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Helmholtz-Zentrum für Ozeanforschung Kiel

RV POSEIDON Fahrtbericht / Cruise Report POS494-2

HIERROSEIS Leg 2: Assessment of the Ongoing Magmatic-Hydrothermal Discharge of the El Hierro Submarine Volcano, Canary Islands by the Submersible JAGO

Valverde – Las Palmas (Spain)
07.02.-15.02.2016

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Participating Organizations:

Leg 2 of POS494 HIERROSEIS was a cooperation of the Spanish Government, Ministerio de Economía y Competitividad, through the projects EACFe (CTM2014-52342-P) and VULCANO (CTM2012-36317) and Vulcana project funded by Instituto Español de Oceanografía. The project was carried out under the new Collaboration Framework Agreement between Plataforma Oceánica de Canarias (PLOCAN), Universidad de Las Palmas de Gran Canaria (ULPGC) and GEOMAR, signed in Las Palmas in November, 2014. The work was an extension of projects to monitor the volcanic unrest of El Hierro led jointly by Dr. J. Magdalena Santana-Casiano and Dr. Melchor González-Dávila, and by Dr. Eugenio Fraile Nuez of the Spanish Institute of Oceanography (IEO, Instituto Espanol de Oceanografia).

Cruise Report POS494 Leg 2 (07.02.16-15.02.16)

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Note:
POS494 Leg 2 was an add-on to the HIEROSEIS Project led by Dr. Dietrich Lange GEOMAR | Helmholtz Centre for Ocean Research Kiel: POS494 Leg 1 Las Palmas-El Hierro 03.02.16-07.02.16.

1. Scientific crew

Shipboard participants:

Name	Function Institute / Affiliation
Hannington, Mark	Chief Scientist, GEOMAR
Petersen, Sven	Senior Scientist, GEOMAR
Santano-Casiano, Magdelana	Observation, ULPGC
Fraile Nuez, Eugenio	Observation, IEO
Klischies, Meike	Multibeam, GEOMAR
Lange, Sabine	Stations, GEOMAR
Hissmann, Karen	JAGO-Team, GEOMAR
Schauer, Jürgen	JAGO-Team, GEOMAR
Striewski, Peter	JAGO-Team, GEOMAR

Shore-based participants:

Nicolai, Maike	Documentation, GEOMAR
van Rouveroy, Maarten	Documentation, GEOMAR
Anderson, Melissa	Shore-based geology, GEOMAR

1=GEOMAR, Helmholtz Centre for Ocean Research Kiel; 2= Instituto de Oceanografía y Cambio Global, Universidad de Las Palmas de Gran Canaria; 3= Instituto Español de Oceanografía, Centro Oceanográfico de Canarias.

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2. Research Programme and Scientific Objectives

2.1 Topic

Monitoring the unrest of El Hierro, Canary Islands, by the submersible JAGO: Assessment of the ongoing magmatic-hydrothermal discharge

2.2 Name

HIERROSEIS Leg 2

2.3 Scientific discipline and field of work

Magmatic and Hydrothermal Systems: Submersible Observations and Sampling

2.4 Operations and equipment

8 days of ship time (1 day for mobilization, personnel transfer and transit; 6 days of on-site operations; 1 day of demobilization) were allocated for the programme.

2.5 Study area

The study area was approximately 1 nm offshore El Hierro Island (27.73N, 18.05W), from 400 meters to 88 meters water depth.

Embarkation port: La Estaca, El Hierro
Destination port: Las Palmas de Gran Canaria (Canary Islands), (140 nm, 49 h transit).
Infrastructure: JAGO submersible

2.6 Short Introduction and Research Background

El Hierro: 4 Years after the Eruption
October 2011-February 2016

El Hierro is the youngest volcanic island of the Canary Archipelago (Figures 1 and 2). The islands were constructed in the Early Miocene as the African plate moved over a mantle hotspot. They show a general age progression from the easternmost islands (>20 Ma) toward El Hierro (<2 Ma). El Hierro is the emergent summit of a shield volcano that rises from 3800–4000 m depth to an elevation up to 1500 m above sea level; the subaerial part having an area of 280 km^2. The oldest subaerial rocks on El Hierro have been dated at 1.12 ± 0.02 Ma. The youngest volcanic eruptions have occurred along three intersecting volcanic rifts (Northeast, Northwest and South). The South Rift dominates the offshore geology, extending more than 30 km south from the study area.

The current offshore degassing and hydrothermal activity at El Hierro started in 2011 with a submarine volcanic eruption 2 km south of the island. Intensive research was carried out in the water column, as the volcano was considered to pose a significant potential hazard for the island and its inhabitants (Fraile-Nuez et al., 2012; Santana-Casiano et al., 2013, 2016). In order to better characterize the seismicity 12 offshore (OBS) and 9 onshore seismic stations were deployed by HIERROSEIS. Leg 1 of POS494 was dedicated to the recovery of the OBSs. POS494-2 was designed as a short add-on leg to deploy the submersible JAGO for the first direct observation of the eruption site since 2011. The objective of POS494-2 was to document the evolution of the eruption site and the continuing hydrothermal activity and to sample the fluids and other volcanic and hydrothermal products that formed at the seafloor, now 4 years after the eruption.

JAGO dives at the volcano confirmed the presence of extensive Fe-oxides and low-temperature venting with bacterial mats at the eruption site, originally identified by the ROV Liropus 2000. A shifting plume of gas discharge near the summit of the volcano (including pH, ORP, and particle anomalies, especially iron) was the main focus of sampling. POS494-2 was the first opportunity to recover vent fluids at their source and to document the nature of the associated mass fluxes and metal deposition. The summit of the volcano was also investigated by a CTD/camera survey.

The diving leg was a cooperation with PLOCAN (Platforma Oceania de Canarias)/ULPGC (University of Las Palmas de Gran Canaria) under the new Collaboration Framework Agreement signed between PLOCAN/ULPGC and GEOMAR in Las Palmas, November, 2014. The work was a natural extension of the Vulcano Project at ULPGC (http://www.vulcanoelhierro.es), led by Dr. J.M. Santana-Casiano and Dr. Melchor González-Dávila, and by Dr. Eugenio Fraile-Nuez of the Spanish Institute of Oceanography (IEO, Instituto Espanol de Oceanografia) and PLOCAN.

3. Major cruise objectives

The Vulcano Project has been remotely monitoring the volcanic unrest of El Hierro since the spectacular undersea eruption in October 2011. Most of the results were focused on the immediate aftermath of the 2011 eruption. However, in March 2104, ROV operations with Liropus 2000 from the Spanish Institute of Oceanography documented what appeared to be extensive Fe-oxides, hydrothermal crusts, hydrothermal sediments and low-temperature venting with bacterial mats at the eruption site. These were never sampled, owing to the limitations of the vehicle. POS494-2 was a unique opportunity to sample the vents and the hydrothermal products that have formed at the seafloor. In particular, we wished to document ongoing hydrothermal activity associated with the volcanic degassing event, to assess the mass fluxes and any metal accumulation, and to observe the longer-term impact on the local environment, including vent-related bacterial biomass. JAGO undertook high-resolution mapping close to the vents, investigated the extent of ongoing gas and hydrothermal fluid discharge at the source, and sampled volcanic and hydrothermal deposits close to the vents. This work complements ongoing research at GEOMAR on shallow submarine hydrothermal venting worldwide, including previous cruises to sites of submarine magmatic-hydrothermal systems in New Zealand (Hocking et al., 2010), Iceland (Hannington et al., 2001; Kuhn et al., 2003) and in the eruption craters of Panarea Island (Monecke et al., 2009, 2011). Until now the focus of this research has been on arc-related volcanoes and mid-ocean ridges; the site at El Hierro provided an important additional case study of magmatic hydrothermal activity associated with shallow-submarine hotspot volcanism.

The main scientific objectives and methods of the POS494 cruise were:

- To conduct high-resolution mapping of the vent site and the local volcanic structure using the JAGO submersible, including investigation of the extent of ongoing hydrothermal fluid discharge.

- To sample the undiluted source fluids that are currently contributing to the near-bottom pH and ORP anomalies documented by Santano-Casiano et al. (2013, 2016).

- To collect low-temperature hydrothermal precipitates associated with the volcanic degassing and seafloor bacterial mats.

- To document the volcanic and structural controls on the recent eruptions and venting, as well as the context with respect to nearby inactive submarine volcanoes and their onshore equivalents.

These objectives complement ongoing research at ULPGC and IEO.

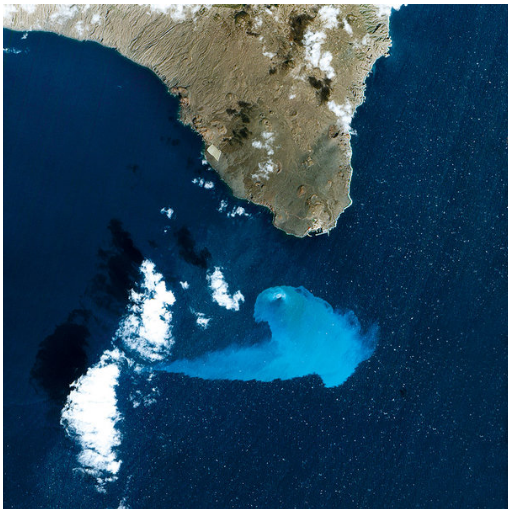


Figure 1A) *View of the port of La Restinga. In the background is a typical scoria cone, similar in size and shaped to the offshore Volcano "E".*

B) *Location of the 2011 eruption site shown by the plume of ash and particles in the water column above cone "E". The line of clouds shows a typical sharp boundary between the calm waters of Mar de las Calmas and the rapidly changing conditions off La Restinga.*

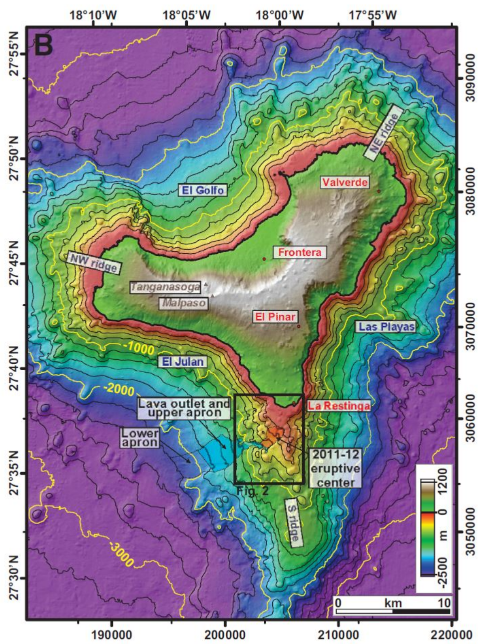
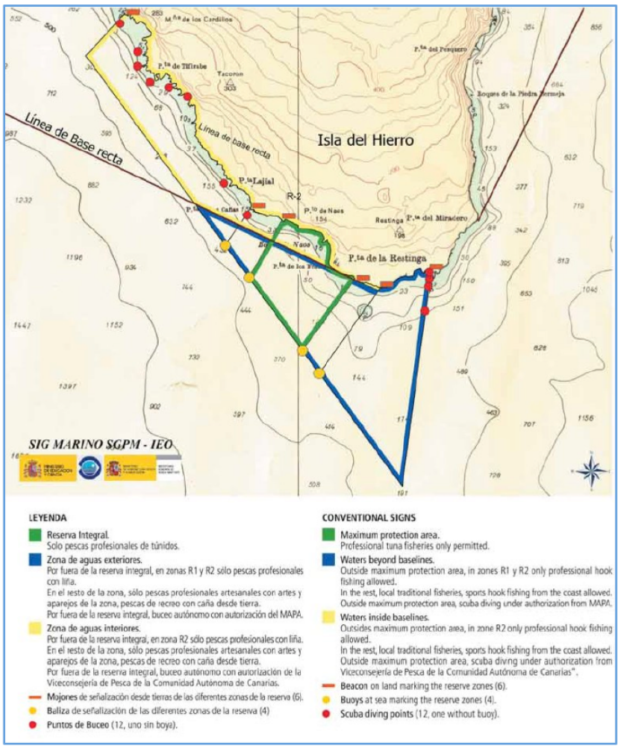


Figure 2A) *Location of the island of El Hierro among the Canary archipelago (GeoMapApp).* ***B)*** *Location of the study area south of La Restinga.*



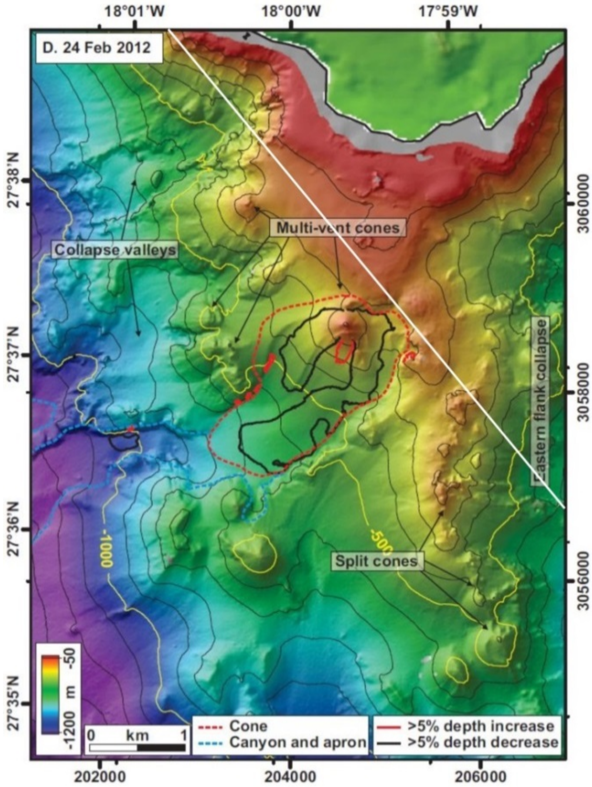


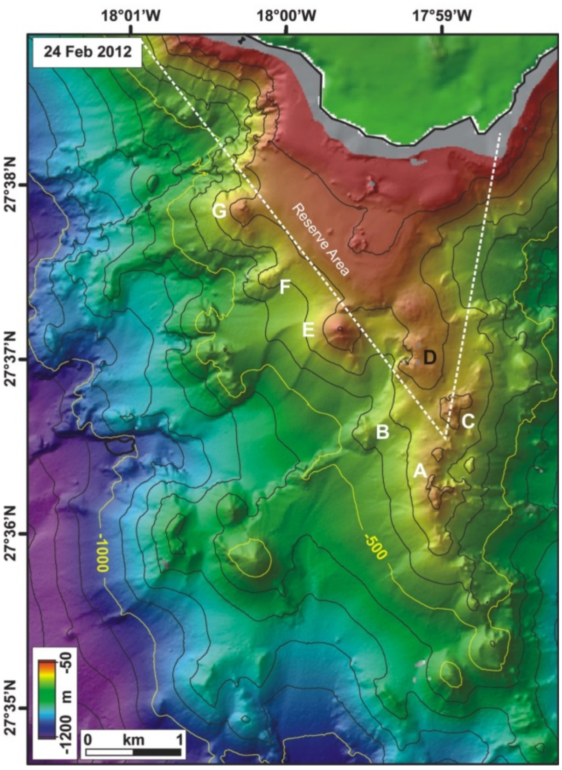
Figure 3A) *Outline restricted areas of the marine reserve off La Restinga. Diving operations were restricted to the area outside the "Reserva Integral" (green) and the "Zona de aguas exteriores" (blue).*

B) *Bathymetric map from Rivera et al. (2013) showing the location of the 2011 eruption site (cone "E") and changes in morphology of the surrounding seafloor resulting from the volcanic construction and slumping. The white line is the limit of the "Zona de aguas exteriores".*

4. Station locations

The study area was approximately 1 nm offshore El Hierro Island (27.73N, 18.05W), from 400 meters to 88 meters depth. 8 days of ship time were allocated for the programme (1 day for mobilization, personnel transfer and transit; 6 days of on-site operations; 1 day of demobilization). The main scientific objectives were achieved in 5 dives with the submersible JAGO, the use of CTD, and larger-scale multibeam surveying with the ELAC 50 Khz multibeam echosounder.

