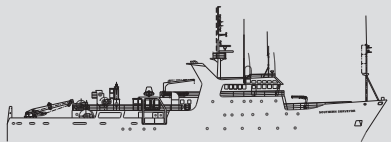

MARINE
NATIONAL FACILITY

RV *Southern Surveyor*

2007
program

CSIRO

voyage summary SS06/2007

SUMMARY SS06/2007

Volcanism and Tectonism of the South Bismarck Microplate, Papua New Guinea

Itinerary

Depart Madang 1000 hrs, Wednesday 25th July, 2007
Arrive Madang 1530 hrs, Monday 13th August, 2007

Principal Investigators

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Scientific Objectives

1. The principal objective of the expedition is to build on background reconnaissance carried out by previous expeditions (most notably RV *Franklin* FR02/2002 and RV *Kilo Moana* 0419 in 2004) in the submerged portions of the Bismarck Arc in order to characterise the petrogenesis and tectonic setting of previously unknown volcanic centres. Dredging and sticky wax coring will recover fresh glassy volcanic rock samples. 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, identify mantle sources likely including "Indian"-type and possible Manus plume components, and hence obtain insights into upper mantle flows associated with arc-continent collision on the northern margin of the Australian Plate.

2. A secondary objective is to test young volcanic features for evidence of associated hydrothermal activity. This will be done using a similar plume-location and characterisation approach used on previous voyages by the Chief Scientist and his collaborators.

Voyage Objectives

We seek to study the space – time distribution of the volcanic activity in order to investigate its relationships to the tectonic development of the South Bismarck Microplate, with the aim of understanding deviations from the normal patterns of volcanic activity associated with subduction and termination of subduction. The following are the objectives of the research voyage and follow-up laboratory studies:

What are the characteristics and linkages between the magmatism and different tectonic variables in the South Bismarck Microplate?

In order to complete our understanding of the volcanic-tectonic relationships of the South Bismarck Microplate, we need to map at high resolution the distribution of deformation and principal stress directions in undersea parts of the Plate. Data are particularly needed in the region of the junction of the volcanic arc with the Bismarck Sea Seismic Zone, and along the strike of the Willaumez Peninsula-Witu Islands to address the following questions:

1. The occurrence and distribution of volcanic vents, including the orientations of elongated vents and aligned vent arrays that indicate principal horizontal stress directions. Swath and backscatter mapping by the 2004 RV *Kilo Moana* voyage (Silver *et al.*, 2004; 2005) discovered a large number of volcanic features, including seamounts, small cones, lava flows and possible intrusions, and significant regional structures. While some of these had been serendipitously dredged by the FR02/2002 voyage, most have not been sampled (the KM0419 voyage made few dredges). Some of the volcanic features and flows occur on the submarine flanks of known subaerial volcanoes, notably Lolobau, Garove, Dakatuau, Langilla, Crown and Karkar while others are discrete features well away from the submerged flanks of subaerial volcanoes. *Silver et al.* (2004) noted a N-S perpendicular elongation of "vents structures" close to the subaerial Bismarck volcanic arc, and a trend more E-W to the north around Witu Islands and near Lolobau, implying a complex variation in regional stress directions. They also noted the previously unknown wide zone of volcanism extending to the north of the subaerial volcanic arc.

2. The distributions and geometries of fault systems and fold structures, especially along and close to the boundaries of the three sections of the South Bismarck Sea Microplate defined above but also within these sections, and their relationships to the distributions and orientations of volcanic vent systems and drowned reefs.

What are the nature and source characteristics of the magmatism in the South Bismarck Microplate?

We know that the nature of the mantle wedge (intrinsic fertility), nature of slab inputs (fluids/melts), and extents of partial melting are linked in terms of arc magma characteristics. The magmatism distributed across the southern part of the South Bismarck Microplate provides a window into slab inputs and mantle variability over a wide range of subduction and possible rifting variables from post-collision uplift, through ongoing subduction to possible pre-backarc basin rifting west of the Manus Spreading Centre.

Does the Manus mantle plume penetrate beneath the South Bismarck Microplate?

Based on the He, Sr, Nd, and Pb isotopic compositions of samples from Manus Island and vicinity, it has been proposed that a mantle plume is present (Macpherson et al, 1998). The strongest evidence for this hypothesis is high 3He/4He. We will obtain radiogenic isotope data for selected samples with which we should be able to detect plume input diminishing from north to south across the Microplate.

What are the characteristics of volatile distribution in the mantle sources of South Bismarck Microplate magmas ?

Submarine-quenched samples are demonstrably superior to degassed subaerial arc magmas for studies of pristine volatile contents. 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 and atmosphere is one of the first order geochemical processes. 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).

What is the incidence and distribution of tsunamigenic volcano collapses?

The KM0419 voyage identified a number of clearly tsunamigenic volcano collapses such as that of the flanks of Ritter. We also identified numerous similar volcano collapses in the Kermadec-Tonga Arc, and these features are generally significant both from the societal hazard point of view, as well as a major mode of redistribution of volcanic materials and arc crustal growth.

Voyage Track

The general area of operations is shown in Figure 1.
The voyage track is shown in Figure 2.

Results

During the West Bismarck Vents Expedition (WeBiVE) SS06/2007, 69 dredges, 35 hydrocasts, and 2 successful video tows were completed in the West Bismarck to New Britain Arc, extending from the North Bam seamount at about 144o 50'E to Target S (northwest of Lolobau Volcano) at about 151o 02'E, and extensive areas were ensonified by 30kHz multibeam swath bathymetry (Figure 1).

The primary results of WeBiVE are: 1. Numerous relatively small, submerged satellite cones and rifts are present around the major subaerial volcanoes of the volcanic arc front, but there are no major submerged volcanoes unlike the case for example, in the Izu-Bonin-Mariana or Tonga-Kermadec intaoceanic arcs. It is clear that the major volcanic edifices in the Bismarck-New Britain arc system are emergent; 2. alignments of the satellite cones and rifts shows the orientation of the major compressive stress in the arc crust is oriented at 010 at the volcanic front and swings to 045 in the Witu Islands; 3. Nine light transmission anomalies were detected at targets South Bam, North Karkar, K3, "Here Be Dragons", N, σ, ϕ, P and Cone 1 to the northwest of Ritter Volcano. Whether these are of hydrothermal or sedimentary plume origin remains to be determined; 4. a global first was achieved in the recovery of peridotite-cored basaltic xenoliths from active arc-front volcanic cones (NW of Ritter).

