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Short Cruise Report RV SONNE SO-271/2 (INDEX 2019)

Port Louis (Mauritius) – Port Louis (Mauritius)
20.12.2019 – 09.01.2020

Chief Scientist: PD Dr. Udo Barckhausen
Captain: Oliver Meyer

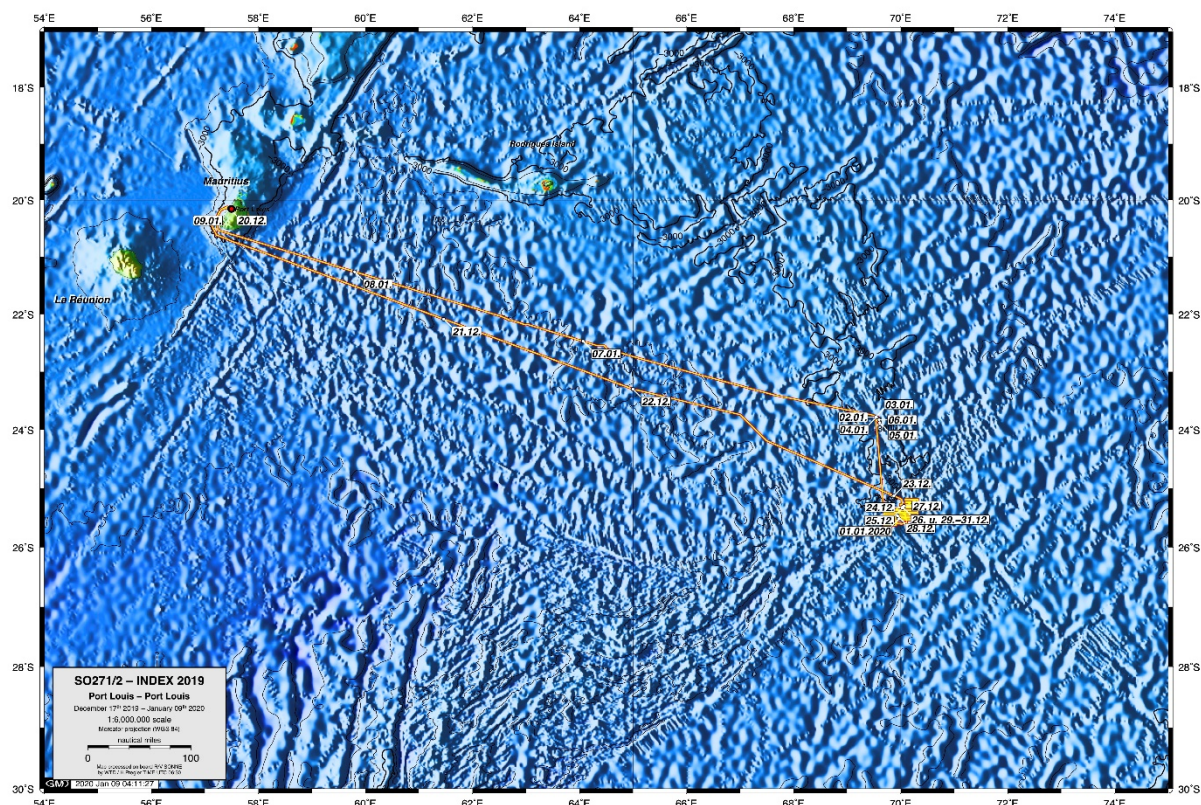


Fig. 1: Track of RV Sonne cruise SO-271/2 (INDEX2019) (map by WTD)

Objectives

BGR, on behalf of the Federal Ministry for Economic Affairs and Energy (BMWi), submitted an application for an exploration license for polymetallic sulfides in the southwestern Indian Ocean. The license covers an area of 10.000 km², subdivided into 100 so-called sulfide blocks each 10 x 10 km in size. This application was adopted by the International Seabed Authority (ISA) during its annual meeting in July 2014. In signing the license contract in May 2015, BGR has permission to carry out a detailed exclusive, resource-oriented exploration program in the license area southeast of Mauritius. The program includes the identification and outline of potential polymetallic sulfide deposits and a resource assessment, but also extensive and detailed base line studies for the sustainable protection of the marine environment. The license contract has a fifteen years lifetime and may allow the application for a subsequent mining license. The exploration license aims at the identification of inactive polymetallic sulfide deposits, formed at and below former discharge zones of hot hydrothermal fluids on the ocean floor ("black smoker"), by modern exploration techniques.