During 2 dives JAGO undertook high-resolution mapping of the summit of Volcano "E" and sampled vent fluids, plume water and volcanic and hydrothermal deposits close to the known vents. During 3 other dives in the area, JAGO documented the erosional canyons on the flank of the island and two other volcanic centers of different age up to 3 km to the NW of the 2011 eruption (sites "F" and "G"). These surveys revealed a complex history of offshore volcanism and mass wasting related to structures associated with the southern part of the El Hierro edifice. The research was supported by an intensive evening multibeam mapping campaign to document the distribution and structural control on similar volcanoes in the working area to depths of 2,000 m.



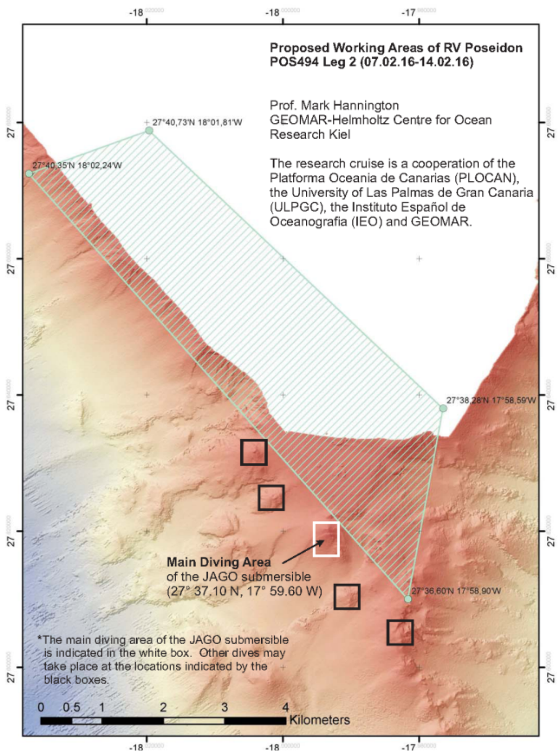


Figure 4A) *Overview of areas where JAGO dives were conducted: See Appendix 1 for station list with ship position coordinates (map from Rivera et al. 2013).*

B) *Originally proposed working area for JAGO. The shaded area is the limit of the "Zona de aguas exteriores".*

Reserve Areas: All provisions of the reserve areas were strictly adhered to throughout the cruise. Any deviations (e.g., for the safe recovery of the submersible) were immediately communicated to the appropriate authorities via the Captain and our Spanish partners on board.

5. Weather and working conditions

The working area was particularly challenging for diving operations because of quickly changing and locally strong wind and swell peculiar to the southernmost tip of the island. The area around La Restinga is generally known for strong winds and underwater currents. The wind statistic (http://www.windfinder.com/windstatistics/hierro) proposes February as one of the calmer month, which was unfortunately not the case for February 2016. Heavy breezes from the NNE are focused around the peninsula of La Restinga (see Figure 1B), with a sharp line of intensified wind and heavy swell to the south and west of La Restinga, as far west as the Mar de las Calmas. Wind speeds changed hourly from <5 to 20 m/s and with dramatic shifts (180 deg) in direction. These conditions were most extreme exactly over the dive targets, forcing the vessel to take frequent refuge in the Mar de las Calmas and significantly impacting the planned dive operations. Weather conditions also affected the ELAC SB3050 and multibeam data collection in deep water (>1500-2000 m). Despite these limitations, the dive operations and mapping far exceeded what might have been expected. This would not have been possible without the patience and professionalism of the ship's crew.

6. Narrative and schedule of operations

Note: In the following narrative all times are reported in local time for El Hierro (equivalent to UTC). The table gives approximate times only; for details see the station list.

5 dives (1300, 1301, 1302, 1303, 1305) at locations "G" and "H", close to the Mar de las Calmas, including 2 dives at Volcano "E"
1 CTD water velocity profile
1 CTD with GoPro video and bottom water sampling at Volcano "E"
6 nights of multibeam surveying

After Leg1/2 team exchange in the Port of La Estaca, POSEIDON departed La Estaca early for the start of operations in La Restinga. We arrived in the main working area at the southern tip of the island on Feb. 07. The wind speed and the local sea conditions did not allow a safe deployment of the submersible for a first test and inspection dive. The main target site (Volcano "E) lay just outside of the lee area that was created by the high-amplitude topography of the island. The local conditions also did not improve during the next day. Wind speed increased rapidly after sunrise and calmer in between periods during daytime remained very short and unpredictable. It was therefore decided to approach the authorities to extend the diving permission to the volcanic slopes closer to the shore within the lee side of the island but still outside of the inner zone of the Marine Reserve Punta de la Restinga Mar de las Calmas. Permission was promptly granted and the first scientific dive then took place in the morning of Feb. 09 followed by a second dive within the same area in the afternoon.

JAGO diving was carried out at locations "G" and "H", close to the Mar de las Calmas, and at Volcano "E" near the eruption site identified by the ROV Liropus 2000. Dives at Volcano "E" confirmed the extensive Fe-oxides, hydrothermal crusts, and low-temperature venting with bacterial mats. A shifting plume of gas discharge documented at the summit of Volcano "E" in 2014 (including pH, ORP, and particle anomalies, especially iron) was the main target. However very strong currents at the summit prevented work in that area. The main location of sampling was a newly identified area of venting in a 25-30 m diameter depression on the SE side of the summit. The summit of the volcano was also investigated by a CTD/camera survey, made possible by attaching 2 GoPro cameras to the CTD frame and using ambient light for illumination.

During 2 dives at Volcano “E”, JAGO undertook high-resolution mapping of the 2011 eruption site and the local volcanic construction to gain a full-scale perspective of the active summit of the volcano, including the distribution of low-temperature discharge. Previous bottom surveys by ROV had only investigated very localized areas of the summit. In addition to mapping, the JAGO collected the first rocks, Fe-oxides and near-vent water samples from the volcano. Details of the physical and chemical water mass properties (temperature, salinity, oxygen, pH, total alkalinity, and inorganic carbon species) and links to local water-column acidification and Fe-fertilization are being studied by the Spanish colleagues. During 3 other dives in the area, JAGO documented several older volcanic cones of different age up to 3 km NW of Volcano “E”. These surveys revealed a complex history of offshore volcanism and mass wasting typical of the southern flank of El Hierro. The surveys of the near-shore volcanoes by JAGO were supported by an intensive evening multibeam mapping campaign to document the distribution and structural control of other volcanoes in the working area to depths of 2,000 m. In total, 5 JAGO dives were completed in 4 working days, together with 6 nights of multibeam mapping. Due to persistent extreme sea conitions and forecasted bad weather for the transit to Las Palmas, science operations were terminated at 15:20 on Saturday, February 13.

On February 5, a full-colour announcement of ULPGC’s use of JAGO and POSEIDON appeared in La Provincia, the local Las Palmas newspaper (“Cientificos alemanes y espanoles: La ULPGC participa en el maestro mas proximo al nucleo del volcan herreno”). Extensive media coverage both in Germany and in Spain followed in the days after the cruise, in particular highlighting a professional video documentary of the operations.

Time	Operation
Thursday, February 04	
–	Loading of submersible JAGO and scientific equipment in Las Palmas (prior to Leg 1).
Thursday-Saturday, February 04-07	
–	Leg 1 of POS-494 HIERROSEIS
Sunday, February 07	
08:00	Boarding of Science Party at La Estaca (Mark Hannington, Sven Petersen, Meike Klischies, Magdalena Santano-Casiano, Eugenio Frailes-Nuez, Sabine Lange).
09:00	Visit of El Hierro journalists, interview with Eugenio, Magdalena, Juergen and Mark.
12:00	Depart La Estaca for JAGO dive site, approximately 1 hr.
13:00	On station – force 7 to 8
14:00	USBL navigation test (no station number)
15:20	Safety induction in mess for science party (incl. Maike and Maarten media team)
15:30	Sustained winds, abandoned dive plan for day 1 in consultation with Captain and JAGO Team
16:30	Established ELAC SB3050 multibeam recording and began transit to SW corner of work area for overnight multibeam (data collected in transit).
18:34	Transit to first multibeam survey. Strong wind of 12-13 m/s.
24:00	Begin first multibeam survey Heading NNE (035) into wind at 2.5 kn (Note: a deep CTD for characterising the water column was postponed until February 10) because of availability of deck crew.
Monday, February 08	
04:00	Continuing multibeam to NNE (043). Relative wind speed to 15 m/s.
09:30	Email request sent from the bridge (in Spanish) to Department of Fisheries as a precaution to extend operations into the reserve area in the lee of the island to avoid wind near the cape.
09:50	End multibeam profile. Sea conditions and wind speed diminishing to state 4. Decision made to return to primary dive target E to assess conditions.
10:30	Transit to Vulcano E to inspect wind conditions; diving not possible.

11:00	Transit from Vulcano Site E to targets F and G and then the northernmost limit of the reserve area to inspect diving conditions.
12:30	Granted request from Dept. of Fisheries and local authorities for diving in the reserve area, but only the outer part (blue zone).
13:00	Diving conditions worsening from 13:00 to 14:00.
14:00	Decision to abandon day 2 of diving due to weather. Commenced transit to multibeam surveying on the west side of the volcanic ridge and unmapped cones SW of Vulcano E. Most data below 2000 m not recoverable due to poor weather conditions; will have to be redone in the following days.
15:30	Commenced multibeam survey for Feb 08.
Tuesday, February 09	
06:00	Ended multibeam and took shelter in the Mar de las Calmas.
07:50	Arrival of the media team.
08:00	Moved to target G to assess wind conditions. Initial dive preparations were made for site G but conditions immediately worsened (sea state up to force 7 to 8).
09:00	Moved back to Mar de las Calmas (west of target G). Stationed over eastern side of erosional feature at target G. Wind speed dropped to less than 10 m/s. Decision made to dive on scarp on west side of Target G.
10:00	JAGO Dive 1300 at 360 m depth (Hannington, observer). Traversed across the canyon immediately below Mña Puerto de Naos volcano.
13:15	JAGO Dive 1300 terminated on west side of canyon, outside the internal reserve area. JAGO surfaced at 13:15.
14:00	Improving conditions. Decision to revisit site E to determine if a short sampling dive would be possible, but wind had already picked up by the time we arrived.
15:00	Returned to Mar de las Calmas to the recovery site of JAGO after dive 1300. Decided to prepare a short media dive (van Rouveroy, observer). Launched JAGO Dive 1301 at 16:15 on the west side of the canyon at 365 m depth for filming descent/ascent.
17:50	JAGO Dive 1301 terminated. On deck at 18:25.
19:00	Departure of the media team. Beginning transit to fill-in multibeam station.
21:00	Commenced multibeam survey for Feb 09
Wednesday, February 10	
06:30	Terminated multibeam profile to transit to dive area in Mar de las Calmas.
08:00	en route to site G (force 7 to 8 conditions)
09:45	Arrived at site G to deploy.
10:00	Launch of JAGO Dive 1302 (Petersen, observer) at 221 m. JAGO drifted in strong current to the SE between volcano F and G.
12:15	Media personnel arrive to film JAGO recovery.
12:30	JAGO on surface near cone G. Recharging batteries in anticipation of the next dive.
15:00	Wind speed picked up again to 17 m/s. Decision to cancel second dive. Begin transit to deep-water CTD for sound velocity.
16:00	Commence CTD profile to 2000 m water depth.
17:15	CTD on deck. Returning to Mar de las Calmas to drop off media personnel.
18:30	Re-commence multibeam terminated in the morning.
Thursday, February 11	
8:00	At site E with wind speeds of 5-7 m/s, increasing to 12 m/s by 9 am.
9:00	Media team arrives. Waiting between F and G for dive weather window.
10:30	Moved slowly to volcano F. Wind dying periodically and then quickly up again.
12:30	Wind back up to force 7-8. Waiting at volcano F for a weather window (12:30-16:00).
16:00	Decision finally to abandon dive and deploy CTD on volcano E. Installed GoPro video on CTD and deployed in a short weather window at the summit of volcano E.
17:30	Distinct temperature anomaly located at the site of the new vent found in 2015 at 127 m on the SE flank of the volcano summit.
17:30	Turned on 12kHz for a short inspection of the vent location on volcano E. No bubble

	plume detected. Retrieved CTD after firing all 12 bottles (including a deep water blank).
18:15	Media team departs.
18:45	Commence multibeam profile with reduced speed to map the deep cones (1800-2000 m) SW of Mña Puerto de Naos volcano.
Friday, February 12	
06:00	Arriving back at volcano E
07:15	JAGO Dive 1303 at volcano E (Santano, observer). Wind speed less than 3-4 m/s. 07:30 at the bottom (160 m) south of the 2015 anomaly and sampling water and rocks. Completed sampling at 12:00 and traversing north over the top of the volcano, then NW to calmer water near F and G for recovery.
13:00	Wind speeds of 15-17 m/s. By 15:00 winds slowly dying down at site G.
14:50	Beginning ascent from 320 m depth near site G. Collected first rocks, Fe-oxide and water samples from the 2015 vent site.
15:05	JAGO on surface.
18:15	Media team pickup.
18:30	Resuming multibeam survey.
Saturday, February 13	
06:30	Arrived at station E to examine weather. Force 6-7 at the site.
07:45	Launched JAGO Dive 1304 (Frailes-Nuez, observer) in a very narrow window to sample fluids at site E. Sampling with a modified fluid sampler at the 2015 anomaly at 10:00. Strong currents at the top of the volcano prevent the exploration of the 2014 anomalies. The final part of the dive examined the ridge SE of the top of the volcanic cone where inactive Fe-oxide deposits were located.
13:45	The dive was terminated after an attempt to make progress toward calm water NW of volcano E. The decision was made to tow the JAGO into calmer water about 2 nm to the NW before pickup.
15:00	Recovery of the JAGO completed.
16:00	Dr. Eugenio Frailes notified the Spanish authorities of the end of scientific operations in the working area.
17:30	Due to persistent sea conditions in the working area and forecasted bad weather for the transit to Las Palmas, science operations were terminated. The final departure of the media team was completed and Poseidon departed the working area.
Sunday, February 14	
–	Transit to Las Palmas.
Monday, February 15	
–	Demobilization of JAGO
Tuesday, February 16	
–	Disembarking of Scientific Crew

