2008 program

RV Southern Surveyor

MARINE
NATIONAL FACILITY

voyageplan
SS07-2008

Structure, Evolution, Petrology, and Hydrothermal Activity of Spreading Centres in the Northern Lau Backarc Basin

Itinerary

Depart Noumea 1000 Wednesday April 30th, 2008
Arrive Suva 1000 Saturday June 7th, 2008
Demobilising Cairns Tuesday July 15th, 2008

The voyage will be in two legs with a port call for refuelling and some personnel changes:
Ist Leg ends in Suva 0800 on May 26th 2008.
2nd Leg departs Suva at 1600 on May 26th 2008.

Principal Investigator

Professor Richard J. Arculus (Chief Scientist) – Research School of Earth Sciences, Australian National University, Canberra, ACT 0200

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CSIRO

Scientific Objectives

The fastest spreading backarc region on Earth forms the northern Lau Basin (NLB), and is the strongest source of mantle-derived 3He-rich hydrothermal plumes in the southwestern Pacific. Following success of RV Southern Surveyor NoToVE voyage (SS11/04) to the northern Tofua arc-Fonualei Rifts (Tonga) system, and building on international collaborative efforts, in the first Leg of SS07/2008, we propose to survey the bathymetry, magnetic characteristics, petrology, hydrothermal activity, and hence origins and evolution of two of four spreading centres within this region (Northwest Lau [NWLSC] and Niuafo'ou [NSC]) which are essentially unstudied. As the Pacific Plate rolls back along strike of the Tonga Trench, rapid backarc crust formation in northern Lau is accommodated by four known centres connected by transform faults and distributed deformation. Recent voyages have surveyed the Fonualei Rifts (east) and Futuna Spreading Center (west), but the NWLSC and NSC in the central NLB are only known from reconnaissance 12 kHz surveys.

Following high resolution 30 kHz multibeam bathymetric surveys, vertical CTD hydrocasts and "tow-yos" coupled with rock (glass) dredging will be used to sample along/across-strike of the spreading centres. Post-voyage laboratory 3-D magnetisation inversions accompanying seafloor geomorphology will be used to construct the tectonic evolution of the Basin. Glasses and bulk rock samples will be analysed for major, trace and volatile elements together with isotopic (radiogenic and stable) abundances to determine the volatile contents and melting processes, and identify mantle sources likely including "Pacific"- and "Indian"-type mid-ocean ridge and Samoan plume components, and hence obtain insights into upper mantle flows.

In the 2nd Leg we will extend the area of exploration planned for SS07/2008 to the Peggy Ridge, a leaky transform linking spreading centres in the southeastern Lau Basin with the NWLSC and Futuna Spreading Centre to the north of Fiji. We will use the same approach as in the first Leg using high resolution 30 kHz multibeam surveys, hydrocasts and "tow-yos" coupled with dredging to sample along and adjacent to the Peggy Ridge. Post-voyage laboratory laboratory studies will use the same techniques and pursue the same objectives as in the Ist leg.

Voyage Objectives

1. **How does the plate tectonics of the rapidly extending NLB work?** In detail, we aim to determine the location and types of the current microplate boundaries, and extents and duration of motions on each of them. Answers to these studies will reveal how the rapid extension and shear deformation of the NLB is accommodated, and how the present configuration of the Basin has evolved. Results will have global significance for plate tectonic processes, and have relevance for zones of rapid sea floor extension and formation, particularly for periods when high ridge length/area of sea floor was prevalent, as deduced for the Archean. With the help of reconnaissance 12 KHz (RV *Kilo Moana*) data, we will complete coverage of the NWLSC and NSC, determine the nature of the tectonic boundary that connects the NWLSC with the NW Peggy Ridge, and characterise the connection between the FFZ, NSC, and the western termination of the Tonga Trench. The NLB between the Tonga Trench and the Peggy Ridge-NFFZ (Fig. 1) forms a large extensional shear and relay zone between the WNW-moving Pacific Plate and east-moving Australian Plate. How this works in detail will be determined by our survey in conjunction with data for the FSC and Fonualei Rifts, and is of basic importance for plate tectonic mechanisms (*Schouten et al.*, 1993).

