-24** and **VG-25**), and 2 sediment cores (**VS-15** and **VS-16**), split equally between the NW basin and the SE 'basin' of the caldera. We were unable to get close to the Karua dome due to the adverse weather and currents. The large number of completed operations reflects the shallow depth of the Kuwae caldera and the consequent short deployment and recovery times.

The grabs indicate that the floor of the caldera consists mostly of black volcanic sand with minor pumice, foraminifera and shell pieces. **VG-25**, from the SE area of Kuwae contained significant quantities of pumice and volcanic pebbles grading upwards into a finer sand silt. This is extremely difficult to recover in the sediment core (mostly grains of volcanic sand in the catcher and sock), and in fact superior results were obtained by the Smith-McIntyre grab.

Refractive index work showed a bimodal population of rock types on the floor of Kuwae. The main type is dacite (63-64% SiO2) and the second, less abundant variety is basaltic andesite (56-57% SiO2). Hydrocast operations showed a weak transmission anomaly at around 180m depth in the NW (**VH-32**) but this position had no corresponding methane anomaly. A strong methane anomaly of around 60nl/l was measured at 464m, about 20mab in **VH-32**. **VH-33**, deployed in the SE 'basin', detected a light transmission anomaly from 220m to ~260m, corresponding to a salinity kick and a temperature drop. This zone also contained anomalous methane of around 55nl/l in a sample at 250m depth. Traces of ethylene were also detected in shallow depth samples at 50m in both hydrocasts. The CTD developed a technical problem but this was rectified.

At around 1600hr we left the Kuwae caldera for Volcano C, east of Epi and around 2.5 miles east of "discoloured water" noted on the nautical chart in quite shallow depths of 39m. This is the same area examined by Exon and Cronan in 1974 who reported the geochemical results of a series of grabs (Exon and Cronan, 1983). We were later to rename Volcano C and associated features, Cioan Volcano, after Mr Chris Ioan, the current Director of the Republic of Vanuatu Department of Geology, Mines and Water Resources. A limited echosounding survey (**VES-43**) was inconclusive in providing a crestal position for Volcano C and a single dip CTD/hydrocast (**VH-34**) was done followed by a grab (**VG-26**). By this time of the day the wind had dropped to around 15kts and the seas were not as bumpy. The grab drifted from the position of the hydrocast and returned a 8cm-thick pumice layer on top of 3cm of brown mud. Petrology and refractive index work showed the pumice to be dacite-rhyodacite in composition (69-72% SiO2), the most siliceous rock recovered thus far on VAVE. The results of the hydrocast were spectacular. Methane gas analyses returned some of the highest concentrations yet found during VAVE and the deepest 3 samples, between 250 and 337m, yielded 68 to 93 nl/l, increasing towards the seafloor. A weak (0.2%) but definite light transmission anomaly was seen at the lowest point of the cast. There may be other light transmission anomalies when the data are looked at in more detail, but the strong hysteresis effects hinder real time interpretation.

We plan to return to Cioan Volcano following sediment coring operations in the Aoba Basin.

At around 1900hr we departed for a 57-mile long transit (**VES-44**) to the southern part of the Aoba Basin. The traverse crossed the off shore extension of a large volcanic rift on Ambrym and we obtained some excellent echosounding images of a raised saddle ridge.

Day 15
Wednesday 19 September 2001

Approximately 30 miles east of Malakula, and on the lee side of Ambrym Island enjoying calmer conditions, we deployed the AGSO corer to obtain a sediment core from 1650m depth in the south Aoba Basin. **VS-17**'s nose cone was lightly smeared with black silt, and a tiny amount was caught on the inside of the core catcher but unfortunately was not retained. A repeat core (**VS-17R**) recovered ~5g of black volcanic sand, again, not a particularly satisfactory result. A grab (**VG-27**) was deployed in an attempt to get a better sample. The grab returned around 300g of very dark coloured viscous silty sediment. This sample was placed in a medium size plastic vial and stored in the freezer.

