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R/V METEOR

Short Cruise Report

M167 (GPF 18-2_040)

"Long-term monitoring of fluid and solid emissions at the African-Eurasian tectonic boundary in the ALBOran Sea and the Gulf of CAdiz"

Emden (Germany) – Emden (Germany)

11.10.2020 – 05.11.2020

Chief Scientist: Dr. Walter Menapace

Captain: Rainer Hammacher

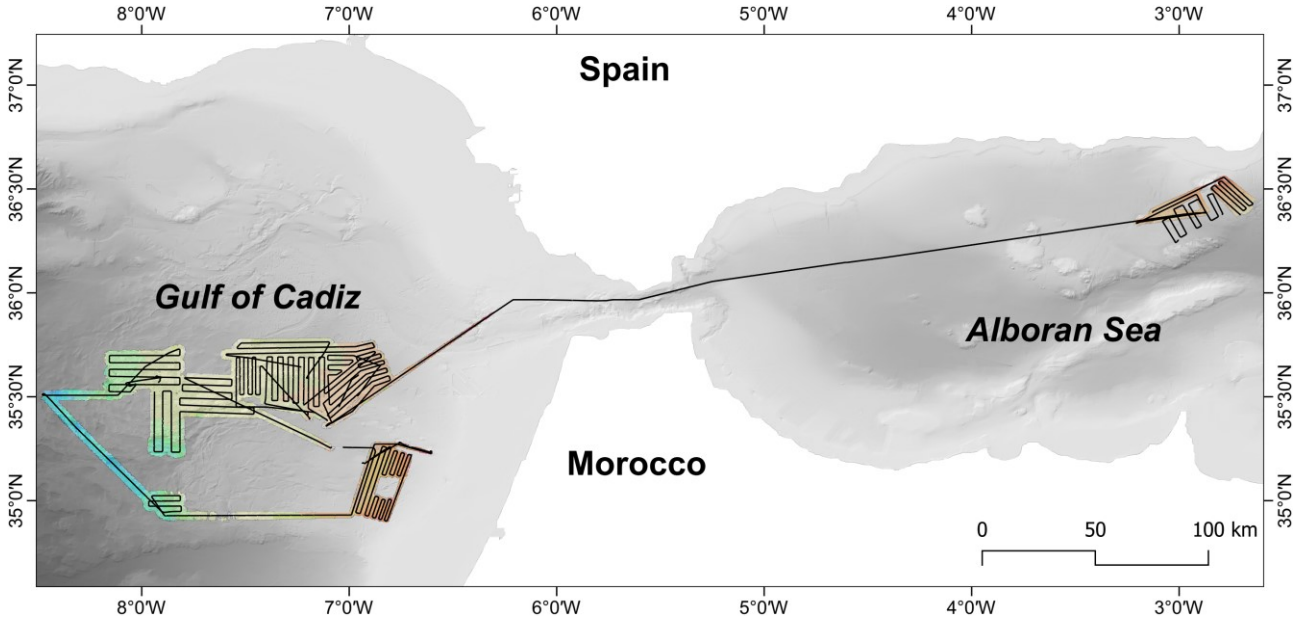

Fig.1: Shiptrack of R/V Meteor during Expedition M167 (black line) with the acquired bathymetry underneath.

Objectives

Earthquakes (EQs) and landslides are the most common causes of tsunamis, all of which represent a major threat along the Southwestern European continental margin (e.g. Great Lisbon EQ of 1755, Mw>8.5). The most crucial knowledge for hazard mitigation is given by the recurrence intervals, the preconditioning factors and the triggers that favor such events in a determined region.

The westernmost portion of the Mediterranean Sea is tectonically complex, given the controversial views on the nature and location of the Africa-Eurasia plate boundary and the significance of the Azores-Gibraltar transform fault. At the same time, this region has suffered from frequent, large magnitude earthquakes with epicenters both on- and offshore, and has an instrumental seismic record too imprecise for reliable risk assessment or determination of recurrence times in the seismic cycle.

In this regard, the aim of expedition M167 was to study the recent condition of fluid and solid emissions at the plate boundary between Eurasia and Africa and retrieve three long-term dataset of in situ temperature, pressure and conductivity data (2018-2020). Due to the privileged location of these so called “MeBo CORKS” observatories on two active faults and on the Ginsburg mud volcano (MV), the monitored parameters will allow us to shed much needed light on the relationship between EQs and fluid emission in the Gulf of Cadiz. The expedition M167 scientific objectives will contribute to understand the episodic nature of the Southwestern Iberian Margin’s seismicity by answering three critical questions:

- What does monitoring of active fluid emission features reveal about seismicity in the 2018-2020 period?
- How is fluid flow in the accretionary prism connected to the distribution of seafloor features in the Gulf of Cadiz?
- Were there any changes related to active tectonics between the M149 and the M167 cruises (e.g. geochemical fluid signatures, morphology, etc.)?

In order to answer these questions, the scientific program included the following approaches: i) recover the “MeBo Corks” observatories to assess episodic emission of sediments and/or fluids in key locations instrumented during the M149 with the ROV SQUID; ii) testing the BlueROV prototype developed by MARUM; iii) sample sediment material from deep-seated faults as well as from active mud volcanoes using gravity coring; iv) acquire photo-/videomosaicking and microbiological samples with the ROV SQUID to investigate ongoing biogeochemical processes on active MVs; and v) sample newly discovered MVs fields and active fluid emission features.

Specifically, the work program encompassed primarily observatories recovery, gravity coring (for sediments, pore fluids and microbiological samples) and the acquisition of hydrographic data (parasound and multibeam). A total of 4 dive sites were visited multiple times with the ROV SQUID. Once completed the main task of retrieving the MeBo observatories, the ROV focused on photomosaicking of key seafloor features. The gravity coring was located in strategic positions along prominent fault zones (e.g., Lineament South and Center, Carboneras fault) as well as on MVs in the vicinity of those same faults (Ginsburg, Yuma, Rabat) and on suspected MVs or seepage features detected during cruise M149 (Fig. 1).

