CRUISE REPORT

JAPAN MARINE SCIENCE AND TECHNOLOGY CENTER

R/V YOKOSUKA YK04-05 LEG 4 CRUISE

COMPOSITION AND CRUSTAL STRUCTURE OF THE EARLIEST ARC CRUST: A SUBMERSIBLE STUDY OF THE WESTERN FLANKS OF THE OGASAWARA RIDGE

MAY 24, 2004 TO JUNE 1, 2004

(HACHIJO-JIMA, JAPAN TO ITO, JAPAN)

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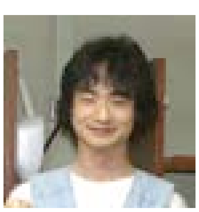

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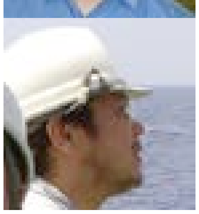

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ACKNOWLEDGEMENTS

We are grateful to captain Sadao Ishida, the Shinkai operation team manager Yoshiji Imai, the crew of R/V Yokosuka , and the Shinkai team for their outstanding efforts to make this scientific program successful. We also thank JAMSTEC for their support of this project. The U.S. science group acknowledges the support of a National Science Foundation grant to the University of Texas at Dallas. Most of the expendable supplies used in the cruise were provided from the Hydrographic and Oceanographic Department of Japan.

SUMMARY:

We conducted four dives using DSV Shinkai 6500 and completed associated geophysical mapping along the western slopes of the Ogasawara Ridge in the forearc of the Izu-Bonin subduction during Leg 4 of cruise YK04-05 aboard R/V Yokosuka. The ship left Hachijo-Jima, Japan, on Monday, May 24, 2004 and returned to Ito, Japan on June 1, 2004.

We completed a bathymetric map of the entire western escarpment of the Ogasawara Ridge and much of its northern extension and identified the major morphologic features of the ridge. A pronounced northwest-southeast fabric is superimposed on the overall north-south trend of the ridge.

The scarp of the Ogasawara Ridge can be subdivided into a northern segment, a central segment (lying about 15 km east of the southward projection of the northern escarpment), and a southern segment. The northern segment is associated with a narrow ridge which trends 010° and is surmounted by relatively small, discrete conical features that could be the remnants of old volcanoes. Dives 823, 824, and 825 were carried out on the northern segment. These dives mapped exposures of debris flows and associated sedimentary rocks, some pillowed volcanic outcrops, and Mn-crusts and nodules. Dives 823 and 824 were on north-south, west facing scarps and samples from these dives had very thick (to 10 cm) manganese rinds. Dive 825 was below and up a very steep fault scarp with a northwest trend, and these samples were only lighted coated with manganese. Clasts in the debris flow are mafic, andesitic, and rarely dacitic. Many of the clasts were abraded or rounded, suggesting that they were redeposited as gravity flows, as opposed to being primary volcanic deposits. The debris flow samples are very similar to rocks described in the Mikazukiyama formation of Eocene to Oligocene age in the northwest part of Chichi-jima. The type of volcanic clasts, absence of boninites, and presence of an unconformity with underlying Eocene boninites suggest that these debris flows may be a volcanic deposit overlying the Eocene exposures of Chichi-jima. These exposures may represent a portion of a substantial but previously unrecognized Oligocene volcanic arc in this part of the Izu-Bonin system.

Dive 826 occurred on the central segment NNW of Chichi-jima. This dive recovered mafic volcanic rocks, sediments, and limestones, including samples with large foraminifera tentatively identified as *Nummulites*. The Nummulitic limestone is quite thick and is apparently interbedded between boninitic pillows. This result establishes the crustal section here to be of Eocene age, and documents the contrast between the rocks of the Chichi-jima platform and those of the northern segment.

These results show that the Eocene section is likely dipping gently to the west or northwest and that the western scarps expose potentially younger Oligocene rocks northwards along the platform. The lower volcanic section and dikes are not exposed along the western escarpment. Samples of these lower crustal forearc units may only be exposed on the large fault scarps south and southeast of Guam; drilling may be required to constrain the composition of those units.

INTRODUCTION:

Understanding the initiation of subduction and the tectonic significance of ophiolites are important geoscientific problems that are intimately related. Recent studies of the Izu-Bonin-Mariana forearc demonstrate that early arc volcanism was characterized by distinctive igneous rocks, including boninite, depleted arc tholeiite, and associated plutonic rocks, that are now preserved in the forearc. The dredged plutonic rocks, particularly when compared to plutonic rocks from back-arc basins and the arc itself, are compositionally similar to seafloor that forms above subduction zones (supra-subduction zone ophiolites), but where exactly in the arc these form is controversial. The diving program that we proposed addressed issues about the earliest history of the Izu-Ogasawara subduction zone.

In recognition of the importance of these problems and because the IBM arc system has become a focus for research about subduction initiation and the significance of ophiolites, the 2002 joint JAMSTEC-NSF MARGINS (Honolulu) workshop on the IBM system recommended that the deeper forearc crust be characterized through field studies, studies of existing dredged samples, and drilling. Our objective on this cruise was to use Shinkai 6500 to study exposures along the steep, western scarp of the Ogasawara (Bonin) Islands, created by uplift and faulting of the forearc. The Shinkai 6500 dives allowed observations and sampling of approximately 3 km of relief to complement the 500 m of exposure on Chichi-jima. Our initial hypothesis suggested the possible exposure of sheeted dikes and isotropic gabbros on the fault scarp. The samples and observations will be used to constrain the early history of the Izu-Bonin arc.

2. GEODYNAMIC BACKGROUND:

The outer forearc of the Izu-Bonin- Mariana system has been studied extensively. Work in the region includes dredge and drill sampling of the forearc basement, studies of the geology and geochemistry of the exposures on the Bonin Islands, and surveys of the Bonin Platform.

The islands of the Bonin platform have been well studied. Boninites were first described from the island of Chichi-jima (Suzuki, 1885; Kikuchi, 1890; Petersen, 1891) and many workers have studied the geology and geochemistry of the islands (Umino, 1985; , 1986a, 1986b; Vidal et al., 1985; Yajima and Fujimaki, 2001; Taylor et al., 1994; Shiraki et al., 1978; Shiraki et al., 1980; Satake et al., 1984; Maruyama and Kuramoto, 1981; Komatsu, 1980; Kuroda and Shiraki, 1975; Kuroda et al,, 1978; Kuroda, 1984; Kuroda et al, 1988; Dobson, 1986; Dobson and O'Neil, 1987; Dobson and Tilton, 1989). There have been fewer studies of Haha-jima and Muko-jima (Iwasaki and Aoshima, 1970; Taylor, 1994; Haraguchi et al., in preparation), but those are sufficient to characterize the principal geologic character of the platform. The Chichi-jima and Muko-jima groups comprise large quantities of boninites and related andesites and dacites. On Chichi-jima, the Marubewan, Asahiyama, and Mikazukiyama Formations expose over 500 m of boninite flows, volcanic breccias, felsic lavas, and tuffaceous sediments. The age of the formations is 42-51 Ma (Hanzawa, 1947; Kaneoka et al., 1970; Matsumaru, 1976; Meijer et al., 1983; Shibata et al., 1984; Dobson, 1986; Yoshiwara, 1902; Tsunakawa, 1983). NNE trending dikes cut the eastern side of Chichi-jima. The formations on the eastern side of the island dip gently westward (Umino, 1985, 1986a, Dobson, 1986). The formations appear to be more flat-lying in the central part of the island and in places on the western side dip slightly to the east. Detailed geologic mapping of Chichijima (including tracing every flow and volcaniclastic unit flow-by-flow and bed-by-bed in the field) has documented very detailed, precise structures of the strata. Open folds prevail over the Bonin Islands with NNW-SSE-striking axes and a wave length of approximately 8 km, a part of which can be ascertained from cross sections (Umino, pers. comm.; Umino and Iwano, 1992). The anticlines run through Minamijima Island and the strait between Chichijima and Higashijima. An axis of anticline also runs along the western side of Hahajima Island. The strata are gently undulated and expose virtually the same stratigraphic level throughout the Bonin Ridge, supporting the inference of lower crustal exposures on the faulted western flanks of the Ridge. The Haha-jima group, and the escarpment to its west expose mostly low-Mg and high-Mg arc tholeiites, rather than boninites (Taylor et al., 1994; Haraguchi, 1999).

The forearc of the Izu-Bonin system has been extensively surveyed, although that work was done largely with an older 16-beam Seabeam system, yielding 30-40% coverage of the seafloor. There has been some sampling of the western escarpment (Ishii, 1985; Haraguchi, 1999). These dredges recovered large volumes of low- and high-Mg tholeiites, similar to the exposures in the Haha-jima group. The nature of dredged samples precludes determining if the samples were from flows, dikes, or other morphologies. Dredge KT95-9 D17 recovered hyaloclastite sediments and small gabbroic pebbles, suggesting there is some at least local exposure of coarser grained rocks. A number of the dredges also recovered only sediment, which is not surprising given the proximity to the thick volcaniclastic fill of the Bonin Trough.

There is also extensive sampling of the Izu and Mariana forearcs to provide comparative data for the Bonin segment of the IBM forearc. Work in the Marianas system includes dredging from south of Guam to 22°N (Bloomer, 1983; Bloomer and Hawkins, 1983; Stern et al., 1991) and DSDP Sites 458 and 459 (Bougault et al., 1981; Hickey and Frey, 1982; Hickey-Vargas, 1989; Hussong and Uyeda, 1981a, 1981b; Natland and Tarney, 1981;). The most relevant sampling in the Izu forearc is ODP Sites 782, 783, 784, 785, 786 and 787 (Arculus et al., 1992; Clift, 1995; Fryer et al., 1990; Fujioka et al., 1992; Hiscott and Gill, 1992; Mottl, 1992; Murton et al., 1992; Parkinson et al., 1992; Pearce, Thirwall, et al., 1992; Pearce, Van Der Laan, et al., 1992; Pezard et al., 1992; Taylor, 1992; Taylor, Fujioka, et al., 1992; Taylor et al., 1992; Van Der Laan et al., 1992). There have also been studies of the forearc exposures on Guam and Saipan (Hickey-Vargas and Reagan, 1987; Meijer, 1980, 1983; Reagan and Meijer, 1984)

3. Objectives of the Cruise:

Subduction of oceanic lithosphere is the primary contributor to the global mass and chemical flux between the lithosphere and the deeper mantle and provides the source of a significant proportion of the world's volcanism (Stern, 2002). In spite of this importance, we have much to learn about how subduction zones operate, including how new subduction zones begin. Forearcs are an integral part of intraoceanic convergent margins and sediment-free forearcs like those of the Izu-

Bonin-Mariana (IBM) system preserve the best record of the early stages in the evolution of the convergent plate margin. Recent studies of the IBM forearc have raised a number of important new hypotheses about the evolution of intraoceanic arc systems. The first, and most striking, is the recognition that the forearc basement formed in the initial phases of volcanism in these subduction zones (middle to late Eocene) nearly synchronously over a zone up to 300 km wide and thousands of kilometers long, at igneous production rates much higher than those of mature arcs and similar to those of slow-spreading ridges (Figure 1; Stern and Bloomer, 1992; Bloomer et al., 1995).

The IBM forearc crust exposes one of the best known recent analogs for ophiolites. The chemical signature of most ophiolites indicate that they must have formed at a convergent plate margin and so are termed 'supra-subduction zone (SSZ) ophiolites'.

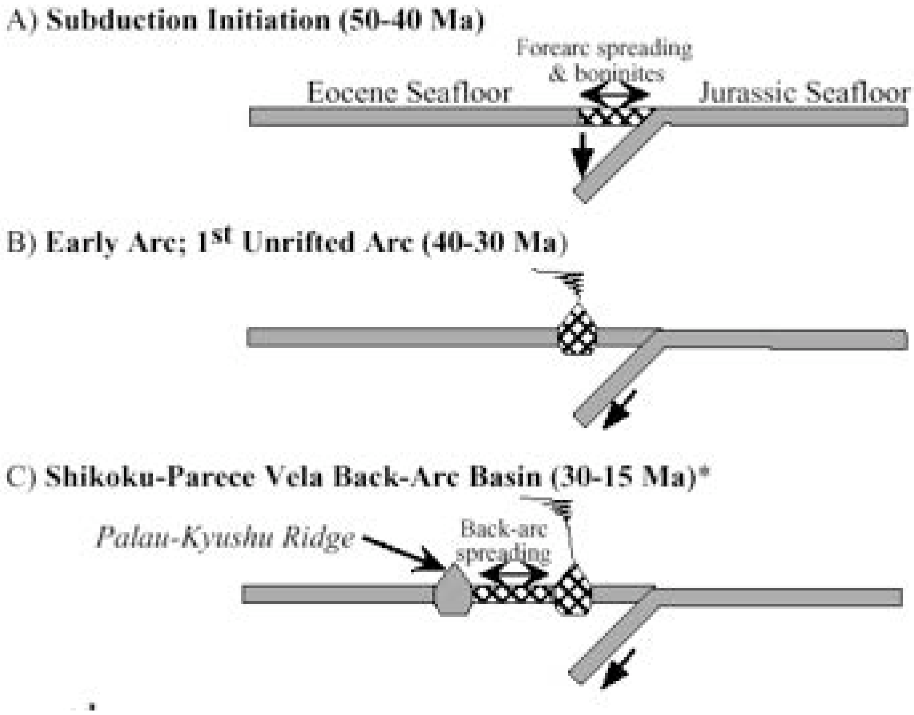

Fig. 1. Evolution of the IBM arc after subduction initiation (from Stern et al., 2002). We think that ophiolites form during stage A and are preserved in the IBM forearc.

Most scientists think that SSZ ophiolites originate in back-arc basins because this is the only modern geotectonic environment where the compositional and structural constraints can be satisfied. The duration of volcanism, volcanic and plutonic rock compositions, and structural setting of the IBM forearc are virtually identical to those of the best preserved ophiolites, and this observation leads us to conclude that SSZ ophiolites mostly form in forearc environments (Bloomer et al., 1995) during the early stages of subduction.

Previous studies of the IBM system lead to hypotheses that have important implications for mass and energy balances at convergent margins. These hypotheses suggest that the earliest arc magma production was different in rate and composition than that of the mature IBM arc and that the early arc crust is an important part of the bulk composition of the system. These much higher rates required extension and a sea-floor spreading type mechanism. This hypothesis must be tested further; in particular we need to better understand forearc crustal structure and composition. The importance of this research is reflected in the recommendations of the 2002 joint JAMSTEC-NSF MARGINS workshop on the IBM system, which strongly encouraged the study of early arc volcanism and the characterization of the lower crustal composition of the forearc through field studies, studies of existing dredged samples, and drilling.