7. Description of operations and preliminary results

7.1 Submersible JAGO (K. Hissmann, J. Schauer, P. Striewski)

The main research equipment used during POS494 was the GEOMAR-owned manned submersible JAGO that can take two persons, a pilot and a scientific observer, to water depths of maximum 400 m (Figure 5). The submersible has a compact size and a low weight of 3 tons that enables shipment in a single 20' ISO container and deployment from smaller and middle-sized vessels like the FS POSEIDON. JAGO is equipped with USBL navigation and positioning system, fluxgate compass, vertical and horizontal sonar, underwater telephone for communication, digital video (HD) and still cameras, CTD sensors and a manipulator arm for collecting and handling various sampling devices and instruments.

Figure 5. *Recovery of submersible JAGO after a dive at the underwater volcano off La Restinga / El Hierro. Photo K.Hissmann / JAGO-Team*

The submersible has been used for research on shallow submarine magmatic-hydrothermal systems during previous cruises to sites at Iceland (RV POSEIDON cruises P229 and P253) and New Zealand (RV SONNE cruise SO-135 and Lake Taupo).

During POS494-2, JAGO was used for

- high-resolution video documentation and mapping,
- investigation of the extent of on-going gas and hydrothermal fluid discharge,
- sampling of volcanic and hydrothermal deposits, hydrothermal fluids and water close to and inside the vents, and
- collection of chemical and physical sensor data around the active sites and inside the sediment (CTD, ORP, pH).

The submersible container left Kiel on the 7th of January 2016 and was trucked to Hamburg, where it was transferred on board the FS POSEIDON for transit from Germany to Gran Canaria. The mobilization of the submersible on board the vessel took place on the 2nd and 3rd of February in the port of Las Palmas de Gran Canaria (installation of the USBL underwater navigation and positioning system, UT-communication, sampling devices etc). The JAGO-Team participated already in leg 1 of POS494 (04.-06.02.2016, lead by Dr. Dietrich Lange / GEOMAR) in order to use the transit day (04.02.) and the two recovery days for OBS stations (05.+06.02.) for further technical preparations.

The first scientific dive took place in the morning of Feb. 09 followed by a second dive within the same area in the afternoon. On the next day, local wind conditions allowed deployment of the submersible slightly further offshore at an older inactive volcanic cone 1.7 km northwest of the main target side. The narrow time window of lower wind speed shortly before sunrise was then used on Feb. 12 and 13 to deploy the submersible close to Volcano “E”. On both days surface weather conditions quickly decreased again shortly after the submersible had submerged. At the end of the first dive at the volcano, the submersible travelled about 2 km to the northwest along the sea floor in order to reach an area with calmer sea surface conditions for safe recovery. At the end of the second dive, strong bottom currents prevented such a long distance transit underwater. After surfacing in relatively rough sea conditions, the submersible had to be towed by POSEIDON’s workboat for about an hour from its surfacing site into a calmer area closer to shore.

While submerged, JAGO was tracked and guided by USBL underwater navigation and positioning system (Trackpoint III from ORE / USA; part of the submersible support

equipment). The position data (ship and sub) were integrated into OFOP navigational software (http://www.ofop-by-sams.eu/) to display and follow both the JAGO and POSEIDON tracks geographically and in real time on a computer screen. The position data were overlaid on GIS based bathymetric maps that were provided by IEO and logged in column-based ASCII files. All dive tracks and sampling sites are available to be plotted on the multibeam maps and to be combined with the individual dive logs, video sea floor observations, CTD and ORP-pH records. Time codes were all set and synchronised to UTC.
Communication between JAGO and POSEIDON during dives were maintained by acoustic underwater telephone (ORCATRON).

For sampling and in situ measurement of environmental parameters the following sampling devices and sensors were mounted on JAGO. Rock and hard substrate samples were selectively picked up from the sea floor with JAGO's manipulator arm and transferred into a sampling box mounted on JAGO's instrument porch at the lower front of the submersible.
Hydrothermal fluids that were vented from small outlets and chimneys at the bottom of the depression were collected with a flow-through system mounted on JAGO's front equipment rack (Figure 7). The fluid sampler consists of two vertically mounted sample cylinders (made of inert and high-temperature resistant PFA, volume 375 ml each, 295.4 mm length, 47.2 mm ID), two lower inlet and two upper outlet valves and appropriate connectors. A mechanical pump (24 VDC) is mounted downstream to the sample columns behind the upper outlet valve. It has a pumping rate of approx. 10 l/min at 24 VDC. The sampling hose, made of PTFE (Teflon®), has an inner diameter of 10 mm and a length of 1500 mm. Fluid enters the hose via a short titanium tube (nozzle) that was guided by JAGO's manipulator arm into the vent. The pumping time per sample was approx. 3-4 min to make sure that the cylinder volume was exchanged at least 2-3 times. The valves at the lower and upper end of the sample cylinders were closed individually with the manipulator arm. During dives #3, 4 and 5, sealed water samples were collected close to the sea floor with a 2.5 liters NISKIN bottle. The NISKIN is triggered with JAGO's manipulator arm.

A Pt100 temperature probe with an accuracy of about 0.1 degrees Celsius was used to measure temperatures inside the vent outlets and up to 20 cm deep inside the sediment. The probe was manually guided into the outlets and stuck into the sediment with JAGO's manipulator arm (Figure 8). A pH-O.R.P. (Redox) sensor (Seabird 27) was attached to the lower part of JAGO's vertical equipment rack in the front of the sub. The sensor was cable-connected to a pressure housing containing the power supply and data storage unit. The housing was attached to JAGO's top grating (Figure 7). A CTD (SAIV A/S SD204 Norway), attached to the stern of the submersible, continuously recorded depth, temperature, salinity and density during de- and ascents and while being stationary at or "flying" close above the seafloor during dives #1, 2, and 5. All CTD data were available as ASCII and Excel files.

Figure 6A) *Recovery of JAGO near volcano "G".* ***B)*** *Image through the widonw of JAGO with externally-mounted GoPro camera.*

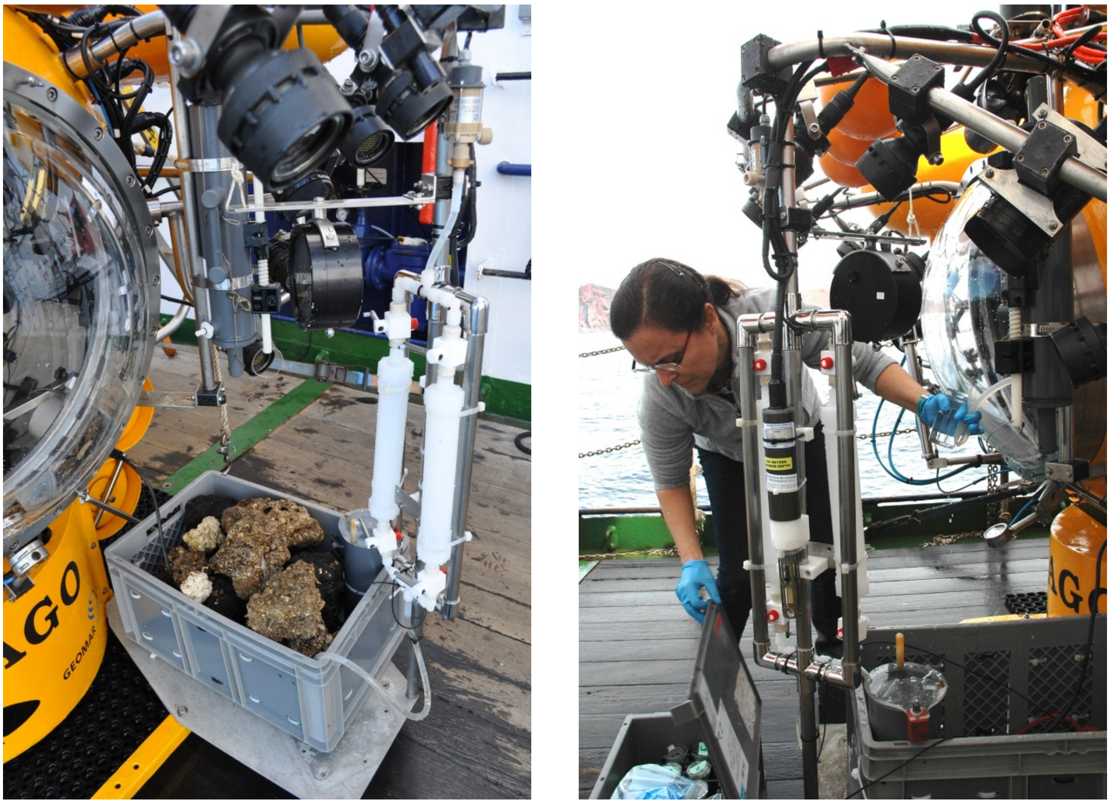


Figure 7. *Instrumentation and sampling devices on submersible JAGO during POS494. Left: Fluid sampler cyclinders mounted on JAGO's vertical equipment rack, Niskin bottle and sampling box. Right: pH-ORP sensor attached to the back of the fluid sampler cylinders.*

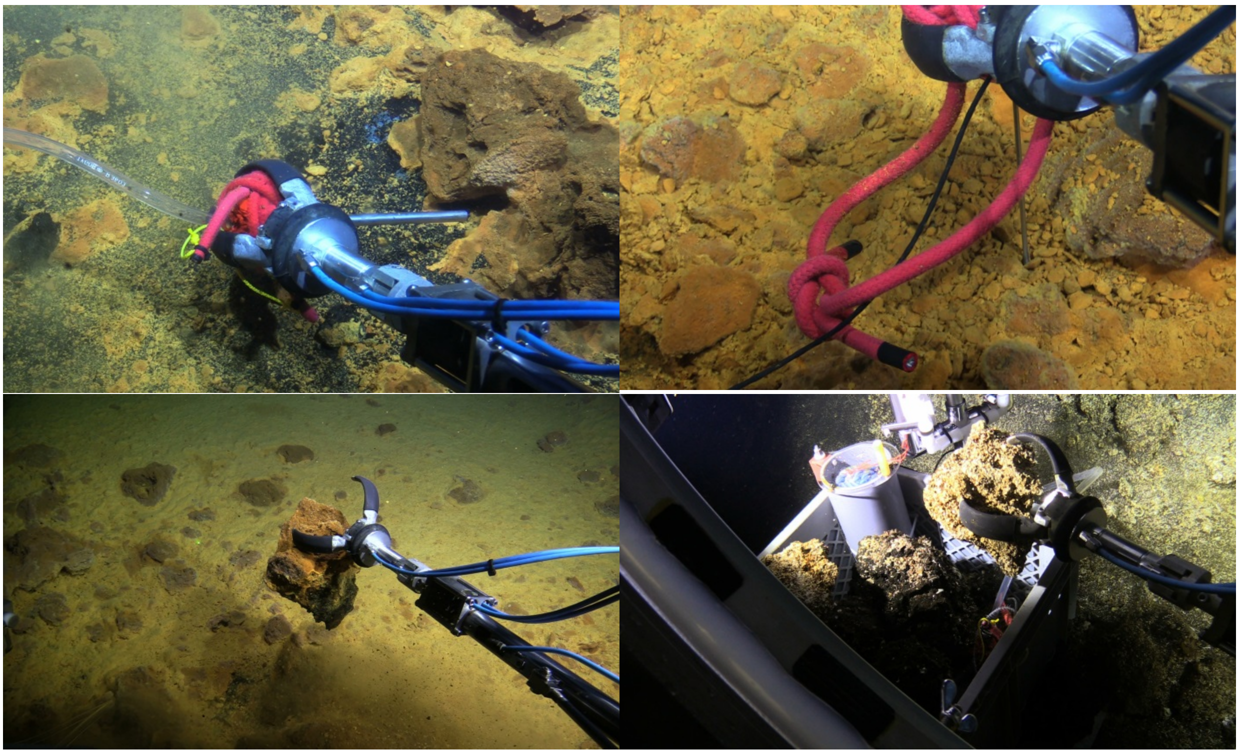


Figure 8. *Upper left: JAGO's manipulator arm guids nozzle of the fluid sampler into warm water outlet. Upper right: temperature probe shortly before being pushed into the sediment. Lower left: collection of vocanic rock. Lower right: JAGO's sampling box filled up with rock samples.*

The seafloor, including habitat and any activity, was continuously video-documented with a CANON XA25 HD-Camcorder mounted in the centre of JAGO's large bow window. After each dive, the original HD footage was copied, converted into a format with less storage volume and overlaid with UTC time stamp for geo-referencing and annotation by the science party. Video still images were captured from the original HD footage by frame-grabbing to assist mapping. A dive protocol was produced by each of the dive participants to log observations and activities.

