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R/V Hakuho-Maru

Cruise Report
KH-24-4

Port Luis (Mauritius) – Penang (Malaysia)
Oct. 12 – Nov. 8, 2024

Acknowledgments

We are grateful to Captain N. Sakai and the crew of R/V Hakuho-maru for their professional work to make the cruise successful. We also thank the staff of the Center for Coordination at the Atmosphere and Ocean Research Institute (AORI), the University of Toyo, and members of the Institute for Marine-Earth Exploration and Engineering (MarE3), Japan Agency for Marine-Earth Science and Technology (JAMSTEC).

We sincerely appreciate the support of the Mauritius Government. This project was carried out under the MoU between AORI and the Prime Minister's Office, Department for Continental Shelf, Maritime Zones Administration and Exploration (CSMZAE), Republic of Mauritius.
We also thank the Centre for Marine & Coastal Studies (CEMACS), University of Science Malaysia, for cooperating with conducting the land gravity observations at Penang.

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1. Cruise Information

- Cruise ID KH-24-4
- Name of vessel R/V Hakuho maru
- Title of project MOWALL (Moho Observation along transform fault WALL)
  JSPS KAKENHI Grant Number 23K22590
- Title of Cruise
  - MOWALL-CIR: Temporal variation of mid-ocean ridge process recorded along long oceanic transform wall
  - Evaluation of the distribution of continental crust fragments in the Indian Ocean
- Chief Scientist OKINO, Kyoko The University of Tokyo
- Cruise period 2024.10.12 – 2024.11.8
- Port of departure Port Luis (Mauritius)
- Port of arrival Penang (Malaysia)
- Research area Indian Ocean
- Representative of Science Party

  OKINO Kyoko Atmosphere and Ocean Research Institute, The University of Tokyo

  SATO Hiroshi Senshu University (onshore)