This cruise took advantage of exposures along the steep, western side of the Ogasawara (Bonin) Ridge, created by uplift and faulting of the forearc (initially in Eocene time, and likely modified in the Oligocene), where a 3 km tall section of forearc crust is exposed (Figure 2, Taylor, 1992). The capabilities of Shinkai 6500 allowed observations and sampling of the entire section to complement the 500 m section of Eocene lavas exposed on Chichi-jima and other Bonin islands. We completed four dives on the steep western escarpment, though the position of those dives was shifted somewhat due to concerns about the long term weather forecast and the available survey data. We also completed a survey of the western flanks of the entire Ogasawara Ridge. This work focused on testing two key hypotheses:

- *The rock assemblages preserved in the IBM and other intraoceanic forearcs are a better analog for ophiolites than those that form at mid-ocean ridges or back-arc basins.*

- *Forearc crust is produced when subduction begins. The initial stages in the formation of a subduction zone are associated with seafloor spreading in the overriding plate. Unusual magmas are produced at rates much higher than those associated with mature arcs.*

Combined with the work on the islands and previous dredge sampling, our work will help establish how uniform the crustal structure of the platform is. If MORB material is entirely lacking, it is strong evidence that the early arc volcanism proceeded at a rate and in a style that made it possible to remove most of the pre-existing crust. The distribution and volumes of boninitic and tholeiitic lavas along the escarpment will have important implications for the nature of the mantle that existed at the earliest phases of subduction.

Verification of these hypotheses by our work will test parts of the model of early arc volcanism as the progenitor of supra-subduction zone ophiolites. The validation of that model has ramifications for modern marine geology and for the interpretation of ophiolites in the geologic record. It would be a fundamental contribution to earth science and set the stage for deep scientific drilling.

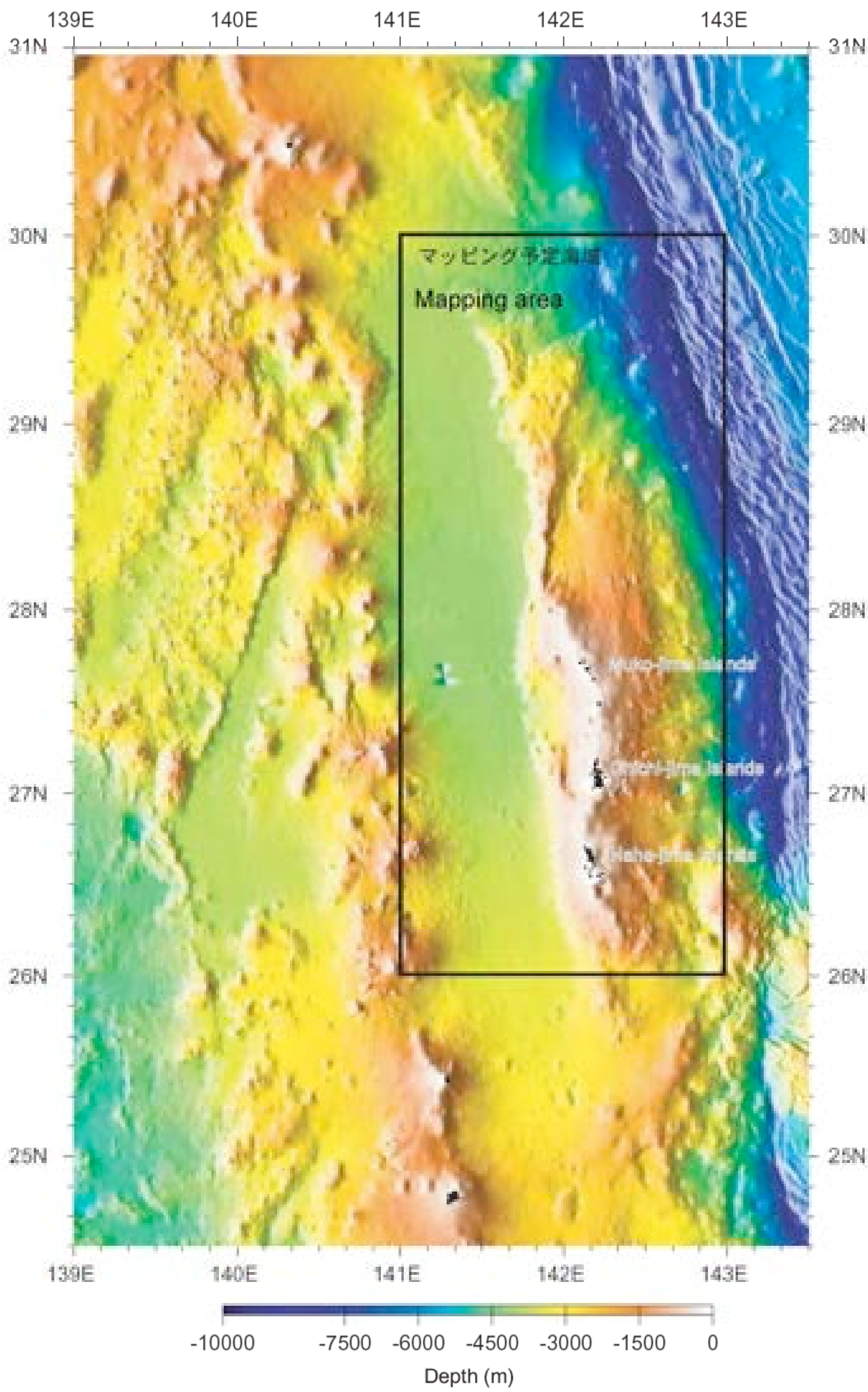

Figure 2: Area of operations for YK04-05 Leg 4

4. RUNNING CRUISE NARRATIVE

Our initial dive plan was to spend the first 36 hours of the cruise proceeding south along the escarpment, collecting multibeam data along the track, to our first dive on the steep scarps west of Chichi-jima. However, concerns about the weather conditions and a potential low pressure front led us to move our first dive to May 25th, instead of May 26th, which required completing our first dive at the northernmost site, after cursory survey work. The second dive was moved northwards, based upon the identification of very steep scarps in our initial surveying. We adjusted our science plan to survey southwards each evening, returning to the next day's dive site by 0700.

Local Time (approximate) All times in Japan Standard Time	Notes
May 24, 2004	YK-04-05 begins; Hachijo-jima, Japan; ship steams SSW to north end of Ogasawara escarpment
0930	Scientists aboard by boat, west side of island (Yaene port); depart for northern end of Ogasawara Ridge at 15 kts
1100-1130	Meeting to discuss ship's rules with Chief Officer and Chief Radio Officer
1200	Efforts to initialize GeoCompass; source code missing
1300-1315	Fire and boar drill at the upper deck
1400-1430	Meeting with Shinkai submersible team
1500-1600	Orientation for scientists participating in submersible observations
1640	Ceremony on bridge to begin cruise ("Konpira-san" ceremony)
1900	Science meeting
2220	Geophysical mapping started (entering south of 30°N)
May 25, 2004	Shinkai 6500 Dive 823 conducted on the western flanks of Ogasawara Ridge at 28°10'N. After recovery, M/V Yokosuka proceeded to survey between 27°40'N and 28°40'N, to prepare for Dive 824
0555	Arrived at Dive 823 launch point
0600	XBT was deployed
0953	Dive 823 started (Shinkai opened vent); Sherman Bloomer as observer
1144	Shinkai on bottom (3771 meters)
1551	Shinkai off bottom (2766 meters); rocks sampled at 8 locations
1653	Shinkai on surface
1800	Yokosuka underway for next survey points
1910-2000	Science meetings
1800-2200	Scientists work on rock description, video archiving
May 26, 2004	Shinkai 6500 Dive 824 conducted on the western flanks of Ogasawara Ridge at 28°32'N. After recovery, M/V Yokosuka proceeded to survey between 27°30'N and 28°40'N, to prepare for Dive 825

0640	Arrived at Dive 824 launch point
0950	Dive 824 started (Shinkai opened vent); Satoru Haraguchi as observer
1114	Shinkai on bottom (2889 meters)
1622	Shinkai off bottom (1721 meters); rocks sampled at 9 locations
1701	Shinkai on surface
1800	Yokosuka underway for next survey points
2000-2030	Science meetings
1700-2200	Scientists work on rock description, video archiving

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May 27, 2004	Shinkai 6500 Dive 825 conducted on the northwest trending scarp on western flanks of Ogasawara Ridge at 28°40'N. After recovery, M/V Yokosuka proceeded to survey between 27°40'N and 28°40'N, to prepare for Dive 826
0620	Arrived at Dive 825 launch point
0949	Dive 825 started (Shinkai opened vent); Mark Reagan as observer
1058	Shinkai on bottom (2301 meters)
1623	Shinkai off bottom (1579 meters); rocks sampled at 9 locations
1659	Shinkai on surface
1800	Yokosuka underway for next survey points
2010-2030	Science meetings
1800-2200	Scientists work on rock description, video archiving

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May 28, 2004	Shinkai 6500 Dive 826 conducted on the western flanks of Ogasawara Ridge at 27°20'N, NNW of Chichi-jima. After recovery, M/V Yokosuka proceeded to survey the western flanks of the Ogasawara Ridge between 27°20'N and 26°10'N
0730	Arrived at Dive 826 launch point
0955	Dive 826 started (Shinkai opened vent); Yasuhiko Ohara as observer
1054	Shinkai on bottom (1750 meters)
1617	Shinkai off bottom (705 meters); 21 rocks sampled at 11 locations
1652	Shinkai on surface
1730	Yokosuka underway for next survey points
2000-2045	Science meetings
1800-2200	Scientists work on rock description, video archiving

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May 29, 2004	M/V Yokosuka proceeded to survey the western flanks of the Ogasawara Ridge between 27°20'N and 26°10'N; work continues curating samples and video records
0819-0831	Figure eight maneuvering was done for calibration of the three-component magnetometer

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May 30, 20004	M/V Yokosuka proceeded to survey the northern end of the Ogasawara Ridge between 28°30'N and 29°30'N; work continues curating samples and video records
0900-1000	Science presentations to crew by Ishii, Ohara and Bloomer
1030	Sampling party for scientific party
1100-2200	Scientists work on sample curation, cruise report
1300	Group photograph of scientific, ship, and Shinkai crew
1800	Depart survey area for Ito, Japan. Survey work completed.
1900	Recpetion in mess for ship's party
May 31, 2004	M/V Yokosuka enroute to Ito harbor @ 15 knots; scientists completing curation and descriptions of samples, video archiving, and cleaning of laboratories
0952-1004	Figure eight maneuvering was done for calibration of the three-component magnetometer (off Hachijo-jima)
June 1, 2003	Yokosuka Cruise 04-05 Leg 4 ends
0900	Yokosuka anchored in Ito, Japan; scientific party disembarks

Table 1. Weather Conditions during the YK04-05 Leg 4 Cruise

Local Time	Weather/wind and (sea condition) at noon
May 24, 2004	c/NNE 4 (2)
May 25, 2004	o/NNE 3 (3)
May 26, 2004	c/ENE 4 (3)
May 27, 2004	bc/NE 4 (3)
May 28, 2004	bc/NE 2 (2)
May 29, 2004	bc/ENE 2 (1)
May 30, 2004	bc/NE 3 (2)
May 31, 2004	
June 1, 2004	-

Weather: b: Blue sky (Cloud 0-2); bc: Fine but Cloudy (cloud 3-7); c: Cloudy (Cloud 8-10); d: Drizzling Rain; r: Rain; q: Squalls; o: Overcast (Cloud 10)

Wind: 0: 0-0.2 m/sec; 1: 0.3-1.5 m/sec; 2: 1.6-3.3 m/sec; 3: 3.4-5.4 m/sec; 4: 5.5-7.9 m/sec; 5: 8.0-10.7 m/sec; 6: 10.8-13.8 m/sec; 7: 13.9-17.1 m/sec; 8:17.2-20.7 m/sec; 9: 20.8-24.4 m/sec; 10: 24.5-28.4 m/sec; 11: 28.5-32.6 m/sec; 12: more than 32.6 m/sec

Sea Condition: 0: Calm (Glassy); 1: Calm (Ripped); 2: Smooth (Wavelets); 3: Slight; 4: Moderate; 5: Rough; 6: Very rough; 7: High; 8: Very high; 9: Phenomena

5. OPERATIONS AND DATA PROCESSION:

Waypoints for the survey lines employed during the YK03-09 cruise are listed in Table 2. Figure 3 shows the survey lines and way points.

5-1. DSV Shinkai 6500

DSV Shinkai 6500 is one of the finest manned submersibles in the world. The operational characteristics of the submersible are described elsewhere.

5-2 Bathymetric Data

Bathymetric data were collected using the SeaBeam 2112 system deployed on M/V Yokosuka. The SeaBeam system uses sound velocity data from XBT data not only for calculating the depth and position of each beam during the ray tracing process, but also for the beam forming process. The sound velocity of the surface layer is very important for this step, so the system measures and uses these surface velocities in real time. Except for the surface layer, data from a CTD installed in the Shinkai 6500 were used for calculating sound velocities (Tables 3). We used XBT data for calculating sound velocities on May 23. The quality of the obtained bathymetry depends mostly on the sea state.

We conducted swath surveys along the western scarp of the Ogasawara Ridge and the northern limits of the Ridge. Two survey lines were completed in the forearc, southwest of Hahajima. Additional data were collected in transit from Hachijo-jima and to Ito. Survey lines and way point locations are shown in Figure 3.

5-3 Gravity data

Gravity data was collected during YK04-05 Leg 4, though it was not processed on board.

5-4 Magnetics data

Three-component magnetometer data (Hx, Hy, Hz) was collected during our survey lines using an SFG-1214 magnetometer (Terra Tecnica Inc.). To determine the effect of the ship's mangetication, we carried out two figure eight tracks towards the southernmost and northernmost limits of our survey (about 26°40'N and 29°30'N; Table 2). Data were collected during our surveys, but no processing was done on board.

The proton magnetometer was not deployed during the cruise.