We departed this station and headed for Norsup (**VES-45**) to bring aboard four guests who will stay on the Franklin for the day. The guests were Mr Chris Ioan, Director of the Department of Geology, Mines and Water Resources, The Republic of Vanuatu; Mr Floyd Cardinal, President, Interwest (Vanuatu) LTD; Mr Nick Pitsas, CSIRO Manager for Multimedia; and Mr Brad Collis, a freelance journalist specialising in science.

At 0700hr, passing Uripiv Island on port, we hove to near the NW side of Norsup Island, well in view of the township of Norsup. The weather was cloudy with patches of blue sky, and a big improvement on yesterday.

Visitors arrived around 0815hr on a small aluminium outboard boat launched south of the jetty on the beach and were all aboard by 0825hr. The plan was to drop them back at the same location at around 1700hr.

During Wednesday, we occupied 3 stations in the western part of the South Aoba Basin, and undertook sediment coring at each site. A single dip CTD/hydrocast was also completed at the third site. We travelled in a clockwise direction, starting to the NE of Norsup (**VES-46**), and each site was around 10 miles from the previous.

Using the AGSO corer, **VS-18** was deployed in 1000m water depth and returned 3.74m of black to dark grey silty mud. The core was kept in the liner, which was cut into 1m lengths, labeled with hole number and depth interval, end-capped and sealed with grey duct tape. Each core section was placed up right (top up) in the Ship's main refrigerated storeroom. Samples from the top and bottom of the hole were collected for subsequent methane analysis. Separate top and bottom hole samples were collected in large plastic vials, and sealed with grey duct tape and stored in the freezer down in the general laboratory. All samples, including each individual core length, were allocated 6-digit CSIRO sample numbers. This same sampling procedure was applied to subsequent sediment core operations for this day.

Having successfully completed **VS-18**, we sailed SE to a WP at 15° 57.644'S and 167° 38.792'E, in 1280m water depth (**VES-47**). Again using the AGSO gravity corer, **VS-19** successfully returned 3.82m of black grey silty mud.

We then sailed (**VES-48**) to the third and final station for the day, where **VS-20** returned 0.54m of black dark grey silty mud, from a water depth of around 900m. Mud on the lead weights indicated that the corer had fallen over on impact, so a repeat core (**VS-20R**) was done at the same location. We were rewarded with 1.50m of black to dark grey silty mud. A single dip CTD/hydrocast, **VH-35** was also completed. Light transmission anomalies associated with salinity highs were noted at several depths in the water column. Eleven samples were collected and analysed for on board methane. The results show spikes at 656m (36nl/l) and 901m (35.6nl/l), collected only several meters above bottom. The shallowest sample taken at 91m had a trace of ethylene, possibly from biogenic sources.

In failing light, we returned to Norsup, arriving at 1715hr (**VES-49**), and were met by the same boat. Our visitors safely disembarked, having had a great day, except for Mr Patsis who unfortunately was sea sick for virtually all the time at sea. The Chief Cook put on a fine lunch that was certainly appreciated by everyone (except for Mr Patsis!).

We departed Norsup at 1730hr and sailed east (**VES-50**) to retry VS-17 and VS-17R, at a new position, 2.6 miles south and 0.5 miles east of the previous station, where a small basin at 1765m depth had been noted on the transit to Norsup the evening before. Unfortunately, using the large corer, **VS-21** recovered only about 10g of black sand. The result was therefore the same as for VS-17 and VS-17R, with the large corer was unable to penetrate the black sand.

