2004

RV Southern Surveyor

program

MARINE

NATIONAL FACILITY

CSIRO

MARINE RESEARCH

voyage summary SS06/2004

SS06/2004

Submarine volcanic and hydrothermal activity in the New Hebrides arc-backarc system.

Itinerary

Departed Noumea 1800hrs, Wednesday 2 June, 2004
Arrived Sydney 0800hrs, Sunday 27 June, 2004

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Scientific Objectives

1. to swath-map the Coriolis Troughs (Vanuatu) with multibeam sonar, in order to identify areas of exposed lavas, including coverage of the known occurrences in the northern end of the Futuna Basin and the Nifonea Ridge in the Vate Trough;

2. to explore for and map the distribution of active hydrothermal venting systems of the Coriolis Troughs;

3. to revisit the Nifonea Ridge hydrothermal vent system discovered on RV *Franklin* voyage *VAVE (FR08/2001)*, and determined whether changes have occurred in the intervening 3 years;

4. to recover fresh igneous and mineralised rock, sediment, and water samples associated with igneous activity in these Troughs.

Voyage Objectives

1. To perform the first detailed, high-resolution swathmap bathymetric survey of the floors and flanks of the Futuna, Erromango, and Vate Basins, using the state-of-the-art Kongsberg EM300 system recently installed on the RV *Southern Surveyor*;

2. Dredge igneous rock targets identified on the floors of the Basins and intervening ridges, in order to recover fresh glassy rock samples for detailed age studies and chemical analysis, particularly of volatile elements and compounds, and stable isotopic characteristics.

3. Dredge hydrothermal sulfide-rich and altered rock samples for studies of base and precious metal mineralisation;

4. To explore with the transmissometer-equipped CTD sledge for hydrothermal plume activity in these basins and intervening ridges, and to recover water samples for immediate analysis (including CH4) on board and subsequent shore-based laboratory analysis. A specific target will be a return to the Nifonea Ridge to examine the changes (if any) to the hydrothermal system discovered during *VAVE (FR08/2001)*.