Table 2: List of survey lines and way points, YK04-05 Leg 4

Way Point	Lat°	Lat'	Lon°	Lon'	Day	Hour	Minute	Note
					UTC (May, 2004)			
0	30	38.7	140	49.8	24	13	20	From Hachijo; SVP1 (May 24, 0:41-21:20, UTC)
1	28	48.5	141	44.5	24	18	28	
2	28	39.5	141	46.8	24	19	4	
3	28	10.4	141	48.1	24	22	54	SVP2 (May 24, 21:20-May 25, 9:05, UTC), using XBT; Dive # 823
(3)	28	10.4	141	48.1				Dive # 823 end point
4	28	10.4	141	52.5	25	8	55	SVP3 (May 25, 9:05-end of the cruise, UTC)
5	28	35	141	52.5	25	10	44	
6	28	35	141	48.1	25	11	3	
7	28	38	141	48.1	25	11	20	
8	28	38	141	52.5	25	11	49	
9	28	38	141	56.5	25	12	10	
10	27	40	141	56.5	25	17	0	
11	27	40	141	48.1	25	17	32	
12	28	8	141	48.1	25	19	46	
13	28	8	141	44	25	20	0	
14	28	30	141	44				Short-cut?
15	28	37	141	48.5	25	21	38	Dive # 824
(15)	28	37	141	48.5	26	8	48	Dive # 824 end point
16	28	35.8	141	54.09	26	9	4	
17	28	29.37	141	54.33	26	9	28	
18	28	29.37	141	50.11	26	9	40	
19	28	14	141	50.11	26	10	46	
20	28	8	141	52	26	11	14	
21	27	43.5	141	52	26	13	17	
22	27	43.5	142	1	26	14	12	
23	27	41.3	142	2	26	14	28	
24	27	41.3	142	0	26	14	39	
25	27	10	142	0	26	17	24	
26	27	10	142	4.5	26	17	42	
27	27	37	142	4.5	26	20	5	
28	27	42	141	55.7	26	20	50	Dive # 825
(28)	27	42	141	55.7				Dive # 825 end point
29	27	45.8	141	54.7	27	9	20	
30	27	45.8	142	1.5	27	9	45	
31	27	40.1	142	3.7	27	10	9	
32	27	36.9	142	6.3	27	10	29	
33	27	26	142	6.3	27	11	24	
34	27	26	142	1.3	27	11	55	
35	27	23.3	142	1.3	27	12	14	
36	27	23.3	142	6.3	27	12	46	

Table 2 (continued)

Way Point	Lat°	Lat'	Lon°	Lon'	Day	Hour	Minute	Note
					UTC (May, 2004)			
37	27	9	142	5	27	15	6	SeaBeam down during 13:46-14:56
38	27	5	142	1	27	15	34	
39	27	5	141	58	27	15	47	
40	27	3	141	58	27	15	52	
41	27	3	142	2	27	16	13	
42	27	0.5	142	2	27	16	25	
43	27	0.5	141	58	27	16	41	
44	26	41	141	58	27	18	17	
45	26	41	141	54	27	18	34	
46	27	23.5	141	54	27	21	55	
47	27	23.6	142	3.5	27	22	5	Dvie # 826
(47)	27	23.6	142	3.5				Dive # 826 end point
48	27	27.15	141	52.3	28	9	5	
49	27	34.2	141	52.3	28	9	32	
50	27	34.2	141	46	28	9	55	
51	27	23	141	45	28	10	49	
52	27	12	141	45	28	11	42	
53	27	4.7	142	4	28	13	12	
54	26	58.5	142	4	28	13	44	
55	26	58.5	142	1	28	13	57	
56	26	41	142	1	28	15	20	
57	26	37	141	57.5	28	15	45	
58	26	22.5	142	0	28	16	59	
59	26	16.5	142	3	28	17	31	
60	26	13	142	5	28	17	53	
61	26	15	142	10	28	18	17	
62	26	20	142	30	28	19	49	
63	26	20	142	47	28	21	3	
64	26	46	142	47	28	23	9	Figure 8 (23:19-23:31, UTC)
65	26	46	142	39	28	23	58	
66	26	27	142	39	29	1	32	
67	26	27	142	30	29	2	13	
68	26	19	142	7	29	4	5	
69	26	23.5	142	5	29	4	30	
70	26	38	142	1.5	29	5	47	
71	26	40	142	2.6	29	5	58	
72	26	56.5	142	3.2	29	7	21	
73	26	58.7	142	5.6	29	7	38	
74	27	6.3	142	4.7	29	8	15	
75	27	11.4	142	5.2	29	8	40	
76	27	12.8	142	2.6	29	8	56	
77	27	15.5	142	2.6	29	9	5	
78	27	22.1	142	5.4	29	9	40	
79	27	22.2	142	5.3	29	9	41	

Table 2 continued

Way Point	Lat°	Lat'	Lon°	Lon'	Day	Hour	Minute	Note
					UTC (May, 2004)			
80	27	36.8	142	6.9	29	10	54	
81	27	36.8	141	55.4	29	11	43	
82	27	36.5	141	40	29	12	49	
83	28	2	141	40	29	12	52	
84	28	2	141	54.5	29	16	3	
85	27	47	141	54.5	29	17	24	
86	27	47	141	55.4	29	17	27	
87	28	2	141	55.4	29	18	32	
88	28	8	141	55	29	19	5	
89	28	8	142	1	29	19	32	
90	28	41.5	142	2	29	22	15	
91	28	41.5	141	51	29	23	2	
92	28	45	141	50	29	23	19	
93	28	45	141	58	29	23	53	
94	28	48.5	141	58	30	0	13	
95	28	53	141	50	30	0	52	
96	28	56	141	50	30	1	5	
97	28	58	141	57	30	1	39	
98	29	12	142	2	30	2	51	
99	29	22	142	5	30	3	41	
100	29	18	141	40	30	5	28	
101	29	34	141	32	30	7	4	
102	29	45	141	25	30	8	10	
103	29	47	141	25	30	8	21	
104	29	47	141	50	30	10	8	
105	29	32	141	50	30	11	19	
106	30	0	141	32.6	30	13	20	Figure 8 (May 31, 00:54-01:04, UTC at off the Hachijo Is.)

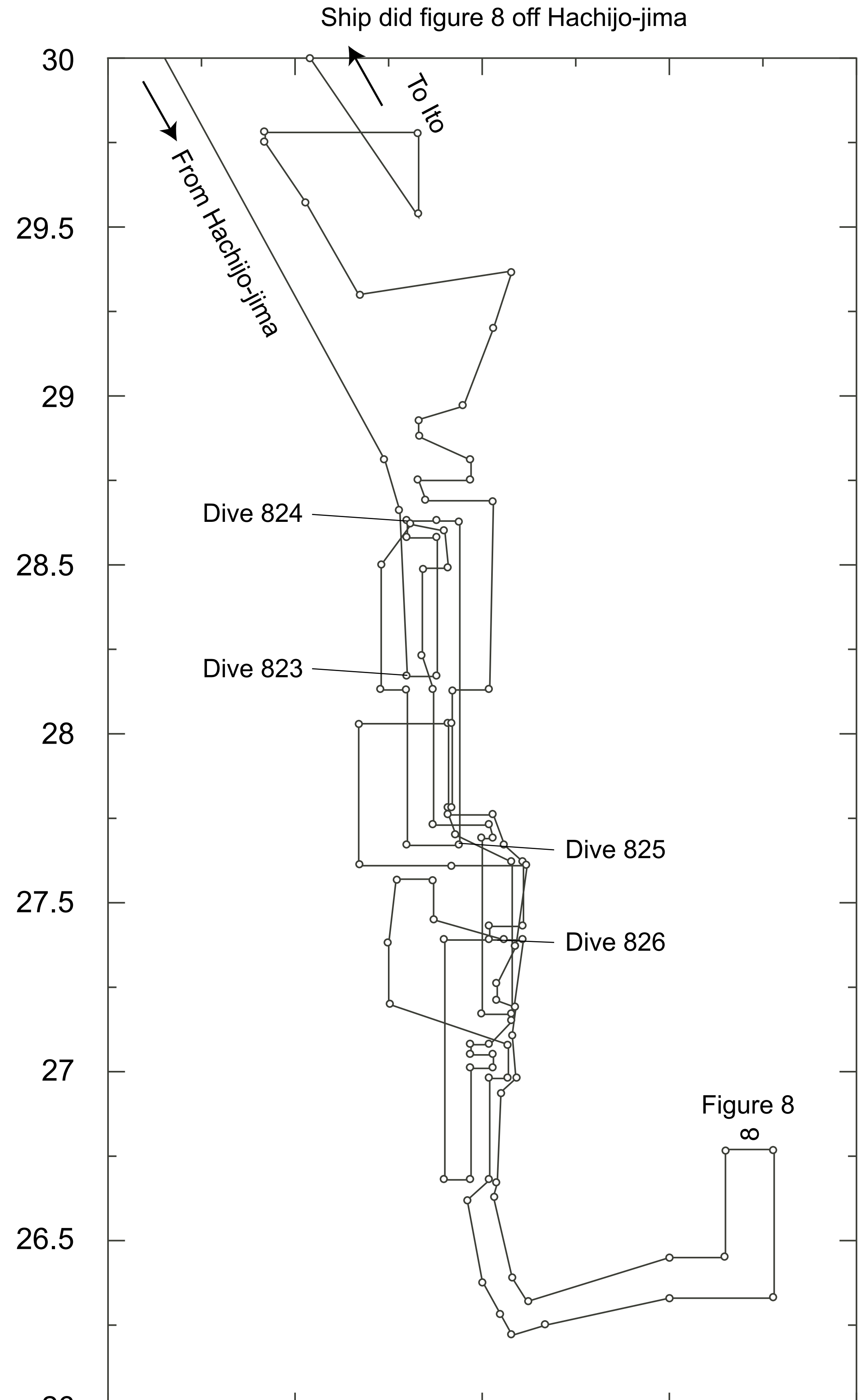
Table 3. List of sound velocity profiles

SVP1	576stdv
Depth (m)	**Velocity (m/s)**
4.5	EXT
43	1542.0
52	1542.1
74	1542.0
113	1534.3
151	1527.0
242	1522.1
380	1516.0
478	1509.7
528	1507.5
579	1501.3
598	1498.3
657	1497.8
824	1486.6
1063	1483.9
1509	1484.9
1607	1486.1
1805	1488.2
2002	1490.7
2505	1497.9
3006	1506.7
4001	1523.2
5000	1541.3
6000	1559.8
7000	1578.5
8000	1597.5

SVP2	040524xbt_576stdv
Depth (m)	**Velocity (m/s)**
4.5	EXT
20	1532.3
50	1522.3
80	1519.0
150	1516.9
200	1515.6
300	1511.7
400	1506.3
500	1498.8
700	1486.8
900	1482.3
1200	1482.8
1800	1488.5
2000	1490.7
2600	1499.6
3000	1506.5
3500	1514.8
4000	1523.1
4500	1532.4
4820	1538.1

SVP3	823_576stdv
Depth (m)	**Velocity (m/s)**
4.5	EXT
30	1524.7
80	1519.3
150	1515.9
260	1513.7
280	1511.0
350	1509.7
430	1503.1
630	1486.1
810	1481.3
880	1481.3
1070	1480.8
1500	1484.3
2000	1490.2
2500	1498.0
3000	1505.7
3500	1514.4
4000	1523.1
4500	1532.4
4820	1538.1

Figure 3. Survey lines and waypoints for Cruise YK04-05 Leg 4 along the western escarpment of the Ogasawara Ridge



6. SCIENTIFIC RESULTS

6-1 Bathymetric Survey

The preliminary Seabeam bathymetric map of the Ogasawara Ridge is shown in Figures 4 and 5. The ridge is bounded by a steep western scarp that is in turn cut by a prominent northwest fabric. The relative age of the two tectonic features is not known, though the northwest-trending fabric must be younger as it cuts the west-facing scarp. The central and northern ridge include a number of small circular to elongate highs. Given the dive observations of layering dipping away from these highs, it is possible that they are the remnants of volcanic centers.

The geophysical surveying yielded a comprehensive map of the western and northern margins of the Ogasawara Ridge. Interpretation of that data, informed by results of shore-based geochemical and geochronologic studies, will provide important geologic constraints on the geology of the Ridge.

6-2 Submersible studies

We conducted four dives during the cruise (Figures 6 and 7); a summary of the video records for those dives is included in Table 5 and short video logs are listed in Appendix A. Appendix B includes plots of the dive tracks for each dive, in X-Y units.

6-2-1 Dive 823, western scarp of Ogasawara Ridge at 28^{o}10'N

The dive began when Shinkai reached bottom at 1137 at a depth of 3774 m. Shinkai headed ENE up a moderately dipping slope with scattered outcrop of tabular to rounded morphology; much of the area was sediment covered. The first half of the dive encountered principally this kind of terrane. Moderate to steep slopes exposed 40-70% outcrop typically with a tabular or slabby appearance. In places it clearly showed sedimentary layering. This layering usually dipped with the slope, though at a shallower angle (15-20o) than the slope. Dip directions appeared to be most commonly to the SW or WSW, though some were W to WNW. Strike and dip directions of these outcrops need careful reexamination in the dive videos. Between the steep slopes exposing outcrop were sediment-covered benches, typically with less than 20% outcrop. All of the exposed rock surface were clearly covered with thick manganese oxy-hydroxide rinds. Samples 1-11 came from this portion of the slope. Those samples included volcaniclastic sandstones, volcanic breccias and conglomerates, and manganese nodules or rinds.

At 1420, at a depth of 3211 m, Shinkai encountered a near vertical scarp of about 50 m relief. Portions of the slope exposed outcrop much like that seen in the lower part of the dive, with a slabby to tabular morphology. However, in the lower part of this slope there were exposures of an irregularly vertically jointed rock that may have been a dike swarm. Further up this slope (about 1423) forms very similar to large pillow basalts could be seen. In places these appeared to be over one meter in length, in some cases with a somewhat tubelike form. At the top of the scarp the sediment covered a surface with low rounded forms, smaller than the pillow-like exposures in the scarp. Sampling was not possible while negotiating the vertical scarp and proved difficult at the upper edge. As Shinkai moved a bit away from the edge of the scarp, the edge of a tabular outcrop was found that yielded samples 12, 13 and 14. These were polymict sandstones with thick Mn-rinds.

Two more exposures like this were encountered before the end of the dive. The first was about 80 m high (15:18-15:34). A review of the video showed large, pillow-like forms in the lower parts of the slopes, with smaller rounded forms and tabular, layered outcrop in the upper portions. The samples taken in all cases came from loose pieces on or near the slopes, since sampling from the large, pillow-like forms was difficult. All of those samples were of volcanic sandstones, breccias, or clasts from them. There was substantial discussion as to whether the large, rounded forms in these exposures could be pillows, or if they represent very large manganese oxy-hydroxide growths.

6-2-2 Dive 824, western scarp of Ogasawara Ridge at 28^{o}10'N

The dive started at 1114 AM at a depth of 2900 m. Shinkai headed up a 45^{o} slope to about a depth of 2500 m. Below 2500m depth, the slope is intermediate and the bottom material is mainly light-colored sediment with some pebbles. Some basement is exposed. Sampling sites on this slope yielded mostly volcanic sandstones, although some rafted in pumice was also sampled. At 2500 m the slope steepened to > 60^{o}. A talus deposit was found at the break in slope. Sampling sites of this slope yielded volcanic conglomerates and breccias as well as angular to subrounded clasts of andesite and dacite. Above 2500m, the slopes are much and basement rocks are exposed and covered with some thin sediment and gravel. At the bottom of the steep escarpment, some debris deposits are found, and volcanic rocks are mainly recovered from this deposit. These volcanic rocks are 2-pyroxene basalt to andesite. Mn crusts beneath about 2200 m were relatively smooth and generally thinner than Mn crusts above this depth. These shallow Mn crusts had botryoidal surfaces.

2899-2790m:
Intermediate slope covered with sediment and some rocks. Ripple marks (current mark?) were observed on the surface. We had two stops and recovered two rocks each other, These rocks are mud blocks with Mn crust.

2790-2580m:
Intermediate slope, covered with sediment and some rocks, debris deposits, and some mussive outcrops. We had two stops and recovered three (Stop 3) and four (Stop 4) rocks. At the former site, recovered rocks are pumice and scoria; volcanic rocks were recovered from the latter site. These are massive volcanic rocks.

2580-2330m:
Steep slope, massive outcrops with some pebbles and sediments, and debris deposits. We had two stops and recovered one (Stop 5) and three (Stop 6) rocks. These rocks are massive volcanic rocks.

2330-1990m:
Steep slope, massive outcrops with some pebbles and sandstomes, and debri deposits. We had two stops and recovered one (Stop 7) and three (Stop 8) rocks. These rocks are mumice and Mn crusts. Volcanic rocks were not recovered.

Shallower than 1990m:
Steep slopes, massive outcrops with some pebbles and sandstones. We had two stops and recovered one (Stop 9) and two (Stop 10) rocks. These rocks are Mn nodules.