In summary, the results reported against the specific voyage objectives were:

1. *30 kHz swath mapping for detailed identification of volcanic targets located using available 12 kHz swath bathymetry from the KM0419 voyage, and previous voyages to the region.* With the exception of Target T (an emergent reef), we swath mapped all of the planned targets and more. Successful dredging and hydrocast operations were performed consequent to this survey activity.

2. *30 kHz swath traverses of two previously unmapped interpreted areas of the submerged Bismarck arc between Manam Island and Karkar Island and north of New Britain (Figure 1). Time constraints will preclude full swath mapping of these areas. However, the ship will be slowed on transit and care will be taken not to duplicate KM0419 tracks.* This objective was achieved but no major submarine volcano-hydrothermal targets were identified in this specific region.

3. *Sampling of submerged volcanic features using dredging, grab sampling and sticky wax coring.* Dredging operations were predominantly successful in returning representative lithologies of bathymetric targets identified by swath bathymetry. Sticky wax coring was not used on this voyage given the absence of extensive volcanically-active ridge/rift-like systems.

4. *Identification of hydrothermally active volcanic structures using CTD hydrocasts, plume water sampling, deep tow video, dredge and grab sampling.* Light transmission anomalies were identified at targets South Bam, North Karkar, K3, "Here Be Dragons", N, σ, ϕ, P and Cone 1 to the northwest of Ritter Volcano. These were all sampled for on-board methane analysis,and shore-based water analyses. In addition to these targets explored with hydrocasts, many other targets were also dredged, in some cases more than once. We completed two video tows over Target N and Cone 1 respectively.

Voyage Narrative

All times in local time (Eastern Australian Standard Time = UTC + 10 hours)

Day 1 Wednesday July 25th Delays in bunkering meant WeBiVE departed Madang at 1826. A short hydrocast operation was carried out to test the functionality of the CTD altimeter, which had not worked during the transit voyage from Darwin to Madang. WBH-01 was deployed at 1933 and returned to deck at 1957. The altimeter, which now had a new cable, functioned perfectly.

Day 2 Thursday July 26th At 1401, swath mapping of Target A (North Bam seamount) was completed, and showed two well defined volcanic cones. The higher, northeastern cone rises to a depth of ~390 metres below sea level (mbsl), looks very young and is cut by a north-south trending rift ridge. The southwestern peak rises to ~450 mbsl and looks older. WBD-01 on the NE cone returned ~100kg of old-looking, dark grey, vesicular, iron-stained, slightly plagioclase-phyric andesite. Following the conclusion of the dredge, a single dip hydrocast, WBH-02 was deployed immediately south of the summit of the northeastern cone. No light transmission anomalies were detected. WBD-02 targeted on the rift zone to the south of the main cone was deployed at 1805. The ship struggled to hold station and the dredge returned to deck empty. The operation was repeated as WBD-03 and returned a piece of old-looking andesite and some pumice, as well as gorgonian and other coral fragments and a brittle seastar. Target A is interpreted to be an old inactive feature. We moved ~5 miles east to Target B, where we commenced a swath survey, revealing a cluster of three small and one large volcanic cones, with the largest feature once again cut by a north-south trending rift and rising to a depth of ~730mbsl.

Day 3 Friday July 27th Dredge WBD-04 of the main cone recovered several pieces of old-looking amphibole-phyric dacite. We then moved ~7 miles north to begin swath mapping of Target C defining an east-west trending ridge, as anticipated, with a high backscatter (hard rock) spine. WBD-05on the spine returned ~20kg of dark grey mudstone, implying the feature is a fault structure, rather than volcanic in nature. WBH-03, a single dip hydrocast, was deployed in a partially enclosed basin off the western end of the ridge. No light transmission anomalies were seen, but 12 bottles were sampled. The vessel moved ~5 miles west to the north of Blup Blup Island, to commence swath mapping of the central portion of Target C and also Target D, a feature to the north of Blup Blup. An acoustically reflective ridge at Target C was dredged by WBD-06 recovering ~200g of light grey mud in 2 of the sediment traps. The feature is interpreted to be an old basement feature. Next a small cone north of Blup Blup Island (Target D) was dredged (WBD-07) recovering dark grey mud in a sediment trap.

Day 4 Saturday July 28th A 400m high acoustically reflective conical feature with a crest depth of 1150m south of Bam was dredged by WBD-08, recovering ~100kg of very fresh looking, weakly vesicular olivine-clinopyroxene- plagioclase phyric basalt. The sediment traps contained gravel and grit of the same material, black volcanic glass shards and grey-green mud (volcanic ash). two hydrocasts were deployed. Hydrocast WBH-04 immediately to the east of the cone showed a possible very weak particulate plume (~0.2% drop in light transmission) at the bottom of the cast. WBH-05 west of the cone showed a distinct bottom hugging plume (1% drop in light transmission) below

1340m. It may represent a sediment plume from the Sepik River. On board analysis showed elevated methane concentrations in the plume up to 88 nL/L, compared with typical background values to date of 20-30 nL/L. We then tracked to the south of Karkar swathmapping acoustically reflective uneven terrain with a strong ~010 fabric to the bathymetry, consistent with the parasitic cones on Karkar Island. The geomorphology suggests small conical eruptive centres along parallel rifts with short lava flows. Two of the cones were dredged: WBD-09 returned a small load of mud, weathered plagioclase-phyric vesicular andesite with iron staining, sponges and coral. WBD-10 returned with a small load of fresher plagioclase-phyric vesicular andesite and a few small corals.

