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# Cruise Report

# R/V Kairei KR16-05

# Acquisition of deep seismic, shallow sub-surface and seafloor bathymetry Survey Data for the Lord Howe Rise (MCS, OBS)

Mar. 23, 2016 – May 11, 2016


Japan Agency for Marine-Earth Science and Technology

Geoscience Australia

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# 1. Preface

## (1) List of onboard scientists, technicians, and crew

### (i) Shipboard Science Party

Leg 1

Dr. Shuichi Kodaira
R&D Center for Earthquake and Tsunami (CEAT)
Japan Agency for Marine–Earth Science and Technology (JAMSTEC)

Ms. Akane Ohira
R&D Center for Earthquake and Tsunami (CEAT)
Japan Agency for Marine–Earth Science and Technology (JAMSTEC)

Mr. George Bernardel
Geoscience Australia

Dr. Andrew Carroll
Geoscience Australia

Leg 2

Dr. Gou Fujie
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Japan Agency for Marine–Earth Science and Technology (JAMSTEC)

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Japan Agency for Marine–Earth Science and Technology (JAMSTEC)

Dr. Saneatsu Saito

R&D Center for Ocean Drilling Science (ODS)
Japan Agency for Marine–Earth Science and Technology (JAMSTEC)

Dr. Ron Hackney
Geoscience Australia

Dr. Andrew Carroll
Geoscience Australia

Dr. Simon Williams
University of Sydney

Mr. Bailey Payten
University of Sydney

Leg 3

Dr. Yuka Kaiho
R&D Center for Earthquake and Tsunami (CEAT)
Japan Agency for Marine–Earth Science and Technology (JAMSTEC)

Mr. Taro Shirai
R&D Center for Earthquake and Tsunami (CEAT)
Japan Agency for Marine-Earth Science and Technology (JAMSTEC)

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Dr. Scott Nichol
Geoscience Australia

Mr. George Bernardel
Geoscience Australia

Mr. Aki Nakamura

Geoscience Australia

Dr. Wanda Stratford
GNS Science

KR16-05 On Shore Personnel

Yoshihisa Kawamura
Japan Agency for Marine–Earth Science and Technology (JAMSTEC)

Seiichi Miura
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Japan Agency for Marine–Earth Science and Technology (JAMSTEC)

Yasuhiro Yamada
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John Pugh
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Andrew Heap
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Jessica Gurney
Geoscience Australia

Ian Hawkshaw
RPS Energy Australia Asia Pacific

Chris Pierpoint,
RPS Energy Australia Asia Pacific

Stuart Henrys
GNS Science

(ii) Marine Fauna Observer List

Leg 2 and Leg 3

| | | |
|---|---|---|
| Timothy P. Lewis | RPS Energy Pty. Ltd. | PAM Operator |
| Patrick Lyne | RPS Energy Pty. Ltd. | PAM Operator |
| Scott Sheehan | RPS Energy Pty. Ltd. | Marine fauna observer |
| Rebecca Lindsay | RPS Australia Asia Pacific | Marine fauna observer |

(iii) Marine Technician List

Leg 1

| | |
|---|---|
| Kaoru Tsukuda | Nippon Marine Enterprises, Ltd. |
| Ikumasa Terada | Nippon Marine Enterprises, Ltd. |
| Toshinori Saijyo | Nippon Marine Enterprises, Ltd. |
| Seiichi Mori | Nippon Marine Enterprises, Ltd. |
| Keita Suzuki | Nippon Marine Enterprises, Ltd. |
| Takuya Maekawa | Nippon Marine Enterprises, Ltd. |
| Naoto Noguchi | Nippon Marine Enterprises, Ltd. |
| Ryo Miura | Nippon Marine Enterprises, Ltd. |

Leg 2

| | |
|---|---|
| Kaoru Tsukuda | Nippon Marine Enterprises, Ltd. |
| Ikumasa Terada | Nippon Marine Enterprises, Ltd. |
| Toshinori Saijyo | Nippon Marine Enterprises, Ltd. |
| Seiichi Mori | Nippon Marine Enterprises, Ltd. |
| Keita Suzuki | Nippon Marine Enterprises, Ltd. |
| Takuya Maekawa | Nippon Marine Enterprises, Ltd. |
| Naoto Noguchi | Nippon Marine Enterprises, Ltd. |
| Ryo Miura | Nippon Marine Enterprises, Ltd. |
| Kyoko Tanaka | Nippon Marine Enterprises, Ltd. |
| Hikaru Iwamaru | Nippon Marine Enterprises, Ltd. |
| Hidenori Shibata | Nippon Marine Enterprises, Ltd. |

Leg 3

| | |
|---|---|
| Yuki Ohwatari | Nippon Marine Enterprises, Ltd. |
| Ikumasa Terada | Nippon Marine Enterprises, Ltd. |
| Toshinori Saijyo | Nippon Marine Enterprises, Ltd. |
| Seiichi Mori | Nippon Marine Enterprises, Ltd. |
| Keita Suzuki | Nippon Marine Enterprises, Ltd. |
| Kaoru Tsukuda | Nippon Marine Enterprises, Ltd. |
| Hikaru Iwamaru | Nippon Marine Enterprises, Ltd. |
| Yuta Watarai | Nippon Marine Enterprises, Ltd. |
| Akie Suzuki | Nippon Marine Enterprises, Ltd. |
| Kaoru Takizawa | Nippon Marine Enterprises, Ltd. |
| Kimiko Serizawa | Nippon Marine Enterprises, Ltd. |

(iv) R/V Kairei Crew List

| | Leg 1 | Leg 2 | Leg 3 | Transit |
|---|---|---|---|---|
| Captain | Shinya Ryono | | | |
| Chief Officer | Hiroyuki Kato | | | |
| 2nd Officer | Yomoyuki Takahashi | | | |
| 3rd Officer | Yoshihiro Ogawa | | | |
| Junior 3rd Officer | * | Keiji Itabashi | | * |
| Chief Engineer | Tadashi Abe | | | Eiji Sakaguchi |
| 1st Engineer | Shinichi Ikuta | | | |
| 2nd Engineer | Takaatsu Inomoto | | | |
| 3rd Engineer | Katsuto Yamaguchi | | Yoichi Yasue | |
| Chief Electronics Operator | Takehito Hattori | | | |
| 2nd Electronics Operator | Shunsuke Fukagawa | | | |
| 3rd Electronics Operator | Takayuki Mabara | | | * |
| Boatswain | Tadahiko Toguchi | | | |
| Quarter Master | Kazumi Ogasawara | | | |
| Quarter Master | Yukito Ishii | | | |
| Quarter Master | Naoki Iwasaki | | | |
| Sailor | Yuta Motooka | | | |
| Sailor | Yusaku Kanada | | Jun Shinoda | |
| Sailor | Kohei Sato | | | |
| No.1 Oiler | Kozo Miura | | | |
| Oiler | Masanori Ueda | | | |
| Oiler | Keiya Taniguchi | | Masaki Tanaka | |
| Oiler | Toshinori Matsui | | | |
| Assistant Oiler | Motohiro Kawano | | | |
| Chief Steward | Toyonori Shiraishi | | | |
| Steward | Tatsunari Onoue | | | * |
| Steward | Toru Murakami | Tuyoshi Nagatomo | | |
| Steward | Koichiro Kashiwagi | | | |
| Steward | Mao Kikuchi | | | |

## (2) Cruise proponents

Name of lead proponent: Shuichi Kodaira

Research team of cruise

| Name | Institution | Note |
|---|---|---|
| Shuichi Kodaira | CEAT/JAMSTEC | Principal Investigator Leg 1 |
| Seiichi Miura | CEAT/JAMSTEC | Cruise Planning |
| Yasuyuki Nakamura | CEAT/JAMSTEC | |
| Gou Fujie | CEAT/JAMSTEC | Leg 2 |
| Yuka Kaiho | CEAT/JAMSTEC | Leg 3 |
| Tetsuo No | CEAT/JAMSTEC | |
| Mikiya Yamashita | CEAT/JAMSTEC | |
| Taro Shirai | CEAT/JAMSTEC | Leg 2 and Leg 3 |
| Ryuta Arai | CEAT/JAMSTEC | |
| Ayako Nakanishi | CEAT/JAMSTEC | |
| Koichiro Obana | CEAT/JAMSTEC | |
| Tsutomu Takahashi | CEAT/JAMSTEC | |
| Yojiro Yamamoto | CEAT/JAMSTEC | |
| Yasuhiro Yamada | ODS/JAMSTEC | |
| Saneatsu Saito | ODS/JAMSTEC | Leg 2 |
| Kazuya Shiraishi | ODS/JAMSTEC | Leg 3 |
| Jun-ichiro Kuroda | ODS/JAMSTEC | |
| Yoshihiko Tamura | ODS/JAMSTEC | |
| Yoshi Kawamura | JAMSTEC | Project coordinator |
| Akane Ohira | CEAT/JAMSTEC | Leg 1 |
| Ron Hackney | Geoscience Australia | Leg 2 |
| Scott Nichol | Geoscience Australia | Leg 3 |
| George Bernardel | Geoscience Australia | Leg 1, Leg 3 |
| Andrew Carroll | Geoscience Australia | Leg 1, Leg 2 |
| Aki Nakamura | Geoscience Australia | Leg 3 |
| Simon Williams | University of Sydney | Leg 2 |
| Bailey Payten | University of Sydney | Leg 2 |
| Wanda Stratford | GNS Science | Leg 3 |

# Acknowledgments

We greatly appreciate Captain Shinya Ryono, all the officers and crew, Chief Technicians Messrs Kaoru Tsukuda, Yuki Owatari, all the technicians, PAM Operators Messrs. Timothy P. Lewis and Patrick Lyne, and Marine Fauna Observers Ms. Rebecca Lindsay and Mr Scott Sheehan for their skillful support.

We would like to thank all individuals in the administration.

## 2. Executive Summary

This survey was designed to collect Survey Data to support a site assessment at locations being considered for deep stratigraphic drilling on the Lord Howe Rise, offshore eastern Australia. Drilling will be conducted as part of the International Ocean Discovery Program (IODP) Proposal 871-CPP titled "First Deep Stratigraphic Record for the Cretaceous Eastern Gondwana Margin: Tectonics, paleoclimate and deep life on the Lord Howe Rise high-latitude continental ribbon."

To reveal large-scale structural features and to elucidate the tectonic background in the Lord Howe Rise area, we conducted an active source seismic survey along a long, approximately 700-km, east–west survey line extending from the Tasman Sea to the Lord Howe Rise crossing the Dampier Ridge and Middleton Basin. Along this survey line, we deployed 100 Ocean Bottom Seismometers (OBSs) and shot the tuned airgun array of R/V Kairei to develop seismic velocity models of the whole crust and the topmost mantle. During the airgun shooting, we towed a 6-km-long hydrophone streamer cable to obtain the multi-channel seismic (MCS) reflection data to constrain the shallow seismic structure. We also obtained many 2D MCS survey data along short lines (about 20–30 km) to clarify details of the shallow sedimentary structure around proposed drill sites. In addition to the seismic data, we obtained other geophysical data such as gravity, magnetic, and bathymetric data using on board instruments of the R/V Kairei.

The cruise was divided into three Legs. Leg 1 was dedicated to the deployment of OBSs. One hundred OBSs were deployed at a spacing of 6 km along the EW line. Subsequently, the tuned airgun array was fired along the EW line at a spacing of 200 m at the beginning of the Leg2. Then, MCS data along many short lines around the proposed deep drill sites (D3A and part of D1B) were obtained. The airgun shot spacing this time was 50 m. In addition, Leg 2 was in charge of the recovery of the western half of OBSs. Leg 3 recovered the remaining OBSs and conducted an MCS survey around the proposed deep drill sites (part of D1B and D2A) and proposed shallow drill sites (BB1B, BV1B, BV2A). Finally, we shot airguns along the EW line with a spacing of 50 m.

# 3. Geological background

The LHR is part of Zealandia, the seventh largest but most submerged continent on Earth (Campbell et al., 2012). This vast, submerged continental ribbon is located eastward of Australia in water depths up to 3,000 m, extending approximately 1,600 km from southwest of New Caledonia to the Bellona Trough (Fig. 3-1). It is currently understood to have detached from eastern Gondwana by the Late Cretaceous and has been largely submerged since that time. The extensional history of the LHR continental ribbon caused submergence, with thinning and cooling of the continental crust. The LHR, the largest extant crustal ribbon, presents an opportunity to study the origin and development of a large, detached continental ribbon that is unaffected by deformation and is not deeply concealed by younger deposits.

The timing and setting of rifting to produce the LHR remain unclear. The eastern Gondwana margin preserved onshore in Australia records a pre-history of subduction-related magmatism, sedimentation, and tectonism during the Paleozoic to Early Triassic (Crawford et al., 2003). The Jurassic–Cretaceous history is, in contrast, dominated by large-volume intraplate and rift-related volcanism (Bryan et al., 1997; Bryan et al., 2012), particularly along the strike to the north of the LHR, where extensional faulting was active by at least 120 Ma (Och et al., 2009). Widespread extension along the eastern Gondwana margin could therefore have been initiated at approximately 130 Ma by emplacement of the Whitsunday Silicic Large Igneous Province in northeastern Australia and equivalents further south (Bryan et al., 1997; Bryan et al., 2012). Rifting in the east–west Otway/Gippsland basin system in southeast Australia, that trends into the LHR, had begun by the Late Jurassic, suggesting that at least the southern parts of the LHR might have a slightly earlier extensional imprint. Seismic interpretations of the sediment fill in LHR basins indicate rocks at least of Early Cretaceous age (Bache et al., 2014; Higgins et al., 2014), but presently there are no direct constraints on the age or provenance of the deep sediments or basement.

An opposing view comes from New Zealand, to the east of the LHR, where Jurassic through Cretaceous igneous rocks interpreted to be subduction-related are preserved (Stampfli et al., 2002). It is unclear whether subduction, if it was occurring off the eastern Gondwana margin, was Andean-style or intra-oceanic in the Early Cretaceous (Matthews et al., 2011). In the former case, the eastern LHR would have been more proximal to the active margin, although in the latter it would have been a passive margin and potentially facing a back-arc basin. In this scenario, rifting would have evolved rapidly after a major plate reorganization that occurred around 105–100 Ma (Matthews et al., 2012; Seton et al., 2012) with a subsequent switch from a convergent-margin setting to a subduction regime involving slab roll-back and trench retreat. The onset or an acceleration of rifting might be linked to this plate reorganization when eastward movement of eastern Gondwana slowed, stopped at 55–50 Ma, and then shifted to a more northerly direction.

No deep drilling has been undertaken in the LHR region. Shallow drilling data from the Deep Sea Drilling Project (DSDP) (Burns and Andrews, 1973; Kennett et al., 1986) provide a near-complete stratigraphic record for the latest Cretaceous – Cenozoic. DSDP Site 208 intersected bathyal Oligocene – recent calcareous chalk and ooze, and Late Maastrichtian – Eocene siliceous and calcareous chalk, marl, and chert. Rhyolite intersected at the base of DSDP Site 207 on the southern LHR (Fig. 3-1) has been dated at 97 Ma (McDougall and van del Lingen, 1974; Tulloch et al., 2009), which suggests that the Whitsunday Silicic Large Igneous Province extends onto the LHR and therefore that played a role in forming the LHR continental ribbon (Bryan et al., 1997).

Pre-Cenozoic dredge samples in the region are very limited (Figure 3-1) because of the cover of Cenozoic post-rift sediments over the region. However, a small number of samples provide some insight into the Cretaceous history of the LHR. For instance, dredge samples from the central LHR yield 97 Ma rhyolite that is similar to DSDP Site 207 core samples (Higgins et al., 2011). Moreover, 216–183 Ma granitoid pebbles and detrital zircons in sandstone suggest the continuation of the Cretaceous magmatic arc from New Zealand (Median Batholith) into the LHR (Mortimer et al., 2015). Material recovered to date does not provide constraints on any potential Cretaceous subduction or for the subduction–rifting transition.

Limited petroleum industry reconnaissance during the 1970s and subsequent data acquisition surveys by the governments of Australia, New Zealand, New Caledonia, France, and Germany have led to sparse regional coverage of seismic reflection, gravity, magnetic, and multibeam bathymetry data (Hackney, 2010; Southerland et al., 2012 ). The highest quality and density of data exists for the Capel and Faust basins within the Australian maritime jurisdiction (Fig. 3-1). For these basins, the GA-302 survey (2006–2007) recorded 6,000 km of seismic reflection data to 12 s two-way time along 23 lines with spacing of 15–35 km (Kroh et al., 2007), and the GA-2436 survey (2007) acquired 24,000 $km^2$ of multibeam bathymetry and 11,000 line km of gravity and magnetic data with line spacing of 3–4 km (Heap et al., 2009). The GA-302 seismic reflection data are interpreted to show a variable pre-rift basement (sedimentary, volcanic, intrusive, and metamorphic), two Cretaceous syn-rift mega-sequences comprising various sediment types and volcanics, and a Late Cretaceous – Recent post-rift sequence that can be tied to DSDP Site 208 (Colwell et al., 2010; Higgins et al., 2014).

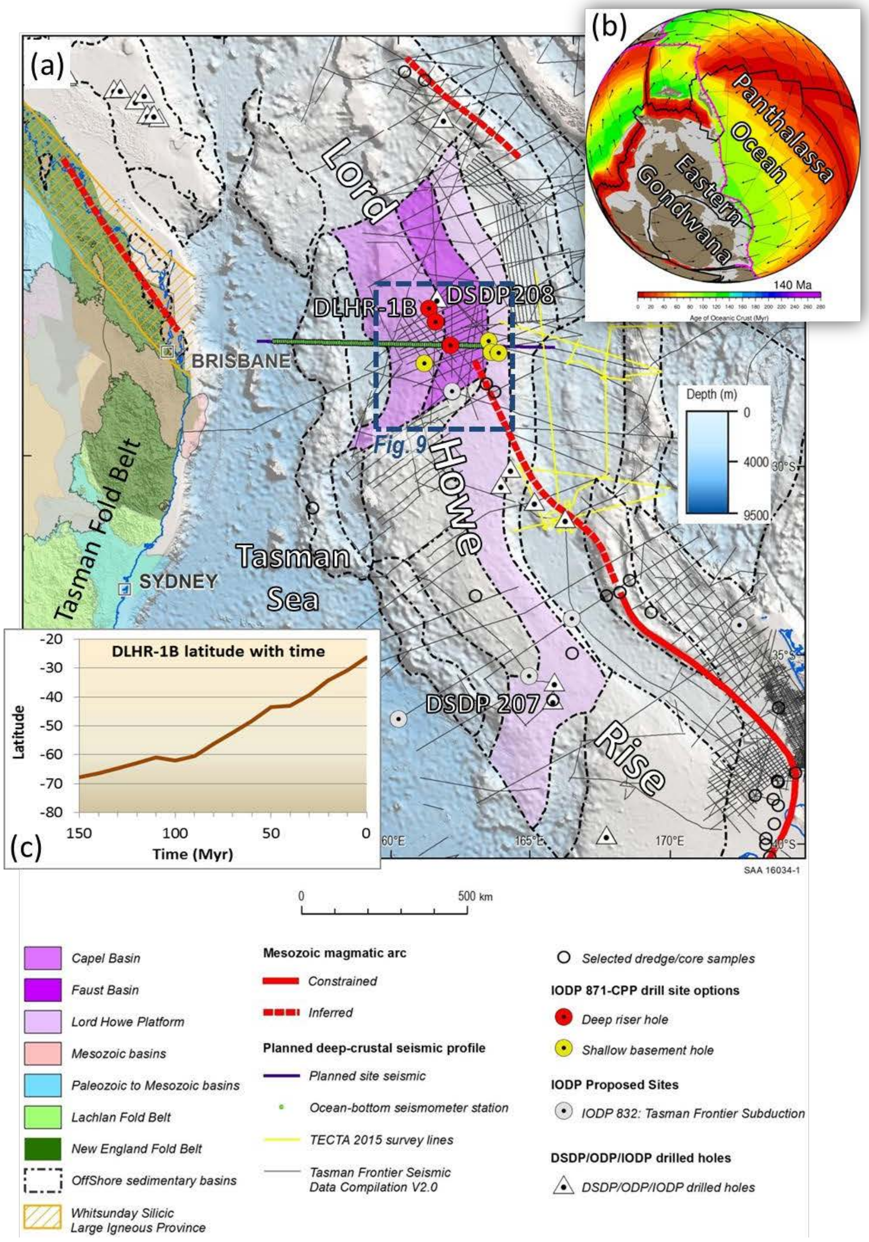


Figure 3-1: (a) Map of the Lord Howe Rise region showing the location of existing and proposed ocean drilling sites (DSDP, ODP and IODP), including sites that form the basis for the IODP proposal that this survey is supporting (red and yellow circles). The map depicts the proposed path of the Mesozoic magmatic arc through the LHR (Mortimer et al., 2015), existing seismic data coverage (Southerland et al., 2012), planned seismic survey lines, and the location of selected dredge/core samples from the GNS Science PetLab database that are relevant to the Cretaceous and older history of the LHR. (b) Configuration of the eastern Gondwana margin in the Early Cretaceous (140 Ma). (c) Paleolatitude of the DLHR-1B drill site from the Early Cretaceous until the present.