We departed the South Aoba Basin at 1000hr and made way (**VES-51**) to west of Ambrym Island, where the trend of a volcanic rift zone had been crossed off shore the previous evening. Both at this location and the previous one, we were enjoying the calmer conditions being on the lee side of Ambrym Island. Here, we conducted a single dip CTD/hydrocast (**VH-36**) to test for hydrothermal activity and a grab (**VG-28**) to collect samples in the rift zone. There were no light transmission anomalies, but sharp boundaries between 300-360m depth defined by lower temperature and salinity. These features are clearly a separate water mass but further analysis is required to ascertain if it is due to hydrothermal input. The grab from the rift recovered a layered load of large rocks on top comprising slabs of sandstone and ferruginous tuff, sitting on top of gravely black sand with many cm-size rocks, underlain by 2cm of black sand. We interpret this range of rock types to represent part of a debris flow deposit from the subaerial volcano on the island.

Day 16
Thursday 20 September 2001

The first operation of the final day of operations for VAVE was a long transit (**VES-52**) from west of Ambrym Island SE to the Cioan Volcano, a distance of around 58 miles, representing 6 hours transit. A strong current to the NW slowed the ship to around 9kt and we arrived at first light to a cloudy day with 15-20kt winds from the ESE. The Master had set the time for departure for Brisbane at 1800h, so we had the remaining daylight hours to investigate Cioan. The reader will recall that we had obtained a significant methane anomaly, and a light transmission anomaly two days before, on September 18 in **VH-34**.

Because the nautical charts showed a shoal at 38m with a note about discoloured water, about three hours of cautious echosounding was done in order to map the seabed to have a good bathymetric reference for further work during the day. We were able to map the discoloured water and the bathymetry with good accuracy. The survey showed a possible caldera, open to the east with a N pinnacle (to 34m), and a southern rim consisting of 2 peaks at around 220m. Following the extensive echosounding survey, a single dip CTD/hydrocast (**VH-37**) was done just south of the zone of discoloured water, in 274m water depth. We obtained a reduction in light transmission at the surface (corresponding to the discoloured water) of around 6% associated with low salinity and higher temperature, another near bottom (below 210m) of up to 1%, and a narrow upper plume signal at 100m, with a transmission anomaly of approximately 0.2%. The bottom peak was larger, and more complex than the one seen in **VH-34**, and is interpreted to be closer to source. Eight bottles were fired and sampled for geochemical studies on land, and 6 were analysed for methane on board. The results of the methane analyses reveal a large anomaly of up to 80nl/l near bottom, and confirm that Cioan Volcano has significant hydrothermal activity.

A precautionary 1 mile ESE echosounding traverse (**VES-53**) was run over a proposed camera tow. This showed very high relief of the seabed and made challenging conditions for the camera pilot. Camera tow **VV-05** showed fields of pumice boulders and pebbles, fish,

coral and other marine life and in places milky cloudy water. The CTD mounted on the camera cage revealed 2 zones of coincident salinity decrease and temperature increase. These were recorded when the camera had crashed and was possibly lying on its side. The results, however, suggest that there must be less saline water trapped below the pumice rubble, which is released when disturbed. No hydrothermal deposits were seen.

A science meeting was held in the Operations Room at 1430h where the previous 2 days were reviewed, and the plans for the rest of the day were discussed.

It was decided to dredge the summit of Cioan with operation **VD-26**. Again as a precaution, a short echosounding traverse run, **VES-54**, was completed over the proposed dredge track. It went directly over the summit, recording peaks at 34m and 38m. This summit is very steep with a 1 in 4 incline. The dredge haul contained a half full bag of mainly pumice with minor black glassy volcanic rocks and rare porphyritic rocks with basaltic xenoliths.

Time was running short by this stage of the afternoon so we completed three back to back grabs in Cioan to maximise rock recovery and cover high priority targets. All three grabs were successful in returning good loads, and they were done extremely efficiently in the short time available. **VG-29,** deployed on the south west rim summit knoll at 220m returned small slabs of red iron rich hydrothermal material, overlying black volcanic sand and minor brown red mud and silt. The material looked similar to some of the hydrothermal deposits we recovered from the Temakons Seamount in the NW of the Vate Basin. **VG-30,** designed to test the southern floor of the caldera contained a crudely layered sample with 2cm of brown mud and silt on top of a gravely layer with occasional cobble size pumice. The final operation of VAVE-2001, **VG-31**, deployed on the crest of the south east rim summit knoll, contained a half-full load of dark grey volcanic sand with no layering.

