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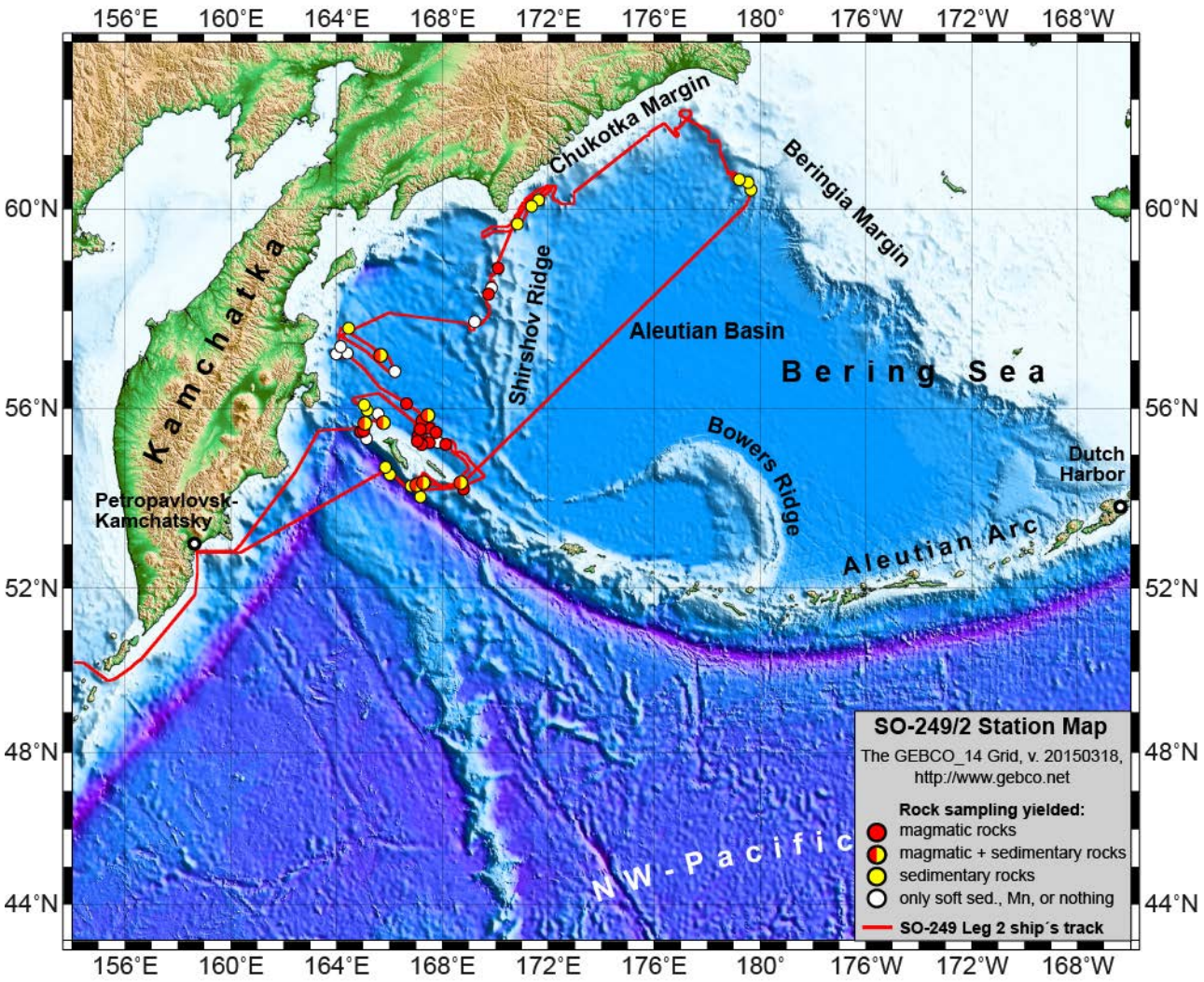
Short Cruise Report
R/V SONNE cruise SO-249 Leg 2

Petropavlovsk-Kamchatsky (Russia) - Tomakomai (Japan)
16.07.2016 - 14.08.2016
Chief Scientist: Dr. Reinhard Werner
Captain: Lutz Mallon