4. Outline of research cruise

(1) Cruise information

i). Cruise number, Ship name
KR16-05, R/V Kairei

ii). Title of the cruise
2016FY Acquisition of deep seismic, shallow sub-surface and seafloor bathymetry Survey Data for the Lord Howe Rise (MCS, OBS)

iii). Title of cruise proposal
IODP related site survey study: 1. Lord Howe Rise project

iv). Cruise period, Port call
Leg 1: 23/March/2016 – 30/March, Brisbane to Brisbane
Leg 2: 2/April/2016 – 20/April, Brisbane to Brisbane
Leg 3: 22/April/2016 – 11/May, Brisbane to Brisbane

v). Research Area
Lord Howe Rise, offshore of eastern Australia

vi). Research Map

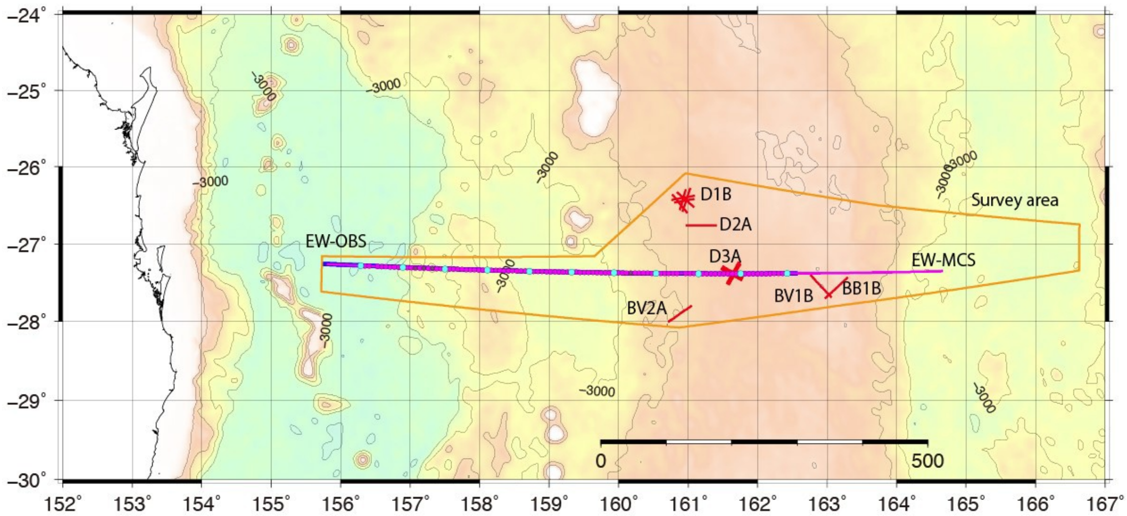


Figure 4-1 Survey area. Wide angle reflection seismic line (blue), MCS seismic lines (magenta and red), and OBS (magenta and sky-blue circles) location on a bathymetric map. Sky blue circles show every tenth OBS.

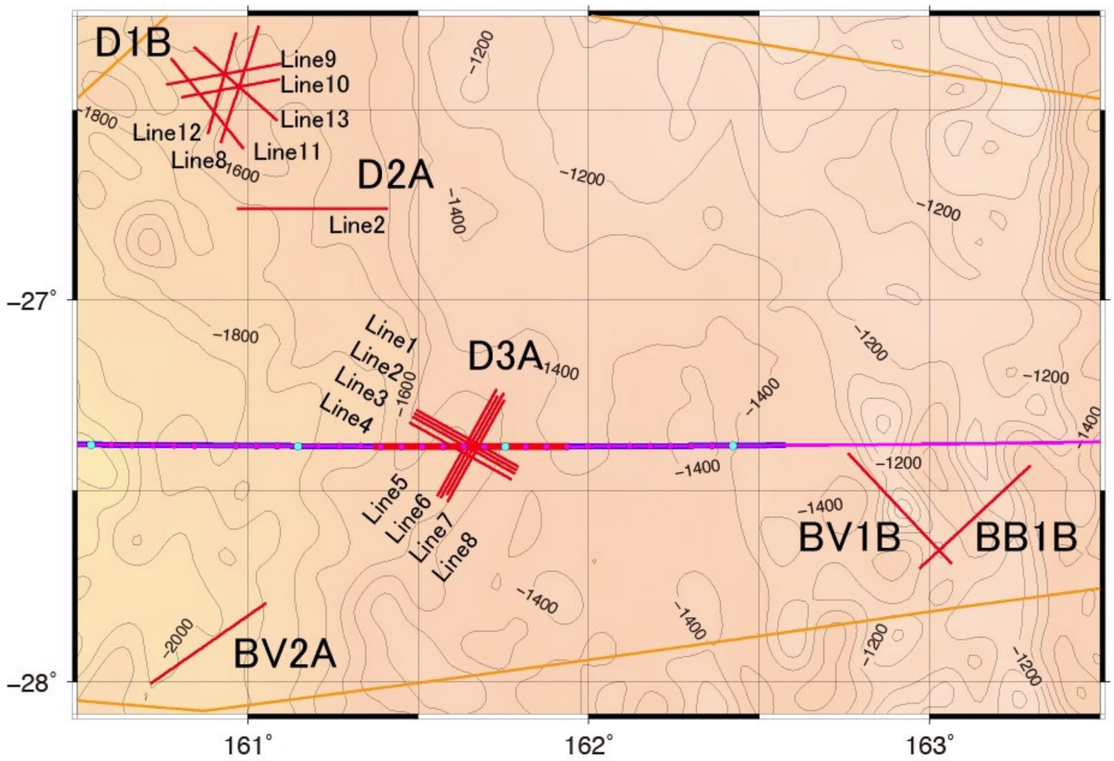


Figure 4-2 Proposed drill site area. Wide angle seismic line (blue), MCS seismic lines (magenta) and OBS (circles) location on bathymetric map. Sky blue circles show every tenth OBS. Red lines are MCS seismic survey lines at proposed drill sites.

## vii). Cruise log

Table 4-1 Daily activity of Leg 1

| Date | | Remarks |
|---|---|---|
| 2016/3/23 | Wed. | Departure from Brisbane, transit |
| 2016/3/24 | Thu. | OBS Deployment |
| 2016/3/25 | Fri. | OBS Deployment |
| 2016/3/26 | Sat. | OBS Deployment |
| 2016/3/27 | Sun. | OBS Deployment |
| 2016/3/28 | Mon. | OBS Deployment |
| 2016/3/29 | Tue. | OBS Deployment, Transit |
| 2016/3/30 | Wed. | Arrival at Brisbane |

Table 4-2 Daily activity of Leg 2

| Date | | Remarks |
|---|---|---|
| 2016/4/2 | Fri. | Departure from Brisbane, transit OBS Deployment |
| 2016/4/3 | Sat. | MCS-Airgun EW_OBS |
| 2016/4/4 | Sun. | MCS-Airgun EW_OBS |
| 2016/4/5 | Mon. | MCS-Airgun EW_OBS |
| 2016/4/6 | Tue. | MCS-Airgun EW_OBS |
| 2016/4/7 | Wed. | MCS-Airgun EW_OBS |
| 2016/4/8 | Thu. | MCS-Airgun EW_OBS |
| 2016/4/9 | Fri. | MCS-Airgun D3A_Lines 2, 7 |
| 2016/4/10 | Sat. | MCS-Airgun D3A_Lines 4, 5 |
| 2016/4/11 | Sun. | MCS-Airgun D1B_Lines 8, 9 |
| 2016/4/12 | Mon. | MCS-Airgun D1B_Line 10, D3A_Lines 3, 6 |
| 2016/4/13 | Tue. | MCS-Airgun D3A_Lines 1, 8 |
| 2016/4/14 | Wed. | MCS-Airgun EW_MCS |
| 2016/4/15 | Thu. | Standby because of weather conditions, MBES |
| 2016/4/16 | Fri. | OBS Retrieval |
| 2016/4/17 | Sat. | OBS Retrieval |
| 2016/4/18 | Sun. | OBS Retrieval |
| 2016/4/19 | Mon. | OBS Retrieval, Transit |
| 2016/4/20 | Tue. | Arrival at Brisbane |

Table 4-3 Daily activity of Leg 3

| Date | | Remarks |
|---|---|---|
| 2016/4/22 | Fri. | Departure from Brisbane, transit |
| 2016/4/23 | Sat. | OBS Retrieval |
| 2016/4/24 | Sun. | OBS Retrieval |
| 2016/4/25 | Mon. | OBS Retrieval |
| 2016/4/26 | Tue. | MBES, Standby because of weather conditions |
| 2016/4/27 | Wed. | Standby because of weather conditions, MBES |
| 2016/4/28 | Thu. | Standby because of weather conditions, MBES |
| 2016/4/29 | Fri. | MCS-Airgun D1B_Line 13 |
| 2016/4/30 | Sat. | MCS-Airgun D1B_Lines 9, 11, 12 |
| 2016/5/1 | Sun. | MCS-Airgun D2A_Line 2 |
| 2016/5/2 | Mon. | MCS-Airgun BB1B, BV1B |
| 2016/5/3 | Tue. | MCS-Airgun EW_MCS |

| | | |
|---|---|---|
| 2016/5/4 | Wed. | MCS-Airgun EW_MCS |
| 2016/5/5 | Thu. | MCS-Airgun EW_MCS |
| 2016/5/6 | Fri. | MCS-Airgun EW_MCS, BV2A |
| 2016/5/7 | Sat. | MCS-Airgun EW_MCS |
| 2016/5/8 | Sun. | MCS-Airgun EW_MCS |
| 2016/5/9 | Mon. | MCS-Airgun EW_MCS, Transit |
| 2016/5/10 | Tue. | MCS-Airgun EW_MCS, MBES, Transit |
| 2016/5/11 | Wed. | Arrival at Brisbane |

(2) Observations

i). Deployment and retrieval of OBSs

One hundred OBSs were deployed along the EW line; 96 OBSs were retrieved.

ii). OBS survey

Air-gun shooting for the OBSs along the EW line while towing a 6-km-long, 444-ch, hydrophone streamer cable. The shot interval was 200 m. The airgun depth was 10 m. The streamer depth was 12 m. The streamer data recording length was 35 s.

iii). MCS survey

Airgun shooting for a hydrophone streamer cable around the proposed drill sites (D1B, D2A, D3A, BB1B, BV1B, BV2A, EW_MCS). We used the same airgun array and streamer cable as that used for the OBS survey, but with 6 m airgun depth. The streamer depth was 8 m. The shot interval was 50 m.

iv). Other geophysical observations

Bathymetric data, sub-seafloor acoustic reflection data and gravity and magnetic data were collected across most of the survey lines using a multi-beam echo-sounder (MBES), sub-bottom profiler, gravity meter, and a three-component magnetometer.

# 5. Cruise narrative

March 20:

R/V Kairei arrived at Brisbane (Queensland Bulk Terminal).

March 21:

R/V Kairei outfitted at Brisbane.

March 22:

Dr. Kodaira, Ms. Ohira, Mr. Bernardel, Dr. Carroll, Dr. Hackney and Mr. Kawamura arrived at Brisbane. Pre-cruise meeting was held.

March 23: Leg 1 start

Dr. Kodaira, Ms. Ohira, Mr. Bernardel and Dr. Carroll were on board. R/V Kairei departed from the Queensland Bulk Terminal Berth, Brisbane at 10 a.m. on schedule.

March 24:

R/V Kairei transited to the eastern OBS, site 101.

March 25:

OBS deployment started from Site 101. Twenty-two OBSs were deployed. The XBT was launched at 4:06.

March 26:

OBS deployment continued from Site 079. Twenty-two OBSs were deployed.

March 27:

OBS deployment continued from site 056. Twenty OBSs were deployed.

March 28:

OBS deployment continued from site 036. Twenty-five OBSs were deployed.

March 29:

OBS deployment continued from 010. Ten OBSs were deployed.

March 30:

Leg 1 end

R/V Kairei arrived at Brisbane (Patricks Container Terminal Berth) at 10 am. Mr. Kawamura arrived at Brisbane.

March 31:

Dr. Fujie, Dr. Saito, Mr. Shirai, Mr. Kawamura, Dr. Hackney, Dr. Williams, and Mr. Payten arrived at Brisbane. A cruise handover meeting between Leg 1 and Leg 2 was held.

April 01:

A pre-cruise meeting for Leg 2 was held.

April 02: Leg 2 start

Dr. Fujie, Dr. Saito, Mr. Shirai, Dr. Hackney, Dr. Carroll, Dr. Williams, and Mr. Payten were on board. R/V Kairei departed from Patricks Container Terminal Berth, Brisbane at 10 a.m. on schedule. R/V Kairei transited to the western end of OBS survey line.

April 03:

An OBS was deployed at Site 000. Then we started airgun shooting along the EW line from the western end of the line eastward (EW_OBS_0). Before deploying the MCS gears, the XCTD was launched at around the western end of the line to measure the acoustic velocity of the water column. The primary purpose of the first airgun shooting along EW line was to reveal the overall structure along the EW line by the wide-angle reflection and refraction data recorded by the OBSs. Therefore, we tuned the survey configuration to enhance the signal-to-noise ratio of the wide-angle seismic data, i.e., to enhance the low frequency energy, we adopted the deeper airgun and streamer depths (10 m and 12 m) and longer airgun shot intervals (200 m). Because the expected average shot time interval was about 80 s, the MCS recording length was set to 35 s, corresponding to depth of more than 100 km.

April 04:

Airgun shooting continued along the EW line (EW_OBS_0).

April 05:

Airgun shooting continued along the EW line (EW_OBS_0).

April 06:

Airgun shooting continued along the EW line (EW_OBS_0). However, we stopped airgun shooting at around the SP 12053 because of mechanical troubles with the No. 3 airgun sub-array and the No. 1 airgun sub-array (air-leaks and sync-error). We retrieved all the gear and fixed all the problems.

April 07:

We redeployed all the survey gear and restarted the airgun shooting along the EW line (EW_OBS_1). Around the proposed drill site D3A, a group of sperm whales was detected by the PAM system. We paused airgun shooting for 2 hr, but we continued eastward at very low speed. Just after the MFO declared "all clear," we restarted airgun shooting, but we lost 14-km airgun shots because of this shutdown (SP12829-SP13025).

April 08:

Airgun shooting continued along the EW line (EW_OBS_1). Again, a group of sperm whales was detected by PAM. This time, we were able to restart the airgun shooting after a short pause (SP14265-SP14285, 1 km). At 5:40, we reached 15 km east of the eastern OBS (Site 101). We halted airgun shooting and made a U-turn to fill the airgun shooting gap because of the presence of the sperm whales. The reshoot along the EW line at 200 m airgun shot interval began at 10:23 from 15 km east of the eastern OBS (Site 101) westward. At 21:00, we finished reshoot for the OBS at around site D3A after filling all the gaps that resulted from the shutdown for whales..

Subsequently, we retrieved all the airgun sub-arrays to change the airgun towing depth from 10 m to 6 m to enhance the high frequency signals that are effective for imaging shallow structures at higher resolution. During replacement of the airgun depth adjustment ropes, we launched a second XCTD to measure the sound velocity in the vicinity of site D3A.

April 09:

We installed all the airgun sub arrays. The towing depth of the hydrophone streamer cable was also changed to 8 m from 12 m. In addition, the shooting interval was changed to 50 m. The expected airgun shooting time interval was less than 20 s, thereby the recording length of the MCS data was set to 15 s this time. At 07:30, we started airgun shooting at site D3A; we obtained MCS data along D3A-Line2 and D3A-Line7.

April 10:

Airgun-shooting continued at site D3A. After finishing D3A-Line4 before dawn, we moved on to D3A-Line5. We started the soft start before entering D3A-Line5 at 10:06 from the northern end of the line, but we had to halt the soft start because of the detection of sperm whales nearby. When the MFO declared "All clear" after all sperm whales had left the area, we had passed halfway of the line. Therefore, we reentered D3A-Line5 from another end of the line (from the southern end). We finished D3A-Line5 before midnight.

The captain predicted that we might have bad weather for several days from April 13. Therefore, in the worst case, we would have been unable to obtain any MCS data at site D1B during Leg 2 if we had stayed at site D3A until April 14. We chose to leave site D3A right away and transited to site D1B, although our priority site had been D3A.

April 11:

We arrived at site D1B at 9:00 and started MCS survey along D1B-Line8. Then we moved to D1B-Line9, but the survey was interrupted by the approach of sperm whales around the middle of D1B-Line9. Reentering the same line would take very long time. For that reason, we terminated D1B-Line9 for the moment and headed to the other line: D1B-Line10.

April 12:

We entered D1B-Line10 and finished it before dawn. Then we moved to site D3A again to resume the remaining MCS survey line there because the weather forecast had improved. We completed two and half lines at site D1B.

We arrived at site D3A at 15:00 and obtained MCS data along D3A-Line3.

April 13:

We continued MCS survey at site D3A and obtained MCS data along D3A-Line6, D3A-Line1, and D3A-Line8. Consequently, we obtained all the planned gridded survey lines at site D3A.

Bad weather was expected on April 14, indicating that we had one more day to conduct MCS surveys there. Therefore, we chose to conduct MCS survey along a small part of the EW line around site D3A to obtain high-resolution MCS data and high-density OBS data there. High-density OBS data are expected to be effective for a Full-waveform inversion approach.

April 14:

We started the MCS survey along the EW line (EW_MCS_0) at 01:20 from around site 094 toward the west, but we stopped shooting at 08:42 because the sea conditions worsened. Consequently, the airgun shot range was about 62 km.

We retrieved all the MCS instruments before dark. During the nighttime, we collected bathymetric data around the center of the survey area.

April 15:

MCS survey was paused because of weather conditions. The XCTD was launched at 12:29. MBES survey was continued.

On the vessel, we heard a lecture related to how to use seismic processing software. The lecturer was Naoto Noguchi, a marine technician from NME, Ltd. Co. Researchers from the Sydney University made an excellent time-migrated seismic section after the lecture.

April 16:

We started OBS recovery operations from site 065 toward west. Sixteen OBSs were recovered. However, we skipped recovery of an OBS at site 064 because the release commands were not accepted by the OBS although the acoustic communication between the R/V and the OBS was very stable.

April 17:

OBS recovery continued from Site 048. Twenty OBSs were recovered.

April 18:

OBS recovery continued from Site 028. Thirteen OBSs were recovered. Recovery of three OBSs at Site 013, Site 015, and Site 017 was skipped because we were unable to receive any acoustic response from these OBSs.

April 19:

OBS recovery continued from Site 012, with 12 remaining OBSs recovered.

R/V Kairei left the survey area for Brisbane.

April 20: Leg 2 end

Dr. Hackney gave an onboard seminar about the Lord Howe Rise Project in the morning.  R/V Kairei arrived at Brisbane (Hamilton wharf).

Dr. Kaiho, Dr. Shiraishi, and Mr. Kawamura arrived at Brisbane.

Dr. Nichol, Mr. Bernardel, Mr. Nakamura, and Dr. Stratford arrived at Brisbane.

April 21:

Cruise handover meeting and pre-cruise meeting of Leg 3 were held.

April 22: Leg 3 start

Dr. Kaiho, Dr. Shiraishi, Mr. Shirai, Dr. Nichol, Mr. Bernardel, Mr. Nakamura, and Dr. Stratford were on board. R/V Kairei departed from Hamilton Wharf, Brisbane at 09 a.m. on schedule. R/V Kairei was bound for Site064.

April 23:

We again attempted the recovery of OBS at site 064 but release commands were not accepted by the OBS, despite the fact that acoustic communication between the R/V and the OBS was very stable. We skipped the recovery of OBS site 64. We restarted OBS recovery from Site 066. Eight OBSs were recovered.

April 24:

OBS recovery continued from Site 074. Twenty-four OBSs were recovered.

April 25:

OBS recovery continued from Site 099. Three OBSs were recovered. The XCTD was launched at 12:30. MCS deployment was suspended because of weather conditions. MBES survey was continued (D1B area)

April 26:

MCS was put on standby because of weather conditions. No acquisition of MBES was conducted because of the high sea state.

April 27:

MCS was put on standby because of weather conditions. MBES survey was restarted (D1B area).

April 28:

MCS was put on standby because of weather condition. MBES survey was continued (D1B area).

April 29:

MCS-Airgun-survey started at site D1B.

D1B-Line 13 was surveyed.

April 30:

Airgun-shooting continued at site D1B.

D1B-Line9, D1B-Line 10, and D1B-Line 12 were surveyed.

D1B-Line9 was a reshoot of the same line which was interrupted by the presence of the whales on April 11.

May 01:

Transit from the proposed drill site D1B to site D2A.

Airgun-shooting started at the D2A site.

D2A-Line 2 was surveyed.

May 02:

Transit from site D2A to site BB1B.

Airgun-shooting started at the proposed shallow drilling sites BB1B and BV1B.

May 03:

Transit from the site BV1B to the eastern end of the Line EW_MCS.