6-2-3 Dive 825, western scarp of Ogasawara Ridge at 28°10'N

The dive started at 10:55 at a depth of 2320 m. Shinkai headed 045° up a broad ridge with a slope of 15-19° to a depth of 1915m. Nearly all of the sea-floor along this traverse was blanketed with sediment. An outcrop a few meters across was encountered at about 2300 m. It appeared to be finely laminated and indurated sedimentary rock standing above the modern sediment surface no more than several cm. Its dip was similar to that of the sea-floor surface. No sample was taken. At 2182 m (11:25) we encountered and collected an ellipsoidal rock about 30 cm in diameter. This turned out to be andesitic pumice. Sample 2, a 30 cm cobble of rhyolitic pumice with a size similar to rock 1, was taken at 1983 m. At 12:20, Shinkai headed 002°. The slope remained unchanged until about 1850m, when large massive outcrops were encountered and the slope steepened to an average angle of about 40°. The sea-floor was composed of about 50 % outcrop at 1850 m, and the proportion of outcrop increased up slope. Sample 3 was collected at 1845 m from a massive outcrop of volcanic conglomerate with subangular to rounded pyroxene andesite clasts.

To find collectable outcrop, Shinkai moved several times over short distances with a general heading of 065°. Samples 4, 5, 6, and 7 were collected close together at about 1815 m from massive outcrops of volcanic breccia and conglomerate. Sample 5 is of note because of its size (35 cm) and freshness. Up slope, beginning at about 1800 m, the rocks began to have half-meter to few-meter scale bedding. The bedding was nearly parallel to the slope, perhaps just slightly shallower. Samples 8 and 9 were collected at about 1796 m from these bedded volcanic breccias and conglomerates. Samples 10 and 11 (a rounded conglomerate clast and a whole volcanic conglomerate respectively) were collected at 1752 m. Shinkai next headed in a direction of about 010°. At about 1660 m the slope steepened to an average of about 75-80°. The strike of these cliffs was guessed to be about 320°. Small valleys 10s of meters across indented the cliff face. These valleys also had nearly vertical sides. Bedding exposed in the cliffs was very similar in character and orientation to the bedding seen at greater depths (ca 25-35°). At about 1595, the slope flattened out again to the ca. 40° range. The final samples (12-15) were collected above this break in slope at a depth of 1585-1579 m. These samples also were of volcanic conglomerate. We departed for the surface at 16:24.

Summary: Outcrops along this dive track consist of bedded polymictic volcanic breccia and conglomerate with clast sizes up to 50 cm or more in diameter. The clasts in these rocks are rounded to subangular porphyritic andesite and related lavas and are commonly supported by the matrix. The dips of the conglomerates are in the range of 25-30°, with probable northwesterly strikes. Steep cliffs encountered at about 1660 m may represent the scarp of a northwesterly trending and perhaps relatively young fault.

6-2-4 Dive 826, western scarp of Ogasawara Ridge at 28º 10'N

The dive started at 10:58 at a depth of 1750 m. The Shinkai headed ~ 090º up to a depth of ~ 1640 m. An outcrop a few meters across was first sampled at ~ 1700 m. Two samples were collected at that site, both of which were calcareous mudstones. At ~ 1640 m depth, The Shinkai crossed a prominent linear ridge-like structure, which appeared like a large dike. The Shinkai first sampled an outcrop just apparently across the liner structure, where three rocks were obtained (calcareous sandstone, altered andesite, and volcanic breccia). After that, the Shinkai attempted to get back to the liner structure, but failed to do so. During this attempt, the Shinkai made a somewhat clockwise maneuver at a depth of ~ 1640 m.

At ~ 12:55, the Shinaki headed ~ 090º uphill. At ~ 13:07 (~ 1520 m), it encountered a whitish outcrop, and collected one rock sample (calcareous mud) as well as one push core. At ~ 13:30 (~ 1440 m), the Shinkai encountered a massive outcrop, where some ropy lava structure was observed (although not apparent in the video images). It collected two samples, which in fact turned out to be andesitic lava. Some ~ 100 m above this point (at ~ 14:00 to ~ 14:20), the Shinkai encountered an massive outcrop, consisting a steep scarp. The Shinkai took three samples there (all calcareous sandstone).

At ~14:30 (~ 1140 m), the Shinkai again looked a ropy lava, but no sampling attempt was occurred. At ~ 14:45 (~ 1130 m), the Shinkai collected one limestone. Between at 15:05 (~ 1000 m) and at ~ 15:30 (~ 800 m), it sampled five calcareous rocks. Above ~ 770 m (at ~ 15:50), the Shinkai observed strong ripple marks on the sedimented seafloor. The Shinkai collected last four samples at sporadic outcrops above there (~ 770 m to ~ 710 m). Among these, the very last sample was turned out to be an altered andesite lava.

The Shinkai left bottom on 16:15 at 705 m.

6-3 Descriptions of Samples

Brief descriptions of the samples collected are included in Appendix C. Samples distributed to shipboard scientists are noted in Appendix D. Photographs of the samples from each dive are shown in Appendix E.

6-3-1 Dive 823

Seventeen rocks were collected during Dive 823, at eight different locations on the sea floor. The samples were predominantly volcaniclastic sandstones, breccias, and conglomerates. Some of the breccias have the appearance of debris flows. Five of the samples were poorly sorted volcaniclastic sandstones and eight were polymictic breccias and conglomerates with subrounded to subangular clasts. All have thick Mn rinds. One large manganese nodule and one manganese crust were collected. A large olivine-plagioclase phyric basalt sample is likely a clast from the debris flow breccia. One push core was attempted but no material was recovered. Samples ranged in weight from 0.15 kg to 12.2 kg.

6-3-2 Dive 824

Twenty-two samples were collected during Dive 824 at 10 sites along the dive track. These included a variety of sediments, some of which were very similar to the debris flow breccias of Dive 823. There were five poorly sorted sandstones/siltsones, three pumice clasts, eight volcaniclastic breccia or conglomerates with andesitic clasts, and three clasts of manganese nodules (sample 21, a Mn nodule, was lost). Most of the breccias have abundant gray andesitic clasts. Sample 11 includes an 11a (an andesite clast) and 11b, a volcanic breccia with andesitic clasts. Thick manganese rinds are common on the samples. Samples weigh from 0.1 kg to 12.2 kg.

6-3-3 Dive 825

Fifteen samples were collected from eight samples stops along the dive track. The samples are distinctive from those of Dives 823 and 824 in the absence of manganese rinds. Most of these samples have only a thin veneer of manganese. Eleven of these samples are similar to the volcaniclastic breccias and conglomerates of Dives 823 and 824. They include abundant dark gray andesitic clasts and some dacitic breccias. Most are clast supported, though some are matrix supported. Two andesite samples are almost certainly clasts weathered from similar breccia and conglomerate. Some of the clasts are subrounded, suggesting an origin by redeposition rather than as a primary volcanic deposit. Samples included two rounded pumice samples, that may have been rafted into the area. Samples range in size from 0.4 kg to 8.8 kg.

6-3-4 Dive 826

Dive 826 was on a steep west-facing scarp NNW. The samples are quite different from those at Dives 823, 824, an 825. There are numerous samples of calcareous sandstones (8), calcareous mudstones (2), and fossiliferous limestones (6). The limestones include abundant large foraminifers, tentatively identified as Nummulites, an Eocene fauna that has been identified in the Eocene sections in Haha-jima, Guam, and the island of ‘Eua in the Tonga forearc. This suggests this exposure is close in time to that exposed in the youngest stratigraphy on Chichi-jima. Associated with the calcareous sediments are clasts of brown-gray andesite (3), altered andesite (1), and volcaniclastic breccia (1). One of the volcanic clasts was initially identified as boninitic, but shipboard thin section study shows that it is a plaioclase-rich two pyroxene andesite. It is not clear if any of the volcanic samples represent pieces of lava flows, or if they are all clasts weathered from volcanic breccias. One push core sampled recovered a small amount of sediment.

Figure 4: Preliminary Seabeam bathymetry from survey work during YK04-05 Leg 4.

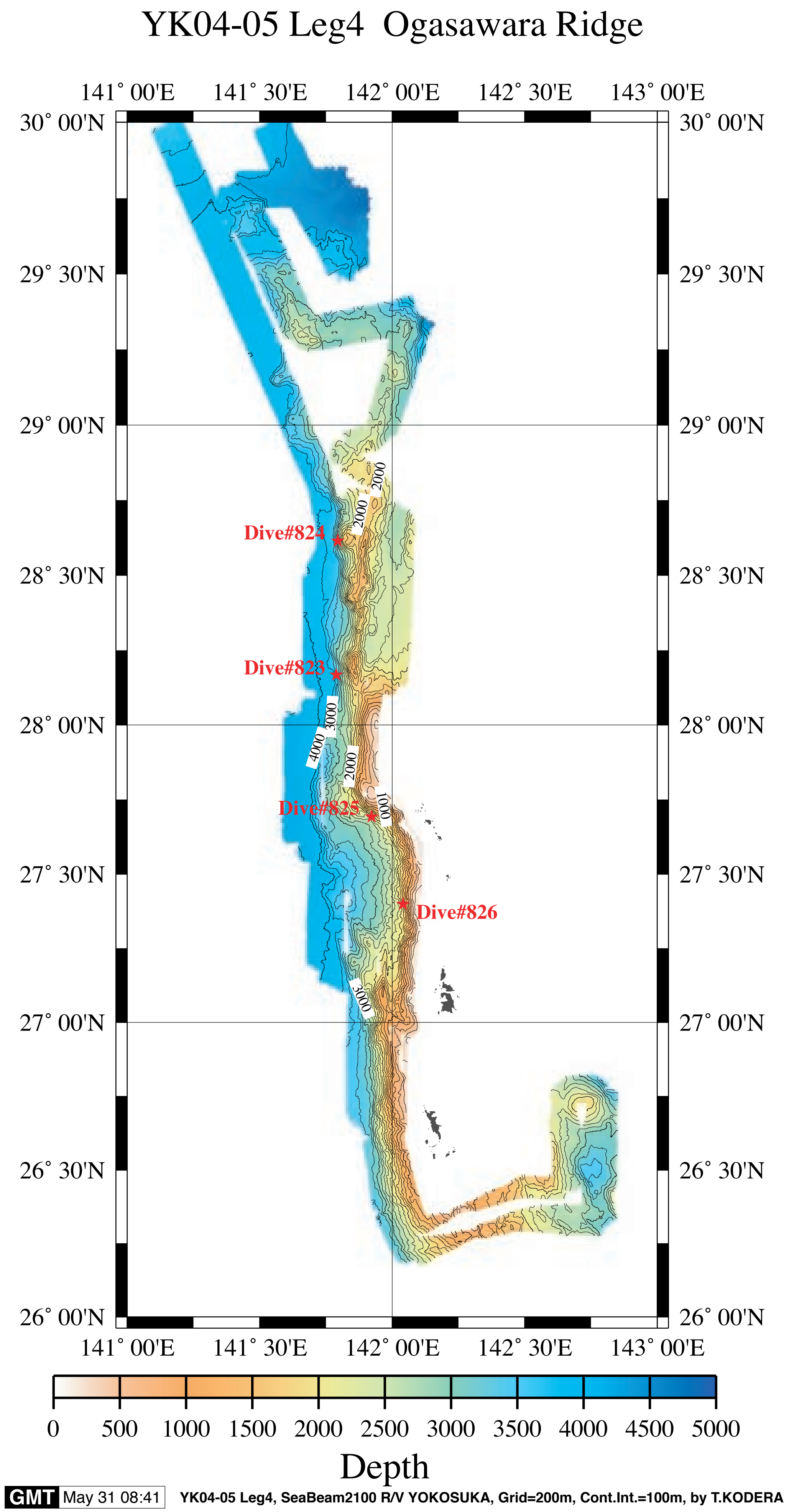


Figure 5: Preliminary Seabeam bathymetry in the area of Dives 823-826

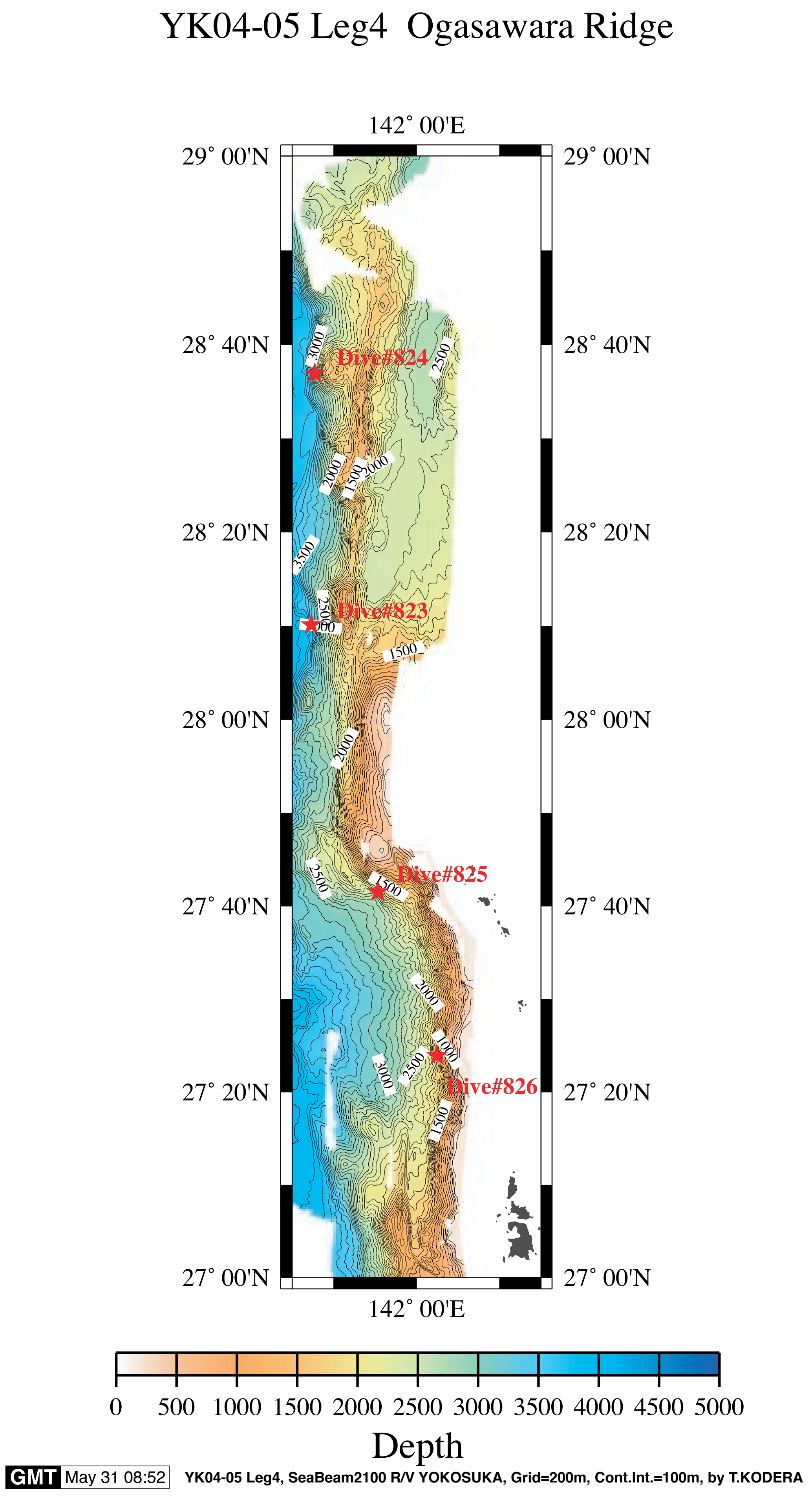


Figure 6: Bathymetry in the areas of Dive 6K#823 (left) and Dive 6K#824 (right)