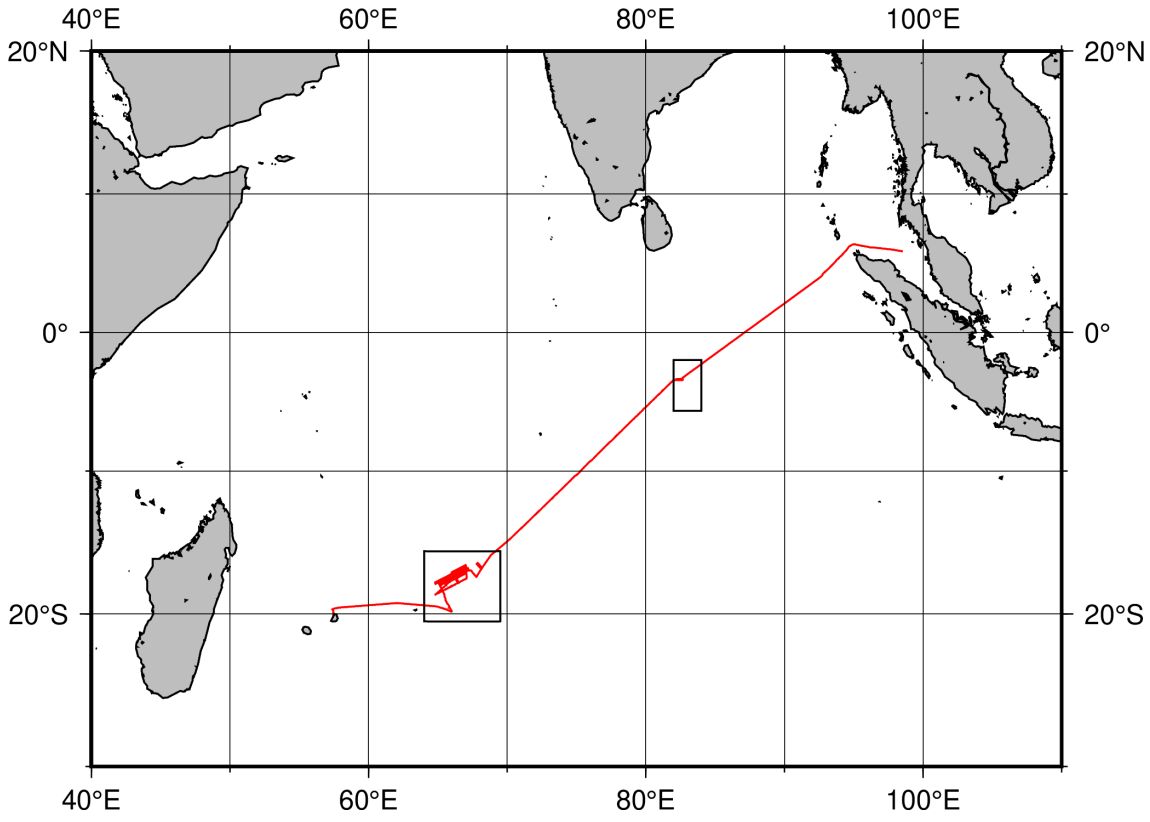

Fig.1 Survey area and track line. Area A: Marie Celeste Transform Fault, CIR, Area B: Apharnasey Nikitin Rise

2. List of Participants

Onboard Scientific Team

Principle Investigator

OKINO Kyoko	The University of Tokyo

Rocks

MACHIDA Shiki	Chiba Institute of Technology
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Geophysics

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MAKABE Akiko	Japan Agency for Marine-Earth Science and Technology
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Mauritian Observers

BISSESSUR, Prithivi Dass

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R/V Hakuho-maru Officers and Crew

SAKAI Naoto	Captain
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ITAHASHI Kazuhiko	First Officer
UEHARA Shuta	Second Officer
SASAKI Takashi	Jr. Second Officer
SHINOHATA Aoi	Third Officer
MUTO Daiya	Jr. Third Officer
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OGAWA Hiroyuki	Associate Boatswain
TERASAKA Yukihiro	Associate Boatswain
YAMAZAKI Myuta	Associate Boatswain
MIYAGI Takumi	Quarter Master
UCHIYAMA Koki	Quarter Master
ANDO Masashi	Quarter Master
KOGANE Sotaro	Sailor
MIYAMOTO Goro	Chief Engineer
YAMAMURA Takatoshi	First Engineer
SAKAMOTO Shota	Jr. First Engineer
YOKOYAMA Yudai	Second Engineer
KISO Subaru	Jr. Second Engineer
USUDA Yusuke	Third Engineer
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YOSHIDA Sakae	No.2 Oiler
TAKEDA Koji	No.3 Oiler
KAI Keishiro	No.4 Oiler
MAEKAWA Hayate	No.5 Oiler
KOBASHI Yuki	No.6 Oiler
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YAMAMOTO Yohei	Second Electronics Officer
HAYASHI Takumi	Chief Steward
KANI Kenji	Associate Steward
KOYAMA Yukiko	Steward
SASAKI Keigo	Steward
YANO Anna	Steward

3. Background and Objectives

The Marie Celeste Transform Fault (MCTF) is a strike-slip plate boundary that offsets the Central Indian Ridge about 215 km at 17-18°S. The relative plate motion between the Capricorn and Somalia plates at the MCTF is 37-40mm/yr. (MORVEL, DeMets et al., 2010), so the age offset of the transform is approximately 11 million years.

The million-year scale temporal variation/fluctuation of oceanic crust formation was first reported along the Vema Transform in the Atlantic Ocean (e.g., Bonatti et al. 2003). They systematically mapped the long oceanic transform and collected rock samples including ultramafic mantle rocks along the transform wall. Both crust thickness derived from gravity anomalies and the degree of melting estimated from Cr# in spinel shows 3-4 million years oscillation. Recent bathymetry/gravity analysis along long, flowline parallel profiles (Roth et al., 2019; Shinevar et al., 2019) also shows the existence of 1-million-year scale cyclicity in the oceanic crust formation. However, the field observations along long time axis are limited and the cause of the fluctuation or cyclicity is still unknown.