Airgun-shooting along the EW line started from the eastern end of the line (EW_MCS_1). This was the reshoot for the EW line, but the shot spacing was 50 m (first shot was 200 m). To enhance the high frequency energy and to obtain higher resolution seismic reflection profile for the shallower part, the airgun and streamer depths were shallower than those of the first shot.

We stopped airgun shooting at around the SP 17703 because of mechanical troubles with the airgun controller.

May 04:

We restarted airgun-shooting along the EW line (EW_MCS_2).

May 05:

Airgun-shooting was continued along the EW line (EW_MCS_2).

We paused airgun shooting from SP 12302 to SP 12202 because of the detection of whales. Soft start began from SP 12201 and full volume shots started from SP 12140. This shooting gap, between SP 12302 and SP 12140, was covered by the previous shots (EW_MCS_0). But, again, we stopped airgun shooting around SP 11905 because of the whales. Five hours later, we reentered the EW line from SP 11970 (EW_MCS_3).

May 06:

Airgun-shooting was continued along the EW line (EW_MCS_3).

We paused MCS survey along EW line at SP 10564 to conduct the MCS survey at the proposed shallow drill site BV2A. MCS data were obtained along the BV2A line. Then, we returned to the EW line to resume the airgun shots along the EW line.

May 07:

Airgun-shooting was restarted along the EW line (SP 10630, EW_MCS_4).

We stopped airgun shooting at around the SP 9105 because of a fishing boat.

May 08:

Airgun-shooting was restarted along the EW line (SP 9171, EW_MCS_5).

May 09:

Airgun-shooting was continued along the EW line (EW_MCS_5).

May 10:

Airgun-shooting was continued along the EW line (EW_MCS_5).

We stopped airgun shooting because of the whales at SP 2048, but continued westward while waiting for the whales to leave the survey area. We restarted the soft start from SP 1756 and turned into full volume from SP 1664. Consequently, there was a shooting gap between SP 2048 and SP 1756, but we did not have enough time to fill this gap. Airgun-shooting finished around the western end of the EW line (SP 1128).

R/V Kairei left the survey area for Brisbane after retrieving all gear.

May 11: Leg 3 end

R/V Kairei arrived at Brisbane (Hamilton wharf).

May 12:

All on-board scientists left Brisbane.

May 14:

R/V Kairei departed from Hamilton Wharf, Brisbane at 10 a.m., bound for Yokosuka, Japan.

May 26:

R/V Kairei arrived at Yokosuka, Japan at 09 a.m.

# 6. Technical description and onboard information

## (1) Airgun array

Fig. 6-1-1: APG airgun on deck.

The airgun array of R/V Kairei has four sub-arrays of 1,950 cu. in. consisting of eight airguns from 100 cu. in. to 600 cu. in. The total volume of the array is 7,800 cu. in. with a multi-channel seismic reflection system (MCS). The airgun model is annular port airgun (APG) produced by Bolt Inc., comprising cylindrical chambers, housings, and shells containing air and electric junctions (Fig. 6-1-1).

Shooting intervals for OBS and MCS were respectively 200 m and 50 m. The reason for sparse shooting for OBS is that a large time interval can suppress the effects of the water waves generated by earlier shots in the offset distance of up to about 100 km. The towing depth of airguns for 200 m shooting was 10 m (Fig. 6-2-7) to enhance the low-frequency energy of the airgun source and thereby detect weak signals propagating at great depth. For 50 m shooting, the gun depth was 6 m (Fig. 6-2-8) for good resolution of shallow structures.

When we started to shoot the airgun array at a new survey line (or reshoot after a pause), we always conducted a “soft start” procedure, during which the volume of the airguns was increased gradually with time (see chapter 7 for additional details).

## (2) Multi-channel seismic reflection system (MCS)

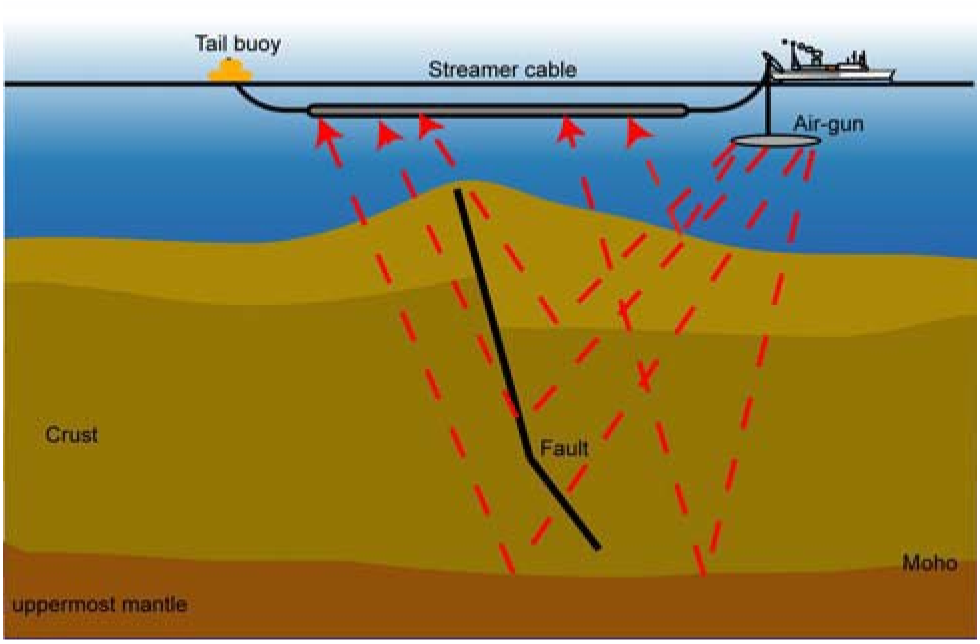


Figure 6-2-1 Schematic illustration of MCS survey

The multi-channel seismic (MCS) reflection system consists of an airgun array, a streamer cable containing hydrophones, and termination with a tail buoy, a navigation system with global positioning system (GPS) receivers, and a shipboard control system to record the data (Fig. 6-2-1). Separate sections in this document describe the airgun array and GPS. Therefore, explanations of these are excluded from this section.

The streamer cable is a digital streamer (Sentinel; Sercel) with a 12.5-m group interval consisting of 8 hydrophones, with a total of 444 channels (Fig. 6-2-2). The sensitivity of each hydrophone is -194.1 dB re 1 V/uPa ±1.0 dB at 20°C, which is equivalent to 19.72 V/Bar. Two channel units have an individual 24 bit A/D converter of the delta-sigma type. Recorded data are compressed by a module called an LAUM, which is a data compressor, data router, and power supplier. LAUMs are located every 60 channels in the streamer. Total lengths of the streamer cable used during this cruise are 5851 m with a 149 m lead-in cable, and 5881 m with a 179 m lead-in cable length, both including active sections, stretch sections, and a towing lead-in cable. The towing depth of the cable is controlled to 8 m or 12 m by 21 depth controllers called 'birds'. Each 'bird' has a depth sensor and a compass sensing its three-dimensional location underwater (Fig. 6-2-3). The tail buoy has a GPS unit to locate the end of the streamer (Fig. 6-2-4).

Figure 6-2-2 Streamer cable and winch.

Figure 6-2-3 Depth controller, "bird"

Figure 6-2-4 Tail buoy

Shipboard MCS systems consist of four main groups: navigation control, airgun control, streamer control, and other navigation (Fig. 6-2-5). The navigation control group SPECTRA is the system name for navigation software on three workstations and an interface unit (Power RTNu). SPECTRA defines coordinate axes, seismic lines, and shot points. Shot times are calculated using SPECTRA with the defined coordinates and position information of the ship and airgun sub-arrays. Then SPECTRA generates System Start signals 200 ms before the target point of a shot (Fig. 6-2-6). They are sent to airgun control and streamer control groups. SPECTRA records shot times and locations, and geometry information for the airguns, streamer, and ship. The airgun control group DigiSHOT controls and monitors all airguns. Air pressure, array depth, and near field wave forms are also monitored. As described above, the System Start signals are sent to DigiSHOT from SPECTRA 200 ms before the target point of a shot (Fig. 6-2-6). Then DigiSHOT sends a Shot Trigger signal to the airguns. Each airgun sends a Time Break signal back to DigiSHOT. The Clock Time Break signals are sent to the Master Clock and True Time, which are shot time recorders in GPS time with milli-second accuracy for data processing. The streamer control group Seal System consists of software on workstations, quality control software, interface units, a power supply for the hydrophone streamer, a recording buffer disk, Network Access Storage (NAS) disks, and tape drives (3590E). The Seal System receives System Start signals from SPECTRA. Then it sends a Recording Start signal to each LAUM in the hydrophone streamer. The hydrophone data are collected by the LAUMs and are sent back via the hydrophone streamer to shipboard units for recording on a buffer disk. After buffering, the data are recorded on NAS disks and 3590E tapes in SEG-D format. The other Navigation group consists of differential GPS (DGPS) of the MCS system (StarFire), relative GPS (RGPS) of the airgun sub-arrays and tail buoy (BuoyLink), depths and compass readings of the birds, and navigation information of R/V *Kairei* as DGPS of SkyFix XP, gyro compass, SENA Original JAMSTEC (SOJ), and radar. The navigation information is sent to SPECTRA and is recorded in P2/91 geometry file format. The navigation data for each shot time are written in a different format: P1/91 which are geometry data applied to seismic data recorded by the Seal System.

The source and receiver configuration are shown in Figs. 6-2-7 and 6-2-8. The source depths were 10 m and 6 m. The respective receiver depths were 12 m and 8 m, optimized for low frequency and deep penetrating signals. The minimum offset was changed during acquisition because the towing length of the lead-in cable was increased to keep the streamer depth at its target depth.

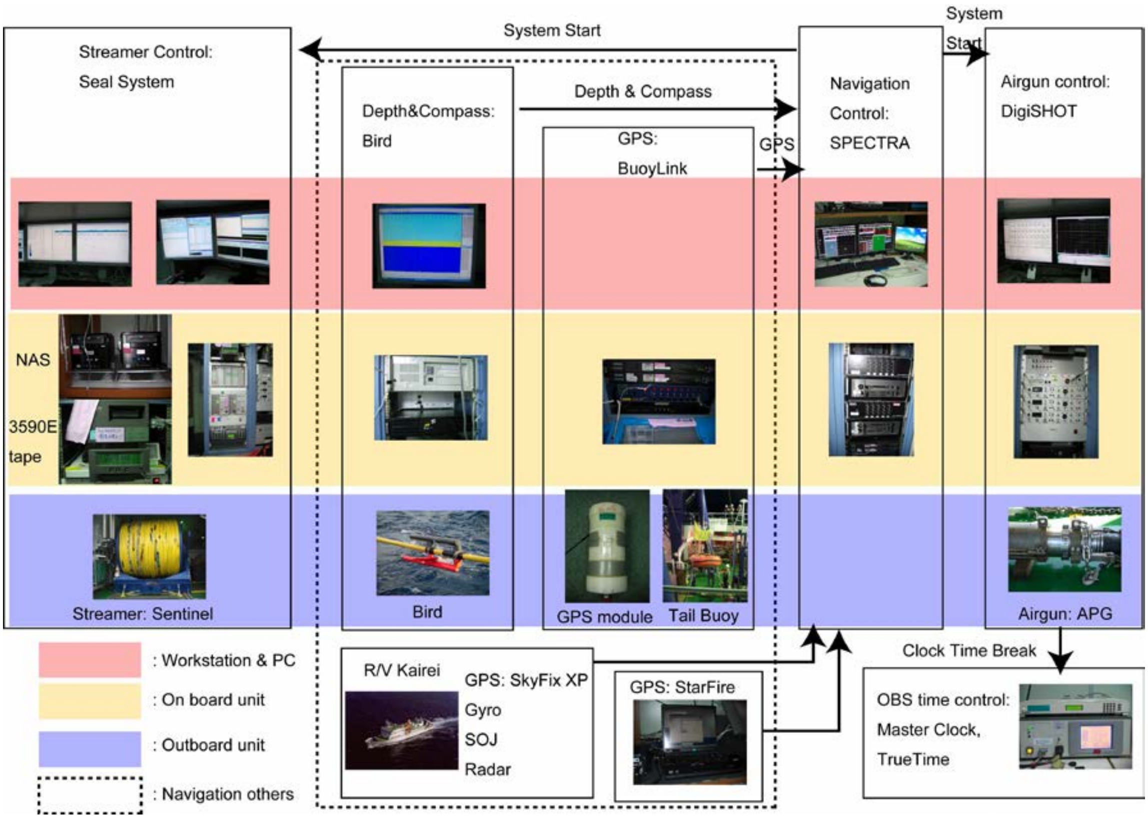


Figure 6-2-5: MCS system of R/V Kairei.

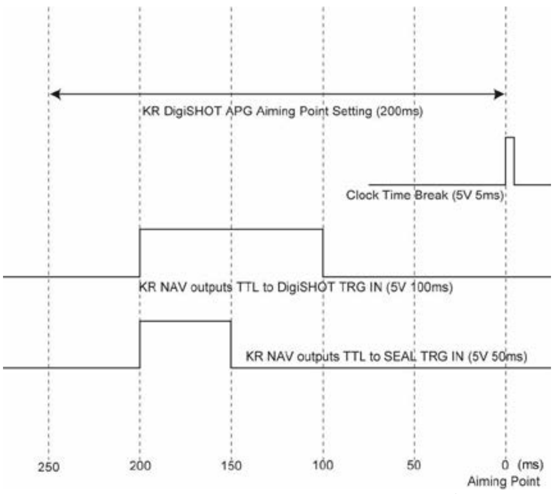


Figure 6-2-6: System time configuration.

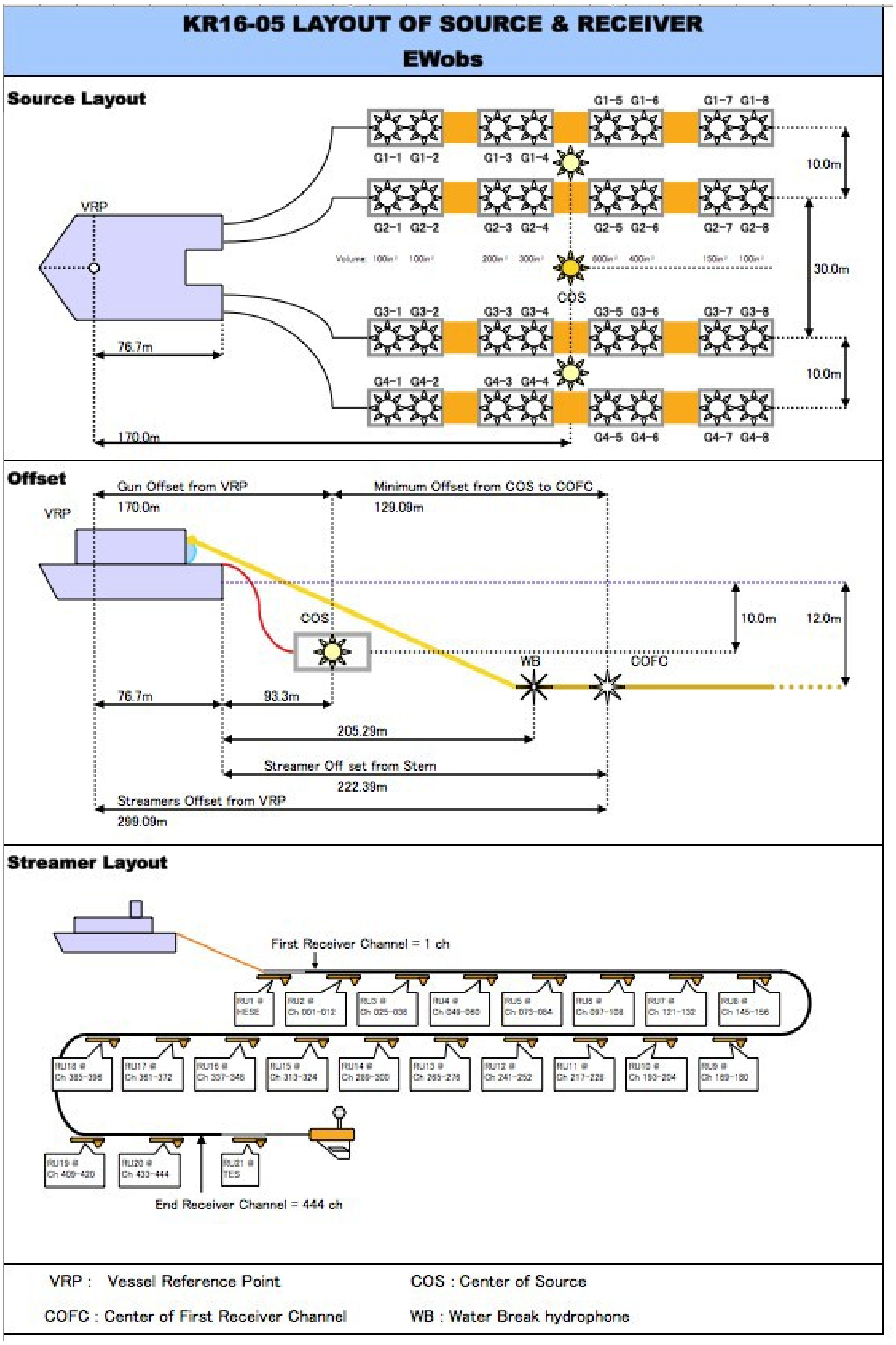


Figure 6-2-7: Configuration of source and receiver for 200 m shooting.

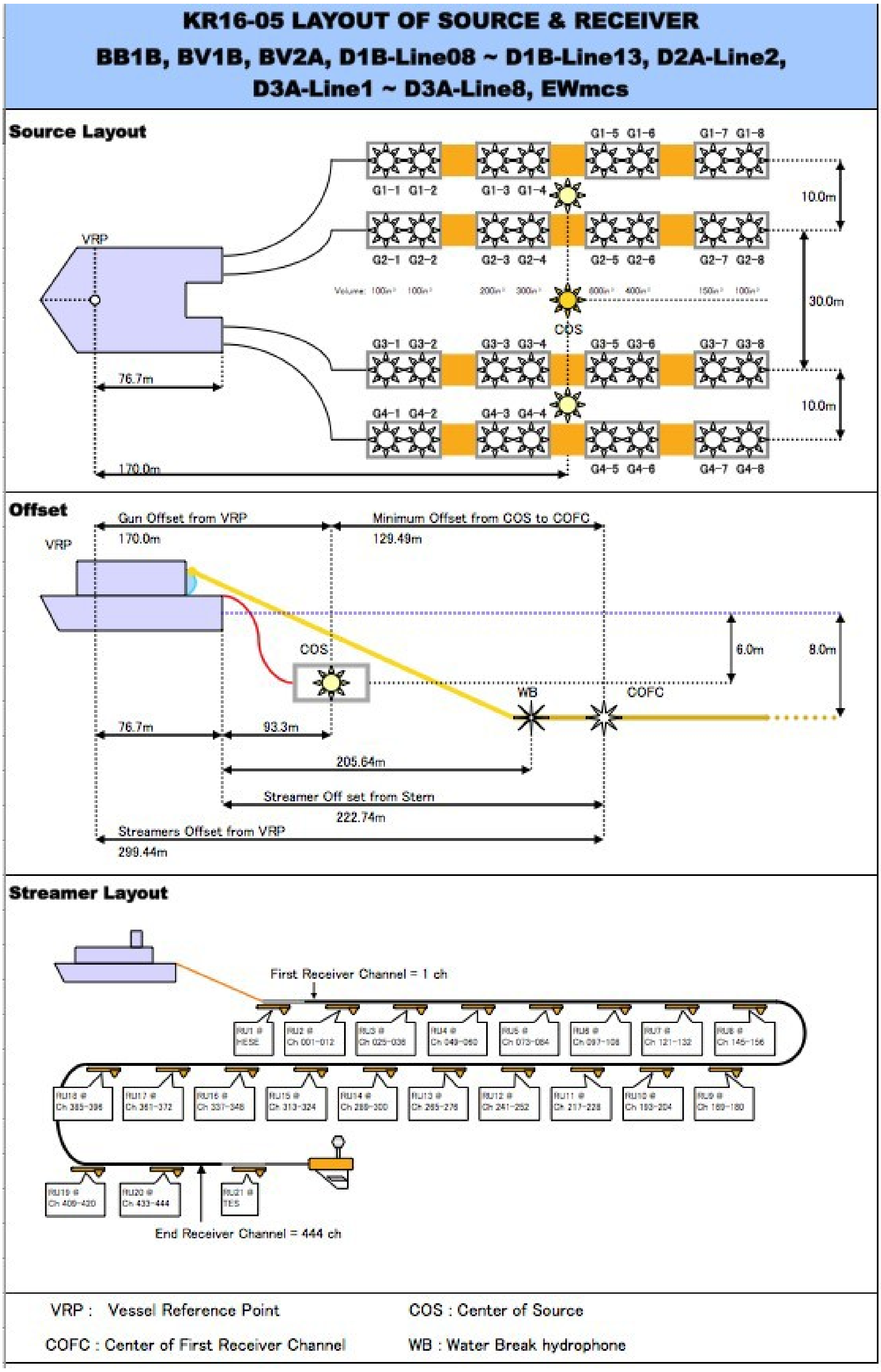


Figure 6-2-8: Configuration of source and receiver for 50 m shooting.