Objectives

The BERING project is a long-term international collaboration between German, Russian, and U.S. American scientists. The project encompasses two legs: (1) from Dutch Harbor, Alaska to Petropavlovsk-Kamchatsky, Russia, and (2) from Petropavlovsk to Tomakomai, Japan. The overall goal of the SO-249 BERING cruises is to study the geodynamic evolution of the southern and western margins of the Bering Sea, formed by the Aleutian Subduction Zone and Chukotka-Beringian continental margin respectively, and the northwestern Pacific seafloor, being subducted beneath the Aleutian and Kamchatka arcs. The ship-based mapping, sediment profiling and rock sampling of seafloor structures by dredging, combined with planned shore-based evaluation of the mapped seafloor morphology and petrographic, petrological, geochemical and geochronological studies of the obtained samples, will contribute to an improved understanding of the origin of marginal seas, the initiation and geodynamic evolution of subduction zones, the affect of variation in the composition and structure of the subduction input on the output at the volcanic arc, as well as the causes and effects of natural hazards, such as explosive volcanic eruptions.

More specific scientific questions of SO-249 Leg 2 include:

1) *Pre-Aleutian subduction history of the Beringian Margin*: What is the nature of the Beringian and Chukotka Margins and their junction? Do they represent (I) an extinct subduction margin extending from Chukotka to Alaska in the Paleogene, (II) a transform fault boundary along the Chukotka margin and subduction zone along Alaskan margin, or (III) amalgamated terranes of different age and composition (e.g. submarine plateau and subduction zone)? Is the cessation of volcanism on these margins correlated with the initiation of the Aleutian Arc and other large-scale tectonic events around the Pacific?
2) *Aleutian arc inception and evolution*: What is the age and composition of the oldest rocks in the western Aleutian Arc? Can inception of the arc be linked to other key tectonic events in the Pacific such as the Hawaiian-Emperor Bend at ~50-47.5 Ma, inception of the IBM and Tonga Arc at 50-52 Ma, or collision of the Olyutorsky Arc with Kamchatka at ca. 51-54 Ma?
3) *Modern Aleutian arc system*: What is the origin and occurrence of recent magmatic activity in the Western Aleutian Arc? Is there a continuous volcanic front in the western Aleutians west of Buldir Island? How is the distinctive geochemical character of western Aleutian volcanic rocks related to volcanism in the central and eastern Aleutians and in island arcs globally?

The SO-249 cruises also included a minor biology program which aims at collecting marine fauna from both hard rocks and sediments yielded by dredging to determine the benthic biodiversity south of the Aleutian Islands and of the incoming Pacific Plate.

Integration of the results of studies conducted by the SO-249 BERING project with those of previous investigations (in particular KOMEX and KALMAR), and of the work being carried out in the GeoPRISMS initiatives will substantially improve our understanding of the magmatic and tectonic evolution of the Aleutian-Kamchatka-Junction and arc systems in general. Combined with the results from recent IODP drilling into the IBM forearc and backarc and with those from the complementary SO-255 VITIAZ SONNE cruise to investigate the Vitiaz-Kermadec Arc/Backarc System, scheduled for the beginning of 2017, we should gain additional important new insights into the workings of subduction systems and the origin of marginal basins.

Narrative

After completing Leg 1 of the SO-249 cruise, R/V SONNE arrived in Petropavlovsk-Kamchatsky early in the morning of July 14, the capital of the Russian region of Kamchatka. This was the first stay of the new R/V SONNE in Russia, and - according to our knowledge - the first port call ever of a German research vessel in Petropavlovsk. During the following days in the harbor, nine SO-249 Leg 1 scientists left the vessel for their return trip home, and 15 new, primarily Russian colleagues came on board. In addition, two groups of scientists of the Russian Institute for Volcanology and Seismology in Petropavlovsk visited R/V SONNE and attended crew- and scientist-led tours that were met with great interest. Finally, apart from the usual harbor operations, crew and scientists of