Cruise SO271 (INDEX2019) had two Legs. Leg 2 largely focused on electromagnetic studies at four known sulfide areas in clusters #04 and #05 of the German license area. In addition, high resolution magnetic mapping was carried out in cluster #05 and an array of Ocean Bottom Seismometers was deployed for a long term observation of local seismicity at the southern tip of the Central Indian Ridge. The electromagnetic profiler GOLDEN EYE (GE) was deployed successfully during 6 stations (plus one sea test) for detailed investigation of the magnetic and electric properties of the sub-seafloor of four sulfide areas, accompanied by biological observations. GE is equipped with two main sensor systems: the frequency domain electromagnetic loop system (active loop system) and the electric dipole-dipole system to measure self potential and induced polarization (SP/IP system). GE is further equipped with high resolution cameras for seafloor biology observations and navigation purposes. Gravity and multibeam bathymetry measurements were carried out throughout the cruise.

The main purpose of SO-271/2 was the acquisition of as many electromagnetic data as possible in order to gain much needed information on the 3D-structure of the sulfide areas Kairei and Kaimana (both cluster #05) and Alpha and Score (both cluster #04). From earlier work at the Edmond-Gauss-Score sulfide area, it was known that significant parts of the massive sulfides can be hidden under a sedimentary cover (Müller et al., 2018). In addition, at the moment electromagnetics is the only method available to us for gaining detailed insight into the upper 30 meters of the massive sulfide bodies.

Narrative

Cruise SO271/2 (INDEX 2019) was carried out without any major problems and all planned scientific work could be completed. The weather and the sea conditions were generally good with fresh wind most of the time. During two relatively short periods with rougher conditions, magnetic mapping was carried out which is not depending on low to moderate sea states as much as instruments like the GOLDEN EYE, which need to be navigated very precisely at the seafloor. The balance of this rather short cruise with 14 working days amounts to 15 stations completed in clusters #04 and #05. Swath bathymetric mapping and scientific echosounder measurements for water column imaging were carried out during the entire cruise outside the EEZ of Mauritius. In the following, times are given in local time, which is UTC +4 hours in Port Louis and UTC +5 hours in the working area.

TFS SONNE arrived in Port Louis, Mauritius, on December 17th, 2019, and docked at Quay D at 06:30. The chief scientist had a first meeting with the captain the same day for logistics, container handling, lab occupation, and scientific crew boarding. Meetings were also held with the ship's agent and the chief scientist of the preceding Leg 1 of cruise SO-271. The first scientific meeting with all cruise participants was held in the evening of Dec. 17th in the hotel where the scientific party stayed. In the morning of Dec. 18th, the containers with the scientific equipment were loaded on the ship's working deck and the scientific crew, assisted by the ship's crew, started unloading the containers and installing the scientific equipment on deck and in the laboratories. A compulsory BGR safety instruction was held at 13:00 for

the scientific crew, followed by a safety instruction and tour of the ship by the chief mate. The shipboard scientific party for cruise SO271/2 (INDEX2019) boarded TFS SONNE in the morning of Dec. 19th and moved into their respective cabins. All participants continued with equipment mobilization and lab installation, which were largely finished by late evening.

On Dec. 20th, the pilot boarded at 08:00 and SONNE departed at 08:30. After maintenance of the magnetic compass and short sea trials of both lifeboats, SONNE was underway for the 750 nm transit to the working area at 10:45. The ship's speed of originally 12 knots (2 diesel engines) had to be reduced slightly in the afternoon due to high sea states. At 15:00, a safety drill called everyone to the muster station. A first scientific introduction to the working area was presented at 19:00 to the scientific party.

The following day (Dec. 21st), deck tests of scientific instruments were carried out and the Ocean Bottom Seismometers (OBS) were prepared for deployment. A regular meeting of the scientific party was established at 08:30 and later in the morning a meeting was held with chief scientist, deputy chief scientist, captain, ship officers, chief engineer, bosun, and ship's doctor for planning of the upcoming program and discussion of requirements and procedures. Meetings in this format were held every Monday and Thursday morning throughout the cruise.