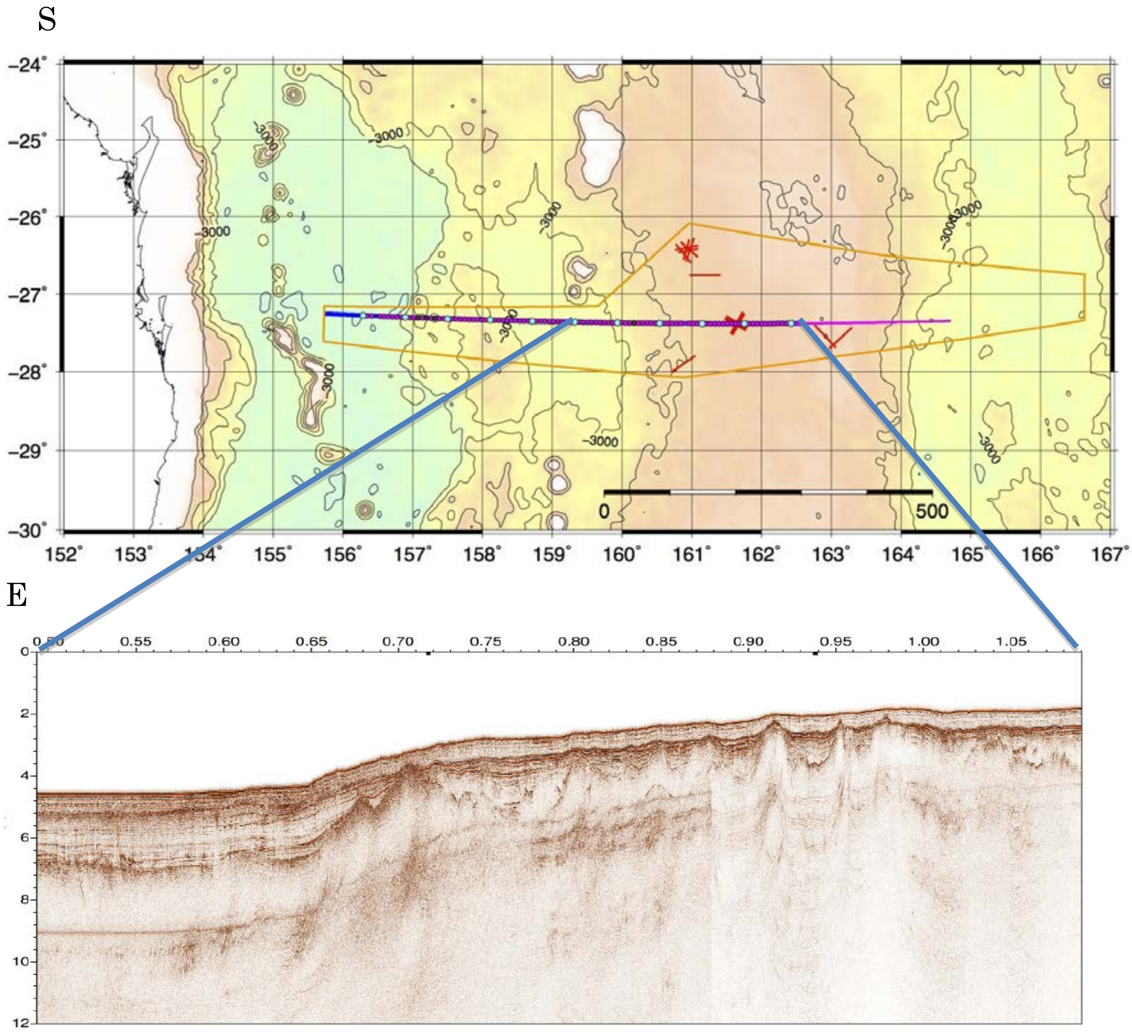


Fig. 6-2-9: MCS profiles for EW-MCS.

## (3) Ocean Bottom Seismometers (OBS)


Fig. 6-3-1: Deployment and recovery of OBSs.

During this cruise, we deployed 100 OBSs to acquire wide-angle reflection and refraction data, thereby revealing the whole crustal structure of the Lord Howe Rise.

The OBS instrument deployed on this cruise was the POBS-150 model, manufactured by Katsujima seisakusho (Fig. 6-3-1) which uses a 17-inch glass sphere as the pressure vessel, enabling the vehicle to descend to 6,000 m water depth. Enclosed in the glass sphere are a geophone sensor with a gimbal system, a recording unit including pre-amp, an A/D converter, storage media (hard-disk drive), and a set of batteries.

Our OBS are powered by rechargeable batteries or lithium-ion batteries. The lithium-ion batteries enable observations to be conducted three times longer (about three months) than when using rechargeable batteries (about 30 days). However, using lithium-ion batteries is expensive. In our cruise plan, the western half of OBSs (site 001 to site 051) was scheduled for recovery within 30 days. Therefore, we used rechargeable batteries for these OBSs and used lithium-ion batteries for the eastern OBSs.

The OBS uses an acoustic system to communicate between the research vessel and the instrument. For this cruise, we used acoustic communication systems of two types: STD-303 of Kaiyo Denshi Co.Co.　Ltd.Ltd. (KDC: Fig. 6-3-5) and NATS-6k of System Giken Kogyo Inc. (SGK: Fig. 6-3-6). The KDC type has a separate transponder that consists of a transducer and a transponder pipe. The SGK type has a monocoque structure that includes both a transducer and a pipe containing electrical parts.

All other specifications were common for all OBSs. The A/D converter was 16 bit type with a sampling rate of 100 Hz. The geophone sensor was a three-component type (with a gimbal case to adjust inclination of the sensors, L-28LBH; Mark Products). In addition, a hydrophone (AQ-18; Benthos – Teledyne Technologies Inc. or HTI-99-DY; High Tech Inc.) was mounted outside of the glass sphere.

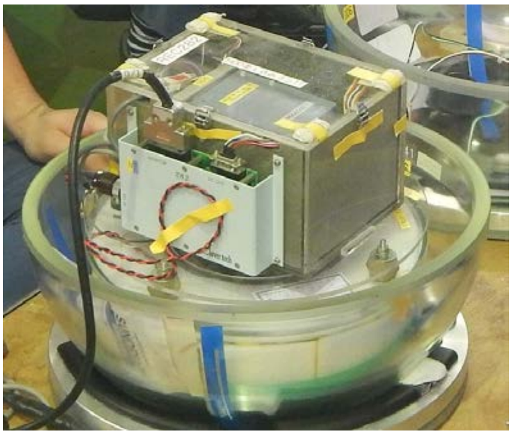

Fig. 6-3-2: OBS sensors in glass sphere. Fig. 6-3-3: OBS recorder and battery.

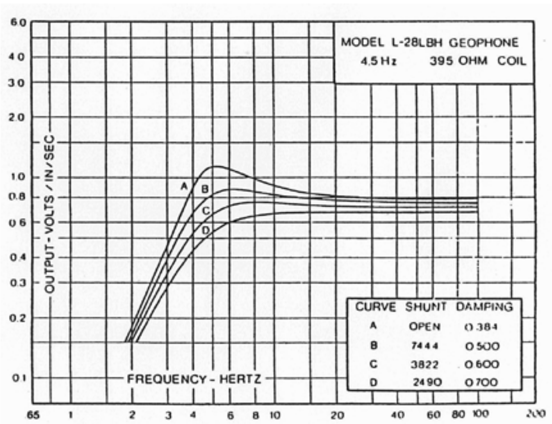


Fig. 6-3-4: Frequency response of geophone. The natural frequency of the geophone is 4.5 Hz and the sensitivity is 0.69 V/Inch/sec. In this cruise, the damping was set to 0.7 (curve D in the above figure).

Deployment of the OBS is by free-fall from the sea surface to the sea bottom; each OBS has an iron weight of about 40 kg attached underneath, which causes it to sink. Its descent speed is about 85 m/min. The OBS position can be determined using the Super Short Baseline (SSBL) system through 14 kHz acoustic communication between the OBSs and R/V Kairei's Acoustic Navigation System (ANS).

Retrieval of the OBS starts with release of the iron weight by an acoustic signal from the ship, which takes about 15–20 min. Once the weight is released and left behind on the seafloor, the buoyancy of the air inside the glass sphere causes the OBS to ascend at a rate of about 65 m/min. When the OBS reaches the sea surface, a radio beacon is activated to generate radio signals with call signs. For nighttime retrieval, a flashing light is also activated. Such equipment enables location of the OBS over a wide area.

The internal clock accuracy is about $10^{-6}$, which is equivalent to a 0.6 s error during a week. Therefore, the internal clock of each OBS drifts from standard time over the time interval of a deployment. To adjust for drift, we measure the drift before deployment and after retrieval. Then we estimate the drift during deployment with a linear calculation.


Fig.6-3-5 OBS with KDC transponder.

Fig.6-3-6: OBS with SGK transponder.

## (4) Global Positioning System (GPS)

The positioning system of R/V *KAIREI* is a Differential Global Positioning System (D-GPS), which uses US satellites and ground-based reference stations. The positioning accuracy is 20 cm under the best satellite conditions (95% confidence level).

The D-GPS system of R/V Kairei is the Starfix.XP2 (StarPack, Fugro). The vessel positions of all geophysical observations, including MBES, gravity, and geomagnetic data, are provided by the Starfix.XP2. For the MCS survey, we use another D-GPS system called StarFire(SF-2050M, NAVCOM) to control the air-gun shot points and the hydrophone streamer cable. because the MCS system requires GPS data in the GGA format, which cannot be provided by the SkyFix-XP. The principles and the accuracy of both D-GPS systems are equivalent, 10cm. The only difference between them is the output data format.

The Starfix.XP2 can provide GPS data in National Marine Electronic Association (NMEA) format.

## (5) Acoustic Navigation System (ANS)

R/V Kairei has underwater acoustic communication and positioning systems for multiple vehicles and deployed observatories like OBSs. The system is called the Acoustic Navigation System (ANS). First, the ANS sends an acoustic signal toward the underwater instruments and then the instruments return the acoustic responses. Because the R/V Kairei has an array of acoustic receivers (16 sensors), it is possible to measure the two-way time between the vessel and the instrument and the incident angle of the acoustic responses based on the phase differences. Using the acoustic velocity structure within the seawater observed from XBT and XCTD observations, the instrument position can be modelled using a ray-tracing technique. Together with the accurate vessel position derived from the GPS data, the ANS can quickly ascertain the instrument position (longitude, latitude, and water depth).

We use this acoustic positioning system to find the OBS position on the seafloor. Additionally, we monitor the OBSs during the deployment and recovery operation. The ANS can accommodate two positioning systems, the Long Baseline (LBL) and Super Short Baseline (SSBL), and two frequency bands, 7 kHz and 14 kHz bands. For OBS operation, we use SSBL and 14 kHz-band.

The OBS position accuracy depends on the distance (slant range) and the angle from the vertical: as one might expect, the accuracy is proportional to the slant range; the vertical down-direction is the most accurate. The estimated error is 0.35% of slant range when the slant range is 4000 m. The angle should be less than 45 deg to determine the position accurately.

Table 6-5-1 Major specification

| | |
|---|---|
| Positioning system | SSBL/LBL |
| Detectable distance | More than 8000 m in slant range |
| Effective aperture angle | 45 deg from the downward vertical direction |
| Accuracy of positioning | Less than 0.35% when the slant range is 4000 m |
| Communication frequency | 14 kHz-band |

| | |
|---|---|
| band<br>(Vessel) | Transmission: 5.0 kHz – 17.0 kHz<br>Reception: 10.0 kHz – 16.5 kHz<br>7 kHz-band<br>Transmission: 5.3 kHz, 5.8 kHz, 6.3 kHz<br>Reception: 5 kHz – 7.5 kHz |
| Transmitted sound pressure | 14 kHz: 190 dB<br>7 kHz: 194 dB |
| Reception sound pressure | 14 kHz: more than -178 dB<br>7 kHz: more than -178 dB |
| Number of reception sensors | 14 kHz: 16 sensors<br>7 kHz: 16 sensors<br>Note: Of these, 4 sensors are commonly used for both frequency bands. |

Figure 6-5-1 The ANS is located in the conductor room on the bridge deck.

## (6) Multi narrow beam Echo Sounder (MBES)

R/V Kairei is equipped with a Multi narrow beam echo sounder (MBES) to map the seafloor topography and its characteristics such as reflectivity. The MBES system of R/V Kairei (ELAC Seabeam 3012; ELAC Nautik) transmits acoustic signals from the transducer and receives their reflections with hydrophone arrays mounted in the keel of the vessel. The system calculates the seafloor bathymetry and its characteristics by consideration of the ship motion and the acoustic velocity in the water.

The system simultaneously emits 301 acoustic signals. The maximum swath angle is 140 degrees. The resolution and the width of the survey area are dependent on the water depth: if the water depth is 1,500 m (typical water depth at the Lord Howe Rise), the expected horizontal resolution is 1m or 0.5% of slant range and the maximum swath width is about 140 degrees in ideal conditions. The accuracy of the water depth derived by the MBES system is dependent on the frequency of the acoustic signals and the sampling intervals. During the Lord Howe Rise cruise, the system used 12 kHz acoustic waves. Therefore, the accuracy of the water depth exceeds the requirements of the International Standards Organization (IHO) for depths if the acoustic velocity in the water is known.

Table 6-6-1 Major specification of the SeaBeam

| | |
|---|---|
| Measurement Depth | 50–11000 m (full ocean depth) |
| Max swath coverage | 140° swath width |
| Transmission Beam Angle | 2° (-3 dB) |
| Receiving Beam Angle | 1.6° (-3 dB) |
| Number of beams | 301 |
| Beam spacing | Equidistance or equiangular |
| Pulse Length | 2–20 ms |
| Frequency | 12 kHz |
| Roll Angle | ±10° |
| Pitch Angle | ±7° |
| Yaw Angle | ±5° |

## (7) Sub-bottom profiler

Sub-bottom profiler is a system for imaging detailed shallow sedimentary structure using very high frequency acoustic signals. R/V Kairei is equipped with a High- resolution 3.5 kHz CHIRP Sub-Bottom Profiler BATHY-2010 system (Table 6-7-1).

Operational water depth range is 10 m – 12,000 m. The vertical resolution within the marine sediment strata is expected to be 8 cm and the maximum signal penetration depth is more than 300 meters. The output data formats are ODC and Standard SEG-Y.

The sub-bottom profiler operates simultaneously with MBES and side scan sonar. However, we did not turn on the sub-bottom profiler during the Leg1 of this cruise. Additionally, we stopped the sub-bottom profiler during the night time at the beginning of the Leg 2 because ship crew worried about the high frequency sound generated by the sub-bottom profiler prevented them from sleeping at night. We did not need to stop the sub-bottom profiler from 04 April.

Table 6-7-1 Bathy 2010 Sub-bottom profiler **specifications**

| | |
|---|---|
| Operational water depth range | 10 m–12,000 m (full ocean depth) |
| Bottom penetration | 300+ m, with up to 8 cm of marine sediment strata resolution |
| Data format | Raw data or processed data storage in SEG-Y format and ODC format |
| Correction | DGPS, Heave Compensation and Sound Velocity inputs |
| Type | CHIRP Sub-Bottom Profiler |
| Frequency | 3.5 kHz |
| Depth Accuracy | ±10 cm to 100 m, ± .3%--6,000 m |

## (8) Shipboard Three-Component Magnetometer

### Outline of system

A shipboard three-component magnetometer system (SFG1214; Tierra Technica Ltd.) on R/V "*KAIREI*" was used for magnetic field measurements. Three-axis flux-gate sensors with ring-cored coils were fixed about 2 m above the deck above the bridge. Outputs of the sensors were digitized using a 20-bit A/D converter (1 nT/LSB), and were sampled at 8 times per second. Ship heading data were also sampled at 8 Hz. They were transmitted directly from a gyro compass for navigation in the bridge. Roll and pitch data of 8 Hz are provided from an attitude sensor (TVM-4) installed on the floor of the gravity meter room. The ship's position (GPS) and speed data are taken from the LAN every second. Data are stored on the internal hard disk drive of a PC in ASCII format, and are transferred to a workstation for processing using FTP.

### Hardware overview

The three-component Magnetometer consists of three major units.

a. Magnetic sensor:

Flux-gate magnetic sensors with ring-cored coils are configured orthogonally to measure the three components of the Earth's magnetic field. This sensor is fixed on an aluminum platform mounted on the top part of foremast to reduce magnetic influences of ship's hull and artificial noise.

b. Measurement unit:

The measurement unit converts the signal of the magnetic sensor into the magnetic field value. At the same time, it reads the data from the gyro compass and attitude sensor. Outputs of the sensors are sampled at 8 times per second, which are transmitted to the data recording unit.

c. Data recording unit

The data recording unit edits data that are transmitted from the measurement unit, the navigation data (time, latitude, longitude, vessel speed, etc.) and the absolute magnetic field value, and outputs the data to the shipboard LAN.

Attitude sensor:

The attitude sensor is a strapped down system that combines an accelerometer and fiber gyro. Roll and pitch data are provided and transmitted to the measurement unit.

Table 6-8-1 Major specifications of three-component magnetometer

| | | |
|---|---|---|
| Magnetic Sensor | System | Flux-gate sensor<br>with ring-cored coils |
| | Number of components | Three orthogonal components |
| | Orthogonal Degree | <±2 min |
| | Cable Length | 50 m |
| | Size, Weight | φ280×130 H (mm), 5 kg |
| Measurement Unit | Measurement Range | ±100,000 nT |
| | Resolution | 1 nT |
| | Noise | 0.5 nT |
| | Temperature Stability | 0.5 T/℃ |
| | Absolute Accuracy and Linearity | <100 nT |
| | AD converter | 20 bit |
| | Conversion Rate | 8 times/s |
| | Digital Input | RS232C 3ports |
| | Size, Weight | 480W 150H 430D (mm), 4 kg |
| Data Recording Unit | Recording Media | Hard disk drive |
| Attitude Sensor | Measurement Item | Roll angle, Pitch Angle |
| | Measurement Range | ±45° |
| | Accuracy | ±0.2° (<30°) |
| | Resolution | 0.0055°/LSB |
| | Output | RS422 compliance |
| | Size, Weight | φ320 180 H (mm), 5 kg |

| | | |
|---|---|---|
| Others | Power Supply | Single Phase AC100 V, 50/60 Hz |
| | Power Consumption | 350 VA |


Figure 6-8-1 Magnetic sensor (Deck)

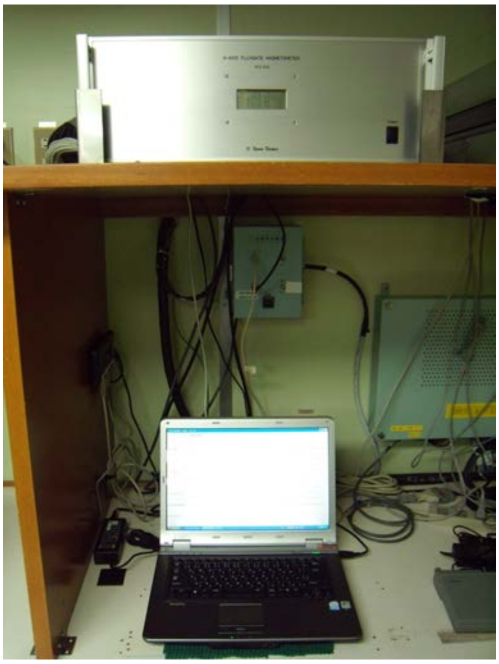

Figure 6-8-2 Measurement unit (upper) and Data recording unit (lower)

Figure 6-8-3 Attitude sensor (Gravity meter room)

Data acquisition

Three components of magnetic field data were recorded from the departure to the arrival date at the Brisbane pier (2016/3/23 to /3/30, 2016/4/2 to 4/20 and 2016/4/22 to 5/11). The measurement interval is 1/8 s. The magnetic measurement resolution is 1 nT.

## (9) Gravity meter

### Outline of System

Shipboard gravity measurements are made using a marine gravity meter system (KSS31; Bodenseewerk) installed in the gravity meter room. The system consists of two main components: a platform containing a gyro and a gravity sensor, and an electronic circuit to determine gravity. An on-line data filter for "Sea State 4" was selected, which enabled us to obtain good gravity data with smooth variation. According to documents provided by the manufacturer, the filter is expected to cause a delay of 123 s. The gravity data were logged every minute during the cruise. Shipboard gravity data were calibrated by placing the portable instrument in a location with a known gravitational acceleration.

The system incorporates the ship's position, speed, and heading through the ship’s LAN, performing Etovös correction on-line. Free-air gravity anomaly data presented in this report are based on the on-line Etovös corrected gravity without drift correction. Readjustment of time differences between filtered gravity and the ship's speed and heading might be necessary for onshore data processing.

### Calibration

A portable gravimeter (CG-5; Scintrex Ltd.) is used for calibration of the shipboard gravimeter. The gravity is measured both at the pier and at the standard point where the absolute gravity is well known. What is necessary is merely that it be installed horizontally because this gravity meter performs measurement and compensation automatically by the tide.

