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R/V METEOR
Short Cruise Report
Cruise M176 (GPF 21-2_048)
Emden, Germany – Emden, Germany
31. July – 29. August 2021
Chief Scientist: Jörg Geldmacher
Captain: Detlef Korte

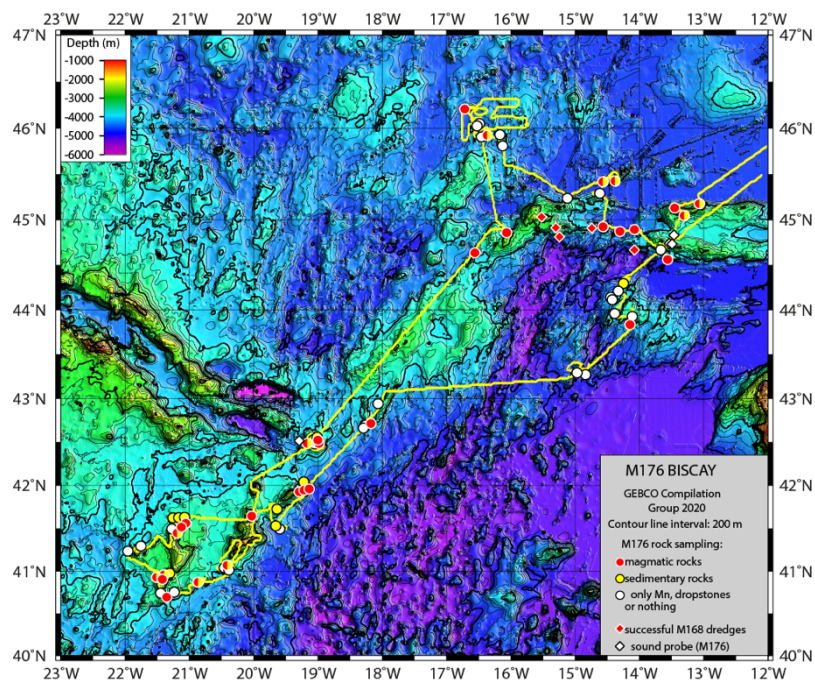


Fig. 1: Cruise track in the working area of R/V METEOR cruise M176

Objectives

R/V METEOR cruise M176 aimed to investigate the geodynamic evolution of the eastern North Atlantic Ocean, in particular the opening of the Bay of Biscay and the origin of the Azores-Biscay Rise (ABR). Although a number of geophysical investigations were conducted over the last decades in this region (that led to several geodynamic models), very little ground truthing by actual rock sampling has been carried out so far. A key region for addressing the objectives of this expedition is the intersection of the former Biscay spreading axis with the early mid Atlantic ridge. Here, the intersection also merges with the ABR, a ~750 km long seamount chain of unknown origin. The main targets of the M176 expedition are the area reflecting the final stages of the Bay of Biscay opening (working area 1), the seamounts located immediately north of the ABR (working area 2), and the crucial transition between the Bay of Biscay / North Atlantic spreading with the ABR and its entire extension (working area 3, see Fig. 2). The combined results of targeted multi-beam mapping and petrological/ geochemical investigations including $^{40}\text{Ar}/^{39}\text{Ar}$ age determinations of the recovered (volcanic) rock samples will allow us to test the different models proposed for this region and to reconstruct the geodynamic evolution of the early East Atlantic.