the ship took part in an excursion organized by our Russian colleagues to Termalny, a village known for its hot springs.
On July 17, R/V SONNE left Petropavlovsk and continued its scientific cruise heading north to the working areas near the Komandorsky Islands and at the Chukotka-Beringian continental margin at 60° - 62°N. Our first two dredges were carried out on a tectonic structure south of the Komandorsky bloc, a formation on which the western-most islands (Medny and Bering) of the Aleutian chain are located. Two previous dredges, made at this feature on the KALMAR expedition SO-201-2, yielded sedimentary rocks. Therefore we presumed at that time, that it represents a fragment of the Komandorsky forearc and not an accreted fragment of oceanic crust as originally postulated. This interpretation seems to have been confirmed by two SO-249 dredges which also recovered exclusively sedimentary rocks. Afterwards R/V SONNE sailed to the Chukotka-Beringian continental margin, where we arrived in the afternoon of June 21. The nature of the northern section of the Chukotka-Beringian margin was completely unknown prior to the SO-249 cruise. SO-249 Leg 2 mapping showed that the slope of the northern Beringian margin is heavily fissured and cut by deep canyons. Its morphology indicates that at least the upper units of the margin are formed by sediment. Three dredges yielding solidified sediment confirmed this observation. Following these dredges we mapped the slope at the junction of the Beringian and Chukotka margins. The satellite-derived (predicted) bathymetry shows seamounts and steep slopes in this area but SO-249 multi-beam mapping revealed that the normally reliable predicted bathymetry failed in this case and that seamounts and steep slopes do not exist in the area. Therefore R/V SONNE headed to the southwest to the southern section of the Chukotka margin. Here, the ocean floor is characterized by NW-SE striking faults which appear to be quite young. These faults provide important information on tectonic processes and may be related to right lateral strike-slip fault at the boundary of the Beringia and North American Plate. Therefore we decided first to conduct comprehensive mapping in this area to be followed by sampling at the most appropriate sites. The dredges at the steep fault scarps, however, yielded apart from a conglomerate containing lava clasts only siltstones and sandstones.
En route to the Beta Rise in the western part of the Komandorsky Basin, we took four dredges on some dome-shaped features located at the western flank of Shirshov Ridge. Previous studies, among them those conducted on KALMAR expedition SO-201-2, indicated that an ophiolite complex may exist in this part of the ridge. SO-249 Leg 2 sampling in this area was very successful and recovered a variety of rocks types including harzburgites, dunites, orthopyroxenites, basalts, dolerites, and partially amphibolitized gabbros. This rock suite not only confirms the observations made on SO-201-2 but also makes it possible to gain new insights in the enigmatic nature and evolution of the Shirshov Ridge and so the geodynamic history of the Bering Sea.
On July 26, R/V SONNE approached the area north of the Beta Rise, which is characterized by a distinct heat flow anomaly. Our studies in this area aimed to test the idea that this anomaly may be associated with recent volcanism. It appears, however, that this is not the case or that if there has been volcanism, its extent has been limited. Apart from the few already known bathymetric highs, we discovered three additional features, all relatively small, up to only 500 m high. It is unclear if these represent young volcanic edifices or tectonic structures. Our dredge recovered basalt fragments from one of these structures. Geochemical analyses of these rocks may help to clarify the origin of these features.
On July 28, we sailed along the Alpha fracture zone to the Volcanologists Massif, on which Piip volcano, the westernmost active volcano of the Aleutian Arc, is located. This complex represents a key area for the reconstruction of temporal and geochemical variation of the magmatism along the Aleutian Arc and of magmatic processes in an area of highly oblique subduction. The Volcanologists Massif and Piip were studied during various Russian expeditions and on SO-201-2. However, major sections of this large complex have not yet been mapped at high resolution or sampled for geochemical studies. SO-249 mapping and sampling focused on a tilted block northwest of the Volcanologists Massif, its largely unstudied eastern base and the upper portions of Piip, which appear to be three, coalesced cones. The combined bathymetric surveys of SO-201-2 and SO-249 Leg 2 have produced the first high-resolution map the Volcanologists Massif including Piip, which provides important information about the tectonic and volcanic structures of this complex. Dredges conducted on the upper slopes of Piip delivered mainly andesitic lava and large quantities of dacitic pumice. At the Volcanologists Massif we dredged a wide variety of rock types, dominated by pillow lava showing frequently fresh glassy margins.