Voyage Track

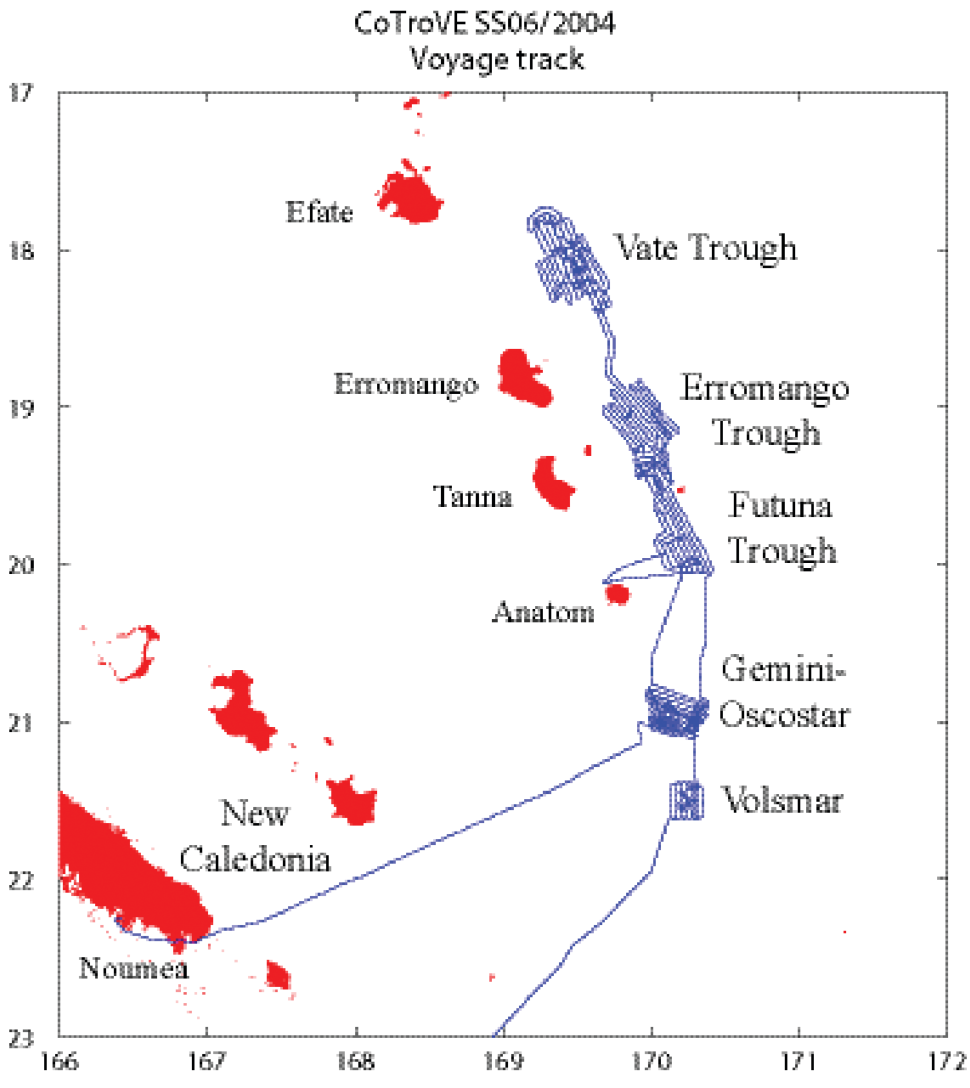

Figure 1

Voyage track of RV Southern Surveyor voyage SS06/2004 (CoTroVE), showing the primary areas of operations. Departure was from Noumea on Wednesday 2nd June, and the end point (not shown) was Sydney on Sunday 27th June 2004.

Results

1. to swath-map the Coriolis Troughs (Vanuatu) with multibeam sonar, in order to identify areas of exposed lavas, including coverage of the known occurrences in the northern end of the Futuna Basin and the Nifonea Ridge in the Vate Trough:

Prior to the Voyage, the performance of the Simrad EM300 in sharply varying bathymetric terrain (and hence beam width), hosted by the RV Southern Surveyor, was uncertain. The initial planning of coverage was based on a ship speed of 8 knots, and it was anticipated that some selectivity in the choice of Trough targets might be necessary. In the event, the majority of the Futuna and Vate Troughs was mapped, and about 75% of the Erromango Trough comprising the most bathymetrically variable portion. This result was better than expected. The detailed bathymetry in combination with the acoustic backscatter permitted clear identification of areas of exposed lavas, as proven by dredging;

2. to explore for and map the distribution of active hydrothermal venting systems of the Coriolis Troughs:

The erratic performance of the transmissometer compromised our ability to satisfy this objective during the Voyage. Despite this difficulty, 13 hydrocasts were conducted, some hydrothermal plumes were identified in the submarine New Hebrides Arc volcanoes, and water samples collected for laboratory analysis.

3. to revisit the Nifonea Ridge hydrothermal vent system discovered on RV Franklin voyage VAVE (FR08/2001), and determined whether changes have occurred in the intervening 3 years:

The erratic performance of the transmissometer compromised our ability to satisfy this objective. A preliminary conclusion however, is that in the intervening 33months, the active hydrothermal venting mapped in 2001 has ceased at Nifonea Ridge. Laboratory analysis of water samples collected at the same hydrocast sites as the VAVE voyage are required for confirmation (or otherwise) of this observation.

4. to recover fresh igneous and mineralised rock, sediment, and water samples associated with igneous activity in these Troughs:

This objective was comprehensively achieved. Forty eight successful dredges, one grab and thirteen hydrocasts were completed. Rock sample types varied from pristine, glassy igneous rocks of varied vesicularity and crystal content/type, mineralized equivalents, and volcanogenic-rich sediments. Water samples were taken from the niskins ported by the CTD sledge; in areas of suspected hydrothermal activity, these included filtered samples.