Day 5 Sunday July 29th started with swath mapping of Target G, a foundered atoll with a 3 phase planation history (terraced at ~1050m, ~750m and ~450m), southwest of Bagabag. WBD-11 of this target recovered a large load of Mn oxide-coated limestone, heavily Mn oxide-coated volcanic rock, coral, crinoids and brittle star fragments, and a 1.5m long piece of wood. Traversing the east coast of Karkar, a small 100m high, sharp crested conical feature was dredged by WBD-12. The dredge returned a few grams of watery dark brown mud and a few rounded granules of volcanic rock in the sediment traps. The bathymetry to the north of Karkar is not as spectacular as that seen to the south and lacks the clear 010° trend seen there. A single obvious volcanic cone was seen and targeted by WBD-13. A large load of fresh, glassy, grey-black, poorly vesicular, very sparsely plagioclase-olivine-phyric pillow basalt was recovered. Hydrocast WBH-06 to the west of this cone detected a broad, weak (0.2% drop in light transmission) plume was seen between 920dB and 1180dB. WBD-14 targeted a smaller cone north of WBD-13 site, recovered a single hand-sized piece of fresh, glassy, dark-grey, vesicular, plagioclase-clinopyroxene-phyric andesite. The sediment traps contained chips of volcanic glass and some light grey mud.

Day 6 Monday July 30th The vessel transited 10 miles east to Target F, an ovoid, ~15km x 10km, relatively flat topped cone, broadly similar in morphology to Target G, with a high point of ~540mbsl. The overall feature is likely to be a foundered atoll. A small (~100m high, 400m diameter) cone on the summit area was selected for dredging in the hope that it would represent more recent volcanic activity. Another smaller volcanic cone lies immediately SE of Target F and was also selected for mapping and sampling. WBD-15 was deployed on the small cone on the summit of Target F returning a moderate load of medium- to dark-grey volcaniclastic sand with some bioclastic components. The floor and eastern wall of the small cone to the southeast was dredged by WBD-16. Initially the material recovered appeared to be similar to WBD-15, and so we proceeded to Target H, some 25 miles ESE. During the transit, the material from WBD-16 was examined more closely and was found to comprise dark green indurated silt (containing foraminifera). Some veins and fractures within the clay are darker green and the material is interpreted to represent hydrothermally-altered sediment, with the green colour possibly due to nontronite. A number of fragments of bladed to nodular Mn-oxide crust were also found in the clay (possibly all from a single piece originally), as well as one angular pebble of plagioclase-phyric vesicular volcanic rock and a rounded pebble of exotic pumice. In light of this result, the decision was made to return to Target F Southeast following operations at Targets H and I. WBD-17 was deployed on the southwest wall of the summit of seamount H,

recovering a load of hemipelagic ooze (containing foraminifera) with some 3-4cm thick Mn Oxide crusts. The vessel moved ~8 miles to the southeast to map and dredge the northwestern slope (WBD-18) of Target I. foraminiferal-bearing mud, with some exotic pumice fragments and pieces of wood were recovered . The volcano was therefore also considered to be extinct and the vessel began transiting back to Target F Southeast.

Day 7 Tuesday July 31st WBH-07 was deployed on into the summit crater of the cone at Target F Southeast but no evidence of a hydrothermal plume was seen. WBD-19 dredged the western slope of the crest of the cone returning ~30kg of plastic, khaki green, hemipelagic ooze. The silt fraction of the ooze consisted of foraminifera and some black volcanic glass. Wood pieces, two 20cm sponge spicules, a handful of rounded pebbles of exotic pumice and a few angular (locally derived) pieces of black glassy amygdaloidal volcanic rock were also extracted from the mud. The amygdales of the volcanic rock are filled with white crystalline material (probably a zeolite). We then transited to North Crown, some 60 miles to the southeast via West and South Hankow Seamounts. Neither of these features, with crests at ~250mbsl were considered targets having been demonstrated as inactive by the Bismarck 2002 Expedition. The swath survey north of Crown Island, identified several cones, the largest of which was dredged by WBD-20, recovering a large load of boulders of andesitic to dacitic hornblende crystal tuff, most obviously sourced as a debris flow from Crown Island. We then dredged (WBD-21) a distinctive cone in the western part of the North Crown area, recovering several rounded, mud-covered, strongly weathered basaltic andesite boulders. No transmission anomalies were seen in WBH-08. A third cone in the North Crown area was sampled by WBD-22.

Day 8 Wednesday August 1st This dredge recovered only one rock– a vesicular andesitic volcanic bomb. Following three dredges and a hydrocast in the North Crown area, it appears that it contains old inactive volcanic cones partially buried beneath a mass flow from Crown Island. The vessel transited ~5 miles to the southeast to map Targets J and K1, proving to be a flat-topped feature, with a crest at ~530mbsl, and a series of irregular ridges trending towards 340º respectively. WBD-23 was deployed on Target J recovering a single fist-sized piece of pink coralline limestone with a dark manganiferous crust. The limestone had a freshly broken surface so was probably outcrop. The dredge haul suggests that the feature is old, as does its flat topped morphology. Strong SE winds prevented the dredging of K1, so we moved 5 miles to the north to map Target K2, proving to be a subdued lozenge shape and not considered a priority target. A feature ~5 miles west of K2 is dome shaped and irregular – potentially a volcanic centre with viscous blocky flows. However, the feature is not acoustically reflective and is likely sediment draped. With conditions still preventing deployment of equipment, the vessel continued in a generally north-northeast direction to map Target K3 and Target L. K3 comprises 2 NNE-trending elongate ridges and a circular feature. The ridges are both ~1.5km long and ~200m high, with crests at ~1300mbsl. The circular feature has a crest at ~1420mbsl. All three are acoustically reflective. Target L is irregular in shape, acoustically reflective, ~200m high, and has a crest at ~1500mbsl. With conditions moderating, a dredge targeted the southernmost ridge of Target K3 (WBD-25), covering a large load of vesicular andesite with weathered surfaces. Next a hydrocast (WBH-09) was deployed to provide a full profile through the water mass. A very weak (<0.1% drop in light transmission) particulate plume was seen at ~1500mbsl.