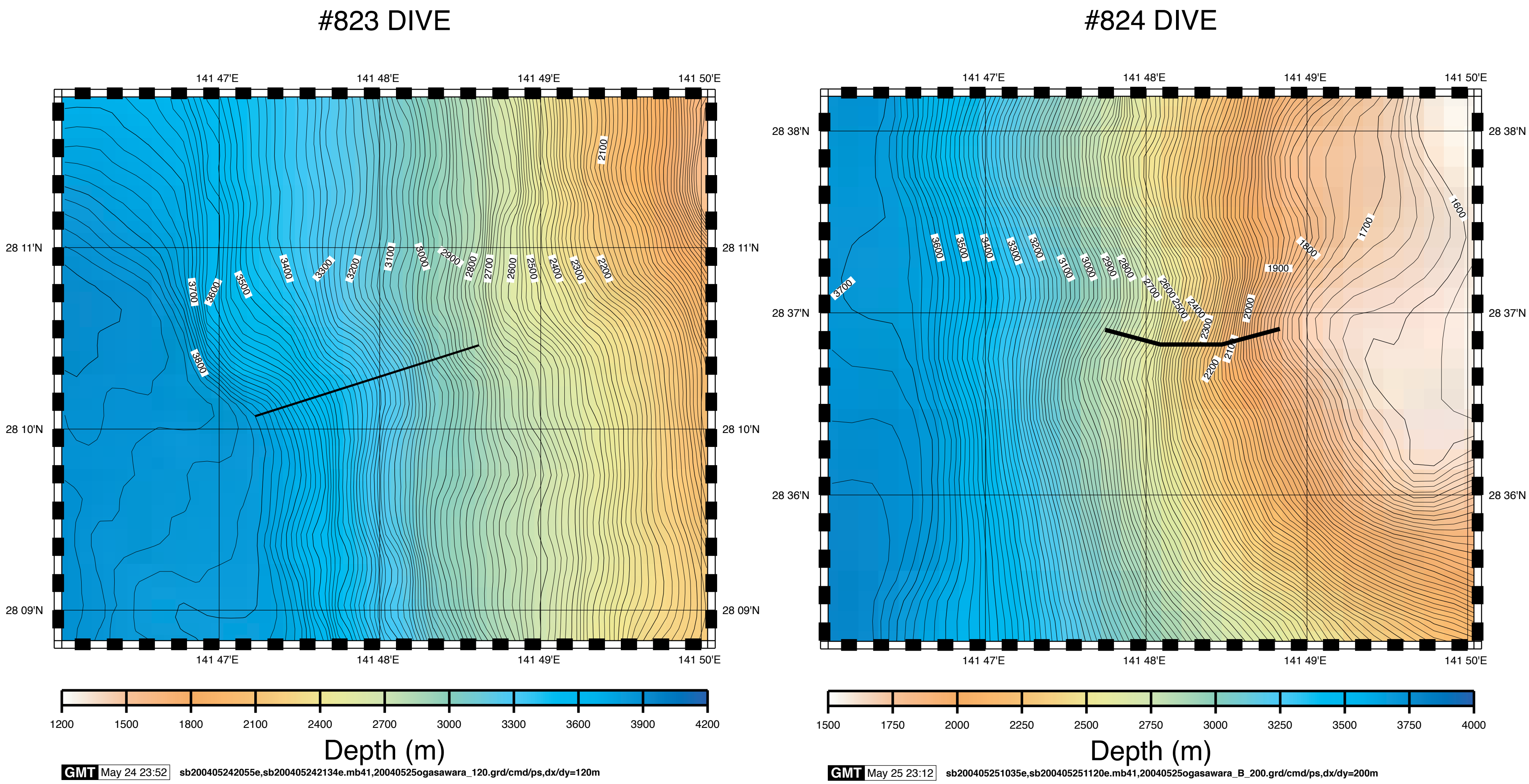
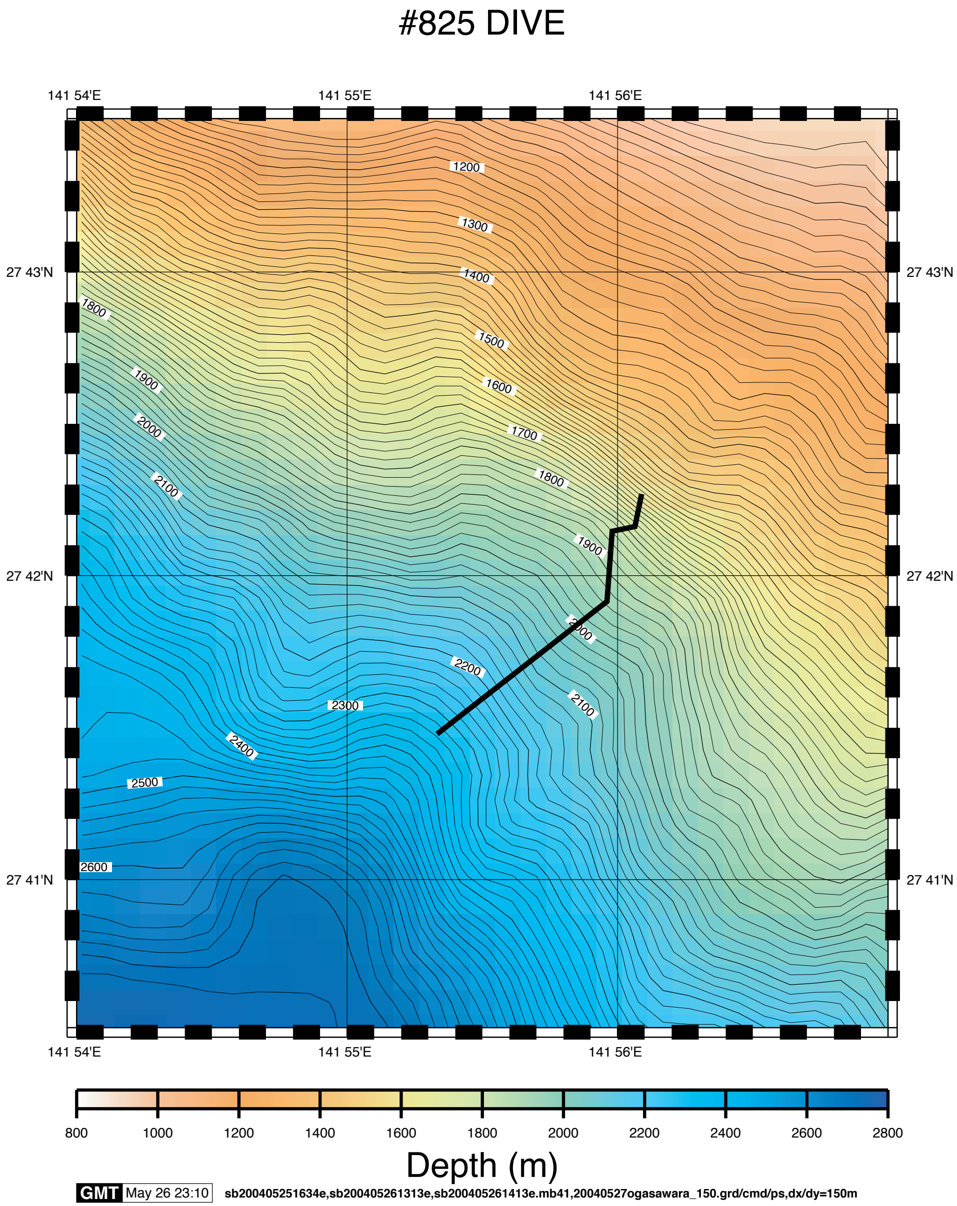


Figure 7: Bathymetric maps of areas for Dive 6K#825 (left) and Dive 6K#826 (right)



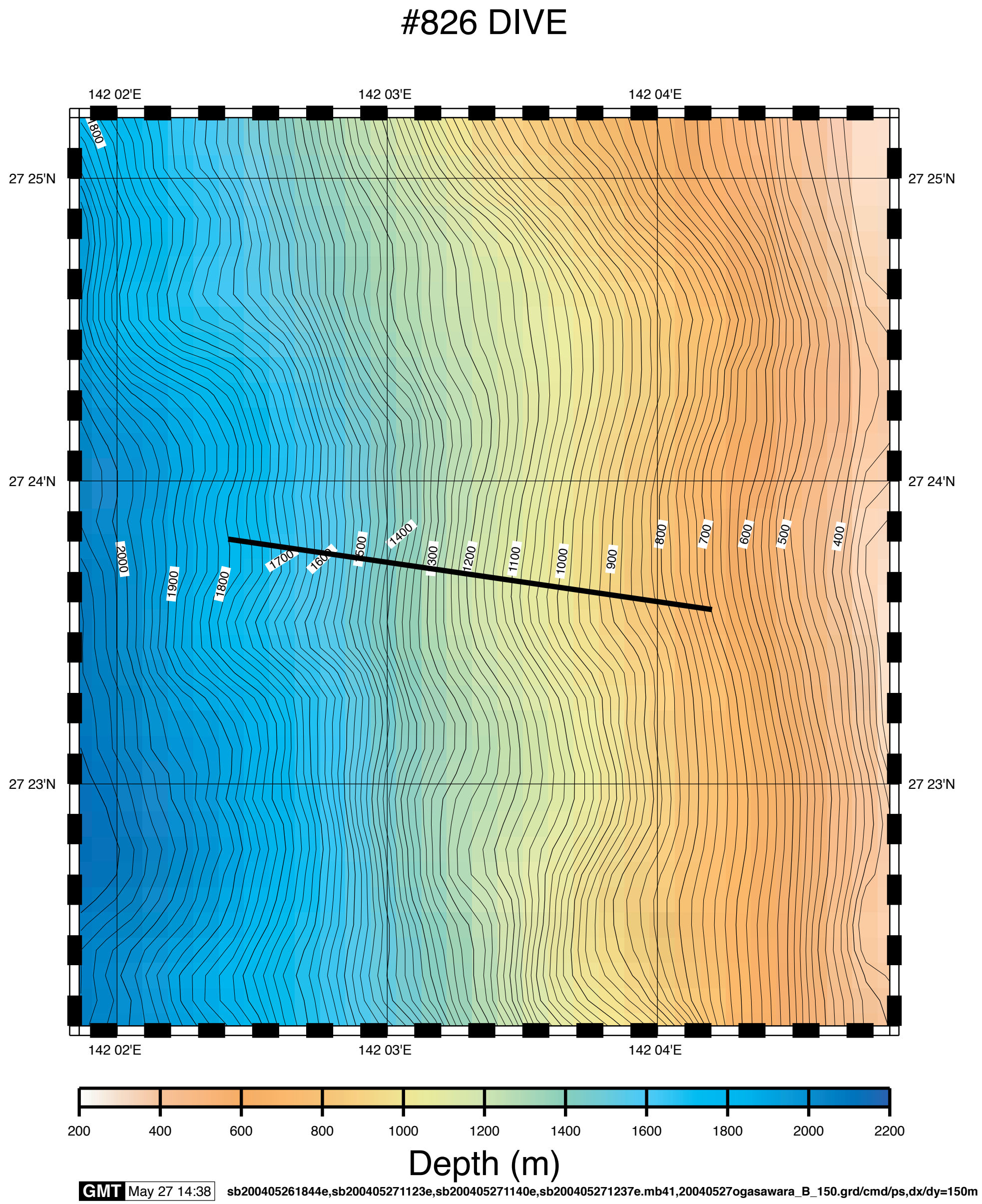


Table 4. List of Shinkai 6500 Dives completed during cruise YK04-05 Leg 4

Dive #	Date (2003)	Observer	Pilot	Co-pilot	Submersible's navigation/ Ship's Navigation	On bottom Off bottom (JST Time)	Lat (N) Lat (N)	Long (E) Long (E)	Sam-ples	Start Depth End Depth	Location
823	May 25th	Sherman Bloomer	Kazuki Iijimia	Yoshinari Ono	SSBL/ D-GPS WGS84	11:44:00 15:51:00	28^{o} 10.0392'N 28^{o} 10.4369'N	141^{o} 47.2897'E 141^{o} 48.5758'E	17 rocks	3771 m 2766 m	Steep scarp, west side Ogasawara Ridge
824	May 26th	Satoru Haraguchi	Toshiaki Sakurai	Masanobut Yanagitani	SSBL/ D-GPS WGS84	11:14:00 16:22:00	28^{o} 36.9000'N 28^{o}. 36.8293'N	141^{o} 47.7163'E 141^{o} 48.8510'E	22 rocks	2899 m 1721 m	Steep scarp, west side Ogasawara Ridge
825	May 27th	Mark Reagan	Tsuyoshi Yoshiume	Hirobumi Ueki	SSBL/ D-GPS WGS84	10:58:00 16:23:00	27^{o} 41.4805'N 27^{o} 42.3072'N	141^{o} 55.3816'E 141^{o} 56.0816'E	15 rocks	2182 m 1579 m	NNW scarp, west side Ogasawara Ridge; W of Muko-jima
826	May 28th	Yasuhiko Ohara	Kazuki Iijimia	Keita Matsumoto	SSBL/ D-GPS WGS84	10:54:00 16:17:00	27^{o} 23.8812'N 27^{o} 23.5729'N	141^{o} 2.4419'E 142^{o} 4.1819'E	21 rocks, 1 push core	1750 m 705 m	Steep scarp, west side Ogasawara Ridge; NNW of Chichi-jima

Table 5. Summary of the video and camera records obtained during Shinkai 6500 dives

Dive #	Date	Observer	Tape #	No. 1 Camera	No. 2 Camera	Handheld digital still photos	Digital video still photos*
823	May 25th, 2004	Sherman Bloomer	1 of 4 2 of 4 3 of 4 4 of 4	1130-1432 1433-1551	 1130-1433 1433-1551	36 stills archived (220 taken)	
824	May 26th, 2004	Satoru Haraguchi	1 of 4 2 of 4 3 of 4 4 of 4	1105-1406 1407-1623	 1105-1406 1407-1623	36 stills	
825	May 27th, 2004	Mark Reagan	1 of 4 2 of 4 3 of 4 4 of 4	1051-1355 1356-1624	 1051-1355 1356-1624	18 stills	
826	May 28th, 2004	Yasuhiko Ohara	1 of 4 2 of 4 3 of 4 4 of 4	1051-1352 1354-1617	 1051-1352 1354-1617	none	

*being processed at JAMSTEC

7. POST-CRUISE WORK

Additional post-cruise work will be completed on the samples distributed to the shipboard party. Preliminary assignment of work includes:

To be done by the Japanese Team:

- Basic petrography: Haraguchi (at ORI, Univ. Tokyo)
- Major elements, XRF (whole rocks and bulk glasses): Haraguchi (at ORI, Univ. Tokyo)
- Major elements, EMP (mineral phases): Haraguchi (at ORI, Univ. Tokyo)
- Trace elements, ICP-MS: Kimura (at Shimane U.)
- PGE elements, ICP-MS: Kimura (at Shimane U.)
- Sr, Nd, and Pb isotopes (excluding Hf), Ar-Ar dating: Ishizuka (at Geol. Survey of Japan)
- Major elements of mineral phases (spots and maps), EPMA: Ishii (at ORI, Univ.Tokyo)
- Trace elements of mineral phases, SIMS: Ishii (at ORI, Univ. Tokyo)

To be done by the US Team:

- Analyses of glass inclusions and glass fragments: Matt Wortel (for thesis at Univ. Iowa)
- Hf isotope work: David Peate (at new laboratory at Univ. Iowa)
- Os isotopes: Katherine Kelley (at DTM)
- O isotopes: John Eiler (at Cal. Tech.)
- Volatiles in glasses, FTIR: John Eiler (at Cal Tech.)
- Volatile element concentrations, in inclusions in mineral phases, SIMS: Wortel/Kelley
- Trace elements in inclujsions in mineral phases, LA-ICP-MS: Reagan/Wortel, and Terry Plank (at Boston U.)