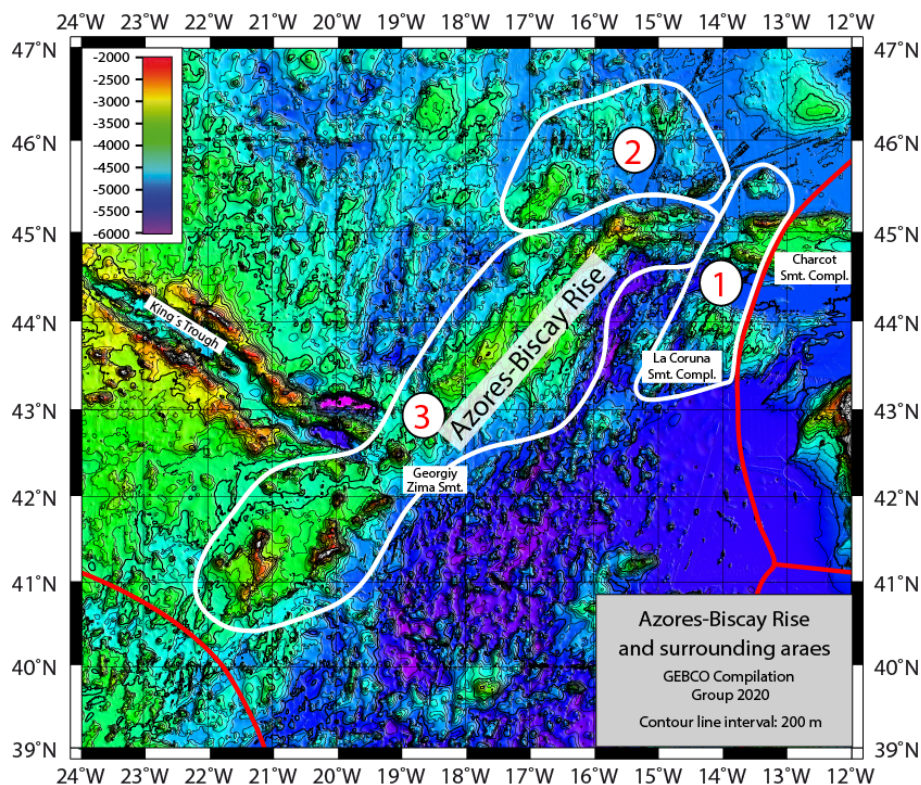


Fig. 2:
Bathymetric map of the three working areas of M176. Red lines mark the boundaries of the Spanish and Portuguese Exclusive Economic Zones (EEZs), respectively.

Narrative of the cruise

With all 14 members of the scientific party tested negative for COVID-19 less than 48h prior to departure from their home towns, all participants arrived in the port of Emden in the afternoon of July 30 and immediately embarked R/V METEOR. The equipment stored in two containers was already loaded in the morning of that day. The vessel left port on the following day July 31 at 09:00, passed the locks and entered the North Sea. The three and a half days transit to the first working area under good weather conditions was used to unpack the containers, set up the laboratories and to conduct other preparations for the cruise (including safety drills and rehearsal of the lab workflow). On the third of August, at 06:17 UTC, METEOR left the exclusively economic zone of France and the collection of underway data, including multibeam swath-mapping of the shipboard Kongsberg EM122 echosounder, started.

First of all, a sound velocity profile was conducted using an XSV sound probe to calibrate the EM 122 multi-beam echo-sounder system. During the following days, dredging focused on the elongated North and South Charcot seamount complex and its transition towards the northern ABR (working area 1), roughly along the 45°N latitude (Fig. 2). Despite sometimes challenging weather conditions, seven out of eleven dredge hauls in this working area returned volcanic rocks, which is a good average. Therefore, we turned our attention towards the neighboring working area 2, the numerous seamounts north of the ABR (Fig. 2). Gaining suitable rock samples from these seamounts turned out to be difficult. Only four of nine dredge hauls conducted here were successful. Relief, however, caused the exclusively negative outcome of the final PCR tests for COVID-19 that were conducted and processed from all cruise participants on August 7 (seven days after departure) which led to the lifting of several pandemic-related restrictions.

While operating in working area 2, the bow thruster of the METEOR broke down on the evening of August 8 and could no longer be used for the remaining days of this expedition. Since the front thruster is crucial for the positioning of the vessel when dredging via the side of the ship ("Schiebebalken") we had to convert operations for future dredging via the large A-frame at the ship's stern. Dredging operations continued on the early morning of August 10. The time required for the conversion and winch testing was used for an extensive mapping program in the working area 2 region, which allowed us to chart this structurally interesting area in previously not intended dense

spatial coverage. On August 11, we left the seamount province and entered working area 3, the ABR, our main study area for this expedition. The following days were spent with alternations of short mappings and sampling of its seamounts and ridge-like structures by working our way down from its northernmost edge at around 45°00'N to its southern termination at around 40°30'N.