The vessel then transited northeast to dredge Target L (WBD-26) recovering mud in the sediment traps. A 90 mile transit to Target M commenced of which very little had previously been swathed by the Kilo Moana. We encountered a large unmapped bathymetric high (informally dubbed "Here Be Dragons"), and diverted, revealing a large (~15 x 10km) 1500m high feature with a sharp 350mbsl crest at ~4° 51'S, 147° 47'E. The feature appears fault bounded by NW-SE and E-W trending faults and has an L-shaped, hard (acoustically reflective) crestal ridge roughly parallel to both these trends.

Day 9 Thursday August 2nd With high winds preventing dredge deployment, a hydrocast (WBH-10) to the northeast of the summit was undertaken. A very weak (~0.1%) light transmission drop was observed between ~320 and 550dB. With seas diminishing, a dredge (WBD-27) of the northern ridge of "Here Be Dragons" recovered half a dozen cobbles of pockmarked, heavily Mn-oxide stained calcarenite. The sediment traps contained foraminiferal sand. Although this result indicates the feature is old, a hydrocast (WBH-11) was completed west of the crest, giving a similar result to WBH-10, with a possible very weak plume below ~350dB. We continued mapping towards Target M, discovering a few low (<150m high) ovoid mounds but none considered to be sufficiently large to warrant further study. Target M is elongate in a SW-NE direction rising 500m to a crest at ~1350mbsl. A dredge (WBD-28) was deployed on the northwestern slope of the main cone retrieving two pieces of weathered vesicular basalt, implying the feature is old. Foraminifera-rich sediment was recovered from the sediment traps. The main cone at Target N ~5 miles SSE of M rises 500m above the surrounding area to a depth of ~1350mbsl, and like Target M is elongate in a SW-NE direction. However, the feature is more irregular than M, possibly indicating it is younger.

Day 10 Friday August 3rd A dredge (WBD-29) targeted the northwestern side of the crest of Target N recovering a few pebbles of exotic pumice and sandstone and minor quantities of foraminiferal mud. A second dredge (WBD-30) targeted the SW ridge and retrieved a large pillow fragment and a couple of smaller pieces of very fresh, weakly iron oxide-stained, strongly vesicular, plagioclase-phyric basalt, with a small amount of brown foraminiferal ooze on the rocks and in the sediment traps. A series of hydrocasts were then executed to test for particulate plumes around N. WBH-12 deployed to the west of the main cone detected no evidence of hydrothermal activity. WBH-13 deployed to the southeast had a similar negative result. WBH-14 deployed directly over the col between the main cone and the SW ridge detected a strong, sharp, multilayered particulate plume from 1525 dB to the bottom of the cast at 1577 dB, with a peak drop in light transmission of ~1.5%. A video tow was planned to run along the spine of the SW ridge of Target N, through the col and up over the crest of the feature. WBV-01 was deployed but within 50 metres of bottom, the brake on the corer winch failed - quick thinking by the winchman saved the camera but the operation had to be abandoned. Examination of the camera system's CTD data revealed a 2% drop in light transmission at ~1545dB, the same pressure as the plume detected in WBH-14, confirming Target N is hydrothermally active. With the vessel unable to deploy the camera system until the winch had been repaired, swath mapping transits were executed to the south (Target N2), and to M2, ~5 miles to the northeast of Target M. We continued in an ENE direction to map targets O and P and an ~18 x 3 mile area trending SSE from Target P. A number of small ridges and cone features were mapped, including one breached caldera. Three areas of interest were dubbed Targets γ, ε, and δ.

Day 11 Saturday August 4th A hydrocast (WBH-15) in the basin to the west of Target γ gave no evidence of a particulate plume. The spine of a sharp, reflective SW-NE trending ridge at Target γ was then dredged (WBD-31) recovering a large load of boulders and cobbles of weathered, vesicular, olivine-plagioclase-phyric (coarse phenocrysts) basalt coated with khaki mud. Following this, the vessel moved ~2 ½ miles to the north to test a breached caldera for hydrothermal activity. WBH-16 showed no evidence of a particulate plume. WBD-32 targeted a resurgent dome within the caldera. recovering a small load of volcaniclastic-formaniferal sand with a few pebbles of exotic pumice. Following recovery of the dredge, the vessel steamed 2 ½ miles to the southwest to test a 200m diameter acoustically reflective crater, termed Target γ West. WBH-17 was deployed with the intention of dropping the CTD into the crater but ship drift meant the CTD reached the bottom of its cast over the NE outer wall of the cone with no particulate plume detected. WBD-33 designed to sample the crater walls returned a large load of boulders and cobbles of very fresh olivine-phyric pillow basalt with beautifully developed glass rinds. Some of the pieces show grey-green (epidote-zeolite?) alteration of fracture surfaces. The load was layered, with khaki-brown ooze at the base of the bag, probably dredged from the outer slope of the crater. A few pieces of exotic pumice were also recovered. Following recovery of the dredge, RV *Southern Surveyor* commenced a short swath mapping exercise to the west of the crater, over an area highlighted in the Kilo Moana data as highly acoustically reflective, termed Target σ. The area comprises a large rubbly shield volcano (viscous flows) with a well defined small shallow crater at its centre. We moved back to the crater tested by WBH-17 and WBD-33 to make a second attempt to deploy the CTD to the crater floor and were successful with flawless execution of WBH-18 and discovery of a sharp plume, with a peak drop in light transmission of ~1.5% seen from 1315 to 1345dB.The acoustically reflective western flank of another cone in Target γ was sampled by WBD-34 with a good load of fresh, glassy, highly vesicular olivine-plagioclase-clinopyroxene-phyric bombs and blocks of basalt. A hydrocast (WBH-19) was then deployed to test the feature for hydrothermal activity but no evidence of a particulate plume was seen. The vessel then moved west to dredge the small crater mapped in area σ. WBD-35 recovered two pieces of basalt and some muddy sediment. Another attempt was then made to sample the particulate plume seen in WBH-18. Unfortunately the vessel failed to hold station during WBH-20 and the CTD missed the crater. No plume was seen.