The MCTF is a long oceanic transform with prominent transverse ridge, where the whole crustal section is expected to expose at the transform valley wall. The objective of this study is to obtain a comprehensive understanding in diversity of crustal structure and mid-ocean ridge process, and spatio-temporal variation of chemical/physical properties of underlying mantle. Our working hypothesis is that the diversity and million-year scale temporal variation of crustal structure and its formation process is controlled by spatial heterogeneity of chemical composition of upper mantle. To achieve this objective and investigate our hypothesis, we plan to conduct the systematic mapping and rock sampling along the MCTF and elucidate the variation of morphology, crustal structure, magma and underneath mantle chemistry since 11 Ma. The pre-existed bathymetry data shows the off-axis volcanoes (excess melt supply) and a couple of oceanic core complexes (poor melt supply) both exists south of the MCTF, suggesting a large variation of melt-supply in the southern ridge segment. We also try to conduct a deep-tow magnetic survey to detect the paleo intensity variation of geomagnetic field, providing a high-resolution timescale.

In terms of water geochemistry and biology, the transform fault valley is a unique semi-closed environment. We try to reveal the structure of water mass and biota within the MCTF valley and to compare with those of deep-sea trenches. The known hydrothermal field along the neighboring ridge axis will be re-visited. In addition, the aquatic biodiversity of the western Indian Ocean is poorly understood, especially in deep-sea zone. To achieve these goals, we will conduct CTD vertical casts with water sampling and NORPAC plankton net sampling.

4. Operation Summar*y*

The KH-24-4 cruise started at Port Luis, Mauritius on 12th October 2024 and ended at Penang, Malaysia on 8th November. We arrived at the survey area (MCTF) on 15th October and stayed there by 30th October morning. We conducted 27 dredge hauls, 7 CTD vertical casts (6 carousel water sampling) and 7 NORPAC sampling. The near-bottom magnetic survey using

wire-line attached magnetometer was done at 8 dredge hauls. Biological samples were also collected from dredged rocks and muds. A 137 km long deep-tow magnetic profile was successfully collected and total 1661 miles of surface mapping (multibeam swath survey, proton precession magnetometer, shipboard three component magnetometer and gravitymeter) was done. On the way to the Penang, we operated two dredge hauls at Aphanasey Nikitin Rise. The Tables 1 and 2 show the time schedule of all operations and the station list, respectively. The station locations are also shown in Figs. 2 and 3. The detailed operation notes and onboard results are shown in the confidential onboard cruise report among participants.

Table 1 Survey schedule.

KH-24-4 Time Table (local time)

	0		2		4		6		8		10		12		14		16		18		20		22	
12-Oct												UTC+4		PortLuis		*X					→UTC+5		
13-Oct																								
14-Oct																								
15-Oct						*8	S01A,B(fail)						S01B											
16-Oct						MC01	MC01	DR01+mag						DR02+mag							V03			
17-Oct	V03						DR03					DR04				DR05						MC03		
18-Oct		MC03						DR06+mag							DR07									
19-Oct							DR08						DR09									*X		
20-Oct		S03				S03		DTM																
21-Oct																						*X *8		
22-Oct							DR10					DR11												
23-Oct							DR12+mag						DR13						DR14+mag					
24-Oct	DR15			DR16																				
25-Oct																								
26-Oct							DR17+mag								MC13				MC13			DR18		
27-Oct							DR19+mag						DR20											
28-Oct							DR21						DR22					DR23						
29-Oct							DR24					MC12				MC12	DR25					DR26		
30-Oct	DR27	→UTC+6					*8																	
31-Oct																								
1-Nov															*8	*X								
2-Nov						→UTC+7																		
3-Nov										*8	*X	AFN02							AFN01					
4-Nov																								
5-Nov																					*8	→UTC+8		
6-Nov													TRANSIT											
7-Nov																								
8-Nov											Penang													
	0		2		4		6		8		10		12		14		16		18		20		22	

Underway Geophys with proton magnetometer
Rock Dredge
CTD hydrocast
NORPAC
Deep-tow magnetometer
transit