2. **What are the nature and source characteristics of the magmatism accompanying the different crustal accretion variables in the NLB?** We know that at MOR, the primary variables controlling crustal accretion are the spreading rate, upper mantle potential temperature, and mantle composition or fertility with respect to basalt production (e.g., *Macdonald*, 1982). In backarc settings, the advection induced in the overlying mantle wedge coupled with the extra melting triggered by fluid released from the subducting lithosphere are additional variables (*Martinez & Taylor*, 2002). In the NLB, analysis of dredged samples will allow us to address all of these variables: a large range of likely spreading rates, proximity to the adjacent Tofua Arc, morphologies (inflated, depressed, rifted, segmented, off-axis seamounts), mantle sources (Indian, Pacific, Samoan plume), and extents of melting. Much of the NLB is anomalously shallow possibly reflecting unusually hot upper mantle and possibly consequent to the rapid subduction rate (*Davies & Stevenson*, 1992). The high FeO and low Na_2O at MgO = 8 wt% of the Fonualei Rift basalts are consistent with a higher than average mantle temperature beneath the NLB than other backarc basins globally. Coupling the compositions of the dredged rocks with the geophysical and tectonic studies outlined in (1) is a powerful approach known to yield results. Recovery of samples from the multiple concurrent spreading centres will allow detailed geochemical mapping of the mantle isotopic domains.

3. **Does the Samoan mantle plume penetrate beneath the NLB?** Based on the He, Sr, Nd, and Pb isotopic compositions of several off-axis (temporally and geomorphologically poorly constrained) dredged samples, it has been proposed that mantle material from the Samoan plume has penetrated the NLB (*Volpe et al.*, 1988; *Ewart et al.*, 1998; *Poreda & Craig*, 1992; *Turner & Hawkesworth*, 1998). The strongest evidence for this hypothesis is high $^3He/^4He$ of samples straddling the NSC (Fig. 3) but these samples lack full geochemical (including radiogenic isotope) characterisation. Clearly further progress with this problem requires spatially well constrained sampling and comprehensive post-voyage laboratory analytical study.

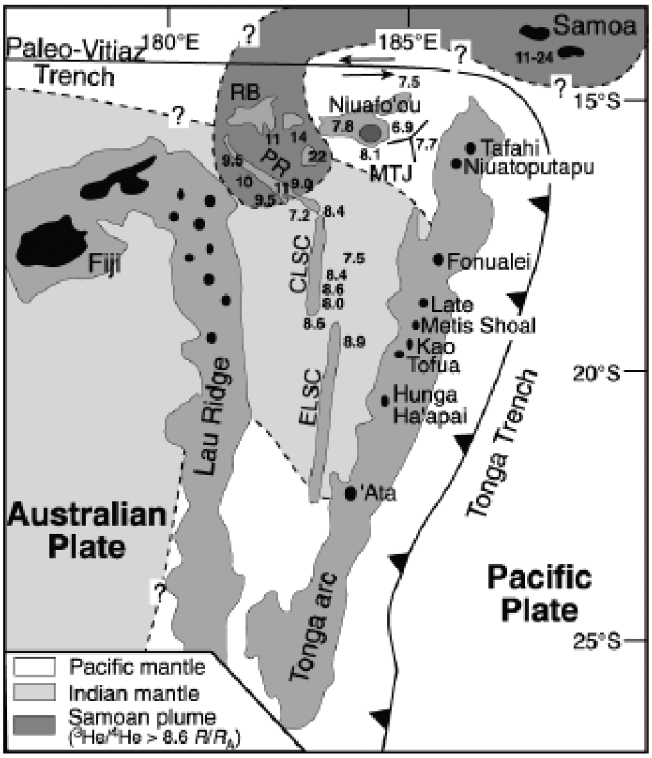

Figure 1: Inferred upper mantle structure (after *Turner & Hawkesworth*, 1998) with domains shown by dashed lines for the Northern Lau Basin-Tofua (Tonga) Arc region. He isotope data ($^3He/^4He$ relative to atmosphere; small bold numbers) have been grouped to delineate extent of the Samoan Plume, highlighted with dark grey shading. The He data are from *Poreda & Craig* (1992) and *Hilton et al.* (1993). The Indian-Pacific mantle boundary is inferred from *Hergt & Hawkesworth* (1994) and Hickey-Vargas et al. (1995).