Day 12 Sunday August 5th The ship then transited to Target δ, about 10 miles to the SSE. On arrival an acoustically reflective cone was dredged. WBD-36 recovered a large load of fresh olivine-plagioclase-phyric basalt, with massive flow interiors and thick Fe-oxide stained glassy rinds, and WBD-37 deployed over another acoustically reflective cone in Target δ returned with a large load of fresh, strongly vesicular, glassy, olivine-plagioclase-phyric basalt and a few pieces of pumice. WBH-21 was deployed at Target δ but no evidence of a particulate plume was seen. A third acoustically reflective cone on the western edge of Target δ, ~2 miles east of Unea Island was then dredged (WBD-38) with the vessel failing to hold station and the dredge dragging across slope. With no tension bites, only a few hundred grams of brown foraminiferal silt in the sediment pipes was recovered. Next we transited west back to Target N for a camera tow (WBV-02) along its ridge and southwestern slope which featured scattered pillow basalt outcrop heavily draped in sediment, with abundant benthic fauna (sea pens, coral, worms and anemones). No evidence of hydrothermal activity was seen in the video but examination

of the CTD data from the tow revealed two coincident positive temperature – negative salinity anomalies. One corresponded with a camera crash, while the second, stronger anomaly occurred after the video ceased to function, as the camera descended the northeastern slope of the volcano. We moved ~4 miles south and dredged Target N2 (WBD-39) retrieving weathered vesicular basalt flow crusts. Following a ~6 mile transit north, WBD-40 on Target N3 recovered only a small quantity of mud. Transiting ~10 miles to the north, we swath mapped Target M3 revealing a generally SW-NE-trending bathymetry with hard lava ridges, similar to that previously seen around the Witu Islands.

Day 13 Monday August 6th Results around the Witus showed clear domination by basaltic volcanism and we decided to transit east to Targets Q and R, west of the Willaumez Peninsula, with the intention of finding some more silicic volcanism and possible associated hydrothermal activity. Target Q is a 2.5km diameter, 800m high feature with a crestal depth of 690mbsl. The crest is slightly flattened and the volcano shows evidence of sector collapse, but the lower NW and SE flanks exhibit acoustically reflective, apparently young, lava flows. WBD-41 dredged the NW flank returning with one large boulder and a collection of smaller pieces of strongly weathered (Fe-oxide stained with epidote-altered rinds) vesicular plagioclase-olivine-clinopyroxene-phyric basaltic andesite. Some minor quantities of amphibole-phyric pumice were also recovered. WBH-22 deployed to the northwest of the summit of showed no evidence of a particulate plume. The crest of Target Q was dredged by WBD-42, which recovered a large load of black, scoriaceous, glassy flow rinds of olivine-clinopyroxene-plagioclase-phyric basalt-basaltic andesite, with some Fe-oxide staining and discolouration, along with minor quantities of pumice. We moved ~7 miles SSE to map Target R which is a 1.5km long, northwest-trending 400m high ridge, with a crestal height of ~550mbsl and an adjacent twin-coned volcano, which rises to a depth of ~750mbsl. WBD-43 returned a single boulder of weathered and Fe-stained plagioclase-olivine-clinopyroxene-phyric vesicular basalt and some volcaniclastic-bioclastic sediment from the summit of R. Given an apparently meagre return despite multiple tension spikes during the dredge operation, the decision was made to replace the circular Lister dredge (used for all operations to date) with one of the vessel's smaller, rectangular dredges and retry the operation. WBD-44 recovered a single boulder of weathered and Fe-stained plagioclase-olivine-clinopyroxene-phyric vesicular basalt, but returned far more mud and volcaniclastic sand and biological material than the Lister dredge. A further dredge (WBD-45) again targeted the volcanic cone at Target R recovering black, scoriaceous, glassy flow rinds of olivine-clinopyroxene-plagioclase-phyric basalt-basaltic andesite and pieces of more massive olivine-minor plagioclase-phyric basalt, with some Fe-oxide staining and discolouration, along with some muddy sediment and pumice. A hydrocast (WBH-23) between the cone and main ridge at Target R showed no evidence of particulate plumes.

Day 14 Tuesday August 7th Following recovery of the CTD, the vessel transited north and then east, around the tip of Willaumez Peninsula crossing two sharp lava ridges ~2 miles off the northeast tip of Willaumez, eastwards across the Bay towards target AG. WBD-46 recovered ~40kg of boulder sized fragments of strongly indurated khaki green and tan mud from the Target's summit. At Target θ, dominated by east-west and north-south-trending lineaments, WBD-47 recovered from the furthest northwest feature, old olivine-plagioclase-phyric vesicular basalt, muddy sediment, several corals and a brittle star. A hydrocast (WBH-24) found no evidence of a particulate plume. Although WBD-48 was planned to follow completion

of the swath mapping of western θ, it was decided to terminate the dredge given the bathymetrically uninteresting character of the terrane. Instead, a short transit to the east followed with dredging (WBD-49) of the largest seamount on the eastern side of Target θ, recovering old, strongly weathered, Mn-oxide-encrusted vesicular basalt, minor pumice and muddy sediment. We moved ~10 miles east to Target S.

Day 15 Wednesday August 8th The main cone at Target S rises ~600m to a crest at ~1500mbsl. Dredging of the crest (WBD-50) returned a small quantity of mud and a few pieces of pumice, while the trailing bucket dredges were filled with mud. Sorting through this material recovered one rounded piece of vesicular black volcanic rock, one piece of more glassy material and one piece of Mn-oxide crust. A hydrocast (WBH-25) deployed to the south of the main cone detected no evidence of a particulate plume. Swath mapping a ridge immediately to the south of the main cone at Target S revealed a 100m-high cone, with a crest at ~1140mbsl at the northern tip of the ridge. WBD-51 deployed on this feature recovered a small quantity of mud. The bucket dredges dominantly contained mud, with some volcaniclastic-bioclastic sand and indurated clay. Two pieces of pumice and one fist-sized piece of vesicular black volcanic rock with a well developed glassy rind were also recovered. Like Target θ, Target S appears to be volcanically and hydrothermally inactive. The Master of the vessel indicated unwillingness to carry out operations within two miles of the summit of Target T, which emerges as Mele Reef. It was therefore decided this target would not be investigated by SS06-2007, and we transited ~12 miles to the WNW, where a gravity coring operation was planned in 2200m of water. WBS-01 recovered 12cm of dark brown mud, increasing in competence downhole. The core barrel and lead weights were streaked with brown mud, indicating that the corer struck bottom and fell to the side after failing to penetrate deeply. The core contained a number of dark layers, possibly rich in volcanic ash. The next Target (AF) is elongate SW-NE, with a steep southeast slope and a flat crest, which slopes more gently to the northwest. It appears to be a fault block. WBD-52 returned from its steep southeastern flank a ¾ full bag, with mud at the base (from the lower part of the slope) and pieces of strongly weathered andesitic volcanic rock, mudstone and Mn-oxide crusts above it (presumably from closer to the crest of the feature). This result confirmed the hypothesis that Target AF is a fault block, rather than a young volcanic feature.