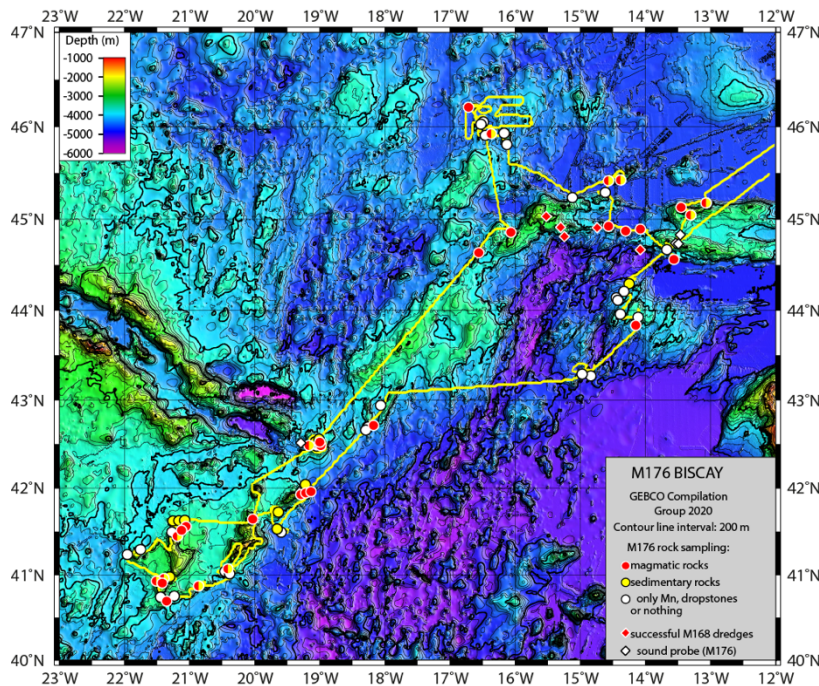


Fig.3: Track chart of R/V METEOR cruise M176 with all dredge sites and principal recovery (map source: GEBCO_2020 (<http://www.gebco.net>)).

Since five successful dredge hauls were already conducted at the northernmost part of the ABR during M168 (Dürkefälden et al. 2020), we only conducted three dredge hauls north of 44°30'N (Fig. 3) and quickly proceeded to further south. In the central ABR region, however, pronounced bathymetric highs (suitable for dredging) are rare as we had already anticipated based on the predicted satellite bathymetry. Additionally, the restriction in dredge directions due to the lack of the bow thruster made sampling on the central ABR even more challenging. Therefore, the solitary Georgiy Zima Seamount became very important for us because its round shape allowed us to approach it from several directions. From August 12 to 13, six dredge hauls were conducted on this seamount of which only one returned empty. However, only three dredge hauls returned igneous rocks. It became apparent that thick (Mn-covered) carbonate crusts cover the seamount top (above c. 3.000 m), an impression that we also got for all ABR seamounts further south. The widespread occurrence of such coverage hampered the effective recovery of suitable volcanic rock samples, particularly in the southern part of the ABR. Often, several dredge hauls had to be

conducted on the same seamount until eventually yielding acceptable material. We managed, however, to gain suitable material from all critical corners of this working areas so that the main scientific questions can all be addressed. On August 17, we reached the southernmost point of the working area at 40°40' N and turned the ship around to work our way back up along the ABR towards northeasterly directions. Between 40°40' N and 41°05'N, we intended to sample the deep edge of the widespread plateau, on which all the solitary seamounts in the southern ABR are mounted. Since these large seamounts could have formed considerably later than their underlying plateau, it was very important to obtain good sample material (suitable for age dating) from this platform. After four attempts, dredge haul 176-57-1 eventually recovered the desired volcanic rocks in suitable quality, which allowed us to proceed towards the NE. After trying to obtain additional deep basement samples from the pronounced edge of the plateau at 41°30'N, 19°40'W to no avail, we concluded sampling of the southern sector of the ABR by successfully dredging the large seamount at 42°N and its underlying plateau. After additional sampling in the southern Central ABR area, we headed back to working area 1, where the widespread La Coruña seamount complex was awaiting our attention. After 10 hour transit, we arrived at the first seamount in the southwestern corner of the complex in the early morning of August 23. On the predicted satellite bathymetry, the La Coruña complex appears as ragged aggregation of thin NNE-SSW ridges where steeply dipping flanks (due to tectonism?) could be expected. Our multibeam mapping revealed, however, that these ridges generally have gently dipping slopes, probably covered by sediments and therefore not suitable for dredging. Several dredging attempts eventually returned igneous rocks from the central part and from the northwesternmost edge of La Coruña (although the local provenance of the single rock dredged at the latter site still needs to be confirmed by thin section examination). On the forenoon of August 25, all dredge operations were ceased because the vessel had to set sail for its long transit back to Emden. The multibeam recording was also soon switched off before entering the Exclusively Economic Zones of Spain and France. In total, we have carried out 78 dredge hauls and swath-mapped 2,404 nm, while our path roughly followed a counter-clockwise loop through our working areas. No deployed device was lost or damaged. After a four-day transit, which was used to pack the containers and to clean the laboratories, R/V METEOR safely arrived at the port of Emden in the morning of Sunday, August 29.

