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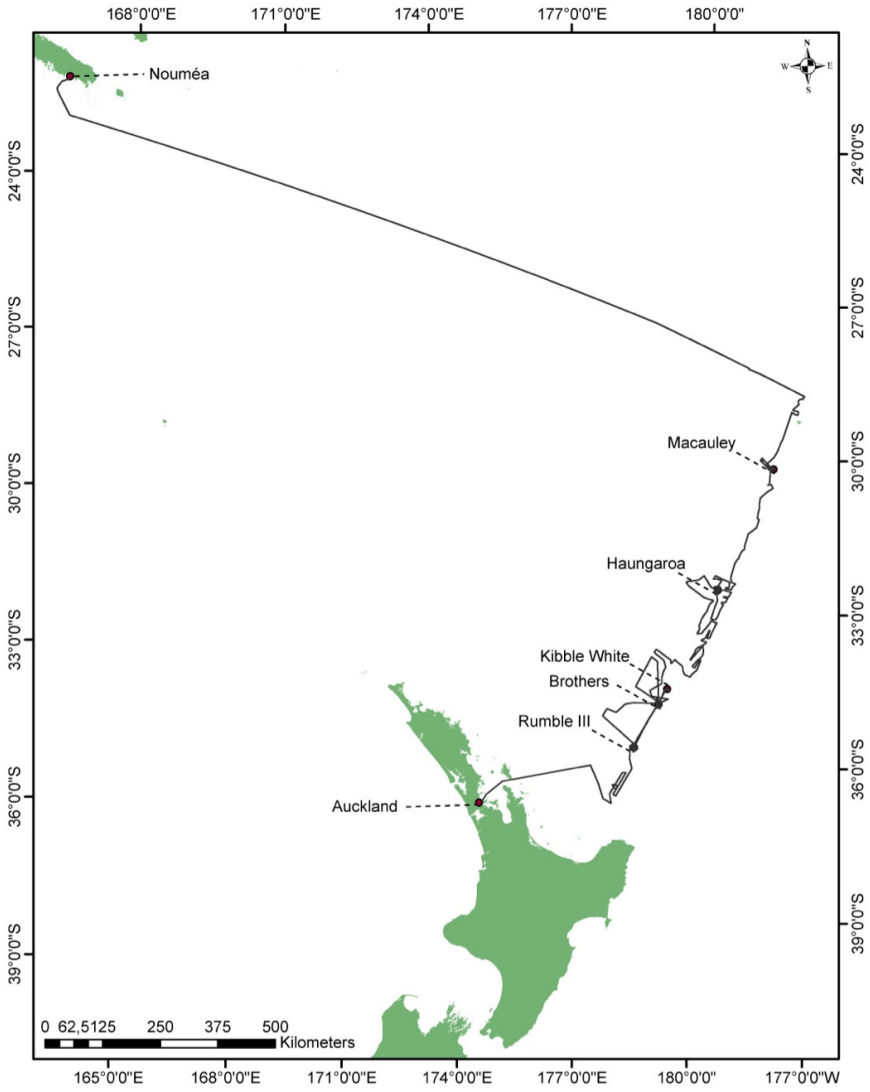
Short Cruise Report
R/V Sonne cruise SO-253
Noumea (New Caledonia) – Auckland (New Zealand)
22.12.2016 – 21.01.2017
Chief Scientist: Prof. Dr. Andrea Koschinsky
Captain: Lutz Mallon



Objectives

Hydrothermal systems along volcanic island arcs are different to those at mid-ocean ridges because of their mostly shallow water depth and strong magmatic input into their fluids and hydrothermal plumes. As these plumes often reach up into the photic zone they discharge large quantities of material into the surface water layers. The goals of our cruise SO 253 included the characterization of hydrothermal systems at the Kermadec Arc and the understanding of their role for the global elemental budget of the ocean and for local chemical and biological processes in the water column and at the seafloor. We want to investigate the relationship between magma degassing, the transport of metals within the bedrock of the seafloor and the connected special chemistry of the hydrothermal fluids. Since hydrothermal systems at volcanic arcs are often highly variable with respect to fluid composition, discharge rates and water depth, we want elucidate the role of these different parameters on associated mineral precipitates, microbial communities, fauna, and on hydrothermal fluxes of nutrient-type elements such as iron into the surrounding seawater including the upper photic layer.

To achieve these goals, we sampled hydrothermal fluids and plumes, rocks and mineral precipitates such as black and white smoker chimneys, iron crusts, as well as biological communities from different hydrothermal systems at submarine volcanoes of the southern and middle Kermadec Arc. We used the ROV Quest (MARUM, Univ. Bremen), CTD/rosette water samplers, in-situ filtration pumps and a trace-metal rosette in this interdisciplinary approach. Furthermore, high-resolution bathymetric mapping and geophysical surveys including gravimeter and magnetometer deployments as well as heat flux measurements helped us to locate hydrothermal systems and estimate their extension and activity.

Our working areas are located on the southern and middle Kermadec Island Arc, which hosts about 18 active, highly diverse, hydrothermal systems. For the detailed interdisciplinary studies, four main working areas (Macauley Cone, Haungaroa, Brothers and Rumble III) in different water depths (between 1600 m and 200 m) were chosen.