Narrative

On October 10 the scientific crew was allowed to embark R/V METEOR after four days of quarantine in a Hotel in Bremerhaven, and being tested negative for COVID-19. A bus transfer from the hotel to the ship, berthed in Emden, delivered the scientists safely to the vessel. R/V METEOR left port on the morning of October 11, passing through the sluice gate that connects the port of Emden with the Wadden Sea, after both the ROV SQUID and all the scientific equipment was safely unpacked and prepared for transit.

For most part of the week from October 12, the ship steamed towards the easternmost of the M167 two study areas, the Alboran Sea. The transit, which started with a somewhat rough crossing of the English Channel, ended on the 17th of October with a quiet entrance into the Mediterranean Sea. During the whole week the scientists, which were mostly new to the ship, had the chance to get acquainted with the life on board, laboratories were prepared for the first “core on deck”, science meetings were held daily in the conference room, and the first multibeam profiles were taken in the Portuguese EEZ, in order to contribute to the DAM Underway Bathymetry project.

On Sunday the 18th the first station was reached and, due to a calm sea state, two ROV SQUID dives were performed, in order to retrieve the first of three CORK observatories deployed on the seafloor during cruise M149 (2018) (Fig. 2). The observatories tasks were to record water pressure and temperature in the boreholes over the years and document the activity of the target structures. Unfortunately, the first dive failed due to an hydraulic problem and on a subsequent deployment the CORK could not be found. After the dive a small COTS-ROV from MARUM was successfully deployed in the water column. This so called “BlueROV” underwent a number of modifications compared to the original product with respect to manipulation, control, etc.; making it a versatile and affordable instrument for shallow seafloor exploration. During the night the Carboneras fault was extensively mapped and a series of interesting Parasound profiles perpendicular to it were produced, showing both ductile and fragile deformation of the sedimentary layers (Fig. 2). Taking advantage of the good weather and the perfect sea conditions on Monday the 19th the ROV SQUID was deployed again to look for the missing CORK. The dive was successful with the instrument safely retrieved, and R/V METEOR then steamed away in the direction of the Gulf of Cadiz (Fig. 3).

The Gulf of Cadiz was reached on the morning of the 20th but prohibitive weather condition impeded a safe ROV SQUID deployment, therefore several meters of sediments were obtained using the gravity corer. Different mud breccia facies, a typical sediment constituting the main solid emissions of mud volcanoes, were retrieved from different structures of the Moroccan mud volcanic field: Ginsburg, Yuma, Boabdil, and Averroes (Fig. 4). For post-cruise gas, fluid and microbiological analyses, the scientists collected numerous sediment and fluid samples immediately after the gravity corer was on deck. In addition, detailed sedimentological descriptions and physical properties analyses were performed onboard. Those samples will be studied in order to determine the geochemical composition of the porewater, as well as the presence of microbial activity, in an effort to shed some light on the origin of the fluids and the life which they could fuel.

On the 21st and part of the 22nd of October the coring continued on different structures, which then proved to be newly discovered MVs situated in the northern part of the Moroccan MV field (Fig. 5). In the afternoon of the 22nd the wave height <2m made possible an ROV deployment, concluded with the retrieval of the second CORK observatory, installed on the active Ginsburg MV. On Friday, Saturday and Sunday (23rd, 24th and 25th), complicit the excellent weather, various dives were performed on Ginsburg

MV, on the Lineament Center and on a coral mound structure, both with the ROV SQUID and with the BlueROV (this last one for testing purposes) (Fig. 6). The goal was to produce a 3D Photomosaiking reconstruction of the seafloor on these extremely interesting targets. Meanwhile, coring and surveying various morphological features which proved to be unknown MVs, circular depressions, diapiric ridges and coral mounds, was also continued between the dives. Preliminary assessment of the pore fluids chemistry done onboard suggests widespread freshening on the active mud volcanoes summits, whereas high salinity fluids were sampled in depressed structures possibly related to upward fluid circulation.

At the beginning of the week starting on October 26 R/V METEOR sailed towards the western part of the Gulf of Cadiz, in order to sample some deep-water MVs and a new MV field. The deeper MVs are interesting because they are following the traces of both Lineament South and Center, potentially showing different source fluids/sediments than the bigger expulsion features on the eastern part of the accretionary prism. The samples acquired will thus allow to paint a more complete picture of the Gulf of Cadiz mud volcanism, possibly revealing key information from the subducting plate. The new MV field in the Portuguese EEZ was reached on the morning of the 27th, after a night spent by thoroughly mapping the area. Some structures in this area were discovered during cruise M149 in 2018, but no complete map was done until now (Fig. 7). The scientists managed to sample and confirm two of the MVs, but then the winch used for gravity coring broke down, making coring operations unfeasible for the rest of the day.

Talking advantage of a window of good weather, on the 28th the vessel headed to the Lineament Center, at the location of the third CORK observatory. Despite a serious hydraulic malfunction which impeded the use of the ROV mechanical arm, the ROV team managed to build an extension for the same arm, making the retrieval of the CORK possible. Unexpectedly, just before arrival on deck, the (flooded) observatory exploded and all its instrumentation got lost in the water column. After that, the scientific program was concluded by coring different structures along the northern boundary of the Southern Lobe. Again, a new MV was discovered and the known Atlas, Student and Jesus Baraza MVs were sampled, showing an amazing variety of mud breccias and confirming once again the extreme variability of these seafloor features in the Gulf of Cadiz (Fig. 8).

On the 29th in the afternoon R/V METEOR started the transit towards Emden, reaching its final destination on November 4. The M167 equipment and samples were safely packed during transit and unloaded on November 6, while the scientist disembarked the vessel a day earlier.