With only seven days at the working area, leg 2 of POS494 was already very short. In addition, the harsh and quickly changing surface weather conditions with wind forces of up to Bft 8 and 3.5 m of sea strongly minimized chances for safe deployment and recovery of the submersible and thus dive time. Nevertheless, a total of 5 dives were conducted, of which two long dives took place at the main target site, a depression with active discharge of gas and warm water at the southeastern flank of the underwater Volcano “E”. All objectives of the submersible mission were achieved during these five dives. Total dive time was 21 hours (Appendix). Each of the four senior scientists participated in a dive (Hannington, Petersen, Santana-Casiano, Fraile-Nuez). The generated video material comprises more than 16 hours of HD sea floor footage at water depths between 90 and 395 m.

Diving operations ended after the last dive on February 13. The submersible container was offloaded from POSEIDON on the 16th of February in the port of Las Palmas de Gran Canaria and was shipped back to Kiel three days later where it arrived on March 3.

Although the local weather conditions were unpredictable and not very much in favour for a submersible operation, the handling of the submersible from on board the POSEIDON was very safe and smooth. The teamwork between the captain of the vessel, its crew and the JAGO-Team during launch and recovery was as excellent and professional as during previous JAGO-POSEIDON cruises. Deployment and recovery of the submersible took only few minutes. The POSEIDON is and remains one of the most suitable support vessels for JAGO operations.

USBL tracks of the 5 JAGO dives are shown in Figure 9. Summaries of each dive are provided below and detailed Dive Logs are provided in chapter 12.

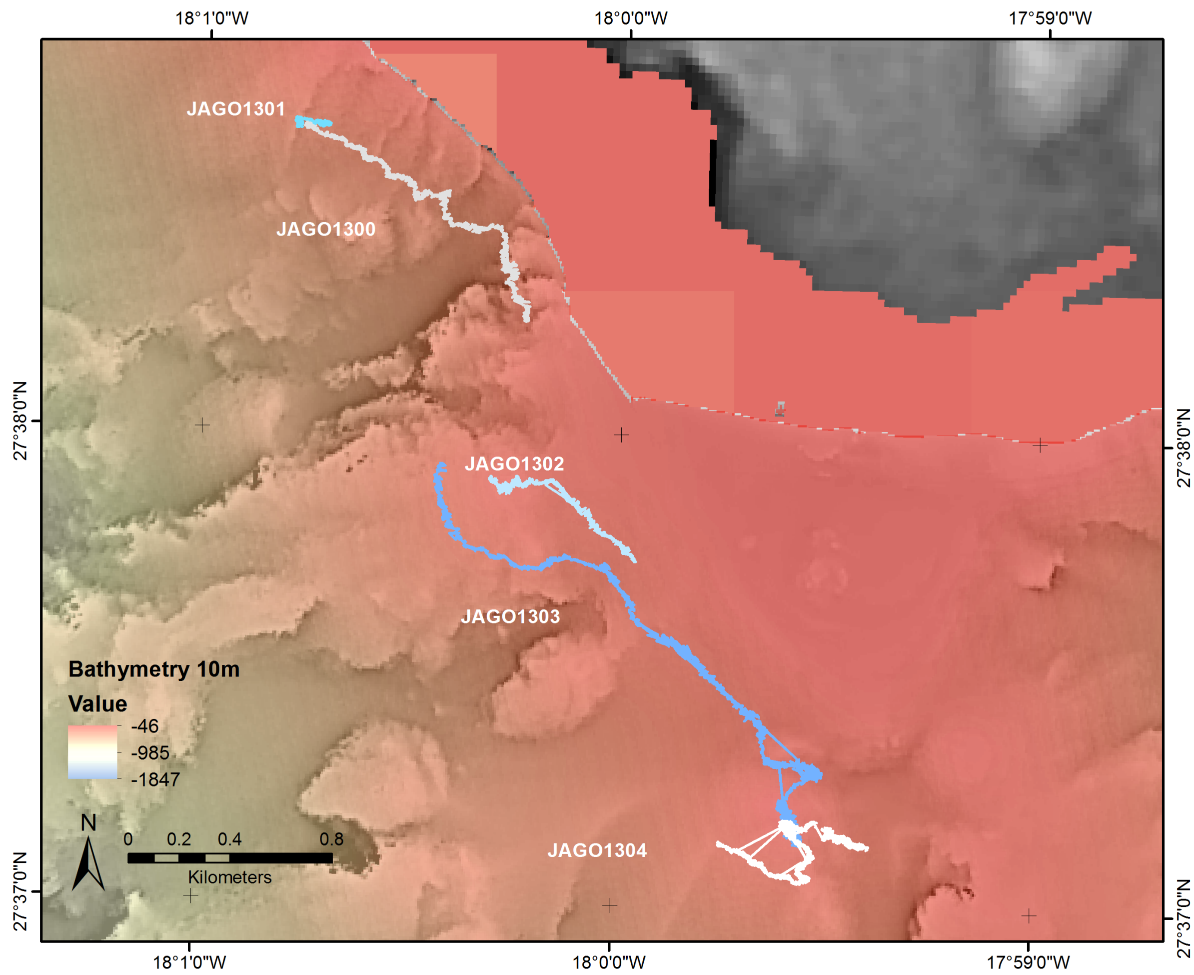


Figure 9. *USBL tracks of five JAGO dives, underlain by IOE bathymetry data (water depth in meters), gridded at 10 m and illuminated with the terrain texture shader (by Leland Brown).*

JAGO Dive 1300(01), Station 17 – 09.02.2016 – SW shoreline canyon

- Start: 27°38.25'N, 18°00.23'W, 247 m water depth
- End: 27°38.61'N, 18°00.76'W, 374 m water depth
- Heading: SE to NW; track length ca. 1200 m
- Observer: Mark Hannington
- Samples: none (restricted sampling area in marine reserve)
- Measures: pH-ORP, CTD
- Media: HD video

The objective of the dive was to inspect the irregular relief on the eastern and western sides of the canyon formed by the collapse of the volcanic edifice on the La Restinga shoreline and determine whether the seafloor topography is mainly from the mass wasting or partly offshore constructional volcanism.

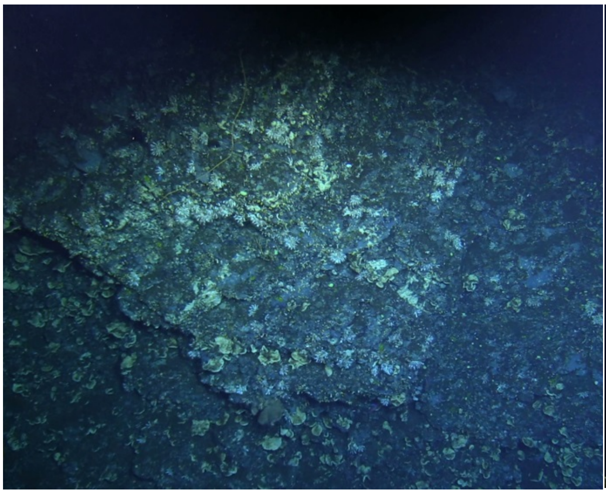
Geology: Mña Puerto de Naos canyon is a deeply incised canyon offshore from the Punto de Las Frailes collapsed volcano. The JAGO landed on the north flank of cone G at 247 m, adjacent to the canyon on the east side. The submersible followed the east wall down to a depth of close to 400 m. The east wall of the canyon is dominated by very steep escarpments (near-vertical steps of 30-40 m) of stratified volcaniclastic sediments, mainly

ash with few blocks. These features appear to be the eroded remnants of a cone flank, very similar to those exposed on shore, with bedding at a moderate to steep but consistent dip to the SW. The central part of the canyon was traversed at a depth close to 400 m and consists of volcaniclastic scree slopes with dark grey to locally white bioclastic material (fossil rhodoliths and debrits of other crustose coralline algae, as well as shell, coral, tube etc fragments). At the west wall of the canyon, the erosional remnants form linear ridges of bedded volcaniclastics, 10-20 m in height. However on several slopes, there was clear evidence of older coherent lava (old tubes Figure 10 F-G, ropy lava, and local sheet-like surfaces) on top of stratified ash layers, suggesting that the western side of the canyon is partly a low-relief constructional feature rather than the eroded remnants of a scoria cone.
Thus, many of the low-relief features on the flank of the La Restinga peninsula are not only products of mass wasting (i.e., material shed from onshore collapse features) but include volcanic constructional forms. These include cones that are partly shaped by landslides and partly buried by material from the failed volcanic edifices on the shoreline.

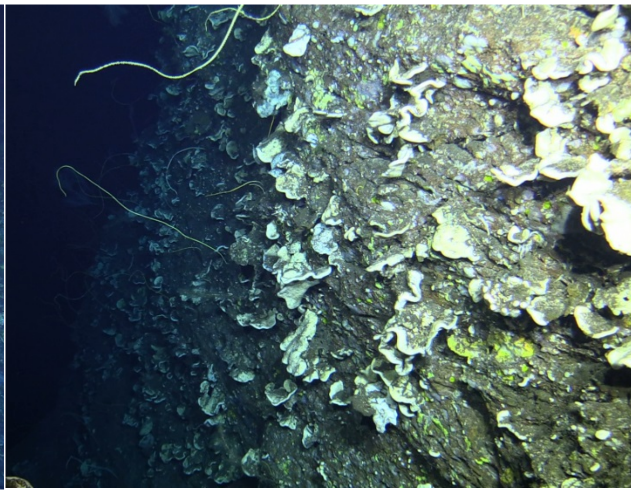
Fauna diversity and community structure: A small portion of the steep wall, faced at first sighting of the bottom at 378 m depth, was colonized by small colonies of deep-water scleractinian corals (probably *Lophelia pertusa*) and many encrusting as well as upright growing lithistid sponges (*Demospongiae),* like the ear-shaped *Corallistes masoni* and probably *Neophrissospongia sp.* (Figure 10 A+B). Lithistid sponges are in general the most common megafauna element on the steep cliffs and bigger blocks encountered during this dive. Prominent on hard substrate are also various forms of gorgonians: unbranched whip corals (probably *Viminella flagellum*, white and yellow color variety, Figure 10 B+C+D) and single specimens of fan-shaped (probably *Callogorgia verticillata*, Figure 10 C) and comp-like colonies (*Ctenocella* sp.? , Figure 10D). Isolated colonies of the yellow scleractinian coral *Dendrophyllia cornigera* were also documented. Small patches of the deep-water oysters, probably *Neopycnodonte cochlearv*were recorded on vertical cliffs and below overhangs.

The mobile fauna was found to be relatively sparse on the rocky cliffs and along the scree slopes. Single specimens of epibenthic fish like scorpionfish (probably *Helicolenus dactylopterus*) were seen on rocky ground and a small unidentified bottom-dwelling fish with iridescent fins and large eyes on the gravel slopes. Large mobile invertebrates were almost completely absent. Only single specimens of a white sea urchins and, attached to gorgonians, some brittle stars were occasionally seen. A single specimen of a *Pyrosoma* sp. colony ('fire-salp'), a free-floating colonial tunicate that forms a long transparent tube (closed at one end and open at the other) drifted in the water-column several meters above the bottom (Figure 10E).

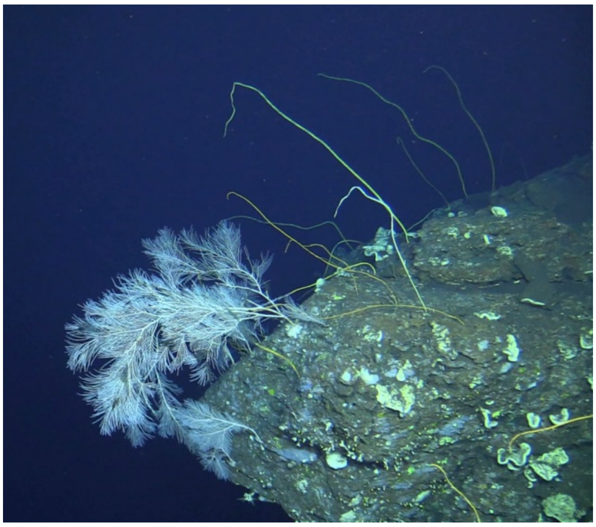
The coarse bioclastic sand and light-coloured gravel on the slope of the central part of the canyon, which partly overlay the dark-grey ash, consist of coral rubble and fragments of other calcifying organisms. The bioclastic material might have been transported downslope by mass-waste and strong bottom currents or derives from carbonate deposit layers that were seen in several of the following dives. An accumulation of fossil rhodoliths and their debris, laying on top of the dark-grey volcaniclastic sediment (Figure 10 H), give evidence for the presence of layers that bear large numbers of fossil rhodoliths and the fragments of other crustose coralline algae. These layers were clearly visible during JAGO dive 1303(4) (see below).