In detail, the work objectives include:

- to determine the initial concentrations of substances in hydrothermal endmembers in relation to water-rock-interactions within the bedrock or magmatic input
- to study the influence of gas- and metal-rich and very acidic fluids on the adaptation and productivity of hydrothermal symbiotic communities.
- to follow the dispersion of emitted fluids within the water column to quantify the fluxes of certain metals of the hydrothermally active island arcs within the water column.
- to study the Impact of physical parameters, such as current and vertical exchange on the horizontal dispersion and dilution of the plume material and its input the oceanic surface layer by vertical mixing
- to investigate the composition and role of dissolved organic matter with respect to the mobilisation of metals.
- to use stable isotopes of major elements and Fe as tracers of hydrothermal processes
- to examine the diversity and distribution of microbial symbionts and their invertebrate hosts
- determine the heat-flow at active hydrothermal vent sites

Cruise narrative

Cruise SO 253 started in Noumea on 21 December, 2016, with the embarkation of 40 scientists from Germany, New Zealand, the USA and France. We left port in the morning of December 22, heading for the Kermadec Arc north of Raoul Island to complete some bathymetric maps on the way to our first working area Macauley. This ended in the morning hours of the 26th with a swath above Macauley Cone, a rather shallow (200-400m) hydrothermally very active volcanic cone with a crater filled with hydrothermal solutions and flanks covered densely with vent mussels. CTD operations at Macauley caldera mapped and sampled the plume from the summit of Macauley Cone (250-300 m deep) with two tows of 5-6 km length each, and several vertical casts directly over the summit vents. The more distal extent of the plume originating at the main cone summit, along with water above and below the plume depth, was also sampled with two additional vertical casts about 500 m to the east and west of the Macauley Cone summit. There was evidence from previous surveys that a smaller, deeper cone to the west of the main cone also hosts active vents. The tow that passed over this cone detected and sampled this plume at a depth of ~685 m depth and another vertical CTD cast was done. ROV dives confirmed intense venting in the pit crater of the main cone and while lots of evidence for low temperature alteration and abundant vent-related animals were seen atop the SW cone summit, no actual venting was found.

Macauley Caldera and the neighboring Giggenbach cone volcano were mapped with high resolution and gravimetry measurements have been running all the time. Both were re-mapped with the higher resolution echosounder aboard the Sonne and we also infilled gaps in the regional bathymetric data base while transiting to and from these volcanoes. Additionally, a magnetometer was deployed and 10 deployments of heat flow blankets helped to estimate the heat flux in this area. From the initial characterization based on the multitude of operations and lab analyses we can already conclude that the hydrothermal fluids with it strongly acidic character (pH around 1.5) at Macauley are rather unique compared to other known vent sites.

We left Macauley in the afternoon of 30 December and started the 15-hour transit to our second largely unexplored working area, Haungaroa. Both the multibeam echosounder and the magnetometer were deployed in transit between Macauley volcano and Haungaroa volcano and during a subsequent survey of the Haungaroa area until the morning of January 1, 2017. The area was mapped by high-resolution multibeam, including both the seafloor and the lower water column, which discovered a significant gas plume.

We started the first ROV dive in the morning of 1 January, targeting a plateau area on the crater rim at 670 m water depth, where the largest plume signal had been recorded. We were lucky to arrive at an actively venting area soon after landing on the seafloor. We used this and the next dive to explore the newly discovered vent field with its spectacular lava structures, abundant fauna and both diffuse and focused venting. We collected rock, chimney, fluid and mussel samples from various places. Small sulfide-barite chimneys, about 50-70 cm in height, were discovered at Haungaroa, emitting fluids as hot as 267°C and with a pH around 4. Older, inactive sulfide chimneys nearby were densely covered by barnacles. Four thermal blankets were deployed during the ROV Quest dives at Haungaroa. The blankets showed a significant heat-flow anomaly at this site located on the caldera rim, with on average 3°C higher temperature than the surrounding seawater. A trace metal rosette was deployed at Haungaroa volcano, north-east of the caldera. A trace

metal rosette was deployed at Haungaroa volcano, north-east of the caldera, which showed that low iron concentrations of the hydrothermal plume could still be found at larger distance from the volcano. Radium isotope analyses showed that the fluids ad plumes have a significantly longer residence time at Haungaroa than at Macauley. The chemosynthetic fauna in Haungaroa is dominated by two species commonly found at many Kermadec volcanoes; the stalked barnacle *Vulcanolepas osheai* and the mussel *Gigantidas gladius*.
We used an additional ROV dive to follow water column indicators for another hydrothermally active site, which we could not locate, despite numerous hints of hydrothermal activity. As the weather conditions did not allow us to deploy the ROV for the next two days, we used the transit to our third working area Brothers Volcano to extend bathymetric mapping coverage by filling gaps in existing maps. The magnetometer was deployed simultaneously,