Stations maps

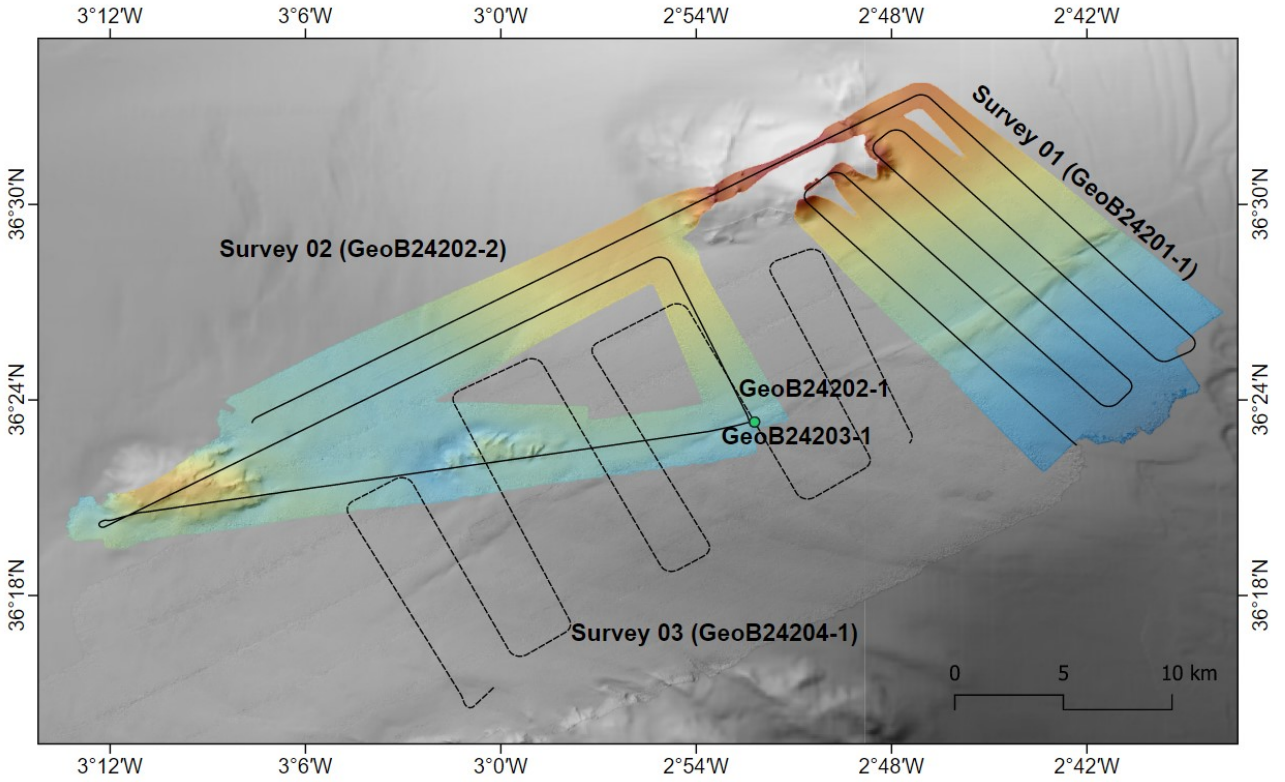

Figure 2: Overview of stations and bathymetry/Parasound profiles in the Alboran Sea main study area.

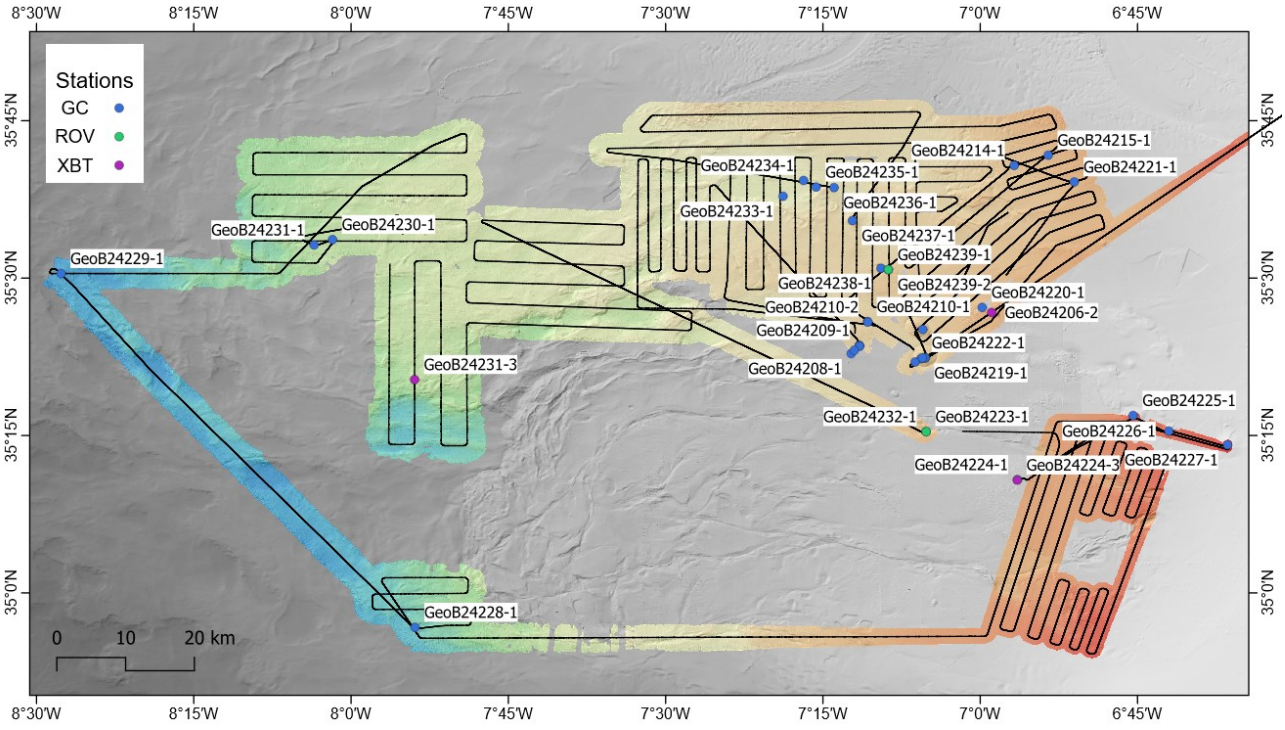

Figure 3: Overview of stations and bathymetry/Parasound profiles in the Gulf of Cadiz main study area.