From August 1 - 6, our studies focused on the southwestern margin of the Bering Sea and there mainly on the Komandorsky Block. This more than 400 km long and up to 110 km wide structure forms the submarine base of the two Russian Aleutian Islands Bering and Medny. Before we started our investigations at the Komandorsky Block, we studied a chain of small enigmatic structures that emanate from the Volcanologists Massif in southeastern direction. Old maps based on single beam echo-sounding data show these features as nearly cone-like edifices. Therefore we hoped to discover a chain of young volcanic cones which may be the missing link between Piip Volcano and the further to the east located "Western Cones", which represent the westernmost recent volcanic structures in the US-part of the Aleutians. SO-249 Leg 2 multi-beam mapping, however, revealed that these structures are tiled blocs with a very smooth morphology. Nevertheless we made two dredge attempts at these features which returned besides a few lava fragments mainly semi-consolidated mud. Now it is almost sure that Piip is the only recent volcano in the Russian section of the Aleutian Arc since we also did not discover any young volcanic structures in the area to the west of Piip Volcano.
Our studies of the Komandorsky Block proceeded very successful. The dredge hauls at its southeastern flanks yielded a large amount of volcanic rocks besides sedimentary rocks which obviously form the lower portions of the slopes in this part of the block. Andesites dominate along the volcanics. At its northeastern flank we mainly dredged partly metamorphized and tectonized diorites and gabbros. At the northeastern tip of the Kommandorsky Block the dredges delivered a particular broad variety of basalts and andesites including highly hornblende-phyric spessartites) and maybe also Adak-type high-Mg andesites (adakites). Furthermore the dredges contained metamorphically overprinted volcanics, iginmbritic rocks, tuffs and other volcaniclastic rocks.
In the early morning of August 7, we finished the SO-249 Leg 2 station work and data recording as scheduled. The last week of the cruise was characterized by the transit to our final destination Tomakomai on Hokkaido (Japan). En route we entered again the port of Petropavlovsk-Kamchatsky, where we said good by to most of our Russian colleagues. On the next day, R/V SONNE headed towards Tomakomai. In order to avoid an upcoming typhoon, we had to cross the Kurile Island Arc and sailed into the Sea of Ochotsk. Among others, the transit was used for preliminary studies of the data and samples as well as for cleaning, maintenance, and packing of our equipment. On Saturday, August 13 we finally reached the port of Tomakomai according to schedule at 08:00 am.
Besides extensive multi-beam mapping and sediment echosounder profiling, a total of 52 dredge hauls in an average water depth of 2,900 m were carried out on SO-249 Leg 2. Of these, 36 delivered *in situ* samples of which 24 obtained volcanic rocks and/or intrusiva, 11 volcaniclastics, 5 metamorphic and 18 sedimentary rocks. No equipment was lost or seriously damaged. The biological sampling during SO-249 Leg 2 were very successful and and yielded besides many sediment samples a wide range of macrofaunal organisms. All macrofaunal specimens collected during SO-249 will be transferred to the Museum für Naturkunde (Berlin, Germany), where they will be re-assessed and then distributed to colleagues for species identification.

Acknowledgements

We would especially like to thank Captain Mallon and the crew of R/V SONNE. Their hard work, high level of experience, great flexibility and willingness to help, as well as the pleasant working atmosphere on board, contributed directly to the success of the SO-249 Leg 2 expedition.
We thank the Government of the Russia for granting permission to work within their territorial waters and we gratefully acknowledge the support of the Ministry for Science and Education of the Russian Federation, the German Ministry of Education and Research, the German Foreign Office and the German Embassy in Moscow in this matter. We also thank the Director of Komandorsky National Reservation for granting permission to work within the protected zone of Komandorsky sanctuary.
We would also like to thank the Institute of Volcanology and Seismology of the Russian Academy of Sciences in Petropavlovsk-Kamchatsky (Russia), in particular Oksana Evdokimova and Dmitry Savelyev, for their tremendous help and support with visa applications for the German scientists and issues related to the port call in Petropavlovsk-Kamchatsky.
We are also grateful to the German Federal Ministry of Education and Research for continuing support of marine research.