4. **What are the characteristics of volatile distribution in the mantle sources of NLB basalts?** The recycling of volatile elements and compounds such as H_2O, CO_2, S and halogen compounds from subducted slab to mantle and thence via arc and backarc basin magmatism to the hydrosphere/atmosphere is one of the first order geochemical processes (e.g., *Arculus*, 2004). A major voyage objective will be to recover fresh glassy rock samples for detailed chemical analysis, particularly of volatile elements and compounds. Our overall primary objective with these (glassy) rock samples is to quantify the volatile fluxes in supra-subduction zone settings, and attempt to distinguish the components involved (mantle wedge, subducted crust, overriding arc lithosphere). Submarine-quenched backarc basin basalts with variable arc influence have been particularly useful in defining characteristics of the volatile component released from the subducted slab (*Stolper and Newman*, 1994; *Kent et al.*, 2002). Our planned sampling of the NLB will complement those previously recovered in the Fonualei Rifts and represent a very large range of distances from the adjacent Tofua Arc, subjacent subducted Pacific lithosphere, and possible Samoan Plume ingress. In addition to the geochemical significance of these studies, it is known that H2O contents of the upper mantle have significant implications for geophysical properties such as viscosity (hence controlling mantle flow), extents of melting, seismic attenuation and anisotropy (e.g., *Karato*, 2003; *Wiens & Smith*, 2003; *Billen & Gurnis*, 2003).

5. **What are the hydrothermal characteristics of the NLB?** On MOR, hydrothermal venting is strongly correlated with spreading rate (with the interesting exception of hot spot–affected ridges), evidently because spreading rate is a reliable proxy for the magma budget. In back-arc basins, the magma budget may be complicated by subduction-induced variations of the melt supply and the systematics of plume incidence, ridge morphology, and chemical characteristics are in the early stages of study (*Massoth et al.*, 2003). *Baker et al*. (2005) have reported the results of hydrothermal plume surveys along relatively slow-spreading (40–60 mm/yr) and arc-proximal (10–60 km distant) sections of the southern Mariana Trough and the Valu Fa Ridge. On both sections, multiple plumes have been found overlying ~15–20% of the total length and comparable to mid-ocean ridges spreading at similar rates. In the case of the Valu Fa, we know from geomorphological characteristics and magma compositions that an extra increment of melting (and hence ridge inflation) is triggered by slab-derived fluid ingress (*Martinez et al.*, 2005). In the NLB, we have the opportunity to study hydrothermal activity associated with backarc spreading centres relatively remote from the subducting slab but also with variable distance (N-S) from any Samoan plume ingress. Our global understanding of the fundamental controls on the geochemically important ocean inputs of backarc hydrothermal plume activity will be significantly advanced through this study.

Voyage Track

From Noumea, we will travel ~960 nautical miles northeast requiring a total of ~80 hours, past the Fiji archepelago to the SW corner (16ºS, 178ºW) of the first survey area of the NWLSC, tracking over the most southerly inferred submarine volcano of the New Hebrides Arc at 16ºS 171ºE (Figure 2).

Continuing to the northern Lau Basin, in addition to the multibeam swath mapping, we will be towing a magnetometer and the optimal orientation of the survey grid is at right angles to the estimated spreading directions of the NWLSC and NSC (Figure 3). Accordingly, our swath mapping grid will be oriented ~ NW-SE at about 3km spacing.