As for the isotopic work, we have the following agreement:

- Osamu Ishizuka will see the time-dependent isotopic evolution of the Bonin Ridge (to compare the Shinkai samples, Chichi-jima samples, and Haha-jima samples) (Note: he already analyzed the latter two samples, and presented the results in the previous Goldschmit conference).
- David Peate will see the spatial isotopic variation of the IBM proto-arc and will examine the manganese rinds and nodules

Where possible, each research group has a thin-section chip of each whole-rock that they intend to analyze (when there was enough sample). This will allow groups to be able to place the data they collect in a petrographic framework immediately. As appropriate and if agreed on by the participants, a few whole rocks and glass samples will be analyzed for ICP-MS trace elements in Terry Plank's lab at Boston University. This work would let us correct for inter-laboratory bias and directly compare the compositions of samples from the dives with compositions of the samples we have analyzed from Guam, Saipan, and DSDP sites 458 and 459.

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APPENDIX A: Video Logs

Video Log for Dive#823 (Observer; Sherman H. Bloomer)

Local time	Depth(m)	Heading(deg.)	Note	Remark
11:30:00			On bottom	
11:39:01	3,775	71	fissure	
11:39:31	3,775	89	Mud stone covered with sedeminmet	
11:40:14	3,771	92	Wthie fish	
11:44:00	3,771		On bottom X=-560,Y=-1400	
12:02:00	3,767	56	Rock sampling	
12:09:00	3,762	58	Big!! rock sampling	
12:31:48	3,658	97	Sampling four rocks X=-430, Y=-1130	
11:35:00	3,649	95	transit to Heading 90deg.	
11:42:00	3,611		X=-450, Y=-1050	
	3,576	129	Rock sample	
13:15:11	3,501	66	Sediment, No rock X=-270, Y=-820	
13:19:11	3,476	96	Spotted rocks	
13:41:11	3,475	98	Stop tp take rock sample	
13:29:11	3,475	111	Rcok sample, X=-260, Y=-700	
13:31:51	3,470	91	Transit start	
13:41:22	3,379	78	X=-250, Y=-450	
13:59:53	3,347		Rock and push core (White) X=-200, Y=-370	
14:00:00			Transit to Head 70 deg.	
14:19:00			Rock sample	
14:30:00	3,134		X=-60, Y=80	
14:39:37	3,038	96	Stop to take rock sample	
15:12:37	3,030	135	Sampling three rocks X=-30, Y=280	
15:20:20	2,980	94	Outcrop covered with manganese	
15:22:27	2,977	157	Red fish	
15:23:49	2,978	147	Sampling three rocks X=50, Y=370	
15:34:55	2,919	97	X=60, Y=460	
15:48:51	2,780	37	Sediment	
15:50:14	2,775		X=80, Y=750	
15:51:58	2,766		Leave bottom	

Video Log for Dive#824 (Observer; Satoru Haraguchi)

Local time	Depth(m)	Heading(deg.)	Note	Remark
11:14:00	2,899		On bottom, X=-170, Y=	
11:24:37	2,896	97	sampling ?	
11:25:45	2,896	135	rock sampling	
11:31:45	2,896	94	rock sampling	
11:44:07	2,827	102	Outcrop covered with sediment	
11:45:19	2,820		X=-220, Y=-1170	
11:46:06	2,814	125	sediment	
11:48:17	2,803	155	Outcrop covered with sediment	
11:49:24	2,738	129	Stop to sample rock	
11:56:10	2,787	118	rock sampling	
11:59:12	2,785	103	Big rock sampling	
12:12:00	2,728	89	X=-330, Y=-1090	
12:17:00	2,683	87	X=-335, Y=-880, sediment	
12:20:34	2,663	57	Stop to sample rock	
12:27:11	2,659	57	rock sampling	
12:32:31	2,665	45	rock sampling	
12:34:24	2,655	56	rock sampling,X=-340, Y=-820	
12:46:50	2,592		X=-300, Y=-760	
12:51:00	2,584	75	Stop to sample rock	
12:54:41	2,581	40	rock sampling	
12:57:31	2,582	49	rock sampling(total 4 rocks)	
12:59:51	2,582		sampling finished	
13:06:14	2,538	67	cliff	
13:18:47	2,506	93	Try to take rock sample	
13:29:21	2,495	65	Sampling rock X=-1170, Y=-670	
13:31:34	2,489	76	start transit to East	
13:36:47	2,436		X=-490, Y=-580	
13:42:35	2,388		Outcrop covered with thin sediment X=-500, Y=-520	
13:44:45	2,378	35	Stop to take rock sample. Something life	
13:52:49	2,366	86	rock sampling	
13:55:21	2,363	88	rock sampling	
13:55:49	2,362	82	Sampling three rocks X=-490, Y=-480	
13:57:49	2,351	73	start transit toward East	
14:10:41	2,239		X=-450, Y=-290	
14:12:20	2,230	132	Stop to take rock sample	
14:25:56	2,187		rock sampling X=-500, Y=-260, Something life	
14:34:33	2,139		X=-460, Y=-140	
14:41:44	2,080		X=-470, Y=-40	
14:52:49	2,055		Sampling three rocks X=-470, Y=0	
15:03:34	1,972	98	Outcrop, Terrace?	
15:06:08	1,965	107	Try to rock sample, X=-430, Y=160, Something life	
15:30:59	1,889	123	X=-470, Y=230	
15:41:11	1,875	84	failure to sampling	
15:43:50	1,853		X=-450, Y=290	
15:46:26	1,850		Try to sample rock	
15:53:50	1,852	99	Sampling rock X=-440, Y=290	
16:01:05	1,803	82	X=-420, Y=390	
16:21:48	1,721		Sampling two rocks X=-320, Y=570	
16:22:51			Leave bottom	

Video Log for Dive#825 (Observer; Mark K. Reagan)

Local time	Depth(m)	Heading(deg.)	Note	Logger
10:32:43	1,680		decending	Trey & Kimura
10:33:55	1,802	18	dito.	
10:40:39	2,000	280	ditto.	
10:51:00	2,234	33	ditto.	
10:59:00	2,301	42	on bottom, mud flat, Flow= 10m, 200 deg, X=-960, Y=-560	
11:04:08	2,294	50	start running, muddy flat	
11:10:00	2,250	49	mud flat	
11:16:00	2,219	57	mud flat	
11:17:20	2,214	53	see anumal tracks	
11:20:00	2,194	51	X=-740, Y=-270	
11:25:00	2,182	295	Sampling @X=-700, Y=-230, rolling ston?e on mud flat	
11:37:00	2,168	46	mud flat	
11:41:00	2,144	46	X=-640, Y=-130	
11:44:56	2,103	48	X=-560, Y=-50, see mud flat	
11:50:00	2,061	47	see mud flat	
11:54:00	2,031	47	X=-410, Y=100, see sea cucumber	
12:05:31	1,983	90	Sampling @X=-270, Y=240, rolling ston?e on mud flat	
12:09:00	1,979	45	start running, muddy flat	
12:17:00	1,920	0	X=-120, Y=400, change course to 0°	
12:34:00	1,848	4	X=290, Y=450, still thick white deposit	
12:47:00	1,844	326	Sampling @X=320, Y=450, outcrop of breccia?	
12:56:00	1,846	73	sampling started	
13:20:00	1,833	0	Sampling finished(1 sample). Start moving.	
13:24:00	1,819	45	Sampling?	
13:28:10	1,819	5	Sampling	
13:49:30	1,815	158	black fish	
13:53:40	1,816	162	Sampling	
13:54:55	1,816	161	Big rock sampling	
14:11:21	1,815	14	Sampling 4 rocks	
14:16:11	1,812	354	x=320, y=520, Start moving	
14:25:21	1,796	125	stop, sampling	
14:33:42	1,795	93	big rock sampling	
14:40:02	1,780	166	Start running, X=360, Y=530	
15:15:51	1,751	74	sampling	
15:26:10	1,735	20	X=380, Y=580, start running, head north	
15:39:20	1,686	35	X=450, Y=590	
15:49:00	1,647	0	X=480, Y=610	
15:55:10	1,614	23	X=490, Y=600	
16:00:00	1,584	61	stop sub., start sampling	
16:10:00	1,585	107	sampling 1 samples	
16:13:00	1,562	60	X=560, Y=610	
16:15:00	1,579	101	sampling start	

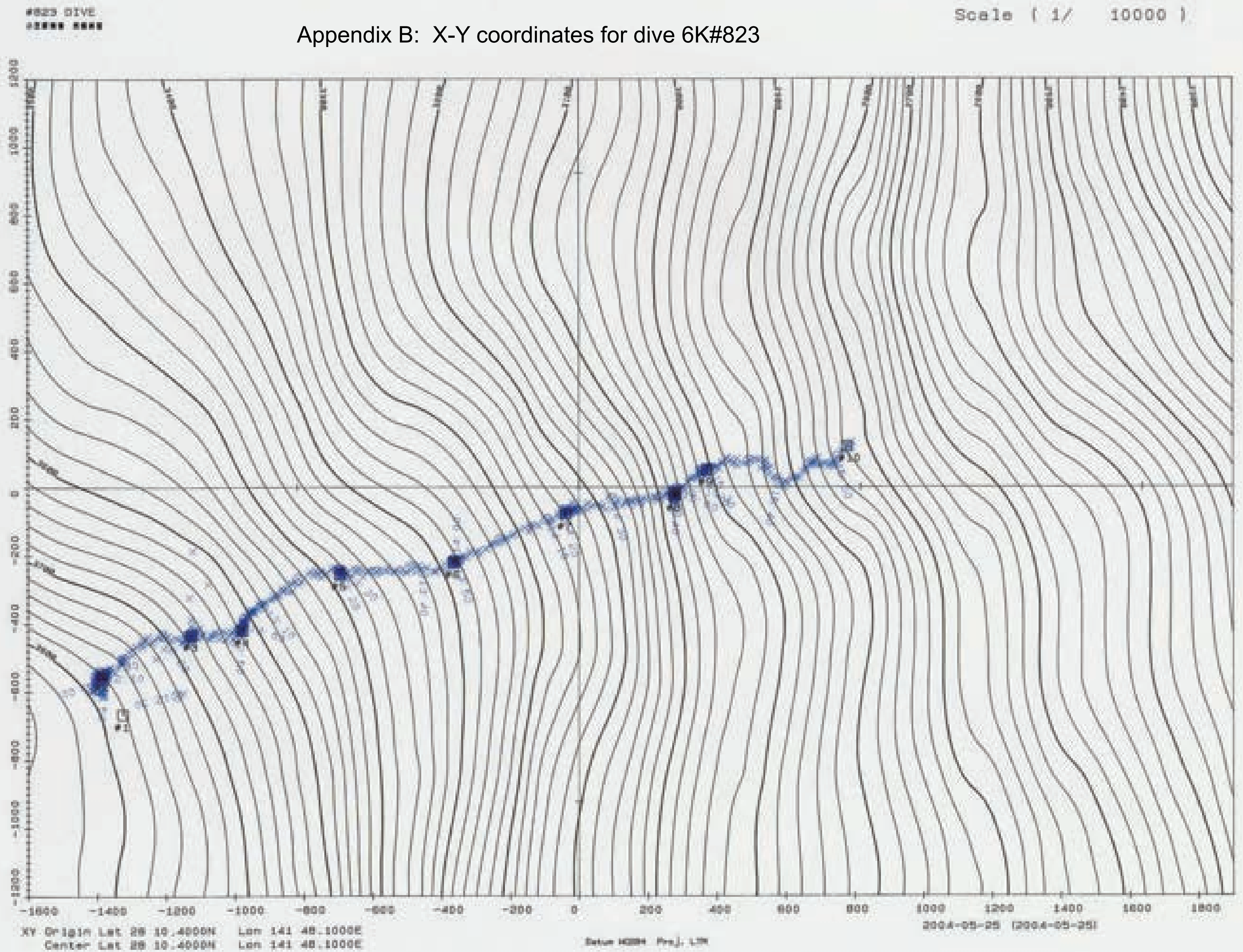
16:21:00	1,579	118	sampling 3 samples
16:23:00	1,579	115	off bottom

Video Log for Dive#826 (Observer; Yasu Ohara)