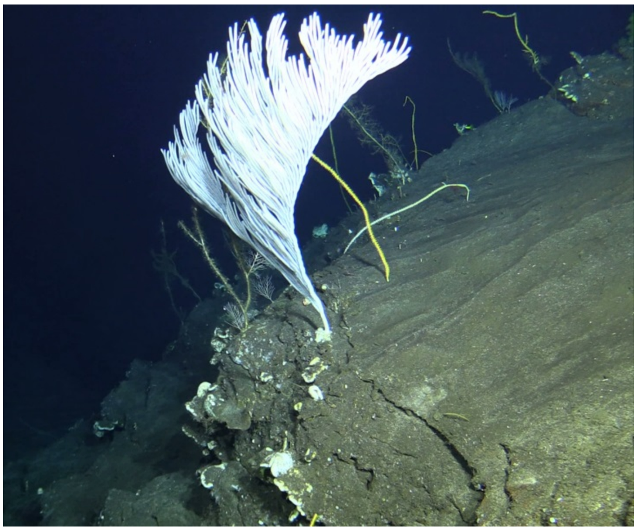
A *Steep wall densely colonized by sponges and small colonies of scleractinian deep-water corals (probably* Lophelia pertusa*), 378 m*



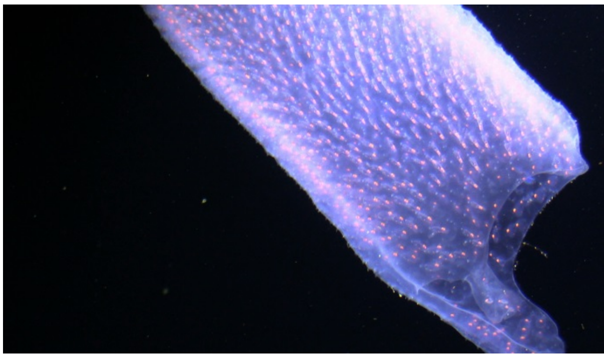
B *Aggregation of sponges and single specimens of unbranched whip corals (*Viminella flagellum*), 380 m*



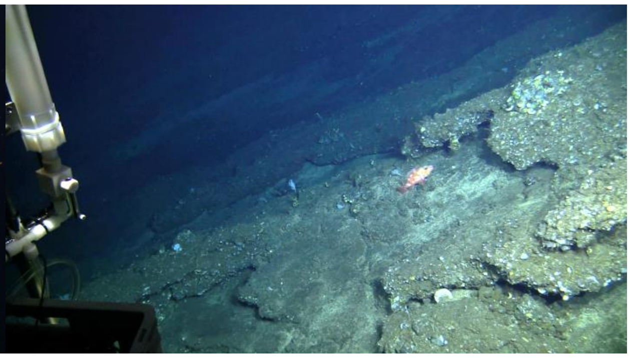
C *White gorgonian* Callogorgia verticillata *and whip corals* Viminella flagelum



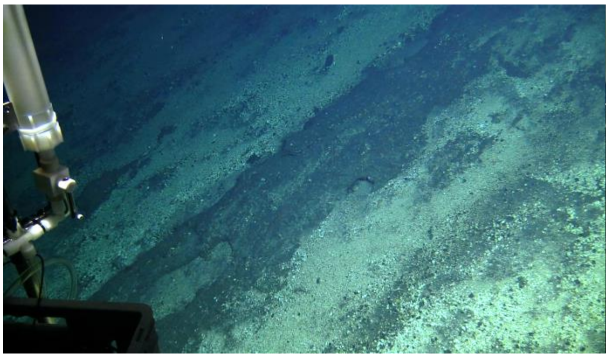
D *White gorgonian* Ctenocella sp. *and whip corals* Viminella flagellum, 372 m



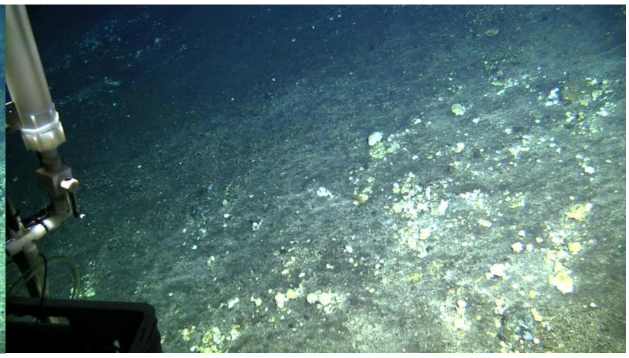
E *Pelagic colonial tunicate* Pyrosoma sp.'fire-salp'



F *Scorpionfish* Helicolenus dactylopterus *on a hollowed out lava tube at 377 m*



G *Lava tube at 377 m*



H *Accumulation of light-coloured fossil rhodoliths on top of volcanic sediment on scree slope, 389 m*

Figure 10. *Images of the habitats and fauna documented during JAGO dive 1300(1)*

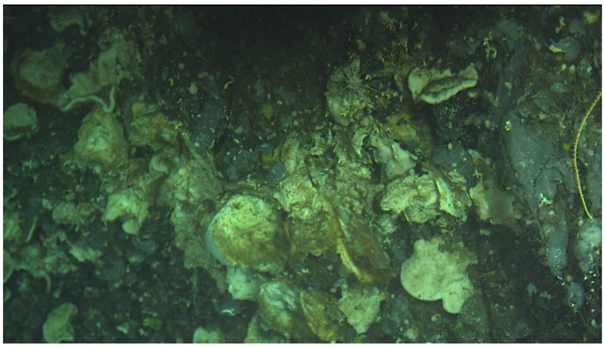
JAGO Dive 1301(02), Station 18 – 09.02.2016 – SW shoreline canyon

- Start: 27°38.65'N, 18°00.72'W, 365 m water depth
- End: 27°38.64'N, 18°00.78'W, 365 m water depth
- Heading: E to W; track length ca. 270 m
- Observer: Maarten van Rouveroy (cameraman)
- Samples: none (restricted sampling area in marine reserve)
- Measures: pH-ORP, CTD
- Media: 4K video
- Short media dive for documentation from within JAGO during launch, descent, bottom landing at >300 m, and ascent.

The objective of the second JAGO dive was to film the procedures performed by the pilot inside the submersible during submerging, diving and surfacing. The footages were needed for the video documentary produced about the cruise. The dive therefore mainly concentrated on a small stretch of a outcrop ridge at the west side of Mña Puerto de Naos Canyon were old volcanic-derived sediment mixed with bioclastic material. Local outcrops of bedded volcaniclastics were observed but with a very high bioclastic component (volcaniclastic gravel with embedded shell fragments). The shallow parts of the canyon 200-300 m are populated by large colonies lithistid sponges, single specimens of finely branched gorgonians (e.g. *Callogorgia verticiiata*, Figure 11B) and deep-water oysters, probably *Neopycnodonte cochlear* (Figure 11C).

A *Scorpionfish* Helicolenus dactylopterus

B *Branched gorgonian* Callogorgia verticillata *at 365 m depth*



C *Deep-sea oysters* Neopycnodonte cochlear, 365 m depth

Figure 11. *Images of the fauna documented during JAGO dive 1301(2)*

JAGO Dive 1302(03), Station 20 – 10.02.2016 – old volcanic cone G

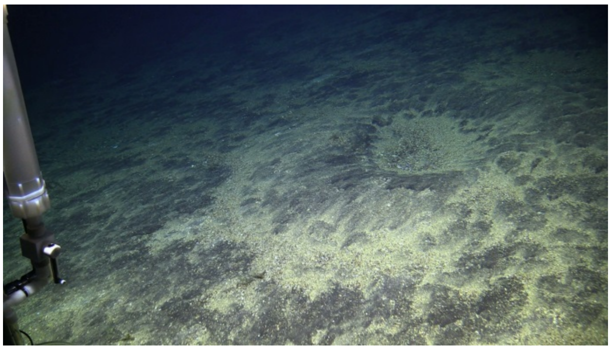
- Start: 27°37.74'N, 17°59.96'W, 207 m water depth
- End: 27°37.90'N, 18°00.31'W, 163 m water depth
- Heading: SE to NW; track length ca. 900 m
- Observer: Sven Petersen
- Samples: near bottom water (Niskin)
- Measures: pH-ORP
- Media: HD video

The objective of the dive was to document the flanks and the summit of an older cone (G) for comparison with the volcanic features and ongoing activities at the 2011-eruption site. Cone G is located about 1600 m northwest of the underwater volcano (cone E) and rises from about the same water depth to a summit of 120 m. The dive started at 207 m depth about 600 m southeast of the summit of cone G, which was then approached in northwestern direction along a gently rising sand-to-gravel slope consisting of fine-grained dark sediment (ash?) associated with coarser-grained and lighter carbonate debris (fragmental remains of bivalve shells, coral and bryozoan skeletons, tubeworm tubes, coralline algae etc), of which some probably derived from shallower water. Some isolated small volcanic rocks were found along the dive track. Benthic fauna was sparse on this slope. Only some flatfish and single specimens of orange sea stars and a small octopus were recorded. Shallow depressions within the substrate that were occasionally noticed (Figure 12A) were probably created by the activities of epibenthic vertebrates like flatfish, rays and octopus. Small irregular patches of lighter coloured sediment, probably displaced material from underlying sediment layers, are hints for activities of some infaunal or epifaunal organisms (bioturbation). Ripple marks give evidence for strong bottom currents that occur also in 200 m water depth.

At 190 m depth the slope became steeper and the portion of hard substrate increased. Close to the pinnacles large areas are almost entirely covered by fine-grained dark grey to black sediment (Figure 12B). While moving further upslope, the carbonate blocks were increasingly colonized by whip corals (*Viminella flagellum*), black corals (Antipatharia) with helicospiral *Stichopathes sp.)* and bushy growth (*Anipathes* sp.) (Figure 12C, D). Finely branched tree-like hydrozoans are also an abundant element of the sessil fauna. Steep-sided pinnacles with vertical wall and overhangs were faced at 158 m depth forming the summit of this cone. The pinnacles consist of a carbonate conglomerate often with abundant holes related to erosion, and cracks. It was also densely populated by whip corals that are occasionally colonized by other sessile organisms such as bryozoans, hydrozoans and soft corals (Figure 12E-F). The surface of the rocky substrate was irregular and knobby, composed of many small whitish and yellowish protuberances. They resemble the surface of encrusting coralline algae reefs. Coralline red algae, however, were widely absent and only noticed as small patches and dots when zoomed in with the video camera. Cervices and depressions between and within the rocks are filled with fine-grained dark sediment, most likely ash from the recent eruption in 2011.

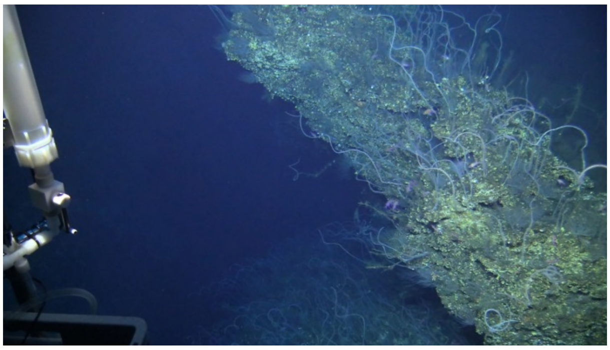
The top of the cone was reached at 123 m. It was found to be 150-200 southwest of the position where it had been localized by earlier multibeam mapping. The entire summit area was very rugged and composed of large irregular rocks, cliffs, crevices and valleys. The dominant benthic organisms at the very top of the cone were purple and yellow coloured gorgonians (fan-shaped colonies, branched in a single plane, and some colonies with both colours on the same colony, perhaps *Paramuricea clavata*) (Figure 12H-J). The fish community consists of swallowtail seaperchs *Anthias anthias* (Figure 12J), which was regularly seen above hard substrate, and demersal fish like the sea brasse *Serranus atricauda* (blacktail comber) (Figure 12H), scorpionfish (probably *Helicolenus dactylopterus*), a Mediterranean moray eel (*Muarena helena*) hiding in a cervice (Figure 12G) and, in particular around and above the summit, comp groupers (probably *Mycteroperca* sp.) and jack fish. Occasionally lost fishing gear (ropes and lines, densely colonized by sessile invertebrates) was encountered.

It is likely that the knobby light-coloured surfaces of most of the hard substrate around the summit of the cone are dead (?) encrusting coralline algae (Corallinales). Crustose coralline algae of different growth forms are abundant on most of the rocky substrate in the shallow waters off La Restinga. In clear water, they usually occur at all depths within the photic zone. Since twilight is still present at the summits of the submarine volcanic cones, it is astonishing that live coralline red algae were almost completely absent on the rocky surfaces at the summit, except for few and very small patches (Figure 12H). One explanation could be that they were killed by historic volcanic activities and never recovered. Bottom currents were generally strong. A Niskin water sample was taken close to the top of the cone. The dive was terminated at 163 m depth in an area of large carbonate blocks that were partly densely colonized by whip corals. The blocks alternated with areas covered with black sand, probably ash, which obviously is overlaying hard substrate since many whip corals were deeply buried by the sand (Figure 12K-L).

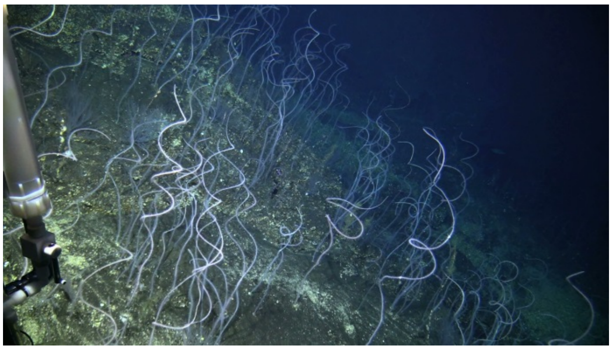


A *Depression within the sediment created by epibenthic fish or octopus, 199 m depth (10:43 UTC)*

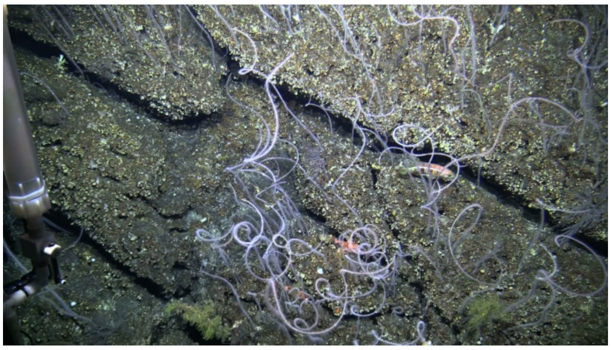
B *Dark grey to black fine-grained sediment in the vicinity of the summit of cone G, 182 m depth (10:55 UTC)*



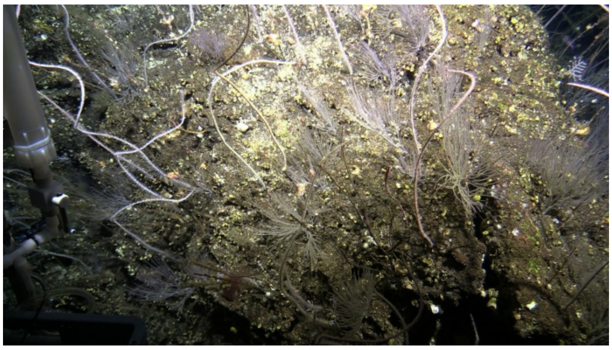
C *Large angular blocks of carbonate conglomerate covered in corals (11:15 UTC)*