During the KR16-05 cruise, gravity data were calibrated on March 22, March 30, April 1, April 20, May 11 and May 26 using a portable gravimeter at the Queensland bulk terminal berth, Patricks container terminal berth, Hamilton berth, JAMSTEC Headquater berth, and the gravity station at Northshore Riverside Park.

Table 6-9-1 Major specifications of onboard gravity meter

| | | | |
|---|---|---|---|
| Accuracy on Profile | Vertical Acceleration | DYNAMIC* (mGal RMS) | EFFECTIVE** (mGal RMS) |
| | <15,000 | 0.5 | 0.2 |
| | 15,000–80,000 | 1 | 0.4 |
| | 80,000–20,0000 | 2 | 0.8 |
| Accuracy during Turn | Vertical Acceleration | DYNAMIC*** (mgal RMS) | EFFECTIVE*** (mGal RMS) |
| | 15,000–80,000 | 2.5 | 1 |
| Drift Rate (mGal/month) | <3 | | |
| Measuring Range (mGal) | 10,000 | | |
| Scale Factor Calibration (standard) | <0.5% | | |
| Platform Freedom | Pitch | ±40° | |
| | Roll | ±40° | |
| Environmental Conditions | Temperature | +10 °C up to +35 °C | |
| | Temperature Gradient | <2℃/h | |
| Response Time | Definition | $t$ = 1/2πfc<br>fc = corner frequency | |
| | Gravity Sensor | τ=36 s (low pass filter first order) | |
| | Selectable Filter | τ=5.2 to 75 s (Bessel filter fourth order) | |
| Data Interface | Analogue Output for Signal Monitor | 2–6 channels | |
| | Digital Data Interface | Standard V24 or RS232C serial data transmission | |

| | | |
|---|---|---|
| Power Supply | All Systems | 220 V, 50 Hz, single phase or<br>110 V, 60 Hz, single phase (transformer) or<br>240 V, 50–60 Hz, single phase (transformer) |
| Weight and Size | Platform, Sensor and Gyro | 72 kg, 68  53  53 (cm$^3$) |
| | Gravity Measurement Electronic Circuit (19-inch rack) | 200 kg, 55  65  183 (cm$^3$) |

* Accuracy without applying data reduction

** Accuracy applying data reduction procedures

*** Depending on the accuracy of navigation data

Figure 6-9-1 Gravity meter system Figure 6-9-2 Gyro and Sensor

## (10) eXpendable Bathy Thermograph (XBT)/ eXpendable Conductivity, Temperature, and Depth (XCTD)

Sound velocity of the water column is measured using an expendable profiling system (XBT/XCTD; Tsurumi Seiki Co. Ltd.; Fig. 6-10-1) wired to a digital converter (TS-MK130; Tsurumi Seiki Co. Ltd.; Fig. 6-10-2) and the computer in the ship's laboratory (Fig. 6-10-3). A T5 type temperature sensor probe, XBT, and XCTD-2 type sensor for conductivity, temperature, and depth, XCTD, were used on this cruise. A probe is dropped from the stern of the ship. During the probe descent, seawater temperature, conductivity, and depth are measured continuously. The maximum depths of the T-5 and XCTD-2 probe are 1830 m. In the case of XBT, the probe depth is calculated from the descent time. The sound velocity information is used for sound speed corrections of Seabeam bathymetric survey data. During this cruise, XBT and XCTD measurements were conducted to correct the sound velocity structure (Table 6-10-1).

Fig. 6-10-1 Probe deployment

Fig. 6-10-2 Digital converter

Fig. 6-10-3 Computer for XBT/XCTD

Table 6-10-1: Sites

| | Date | Time (UTC) | Latitude | Longitude | Type |
|---|---|---|---|---|---|
| XBT | 20160324 | 180644 | 27-22.9720S | 162-26.4646E | T05 |
| XCTD | 20160402 | 224128 | 27-13.0832S | 155-33.4541E | CT2 |
| XCTD | 20160408 | 120230 | 27-23.0842S | 161-34.4947E | CT2 |
| XCTD | 20160415 | 022902 | 27-31.1244S | 160-10.1520E | CT2 |
| XCTD | 20160425 | 023019 | 26-25.6134S | 161-14.2481E | CT2 |

# 7. Marine Fauna observation and mitigation

To mitigate the risk of acoustic disturbance from the seismic source on marine fauna, Marine Fauna Observers (MFO) and Passive Acoustic Monitoring (PAM) operators were active during seismic data acquisition. Seismic acquisition and source operational procedures were undertaken in accordance with the Environmental Protection and Biodiversity Conservation (EPBC) Act Policy Statement 2.1 Interaction between offshore seismic exploration and whales (DEWHA 2008), and as outlined in EPBC Referral Decision 2015/7623.

MFOs conducted daylight visual observations for marine fauna during the survey and coordinated mitigation for whales during seismic (Fig. 7-1), multi-beam echo-sounder (MBES) and sub-bottom profiler (SBP) operations. PAM operators also maintained 24-hr acoustic monitoring for whales during periods of seismic acquisition.

Monitoring was conducted over a period of 39 days. The total time of visual observations was 442 hr and 33 min. Passive acoustic monitoring was done for 456 hr and one minute. Of the 29 marine fauna sighted and 50 marine fauna detected, sperm whales accounted for 21 (72%) and 35 (70%), respectively (Fig 7-2, 7-3). In all, seven seismic source shutdowns and nine MBES/SBP shutdown events were instigated respectively by an applicable species detected within the 2 km and 500 m mitigation zones. Cumulatively, the seismic shutdown events were responsible for 24 hr and 33 min of lost acquisition time.

Further details are provided in the Marine Fauna Observer's Report available separately from the Data Research System for Whole Cruise Information in JAMSTEC(DARWIN).

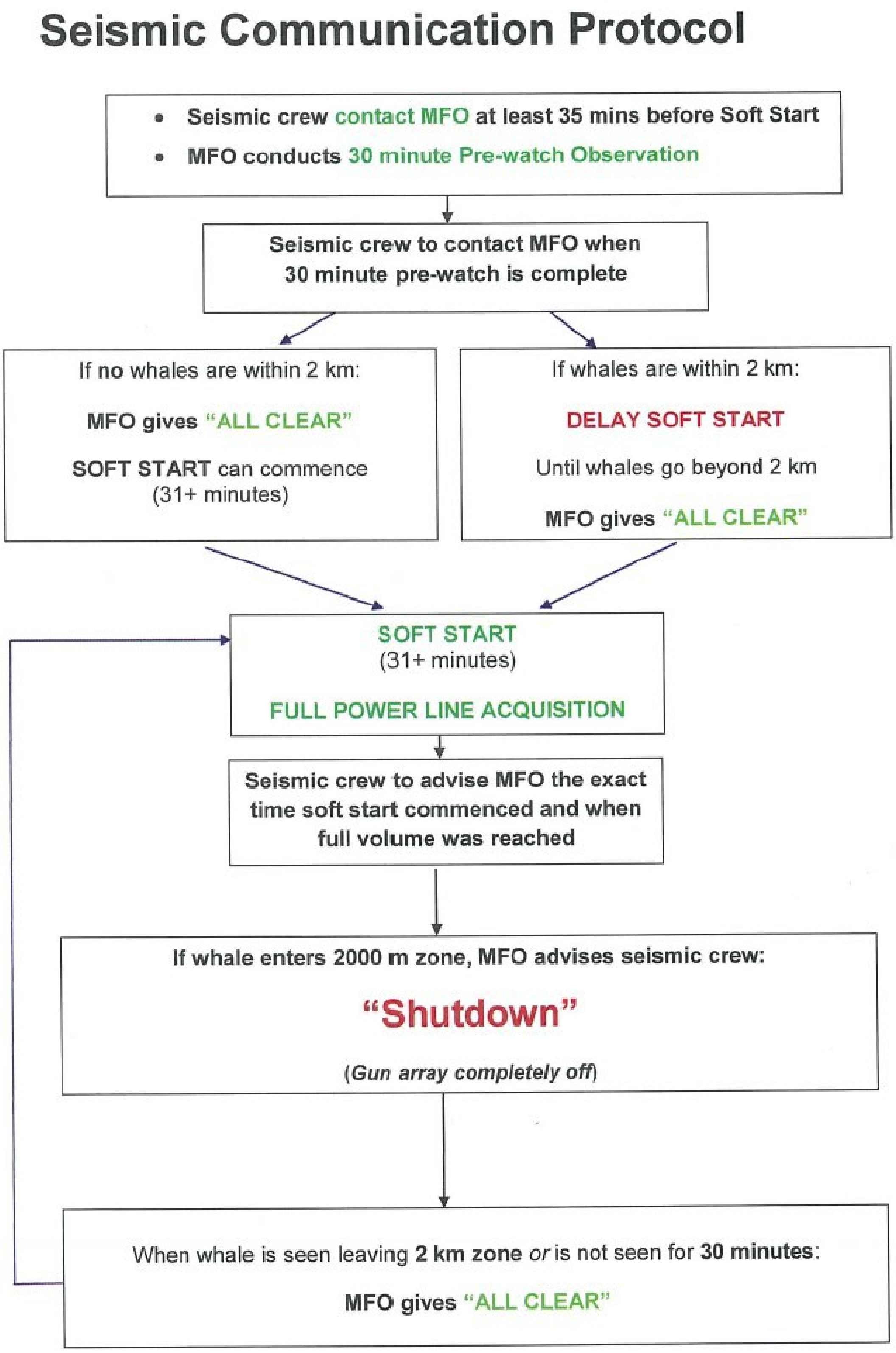


Figure 7-1 Procedure of airgun shooting mitigation for whales.

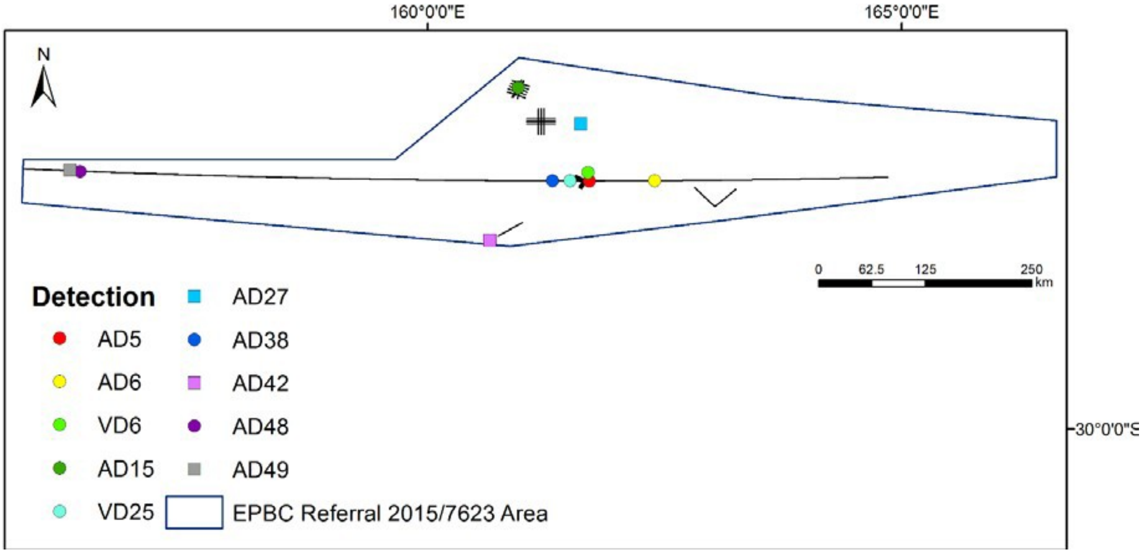


Figure 7-2 Location of mitigation of the Airgun shooting. Black lines show the survey line. Circles show shutdown events. Squares denote start-up delay events.

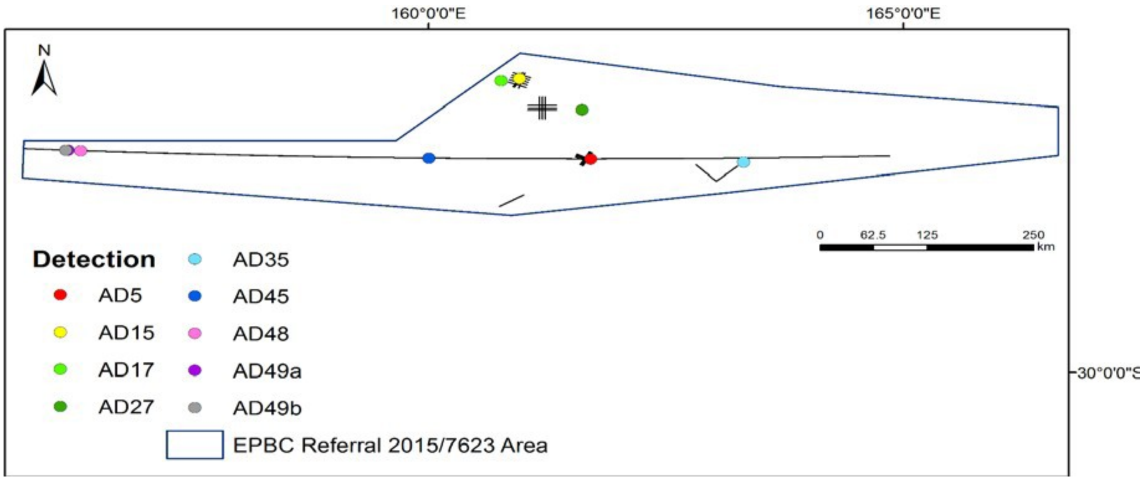


Figure 7-3 Location map of shutdown of the MBES and SBP.

## 8. Notice on use:

This cruise report is preliminary documentation prepared at the end of the cruise.

This report may not be corrected even if changes on contents (i.e. taxonomic classifications) may be found after its publication. This report may also be changed without notice. Data presented in this cruise report may be raw or unprocessed. Please ask the Chief Scientist for the latest information if you are going to use or refer to data presented in this report. Users of data or results on this cruise report are requested to submit their results to the Data Management Group of JAMSTEC.

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# A-1 Cruise log

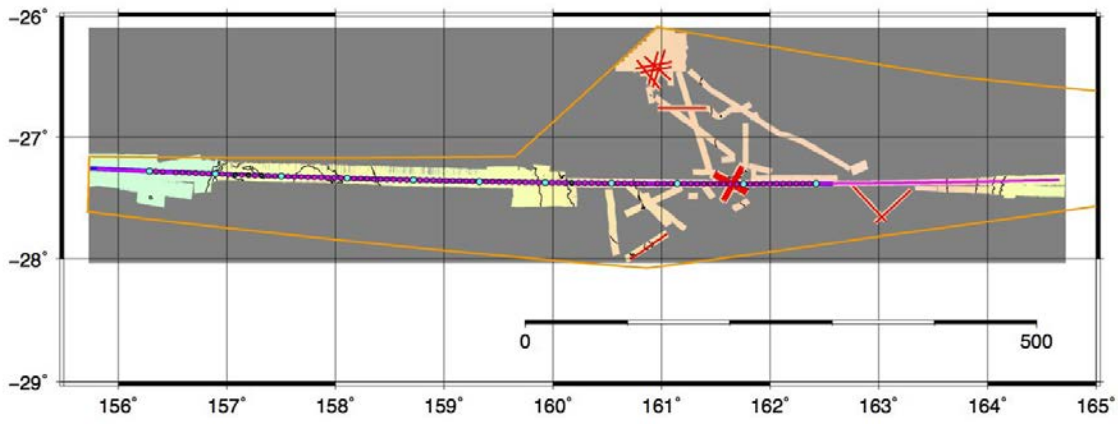
| | | |
|---|---|---|
| March 20 | 11:00 R/V Kairei arrived at Brisbane. | Queensland Bulk Terminals Berth |
| March 21 | R/V Kairei were outfitted at Brisbane. | Queensland Bulk Terminals Berth |
| March 22 | Pre-cruise meeting were assembled. | Queensland Bulk Terminals Berth |
| Leg1: | | |
| March 23 | 10:00 R/V Kairei departed from Brisbane. | Queensland Bulk Terminals Berth |
| March 24 | R/V Kairei was heading for the eastern OBS, site 101. | Transit |
| March 25 | 4:06 XBT was launched.<br>5:01 OBS deployment was started. | OBS Site 101~080 |
| March 26 | OBS deployment was continued.<br>21:00 deployment was suspended due to long-line fishing.<br>23:23 OBS deployment was restarted. | OBS Site 079~077, 075~058<br>OBS Site 050 |
| March 27 | OBS deployment was continued. | OBS Site 049~043<br>OBS Site 051~057<br>OBS Site 042~037 |
| March 28 | OBS deployment was continued.<br>20:21 OBS response was stopped at site 015.<br>OBS deployment was continued. | OBS Site 036~0 16<br>OBS Site 015<br>OBS Site 014~012 |
| March 29 | OBS deployment was continued.<br>10:47 Site 001 OBS was deployed.<br>13:33~15:30 NBES survey<br>15:30 R/V Kairei left the survey area for Brisbane. | OBS Site 011~004<br>OBS Site 002~001 |
| March 30 | 10:40 R/V Kairei arrived at Brisbane. | Patricks Container Terminal Berth |
| March 31 | A cruise handover meeting between Leg 1 and Leg 2 was held. | Patricks Container Terminal Berth |

| | | |
|---|---|---|
| April 01 | A pre-cruise meeting for the Leg 2 was held. | Patricks Container Terminal Berth |
| Leg2: | | |
| April 02 | 10:00 R/V Kairei departed from Brisbane. | Patricks Container Terminal Berth |
| April 03 | 05:03 Site 000 OBS was deployed.<br>08:29 XCTD was launched.<br>16:58 MCS-Airgun-survey was sterted. | OBS Site 000<br><br>EWobs_0(200m shot) |
| April 04 | MCS-Airgun-survey was continued. | EWobs_0 |
| April 05 | MCS-Airgun-survey was continued. | EWobs_0 |
| April 06 | MCS-Airgun-survey was continued. | EWobs_0 |
| April 07 | MCS-Airgun-survey was continued. | EWobs_1 |
| April 08 | MCS-Airgun-survey was continued.<br>22:02 The XCTD was launched. | EWobs_2 |
| April 09 | R/V Kairei was moving to Site D3A.<br>MCS-Airgun-survey was continued. | (50m shot)<br>D3A-Line2,Line7 |
| April 10 | MCS-Airgun-survey was continued. | D3A-Line4,Line5 |
| April 11 | R/V Kairei was moving to Site D1B.<br>MCS-Airgun-survey was continued. | (50m shot)<br>D1B-Line8,Line9A |
| April 12 | MCS-Airgun-survey was continued.<br>R/V Kairei was moving to Site D3A.<br>MCS-Airgun-survey was continued. | D1B-Line10<br><br>D3A-Line3 |
| April 13 | MCS-Airgun-survey was continued. | D3A-Line6,Line1,Line8 |
| April 14 | R/V Kairei was moving to EW_mcs.<br>MCS-Airgun-survey was continued. | (50m shot)<br>EWmcs-0 |
| April 15 | MCS survey was paused due to weather condition.<br>12:29 The XCTD was launched.<br>MBES survey was keep going. | EWmcs-0 |
| April 16 | 05:01 OBS recovery operation started.<br>OBS 064 was not recovered.<br>OBS recovery operation was continued. | OBS Site 065<br><br>OBS Site 064~Site 049 |
| April 17 | OBS recovery operation was continued. | OBS Site 048~Site 029 |
| April 18 | OBS recovery operation was continued.<br>OBS 017, 015 and 013 were not recovered. | OBS Site 028~Site 018 |