*8 Figure eight turn
*X XCTD

Table 2a List of dredge stations

No.	Site	Longitude	Latitude	Depth[m]	Date (UTC)	Memo
DR01	MC01 shallow	65°15.1535'E	17°58.0037'S	3200	2024/10/16 03:52	Mag
DR02	MC02 shallow	65°23.9956'E	17°53.3140'S	3320	2024/10/16 09:47	Mag
DR03	MC04 deep	65°43.6293'E	17°41.9054'S	5640	2024/10/17 03:28	
DR04	MC04 shallow	65°44.7919'E	17°45.4774	3210	2024/10/17 08:36	
DR05	MC04 middle	65°43.9190'E	17°43.4469'S	4280	2024/10/17 13:15	
DR06	MC06 deep	65°52.8584'E	17°36.9871'S	5470	2024/10/18 03:57	Mag
DR07	MC06 shallow	65°54.0998'E	17°38.7917'S	2960	2024/10/18 11:14	
DR08	MC06 middle	65°53.4988'E	17°37.9082'S	4080	2024/10/19 02:26	
DR09	MC07 shallow	66°02.9784'E	17°35.3151'S	2230	2024/10/19 07:30	
DR10	MC03 middle	65°34.3401'E	17°54.095'S	3210	2024/10/22 03:52	
DR11	MC03 shallow	65°32.01'E	17°49.477'S	3820	2024/10/22 08:12	
DR12	MC07 deep	66°01.4845'E	17°32.7374'S	5220	2024/10/23 02:13	Mag
DR13	MC07 middle	66°02.3226'E	17°34.3226'S	3680	2024/10/23 08:59	
DR14	MC09 deep	66°22.5807'E	17°21,670'S	5080	2024/10/23 15:04	Mag
DR15	MC09 shallow	66°23.8179'E	17°23.6564'S	2520	2024/10/23 21:00	
DR16	MC08 shallow	66°15.0654'E	17°28.9213'S	2460	2024/10/24 00:49	
DR17	MC08 deep	66°13.8266'E	17°26.9039'S	2470	2024/10/26 03:02	Mag
DR18	MC10 shallow	66°34.5631'E	17°17.4503'S	1950	2024/10/26 17:31	
DR19	MC10 deep	66°33.2902'E	17°15.7377'S	4990	2024/10/27 02:54	Mag
DR20	MC10 middle	66°33.9193'E	17°16.7439'S	3690	2024/10/27 08:18	
DR21	MC08 middle	66°14.4521'E	17°27.8403'S	4020	2024/10/28 02:24	
DR22	MC10 deep/mid	66°33.7283'E	17°16.0183'S	4430	2024/10/28 08:31	
DR23	MC10 mid/shall	66°34.3949'E	17°16.9978'S	2860	2024/10/28 13:16	
DR24	MC10 shallow	66°34.9066'E	17°18.1217'S	1380	2024/10/29 0:02	
DR25	MC12 deep	66°51.1651'E	17°03.4251'S	5170	2024/10/29 12:48	Mag
DR26	MC12 shallow	66°52.6449'E	17°05.47457S	2250	2024/10/29 18:21	
DR27	MC12 middle	66°51.7053'E	17°04.1030'S	4270	2024/10/29 22:13	
DR28	Nikitin Rise S	82°21.7858'E	3°26.9566'S	4930	2024/11/03 05:14	
DR29	Nikitin Rise N	82°31.5700'E	3°24.2790'S	2080	2024/11/03 12:03	

*Position, Dept, DateTime at "on bottom"

Table 2b List of CTD stations

No	Site	Longitude	Latitude	DateTime (UTC)	Max depth	Memo
S01A	Solitaire Vent	65°50.987'E	19°33.305'S	2024/10/15 01:45	2615	no sampling
MC01	MCTF west	65°15.092'E	17°58.025'S	2024/10/16 00:26	200	test cast
V03	MCTF middle	65°49.234'E	17°38.257'S	2024/10/16 15:40	5890	KH-15-5 station
MC03	MCTF west	65°31.461'E	17°47.114'S	2024/10/17 16:49	5017	
S03	Dodo Vent	65°17.753'E	18°20.428'S	2024/10/19 20:39	2772	
MC13	off MCTF	65°59.672'E	17°12.010'S	2024/10/26 09:43	3811	
MC12	MCTF east	66°50.824'E	17°03.441'S	2024/10/29 06:12	5262	