The Mauritian EEZ was left at 05:30 on Dec. 22nd and the ship was stopped for a test deployment of GE in relatively rough, but manageable conditions (station *INDEX2019-132GE*). After a successful test of its functionalities, the instrument was back on deck at 07:55 and immediately the CTD was lowered over the side for a sound velocity profile down to 2500 m (station *INDEX2019-133CTD*). At this depth, the releasers of the OBS, which had been attached to the CTD before, were pinged for test release one after the other between 09:00 and 09:45. The CTD was back on deck at 10:30 with all releasers open as desired. Directly after this, the towed magnetometer was deployed with two sensors on a 900 m long cable (station *INDEX2019-134MAG*). The ship was underway again, with the swath bathymetry system EM122 and the echosounder EK60 switched on, at 11:00.

Cluster #05 was reached at 11:10 on Dec. 23rd and the magnetometer was recovered near the Kairei sulfide area. Station *INDEX2019-135GE* started at 12:15 with the deployment of GE. The instrument reached the sea bottom and measurements and observations began at 14:50 along a grid of 800 m long parallel profiles 50 m apart over the Kairei area. From this moment on, everyone in the scientific crew was involved in going watches for operation of the GE's systems, writing a permanent observation protocol, and handling data and video image storage and documentation. GE was landed on the seafloor roughly every 50 m, depending on the local seafloor morphology. In order to avoid damage to the instrument, it was not landed in terrain with large rocks and boulders and in places where the inclination angle was more than about 35°. Also, landings in areas with active fluid venting and associated fauna were avoided in order to protect this precious type of underwater environment from unnecessary damage.

During the night, the ship's clocks were set forward by one hour, bringing local time to UTC +5 hours. The GE station was successfully completed after 84 landings on the seafloor along five profiles on Dec. 24th and at 13:15 GE was back on deck. While some necessary maintenance work was carried out on GE, the magnetometer was deployed again at 13:45 (station *INDEX2019-136MAG*) for systematic mapping of the northern half of cluster #05 with a line spacing of 2.5 km over the next 22 hours.

Magnetic mapping was stopped just south of Kairei at 11:20, Dec 25th. In nice weather conditions, deployment of 6 OBS (station *INDEX2019-137OBS*) around the Kairei area was carried out between 11:40 and 13:50. After a short transit, GE was redeployed at 14:10 for continuation of measurements at the Kairei area (station *INDEX2019-138GE*). Another eight lines with 99 landings were completed using the active loop system on GE by Dec. 26th at 18:15. Before bringing GE back to the surface, one diagonal line was "flown" across Kairei at a low elevation of 2-3 m above the seafloor while carrying out passive self-potential measurements until 19:25. The instrument was back on deck at 21:00. Beginning 22:00, another 10 OBS were deployed in a somewhat wider area along the southernmost part of the Central Indian Ridge (station *INDEX2019-139OBS*). The OBS are intended to be recovered in September 2020 during cruise SO-277 and will record local seismicity related to the active spreading systems, but possibly also to hydrothermal activity, over a period of 10 months.

At 03:55 on Dec. 27th, the last of the OBS was deployed and the ship transited back to the Kairei area, where the deep-towed multibeam bathymetry system HOMESIDE was deployed at 05:45 for a tow that

was designed to fill some remaining gaps in data coverage from earlier measurements at this site (station *INDEX2019-140HMS*). HOMESIDE was equipped with a magnetometer for this tow. The measurements began at 07:40, flying the instrument roughly 100 m above the seafloor. At the same time, maintenance work was carried out on GE on deck.

With winds and sea-state increasing, it became impossible to navigate HOMESIDE on a profile in southern direction during the afternoon. Therefore, the course was changed first and then the station was ended early at 17:00 on Dec. 27th; HOMESIDE was safely back on deck at 17:40. After a short transit to the Kaimana sulfide area and waiting a short time for weather improvement, GE was deployed for station *INDEX2019-141GE* at 20:00. A similar profile pattern as in the Kairei area with 50 m line spacing and landings 50 m apart was carried out, beginning with the active loop system again.