D *Black coral garden on hard substrate at the flank of the cone (11:02 UTC)*

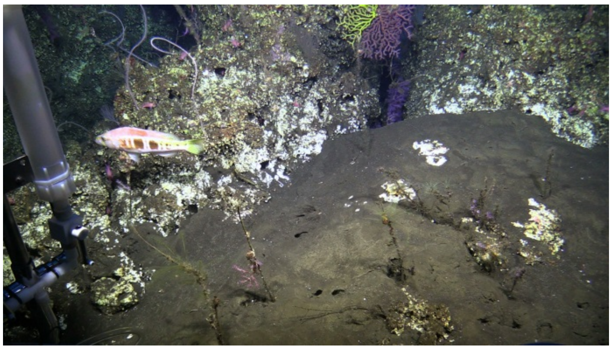


E *Wire corals (*Stichopathes sp.*) on the knobby face of a large block. Blacktail comber (*Serranus atricauda*) and scorpionfish* (Helicolenus dactylop-terus*) (11:03 UTC)*

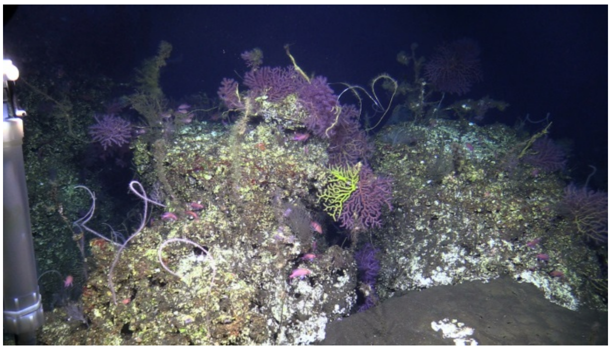


F *Aggregation of whip corals and bushy antipatharians (*Anipathes sp.*) (11:20 UTC)*

G *Moray eel (*Muarena helena*) in a crack close to the summit. Note small patches of coralline red algae and green algae(?), 140 m depth (11:24 UTC)*

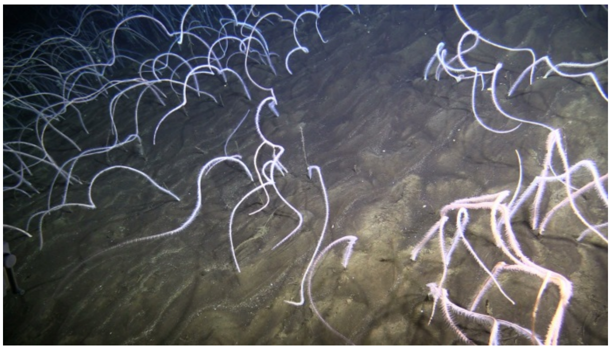


H *Dark-grey ash covering the summit of cone G at 123 m. Purple and yellow gorgonian sea fans, whip corals, blacktail comber fish (Serranus* atri-cauda*) and swallowtail seapearch (*Anthias anthias), *123m depth (11:52 UTC)*

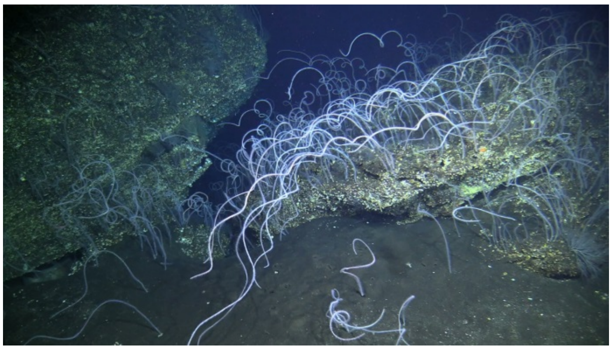


I *Purple and yellow gorgonians, whip corals, swallowtail seapearch (*Anthias anthias*) at the summit, 123 m depth (11:52 UTC)*

J *Close-up of the two-coloured gorgonian and swallowtail seapearch (*Anthias anthias*) (11:52 UTC*



K *Antipatharian wire corals buried in thick layer of fine-grained ash at slope below summit, 170 m depth (12:13 UTC)*



L *Large conglomerate block below summit of cone G, densely colonized by black corals, 172 m depth (12:17 UTC)*

Figure 12. *Images of habitats and prominent megafauna documented during JAGO dive 1302(3) at cone G.*

JAGO Dive 1303(04), Station 25 – 12.02.2016 – uw volcano (cone E)

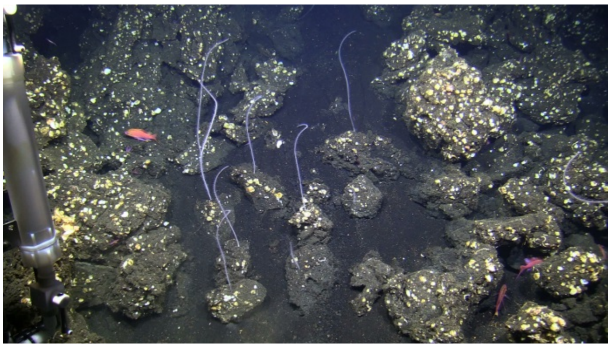
- Start: 27°37.15'N, 17°59.55'W, 160 m water depth
- End: 27°37.93'N, 18°00.42'W, 290 m water depth
- Heading: SE to NW; track length ca. 2600 m
- Observer: Magdalena Santana-Casiano
- Samples: rocks, crusts, near bottom water (Niskin), vent fluid for pH, AT, CT, Fe(II)
- Measures: pH-ORP, temperature inside sediment
- Media: HD video

The dive aimed to inspect and sample the eruption site of 2011 at cone E. Previous investigations in 2015 had revealed, that gas discharge and low-temperature venting had moved from the summit of the volcano to a lower area southeast of it. The dive started at the southeastern flank of the underwater volcano not far from the area where strong chemical anomalies were measured in 2015.

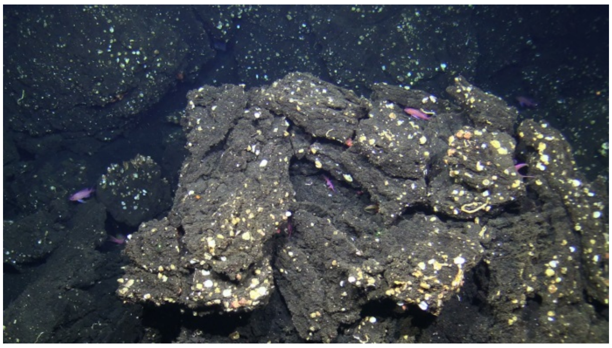
At the landing site, the seafloor was covered with rugged volcanic rocks and black ash. The black rocks are already partly colonized by bivalves (small oysters), brachiopods, sponges and whip corals (Figure 13A-B). The first visual inspection of the anomalous area showed, that this area is an oval-shaped depression of at least several meters in depth and about 10-15 m in diameter. It is situated at the southeastern flank of the volcano in 130 m water depth, about 40 m lower than the actual summit of the volcano at 90 m. Already while approaching the area, a milky white plume above the crater was observed (Figure 13C). The ash and the volcanic rocks at the edges and inside the depression are coated in orange-coloured Fe-oxides (Figure 13D). Warm water is seeping diffusely through sediment pores at the bottom of the crater, and occasionally more focused through small vent holes and chimneys that are up to 5-cm high (Figure 13G-I). A fluid sample was taken above such a diffuse vent. A thin coat of whitish bacteria covers most of the surfaces around the vents (Figure13 E-F). Temperature measurements 20 cm inside the sediment close to a vent site revealed 38°C, the temperature of the ambient sea water was 20°C. The ambient sea water within the depression was sampled with the Niskin bottle 0.5 m above the seabed. A sample of the crumbly Fe-oxides layer on top of the ash was scraped off the sea floor with a fine-meshed net. Several pieces of volcanic rock and crusts were collected (Figure13 K-L). Water samples were taken for pH, AT, CT and Fe(II). In the area of active venting in the shallow depression. The pH was measured on board and an anomalous value of 7.4 was obtained. pH-ORP data were recorded by the IEO-ULPGC sensor attached to JAGO's lower front to more accurately assess the degassing over the volcano.

No evidence for a sessile benthic fauna was observed within the crater. The fish *Anthias anthias* and *Serranus atricauda* were the most frequently encountered mobile species in this area and also at the top of the volcano (Figure 13M, N, S-U). Single specimens of the fireworm *Hermodice carunculata*, a colourful polychaet that is abundant in shallow water, was observed on top and among volcanic rocks below the summit of the cone (Figure 13P). Currents at the rugged top of the volcano were strong; they made it difficult to maintain position. A second water sample was taken with the through-flow system below the summit for comparison with the one that was taken inside the depression. A large school of *Anthias anthias* were recorded at the sampling site (Figure 13T). The volcanic rocks at around 200 m on the northeastern flank of the volcano are again sparsely colonized by some sessile fauna (hydrozoans, small oyster shells, calcareous tubes of serpulid tubeworms like *Hydroides* sp., sponges, antipatharians). Some of the rocks were collected.

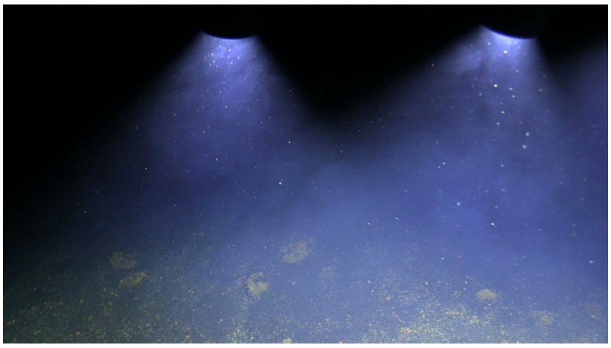
The NW side of the cone was buffeted by strong currents. The seafloor surrounding the summit area is covered in bomb-sized scoria with a dusting of fine ash. Obvious hydrothermal activity and Fe-oxide precipitates are restricted to patches near the summit and in the depression of the SE side. The summit area is composed of visibly older lava, locally with a more massive appearance (larger blocks and some coherent lava). The dive proceeded in northwestern direction along the 200 m contour line in order to reach an area where the sea surface conditions would allow a smoother recovery of the submersible. Large areas of the slope between cone E (the underwater volcano) and cone G (the old inactive volcano) are mainly covered with dark ash and, on top of the ash, bioclasts composed of shells, scleractinian corals, tubeworm tubes, coralline algae etc, of which some probably derived from the benthic fauna in shallower water. Isolated boulders were embedded in the sediments, some of them were volcanic rocks, while others appeared to be carbonate rocks (Figure 13DD). Several large sheets and shallow ridges of rocky outcrop were passed, of which again some were of volcanic material or/and some carbonate (Figure13 AA). Some of these sheets overlay old layers of carbonate deposits that bear large amounts of fossil rhodoliths embedded in a light-coloured matrix. The rocky sheets erode at their edges, some rhodoliths and their fragments become lose and then mobilized and dispersed along the slope by bottom currents and mass wasting (Figure 13Y-Z). Several pieces of these fossil rhodoliths were collected. Some of the isolated volcanic blocks, which were passed along the slope, were coated with a thin layer of loosely cemented sediment that consists of course-grained bioclastic and volcanoclastic components (Figure 13W). The sediment is sometimes compressed and consolidated to crumbly rocks which were also sampled (Figure 13X). The single blocks and the rocky outcrop were scarcely colonized. The deepbody boarfish *Antigonia capros* was occasionally seen around the blocks. Small specimens of whitish soft corals settled on rocks and on sediment (Figure 13GG). A large specimen of common stingray *Dscyatis pastinaca* was documented (Figure 13HH), and here and there specimens of a small cross-banded bottom-dwelling fish with iridescent fins and large eyes, about 20 cm in length (Figure 13EE-FF). The Cone G was surveyed at its lower southern and western flank between 240 and 290 m. The dive ended after 8 hours west of cone G.



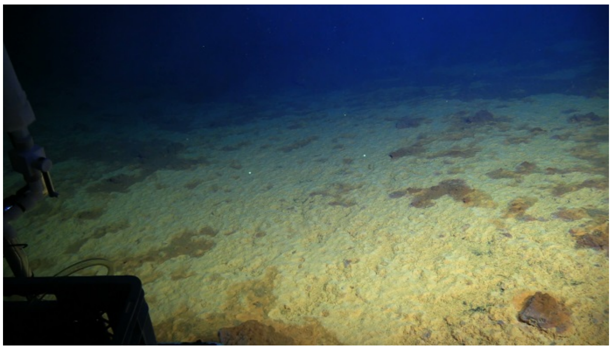
A *Bivalve shells, sponges and whip corals on volcanic rock at the southeastern flank of cone E. Fish: Swallowtail seapearch (*Anthias anthias*)*



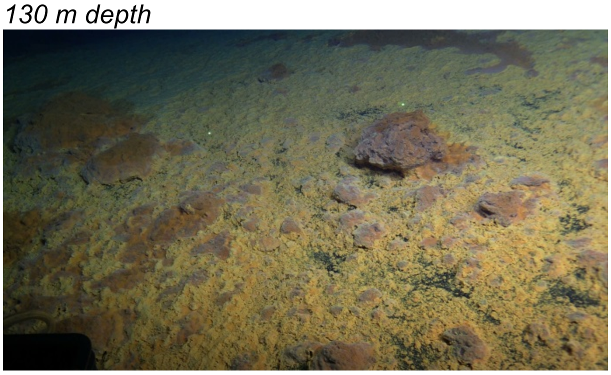
B *Volcanic rock at the southeastern flank of cone E, colonized by bivavles and sponges. Fish: Swallowtail seapearch (*Anthias anthias*), at 160 m*



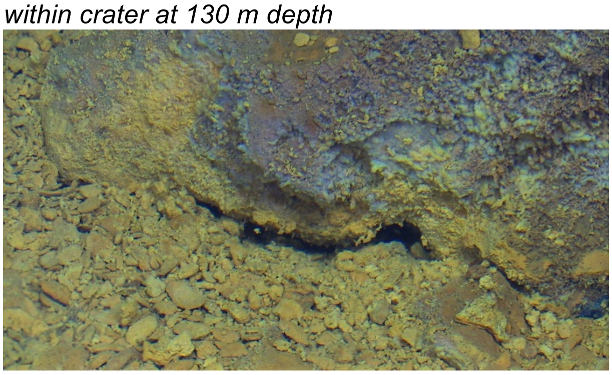
C *Milky white bacterial cloud above the crater at 130 m depth*