Upon our arrival on 7 January we carried out two ROV dives at the two cones of Brothers Volcano, albeit under difficult conditions due to strong underwater currents, although we were still able to collect some diffuse and hot fluid samples, and iron and manganese crusts. Two CTD-Tow-yos and two in-situ pump stations helped us to survey and sample the different plume layers originating from at least three different hydrothermally active sites. Since the weather had once again become too rough for ROV dives, we transited to the neighboring (ca. 30 km to the NE) Kibblewhite volcano, for which evidence for hydrothermal activity also exist from former cruises, and carried out a bathymetric survey and a CTD station. On 10 January we resumed our station work at Brothers Volcano and completed 7 ROV dives, 4 tow-yos, 5 vertical CTD casts, 4 in-situ pumps, and 3 trace metal rosette deployments plus several echosounder and gravimeter survey tracks. We sampled hydrothermal fluids, fauna and geological samples from the magmatically influenced Upper and Lower Cones in the SE of the caldera and from the water-rock interaction driven vent sites at the NW caldera wall. There we also discovered abundant massive sulfide mineralization, found previously unknown active vent site and the first alive mussels at Brothers and measured the highest temperatures of 311°C. The intensive spread and age of the hydrothermal plumes extending far beyond the caldera rim was followed by the CTD and pump stations.

On 15 January we started our work in our fourth and last working area, Rumble III, an active volcano with several recent eruptions. Our mapping showed that the large volcanic cone that had grown on the summit of the volcano had largely collapsed since it was last mapped in 2010, with only a 90 m tall lave column with some diffuse venting and young fauna left, protruding from the seafloor. During two ROV dives, diffuse vent fluids and very small mussels could be sampled and two CTD stations confirmed hydrothermal activity. However, since we were not able to locate further hydrothermal vent sites on the seafloor, despite an obvious turbidity cloud, and since further water column work occurred too risky because of the high lava column, we returned to Brothers Volcano, deploying the CTD for a background station during the transit. At Brothers we carried out two more ROV dives at the NW caldera wall and some more CTD, trace metal rosette and pump stations to explore the far-field extension of the multiple hydrothermal plumes to the N and the S of the caldera.

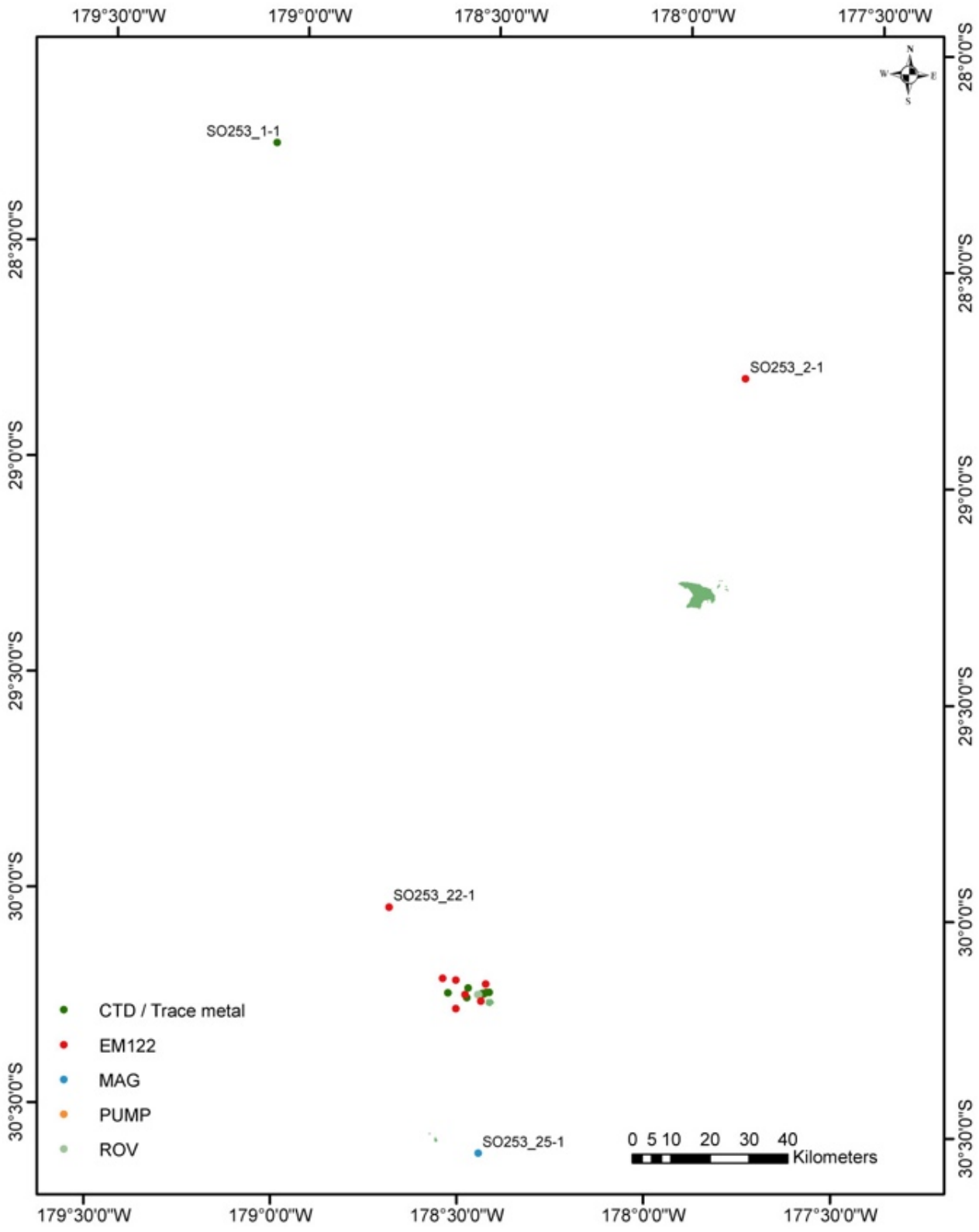
On 18 and 19 January during the transit to Auckland we carried out the last echosounder and magnetometer tracks. The cruise ended after 87 stations including 19 ROV stations and successful completion of all planned activities in the port of Auckland on 21 January, 2017.