Cruise Participantes

1.	Werner, Reinhard	Fahrtleiter / *Chief Scientist*	GEOMAR
2.	Baranov, Boris	Bathymetrie, Tektonik / *Bathym., Tectonics*	IO RAS
3.	Bocharnikov, Roman	Gesteinsbeprobung / *Rock Sampling*	Univ. Hannover
4.	Davydova, Mariia	Gesteinsbeprobung / *Rock Sampling*	FEGI FEB RAS
5.	Ferdorchenko, Pavel	Beobachter / *Observer*	FSB
6.	Gorbach, Natalia	Gesteinsbeprobung / *Rock Sampling*	IVS FEB RAS
7.	Hauff, Folkmar	Gesteinsbeprobung / *Rock Sampling*	GEOMAR
8.	Hauff, Silke	Gesteinsbeprobung / *Rock Sampling*	GEOMAR
9.	Huttenlocher, Lisa	Gesteinsbeprobung / *Rock Sampling*	GEOMAR
10.	Jensen, Owen	Gesteinsbeprobung / *Rock Sampling*	USC
11.	Krasheninnikov, Stepan	Gesteinsbeprobung / *Rock Sampling*	GEOKHI RAS
12.	Ladwig, Amrei	Gesteinsbeprobung / *Rock Sampling*	GEOMAR
13.	Mironov, Nikita	Gesteinsbeprobung / *Rock Sampling*	GEOKHI RAS
14.	Nazarova, Daria	Gesteinsbeprobung / *Rock Sampling*	GEOKHI RAS
15.	Ostapenko, Dmitrii	Gesteinsbeprobung / *Rock Sampling*	FEGI FEB RAS
16.	Portnyagin, Maxim	Gesteinsbeprobung / *Rock Sampling*	GEOMAR
17.	Rahmsdorf, Charlotte	Gesteinsbeprobung / *Rock Sampling*	GEOMAR
18.	Savelyev, Dmitry	Gesteinsbeprobung / *Rock Sampling*	IVS FEB RAS
19.	Siegrist, Max	Gesteinsbeprobung / *Rock Sampling*	USC
20.	Stepanov, Oleg	Gesteinsbeprobung / *Rock Sampling*	Univ. Moscow
21.	Treff, Florian	Gesteinsbeprobung / *Rock Sampling*	GEOMAR
22.	Tsukanov, Nukolay	Bathymetrie, Tektonik / *Bathym., Tectonics*	IO RAS
23.	Yogodzinski, Gene	Gesteinsbeprobung / *Rock Sampling*	USC
24.	Ziegler, Alexander	Biologie / *Biology*	Univ. Bonn

Institutes

FEGI FEB RAS	Geolological Institute of the Russian Academy of Sciences, Vladivostok, Russia
FSB	Federal Security Service of the Russian Federation, Petropavlovsk-Kamchatsky, Russia
GEOKHI RAS	Vernadsky Institute of the Russian Academy of Sciences, Moscow, Russia
GEOMAR	Helmholtz-Zentrum für Ozeanforschung Kiel, Germany
IO RAS	P.P. Shirshov Institute of Oceanology of the Russian Academy of Sciences, Moscow, Russia
IVS FEB RAS	Institute of Volcanology and Seismology of the Russian Academy of Sciences, Petropavlovsk-Kamchatsky, Russia
Univ. Bonn	Institut für Evolutionsbiologie und Ökologie, Rheinische Friedrich-Wilhelms-Universität Bonn, Germany
Univ. Hannover	Institut für Mineralogie, Leibniz Universität Hannover, Hannover, Germany
Univ. Moscow	Moscow State University (Lomonossow University), Moscow, Russia
USC	University of South Carolina, Columbia, U.S.A.