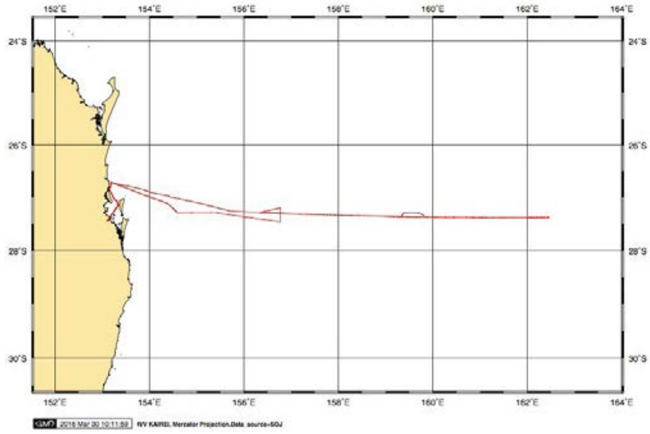
| | | |
|---|---|---|
| | OBS recovery operation was continued. | OBS Site 016 Site 014 |
| April 19 | OBS recovery operation was continued.<br>17:17~19:00 MBES survey<br>19:00 R/V Kairei left the survey area for Brisbane | OBS Site 012~Site 004<br>Site 002~Site 000 |
| April 20 | 10:00 R/V Kairei arrived at Brisbane. | Hamilton Whalf No.4 |
| April 21 | Cruise handover meeting and pre cruise meeting of Leg 3 were assembled. | Hamilton Whalf No.4 |
| Leg3: | | |
| April 22 | 9:00 R/V Kairei departed from Brisbane. | Hamilton Whalf No.4 |
| April 23 | 14:00 R/V Kairei arrived at survey area.<br>OBS recovery operation was started.<br>OBS 064 was not recovered.<br>OBS recovery operation was continued. | OBS Site 064: Retry<br>OBS Site 066~073 |
| April 24 | OBS recovery operation was continued. | OBS Site 074~098 |
| April 25 | OBS recovery operation was continued.<br>12:30 The XCTD was launched.<br>MCS deployment was suspended due to weather condition.<br>MBES survey was continued. | OBS Site 099~101<br>D1B area |
| April 26 | MCS was standby due to weather condition.<br>No acquisition of MBES due to high sea state. | |
| April 27 | MCS was standby due to weather condition.<br>MBES survey was restarted. | D1B area |
| April 28 | MBES survey was continued. | D1B area |
| April 29 | MCS-Airgun-survey started. | D1B-Line13 |
| April 30 | Airgun-shooting was continued. | D1B-Line9B,Line10 and Line12 |
| May 01 | Transit to the drill site D2A.<br>Airgun-shooting was restarted. | D2A-Line2 |
| May 02 | Transit to the site BB1B.<br>Airgun-shooting was restarted. | Site BB1B and BV1B |
| May 03 | Transit to the eastern end of the Line | |

| | | |
|---|---|---|
| | EW_MCS.<br>Airgun-shooting was started. | EW_mcs_1 |
| May 04 | Airgun-shooting was continued. | EW_mcs_1, EW_mcs_2 |
| May 05 | Airgun-shooting was continued. | EW_mcs_2 |
| May 06 | Airgun-shooting was continued. | EW_mcs_2, EW_mcs_3 |
| May 07 | Airgun-shooting was continued. | BV2A_0, EW_mcs_4 |
| May 08 | Airgun-shooting was continued. | EW_mcs_4, EW_mcs_5 |
| May 09 | Airgun-shooting was continued. | EW_mcs_5 |
| May 10 | Airgun-shooting was continued.<br>16:56~20:55 MBES survey<br>21:00 R/V Kairei left the survey area for Brisbane | EW_mcs_5 |
| May 11 | 11:30 R/V Kairei arrived at Brisbane. | Hamilton Whalf No.4 |
| May 12 | R/V Kairei were outfitted at Brisbane. | Hamilton Whalf No.4 |
| May 13 | R/V Kairei were outfitted at Brisbane. | Hamilton Whalf No.4 |
| May 14 | 10:00 R/V Kairei departed from Brisbane. | Hamilton Whalf No.4<br>Transit to Japan |
| May 26 | 9:00 R/V Kairei arrived at Yokosuka | Yokosuka |

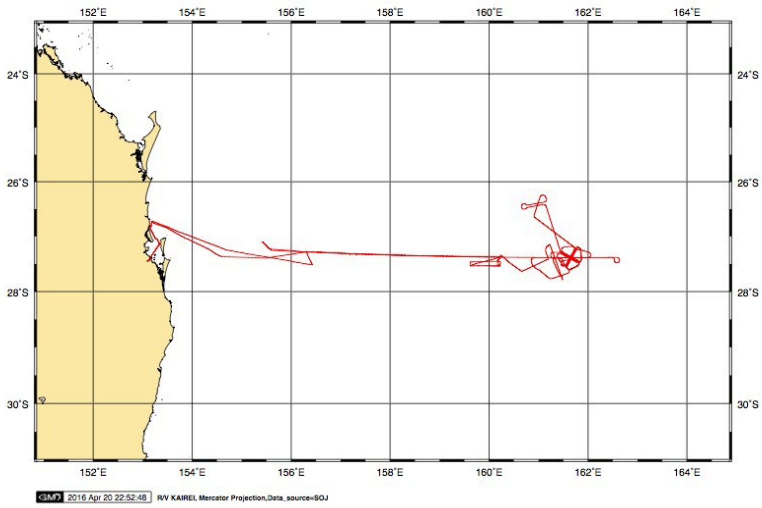
MBES map



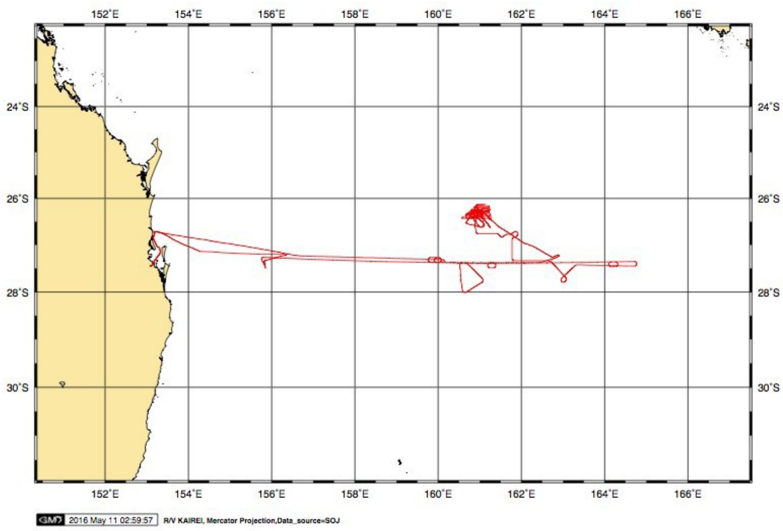
Leg1 ship track:



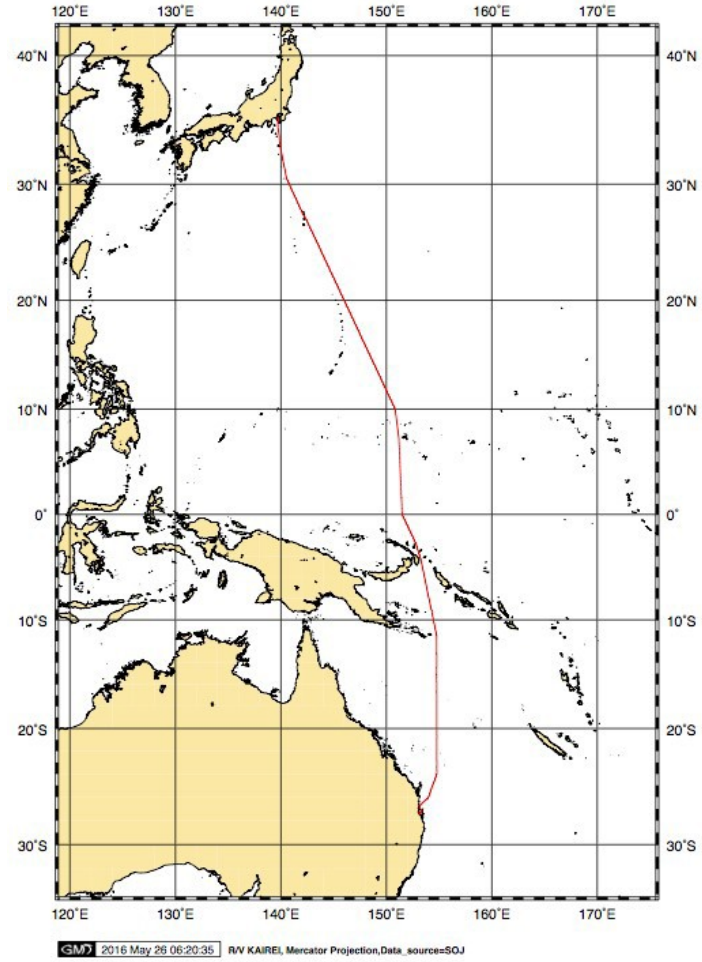

Leg2 ship track:




Leg3 ship track:



Transit:


120°E
130°E
140°E
150°E
160°E
170°E
40°N
30°N
20°N
10°N
0°
10°S
20°S
30°S
2016 May 26 06:20:35
R/V KAIREI, Mercator Projection,Data_source=SOJ

## A-2 MCS information

(1) MCS survey lines

| | Start | | End | | Total Length | Shot interval |
|---|---|---|---|---|---|---|
| | Latitude | Longitude | Latitude | Longitude | km | m |
| EW[1] | 27_15.57921'S | 155_44.29178'E | 27_22.90896'S | 162_34.65093'E | 677.00 | 200 |
| EW[2] | 27_23.07043'S | 161_22.12993'E | 27_23.07359'S | 161_56.59841'E | 56.85 | 50 |
| EW[3] | 27_15.74638'S | 155_48.28904'E | 27_21.16863'S | 164_39.87704'E | 877.35 | 50 |
| D1B-Line8 | 26_32.76218'S | 160_56.09821'E | 26_16.58920'S | 161_01.92622'E | 31.40 | 50 |
| D1B-Line9 | 26_25.91714'S | 160_45.59383'E | 26_23.05075'S | 161_03.04574'E | 29.50 | 50 |
| D1B-Line10 | 26_27.48610'S | 160_51.02199'E | 26_25.09127'S | 161_05.57754'E | 24.60 | 50 |
| D1B-Line11 | 26_23.75151'S | 160_48.25019'E | 26_36.06539'S | 160_59.22631'E | 29.15 | 50 |
| D1B-Line12 | 26_33.66383'S | 160_52.98207'E | 26_20.09693'S | 160_57.16332'E | 26.00 | 50 |
| D1B-Line13 | 26_19.93191'S | 160_50.49882'E | 26_29.89058'S | 161_02.99616'E | 27.75 | 50 |
| D2A-Line2 | 26_45.56725'S | 161_00.95118'E | 26_45.56347'S | 161_24.65321'E | 39.30 | 50 |
| D3A-Line1 | 27_18.56746'S | 161_32.10953'E | 27_26.31276'S | 161_47.67917'E | 29.40 | 50 |
| D3A-Line2 | 27_19.12369'S | 161_31.83099'E | 27_26.84633'S | 161_47.34665'E | 29.30 | 50 |
| D3A-Line3 | 27_19.65440'S | 161_31.49887'E | 27_27.37330'S | 161_47.01811'E | 29.30 | 50 |
| D3A-Line4 | 27_20.53813'S | 161_30.87657'E | 27_28.28814'S | 161_46.44794'E | 29.40 | 50 |
| D3A-Line5 | 27_28.68319'S | 161_34.73950'E | 27_14.82923'S | 161_43.31875'E | 29.25 | 50 |
| D3A-Line6 | 27_28.97417'S | 161_35.32397'E | 27_15.14925'S | 161_43.96256'E | 29.25 | 50 |
| D3A-Line7 | 27_30.72869'S | 161_35.00080'E | 27_16.85797'S | 161_43.67445'E | 29.35 | 50 |
| D3A-Line8 | 27_29.56750'S | 161_36.51657'E | 27_15.73589'S | 161_45.14202'E | 29.25 | 50 |
| BB1B | 27_41.53810'S | 163_03.92808'E | 27_26.03834'S | 162_47.61966'E | 39.30 | 50 |
| BV1B | 27_40.52160'S | 163_00.32902'E | 27_26.07277'S | 163_17.80194'E | 39.30 | 50 |
| BV2A | 27_58.90512'S | 160_42.89640'E | 27_47.68492'S | 161_03.20779'E | 39.25 | 50 |

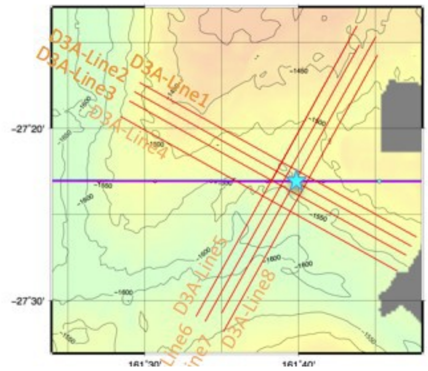
[1,2,3] we shot EW line for three times; 1: 200m shot for OBS, 2: 50m shot for OBS, 3: 50m shot for MCS

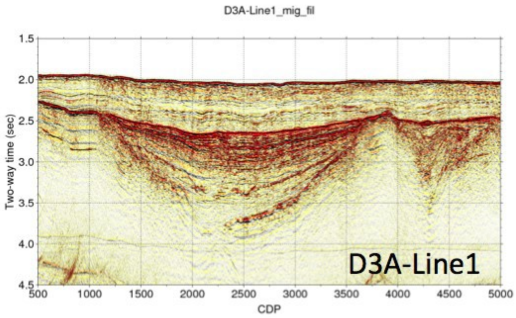
# airgun depth was 10m and streamer depth was 12m during 200 m shot interval

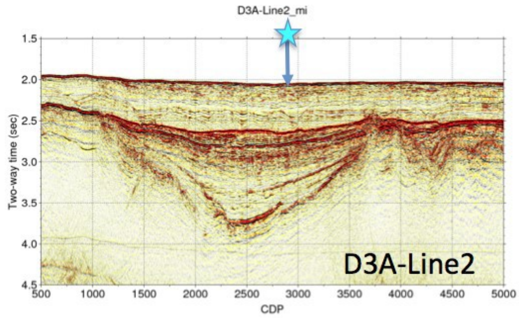
# airgun depth was 6m and streamer depth was 8m during 50 m shot interval

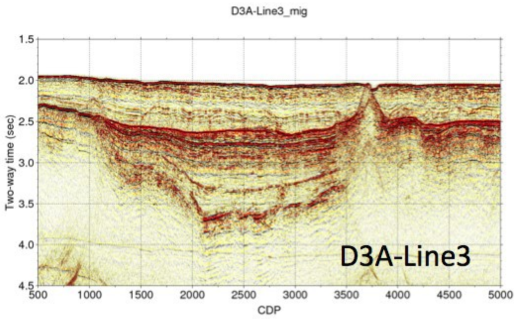
(2) MCS profiles

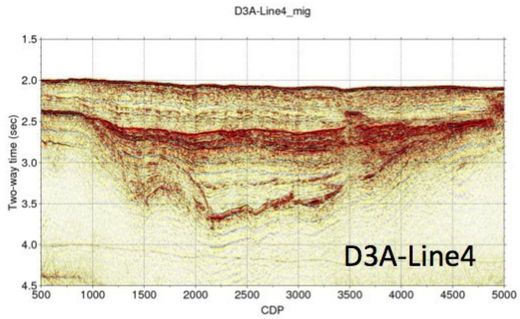
D3A

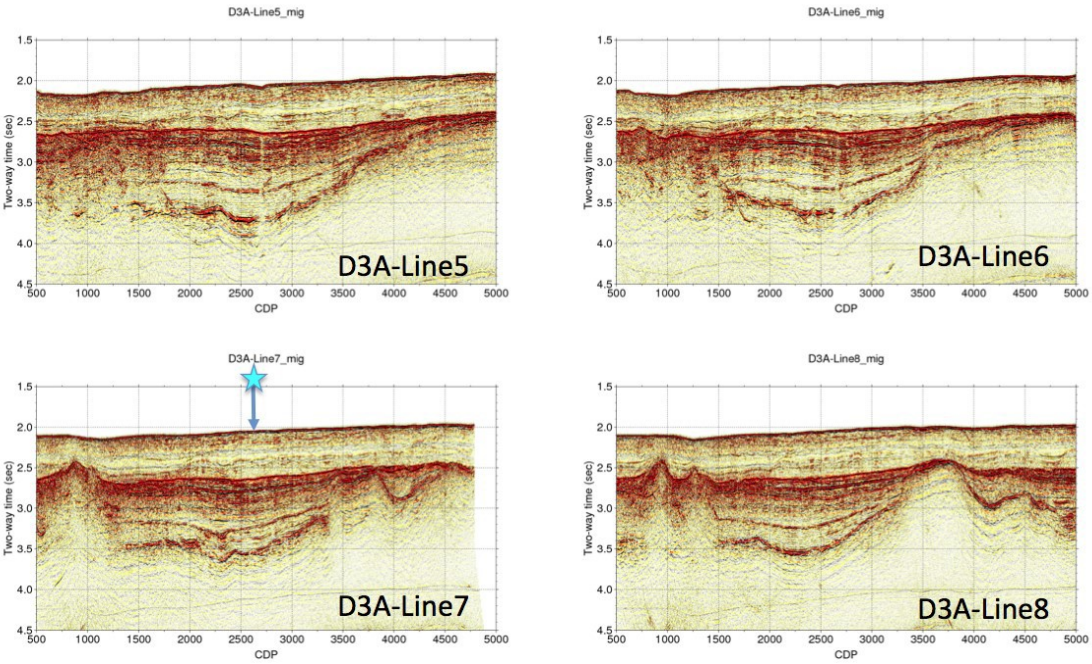


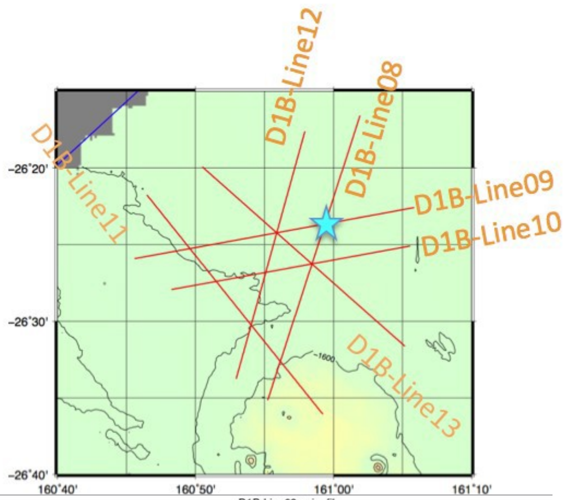



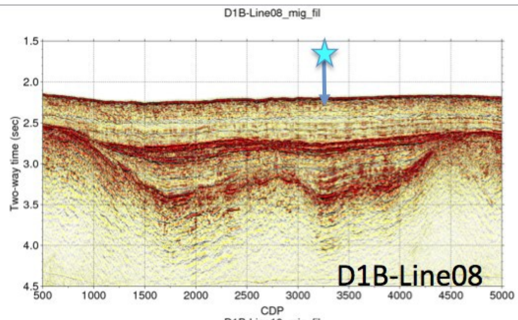



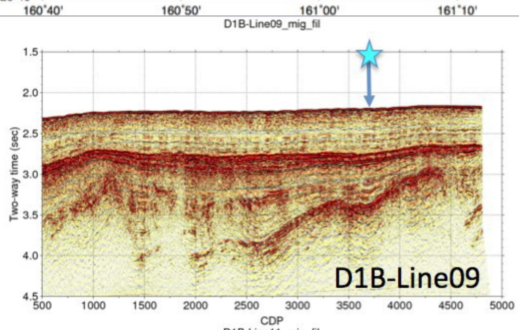



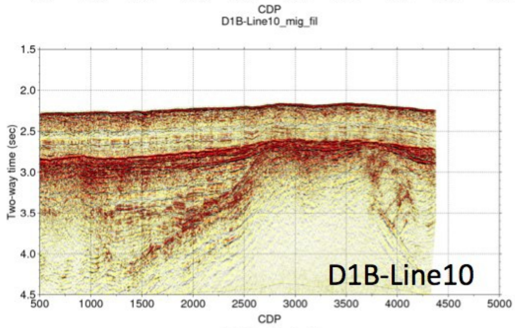

D3A-Line5_mig
D3A-Line5
D3A-Line6_mig
D3A-Line6
D3A-Line7_mig
D3A-Line7
D3A-Line8_mig
D3A-Line8
Two-way time (sec)
CDP
1.5
2.0
2.5
3.0
3.5
4.0
4.5
500
1000
1500
2000
2500
3000
3500
4000
4500
5000

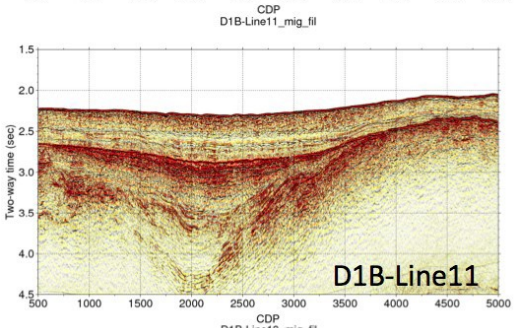
D1B

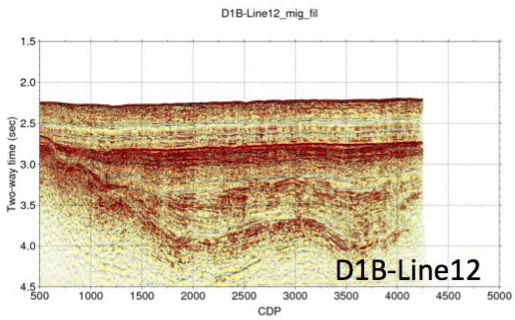

D1B-Line12
D1B-Line08
D1B-Line11
D1B-Line09
D1B-Line10
D1B-Line13
-26°20'
-26°30'
-26°40'
160°40'
160°50'
161°00'
161°10'
-1600