Our journalist joining the cruise for public outreach activities wrote daily reports of all the research activities, that took place onboard, and published them in the cruise blog geschichten.ptj.de/so253 and geschichten.ptj.de/so253-en (English version). Also many other outreach activities were carried out and material for the Open Ship Day in Auckland following our cruise was prepared and displayed to the visitors.

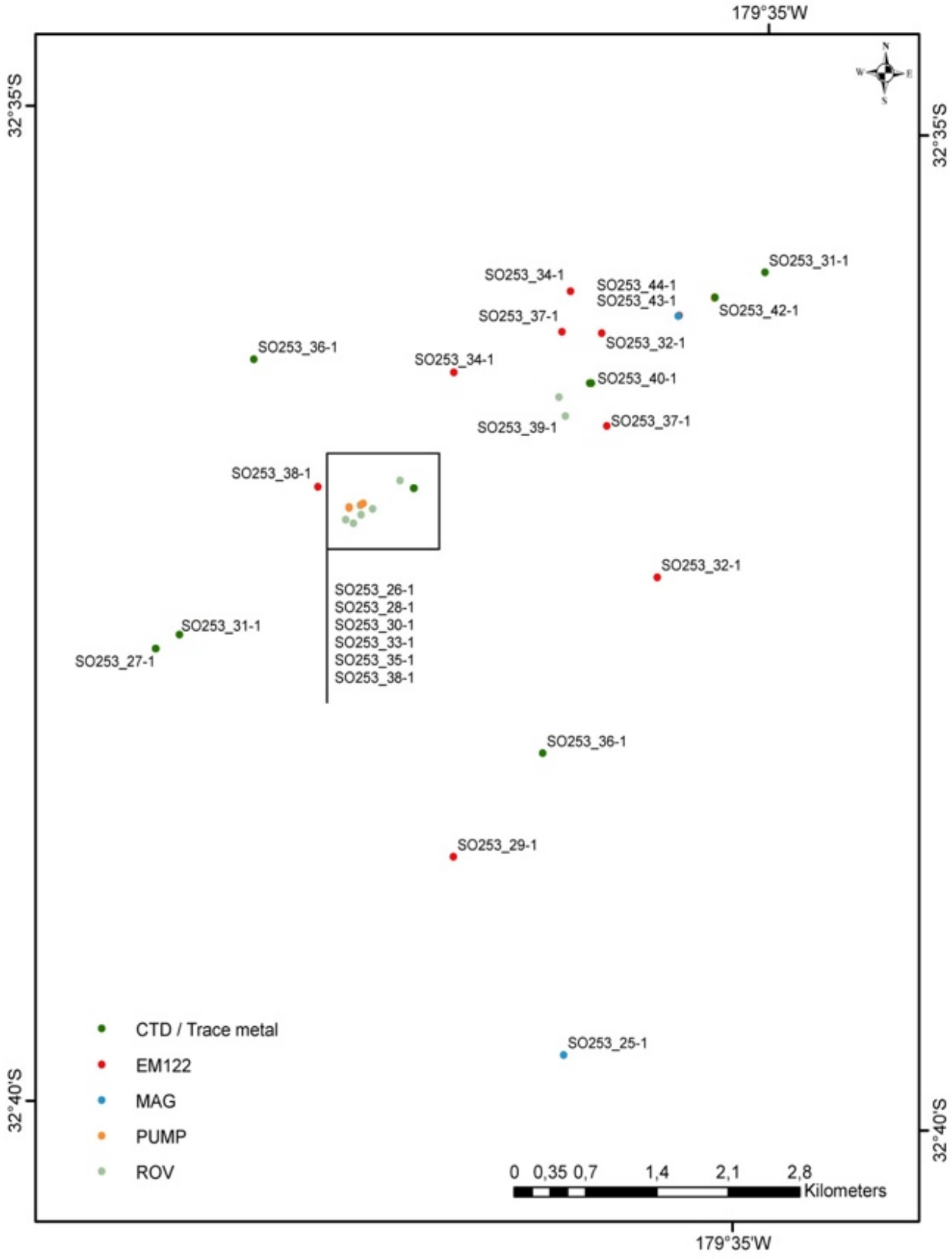
Acknowledgements

The scientific team would like to express its sincere thanks to the Captain and crew of R/V SONNE and the ROV-Team for their skillful operations. Funding for this cruise was granted by the Federal Ministry of Education and Research (BMBF, project 03G0253), Germany. Permission to work in the Kermadec Arc by the New Zealand authorities is gratefully acknowledged. We also appreciate the support by the Control Station (Leitstelle Deutsche Forschungsschiffe) and the shipping company Briese during all activities related to cruise SO253.