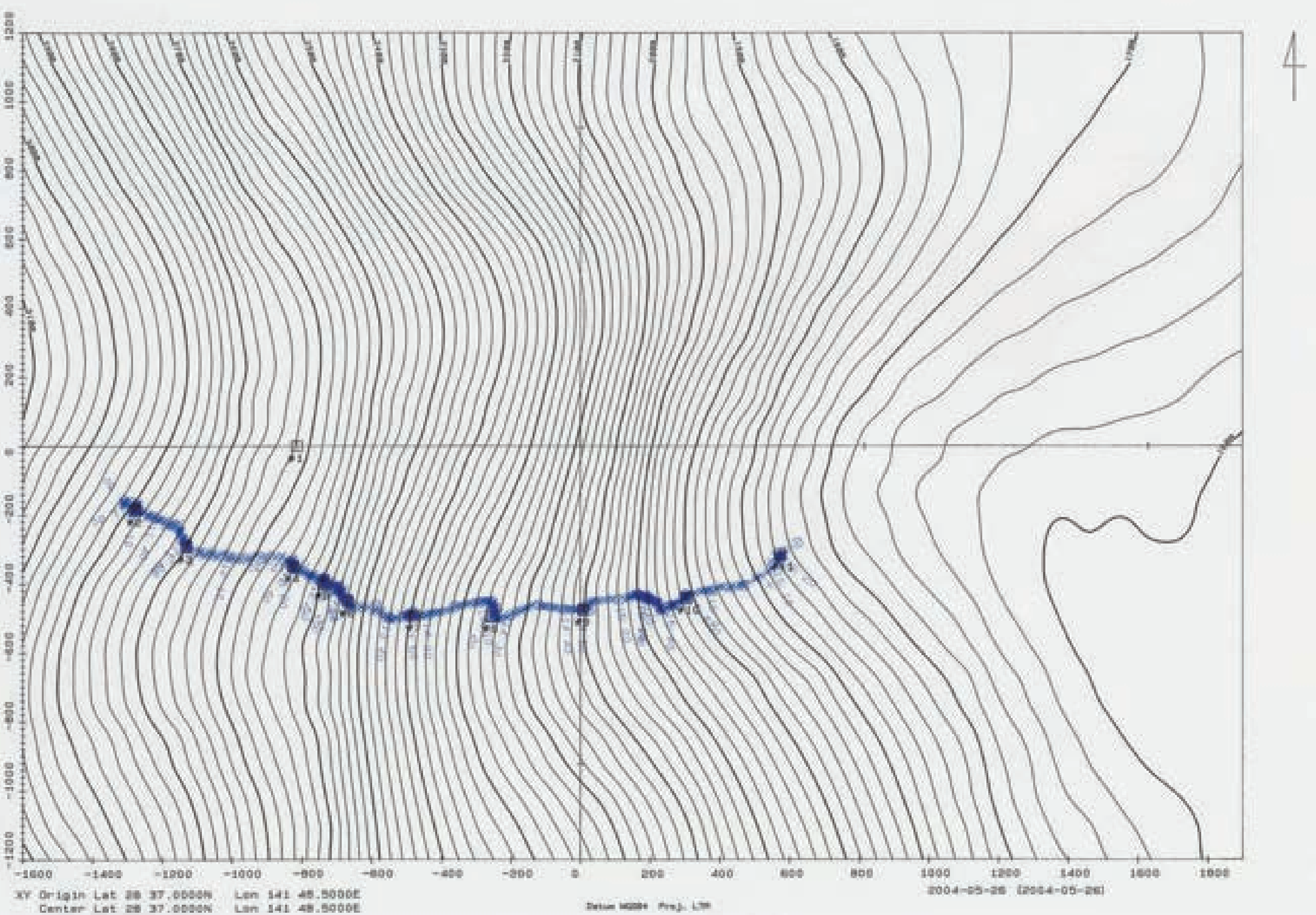
Local time	Depth(m)	Heading(deg.)	Note	Remark
10:33:31			X=530, Y=-1730	
10:42:00			X=520, Y=-1730	
10:42:42	1,679	184	landing	
10:50:46	1,758	14	see sea floor	
10:53:50	1,750	16	see ripple mark?	
10:54:43	1,750	16	mud flat, X=520, Y=-1740, sampling attempted	
11:18:39	1,749	21	see flactures	
11:25:23	1,746	32	sampling #1, #2	
11:36:07	1,674	23	X=580, Y=-1560	
11:43:05	1,632	101	running	
11:59:16	1,628	69	hummocky surface outcrop, sampling attempted	
12:04:00	1,628		sampling finished.	
12:14:00	1,602	43	X=470, Y=-1260	
12:24:00	1,568	107	X=490, Y=-1200	
12:34:00	1,650	328	X=490, Y=-1330	
12:41:00	1,643	282	X=580, Y=-1440	
12:57:00	1,623	92	X=440, Y=-1320	
13:13:10	1,516	74	Push core sampling	
13:17:30	1,517	69	sampling	
13:22:40	1,515	102	Fish	
13:48:45	1,425	111	2 rocks sampling	
13:50:15	1,418	109	sampling finished, moving from X=310, Y=-820	
14:08:50	1,316	75	sampling	
14:11:00	1,316	53	X=340, -Y=640	
14:19:00	1,258	143	some rocks were observed	
14:21:10	1,252	146	pebble floor	
14:22:50	1,240	92	sampling 2 rocks	
14:23:00	1,237	92	X=340, Y=-480	
14:24:10	1,233	95	mud floor	
14:25:21	1,189	117	fish	
14:28:21	1,184	113	rock escarpment	
14:31:11	1,173	117	mud floor	
14:33:11	1,141	116	X=220, Y=-240	
14:35:21	1,132	117	rock escarpment	
14:37:11	1,129	84	massive rock covered with thin sediment	
14:38:11	1,128	115	sampling start	
14:40:15	1,126	98	samplng 1 samples	
14:41:15	1,125	98	X=190, Y=-290	
14:48:45	1,114	91	mud with some rocks	
14:49:55	1,099	91	rock escarpment	

14:50:35	1,092	91	mud surface
14:53:51	1,072	91	rock escarpment
14:54:11	1,068	91	mud surface
14:56:15	1,037	90	rock escarpment
14:57:15	1,024	90	X=140, Y=160
15:01:00	1,000	90	rock escarpment
15:04:11	1,000	2	sampling start
15:08:00	1,000	19	sampling 3 samples
15:08:30	1,000	19	X=120, Y=250
15:11:06	963	90	goothfish
15:13:50	939	91	rock escarpment
15:19:40	917	62	sampling start
15:29:00	906	43	sampling 2 samples
15:30:20	904	92	X=110, Y=480
15:32:20	882	92	rock escarpment
15:42:45	802	86	rock escarpment
15:52:59	758		sampling start X=-69, Y=1002
15:59:00	758	102	sampling 2 samples, X=-80, Y=1000
16:00:00	744	93	sand floor, current marks
16:00:50	735	79	rock escarpment
16:16:10	705		sampling 2 rocks
16:17:20	705		off bottom

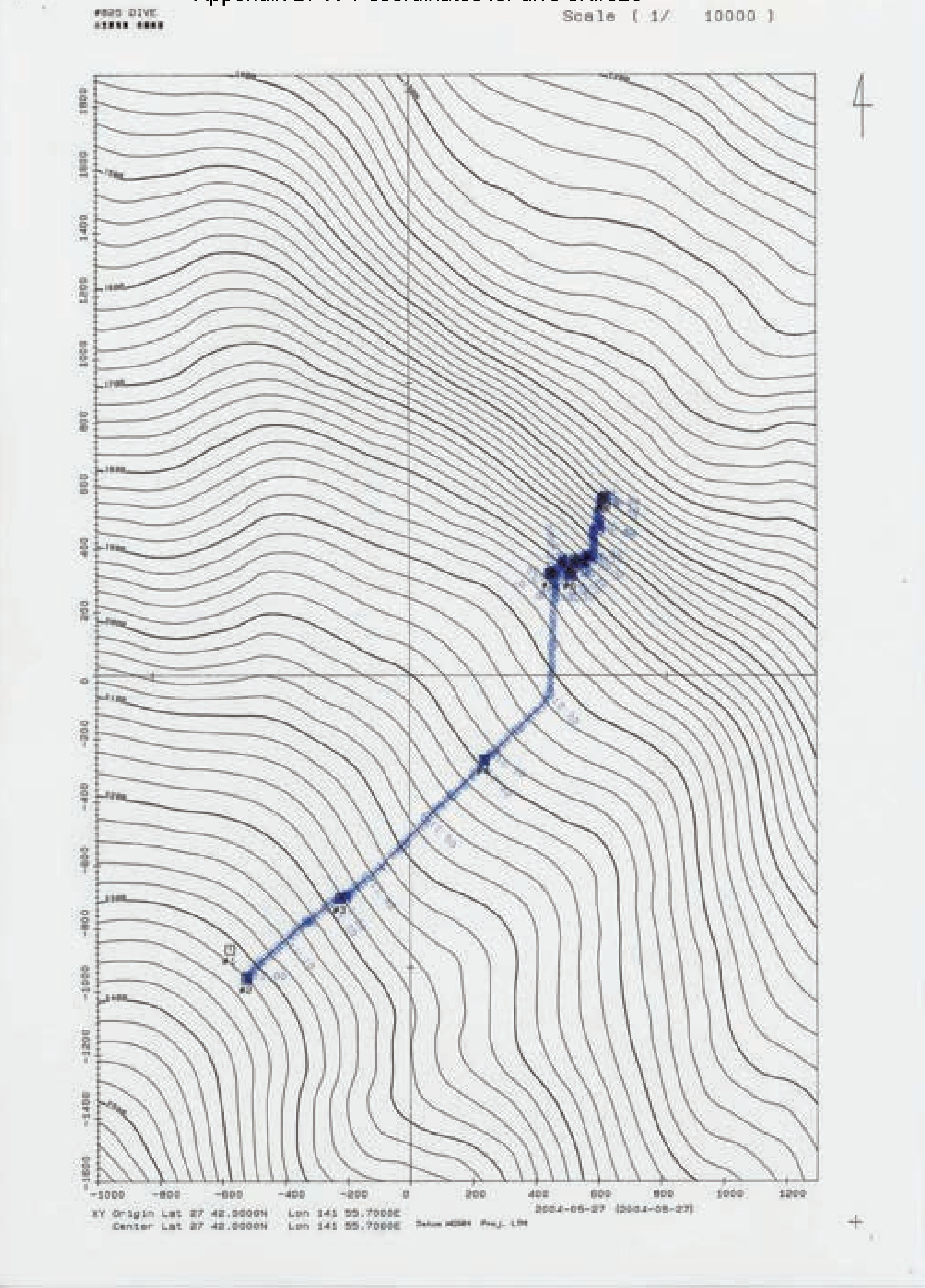
Appendix B: X-Y coordinates for dive 6K#823



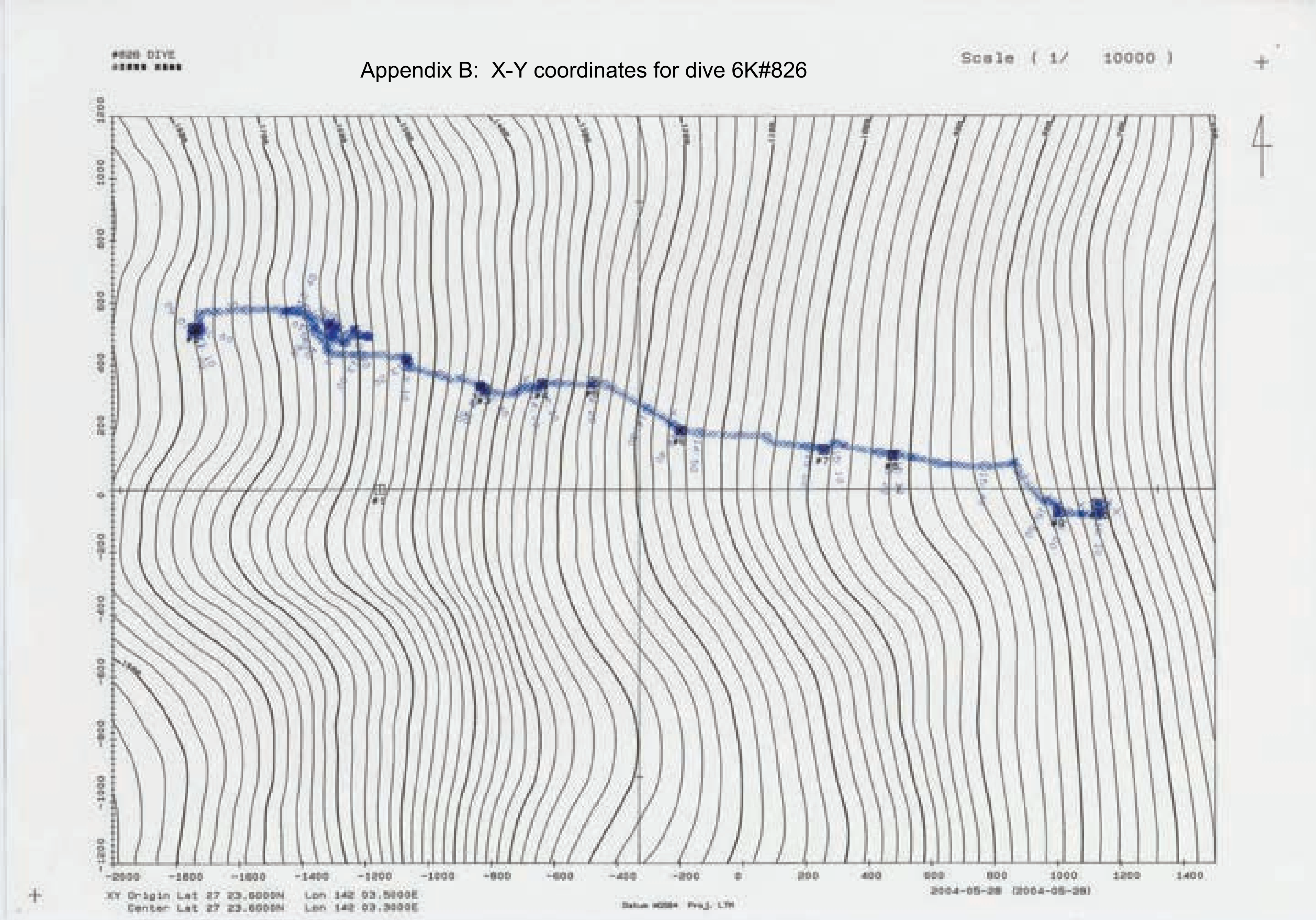
Appendix B: X-Y coordinates for dive 6K#824



Appendix B: X-Y coordinates for dive 6K#825



Appendix B: X-Y coordinates for dive 6K#826



APPENDIX C: Preliminary Sample Descriptions

CRUISE & LEG NO.	STATION NO.	LOCALLITY	DAY	MONTH	YEAR			NO.
YK04-05	# 823		25	5	2004			1

APPENDIX C: Sample Descriptions

Sample No	Size of rock sample a (cm)	b (cm)	c (cm)	Weight (kg)	Round-ness	Mn- (mm)	Phenocryst (%, mm) ol	px	pl	hb	others	Comment Described by Ishizuka, Hargrove
1	18	12	4	0.9	sub rnd.	1						volcaniclastic sandstone with acidic ash layer(?)
2	25	16	17	9	well rnd.	2		5,2	8,10			conglomeratic breccia w/ clasts of cognate lava & crystal frags., incl. 1 large clast of andesite/dacite
3	13	11	7	0.8	well rnd.	3						sandstone, coarse-grained, very poorly sorted, rounded to sub ang., moderate sphericity
4	9	6	5	0.15	sub ang.	<1						conglomeratic breccia w/ clasts subang., very low sphericity, mostly lithic frags., & muddy matrix
5	10	7	5	0.4	sub rnd.	8						conglomeratic breccia w/ clasts subang., very low sphericity, mostly lithic frags., & muddy matrix
6	12	9	7	0.65	sub rnd.	1						conglomeratic breccia w/ clasts subang., very low sphericity, mostly lithic frags., & muddy matrix
7	20	14	9	3.6	well rnd.	2						conglomerate, clasts rounded to subangular, low to moderate sphericity, muddy matrix, 1 large clasts of plag-cpx-phyric andesit
8	20	16	12	5.6	well rnd.	14	<1,<1	7,2	5<1			fragmented ol-plag-cpx-phyric basalt within conglomerate w/ thick Mn crust,
9	28	20	12	7.4	sub rnd.	2						polymict breccia w/ angular clasts including laminated sandstone, lithics, & crystal frags.
10	13	11	9	4.5	rnd.	2						polymict sandstone, coarse-grained poorly sorted sandstone 1 long mudstone lens
11	21	18	8	2	ang.	1						polymict sandstone, medium-grained, very poorly sortedangular to subangular, low sphericity
12	16	11	9	1.5	sub ang.	90						laminated Mn deposit
13	20	17	8	2.8	sub ang.	1						mudstone,poorly consolidated, very poorly sorted withmedium-grained clasts of Mn & crystal frags.
14	22	16	10	2.8	sub ang.	100						laminated Mn deposit
15	21	15	14	4.1	sub ang.	33		3,<2	7,<2			volcaniclastic breccia, very poorly sorted, w/ clasts of heavily altered pyx-plag-phyric andesite & sandstone in an ashy matrix
16	24	16	12	4.5	sub rnd.	22						volcaniclastic breccia, very poorly sorted, w/ clasts of heavily altered pyx-plag-phyric andesite & sandstone in an ashy matrix
17	21	13	11	3.5	sub rnd.	25						volcaniclastic breccia, very poorly sorted, w/ clasts of heavily altered pyx-plag-phyric andesite & sandstone in an ashy matrix