Acknowledgements

First of all, we would like to thank Master Detlef Korte and his skillful crew for their excellent support, professionalism and for providing a very pleasant working atmosphere on board, which contributed directly to the success of this expedition. We also thank Andreas Raeke from the German National Meteorological Service (DWD) for his daily weather briefings, which were very helpful for planning our operations ahead. We are grateful to Dr. Anne-Cathrin Wölfl (GEOMAR) for providing existing multi-beam bathymetric data and to Maik Lange (GEOMAR) for his invaluable help with cruise preparations at GEOMAR. We are also grateful to the Review Panel German Research Vessels (GPF), the German Research Fleet Coordination Centre (University of Hamburg) and the shipping company Briese Research for their support. This cruise was funded by the German Research Foundation (DFG) and the GEOMAR Helmholtz Centre for Ocean Research Kiel.

Cruise participants (scientific party)

Name	Discipline	Institution
Geldmacher, Jörg, PD Dr.	Chief Scientist	GEOMAR
Werner, Reinhard, Dr.	Co-Chief Scientist / Logistics	GEOMAR
Dürkenfälden, Antje, Dr.	Shift-Leader	GEOMAR
Portnyagin, Maxim, Dr.	Shift-Leader	GEOMAR
Rahmsdorf, Charlotte V.	Shift-Leader	GEOMAR
Hampel, Fabian	Co-Shift-Leader	GEOMAR
Hoyer, Patrick	Co-Shift-Leader	Univ. Erl.-Nbg.
Deutloff, Jacob	Rock Sampling	GEOMAR
Krohne, Kevin	Rock Sampling	GEOMAR
Massaro, Guilia	Rock Sampling	Univ. Erl.-Nbg.
Renzelmann, Henri	Rock Sampling	GEOMAR
Scheffler, Janne	Rock Sampling	GEOMAR
Schenk, Johanna	Rock Sampling	GEOMAR
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Station list