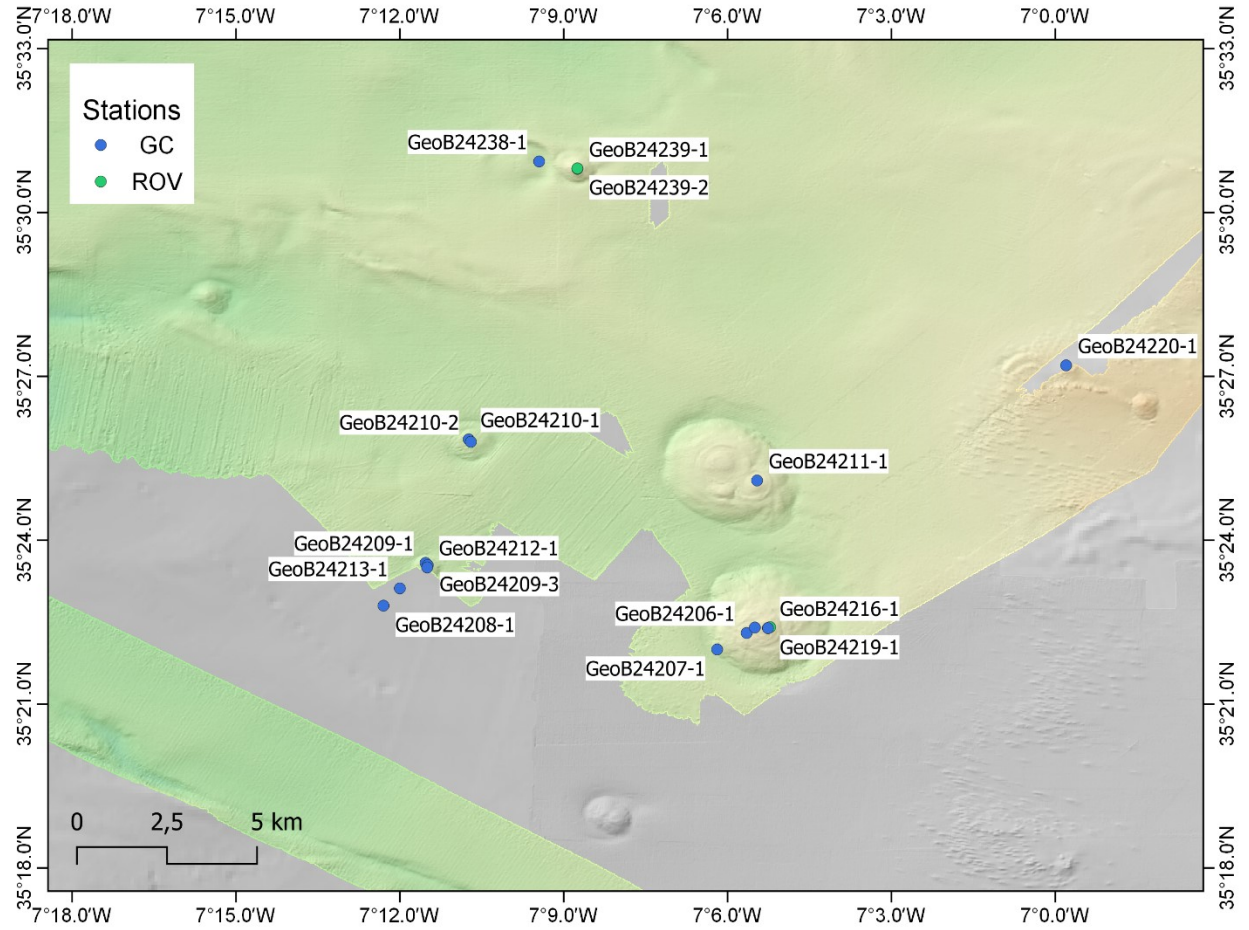

Figure 4: Detailed map of stations in the Moroccan MVs Field.