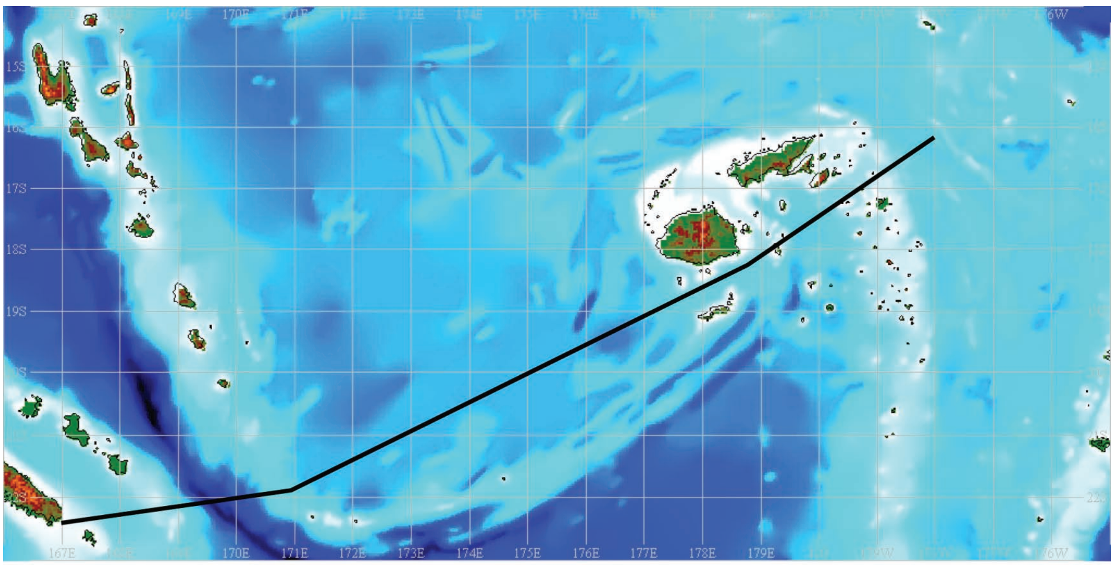

Figure 2: Voyage track from Noumea to the survey area of NWLSC and NSC (see figure 3).

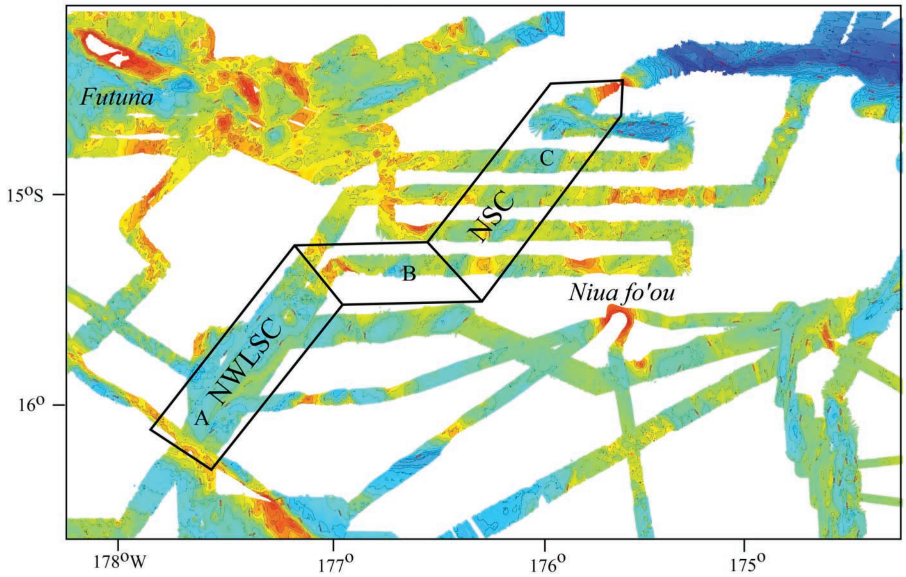

Figure 3: Generalised bathymetry based on available high-resolution 12 and 30 kHz swath bathymetry for the North Lau Basin, showing planned areas of operation for first leg of SS07-2008 in the Northwest Lau and Niau fo'ou Spreading Centres (NWLSC and NSC respectively).

Time Estimates

The target area is ~ 15,390 km^2 comprising of sub-areas A (5980 km^2); B (2580 km^2), and C (6,830 km^2). Assuming a swath mapping speed of 8 knots, and a beam coverage width allowing for overlap of 3 km, then about 42 km^2 can be mapped per hour. This gives a total of 6 days mapping for Sub-Area A, 2.5 days for sub-Area B, and 6.8 days for Sub-Area C.

Allowing 20 hours for the 240 nautical miles from the planned terminal point of the first Leg of the Voyage at 16ºS, 178ºW to Suva in Fiji for refuelling, gives ~6.4 days for hydrocast, dredging, and deep-tow camera operations in Sub-Areas A, B, and C; assuming these operations require ~ 2 to 3 hours each, this gives a total of ~ 70 operations. Some trade-offs in terms of time for swath mapping and investigations of the water column versus dredging of targets will be made during the Voyage.

The 2nd Leg of the Voyage will commence with a 270 nautical mile transit from Suva to the Peggy Ridge at 16º 25'S 177º 25'W taking 22.5 hours. We will then proceed southeast along the Peggy Ridge to 16º 45'S 177ºW to commence swath mapping, hydrocasting and dredging of the area (D) shown in Figure 4. Return to Suva will be from close to the 16º 45'S 177ºW waypoint, allowing 22.5 hours again for the transit.