Voyage Narrative

The CoTroVE Voyage (SS06/2004) departed from the Main Container Wharf in Noumea over two days later than scheduled at 6pm on Wednesday, 2nd June, 2004. The delay resulted from the critical decay of the main hydraulic return pipework on the afterdeck, and its consequent repair in Noumea. Despite this dismal start, the Voyage subsequently progressed with minimal downtime due to mechanical or equipment failures, although the chronic poor performance of the transmissometer on the CTD was an impediment to our search for hydrothermal plume activity. A total of 49 (1 empty return) dredges, 14 vertical hydrocasts, 1 grab, and 13,114 km2 ensonified by the Simrad EM300 multibeam system were completed of volcanic complexes in the arc and backarc basins. In terms of a Voyage narrative, a summary by area of operations is chosen as the best way to convey an impression of when, where, and how this work was completed. In general, we had winds in excess of 20 knots, in some places strong currents, and occasional rough seas. Despite these conditions, we managed to use all the available time constructively with either swathmapping or deck-launched operations. En route to the first target area, the scientific aims of the Voyage and associated safety issues were analysed through "tool box" meetings on the bridge.

Gemini-Oscostar. There is a gap in the subaerial chain of volcanoes forming the New Hebrides[1] Island Arc from Anatom (at about 20° 10'S) to Mathew Island (at 22° 30'S). At least two major submarine volcanic structures were known prior to the *CoTroVE* voyage in the gap: Gemini-Oscostar at about 21oS (last erupted above sea surface in 1996; visited on *VAVE*) and Volsmar Seamount at about 21o 27'S. Gemini-Oscostar was the first and Volsmar the last targets of *CoTroVE*. Gemini-Oscostar was reached about 20 hours after departure from Noumea, and swathmapping commenced with a WNW-ESE grid defined by the prevailing wind and sea state, at about 8.5 to 9 knots. Coverage varied as a function of depth; this kind of submarine volcanic terrain is in fact a challenge with rapid bathymetric changes from about 2500m to 50m below sea surface.

Over the course of the next two days however, the details of a fascinating, multi-centred volcanic complex emerged comprising three major edifices (Gemini South, Gemini North, and Oscostar) and many satellite cones, all criss-crossed by multigenerational faulting. In addition, a marked zone of sea surface discolouration (greenish yellow) was encountered in a slick to the east of the summit of Oscostar. Identifying targets for dredging and hydrocasting is informed enormously with the particular advantages of a high resolution (30 kHz) swath map. A variety of morphologies was selected: flanks of

[1] The term "New Hebrides Island Arc" (and its adjacent backarc troughs and basins) refers to the geologic or geographic entity stretching from Ndende Island in the north to Mathew and Hunter Islands in the south. The northern portion of this entity is politically part of the Solomon Islands whereas the southern is part of Vanuatu. The terminology used in this Summary will use the appropriate name for either the geologic or political context.

summit cones, central craters within calderas, satellite cones both faulted and unfaulted, and monogenetic cones at the periphery of the volcanic complex. Except for the first of these, the rest would not have been identified within any reasonable length of single trace echo-sounding survey time. The particular sampling importance of this observation is that more Mg-rich lavas tend to be erupted from satellite cones; these types are especially useful for deducing the composition of the mantle sources from which the magmas are derived. In contrast, our experience is that summit calderas are potential sites of hydrothermal activity and mineralisation. This proved to be the case within the caldera forming the summit region of Gemini South, where the following were recovered: clasts of dark grey, fine-grained, sulfide-bearing dacite; angular, white clayey (possibly pyrophyllite), acid sulfate-altered rock; fine-grained dark grey, sulfide-altered rocks; and cobble-sized pieces of reddish-brown ironoxyhydroxide. Shallow hydrothermal plumes were identified associated with both the summit regions of Gemini South and Oscostar.