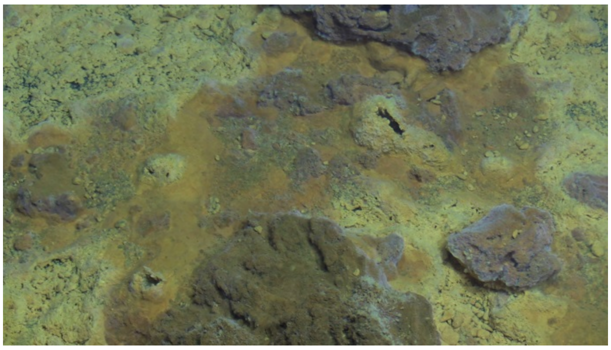
D *Yellow Fe-oxide coat on ash field and rocks within crater at 130 m depth*



E *Thin coat of white bacteria covering Fe-oxide crusts and rocks*

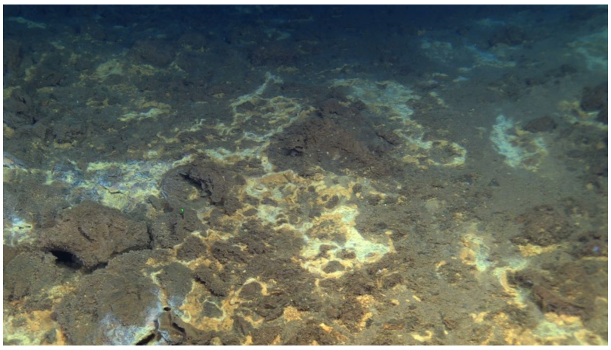


F *Thin layer of white bacteria covering rock with a warm-water outlet below*

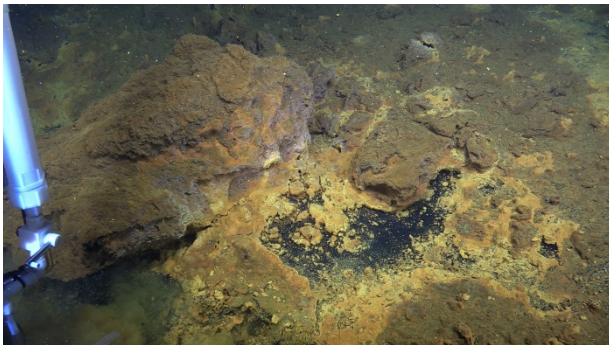


G *More focused discharge of warm water at discrete vents, surrounded by denser bacteria mats*

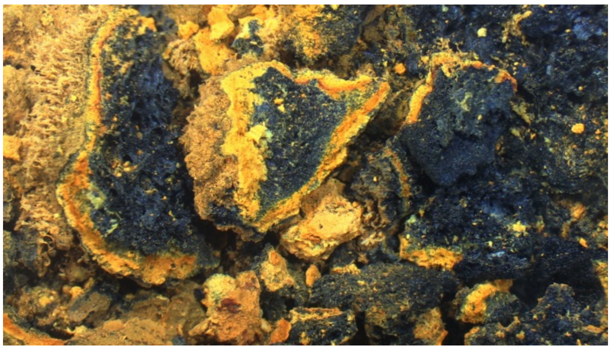
H *Discrete venting of warm water through small, 5-cm high chimney; schlieren in water column constrain focussing of video camera*



I *Patches of diffuse and more focused warm water discharge in between and below rocks at the bottom of the crater*



J *Black ash visible below Fe-oxide coat after being removed with JAGO's manipulator arm*

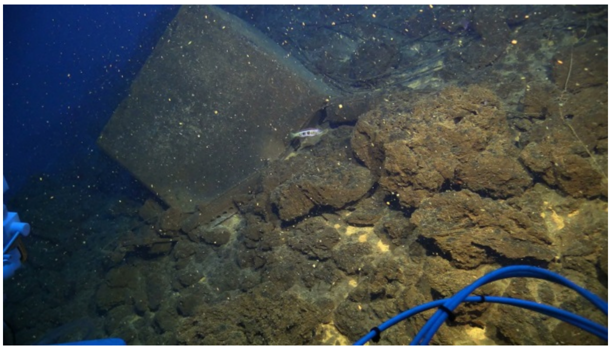


K *Black glassy volcanic gravel coated with Fe-oxide crust and layer of filamentous bacteria (left)*

L *Collection of young volcanic rock coated with Fe-oxide crust*

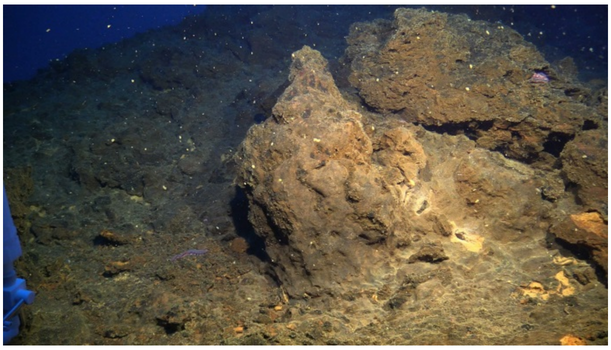
M *Volcanic rock on top of Fe-oxide coated ash. Blacktail comber (*Serranus atricauda*) hiding below rock*

N *Swallowtail seaperch (*Anthias anthias*) hiding below volcanic rock*

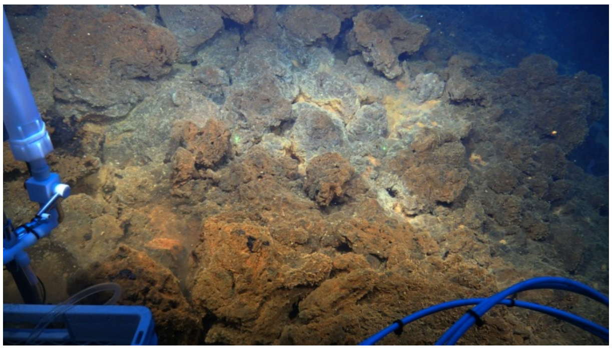


O *Concret block / mooring weight left behind by one of the Vulcano cruises below summit*

P *Polychaet fireworm (*Hermodice carunculata*) on volcanic rock below summit of volcano*



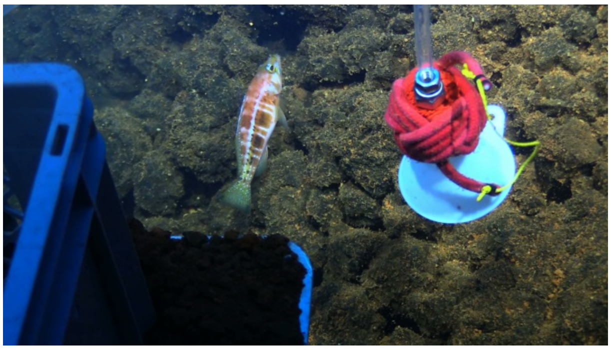
Q *Fe-oxide covered volcanic rocks below the summit with warm water outlets*



R *Thin bacteria coat in area of diffuse warm water discharge below the summit*

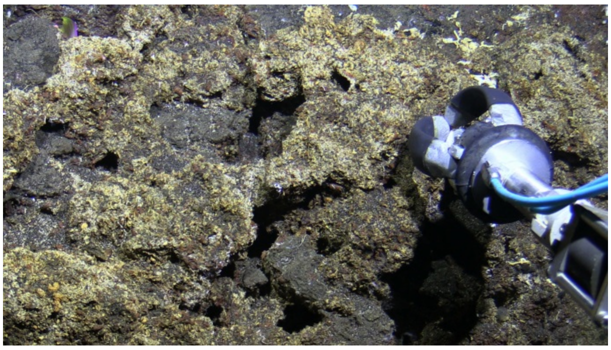
S *Large school of swallowtail seaperch (*Anthias anthias*) below summit*

T *Swallowtail seaperches (*Anthias anthias*)*



U *Blacktail comber (*Serranus atricauda*) attracted by one of JAGO's sampling devices*

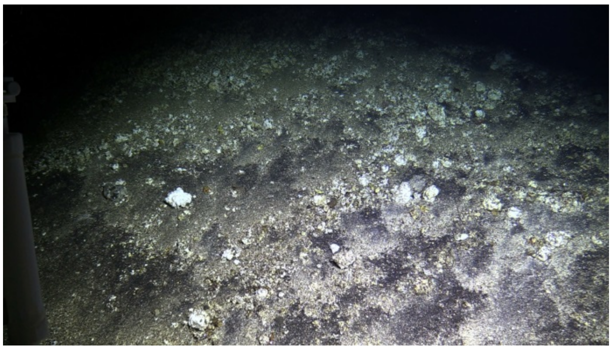
V *Deepbody boarfish* (Antigonia capros*) occasionally seen around dropstones passed during transit along 200 m contour*



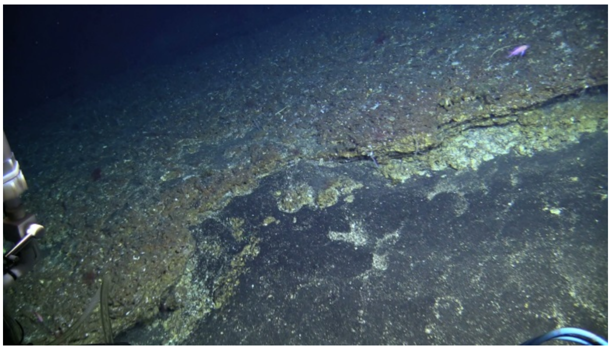
W *Crust of cemented bioclastic sediment on top of isolated volcanic block*

X *Collection of soft sedimentary rock consisting of bioclasts and volcaniclastic grains*

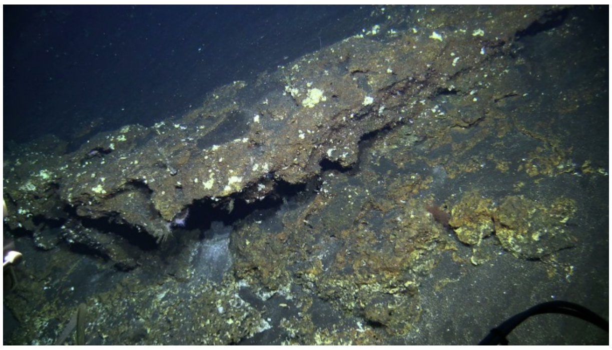
Y *Eroded layers of fossil rhodolith and maerl deposits below massive conglomerate sheet made up by bioclastic and volcanoclastic components*



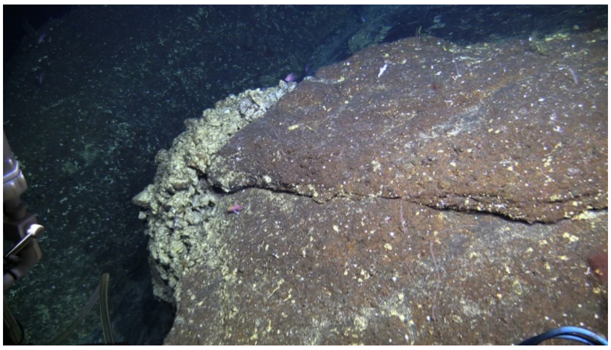
Z *Accumulation of eroded fossil rhodoliths and coarse bioclastic sediment on top of dark-grey volcanic ash*



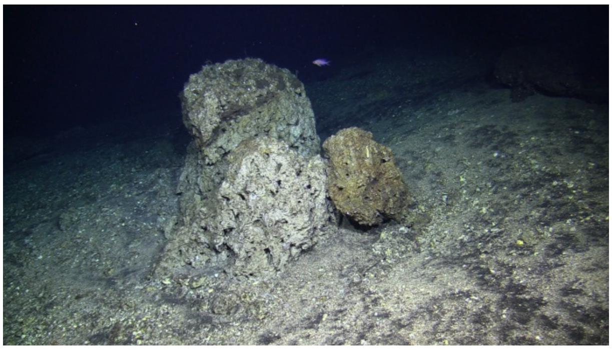
AA *Massive sheet of semilithified bioclastic and volcaniclastic material*



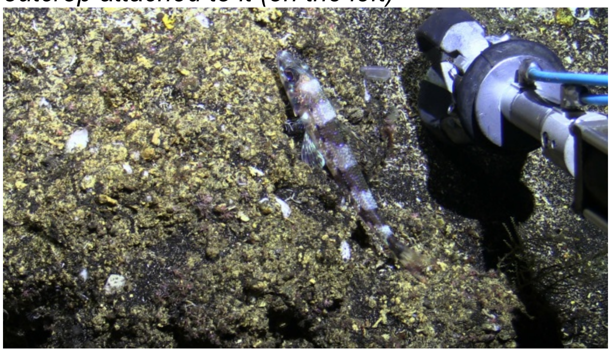
BB *Volcanic rock outcrop with embedded fragments of light-coloured fossil rhodolith surrounded by volcanic ash*



CC *Large volcanic (?) boulders with carbonate outcrop attached to it (on the left)*



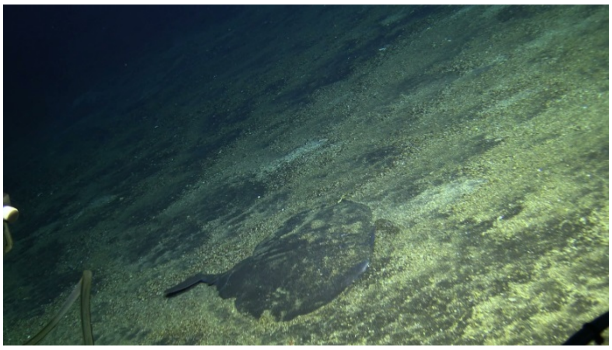
DD *Carbonate boulders*



EE *Unidentified bottom-dwelling fish on conglomerate rock*

FF *Unidentified bottom-dwelling fish with iridescent fins and large eyes, regularly encountered on sand and gravel slopes*

GG *White soft corals (*Octocorallia*) on volcanic dropstone*



HH *Common stingray* Dscyatis pastinaca *on sediment slope*

Figure 13. *Images of habitats and prominent megafauna captured during JAGO dive 1303(4) at cone E and along the slope while moving from cone E to cone G*

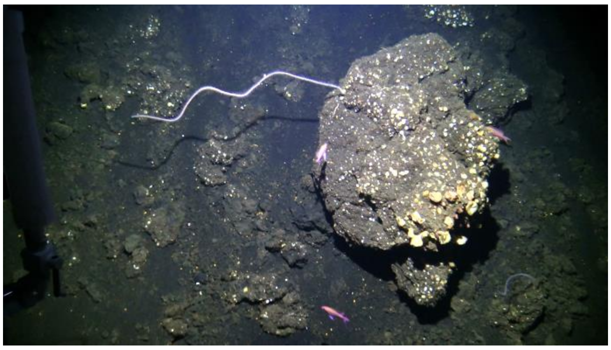
JAGO Dive 1304(05), Station 27 – 13.02.2016 – uw volcano (cone E)

- Start: 27°37.14'N, 17°59.39'W, 273 m water depth
- End: 27°37.14'N, 17°59.74'W, 253 m water depth
- Heading: SE to NW; N to S; E to W; track length ca. 1100 m
- Observer: Eugenio Fraile Nuez
- Samples: rocks, near bottom water in bacteria plume (Niskin), vent fluid
- Measures: CTD, pH-ORP, temperature inside sediment
- Media: HD video

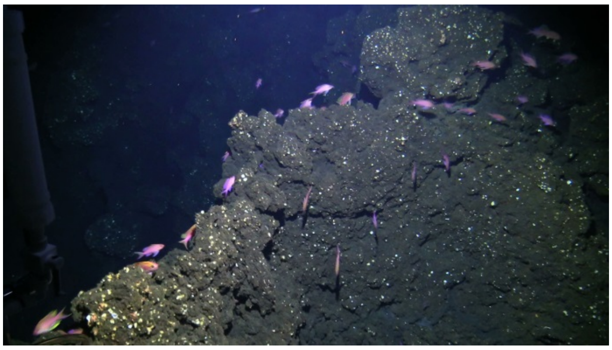
The objective of dive 1304(05) was to re-visit the depression below the summit of the volcano in order to collect more sensor data on the chemical and physical parameters and to continue sampling of discharged fluids, water and rocks. A smaller cone on the southern flank of the volcano adjacent to the depression also was surveyed.