Optional Figures: Maps with stations



First stations , Macauley and Giggenbach


179°35'W
32°35'S
32°40'S
SO253_34-1
SO253_44-1
SO253_43-1
SO253_31-1
SO253_42-1
SO253_37-1
SO253_32-1
SO253_36-1
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SO253_40-1
SO253_39-1
SO253_37-1
SO253_38-1
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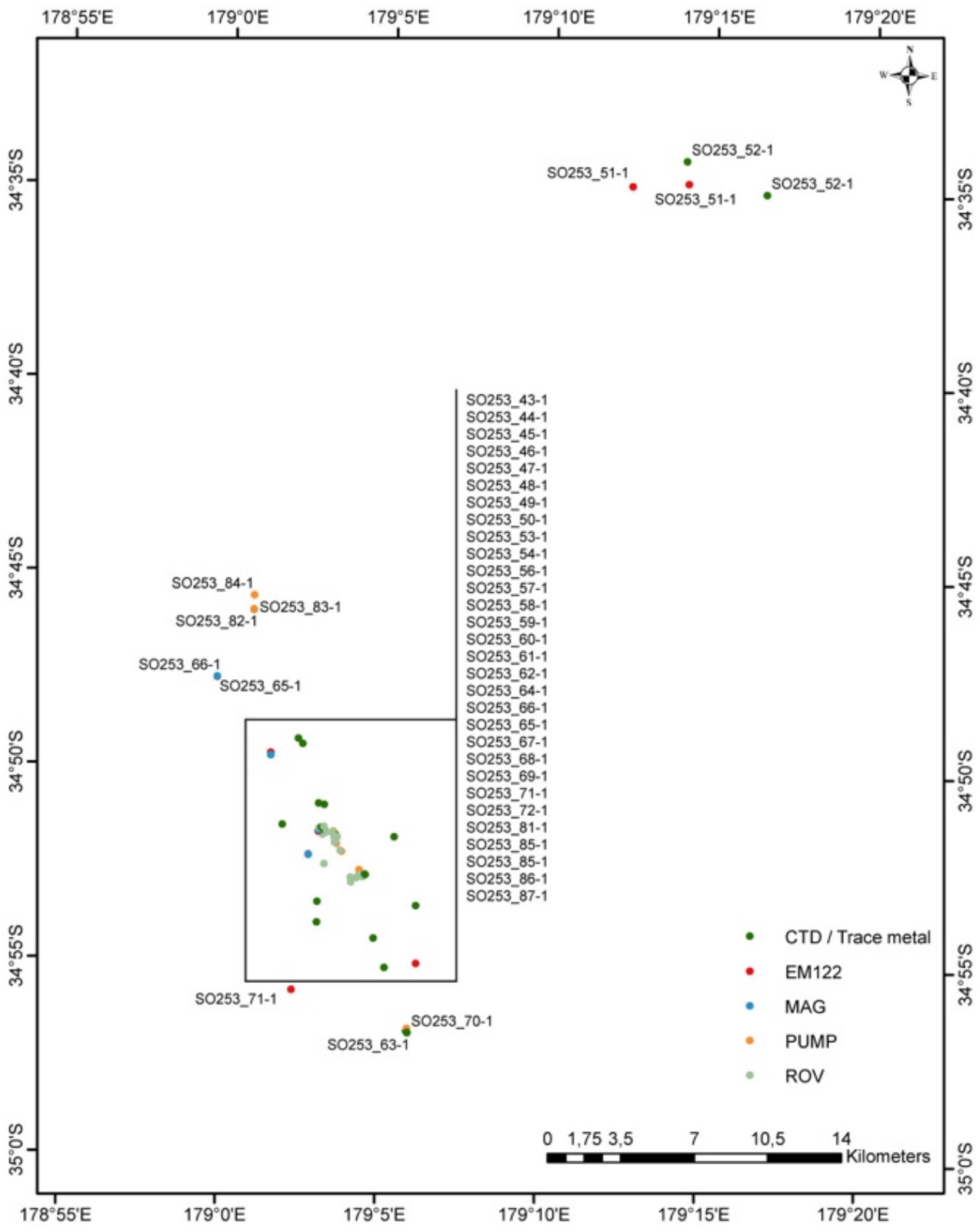
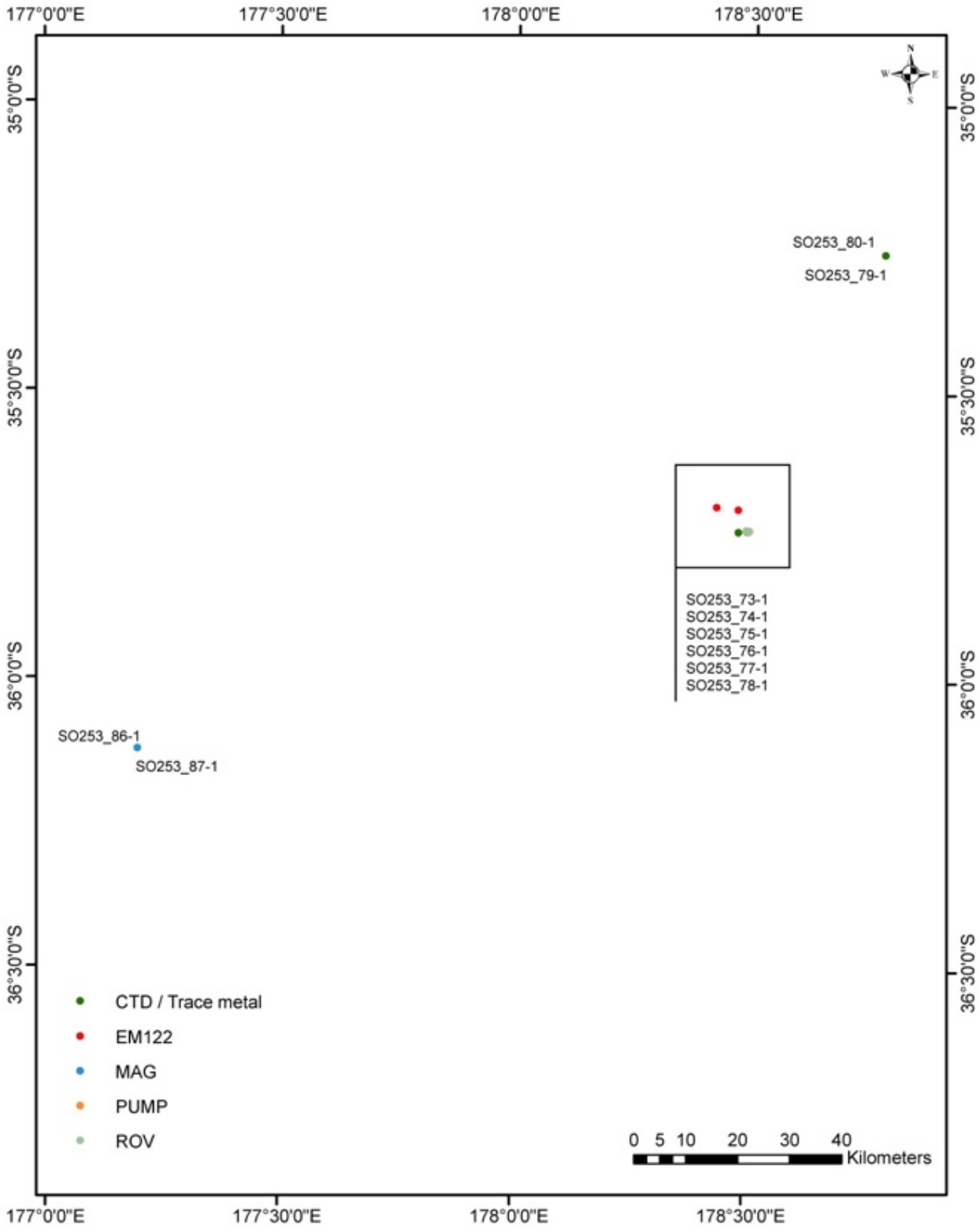
SO253_29-1
SO253_25-1
CTD / Trace metal
EM122
MAG
PUMP
ROV
0 0,35 0,7 1,4 2,1 2,8
Kilometers