Station List

Type	Stat.	Location	total volume	Rec. DR	Rock summary	on bottom / start lat °N	long °	off bottom / end lat °N	long°	depth (m) begin	end
CTD	102	Komandorsky Block			*for sound profile*	54.519	165.532	54.519	165.532		2500
DR	103	Komandorsky Block	1/6 full	1	sedimentary rocks	54.615	165.871	54.622	165.872	5126	4704
DR	104	Komandorsky Block	few rocks	1	sedimentary rocks	54.699	165.821	54.692	165.815	5383	5014
CTD	105	Beringia Margin			*for sound profile*	60.000	179.499	60.000	179.500		2500
DR	106	Beringia Margin	full	0	semi-consolidated sediment, biology	60.333	179.565	60.328	179.568	2496	2109
DR	107	Beringia Margin	1/5 full	0	semi-consolidated sediment, biology	60.483	179.427	60.489	179.429	2316	2003
DR	108	Beringia Margin	1/4 full	0	semi-consolidated sediment, biology	60.598	179.082	60.603	179.081	2192	1729
DR	109	Chukotka Margin	few rocks	1	sedimentary rock (conglomerate), biology	60.148	171.481	60.153	171.487	2720	2099
DR	110	Chukotka Margin	1/2 full	0	semi-consolidated sediment, biology	60.052	171.296	60.051	171.308	2411	1941
DR	111	Chukotka Margin	1/2 full	0	semi-consolidated sediment, biology	59.678	170.726	59.671	170.727	1721	1195
DR	112	Shirshov Ridge	1/2 full	1	metamorphic rocks	58.785	170.004	58.785	169.906	1909	1447
DR	113	Shirshov Ridge	1/4 full	0	semi-consolidated sediment	58.361	169.717	58.367	169.729	2721	2291
DR	114	Shirshov Ridge	full	1	metamorphic rocks	58.256	169.652	58.249	169.645	2739	2262
DR	115	Shirshov Ridge	few rocks	0	unconsolidated sediment, dropstones	57.689	169.149	57.683	169.149	2921	2557
CTD	116	Beta Rise			*for sound profile*	57.907	165.960	57.907	165.960		2000
DR	117	Beta Rise	1/6 full	1	sedimentary rocks	57.543	164.358	57.537	164.360	2984	2763
DR	118	Beta Rise	few rocks	0	semi-consolidated sediments (mud), dropstones	56.674	166.106	56.667	166.101	3591	3273
DR	119	Beta Rise	1/4 full	1	lava fragments, semi-consolidated sediment, dropstones	57.041	165.682	57.046	165.671	3457	3189
DR	120	Alpha FZ	2/3 full	0	Mn-nodules, semi-consolidated sediment, dropstones	57.193	164.071	57.185	164.068	2713	2367
DR	121	Alpha FZ	1/8 full	0	unconsolidated sediment, biology	57.070	164.039	57.077	164.042	3264	2997
DR	122	Alpha FZ	1/4 full	0	semi-consolidated sediment, wood	57.081	164.321	57.087	164.324	2750	2438
DR	123	Alpha FZ	few rocks	1	lava or tuff (probably in situ), dropstones	56.035	166.574	56.044	166.577	3698	3287
DR	124	Volcanologists Massif	1/4 full	1	lava fragments, dropstones	55.697	167.127	55.689	167.117	3879	3460
DR	125	Alpha FZ	few rocks	1	volcaniclastic rocks, sedimentary rocks, dropstones	55.798	167.359	55.806	167.361	4215	3668
DR	126	Volcanologists Massif	3/4 full	1	lava fragments	55.457	167.504	55.450	167.508	2954	2384
DR	127	Volcanologists Massif	1/2 full	1	lava fragments, volcaniclastic rocks	55.337	167.474	55.343	167.472	2548	2158
DR	128	Piip Volcano	full	1	lava fragments	55.422	167.273	55.418	167.274	670	460
DR	129	Piip Volcano	full	1	volcaniclastic rocks, unconsilidated sediments	55.395	167.272	55.400	167.269	878	642
DR	130	Piip Volcano	full	1	volcaniclastic rocks	55.395	167.236	55.399	167.239	1145	904
DR	131	Piip Volcano	full	1	lava fragments, volcaniclastic rocks	55.384	167.271	55.382	167.266	712	537
DR	132	Volcanologists Massif	1/5 full	1	lava fragments, volcaniclastic rocks	55.284	167.301	55.290	167.300	3036	2607
DR	133	Volcanologists Massif	full	1	lava fragments, volcaniclastic rocks	55.253	167.335	55.258	167.347	3792	3271
DR	134	Komandorsky Block	1/2 full	1	lava fragments, volcaniclastic and sedimentary rocks	54.348	168.685	54.343	168.682	1645	1220
DR	135	Guyot southeast of Medny Island	full	1	lava fragments	54.283	168.746	54.276	168.743	898	344
DR	136	Komandorsky Block	1/4 full	1	sedimentary rocks	54.345	166.796	54.354	166.795	3866	3350