Table 2c List of NORPAC stations

No	Site	Longitude	Latitude	DateTime (UTC)
S01B	Solitaire Vent	65°50.987'E	19°33.305'S	2024/10/15 01:45
MC01	MCTF west	65°15.092'E	17°58.025'S	2024/10/16 00:26
V03	MCTF middle	65°49.234'E	17°38.257'S	2024/10/16 15:40
MC03	MCTF west	65°31.461'E	17°47.114'S	2024/10/17 16:49
S03	Dodo Vent	65°17.753'E	18°20.428'S	2024/10/19 20:39
MC13	off MCTF	65°59.672'E	17°12.010'S	2024/10/26 09:43
MC12	MCTF east	66°50.824'E	17°03.441'S	2024/10/29 06:12

Table 2d Deep-tow magnetic line

	Site	Longitude	Latitude	DateTime (UTC)
DTM-s	CIR-S16	65°21'E	18°25'S	2024/10/20 02:31
DTM-e		66°27'E	17°25'S	2024/10/21 12:38

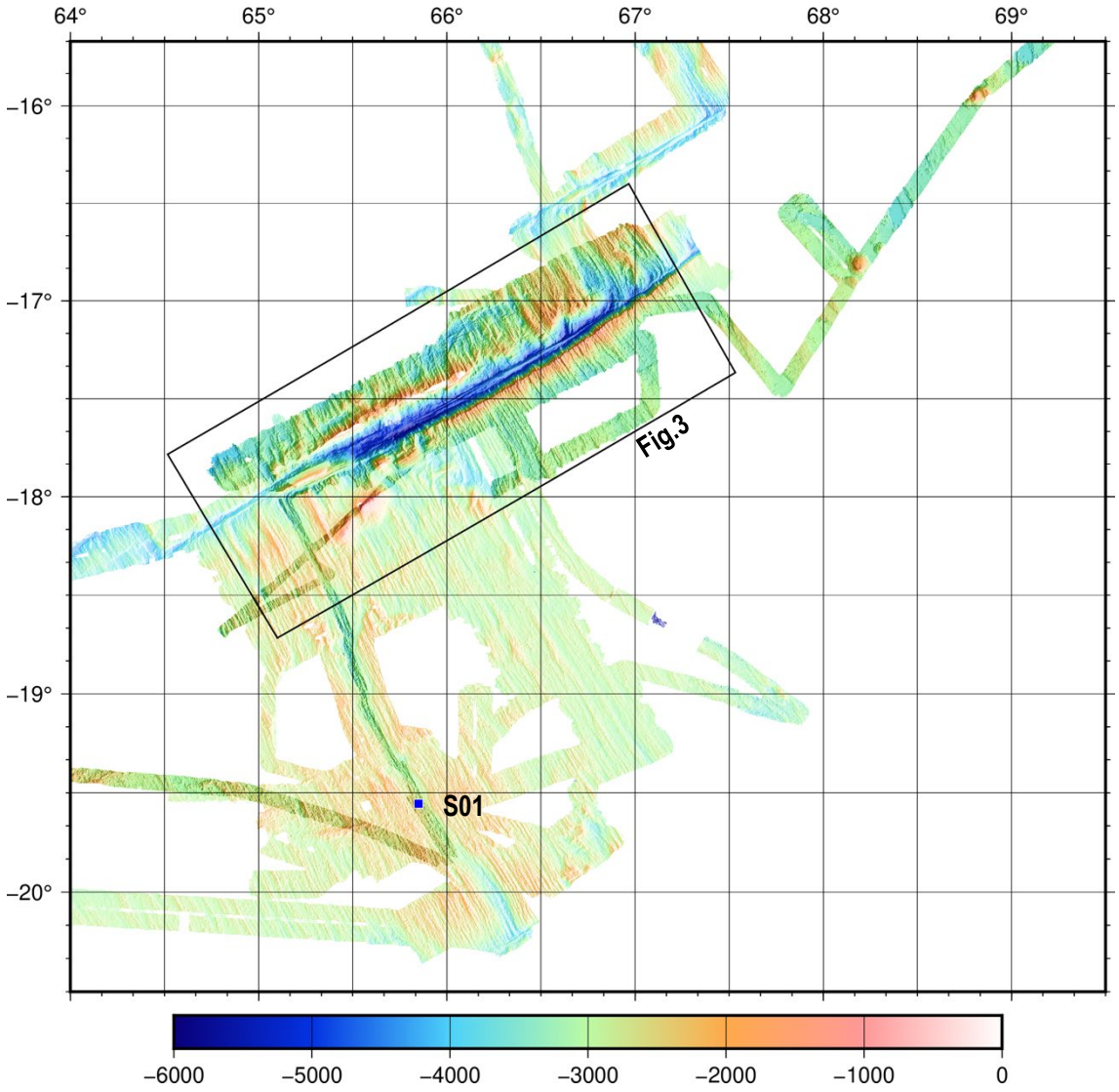

Fig.2 Location of S01 site on bathymetry map. Pale color bathymetry was collected previous cruises. The box shows the region of enlarged map (Fig.1.3).