Station No.	Sample Station No.	Date (UTC)	Time (UTC)	Latitude	Longitude	Water Depth	Device	Recovery
METEOR		2021	h	[°N]	[°W]	[m]		
M176_1-1	01	03.08.	14:24	46° 03,556' N	11° 28,131' W	2000	XSV	n.a.
M176_2-1	02	04.08.	00:15	45° 10,566' N	13° 02,890' W	3987	Dredge	Mn
M176_3-1	03	04.08.	03:36	45° 10,562' N	13° 02,747' W	3963	Dredge	Sed
M176_4-1	04	04.08.	08:06	45° 06,826' N	13° 25,772' W	2845	Dredge	V
M176_5-1	05	04.08.	12:08	45° 02,924' N	13° 18,138' W	3170	Dredge	V
M176_6-1	06	04.08.	16:25	44° 48,556' N	13° 27,961' W	2000	SVP	n.a.
M176_7-1	07	04.08.	18:29	44° 42,858' N	13° 31,423' W	2000	SVP	n.a.
M176_8-1	08	04.08.	21:32	44° 38,866' N	13° 39,128' W	4206	Dredge	
M176_9-1	09	05.08.	01:51	44° 32,652' N	13° 32,320' W	4843	Dredge	V
M176_10-1	10	05.08.	10:11	44° 52,652' N	14° 03,903' W	4600	Dredge	
M176_11-1	11	05.08.	13:49	44° 52,698' N	14° 04,142' W	4619	Dredge	V
M176_12-1	12	05.08.	20:33	44° 51,370' N	14° 16,648' W	4552	Dredge	V
M176_13-1	13	06.08.	01:37	44° 54,627' N	14° 32,102' W	4664	Dredge	V
M176_14-1	14	06.08.	09:43	45° 16,384' N	14° 34,864' W	4770	Dredge	
M176_15-1	15	06.08.	17:40	45° 26,337' N	14° 21,726' W	3303	Dredge	V, Sed,
M176_16-1	16	06.08.	21:51	45° 25,635' N	14° 31,999' W	3954	Dredge	V, Sed
M176_17-1	17	07.08.	03:41	45° 13,887' N	15° 05,222' W	4044	Dredge	
M176_18-1	18	07.08.	16:02	45° 48,871' N	16° 07,239' W	4393	Dredge	
M176_19-1	19	07.08.	21:18	45° 54,659' N	16° 08,481' W	4031	Dredge	
M176_20-1	20	08.08.	02:35	45° 54,859' N	16° 23,048' W	4349	Dredge	
M176_21-1	21	08.08.	07:49	45° 55,514' N	16° 22,999' W	4435	Dredge	
M176_22-1	22	10.08.	08:42	46° 13,211' N	16° 42,426' W	4287	Dredge	V
M176_23-1	23	10.08.	13:51	46° 01,298' N	16° 27,735' W	4248	Dredge	
M176_24-1	24	10.08.	17:18	46° 02,413' N	16° 28,183' W	3948	Dredge	Mn
M176_25-1	25	11.08.	03:11	44° 50,990' N	16° 02,757' W	3381	Dredge	V
M176_26-1	26	11.08.	10:25	44° 37,875' N	16° 31,473' W	3797	Dredge	
M176_27-1	27	11.08.	13:57	44° 37,792' N	16° 31,340' W	3750	Dredge	V, Mn
M176_28-1	28	12.08.	09:21	42° 28,769' N	19° 09,416' W	2000	SVP	n.a.
M176_29-1	29	12.08.	11:14	42° 28,711' N	19° 09,421' W	3430	Dredge	V, Sed
M176_30-1	30	12.08.	17:17	42° 31,115' N	18° 59,630' W	2655	Dredge	V, Mn
M176_31-1	31	12.08.	20:42	42° 29,523' N	18° 59,558' W	2289	Dredge	
M176_32-1	32	13.08.	03:35	42° 31,361' N	19° 00,175' W	2680	Dredge	Sed
M176_33-1	33	13.08.	06:25	42° 31,011' N	19° 02,376' W	2290	Dredge	Sed, Mn
M176_34-1	34	13.08.	10:02	42° 28,477' N	18° 58,574' W	2659	Dredge	V, Mn
M176_35-1	35	14.08.	07:53	41° 27,227' N	21° 09,200' W	2444	Dredge	V, Sed,
M176_36-1	36	14.08.	11:17	41° 30,844' N	21° 05,684' W	2878	Dredge	V
M176_37-1	37	14.08.	15:51	41° 31,871' N	21° 03,936' W	2924	Dredge	V
M176_38-1	38	14.08.	19:41	41° 35,936' N	21° 05,140' W	3201	Dredge	Sed
M176_39-1	39	15.08.	03:55	41° 36,786' N	21° 13,060' W	3349	Dredge	Sed
M176_40-1	40	15.08.	07:02	41° 36,019' N	21° 10,529' W	2669	Dredge	Sed
M176_41-1	41	15.08.	10:49	41° 29,264' N	21° 14,114' W	2440	Dredge	Mn
M176_42-1	42	15.08.	17:19	41° 23,349' N	21° 29,293' W	3044	Dredge	V, Sed
M176_43-1	43	15.08.	20:26	41° 23,536' N	21° 29,849' W	3163	Dredge	Sed
M176_44-1	44	16.08.	01:59	41° 16,850' N	21° 42,453' W	3112	Dredge	