After completing three lines, a technical problem on GE forced an interruption at 09:00 on Dec. 28th and GE was back on deck for repair at 10:40. At 13:40, GE was ready for redeployment and measurements resumed at 15:10. Active loop measurements were completed after a total of 177 landings on the seafloor at 13:30 on Dec. 29th. For continuation with the SP/IP system, the ship returned to the starting point of the Kaimana survey while flying GE at low elevation above the seafloor. Then the profiles were repeated with SP/IP measurements while occasionally landing the GE in good weather conditions with moderate winds and low sea-state.

After completing 4 lines and 20 landings, the downward-looking camera on the GE failed at 05:30 on Dec. 30th. It turned out to be possible continuing the survey by controlling the terrain situation with the forward looking camera and the aid of three laser altimeters. However, landing the instrument without a direct observation of the seafloor below the GE seemed to be too risky and therefore three more lines were completed without any further landings. The SP/IP survey at the Kaimana area was stopped at 08:05 and GE was back on deck at 10:00.

While the ship transited back to the Kairei area, the camera problems of the GE could be solved and the instrument was redeployed at 14:00 on Dec. 30th for completing the SP/IP measurements at the Kairei area (station *INDEX2019-142GE*). During the following night, heavy rainfall set in due to a tropical storm hovering west of our position near Mauritius. With the storm predicted to move in southeastern direction, we were more or less safe on its backside, however, more rain and increasing wind and sea-state had to be expected for the coming days.

Station *INDEX2019-141GE* was completed after 47 GE landings using the active SP/IP system at 14:30 on Dec. 31st, 2019. GE was back on deck at 16:00 and after a short transit, the magnetometer was deployed for mapping the southern half of cluster #05 at 16:30 (station *INDEX2019-143MAG*). In the following hours, the wind picked up significantly, but magnetic mapping could be continued and was completed by 20:23 on Jan. 1st, 2020. This ended the work in cluster #05 and after recovering the magnetometer, the ship started the transit north to cluster #04 in rough seas.

Upon arrival in cluster #04 the weather had improved and GE could be deployed for station *INDEX2019-144GE* at the Alpha sulfide area at 09:20 on Jan. 2nd, starting with the SP/IP survey along the grid with 1 km long parallel profiles at 11:35. After 64 landings and two diagonal profiles flown at heights of 5 m and 20 m above the seafloor, the second run with the active loop system began at 21:00 on Jan. 3rd along the same grid. Weather conditions were somewhat unstable all the time with gusty winds and heavy rain showers, but measurements could be continued without interruption all day during Jan. 4th.

After 84 landings with the active loop system, the acquisition of electromagnetic data at the Alpha area was completed at 03:00 on Jan. 5th. At 05:10, GE was back on deck after 68 hours of nonstop surveying. A short transit took us to the Score sulfide area (also cluster #04), where GE was deployed again at 06:20 and measurements began at 08:10 (station *INDEX2019-145GE*).

In view of the time remaining, it was decided to do a regular profile pattern as at the other sulfide areas, but to fly GE at a height of 2.5 m above the seafloor without landings. Comparison is possible with data from an earlier GE survey at the Score sulfide area that included landings and was carried out during cruise INDEX2015. The mapping was completed at 09:00 on Jan. 6th and GE was back on deck at 11:00 right in time for the transit back to Mauritius. Cleaning and disassembling of GE and other instruments began immediately.

The magnetometer was deployed for the last time and SONNE was underway at 11:20 (station *INDEX2019-146MAG*). A track was chosen that filled some gaps in the data coverage of magnetic and bathymetric mapping resulting from the many transits to and from the German license area in the last years. Shortly before entering the Mauritian EEZ, data acquisition was stopped at 06:25 on Jan 7th and the magnetometer was retrieved. The remaining outboard gear was cleaned and packed, data backup copies completed and lab equipment packed into boxes and finally into the containers.

During the following night, the ship's time was adjusted to Mauritian time (UTC +4 hours). On Jan 8th, packing continued and in the evening the emptied and cleaned labs were inspected by the chief mate. SONNE arrived at Port Louis pilot station at 06:00 on Jan. 9th and docked at Quay A at 08:45. The scientific work was completed with final gravity tie-measurements in port. During the morning hours, last boxes were stowed and the containers were closed. The scientific crew left SONNE in the afternoon of Jan. 9th and people returned home in groups in the following days.