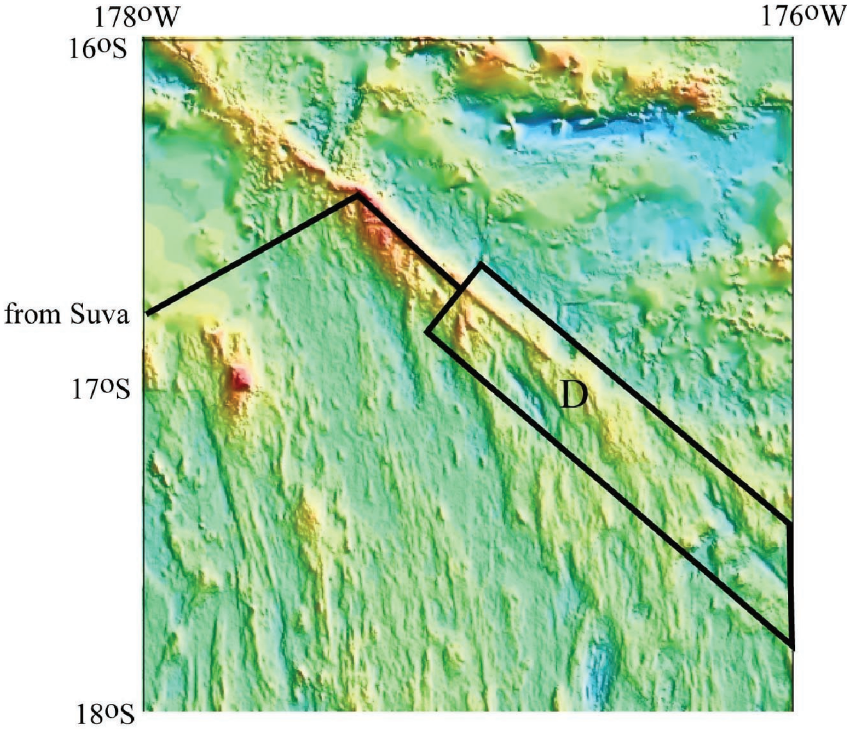

Figure 4: Planned areas of operations for 2nd Leg of SS07/2008

Southern Surveyor Equipment

Communications – voice, fax and data

- Navigation – archiving of underway data (time, position, bathymetry)
- Oceanographic data – (sea surface temperature, salinity)
- Echo sounders (12, 38, 120 kHz)
- General computing facilities and charting software
- Smith Macintyre grab sampler (x2)
- Rock dredge (x2) with weak links
- CTD (Seabird SBE 911 plus)
- Pressure sensor for wax-core casts
- Rosette (24 x 10 litre Niskin bottles)
- MilliQ water supply
- Swath mapper (EM300) and software
- Controlled temperature laboratory
- "Fish Laboratory" for rock sorting
- rock saw
- dredging, towing, coring, and hydrowinches

User Equipment

- magnetometer (from GA, on board from SS06/2008)
- underwater video camera sledge (from CSIRO Exploration and Mining)
- small gravity corer (from CSIRO Exploration and Mining)
- small gravity corer with sticky wax head (from ANU)
- copper tube crimping gear (for He, from NOAA; to be installed in Wet Lab)
- extra dredges (x2 from GA, on board from SS06/2008)

Personnel List

Richard Arculus	ANU	Chief Scientist
Charles Tambiah (Leg 1)	ANU	Photographer
Joanna Parr (Leg 1)	CSIRO E&M	Hydrothermal activity
Shannon Johns	CSIRO E&M	Hydrothermal activity
Zarah Heyworth	UQ	Petrology
Katie Kelley	URI	Petrology
Marion Lytle	URI	Petrology
James Cowlyn	MU	Petrology
Ron Greene (Leg 1)	NOAA	Helium
Michael Chandler	UH	Magnetics
Jelena Puzic (Leg 2)	Teck Cominco	Geologist
Pete Dunn (Leg 1)	CMAR	MNF Voyage Manager/Electronics Support
Jeff Cordell (Leg 2)	CMAR	MNF Voyage Manager/Electronics Support
Bernadette Heaney (Leg 2)	CMAR	MNF Computing Support
Hiski Kippo (Leg 2)	CMAR	MNF Computing Support
Anne Kennedy	CMAR	MNF Swath Support

As per AMSA requirements for additional berths on Southern Surveyor, the following personnel are designated as System Support Technicians and are required to carry their original AMSA medical and AMSA Certificate of Safety Training on the voyage:

Name	AMSA Certificate of Safety Training No.
Pete Dunn	AS03164
Jeff Cordell	AS02398
Bernadette Heaney	AS02397
Hiski Kippo	AS02377

This voyage plan is in accordance with the directions of the Marine National Facility Steering Committee for the Research Vessel Southern Surveyor.

Richard J.Arculus
Chief Scientist