M176_45-1	45	16.08.	06:36	41° 13,993' N	21° 55,350' W	3636	Dredge	
M176_46-1	46	16.08.	13:40	40° 54,828' N	21° 27,240' W	2849	Dredge	V
M176_47-1	47	16.08.	16:30	40° 55,339' N	21° 24,879' W	2835	Dredge	
M176_48-1	48	16.08.	21:10	40° 58,351' N	21° 17,968' W	2925	Dredge	Sed
M176_49-1	49	17.08.	00:32	40° 56,915' N	21° 22,415' W	2750	Dredge	V, Sed,
M176_50-1	50	17.08.	03:53	40° 54,631' N	21° 28,826' W	3028	Dredge	V, Sed
M176_51-1	51	17.08.	09:33	40° 42,652' N	21° 20,773' W	3545	Dredge	V
M176_52-1	52	17.08.	14:13	40° 45,136' N	21° 12,477' W	3288	Dredge	
M176_53-1	53	17.08.	20:38	40° 53,294' N	20° 50,434' W	3332	Dredge	V, Sed
M176_54-1	54	18.08.	13:32	41° 02,671' N	20° 22,862' W	3729	Dredge	
M176_55-1	55	18.08.	17:02	41° 01,131' N	20° 20,375' W	4237	Dredge	
M176_56-1	56	18.08.	20:40	41° 01,008' N	20° 20,658' W	4219	Dredge	
M176_57-1	57	19.08.	00:38	41° 03,575' N	20° 24,140' W	3351	Dredge	V, Sed
M176_58-1	58	19.08.	10:08	41° 38,110' N	20° 00,791' W	3007	Dredge	V
M176_59-1	59	19.08.	13:31	41° 38,373' N	20° 00,039' W	3212	Dredge	
M176_60-1	60	19.08.	19:23	41° 42,694' N	19° 37,014' W	3669	Dredge	Sed
M176_61-1	61	20.08.	03:50	41° 29,242' N	19° 34,699' W	4747	Dredge	
M176_62-1	62	20.08.	07:48	41° 31,437' N	19° 38,367' W	4646	Dredge	Sed
M176_63-1	63	20.08.	14:54	41° 58,322' N	19° 12,060' W	3037	Dredge	
M176_64-1	64	20.08.	18:17	42° 00,649' N	19° 12,364' W	3742	Dredge	Sed, Mn
M176_65-1	65	20.08.	22:00	41° 57,212' N	19° 08,539' W	4068	Dredge	
M176_66-1	66	21.08.	01:20	41° 58,057' N	19° 08,931' W	3873	Dredge	
M176_67-1	67	21.08.	06:22	41° 54,968' N	19° 14,811' W	3327	Dredge	V
M176_68-1	68	21.08.	10:22	41° 56,299' N	19° 12,525' W	3254	Dredge	V
M176_69-1	69	21.08.	14:08	41° 57,034' N	19° 08,546' W	4206	Dredge	V
M176_70-1	70	21.08.	23:08	42° 39,805' N	18° 14,044' W	4454	Dredge	
M176_71-1	71	22.08.	03:31	42° 38,738' N	18° 14,607' W	4470	Dredge	
M176_72-1	72	22.08.	08:02	42° 41,349' N	18° 13,254' W	4481	Dredge	V
M176_73-1	73	22.08.	13:49	42° 54,253' N	18° 02,068' W	4102	Dredge	
M176_74-1	74	23.08.	08:13	43° 16,388' N	14° 56,931' W	4604	Dredge	
M176_75-1	75	23.08.	13:21	43° 15,897' N	14° 48,809' W	4745	Dredge	
M176_76-1	76	23.08.	23:34	43° 49,767' N	14° 07,542' W	4240	Dredge	V
M176_77-1	77	24.08.	03:27	43° 53,007' N	14° 05,439' W	3996	Dredge	
M176_78-1	78	24.08.	09:41	43° 56,245' N	14° 20,881' W	4091	Dredge	
M176_79-1	79	24.08.	15:24	44° 06,622' N	14° 24,400' W	4392	Dredge	
M176_80-1	80	24.08.	18:54	44° 06,839' N	14° 24,476' W	4417	Dredge	
M176_81-1	81	25.08.	00:25	44° 10,884' N	14° 17,552' W	4229	Dredge	
M176_82-1	82	25.08.	06:23	44° 17,263' N	14° 13,950' W	4578	Dredge	V?

Abbreviations:

SVP - Sound velocity profile

XSV - Lockheed Martin expendable sound velocimeter

Mn - Manganese crust

Sed - Sedimentary rock (e.g. carbonate crust)

V - Igneous rock (volcanic or volcanoclastic)