There was insufficient time to do another grab, so we called an end to operations at 1735hr at which time the Franklin commenced her path to Brisbane.

Day 17
Friday 21 September 2001

Seas abated overnight and we are getting a smooth ride in 10kt easterly winds.

A science meeting was convened at 0900hr. The whole cruise was reviewed and each member of the scientific team gave his/her highlights. These ranged from the team's discovery of the new vent field at Nifonea and sulfides at Oscostar, to being a team member of VAVE. A plan was formulated to prepare for cruise closure, and various tasks were assigned. We decided to concentrate on getting the sections and maps for the cruise report done by 1800hr Sunday 23 September, and to pack gear on Monday. The quarantine list of samples needs to be handed to the Master by 1800hr on Sunday.

The fine weather and calm seas continued throughout the day and evening and made for pleasant sailing.

Day 18
Saturday 22 September 2001

Conditions at 0630hr were much the same as yesterday with calm seas and a pleasant 11kt wind from 110°. Early morning we had rounded the northern tip of New Caledonia where we changed course to from WSW to SW.

At breakfast, the Master forecast stronger wind and lumpy seas on Monday and suggested that if we wished to get the hold open and pack our equipment, then today's excellent conditions might be a better time to do it.

Accordingly, at the science meeting held at 0900hr, the plan for the day was changed to packing and cleaning up. Tasks were assigned and we got to work. At 1315hr the afterdeck hatch was raised and crates were lifted out of the hold and packed with gear, and placed back down, finishing around 1430hr.

By about dinner time the seas were picking up and most of the scientific team had an uncomfortable night. Clocks were retarded by 1 hour at 1800hr but, judging by the queue for breakfast the next day at "0800hr", not all had turned their watches back

Day 19
Sunday 23 September 2001

By 0730hr, the seas had abated a little on the port quarter, making a more comfortable journey, a 15-20kt SE wind and clear blue sky.

A science meeting was held at 0900hr and a review of progress of the cruise report and other matters was completed. In most instances, progress looks fine. In light of yesterday's change of plan and packing gear, the deadline for 'final drafts' was revised for 1800hr Monday 24 September.

Customs declarations and entry forms were filled out after lunch. A quarantine declaration for deep sea water, rock, sediment and fauna samples was also prepared and handed to the Master at around 1900hr.

Day 20
Monday 24 September 2001

A more comfortable night was had by all and at 0600hr we are enjoying a smooth ride with 15-18kt winds from 110. The ship has slowed to 9kt and we are 183 miles from port.

A final science meeting was held at 0900hr to review progress on cruise report and other matters. A bottleneck in map drawing was highlighted, so several of the scientists took up the cudgel with software packages to speed the process. Work continued during the day.

In the recreation room at 1830hr, the Chief Scientist gave a short presentation of the results of VAVE to the Master and his crew, which included a short video of operations and footage of the sea bed at the newly discovered vent field, Nifonea. He also thanked the Master and crew for their unfailing and professional assistance during VAVE, without which VAVE would not have been the success it was.

Day 21
Tuesday 25 September 2001

Having picked up the pilot earlier in the morning we made our way to port in calm seas and sunny skies. We arrived at Forgarcs on the Brisbane River at around 0830hr. Customs was cleared by around 1000hr, but there was a delay with Quarantine as the official had to refer our deep sea samples to his superior in Brisbane who then referred the matter to officials in Canberra. Quarantine clearance was received at around 1130hr, just in time for the samples to be loaded onto the NQX truck for Sydney along with all our other gear and equipment. At 1250hr, refrigerated and frozen core samples were taken to Danzas AEI Pty Ltd at Eagle Farm for shipment overseas to Indonesia and USA. All the scientific party had disembarked by around 1400hr.