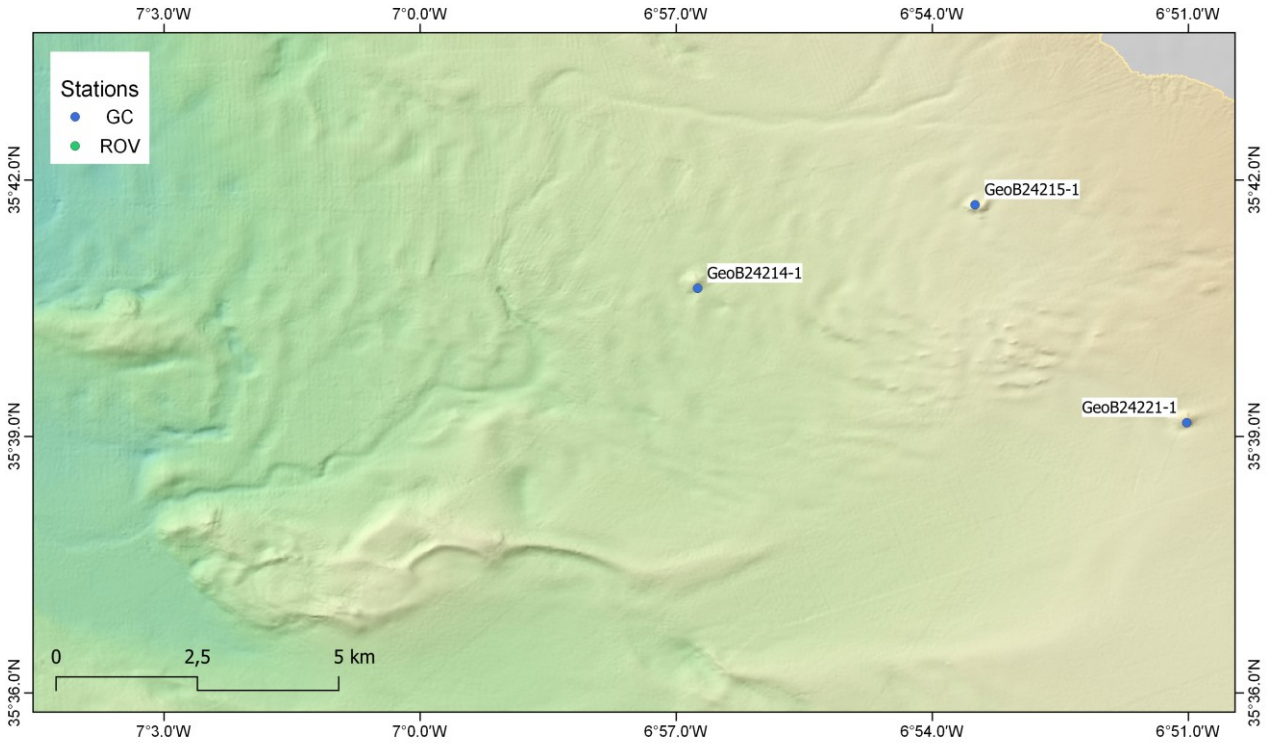

Figure 5: Detailed map of stations on a group of three newly discovered mud volcanoes.