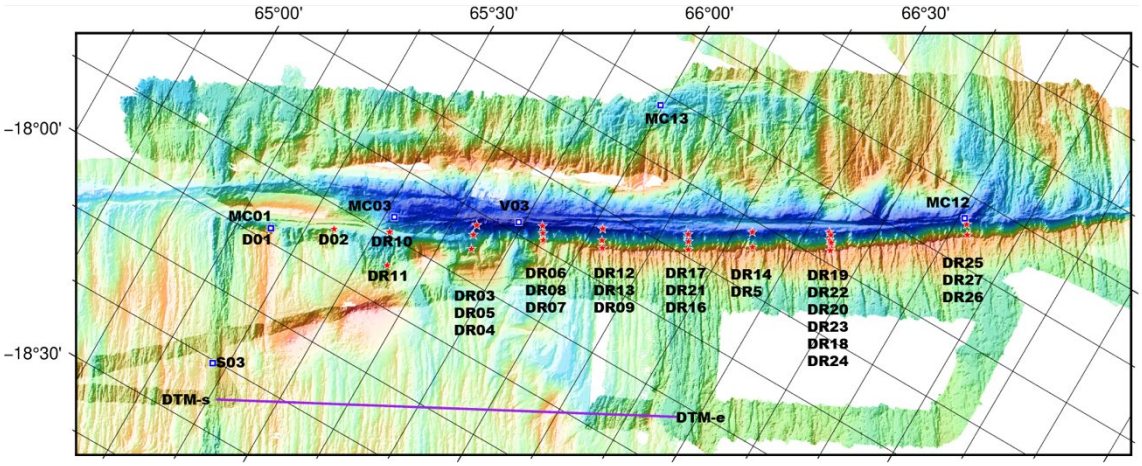

Fig.3 Location of station surveys along the Marie Celeste Transform Fault. Pale color bathymetry was collected previous cruises.

5. Preliminary Results

During KH-24-4 cruise by R/V Hakuho-maru, we conducted surface geophysical mapping, deep-tow and wire-attached magnetic surveys, rock dredges, CTD hydrocasts and NORPAC plankton sampling mainly along the Marie Celeste Transform Fault at the Central Indian Ridge, under the collaboration with Mauritian Government. The principal results of the cruise are summarized as follows.

1. Underway geophysical survey was conducted along 1661 miles in the MCTF area. Additional dataset was collected along the ~mile transit from the area to Penang. We completed the mapping of the whole MCTF and adjacent seafloor with high quality bathymetry, magnetic and gravity anomaly data.
2. Total 137 km long deep-tow magnetic profile was obtained from the current ridge axis to eastern off-axis, well-ordered abyssal hill plain. The toing altitude was approximately 200-500 m. We recognized high amplitude and short wavelength variation of magnetic anomaly along the profile, that likely reached ~9 Ma, including the change of paleomagnetic intensity.
3. Total 29 rock dredge hauls were conducted: 27 towing at the MCTF southern wall and 2 at Aphanasey Nikitin Rise. Along the long MCTF, we operated the dredge at 10 sites every 10 to 40 km apart. At western three sites, we obtained basalts from shallow part of the fault wall. One site is the lower part of an oceanic core complex. Eastern sites are located at the steep slope of well-developed transverse ridge, and we collected mainly gabbro from the

deeper slope, then dolerite and basalt from middle to shallow parts. Many hydrothermally altered basalt samples were also collected. We got only small number of ultramafic rocks.