Haungaroa



Brothers / Kibble White



Rumble 3 and last stations

Cruise participants (Name – Function – Institute)

Family name	First name	Function / task	Institute
Bach	Wolfgang	Petrology, gas chemistry	UBremen
Borowski	Christian	Hydrothermal symbioses	MPI
Buettner	Kathrin	Metagenomics	MPI
Buettner	Hauke	ROV deployments	MARUM
Caratori Tontini	Fabio	Geophysics	GNS
De Ronde	Cornel Edwin Jan	Geology and geophysics	GNS
Diehl	Alexander	Gas chemistry	UBremen
Froehberg	Nico	Fluid chemistry	JUB
Geier	Benedikt Konstantin	Hydrothermal symbioses	MPI
Hansen	Christian Tobias	Organic fluid chemistry	UOL
Hartmann	Jan Frederik	Fluid chemistry	JUB
Heidenreich	Marie Christine	Public outreach	PTJ
Hourdez	Stéphane Marc Yvon	In-situ mass spectrum.	SB Roscoff
Klar	Steffen	ROV deployments	MARUM
Kleint	Charlotte	Fluid chemistry	JUB
Koschinsky-Fritsche	Andrea Maria	Chief scientist	JUB
Lehners	Carola Regina	Nutrient analyses	UOldenburg
Mai	Hoang Anh	ROV deployments	MARUM
Meyerdierks	Anke	Metagenomics	MPI
Moje	Annika	Fluid sampling and prep.	JUB
Neuholz	René	Radium isotopes	UOldenburg
Oster	Corinna	Organic fluid chemistry	UOldenburg
Ratmeyer	Volker	ROV deployments	MARUM
Sander	Sylvia Gertrud	Trace metal chemistry	UOtago
Sass	Katharina	Microbiology	UHamburg
Schade	Tobias	ROV deployments	MARUM
Schmidt	Werner	ROV deployments	MARUM
Schnetger	Bernhard G. Karl	Radium isotopes	UOldenburg
Schroeder	Marcel Karsten	ROV deployments	MARUM
Seiter	Christian Gerd	ROV deployments	MARUM
Sopke	Stefan	Gas analytics	UBremen
Stewart	Lucy Clementine	Microbiology	GNS
Strauss	Harald Wolfgang	Sulfur geochemistry	UMünster
Stucker	Valerie Katherine	Fluid chemistry	GNS
Thal	Janis	Geology, mapping	UBremen
Tietjen	Malin	Hydrothermal symbioses	MPI
Tuerke	Andreas	CTD, water column	UBremen
Walker	Sharon Leslie	CTD, water column	NOAA
Walter	Maren	CTD, helium	UBremen
Zitoun	Rebecca	Trace metal chemistry	UOtago