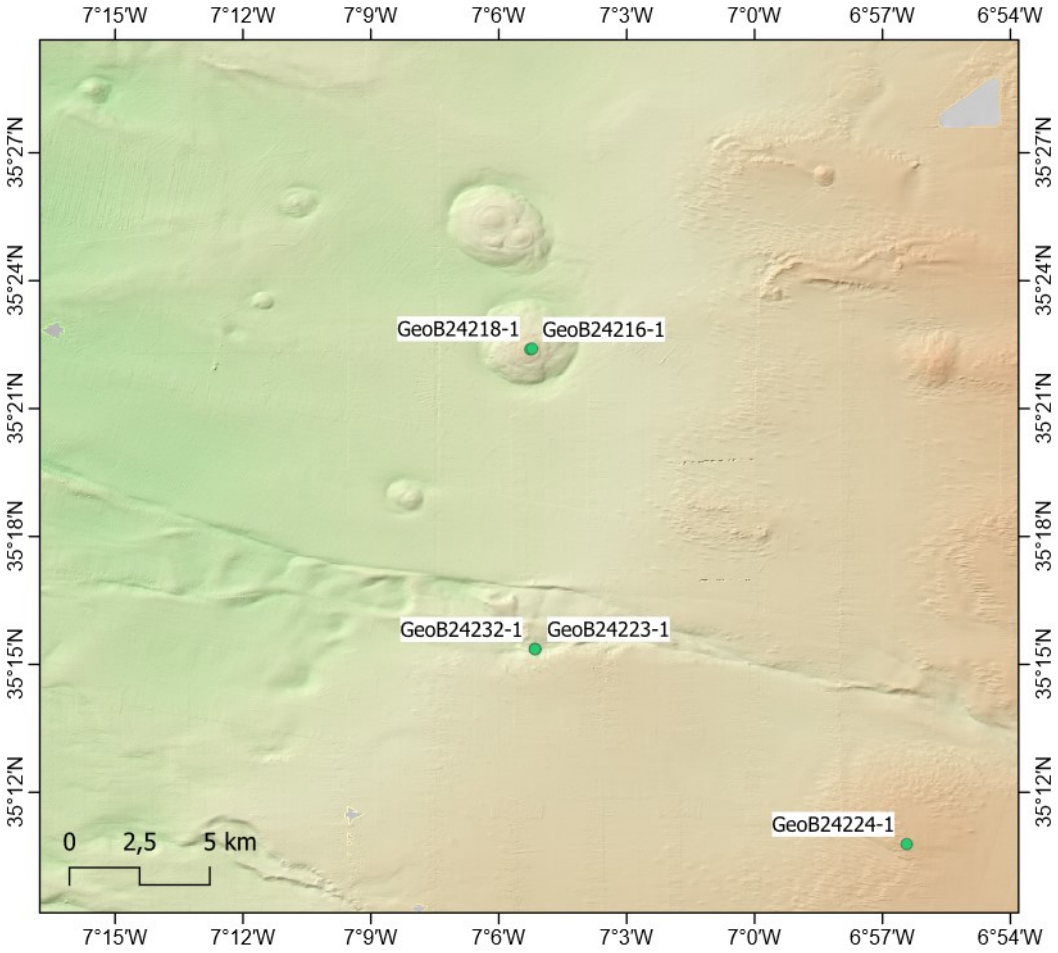

Figure 6: Detailed map of ROV SQUID dives in the Gulf of Cadiz

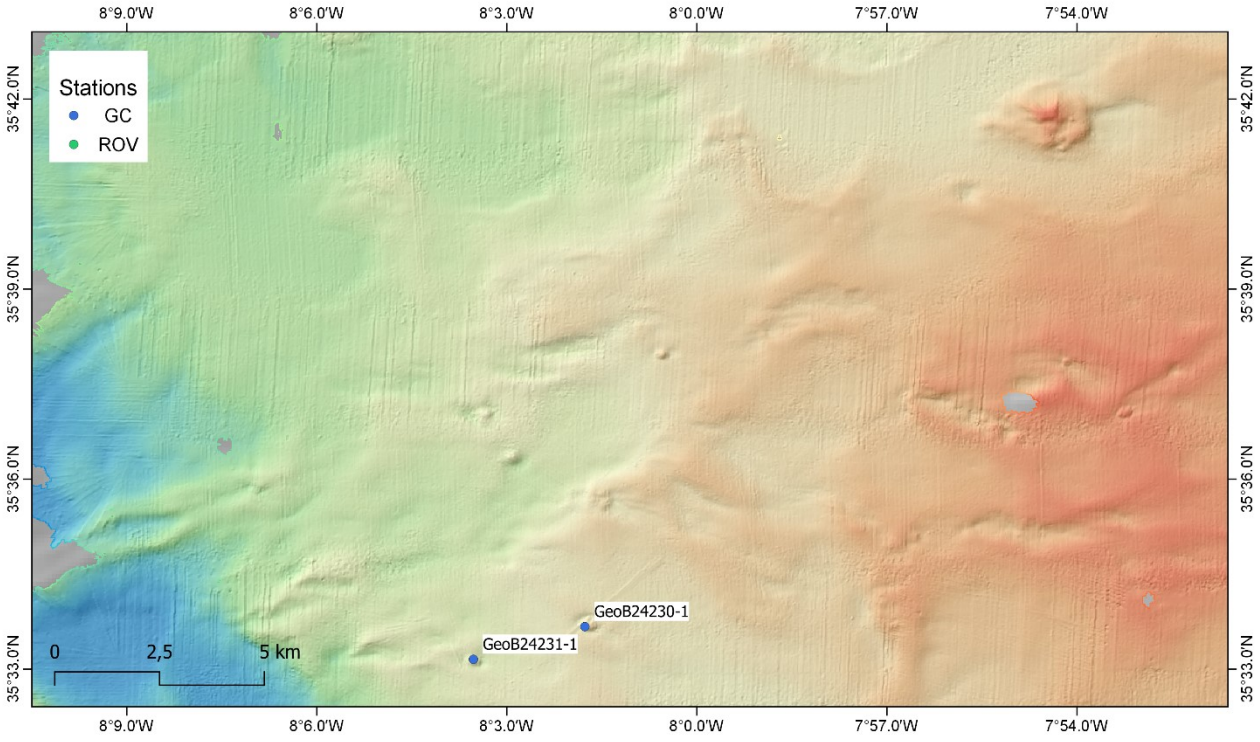

Figure 7: Detailed map of stations on a group of seven newly discovered mud volcanoes.

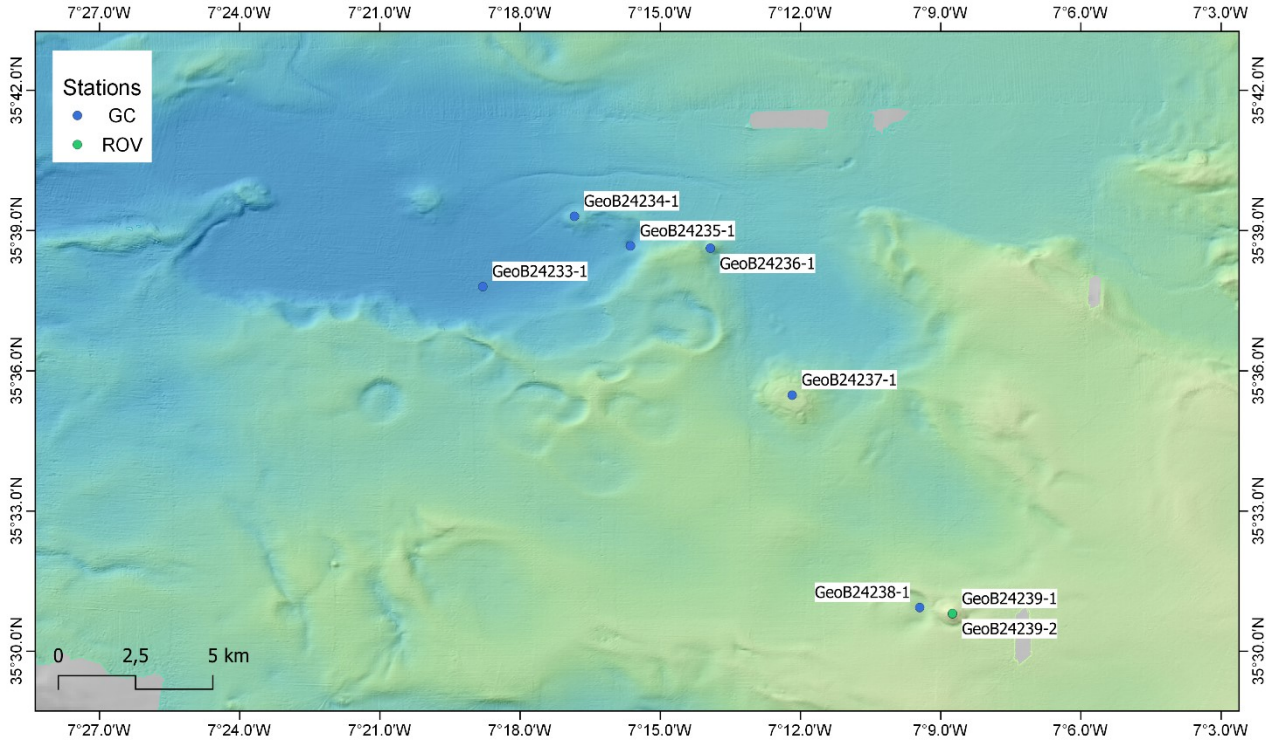

Figure 8: Detailed map of stations in the Tasyo MVs field.

Acknowledgements

All participants of Expedition M167 thank the countries of Morocco, Portugal and Spain for the permission of research in their Exclusive Economic Zone. The captain and crew of R/V METEOR are thanked for their support, which immensely contributed to the success of the expedition. Particular gratitude goes also to the German Science Foundation, the German Research Fleet Coordination Centre and the shipping company Briese Research for the tremendous support they have provided. The cruise was funded by the EU Marine Robots project.