4. Newly developed small magnetometer system was attached to the dredge wireline, and we obtained the magnetic field data at eight deep dredge operations. The upslope data during the recovery of dredge likely reflects the lithology of oceanic crust.
5. CTD data were recorded at 7 stations, and eDNA samples, samples for microbial and ammonium analyses were collected at 6 of 7 stations. Four stations are located within the transform valley, two at the known hydrothermal vent field along the ridge axis, and one north of the transform.
6. NORPAC plankton net sampling was conducted at the same points as CTD hydrocast. A total of 26 samples were collected. Morphological and DNA-based species identification will be performed.
7. Biological sampling was also tried from sediment and rock surfaces after the rock dredge operation. The collected sediment mainly consists of foraminifera despite the deep depth. At least 15 taxa (49 indiv.) were collected.

Notice on Using

白鳳丸　共同利用研究航海報告書

＊ 航海番号　　KH-24-4次研究航海

＊ 航海名称　　MOWALL-CIR:トランスフォーム断層のカベから海洋地殻生産プロセスの時間変動を追うインド洋における大陸地殻片の分布の検証
MOWALL-CIR: Temporal variation of mid-ocean ridge process recorded along long oceanic transform wall Evaluation of the distribution of continental crust fragments in the Indian Ocean

＊ 観測海域　　インド洋
Indian Ocean

＊ 航海期間　　令和　6年　10月　12日（土）～令和　6年　11月　8日（金）

＊ 出港日時・場所　　10月　12日　14時 ポートルイス（モーリシャス）港

＊ 入港日時・場所　　11月　8日　10時 ペナン（マレーシア）港

＊ 寄港期間・場所　　なし

＊ 研究課題　　MOWALL-CIR:トランスフォーム断層のカベから海洋地殻生産プロセスの時間変動を追うインド洋における大陸地殻片の分布の検証

＊ 主席研究員（氏名・所属・職名）
沖野郷子・教授

＊ 研究内容，主調査者，観測項目
1. 海底浅部構造とテクトニクスの研究
沖野郷子，地形・磁気・重力・サブボトムプロファイラ観測
2. 海洋地殻・マントル物質の岩石学的研究
町田嗣樹，岩石ドレッジ
3. 海洋地殻の磁化特性に関する研究
島伸和，ドレッジワイヤ装着磁力計
4. 高解像度磁気観測による海底年代の研究
藤井昌和，深海曳航磁力計
5. トランスフォーム断層内外の水塊特性と環境 DNA の研究
峰岸有紀，CTD 採水
6. インド洋西部表層生態系の研究
矢萩拓也，NORPAC ネット
7. インド洋の大陸地殻片の分布の検証
佐藤暢，岩石ドレッジ

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眞壁明子・海洋研究開発機構超先鋭研究開発部門・准研究副主任
李毅兵・中国地質科学院・准教授
BISSESSUR, Dass・モーリシャス首相府・大陸棚海域管理探査局・部門長
DYMENT, Jérôme・モーリシャス首相府・大陸棚海域管理探査局・アドバイザー
宮嶋優希・マリン・ワーク・ジャパン・観測技術員
鈴木由宇・MOL マリン&エンジニアリング・観測技術員