Futuna Trough. By 0615 hours on Monday 7th June, the campaign of dredging and hydrocasting at Gemini-Oscostar was finished, and the ship transited northwards while swathmapping to the Futuna Trough. The track we took was along the line of a series of narrow “deeps” which have been called the "Anatom Trough", possibly linking the structure of the frontal volcanic arc with the backarc troughs.

In 2001 on *VAVE*, two attempts were made to retrieve sediment samples from the reputedly amagmatic, sediment-filled basin forming the Futuna Trough. The first, with the small (1.5m) National Facility gravity corer, in the southern part of the Trough successfully recovered about 1.5m of sediment. But an attempt in the northern part of the Trough with the 4m Geoscience Australia gravity corer (aka “Thomas”) was retrieved with a damaged nose cone containing fragments of embedded black basaltic glass. This was incontrovertible evidence for the existence of magmatic activity at least in a portion of the Futuna Trough. Our strategy for *CoTroVE* was initially to swathmap the southern portion of the Trough to examine the transition between extended and non-extended terrain. Several hours of this survey had been completed when a developing engine problem (fresh water leak) emerged (at about 1900 hours) that required some modification to our plan. Given the sea state, calm water in the lee of Anatom was required while the main engine was shut down for repair. Prior to the repairs, it was decided to make an extended run along the entire length of the Futuna Trough (~80km) to make an assessment of the morphology of the region where VAVE recovered basaltic glass. This information could then be used to make informed decisions on possible dredging targets, both in the southern part of the Futuna Trough, and later elsewhere in the same and other troughs. By 0100 hours on Tuesday 8th June, this extended run was completed, the transit to the north side of Anatom (4 hours) was made, the engineers completed the repairs within their declared time frame (4 hours), and we transited back (4 hours) to the southern end of the Futuna Trough and continued swathmapping for the rest of the day. The next two days were spent with a mixture of dredging, hydrocasting and swathmapping. The important results were identification of the southern limit of recoverable igneous rocks (~ 19o 32'S), the increased extent of igneous outcrop on the floor of the Trough towards its northern margin, the absence of any sign of current hydrothermal activity, and the marked structural fabric indicative of transtensional stress. In the assessment of outcrop, the acoustic backscatter accompanied by dredging ground truth were the prime lines of evidence. During the relatively deep (~ 3100m) hydrocasts in the Trough, unfortunately the SeaTech transmissometer first showed signs of chronic problems that became worse as the Voyage progressed: erratic behaviour oscillating between transmission extremes on downcast, followed by relatively stable (but possibly inaccurate) behaviour on upcast. Given the search for hydrothermal plumes was critically dependent on the transmissometry signal, these defects impacted on our plume program.

At this point, it seemed the best strategy in terms of distribution of effort would be to transit north to the Vate Trough and the known igneous/hydrothermal activity of the Nifonea Ridge, and then work our way back southwards via the Erromango Trough. So at 0015 hours on Friday 11th June, we commenced this transit via a series of relatively shallow points that might be sites of cross-trough igneous activity.

Vate Trough. Over the course of a day and a half, outstanding bathymetric and acoustic backscatter images emerged from the EM300 system, allowing us to target precisely, a comprehensive rock dredging and hydrocasting campaign. For example, a series of nested calderas form the summit zone of Nifonea Ridge. The youngest and currently active caldera on the Ridge is about 8 km in diameter. The tectonic evolution of the Trough is clearly revealed by the swath mapping, and we can now understand the reasons for the distribution of the volcanic activity in a dominant transtensional tectonic setting. We discovered for the first time that about 100km along the axial floor of this Trough is covered with basalt lavas – many of the dredged samples look as though they were erupted yesterday, with jet-black glassy exteriors and features indicating high fluidity. In addition to the major edifice of the Nifonea Ridge, there is an extensive system of rifts from which the lavas have been sourced, reflecting an underlying tectonic control and spreading of the crust. A surprising and critical finding has been the apparent cessation of the hydrothermal plume centred in the active caldera that was discovered during the *VAVE* voyage in 2001. Confirmation of this finding based on the erratic transmissometer will however, have to wait confirmation with post-Voyage chemical analyses of the water samples. It is worth noting that the lifetimes of plumes are important from the point of view of water circulation through the crust, and survival/migration of vent-dependent flora and fauna.