Institutes
GNS: GNS Science, New Zealand
JUB: Jacobs University Bremen
MARUM: MARUM - Center for Marine Environmental Sciences, University of Bremen
MPI: Max Planck Institute for Marine Microbiology, Bremen
NOAA: NOAA/PMEL, USA
PTJ: Projektträger Jülich
SB Roscoff: Station Biologique de Roscoff, France
UH: University of Hamburg

UM: University of Münster
UOtago: Universiy of Otago, New Zealand
UOldenburg: University of Oldenburg, ICBM

Station list

Station	Date and Time [UTC]	Device	Latitude	Longitude	Max. Water Depth [m]
SO253_001	24/12/2016 22:00	CTD-V	28° 15.577' S	179° 4.518' W	2043
SO253_002	25/12/2016 05:57	EM122	28° 45.913' S	177° 49.402' W	1764
SO253_003	26/12/2016 01:42	ROV	30° 12.657' S	178° 27.080' W	417
SO253_004	26/12/2016 06:05	CTD-T	30° 12.563' S	178° 26.019' W	1030
SO253_005	26/12/2016 09:50	EM122	30° 12.990' S	178° 29.855' W	1044
SO253_006	26/12/2016 12:18	CTD-V	30° 12.787' S	178° 26.931' W	327
SO253_007	26/12/2016 13:23	EM122	30° 12.784' S	178° 26.936' W	641
SO253_008	26/12/2016 17:08	PUMP	30° 12.785' S	178° 26.929' W	323
SO253_009	26/12/2016 21:25	ROV	30° 12.659' S	178° 27.066' W	381
SO253_010	27/12/2016 09:17	CTD-T	30° 12.868' S	178° 32.635' W	1094
SO253_011	27/12/2016 14:26	EM122	30° 11.064' S	178° 31.452' W	818
SO253_012	27/12/2016 15:57	CTD-V	30° 12.914' S	178° 27.714' W	729
SO253_013	27/12/2016 18:06	ROV	30° 12.672' S	178° 27.069' W	411
SO253_014	28/12/2016 07:21	PUMP	30° 12.783' S	178° 26.929' W	317
SO253_015	28/12/2016 11:25	PUMP	30° 12.855' S	178° 27.171' W	430
SO253_016	28/12/2016 15:18	TMR	30° 12.923' S	178° 27.718' W	729
SO253_017	28/12/2016 16:36	PUMP	30° 12.914' S	178° 27.713' W	730
SO253_018	28/12/2016 19:46	ROV	30° 12.978' S	178° 27.646' W	686
SO253_019	29/12/2016 07:39	CTD-V	30° 12.857' S	178° 27.168' W	428
SO253_020	29/12/2016 09:00	CTD-V	30° 12.730' S	178° 26.686' W	464
SO253_021	29/12/2016 10:28	TMR	30° 12.912' S	178° 27.716' W	730
SO253_022	29/12/2016 11:50	EM122	30° 12.908' S	178° 27.718' W	1156
SO253_023	29/12/2016 19:00	ROV	30° 12.980' S	178° 27.651' W	685
SO253_024	30/12/2016 03:18	EM122	30° 13.816' S	178° 27.272' W	685
SO253_025	30/12/2016 07:36	Magnetometer	30° 34.948' S	178° 26.719' W	3148
SO253_026	31/12/2016 19:00	ROV	32° 37.044' S	179° 37.513' W	707
SO253_027	01/01/2017 08:46	CTD-T	32° 37.707' S	179° 38.728' W	1556
SO253_028	01/01/2017 11:10	PUMP	32° 36.964' S	179° 37.544' W	685
SO253_029	01/01/2017 13:59	EM122	32° 36.868' S	179° 37.743' W	2638
SO253_030	01/01/2017 19:44	ROV	32° 36.821' S	179° 37.230' W	674
SO253_031	02/01/2017 09:20	CTD-T	32° 37.708' S	179° 38.726' W	1804
SO253_032	02/01/2017 14:55	EM122	32° 36.048' S	179° 35.995' W	1888
SO253_033	02/01/2017 15:45	CTD-V	32° 36.859' S	179° 37.141' W	864
SO253_034	02/01/2017 17:13	EM122	32° 36.268' S	179° 36.914' W	1329
SO253_035	02/01/2017 19:00	ROV	32° 36.952' S	179° 37.475' W	676
SO253_036	03/01/2017 07:52	CTD-T	32° 36.236' S	179° 38.169' W	1479
SO253_037	03/01/2017 12:54	EM122	32° 36.512' S	179° 35.944' W	1273