Participants list

#	*Name*	*Task*	*Institute*
1.	Walter Menapace	Chief Scientist	MARUM
2.	Timo Fleischmann	In-situ Observatories/Coring	MARUM
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5.	Tom Leymann	ROV SQUID	MARUM
6.	Shuhui Xu	Hydroacoustics/Phys. Props.	MARUM
7.	Szymon Krupiński	BlueRov/Coring	MARUM
8.	Junli Zhang	Physical Properties	MARUM
9.	Hanna Zehnle	Microbiology/Geochemistry	MPI
10.	Laura Kramer	Hydroacoustics	Univ. Bremen - HiWi
11.	Christopher Schmidt	Geochemistry	GEOMAR
12.	Leonardo Tamborrino	Sedimentology	MARUM
13.	Natasha Morales	Sedimentology/Curator	MARUM - HiWi
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15.	Debora Duarte	Hydroacoustics (Observer)	IPMA
16.	Carola Heitmann-Bacza	Meteorologist	DWD
17.	Frank Otte	Meteorologist (technician)	DWD

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Stations list

GeoB Number: Curation number of the MARUM core repository
Abbreviations: EM122/ParaS = Ship-mounted Multibeam and Parasound systems; XBT = expendable bathythermograph; ROV = Remotely Operated Vehicle SQUID; B_ROV = Remotely Operated Vehicle BlueROV; GC = Gravity Corer.
NOTE: date/time/LAT/LONG/WaterDepth are relative to either start of the operation (for EM122/ParaS, ROV, XBT, B_ROV) or seafloor conditions (GC, ROV_CORK, ROV_PHOTOMOSAIC)

GeoB Nr.	Shipsite	Name/Area	Gear Type	Date	Time (UTC)	LAT (°N)	LONG (°W)	Water Depth (m)	Recovery (cm)
GeoB24201-1	M167_1-1	Carboneras Fault, Alboran Sea	EM122	17-10-20	23:00	36°22.624'N	2°42.340' W	1205	
GeoB24201-2	M167_1-1	Carboneras Fault, Alboran Sea	XBT	17-10-20	8:32	36°10.450'N	3°59.047'W	1230	
GeoB24202-1	M167_2-1	Carboneras Fault, Alboran Sea	ROV	18-10-20	7:17	36° 23.336' N	2° 52.231' W	953	
GeoB24202-2	M167_3-1	Carboneras Fault, Alboran Sea	EM122	18-10-20	9:14	36°23.149'N	2°52.306'W	963	
GeoB24203-1	M167_4-1	Carboneras Fault, Alboran Sea	ROV	18-10-20	14:11	36°23.3149'N	2°52.22545'W	961	
GeoB24204-1	M167_5-1	Carboneras Fault, Alboran Sea	ParaS	18-10-20	19:21	36°15.182'N	3°01.367'W	914	
GeoB24204-2	M167_7-1	Carboneras Fault, Alboran Sea	XBT	19-10-20	7:58	36°23.342'N	2°52.166'W	957	
GeoB24205-1	M167_6-1	Carboneras Fault, Alboran Sea	ROV	19-10-20	8:13	36°23.3257'N	2°52.2100'W	960	
GeoB24205-2	M167_6-1	Carboneras Fault, Alboran Sea_CORK	ROV	19-10-20	10:46	36°23.3196'N	2°52.2828'W	938	
GeoB24205-5	M167_6-1	Carboneras Fault, Alboran Sea	B_ROV	19-10-20	13:08	36°23.312'N	2°52.245'W	958.5	
GeoB24206-1	M167_9-1	Summit MV Ginsburg	GC	20-10-20	11:45	35°22.300'N	7°05.618'W	936	255
GeoB24206-2	M167_8-1	W Morocco, Atlantic Ocean	XBT	20-10-20	9:52	35°26.718'N	6°58.904'W	1991	
GeoB24207-1	M167_10-1	MV Ginsburg- W Flank	GC	20-10-20	13:24	35°22.0237'N	7°06.1676'W	1012	360
GeoB24208-1	M167_11-1	Pockmarks SW Averroes MV	GC	20-10-20	15:33	35°22.8020'N	7°12.2334'W	1190	369
GeoB24209-1	M167_12-1	Averroes MV	GC	20-10-20	17:16	35°23.5773'N	7°11.4617'W	1100	100
GeoB24209-2	M167_13-1	N Ginsburg MV area	EM122+ParaS	20-10-20	18:33	35°25.482'N	7°10.179'W	1678	
GeoB24209-3	M167_14-1	Averroes MV	GC	21-10-20	8:15	35°23.5677'N	7°11.4806'W	1100	61
GeoB24210-1	M167_15-1	Boabdil MV	GC	21-10-20	10:00	35°25.8418'N	7°10.7104'W	1100	46
GeoB24210-2	M167_15-2	Boabdil MV	GC	21-10-20	11:34	35°25.8408'N	7°10.7099'W	1094	69
GeoB24211-1	M167_16-1	Yuma MV	GC	21-10-20	13:23	35°25.0561'N	7°05.4521'W	950	225