During the course of one of the dredging operations in the Vate Trough, the Bosun noted the roller that keeps the starboard trawl (i.e., dredging) cable away from the rear of the ship had suffered a deep groove from the cable. Repairs were required which consisted of welding in a piece of cut crow bar, filling and smoothing. The preferred option of swapping the port roller with the starboard was not possible because the roller housing is welded to the ship in addition to being held in place by bolts. In addition, the practice of getting the ship underway slowly once the dredge had cleared bottom helped keep the trawl wire away from the Ship's transom and clear of the roller for most of the retrieval.

Erromango Trough. By 1000 hours on Wednesday 16th June, operations in the Vate Trough were completed. A transit southwards doubled up the swath path previously taken on our route northwards. Noting an area where several moderately elevated mounds on the sea floor had been mapped at about 18º 22'S, we turned to the west and dredged one of these to find relatively fresh basaltic pillow lava. Through the evening of Friday 18th June, an extended area of the central portion of the Erromango Trough was swathmapped, concentrating on some of the most prominent bathymetric highs and deeps. Unlike the Vate to the north and Futuna to the south, the result of this effort is the Erromango Trough does not appear to have stretched far enough yet to allow the underlying mantle to decompress, partially melt, and hence have lavas forming new crust on the floor of the basin. But the "scenery" revealed by the swath survey is nonetheless spectacular and instructive in terms of the structural evolutionary history of the troughs as a group. For example, the Erromango Trough consists of a series of tilted *en echelon* blocks surrounded by cliffs up to 2000m high. If exposed on land, this would rival the Grand Canyon of the Colorado River for scale. This kind of bathymetry with extreme elevation changes over very short distances is technically demanding of the Simrad EM300, but it performed superbly.

Turning our attention to the tectonically and magmatically complex junction between the Erromango and Futuna Troughs, we targeted a number of dredge sites at zones of rift-associated and isolated examples of volcanism, retrieving igneous rocks of varying apparent ages in terms of seafloor weathering. At 2300 hours on Saturday 19th June, a transit commenced via the easternmost flank of the Futuna Trough, following the extreme topography of the ~2000m-bounding cliffs, and headed southward to submarine volcanoes forming the extension of the New Hebrides Island Arc. Because the prevailing wind and current had prevented us from dredging and hydrocasting on the eastern flank of the huge Oscostar volcanic complex visited in the first few days of the Voyage, the opportunity of favourable weather was taken on our return transit to complete this task. We then continued southwards to the next known "volcano" in the Arc called the "Volsmar Seamount", arriving at about 0800 hours on Sunday 20th June.

Volsmar Seamount. Volsmar Seamount (so named by Monzier et al., 1993) was in fact revealed by the EM300 swath mapper over the course of the next 14 hours to comprise a thoroughly complex region of 2 major volcanic cones with at least 10 large satellite cones, the majority showing extensive faulting. Informed by the remarkably detailed bathymetric and acoustic backscatter images obtained, a campaign of targeted dredging and a single hydrocast of these morphologically-varied volcanic features was completed. The last dredge in fact recovered some of the most magnesium-rich lava ("picritic ankaramite") of the whole Voyage – much sought-after by petrologists for the possibility of inferring most directly the nature of the upper mantle sources from which the arc and backarc basin lavas are primarily derived. With operations completed at 1900 hours on Monday 21st June, we completed part of a clockwise circuit extending the swath coverage of the Volsmar area, and headed southwest for Australia via the Derwent Hunter seamount. With contingency time available, a single swath circumnavigation was completed of Derwent Hunter, followed by a dredge (at 1100m, northeast ridge), recovering blackened branching coral. By 2100 on Friday 25th June, we headed for Sydney, arriving at 0710 hours, Sunday 27th June.