We transited ~ 15 miles northwest to map Target AD which is elongate in an E-W direction and rises 600m to a crest at ~1580m, but all with low acoustic reflectivity. A dredge (WBD-53) deployed on the crest recovered a large quantity of mud, mudstone, black andesitic pumice, Mn-oxide crusts and pieces of olivine-plagioclase-phyric volcanic rock. Target AD is clearly an old, extinct feature.

Day 16 Thursday August 9th Target ϕ is a ~3km diameter, 600m high ovoid conical feature, elongate in a NW-SE direction, with a crest at 1425mbsl crossed by RV Franklin during the Bismarck 2002 Expedition. The cone has low acoustic reflectivity and shows evidence of erosional features around its lower slopes. A dredge (WBD-54) over the southwest slope and summit recovered mostly mud, but contained one large 50x50x5cm slab and a number of smaller pieces of Mn-oxide, pieces of bioturbated mudstone and sandstone and a number of pieces of pumice. Manganese oxide is intimately associated and replaces greenish bioclastic siltstone and a handful of pieces

of the oxide exhibit either fluid conduits or Mn-oxide replacement of worm burrows, indicating hydrothermal origin for the oxide.Two hydrocasts tested ϕ for hydrothermal activity: WBH-26 deployed directly over the summit; WBH-27 deployed over the southwest flank. Neither saw clear evidence of hydrothermal activity, although a very weak particulate plume (~0.1% drop in light transmission) was seen at 1370dB in WBH-27. Following these unpromising hydrocast results we swath mapped to the north of Garove Island revealing little of interest, other than a 80m high, 100m diameter circular "pimple" to the northwest of Garove, with a crestal depth of 270mbsl, which was named Target ω. The summit of Target P was next dredged (WBD-55) recovering a huge haul of old, very strongly weathered olivine-plagioclase-clinopyroxene-phyric, variably vesicular basalt/basaltic andesite and bioturbated mudstone. A hydrocast (WBH-28) deployed just southwest of the summit detected a possible very weak (≤0.1%) drop in light transmission at ~800dB, approximately coincident with the crest of the volcano. The water sample taken at this depth was filtered, but no particulate material was visible on the filter. We transited ~5 miles back northeast to dredge Target ω. The dredge (WBD-56) got badly anchored during the operation and on return to deck had lost one of its trailing buckets. The operation recovered a few fragments of reefal limestone and some volcaniclastic-bioclastic sand, indicating Target ω is a foundered reef.. We moved some 10 miles to the southwest to dredge Target O. WBD-57 returned Mn-oxide encrusted vesicular pillow basalt. The ship commenced a transit to an area of suspected fresh volcanic flows north of Cape Gloucester (designated as Target ψ) at 2015.

Day 17 Friday August 10th We arrived at approximately 0100 and began mapping the area. When the swath bathymetry was examined, it became apparent the area is dominated by erosional channelling and sedimentation so we headed for Ritter. Conditions remained windy throughout the day during swath mapping until 1607 when the main engine of the vessel stopped, with the ship less than 2 miles to the windward side of Ritter. Fortunately the engines were shortly restarted. After a brief detour to open waters while the ship's engineers assessed the cause of the problem (diagnosed as fuel lines), the vessel continued mapping revealing a number of features of interest: a 250m high cone (crest at 225mbsl) with a 300m diameter, 60m deep crater at its summit immediately to the west of Ritter, interpreted to be the current eruptive centre; Three acoustically reflective volcanic cones to the northwest of Ritter, between Sakar and Umboi. Sustained high winds through the Dampier Strait meant no deployment of equipment was permitted by the bridge, so we transited to North Tolokiwa with the intention of returning to Ritter if conditions eased. At North Tolokiwa, two acoustically reflective cones were selected as potential dredge targets.

Day 18 Saturday August 11th WBD-58 contained brown mud and approximately a dozen boulders and cobbles of vesicular flow-banded olivine-plagioclase-clinopyroxene-phyric basalt/basaltic andesite. About ~1 mile to the North, WBD-59 recovered a similar haul of rounded cobbles and boulders of vesicular olivine-plagioclase-clinopyroxene-phyric basalt plus brown ooze in a sediment trap. A hydrocast (WBH-29) between the two dredge targets showed no evidence of a particulate plume. At 0500, RV *Southern Surveyor* departed North Tolokiwa for North Sakar reaching the area of interest at 0817 and completed mapping at 0930. An acoustically reflective, 3km long, ~300m high, northeast trending ridge with its

crest at ~1130mbsl, featuring two distinct volcanic cones was selected for dredging. During WBD-60,the vessel failed to hold station drifting parallel to ridge, failing to cross the crest, and recovering one small boulder and a few pebbles of weathered olivine-clinopyroxene-plagioclase-phyric basalt, along with some silty brown ooze.