＊ 航跡・測点図

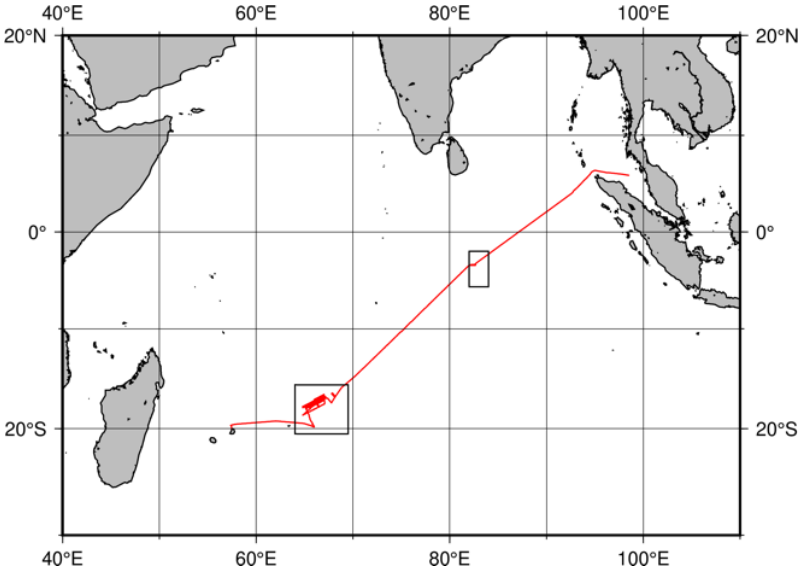

図1　全航跡図

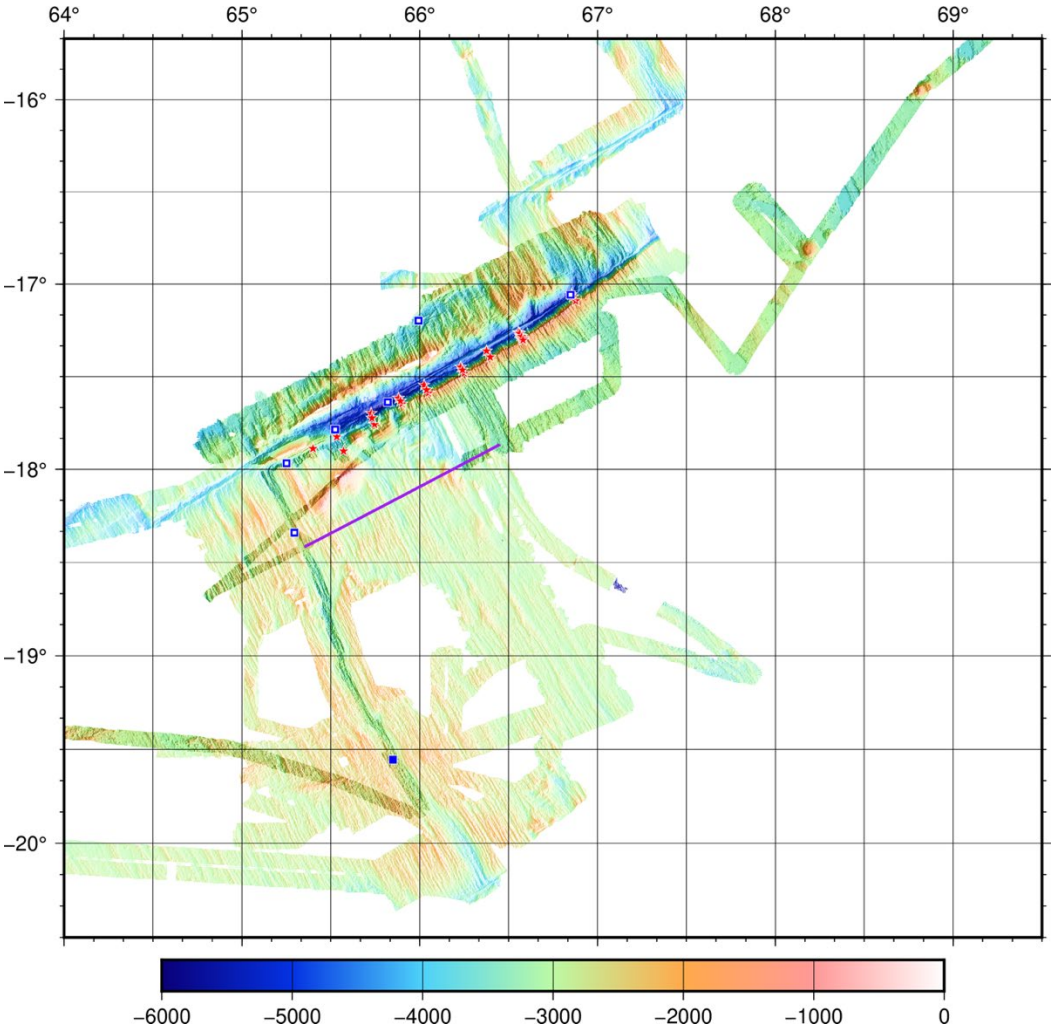

図2　主観測域での測点図（星印：岩石ドレッジ，四角：CTD，NORPAC，紫線：深海曳航磁力計）
地球物理マッピングの成果を濃色で示す（淡色地形は既存観測データ）