Summary

Overall, *CoTroVe* was an outstanding success scientifically. The advent of the 30 kHz swathmapper has revolutionised the way in which the study of seafloor volcanic and hydrothermal systems can be conducted - like giving 3-D vision to a blind person equipped with a stick. We used older 12 kHz swath surveys to guide our overall studies, but have demonstrated the distinctive advantage of the higher frequency swathmaps for detailed geological work.

We have within a period of 3 weeks defined the extent and detailed morphology of two huge but poorly known submarine volcanoes in the New Hebrides Island Arc. The first high resolution bathymetric maps of some of the youngest backarc basins in the world have been generated, and the extent of the constructional magmatism occurring in these basins defined together with associated structural deformation patterns. In addition to extensive sampling of the magmas forming the arc edifices and the floors of the Vate and Futuna Troughs, we have gained insight into the initial tectonic stages of formation of arc volcanoes and backarc basins.

The RV *Southern Surveyor* is fundamentally well equipped for this particular kind of research. An enhancement would be a functioning sub-bottom profiler. A working transmissometer (or preferably, a nephelometer) is also essential for hydrothermal plume mapping on future National Facility voyages.

Personnel

Scientific Participants

Professor Richard J. Arculus	ANU	Petrology/tectonics
Dr. Timothy F. McConachy	CEM	Hydrothermal plumes/sulfides
Associate Professor David A. Gust	QUT	Petrology
Dr. Kurt Knesel	UQ	Petrology/tectonics
Mr. Roman Leslie	CODES	Petrology
Mr. Hadley Craig	University of Waikato	Petrology
Mr. Matthew Stevens	ANU	Petrology/water sampling
Mr Don McKenzie	National Facility	Voyage Manager
Mr Lindsay Pender	National Facility	Computing
Mr Lindsay MacDonald	National Facility	Electronics
Mr Cameron Buchanan	Geoscience Australia	Swath mapping
Mr Brooks Rakau	GMRWS	Vanuatu Observer
Mr Toney Tevi	GMRWS	Vanuatu Observer

Marine Crew

Les Morrow	Master
Otto Weysenfeld	Chief Officer
Drew Meincke	2nd Officer
Roger Thomas	Chief Engineer
Robert Cave	First Engineer
Seamus Elder	2nd Engineer
Malcolm McDougall	Bosun
Ruben Ifill	Integrated Rating
Manfred German	Integrated Rating
Michael Chalk	Integrated Rating
Phillip French	Greaser
Peter Williams	Chief Steward
Warren Leary	Chief Cook
Geraldine Byrne	2nd Cook
Craig Dawkins	Trainee Integrated Rating

Acknowledgments

Prior to SS06/2004, the assistance received by the Chief Scientist in designing the research and operations plan from the Southern Surveyor Operations Officer and other CSIRO support personnel, was efficient, timely, and comprehensive. Without the large practical and logistical support of our swath mapping operations by Geoscience Australia (GA), pre- and during the Voyage, we could not have successfully attained our objectives. The logistics of equipment and expendables purchase and delivery to and from the ship by GA was essential, efficiently executed, and much appreciated.

On board, the support of and enthusiasm for the Voyage objectives displayed by the Voyage Manager (Don McKenzie), computing (Lindsay Pender), and electronics (Lindsay MacDonald) was outstanding and a sustained boost to morale. The dedication to our swath mapping goals and the expertise displayed in the achievement of these goals by Cameron Buchanan (GA) was inspirational and contributed hugely to the overall scientific success of CoTroVE. The safe and efficient conduct of operations by the RV Southern Surveyor's crew was exemplary, and the vital nutritional support during these efforts much appreciated. Finally, the Government and people of the Republic of Vanuatu are thanked for their permission to conduct this research in their territorial waters.

Richard J. Arculus
Chief Scientist