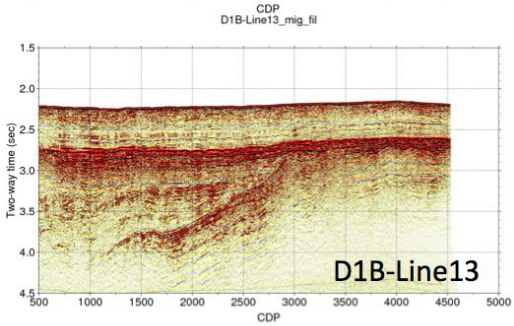

D1B-Line08_mig_fil
Two-way time (sec)
CDP
D1B-Line08


D1B-Line09_mig_fil
Two-way time (sec)
CDP
D1B-Line09

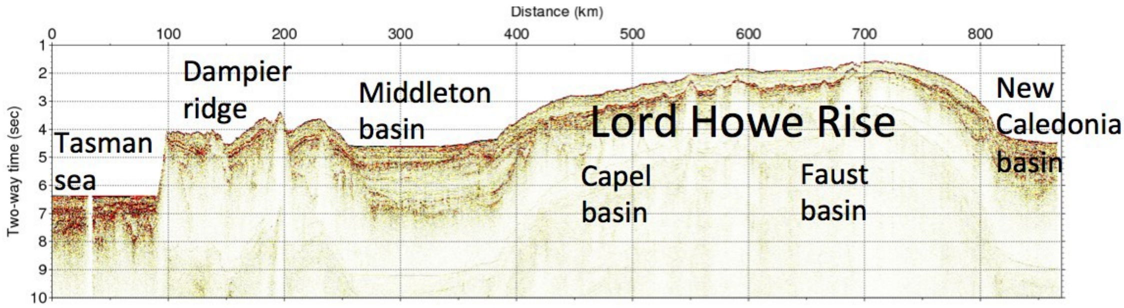

D1B-Line10_mig_fil
Two-way time (sec)
CDP
D1B-Line10

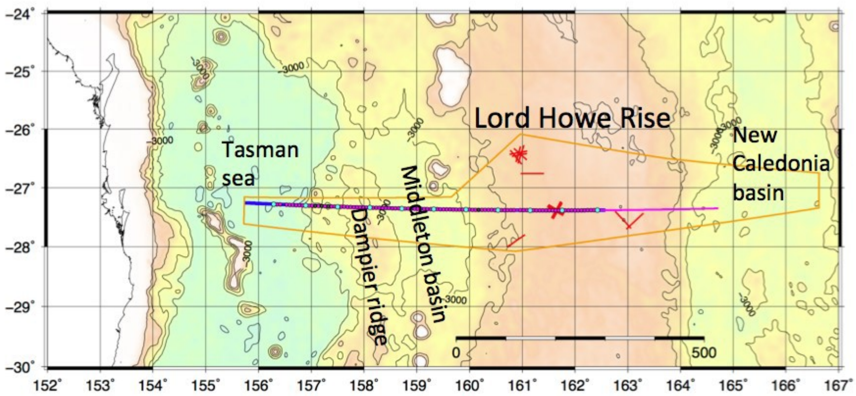

D1B-Line11_mig_fil
Two-way time (sec)
CDP
D1B-Line11

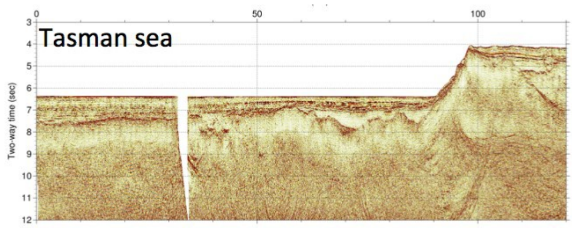

D1B-Line12_mig_fil
Two-way time (sec)
CDP
D1B-Line12

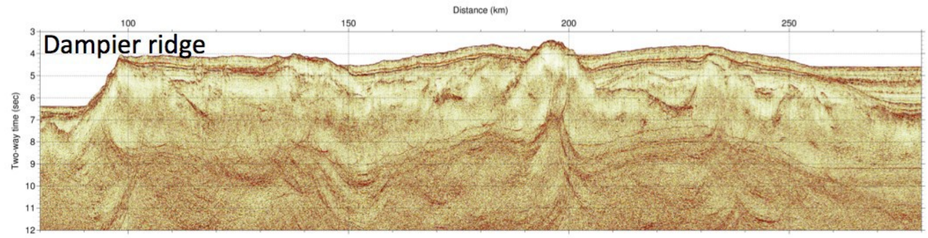

D1B-Line13_mig_fil
Two-way time (sec)
CDP
D1B-Line13

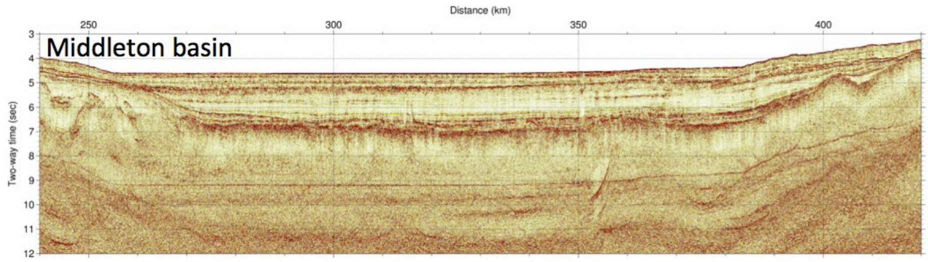
Reflection profile along EW line

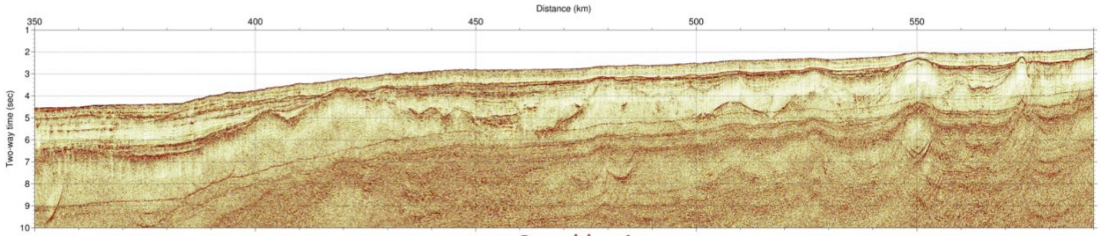


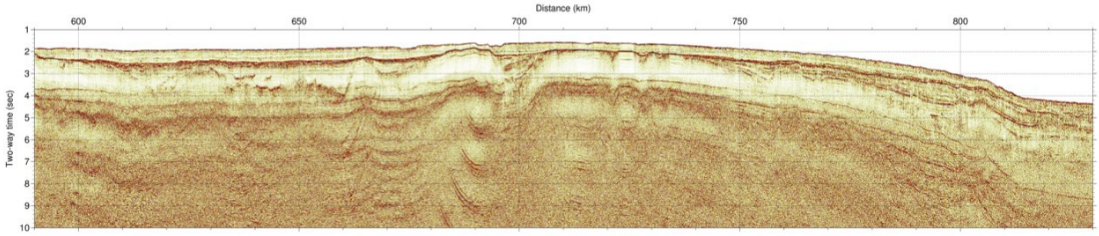






Capel basin




Faust basin

# A-3 OBS information

## (1) OBS List

Table A-3-1: OBS position list

| | Deploy | Recovery | Calibrated position | | | Battery Type | Trans-ponder | Note |
|---|---|---|---|---|---|---|---|---|
| Site | Time(UTC) | Time(UTC) | Latitude | Longitude | Depth | | | |
| 000 | 2016/04/02 19:03:59 | 2016/04/19 05:33:13 | 27_16.6250 | 156_17.4057 | 4930.0 | Rechargeable | KDC | |
| 001 | 2016/03/29 00:47:21 | 2016/04/19 04:18:42 | 27_17.0723 | 156_20.9801 | 4831.0 | Rechargeable | SGK | |
| 002 | 2016/03/28 23:42:00 | 2016/04/19 03:08:28 | 27_17.1240 | 156_24.4349 | 5004.0 | Rechargeable | SGK | |
| 004 | 2016/03/28 22:10:26 | 2016/04/19 00:52:50 | 27_17.3612 | 156_31.8148 | 5011.0 | Rechargeable | SGK | |
| 005 | 2016/03/28 21:03:14 | 2016/04/18 23:42:51 | 27_17.4649 | 156_35.4563 | 4972.0 | Rechargeable | SGK | |
| 006 | 2016/03/28 19:56:10 | 2016/04/18 22:20:28 | 27_17.5932 | 156_39.0892 | 4955.0 | Rechargeable | SGK | |
| 007 | 2016/03/28 18:48:02 | 2016/04/18 21:10:05 | 27_17.7819 | 156_42.7114 | 4985.0 | Rechargeable | SGK | |
| 008 | 2016/03/28 17:43:00 | 2016/04/18 19:52:48 | 27_17.9392 | 156_46.3455 | 5018.0 | Rechargeable | SGK | |
| 009 | 2016/03/28 16:38:20 | 2016/04/18 18:50:17 | 27_18.0790 | 156_49.9923 | 4872.5 | Rechargeable | SGK | |
| 010 | 2016/03/28 15:40:09 | 2016/04/18 17:44:05 | 27_18.1833 | 156_53.6521 | 3748.0 | Rechargeable | SGK | |
| 011 | 2016/03/28 14:45:49 | 2016/04/18 16:27:38 | 27_18.2842 | 156_57.2651 | 3288.9 | Rechargeable | SGK | |
| 012 | 2016/03/28 13:51:37 | 2016/04/18 15:21:38 | 27_18.4084 | 157_00.9136 | 3186.8 | Rechargeable | SGK | |
| 013 | 2016/03/28 12:55:23 | | 27_18.6167 | 157_04.6063 | 3260.0 | Rechargeable | SGK | Not recovered |
| 014 | 2016/03/28 11:58:23 | 2016/04/18 11:15:07 | 27_18.6500 | 157_08.1993 | 3223.0 | Rechargeable | SGK | |
| 015 | 2016/03/28 10:17:12 | | | | | Rechargeable | SGK | Not recovered |
| 016 | 2016/03/28 09:20:22 | 2016/04/18 07:14:57 | 27_18.8689 | 157_15.4771 | 3250.0 | Rechargeable | SGK | |
| 017 | 2016/03/28 08:23:13 | | 27_18.9681 | 157_19.1407 | 3093.0 | Rechargeable | SGK | Not recovered |
| 018 | 2016/03/28 07:26:29 | 2016/04/18 02:22:31 | 27_19.0987 | 157_22.7984 | 3286.0 | Rechargeable | SGK | |
| 019 | 2016/03/28 06:27:46 | 2016/04/18 01:07:24 | 27_19.1953 | 157_26.4220 | 3556.0 | Rechargeable | SGK | |
| 020 | 2016/03/28 05:29:12 | 2016/04/17 23:57:41 | 27_19.3309 | 157_30.0614 | 3481.3 | Rechargeable | SGK | |
| 021 | 2016/03/28 04:30:40 | 2016/04/17 22:37:06 | 27_19.4429 | 157_33.7104 | 3308.7 | Rechargeable | SGK | |
| 022 | 2016/03/28 03:31:27 | 2016/04/17 21:17:56 | 27_19.5545 | 157_37.3793 | 3118.5 | Rechargeable | SGK | |
| 023 | 2016/03/28 02:33:01 | 2016/04/17 20:00:10 | 27_19.6739 | 157_41.0071 | 2997.0 | Rechargeable | SGK | |
| 024 | 2016/03/28 01:39:20 | 2016/04/17 18:57:53 | 27_19.7723 | 157_44.6408 | 2848.0 | Rechargeable | SGK | |
| 025 | 2016/03/28 00:46:35 | 2016/04/17 17:45:24 | 27_19.9142 | 157_48.2063 | 2881.0 | Rechargeable | SGK | |
| 026 | 2016/03/27 23:53:49 | 2016/04/17 16:40:29 | 27_20.0010 | 157_51.7787 | 2846.0 | Rechargeable | SGK | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 027 | 2016/03/27 22:58:54 | 2016/04/17 15:30:42 | 27_20.1182 | 157_55.5349 | 2866.0 | Rechargeable | SGK | |
| 028 | 2016/03/27 22:02:52 | 2016/04/17 14:23:28 | 27_20.2273 | 157_59.1475 | 3143.0 | Rechargeable | SGK | |
| 029 | 2016/03/27 21:06:02 | 2016/04/17 13:14:58 | 27_20.3538 | 158_02.8298 | 3092.0 | Rechargeable | SGK | |
| 030 | 2016/03/27 20:11:31 | 2016/04/17 12:06:28 | 27_20.4285 | 158_06.4792 | 2960.0 | Rechargeable | SGK | |
| 031 | 2016/03/27 19:17:16 | 2016/04/17 11:00:17 | 27_20.5225 | 158_10.1162 | 2852.0 | Rechargeable | SGK | |
| 032 | 2016/03/27 18:23:48 | 2016/04/17 09:54:51 | 27_20.6200 | 158_13.7501 | 2850.0 | Rechargeable | SGK | |
| 033 | 2016/03/27 17:29:47 | 2016/04/17 08:42:24 | 27_20.6720 | 158_17.4337 | 2898.9 | Rechargeable | SGK | |
| 034 | 2016/03/27 16:35:24 | 2016/04/17 07:07:51 | 27_20.9121 | 158_21.0852 | 3088.7 | Rechargeable | SGK | |
| 035 | 2016/03/27 15:39:13 | 2016/04/17 06:05:38 | 27_20.8330 | 158_24.7117 | 3235.9 | Rechargeable | SGK | Vertical Signal is weak |
| 036 | 2016/03/27 14:42:15 | 2016/04/17 05:02:37 | 27_20.9409 | 158_28.3194 | 3387.0 | Rechargeable | SGK | |
| 037 | 2016/03/27 13:45:24 | 2016/04/17 03:57:21 | 27_21.0412 | 158_31.9686 | 3528.0 | Rechargeable | SGK | |
| 038 | 2016/03/27 12:49:24 | 2016/04/17 02:43:50 | 27_21.1538 | 158_35.5663 | 3611.0 | Rechargeable | SGK | |
| 039 | 2016/03/27 11:52:22 | 2016/04/17 01:36:09 | 27_21.1849 | 158_39.2051 | 3619.0 | Rechargeable | SGK | |
| 040 | 2016/03/27 10:55:06 | 2016/04/17 00:27:53 | 27_21.2262 | 158_42.8635 | 3580.0 | Rechargeable | SGK | |
| 041 | 2016/03/27 09:55:35 | 2016/04/16 23:20:23 | 27_21.2782 | 158_46.5302 | 3598.0 | Rechargeable | SGK | |
| 042 | 2016/03/27 08:55:06 | 2016/04/16 22:12:39 | 27_21.3774 | 158_50.1998 | 3586.0 | Rechargeable | SGK | |
| 043 | 2016/03/26 20:30:15 | 2016/04/16 21:05:50 | 27_21.4278 | 158_53.8927 | 3566.0 | Rechargeable | SGK | |
| 044 | 2016/03/26 19:31:09 | 2016/04/16 19:55:17 | 27_21.6940 | 158_57.3570 | 3579.0 | Rechargeable | SGK | |
| 045 | 2016/03/26 18:30:20 | 2016/04/16 18:04:55 | 27_21.5780 | 159_01.1528 | 3583.0 | Rechargeable | SGK | |
| 046 | 2016/03/26 17:29:49 | 2016/04/16 17:31:16 | 27_21.6628 | 159_04.7943 | 3563.2 | Rechargeable | SGK | |
| 047 | 2016/03/26 16:30:12 | 2016/04/16 16:17:02 | 27_21.7428 | 159_08.4600 | 3583.0 | Rechargeable | SGK | |
| 048 | 2016/03/26 15:27:54 | 2016/04/16 15:07:50 | 27_21.7760 | 159_12.1408 | 3590.0 | Rechargeable | SGK | |
| 049 | 2016/03/26 14:26:27 | 2016/04/16 13:50:22 | 27_21.8525 | 159_15.7530 | 3595.7 | Rechargeable | SGK | |
| 050 | 2016/03/26 13:23:45 | 2016/04/16 12:33:21 | 27_21.9394 | 159_19.3689 | 3578.1 | Rechargeable | SGK | |
| 051 | 2016/03/26 23:04:05 | 2016/04/16 11:18:38 | 27_22.0258 | 159_23.0873 | 3570.0 | Rechargeable | SGK | |
| 052 | 2016/03/27 00:02:59 | 2016/04/16 09:58:34 | 27_22.0867 | 159_26.6489 | 3463.0 | Li-ion | KDC | |
| 053 | 2016/03/27 01:01:48 | 2016/04/16 08:49:16 | 27_22.1533 | 159_30.3519 | 3539.0 | Li-ion | KDC | |
| 054 | 2016/03/27 02:02:13 | 2016/04/16 07:40:38 | 27_22.1737 | 159_33.9692 | 3371.6 | Li-ion | KDC | (*1) |
| 055 | 2016/03/27 03:02:48 | 2016/04/16 06:26:33 | 27_22.2198 | 159_37.5907 | 3330.6 | Li-ion | KDC | |
| 056 | 2016/03/27 04:04:31 | 2016/04/16 05:17:26 | 27_22.2596 | 159_41.2868 | 3389.9 | Li-ion | KDC | |
| 057 | 2016/03/27 05:04:00 | 2016/04/16 04:11:56 | 27_22.1759 | 159_44.7944 | 3375.0 | Li-ion | KDC | |
| 058 | 2016/03/26 | 2016/04/16 | 27_22.3271 | 159_48.5895 | 3244.0 | Li-ion | KDC | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 10:30:21 | 03:04:12 | | | | | | |
| 059 | 2016/03/26 09:33:37 | 2016/04/16 01:52:25 | 27_22.4065 | 159_52.2825 | 3047.0 | Li-ion | KDC | |
| 060 | 2016/03/26 06:56:52 | 2016/04/16 00:46:32 | 27_22.4185 | 159_55.8401 | 3013.0 | Li-ion | KDC | |
| 061 | 2016/03/26 05:57:08 | 2016/04/15 23:46:02 | 27_22.4553 | 159_59.5349 | 2785.0 | Li-ion | KDC | |
| 062 | 2016/03/26 04:59:17 | 2016/04/15 22:45:32 | 27_22.5072 | 160_03.1742 | 2727.8 | Li-ion | KDC | |
| 063 | 2016/03/26 04:02:11 | 2016/04/15 21:44:09 | 27_22.5331 | 160_06.8295 | 2627.4 | Li-ion | KDC | |
| 064 | 2016/03/26 03:07:40 | | 27_22.5790 | 160_10.4346 | 2509.0 | Li-ion | KDC | Not recovered |
| 065 | 2016/03/26 02:13:49 | 2016/04/15 19:56:15 | 27_22.6345 | 160_14.1023 | 2419.0 | Li-ion | KDC | |
| 066 | 2016/03/26 01:21:49 | 2016/04/23 06:43:04 | 27_22.6936 | 160_17.7407 | 2316.0 | Li-ion | KDC | |
| 067 | 2016/03/26 00:29:41 | 2016/04/23 07:44:11 | 27_22.7310 | 160_21.3733 | 2252.0 | Li-ion | KDC | |
| 068 | 2016/03/25 23:38:31 | 2016/04/23 08:40:21 | 27_22.7475 | 160_25.0183 | 2160.0 | Li-ion | KDC | |
| 069 | 2016/03/25 22:49:09 | 2016/04/23 09:30:42 | 27_22.7919 | 160_28.6681 | 2165.0 | Li-ion | KDC | |
| 070 | 2016/03/25 21:58:27 | 2016/04/23 10:22:58 | 27_22.8025 | 160_32.3055 | 2127.0 | Li-ion | KDC | |
| 071 | 2016/03/25 21:06:38 | 2016/04/23 11:31:42 | 27_22.8376 | 160_35.9382 | 2140.0 | Li-ion | KDC | |
| 072 | 2016/03/25 20:15:03 | 2016/04/23 12:26:33 | 27_22.8600 | 160_39.5814 | 2150.0 | Li-ion | KDC | |
| 073 | 2016/03/25 19:22:19 | 2016/04/23 13:23:47 | 27_22.8764 | 160_43.2411 | 2057.0 | Li-ion | KDC | |
| 074 | 2016/03/25 18:29:47 | 2016/04/23 14:28:34 | 27_22.8769 | 160_46.8755 | 1979.0 | Li-ion | KDC | |
| 075 | 2016/03/25 17:45:03 | 2016/04/23 15:35:15 | 27_22.9451 | 160_49.9243 | 1958.0 | Li-ion | KDC | |
| 077 | 2016/03/25 16:30:31 | 2016/04/23 16:58:37 | 27_22.9860 | 160_57.8329 | 1943.0 | Li-ion | KDC | |
| 078 | 2016/03/25 15:39:25 | 2016/04/23 17:56:53 | 27_22.9806 | 161_01.5175 | 1908.0 | Li-ion | KDC | |
| 079 | 2016/03/25 14:46:56 | 2016/04/23 18:58:50 | 27_23.0016 | 161_05.1425 | 1785.0 | Li-ion | KDC | |
| 080 | 2016/03/25 13:57:01 | 2016/04/23 19:55:54 | 27_23.0170 | 161_08.7688 | 1868.9 | Li-ion | KDC | |
| 081 | 2016/03/25 13:07:26 | 2016/04/23 20:58:34 | 27_23.0043 | 161_12.4092 | 1833.0 | Li-ion | KDC | |
| 082 | 2016/03/25 12:18:57 | 2016/04/23 22:02:31 | 27_23.0457 | 161_16.0849 | 1776.0 | Li-ion | KDC | |
| 083 | 2016/03/25 11:30:30 | 2016/04/23 23:03:58 | 27_23.0797 | 161_19.6634 | 1800.0 | Li-ion | KDC | |
| 084 | 2016/03/25 10:41:33 | 2016/04/24 00:04:34 | 27_23.0755 | 161_23.3461 | 1746.0 | Li-ion | KDC | |
| 085 | 2016/03/25 09:48:24 | 2016/04/24 01:03:07 | 27_23.0486 | 161_27.0318 | 1637.0 | Li-ion | KDC | |
| 086 | 2016/03/25 08:54:17 | 2016/04/24 01:56:46 | 27_23.0710 | 161_30.6638 | 1561.0 | Li-ion | KDC | |
| 087 | 2016/03/25 08:00:11 | 2016/04/24 02:56:45 | 27_23.0833 | 161_34.3110 | 1599.0 | Li-ion | KDC | |
| 088 | 2016/03/25 07:05:40 | 2016/04/24 03:49:05 | 27_23.0741 | 161_37.9797 | 1586.0 | Li-ion | KDC | |
| 089 | 2016/03/25 06:09:01 | 2016/04/24 04:49:12 | 27_23.0179 | 161_41.6069 | 1564.0 | Li-ion | KDC | |
| 090 | 2016/03/25 05:14:21 | 2016/04/24 05:49:34 | 27_23.1021 | 161_45.3022 | 1536.8 | Li-ion | KDC | |
| 091 | 2016/03/25 | 2016/04/24 | 27_23.1134 | 161_48.9853 | 1471.3 | Li-ion | KDC | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 04:19:16 | 06:46:34 | | | | | | |
| 092 | 2016/03/25 03:24:05 | 2016/04/24 07:45:37 | 27_23.1323 | 161_52.7066 | 1428.0 | Li-ion | KDC | |
| 093 | 2016/03/25 02:28:41 | 2016/04/24 08:41:51 | 27_23.1280 | 161_56.2791 | 1434.0 | Li-ion | KDC | |
| 094 | 2016/03/25 01:30:25 | 2016/04/24 09:38:46 | 27_23.0305 | 161_59.9043 | 1446.0 | Li-ion | KDC | |
| 095 | 2016/03/25 00:26:46 | 2016/04/24 10:38:42 | 27_23.1586 | 162_03.5433 | 1465.0 | Li-ion | KDC | |
| 096 | 2016/03/24 23:31:54 | 2016/04/24 11:33:06 | 27_23.0928 | 162_07.2364 | 1526.0 | Li-ion | KDC | |
| 097 | 2016/03/24 22:35:09 | 2016/04/24 12:22:47 | 27_23.0968 | 162_10.8356 | 1491.0 | Li-ion | KDC | |
| 098 | 2016/03/24 21:39:28 | 2016/04/24 13:21:34 | 27_23.0863 | 162_14.4875 | 1470.0 | Li-ion | KDC | |
| 099 | 2016/03/24 20:43:21 | 2016/04/24 14:17:13 | 27_23.0587 | 162_18.1506 | 1439.6 | Li-ion | KDC | |
| 100 | 2016/03/24 19:47:21 | 2016/04/24 15:23:23 | 27_23.0257 | 162_21.7909 | 1451.6 | Li-ion | KDC | |
| 101 | 2016/03/24 19:01:04 | 2016/04/24 16:17:30 | 27_22.9986 | 162_25.4304 | 1419.0 | Li-ion | KDC | |