SO253_038	03/01/2017 15:00	PUMP	32° 36.944' S	179° 37.456' W	675
SO253_039	03/01/2017 19:10	ROV	32° 36.375' S	179° 36.250' W	1175
SO253_040	04/01/2017 07:52	CTD-V	32° 36.300' S	179° 36.049' W	1166
SO253_041	04/01/2017 09:58	PUMP	32° 35.850' S	179° 35.295' W	1584
SO253_042	04/01/2017 14:19	TMR	32° 35.848' S	179° 35.292' W	1583
SO253_043	04/01/2017 16:52	EM122	32° 35.945' S	179° 35.514' W	1964
SO253_044	04/01/2017 16:52	Magnetometer	32° 35.948' S	179° 35.518' W	4012
SO253_045	06/01/2017 18:45	ROV	34° 52.802' S	179° 4.435' E	1332
SO253_046	07/01/2017 08:00	CTD-T	34° 50.950' S	179° 3.185' E	1957
SO253_047	07/01/2017 14:03	PUMP	34° 52.620' S	179° 4.322' E	1351
SO253_048	07/01/2017 18:53	ROV	34° 52.752' S	179° 4.299' E	1347
SO253_049	08/01/2017 08:27	CTD-T	34° 51.754' S	179° 5.396' E	1967
SO253_050	08/01/2017 14:03	PUMP	34° 51.727' S	179° 3.560' E	1721
SO253_051	08/01/2017 22:43	EM122	34° 34.861' S	179° 12.427' E	2158
SO253_052	09/01/2017 02:12	CTD-T	34° 35.007' S	179° 16.611' E	1624
SO253_053	09/01/2017 08:12	CTD-V	34° 51.727' S	179° 3.571' E	1717
SO253_054	09/01/2017 11:14	CTD-V	34° 52.159' S	179° 3.759' E	1807
SO253_055	09/01/2017 14:03	TMR	34° 56.797' S	179° 5.923' E	2038
SO253_056	09/01/2017 18:50	ROV	34° 52.825' S	179° 4.232' E	1308
SO253_057	10/01/2017 02:26	CTD-T	34° 51.487' S	179° 1.884' E	2090
SO253_058	10/01/2017 08:54	CTD-V	34° 52.736' S	179° 4.502' E	1466
SO253_059	10/01/2017 11:14	PUMP	34° 52.160' S	179° 3.762' E	1864
SO253_060	10/01/2017 16:36	TMR	34° 49.392' S	179° 2.473' E	2217
SO253_061	10/01/2017 19:32	ROV	34° 51.783' S	179° 3.545' E	1643
SO253_062	11/01/2017 07:53	CTD-T	34° 50.925' S	179° 3.008' E	1863
SO253_063	11/01/2017 12:52	PUMP	34° 56.798' S	179° 5.925' E	2250
SO253_064	11/01/2017 19:31	ROV	34° 51.804' S	179° 3.589' E	1809
SO253_065	12/01/2017 07:42	Magnetometer	34° 51.617' S	179° 3.030' E	3338
SO253_066	12/01/2017 07:42	EM122	34° 51.644' S	179° 3.016' E	2396
SO253_067	12/01/2017 19:00	ROV	34° 51.769' S	179° 3.614' E	1580
SO253_068	13/01/2017 07:24	CTD-V	34° 51.549' S	179° 3.102' E	1456
SO253_069	13/01/2017 10:18	CTD-V	34° 55.125' S	179° 5.162' E	2205
SO253_070	13/01/2017 12:25	TMR	34° 56.797' S	179° 5.924' E	2240
SO253_071	13/01/2017 15:30	EM122	34° 55.745' S	179° 2.267' E	2264
SO253_072	13/01/2017 19:00	ROV	34° 52.486' S	179° 3.218' E	559
SO253_073	14/01/2017 13:00	EM122	35° 42.236' S	178° 28.425' E	2050
SO253_074	14/01/2017 20:15	ROV	35° 44.528' S	178° 29.639' E	559
SO253_075	15/01/2017 07:35	CTD-V	35° 44.399' S	178° 29.453' E	620
SO253_076	15/01/2017 10:18	CTD-T	35° 44.389' S	178° 30.601' E	1192
SO253_077	15/01/2017 13:24	PUMP	35° 44.441' S	178° 29.863' E	439
SO253_078	15/01/2017 19:06	ROV	35° 44.479' S	178° 29.798' E	392
SO253_079	16/01/2017 10:14	CTD-V	35° 15.505' S	178° 46.620' E	3151
SO253_080	16/01/2017 12:35	TMR	35° 15.498' S	178° 46.627' E	3149
SO253_081	16/01/2017 19:00	ROV	34° 51.920' S	179° 3.523' E	1825
SO253_082	17/01/2017 08:28	CTD-V	34° 45.952' S	179° 0.868' E	2412

SO253_083	17/01/2017 10:36	TMR	34° 45.953' S	179° 0.872' E	2405
SO253_084	17/01/2017 13:10	PUMP	34° 45.951' S	179° 0.870' E	2421
SO253_085	17/01/2017 19:38	ROV	34° 52.135' S	179° 3.715' E	1585
SO253_086	18/01/2017 07:31	EM122	34° 49.640' S	179° 1.488' E	2157
SO253_087	18/01/2017 07:33	Magnetometer	34° 49.701' S	179° 1.481' E	3025

Devices:
TMR: Trace-metal rosette (Univ. Otago)
CTD-V: vertical CTD cast with rosette water sampler
CTD-T: Tow-you CTD with rosette water sampler
ROV: ROV Quest (MARUM)
Pump: McLane in-situ pumps with filters
EM122: Kongsberg EM122 echosounder