A subsequent hydrocast (WBH-30) also experienced weather difficulties so the operation was abandoned. The Master agreed to return to the area to the northwest of Ritter and assess conditions which proved adequate to dredge an acoustically reflective volcanic cone ~3 miles to the northwest of Ritter (Cone #1).WBD-62 recovered a haul of fresh scoriaceous olivine-clinopyroxene-plagioclase-phyric basalt, some of which have xenolithic cores of peridotite (harzburgite) and olivine-bearing gabbro.A hydrocast to the northwest of Cone #1 (WBH-31) measured a broad particulate plume from ~790dB to the bottom of the cast at 960dB, with two distinct peaks – a ~1% drop in light transmission at ~840dB and a sharp, ~2% drop immediately above bottom. A second acoustically reflective cone (Cone #2) ~2 ½ miles northwest was dredged (WBD-63) recovering a haul of fresh scoriaceous olivine-clinopyroxene-plagioclase-phyric basalt, some with xenolithic cores of peridotite and gabbro, and muddy volcaniclastic sediment. With excitement levels high amongst the igneous petrologists, a decision was made to re-dredge Cones #1 and #2, in order to recover additional xenolithic material. WBD-64 at Cone #2, and WBD-65 gave similar results to WBD-62 and WBD-63 respectively. WBH-32 was deployed to the southeast of Cone #2 recording a broad light transmission anomaly from ~770dB to the bottom of the cast at 990dB, with a distinct peak of ~0.8% at ~880dB. The strong bottom hugging plume seen in WBH-31 was not detected.

Day 19 Sunday August 12th Shortly after midnight, the vessel moved ~1½ miles to the northwest of Cone #2 to dredge Cone #3, a feature on a ridge that runs northeast from Umboi Island. WBD-66 recovered a load of Fe-oxide stained vesicular olivine-phyric basalt and muddy volcaniclastic sediment. WBD-67 at Cone #4, 1 ½ miles east recovered ~30kg of peridotite xenoliths wrapped in fresh, glassy basalt, as well as one eroded piece of more massive weathered basalt and a galatheid crab. WBH-33 north of Cone #2 recorded a broad light transmission anomaly from 770dB to the bottom of the cast at 1075dB. The maximum drop in light transmission was approximately 0.5% and the distinct peaks seen in WBH-31 and WBH-32 were not present.WBD-68 dredeged a low walled crater ~1 mile to the northeast of Cone #2, recovering one fist-sized piece of fresh glassy dark grey basaltic andesite. The pipe dredges contained sand, grit and gravel of black glassy volcanic rock, some pumice, 1 or 2 small pieces of peridotite and minor brownish ooze. The ship returned to Cone #1 and executed a hydrocast (WBH-34) to the southeast of the feature recording a broad, moderate intensity (maximum drop in light transmission of 0.8%) particulate plume from 795dB to the bottom of the cast at 910dB - it appears the source of the plume in the area lies close to or at Cone #1. WBD-69 dredged Cone #5, ~2 ½ miles northeast close to Sakar Island, retrieving ~20kg of peridotite xenoliths with basalt rinds and the sediment pipes containing gravel and pebbles of similar material and some brownish ooze. WBH-35 was deployed to the northwest of Cone #5 and detected a broad particulate plume from 770dB to the bottom of the cast at 860dB. A peak drop in light transmission of ~0.6% was seen in a plume at ~810dB. After the conclusion of the hydrocast, a short mapping exercise around the eastern side of Ritter was carried out, in an attempt to extend our swath coverage there

closer to the island. The vessel then made position for a video tow across Cone #1. WBV-03 crossed the crest of Cone #1 shwoing seafloor to the north of the cone and its lower flanks are heavily sedimented and the crest is hydrothermally active, with weak temperature anomalies and apparent Fe-oxyhydroxide deposits. While the video tow data were being assessed, with winds exceeding 30 knots, trouble with RV *Southern Surveyor*'s thrusters (two inoperable and the remaining two leaking oil profusely) meant that all operations requiring deployment of equipment were suspended. A decision was made to carry out further mapping around Sakar Island, prior to beginning the transit back to Madang.We swath mapped the western side of Sakar, before tracking north and east of the island. At 2107 the vessel executed a "U-turn" to the southeast of Sakar and began its transit to Madang. Midnight saw the ship ~7 miles northwest of Sakar.

Day 20 Monday August 13th At 0700 RV *Southern Surveyor* was steaming at ~9.5 knots between Crown and Long islands en route to Madang. After exchanging sentiments of amiability with the USN mini-carrier Pelieu conducting a good-will mission to Madang, we docked at 1530 hours.

Summary

Overall, WeBiVE was very successful scientifically. The 30 kHz swathmapper once again demonstrated its fundamental importance for surveys of seafloor volcanic, tectonic and hydrothermal activity.

Within a period of 3 weeks, we defined the occurrence and distribution of submarine volcanic activity in the western Bismarck and New Britain arcs together with associated structural deformation patterns. In addition to extensive sampling of the magmas forming numerous small volcanic edifices, many of them basaltic in character, we established the sporadic occurrence of hydrothermal systems. We mapped at high resolution the debris field of the 1888 collapse of Ritter, and for the first time in any submarine oceanic arc systems from eruptive centres on the volcanic front, recovered samples of the upper mantle below the arc.

The RV *Southern Surveyor* is fundamentally well equipped for this particular kind of research. While the transmissometer performed reasonably well on this voyage, experience has continued to show that a nephelometer would be more sensitive in the hunt for hydrothermal plumes on future National Facility voyages.

Personnel

Scientific Participants

Professor Richard J. Arculus	ANU-Earth & Marine Sciences	Petrology/tectonics
Dr Samantha Burgess	University of Oxford	Geochemistry
Ms Heather Cunningham	Macquarie University	Petrology-isotopes
Dr David Fuentes	CSIRO Petroleum	Water chemistry
Ms Shannon Johns	CSIRO Exploration & Mining	Ore deposit geology
Ms Sarah O'Callaghan	ANU-Earth & Marine Sciences	Petrology/tectonics
Mr Tarum Whan	ANU-Earth & Marine Sciences	Petrology
Dr Chris Yeats	CSIRO Exploration & Mining	Ore deposit geology
Mr Bob Beattie	MNF	Computing Support/ Voyage Mgr
Mr Drew Mills	MNF	Electronics Support