(*1) Data was not decodable from 2016/04/08 00:12:54 to 2016/04/08 02:10:26.

(2) OBS sections

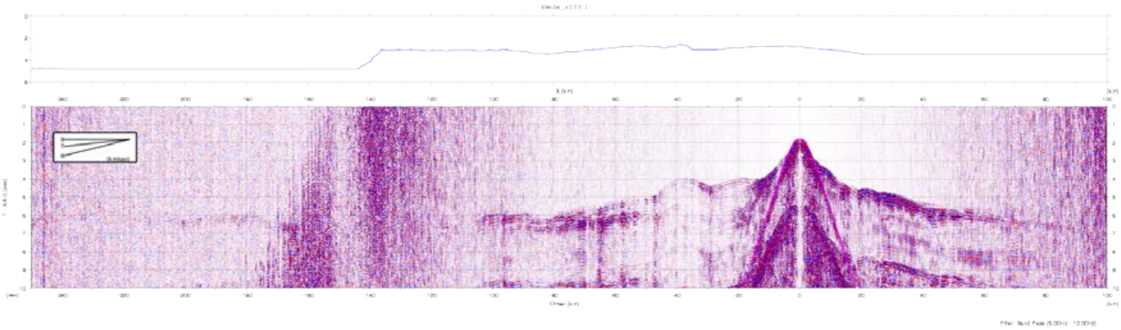


Fig. A-3-1 OBS section of site 033 vertical

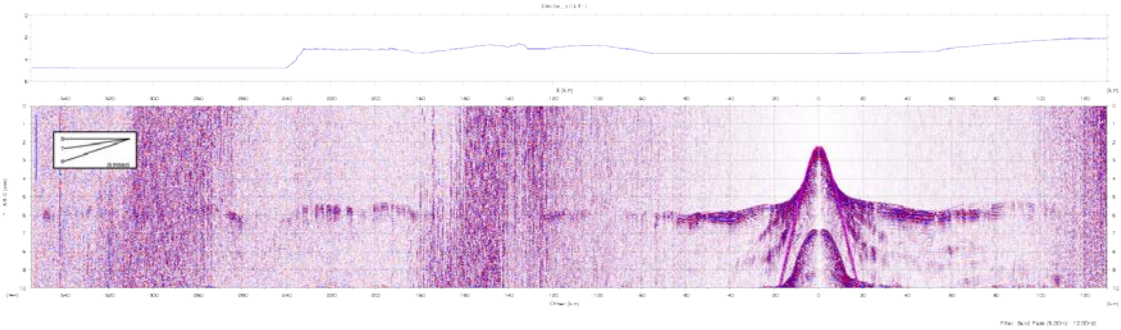


Fig. A-3-2 OBS section of site 049 vertical

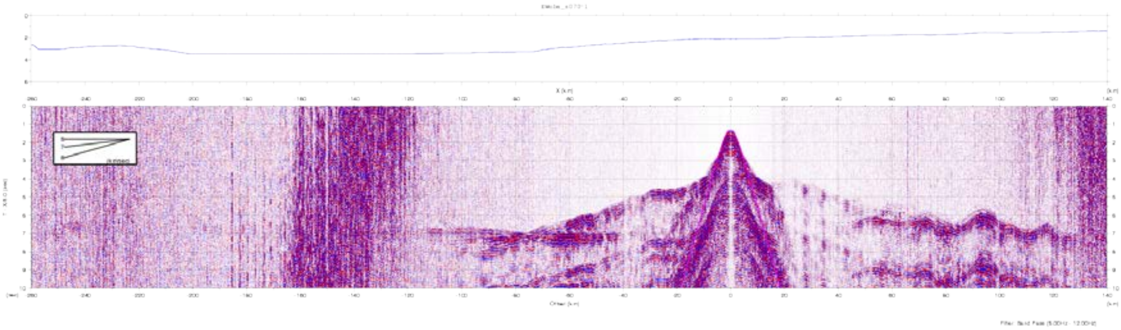


Fig. A-3-3 OBS section of site 070 vertical

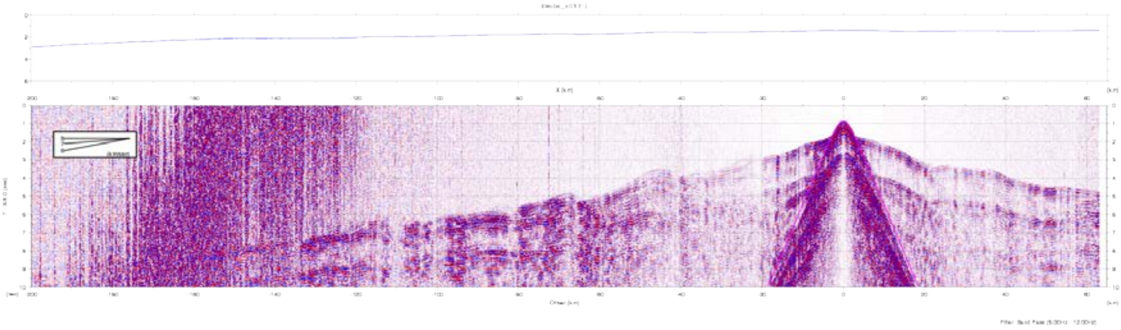
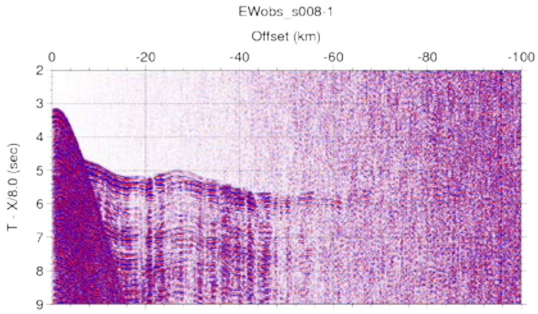
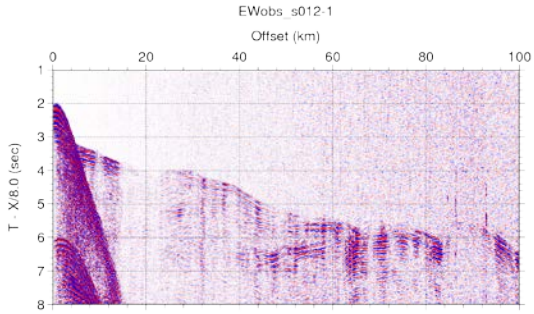


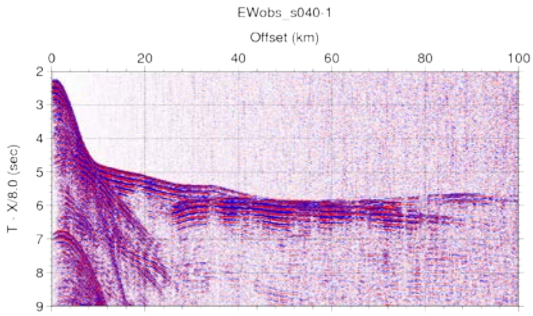
Fig. A-3-4 OBS section of site 093 vertical



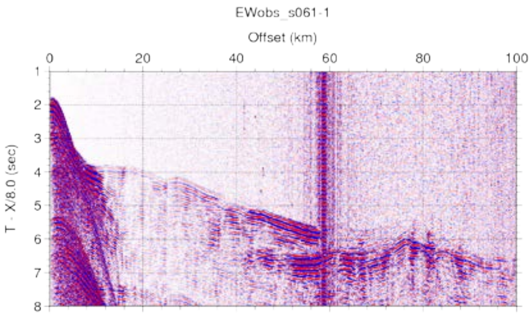

(1) Tasman sea (Site008)



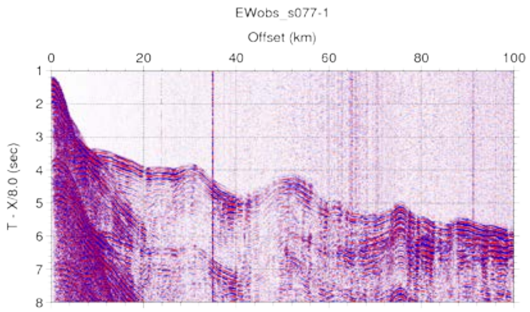

(2) Dampier ridge (Site012)



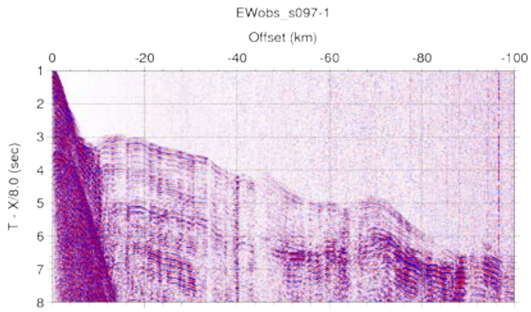

(3) Middleton basin (Site040)




(4) Capel basin (Site061)




(5) Capel basin (Site077)




(6) Faust basin (Site097)

Figure A-3-5 Variations in Moho reflections in OBS sections

Moho reflection is unclear in Tasman sea, suggesting the Tasman sea area is different from the normal oceanic plate. In contrast, seismic sections in Middleton basin are very similar to the normal oceanic plate (very thin crust and clear Moho reflection). Crust should be very thick in Lord Howe Rise (Site061-Site097). These OBS data will reveal variations in crustal thickness and the nature of Moho discontinuity along the EW profile.

## A-4 Data and formats

1. Data volume acquired during this cruise

(1) MCS data

| | Lines | Total length | Shots |
|---|---|---|---|
| 200m shot spacing | 1 | 677 km | 3,385 |
| 50m shot spacing | 20 | 1494km | 29,885 |
| Total | 21 | 2171km | 33,270 |

(2) OBS

| Deployed OBSs (data recovered) | Shots | Seismic traces |
|---|---|---|
| 100 (95) | 4,006 | 384,576 |

# We could not recover 4 OBSs and one of recovered OBSs did not record any data due to mechanical troubles.

(3) MBES (Multi-Beam Echo Sounder)

| | Length of survey lines*1 | Good data*2 |
|---|---|---|
| Leg1 | 1,884 km | 614 km |
| Leg2 | 3,757 km | 2,809 km |
| Leg3 | 4,620 km | 2,839 km |
| Total | 10,079 km | 6,262 km |

*1: Ship track length during MBES survey (including overwrap along the same lines)

*2: Ship track length during MBES survey at a low vessel speed (less than 8 knots)

(4) Sub bottom profiler

| | Length of survey lines | Number of SEG-Y traces |
|---|---|---|
| Leg2 | 3,179 km | 140,565 |
| Leg3 | 2,756 km | 79,309 |
| Total | 5,935 km | 219,874 |

# We did not use the sub bottom profiler during the Leg 1.

(5) XBT/XCTD (measurements of sound velocity in the water column)

| | XBT | XCTD | Maximum measured depth |
|---|---|---|---|
| Leg 1 | 1 | 0 | 1765 m |
| Leg 2 | 0 | 3 | 5244 m |
| Leg 3 | 0 | 1 | 1600 m |

(6) Gravity

| | Observation period | Length of ship track |
|---|---|---|
| Leg1 | 168 hours | 2,363 km |
| Leg2 | 433.5 hours | 4,196 km |
| Leg3 | 457 hours | 5,086 km |
| Total | 1058.5 hours | 11,645 km |

# Gravity data were continuously observed during the cruise.

(7) Magnetic

| | Observation period | Length of ship track |
|---|---|---|
| Leg1 | 168 hours | 2,363 km |
| Leg2 | 433.5 hours | 4,196 km |
| Leg3 | 448 hours | 5,007 km |
| Total | 1049.5 hours | 11,566 km |

# Magnetic data were continuously observed during the cruise, but recording stopped from May 1, 14:57:40 to May2, 00:21:21 (local time) due to a recording trouble.

2. Data format

(1) MCS data

SEG-D and SEG-Y

Recording length: 15 sec (50 m shot spacing), 35 sec (200 m shot spacing)

(2) OBS data

Raw data : continuous data in a special data format of OBS manufacturer

Shot data : 160 second from every shots in IASPEI SEG-Y format

(3) Gravity

Raw data and calibration sheet

(4) Magnetic data
STCM data format

(5) MBES data
Raw data： standard data format of ELAC Seabeam 3012
All the raw data are converted into Caris format.
In addition, onboard processed Ascii data (longitude, latitude, depth) and grid format (netCDF) are also available.

(6) Subbottom profile
Raw and Seg-Y

(7) XBT and XCTD data
Raw data are in the Ascii format.

(8) SOJ data
Vessel data, like vessel position and speed including some geophysical observations, are store in the SOJ files. SOJ is a fixed column, line-oriented ASCII data format adopted by the research vessels of JAMSTEC. An example line and its explanations are shown in the following. During the cruise, we obtained SOJ data every 1 second.

| Example | Item | Content | byte | offset | remarks |
|---|---|---|---|---|---|
| $SOJ: | header info | fixed | 5 | 0 | |
| +10.0 | offset time from UTC | ±hh.h | 5 | 5 | |
| 20160501 | UTC date | YYYYMMDD | 8 | 11 | |
| 235959 | UTC time | hhmmss | 6 | 20 | |
| W84 | Datum | W84/W72/TD_/NAx/ I92/LCL | 3 | 27 | NAx; x is a datum number in North America |
| GP1 | GPS No. | HYB/GPn/LC1/LC2/ DR_/NG_ | 3 | 31 | |
| V | status 1 | V/I | 1 | 35 | V：valid / I：invalid |
| 999.9 | status 2 | HDOP | 5 | 37 | |
| 12 | status 3 | GPS satellite total number | 2 | 43 | |
| 27-10.1234 5S | Latitude | LAT | 12 | 46 | |
| 159-35.123 45E | Longitude | LON | 13 | 60 | |
| HYB | data sensor | HYB/GPn/LC1/LC2/ DS_/ADC | 3 | 78 | HYB：hyb / GP1：gps1 / LC1：loranC1 / DS：doppler-sonar / ADC：adcp |
| G | LOG speed status | G：ground / W：water / I：invalid | 1 | 82 | |
| -99.9 | LOG speed | speed(m/s) | 5 | 83 | |
| HYB | data sensor | HYB/GPn/LC1/LC2/ DS_/ADC | 3 | 89 | HYB：hyb / GP1：gps1 / LC1：loranC1 / DS： |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | doppler-sonar / ADC：adcp |
| G | SOG status | G：ground / W：water / I：invalid | 1 | 93 | |
| 359.9 | SOG | COURSE | 5 | 94 | |
| V | DS status | V：valid / I：invalid | 1 | 100 | DS：doppler-sonar |
| -99.9 | LOG speed | doppler-sonar | 5 | 101 | |
| V | GYRO status | V：valid / I：invalid | 1 | 107 | |
| 359.9 | GYRO Co. | ship heading | 5 | 108 | |
| T: | header info | fixed | 2 | 114 | |
| V | Air temp status | V：valid / I：invalid | 1 | 116 | |
| -99.99 | Air Temp | degrees(℃) | 6 | 117 | |
| V | Temp status | V：valid / I：invalid | 1 | 124 | |
| -99.99 | Surface seawater temperature | degrees (℃) | 7 | 125 | |
| D: | header info | fixed | 2 | 133 | |
| P | data sensor | P：pdr / M：mnb / A：adcp | 1 | 135 | |
| V | Depth status | V：valid / I：invalid | 1 | 137 | |
| 19999.9 | water depth | DEPTH (m) | 7 | 138 | MNB data (directly beneath the vessel) |
| A: | header info | fixed | 2 | 146 | |
| V | Atmospheric status | V：valid / I：invalid | 1 | 148 | |
| 9999.9 | Barometric pressure | hPa | 6 | 149 | |
| V | humidity status | V：valid / I：invalid | 1 | 156 | |
| 999 | Humidity | % | 3 | 157 | |
| W: | header info | fixed | 2 | 161 | |
| V | Wind status | V：valid / I：invalid | 1 | 163 | |
| 999 | Relatively wind direction | direction(Deg) | 3 | 164 | |
| 99.9 | Relatively wind speed | speed(m/s) | 4 | 168 | |
| 999 | True wind direction | direction(Deg) | 3 | 173 | |
| 99.9 | True wind speed | speed(m/s) | 4 | 177 | |
| R: | header info | fixed | 2 | 182 | |
| V | Rainfall status | V：valid / I：invalid | 1 | 184 | |
| 99.9 | Rainfall | (mm) | 4 | 185 | |
| V | volume of sunlight status | V：valid/I：invalid | 1 | 190 | |
| 9.99 | volume of sunlight | (kw/m^2) | 4 | 191 | |

| | | | | | |
|---|---|---|---|---|---|
| E: | header info | fixed | 2 | 196 | |
| V | EPCS status | V : valid / I : invalid | 1 | 198 | |
| 99.9999 | salinity status | (%) | 7 | 199 | |
| H: | header info | fixed | 2 | 207 | |
| V | Height of GPS status | V : valid / I : invalid | 1 | 209 | |
| -999.9 | height | height of GPS(m) | 6 | 210 | |
| V | Magnet status | V : valid / I : invalid | 1 | 217 | |
| 999999 | Proton magnetic force | 0.1 (nT) | 6 | 218 | |
| V | Gravity status | V : valid / I : invalid | 1 | 225 | |
| -99999.99 | Gravity | (mGal) | 9 | 226 | |
| V | current status | V : valid / I : invalid | 1 | 236 | |
| 999.9 | current direction | (Deg) | 5 | 237 | |
| 99.9 | current speed | (m/s) | 4 | 243 | |
| <0D><0A> | terminate | CR,LF | 2 | 248 | |