Type	Stat.	Location	total volume	Rec. DR	Rock summary	on bottom / start lat °N	long °	off bottom / end lat °N	long°	depth (m) begin	end
DR	137	Komandorsky Block	few rocks	1	sedimentary rocks	54.135	167.100	54.138	167.105	3958	3591
DR	138	Komandorsky Block	1/3 full	1	lava fragments, subvolcanic and sedimentary rocks	54.375	167.061	54.379	167.069	1390	1052
DR	139	Komandorsky Block	full	1	lava fragments, volcaniclastic and sedimentary rocks	54.427	167.150	54.435	167.146	920	424
DR	140	Bathymetric Highs SE Volcanologists M.	few rocks	1	lava fragment (in situ?), crust, dropstones	55.219	168.036	55.215	168.042	3719	3508
DR	141	Bathymetric Highs SE Volcanologists M.	few rocks	0	semi-consolidated sediments (mud), dropstones	55.255	167.733	55.261	167.734	3832	3597
DR	142	Volcanologists Massif	2 rocks	1	lava fragment	55.528	167.452	55.531	167.459	3737	3565
DR	143	Volcanologists Massif	empty	0		55.464	167.417	55.468	167.413	3271	3116
DR	144	Volcanologists Massif	full	1	lava fragments	55.438	167.334	55.442	167.333	2360	2020
DR	145	Volcanologists Massif	empty	0		55.321	167.340	55.327	167.338	2589	2251
DR	146	Volcanologists Massif	few rocks	1	lava fragments	55.250	167.257	55.258	167.255	3934	3454
DR	147	Komandorsky Block	1/3 full	1	intrusive and metamorphic rocks	55.225	167.166	55.218	167.166	2940	2476
DR	148	Komandorsky Block	1/3 full	1	intrusive and volcaniclastic rocks	55.269	167.065	55.261	167.065	3508	3091
DR	149	Komandorsky Block	1/8 full	1	sedimentary and volcaniclastic rocks	56.012	165.023	56.018	165.026	4672	4176
DR	150	Komandorsky Block	1/2 full	1	sedimentary rocks	55.937	165.066	55.930	165.061	4447	4030
DR	151	Komandorsky Block	few rocks	0	unconsolidated sediment, dropstones	55.827	165.446	55.819	165.435	3520	3170
DR	152	Komandorsky Block	1/3 full	1	lava frag., metamorphic, volcaniclastic and sed. rocks	55.646	165.701	55.640	165.700	3386	2947
DR	153	Komandorsky Block	3/4 full	1	lava fragments, sedimentary rocks, Mn-crusts	55.639	165.012	55.633	165.023	2160	1630
DR	154	Komandorsky Block	empty	0		55.348	165.012	55.355	165.016	4715	4289
DR	155	Komandorsky Block	1/4 full	1	lava fragments, volcaniclastic rocks	55.519	164.888	55.521	164.889	1939	1805
DR	156	Komandorsky Block	1/2 full	1	lava fragments, volcaniclastic rocks	55.519	164.854	55.526	164.856	2912	2423
				36	yielded rocks						
Dredge Stations (DR): 52				16	returned empty or only soft sediment and / or Mn and / or dropstones				average depth:	2909	
CTD Stations (CTD): 3									max. depth:	5383	
									min. depth:	670	