Appendix C: continued, Dive 824

CRUISE & LEG NO.	STATION NO.	LOCALLITY	DAY	MONTH	YEAR
YK04-05	# 824		26	5	2004

Location	Sample No	Size of rock sample a (cm)	b (cm)	c (cm)	Weight (k g)	Round-ness	Mn- (mm)	Phenocryst (%, mm) ol	px	pl	hb	others	Comment Described by Ishizuka, Kimura
1	1	27	25	14	6.4	sub rnd.	16						siltstone/sandstone, light brown
1	2	14	9	3	0.4	angular	19						siltstone/sandstone, light brown
2	3	17	12	4	1.1	sub ang.	4						siltstone/sandstone, light brown
2	4	30	22	19	12.2	sub rnd.	7						siltstone/sandstone, light brown
3	5	12	10	4	0.7	sub ang.	<1						pumice, grey, altered
3	6	14	11	4	0.7	sub ang.	7						scoria with clay matrix
3	7	22	16	10	1.9	sub rnd.	4						sandstone
4	8	20	16	12	3.6	sub rnd.	23		cpx?		?		altered dacite/andesite breccia clasts surrounded by Mn clasts in clay matrix
4	9	19	11	11	2.4	sub rnd.	6		cpx?	7,2			dark gray andesite with palagonite rim (2 mm)
4	10	15	10	8	1.6	sub rnd.	4		v				dark gray andesite breccia with palagonite rim, various types of breccia
4	11	33	0.31	15	16.3	sub ang.	15		3,3	8,3			(a) gray andesite, weakly altered, vesicles 15-20%, fresh phenocrysts; (b) breccia, dark andesite compact & vesiculated, 2-3 mm palagonite
5	12	34	18	14	6.4	angular	5		3,2	10,2			breccia, dark gray andesite with palagonite rim (1-2 mm), clay matrix
6	13	22	14	14	4.3	sub ang.	23		5,2	9,2			dark gray andesite breccia with light brown clay matrix
6	14	30	9	9	4.4	angular	2		5,2	9,2			dark gray andesite with palagonite rim (3 mm)
6	15	32	14	11	4.2	angular	2		5,2	9,2			dark gray andesite with palagonite rim (3 mm), some cpx altered
7	16	30	15	12	4.3	angular	8						sandstone, including light gray breccia
8	17	36	20	13	6.2	angular	6.2						Mn clast
8	18	26	13	9	2.2	sub rnd.	<1						white pumice, highly vesiculated
8	19	21	13	5	1.7	sub ang.	60						Mn clast 60 mm
9	20	33	17	9	6	sub ang.	7						volcanic breccia (lapillistone), pumice 70%, andesite 30%
10	21	7	5	4	0.1	angular							Mn nodule - lost
10	22	14	11	9	1.2	rounded	40						Mn nodule

Appendix C continued: Dive 825

CRUISE & LEG NO.	STATION NO.	LOCALLITY	DAY	MONTH	YEAR
YK04-05	# 825		27	5	2004

Sample No	Size of rock sample a (cm)	b (cm)	c (cm)	Weight (kg)	Round-ness	Mn- (mm)	Phenocryst (%, mm) ol	px	pl	hb	others	Comment Described by Ishizuka, Kimura
1	22	18	12	4.5	sub ang.	0			2,10			scoria, vesicles (floated?)
2	25	18	15	3.6	rounded	0						pumice, vesicles (floated?)
3	18	14	10	3	sub ang.	1		5,1.5	5,1.5			andesite breccia
4	20	11	8	1.9	angular	1						breccia, dacite/andesite breccias, altered, clast supported
5	23	27	17	12	angular	<1		6,10	7,5			dark grey andesite clast attached with matrix
6	20	11	10	2.9	sub ang.	<1		2	5,1			large andesite lava clast in breccia, slightly altered
7	9	9	5	0.5	sub ang.	1		6,10	7,5			andesite lava clast, subrounded, same as #5
8	20	16	5	2	angular	<1						breccia
9	14	6	4	0.4	angular	<1						breccia
10	20	14	12	4.2	sub ang.	<1		5,3	5,2			breccia, extensively altered + rounded dark grey andesite
11	13	10	4	0.55	angular							breccia
12	24	10	10	2.5	sub ang.	<1		5,3	5,2			andesite lava clast, altered
13	18	12	10	2.5	angular	<1						breccia, extensively altered + rounded dark grey andesite
14	25	23	12	8.5	sub ang.	<1						breccia, extensively altered (no matrix hyaloclastite)
15	30	18	15	8.8	sub ang.	1						breccia, extensively altered (no matrix hyaloclastite)

Appendix C continued: Dive 826

CRUISE & LEG NO.	STATION NO.	LOCALLITY	DAY	MONTH	YEAR
YK04-05	# 826		28	5	2004

Sample No	Size of rock sample a (cm)	b (cm)	c (cm)	Weight (kg)	Round-ness	Mn- (mm)	Phenocryst (%, mm) ol	px	pl	hb	others	Comment Described by Ishizuka, Kimura
1	20	14	14	3.5	angular	<1						calcareous mudstone
2	13	8	7	1.1	angular	<1						calcareous mudstone, foraminifera?, non-volcanic
3	12	9	6	0.6	angular	<1						calcareous a\sandstone, non-volcanic
4	16	12	10	2	subang.	<1						altered plag-cpx-phyric andesite with veins
5	27	19	13	5.4	subang.	<1						indurated volcaniclastic breccia, with boninitic aphyric lava breccias
6	8	7	1	0.2	rounded	none						calcareous mud, soft
7	18	12	14	6.3	angular	<1	1,1	12,2	1,1			dark grey andesitic lava, plag poor
8	15	13	12	3.7	subang.	<1		7,<8	4,<2			gray-brown andesitic lava
9	25	23	8	2.8	subrnd.	none						calcareous mud (lightly indurated)
10	19	17	10	8.1	subang.	<1						calcareous sandstone (muddy)
11	29	18	8	4.1	subang.	<1						calcareous sandstone (muddy)
12	17	11	3	0.4	angular	<1						limestone (fossils pebble sized - Nummerites)
13	26	13	13	3.8	subrnd.	<1						limestone (fossils pebble sized - Nummerites)
14	15	12	11	1.5	subang.	<1						limestone (fossils pebble sized - Nummerites)
15	19	17	8	3.1	subrnd.	<1						calcareous sandstone (coarse)
16	15	14	8	1.2	angular	<1						limestone (fossils)
17	24	22	9	4.8	angular	<1						limestone (fossils)
18	21	12	8	1.7	angular	<1						calcareous sandstone
19	33	1	11	7	subang.	<1						calcareous sandstone
20	40	28	16	17.3	angular	<1						limestone
21	24	20	11	4.9	rounded	<1						brown-gray altered andesite lava, same as #4
C-01												push core (white)

Appendix D: List of samples distributed for on-board and shore-based samples (as of May 31, 2004)

TS indicates a standard thin section size slab
TS (lg) indicates a large size thin section slab
slab indicates a piece for analytical work at least 100 g in weight
fractions indicate a proportion of the sample was distributed
Mn indicates a sample of thick Mn slab or nodule
TsMn indicates a thin section slab including Mn rind

Dive 823	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15	R16	R17
Dr. Yasuhiko Ohara																	
Dr. Sherman Bloomer		TS	TS	TS (lg)			TS (lg)	TS	TS (lg)						TS (lg)*	TS (lg)	TS
Dr. Teruaki Ishii		slab	slab			slab	slab	slab	slab	slab					slab	slab	slab
Dr. Jun-Ichi Kimura		slab					slab	slab							slab	slab	slab
Dr. Osamu Ishizuka		slab					slab+	slab							slab	slab	slab
Dr. Robert Stern														Mn[1]			
Dr. Mark Reagan		slab					slab	slab	TS					Mn[1]			
Dr. Katherine Kelley		slab					slab	slab	TS					Mn[1]			
Mr. Ulysses Hargrove III																	

* with carbonate
[1] - thick Mn slab

Dive 824	R5	R8	R9	R10	R11A	R11B	R12	R13	R14	R15	R16	R17	R18	R19	R20	R22
Dr. Yasuhiko Ohara																
Dr. Sherman Bloomer			TsMn	vith Mn	vith Mn rind			TS with Mn rind		TS with Mn rind						
Dr. Teruaki Ishii	slab	slab	slab	slab	slab	slab	slab	slab	slab	slab			slab		slab	
Dr. Jun-Ichi Kimura	slab	slab	slab	slab	slab		slab	slab	slab	slab			slab		slab	
Dr. Osamu Ishizuka		slab	slab	slab	slab		slab	slab	slab	slab			slab		slab	
Dr. Robert Stern							TS(lg)							TS(lg)	TS(lg)	1/8
Dr. Mark Reagan	TS	TS	slab	slab	slab		TS	vith Mn	slab	slab		Mn[1]	TS	Mn[1]	TS	1/4
Dr. Katherine Kelley			slab		slab				slab						slab	
Mr. Ulysses Hargrove III		TS(lg)			TS(lg)		TS(lg)				TS(lg)					1/8

[1] - thick Mn slab

Dive 825	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	R12	R13	R14	R15
Dr. Yasuhiko Ohara															
Dr. Sherman Bloomer				TS (lg)	TS				TS	TS	TS	TS		TS	TS
Dr. Teruaki Ishii	slab	slab	slab	slab	slab	slab	slab	slab	slab	slab	slab	slab	slab	slab	slab
Dr. Jun-Ichi Kimura	slab	slab	slab		slab	slab	slab	slab		slab		slab	slab		
Dr. Osamu Ishizuka			slab		slab	slab	slab	slab		slab		slab	slab		
Dr. Robert Stern					TS (lg)										TS (lg)
Dr. Mark Reagan			slab	TS	slab	slab	slab	TS	TS	TS	TS	slab	TS		TS
Dr. Katherine Kelley			slab		slab	slab						slab			
Mr. Ulysses Hargrove III		TS(lg)													

Dive 826	R3	R4	R5	R7	R8	R11	R13	R15	R16	R20	R21
Dr. Yasuhiko Ohara											
Dr. Sherman Bloomer		TS (lg)	TS (lg)	TS			TS (lg)	TS (lg)	TS (lg)	TS (lg)	TS (lg)
Dr. Teruaki Ishii		slab	slab	slab	slab						slab
Dr. Jun-Ichi Kimura		slab	slab	slab	slab						slab
Dr. Osamu Ishizuka		slab	slab	slab	slab			TS			slab
Dr. Robert Stern			TS (lg)	TS (lg)	TS (lg)			TS (lg)			
Dr. Mark Reagan	TS	TS	TS	slab	slab	TS					slab
Dr. Katherine Kelley											
Mr. Ulysses Hargrove III								TS (lg)			

Note that Ohara, Haraguchi, Li, and Machida will work with samples allocated to Ishii, as appropriate
Wortel will work with samples allocated to Reagan as appropriate

YK04-05 6K Dive 823:

YK04-05 6K#823-all samples

YK04-05 6K#823-R1

YK04-05 6K#823-R2

YK04-05 6K#823-R3

YK04-05 6K#823-R4

YK04-05 6K#823-R5

YK04-05 6K#823-R6

YK04-05 6K#823-R7

Appendix E (Dive 823 continued)

YK04-05 6K#823-R8

YK04-05 6K#823-R9

YK04-05 6K#823-R10

YK04-05 6K#823-R11

YK04-05 6K#823-R12

YK04-05 6K#823-R13

Appendix E (Dive 823 continued)


YK04-05 6K#823-R14


YK04-05 6K#823-R15


YK04-05 6K#823-R16


YK04-05 6K#823-R17

YK04-05 6K Dive 824:


YK04-05 6K#824-Tray 1


YK04-05 6K#824-Tray 2


YK04-05 6K#824-Tray 3


YK04-05 6K#824-Tray 4

Appendix E (Dive 824 continued)

YK04-05 6K#824-R1

YK04-05 6K#824-R2

YK04-05 6K#824-R3

YK04-05 6K#824-R4

YK04-05 6K#824-R5

YK04-05 6K#824-R6

YK04-05 6K#824-R7

YK04-05 6K#824-R8

Appendix E (Dive 824 continued)

YK04-05 6K#824-R9

YK04-05 6K#824-R10

YK04-05 6K#824-R11A

YK04-05 6K#824-R11B

YK04-05 6K#824-R12

YK04-05 6K#824-R13

YK04-05 6K#824-R14

YK04-05 6K#824-R15

Appendix E (Dive 824 continued)

YK04-05 6K#824-R16

YK04-05 6K#824-R17

YK04-05 6K#824-R18

YK04-05 6K#824-R19

YK04-05 6K#824-R20

YK04-05 6K#824-R22

Note that sample YK04-05 6K#824-R21 was lost

YK04-05 Dive 825


YK04-05 6K#825-Tray 1


YK04-05 6K#825-Tray 2


YK04-05 6K#825-Tray 3

YK04-05 6K#825-R1

YK04-05 6K#825-R2

YK04-05 6K#825-R3

YK04-05 6K#825-R4


YK04-05 6K#825-R5

YK04-05 6K#825-R6

Appendix E (Dive 825 continued)

YK04-05 6K#825-R7

YK04-05 6K#825-R8

YK04-05 6K#825-R9

YK04-05 6K#825-R10

YK04-05 6K#825-R11

YK04-05 6K#825-R12

YK04-05 6K#825-R13

YK04-05 6K#825-R14

Appendix E (Dive 825 continued)


YK04-05 6K#825-R15

YK04-05 Dive 826


YK04-05 6K#826-Tray 1


YK04-05 6K#826-Tray 2


YK04-05 6K#826-Tray 3

YK04-05 6K#826-R1

YK04-05 6K#826-R2

YK04-05 6K#826-R3

Appendix E (Dive 826 continued)

YK04-05 6K#826-R4

YK04-05 6K#826-R5

YK04-05 6K#826-R6

YK04-05 6K#826-R7

YK04-05 6K#826-R8

YK04-05 6K#826-R9

Appendix E (Dive 826 Continued)

YK04-05 6K#826-R10

YK04-05 6K#826-R11

YK04-05 6K#826-R12

YK04-05 6K#826-R13

YK04-05 6K#826-R14

YK04-05 6K#826-R15

Appendix E (Dive 826 Continued)

YK04-05 6K#826-R16

YK04-05 6K#826-R17

YK04-05 6K#826-R18

YK04-05 6K#826-R19

YK04-05 6K#826-R20

YK04-05 6K#826-R21

YK04-05 6K#826-C1