Marine Crew

Neil Cheshire	Master
John Boyes	Chief Officer
Peter Gridley	Second Officer
John Morton	Chief Engineer
Dave Jonker	First Engineer
Gilbert Elder	Second Engineer
Tony Hearne	Bosun
Matthew Barrett	Integrated Rating
John Hall	Integrated Rating
John Howard	Integrated Rating
Jonathon Lumb	Integrated Rating
Charmayne Aylett	Chief Steward
Rebecca Lee	Chief Cook
John Leonard	Second Cook
Tony Kennard	TIR
Daniel Nicholson	TIR

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Professor Richard J. Arculus (Australian National University)
Chief Scientist

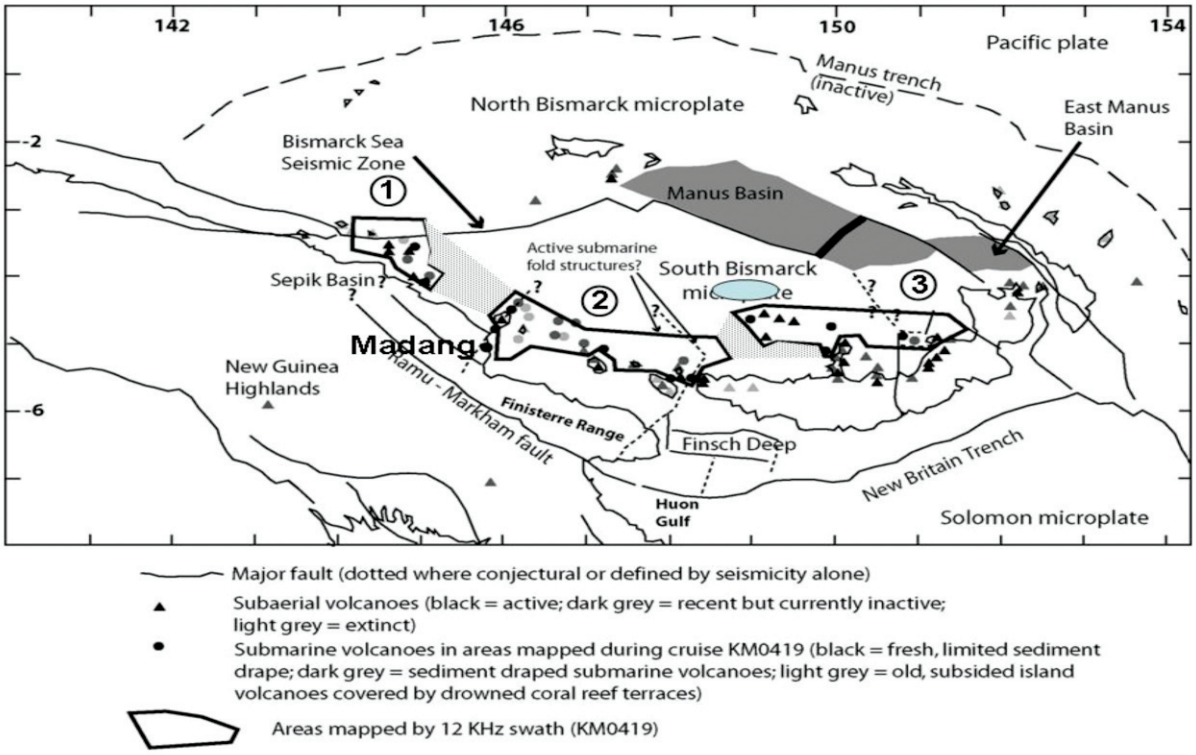

Figure 1: The Bismarck Arc in regional context indicating the location of active and inactive plate boundaries, other major geographical and tectonic features, known volcanoes, the target areas swath mapped by the KM0419 research voyage (Areas 1 to 3).

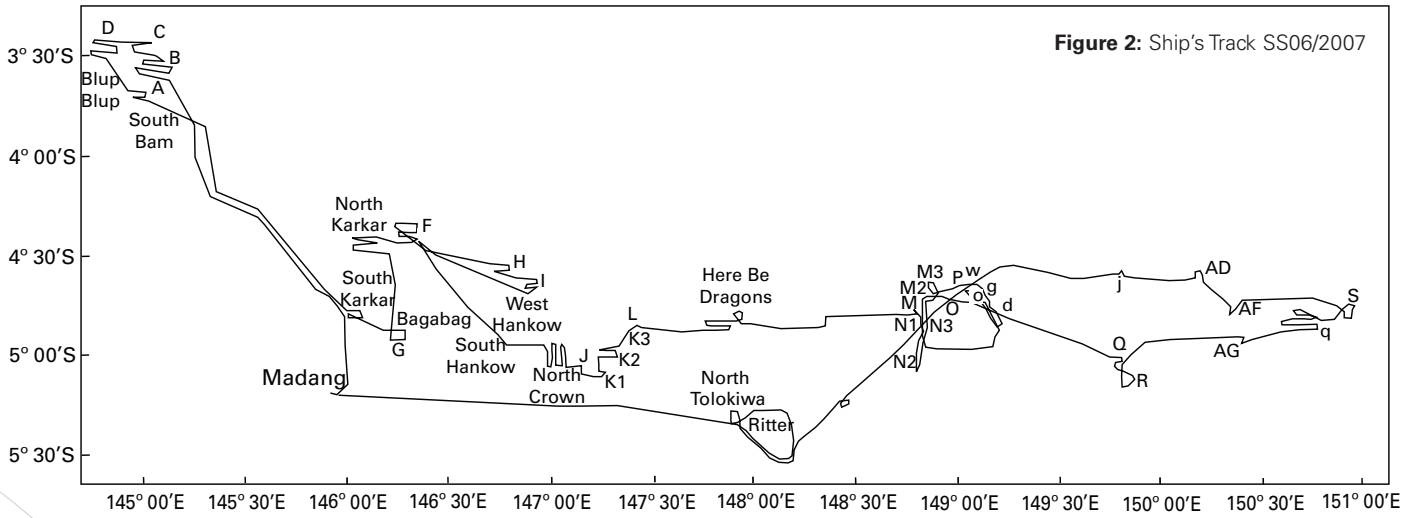

Figure 2: Ship's Track SS06/2007