Fig. 2: Scientific crew of SO-271/2, photo: Miriam Plöger

Acknowledgements

The cruise was carried out based on an agreement between the Federal Ministry for Science and Education and the Ministry for Economic Affairs and Energy. This was the third time that BGR was provided a German research vessel to carry out exploration activities in the German license area for polymetallic sulfides under this agreement. We thank the German Research Fleet Coordination Centre, Institute of Geology, Hamburg University, and BRIESE research for their comprehensive support in logistic preparation of the cruise. On behalf of the scientific crew, I would like to thank Captain Oliver Meyer and the ship's crew for their outstanding and flawless assistance and support during all survey operations.

Participants

1. Barckhausen, Udo, Dr. habil.	Fahrtleiter / <i>Chief Scientist</i>	BGR
2. Deppe, Joachim	Magnetics	BGR
3. Ebert, Timo	OBS/Electromagnetics	BGR
4. Ehrhardt, Axel	OBS/Hydroacoustics	BGR
5. Gerdes, Klaas	Biology	DZMB-INES
6. Hahn, Boris	OBS/Electromagnetics	BGR
7. Hagedorn, Dennis	Electromagnetics	BGR
8. Heyde, Ingo, Dr.	Magnetics/Gravity	BGR
9. Hilgenfeldt, Christian	Electromagnetics	UHB
10. Kniesz, Katharina	Biology	DZMB
11. Müller, Hendrik, Dr.	Electromagnetics	BGR
12. Schneider, Elisabeth	Data management	LBEG
13. Schwalenberg, Katrin, Dr.	Electromagnetics	BGR
14. Sommerfeldt, Robert	Data management	BGR

Participating institutions

BGR	Federal Institute for Geosciences and Natural Resources
DZMB	Deutsches Institut für Biodiversitätsforschung Senckenberg am Meer
LBEG	Landesamt für Bergbau und Energie Niedersachsen
UHB	University of Bremen, Research Group Marine Geophysics

Stationlist

Station	Date / Time UTC	Device	Station (BGR)	Depth (m)	Latitude	Longitude
SO271/2_1-1	22.12.2019 02:10:50	CSEM	INDEX 2019-132GE	3670	23°17.998' S	065°00.002' E
SO271/2_2-1	22.12.2019 04:02:35	CTD	INDEX2019-133CTD	3705	23°18.044' S	064°59.964' E
SO271/2_3-1	22.12.2019 07:05:27	MAG	INDEX2019-134MAG	3574	23°18.925' S	065°04.206' E
SO271/2_3-1	22.12.2019 07:31:30	MAG	INDEX2019-134MAG	3714	23°19.375' S	065°06.206' E
SO271/2_4-1	23.12.2019 08:18:37	CSEM	INDEX2019-135GE	2544	25°19.242' S	070°02.108' E
SO271/2_5-1	24.12.2019 08:45:25	MAG	INDEX2019-136MAG	2820	25°18.455' S	070°04.217' E
SO271/2_6-1	25.12.2019 06:55:21	OBS	INDEX2019-137OBS	2410	25°18.853' S	070°02.120' E
SO271/2_7-1	25.12.2019 09:14:26	CSEM	INDEX2019-138GE	2542	25°19.459' S	070°02.526' E
SO271/2_8-1	26.12.2019 17:11:41	OBS	INDEX2019-139OBS	3284	25°22.014' S	069°55.735' E
SO271/2_9-1	27.12.2019 00:20:27	SS	INDEX2019-140HMS	3132	25°23.241' S	070°04.977' E
SO271/2_10-1	27.12.2019 15:03:41	CSEM	INDEX2019-141GE	2898	25°27.845' S	069°55.893' E
SO271/2_11-1	30.12.2019 09:00:55	CSEM	INDEX2019-142GE	2504	25°19.206' S	070°02.156' E
SO271/2_12-1	31.12.2019 11:56:00	MAG	INDEX2019-143MAG	3707	25°22.993' S	070°01.102' E
SO271/2_13-1	02.01.2020 04:22:57	CSEM	INDEX2019-144GE	3026	23°46.832' S	069°32.104' E
SO271/2_14-1	05.01.2020 01:22:11	CSEM	INDEX2019-145GE	3118	23°52.766' S	069°36.585' E
SO271/2_15-1	06.01.2020 06:50:00	MAG	INDEX2019-146MAG	3331	23°45.888' S	069°33.790' E