GeoB24212-1	M167_17-1	Averroes MV	GC	21-10-20	15:15	35°23.5124'N	7°11.5472'W	1116	0
GeoB24213-1	M167_18-1	Background pockmark	GC	21-10-20	16:37	35°23.1351'N	7°11.9814'W	1146	416
GeoB24213-2	M167_19-1	NE Ginsburg MV	EM122+ParaS	21-10-20	17:53	35°25.709'N	7°12.294'W	1158	
GeoB24214-1	M167_20-1	Possible MV #1- N of Tangier MV	GC	22-10-20	8:00	35°40.7983'N	6°56.7317'W	975	215
GeoB24215-1	M167_21-1	Possible MV #2- N of Tangier MV	GC	22-10-20	9:40	35°41.710'N	6°53.4879'W	890	0
GeoB24215-2	M167_21-2	Possible MV #2- N of Tangier MV	GC	22-10-20	10:35	35°41.686'N	6°53.496'W	868	0
GeoB24216-1	M167_22-1	Ginsburg MV	ROV	22-10-20	14:23	35°22.3910'N	7°05.2618'W	902	
GeoB24216-2	M167_22-1	Ginsburg MV_CORK	ROV	22-10-20	16:22	35°22.3812'N	7°05.3114'W	910.5	
GeoB24217-1	M167_23-1	N Ginsburg MV area	EM122+ParaS	22-10-20	18:31	35°23.570'N	7°06.757'W	1158	
GeoB24218-1	M167_24-1	Ginsburg MV	ROV	23-10-20	8:30	35°22.4061'N	7°05.2280'W	905	
GeoB24218-2	M167_24-1	Ginsburg MV_PHOTOMOSAIC	ROV	23-10-20	9:42	35°22.4043'N	7°05.2317'W	903.8	
GeoB24219-1	M167_25-1	Ginsburg MV	GC	23-10-20	14:12	35°22.389'N	7°05.2620'W	899	129
GeoB24220-1	M167_26-1	Possible MV W of Al Gacel	GC	23-10-20	15:59	35°27.0857'N	6°59.7623'W	833	0
GeoB24221-1	M167_27-1	Possible MV #3	GC	23-10-20	18:05	35°39.0864'N	6°51.0523'W	858	430
GeoB24221-2	M167_28-1	N Ginsburg MV area	EM122+ParaS						
GeoB24222-1	M167_29-1	Ginsburg MV	GC	24-10-20	7:30	35°22.4042'N	7°05.4620'W	915	241
GeoB24223-1	M167_30-1	Lineament center	ROV	24-10-20	11:07	35°15.3582'N	7°05.1501'W	1021	
GeoB24223-2	M167_30-1	Lineament center_PHOTOMOSAIC	ROV	24-10-20	11:50	35°15.3516'N	7°05.1554'W	1020.3	
GeoB24223-3	M167_31-1	E lineaments area	EM122+ParaS	24-10-20	14:59	35°14.035'N	6°52.446'W	759	
GeoB24224-1	M167_32-1	Coral Mound	ROV	25-10-20	9:04	35°10.7838'N	6°56.4353'W	735	
GeoB24224-2	M167_32-1	Coral Mound_PHOTOMOSAIC	ROV	25-10-20	10:34	35°10.7679'N	6°56.4482'W	730.5	
GeoB24224-3	M167_32-2	Coral Mound	XBT	25-10-20	8:12	35°10.741'N	6°56.464'W	741	
GeoB24224-4	M167_32-3	Coral Mound	B_ROV	25-10-20	13:43	35°10.720'N	6°56.459'W	740	
GeoB24225-1	M167_33-1	Gemini 2 MV	GC	25-10-20	16:54	35°16.863'N	6°45.433'W	421	274
GeoB24226-1	M167_34-1	Fiuza MV	GC	25-10-20	18:00	35°15.363'N	6°41.946'W	387	161
GeoB24227-1	M167_35-1	Al Idrisi MV	GC	25-10-20	19:01	35°14.085'N	6°36.371'W	211	67
GeoB24227-2	M167_36-1	Southern accretionary prism	EM122+ParaS	25-10-20	19:43	35°13.722'N	6°36.546'W	225	
GeoB24228-1	M167_37-1	Potential MV #1 Lineament South	GC	26-10-20	7:51	34°56.7181'N	7°53.9750'W	2030	65
GeoB24228-2	M167_37-2	Potential MV #1 Lineament South	GC	26-10-20	9:50	34°56.7051'N	7°53.9616'W	2017	0
GeoB24229-1	M167_38-1	Potential MV #3 Lineament Center	GC	26-10-20	15:26	35°30.4016'N	8°27.6926'W	2276	343
GeoB24229-2	M167_39-1	Newly discovered MV field	EM122+ParaS	26-10-20	16:54	35°30.425'N	8°28.492'W	2373	

GeoB24230-1	M167_40-1	Potential MV#1 New MVs Field	GC	27-10-20	6:36	35°33.6676'N	8°01.7118'W	1670	31
GeoB24231-1	M167_41-1	Potential MV#2 New MVs Field	GC	27-10-20	8:26	35°33.1070'N	8°03.5386'W	1717	266
GeoB24231-2	M167_42-1	Lineament North	EM122+ParaS	27-10-20	11:05	35°31.483'N	7°56.250'W	1594	
GeoB24231-3	M167_42-2	Lineament North	XBT	27-10-20	13:30	35°20.320'N	7°53.940'W	1727	
GeoB24232-1	M167_43-1	Lineament Center	ROV	28-10-20	7:32	35°15.3530'N	7°05.1529'W	1019	
GeoB24232-2	M167_43-1	Lineament Center_CORK	ROV	28-10-20	8:52	35°15.3387'N	7°05.1619'W	1018.9	
GeoB24233-1	M167_44-1	Plain SW Atlas MV	GC	28-10-20	12:57	35°37.7627'N	7°18.7322'W	1413	145
GeoB24234-1	M167_45-1	Atlas MV	GC	28-10-20	14:31	35°39.3028'N	7°16.8160'W	1302	272
GeoB24235-1	M167_46-1	Pockmark E of Atlas MV	GC	28-10-20	16:15	35°38.6690'N	7°15.6359'W	1380	0
GeoB24236-1	M167_47-1	Potential MV E of Atlas MV	GC	28-10-20	17:42	35°38.6229'N	7°13.892'W	1194	241
GeoB24236-2	M167_48-1	Lineament North	EM122+ParaS	28-10-20	20:13	35°42.358'N	7°35.039'W	1441	
GeoB24237-1	M167_49-1	Jesus Baraza MV	GC	29-10-20	6:29	35°35.4288'N	7°12.0791'W	1090	132
GeoB24238-1	M167_50-1	Depression W of Student MV	GC	29-10-20	8:32	35°30.959'N	7°09.410'W	1131	433
GeoB24239-1	M167_51-1	Student MV	GC	29-10-20	9:49	35°30.807'N	7°08.755'W	950	209
GeoB24239-2	M167_51-1	Student MV	B_ROV	29-10-20	10:25	35°30.807'N	7°08.750'W	948	