JAGO approached the volcano from the SE on a gently sloping plain of black to grey ash and then entered the depression along a similar path to dive 1303 and collected additional samples near the depression on the SE flank. The dive started at 273 m depth and ca. 350 m east of the flank crater at cone E on a shallow slope covered by ash and smaller volcanic rocks sparsely colonized by benthic organisms (Figure14 A-B). Fauna drastically thinned out at the rugged rim of the crater (Figure14 C), and in general the youngest lavas are colonized by far fewer animals. A Niskin water sample was taken while hovering in the milky cloud above the bottom of the depression at 130 m. The fluid sampler was used to collect warm water at an outlet below a volcanic rock in the depression (Figure 14F). Temperature measurements 20 cm deep inside the sediment at the bottom of the depression revealed temperatures of 32- 34°C, while the temperature of the ambient water was 18-19°C. The highest temperature that was measured at a warm water outlet was 39°C.

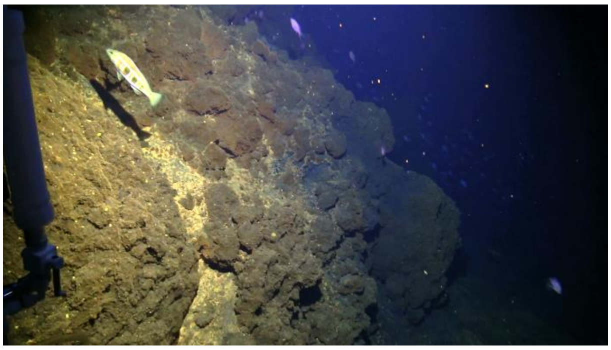
Slightly west and a few meters shallower but still close to the depression lies another area where high chemical anomalies were measured during a cruise of the Vulcano project in 2015. JAGO attempted to cross the ridge leading up to these vents but currents were too strong. The peak of the ridge has several large spines, which appear to be composed of coherent lava (jointed). The spines are aligned N20E and are most likely the exposed parts of a feeder dike (?) which extends several hundreds of meters along the SE flank of the volcano. Older, coarser blocks occur on the west side of the ridge; relatively fresh volcanic ash and scoria dominate on the east side. The two dike-like structures were captured on video (Figure14 G-J). Due to the extremely strong current at the ridge it was impossible to inspect the area in more detail. The dive was continued downslope in southeastern direction to reach a smaller volcanic peak at 206 m. It was covered by large blocks of lava and boulders of which some were pillow- and tube-shaped (Figure 14K-N). Rocks and the surface of the volcanic gravel in between the blocks were coated with Fe-oxides (Figure 14 O-V). The temperature inside the sediment and of the ambient sea water was 14°C and no evidence of any warm water discharge was observed (no shimmering water). Several rock samples were taken in this area (Figure 14W-Z). The dive continued parallel to the slope in direction of 290° between 210 and 240 m water depths in order to reach an area with calmer sea surface conditions for recovery. After covering a distance of about 400 m the dive was abandoned because the bottom currents became too strong.



A *Lava rock and ash at the slope below crater, colonized by whip coral, bivalve shells, sponges*



B *Swarm of* Anthias anthias above *lava tube passed during moving towards crater rim*

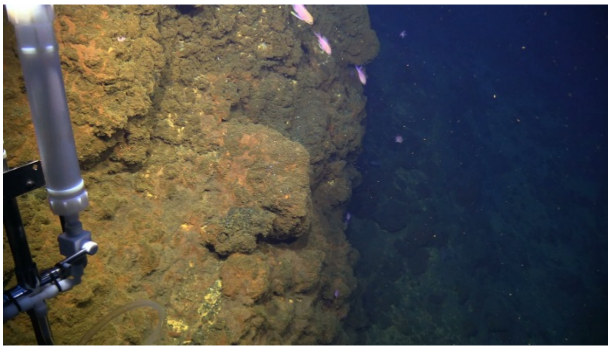


C *Rugged volcanic blocks at the crater rim. Blacktail comber (*Serranus atricauda*)*

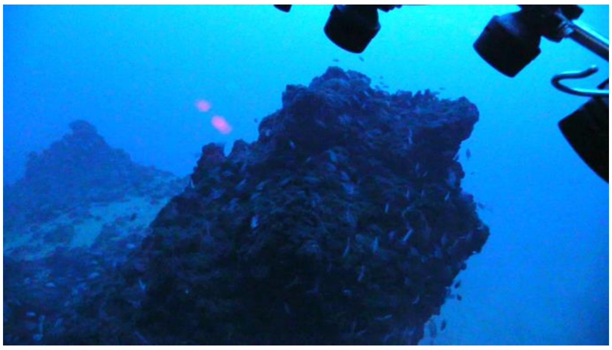
D *Marker deployed at the bottom of the crater*

E *Black sand and gravel visible below thin layer of Fe-oxide that has been blown off the bottom by the current and JAGO's activities*

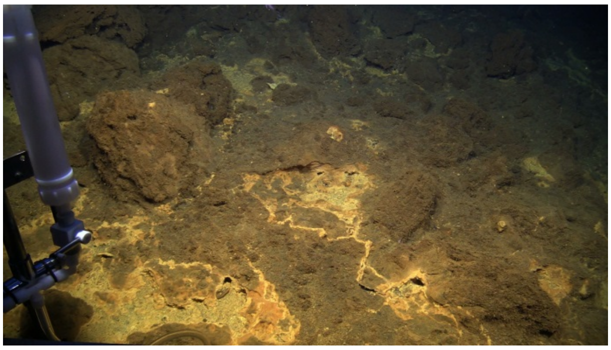
F *Fluid sampling at a warm water vent below a volcanic rock*



G *At the ridge, which is probably a dike, between the crater and the second anomalous area at the southern flank of the volcano*

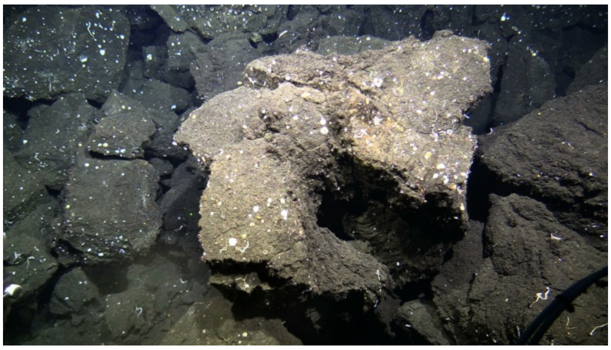


H *The ridge (dike) below the summit of the volcano documented without artifical light*

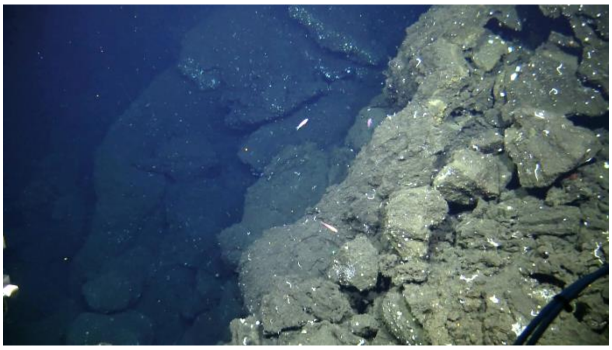


I *Lava rocks, Fe-oxide crusts and small vent openings at the bottom below dike*

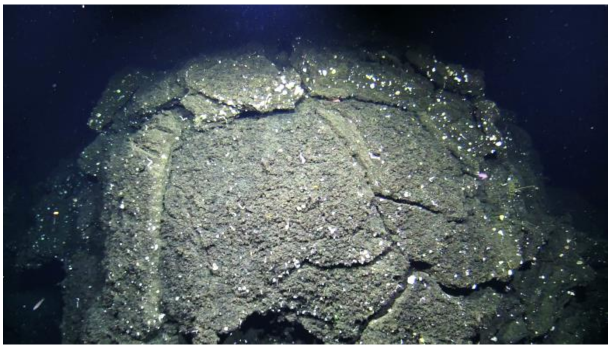
J *Upper part of the ridge below the summit of the volcano in natural light. Jack fish passing by*



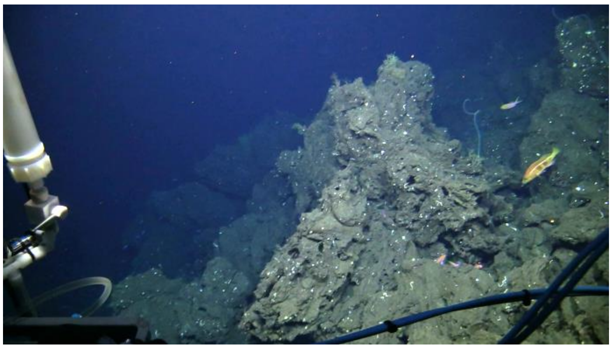
K *Large volcanic structures at the lower smaller peak at 206 m at the southern flank of the volcano*



L *Lava tubes at the 206-m-peak south of the volcano summit*

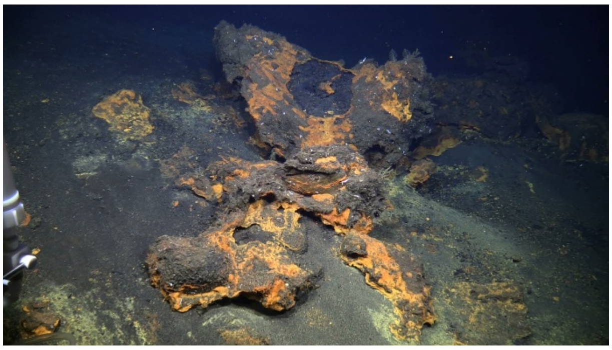


M A giant block of *pillow lava at the 206-m-peak*



N *Rugged lava structures at the 206-m-peak*

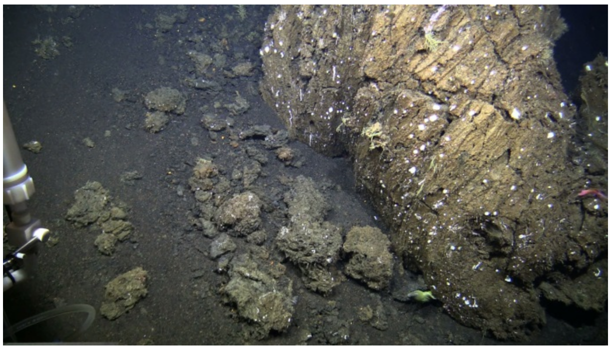
O *A large lava block with Fe-oxide coat at the 206-m-peak, with a conger eel hiding below it*



P *Fe-oxidized lava formations at the 206-m-peak, surrounded by ash*

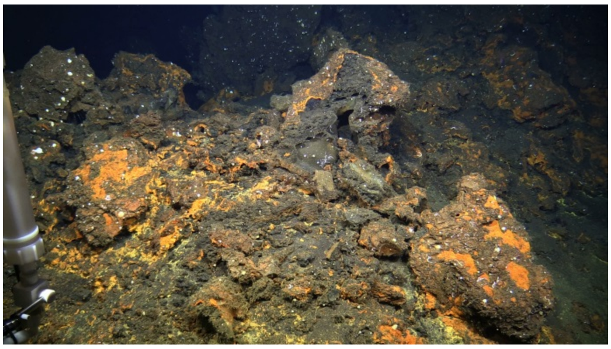
Q *Fe-oxide coated lava block at the 206-m-peak*

R *Rugged lava formation at the 206-m-peak*

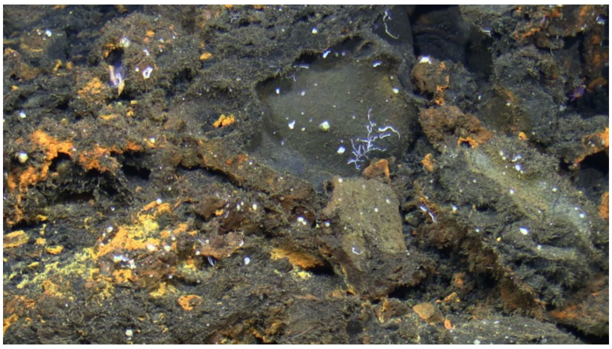


S *Rugged lava formation at the 206-m-peak*

T *The upper part of the same formation*



U *Lava rocks and ash with Fe-oxide coat*

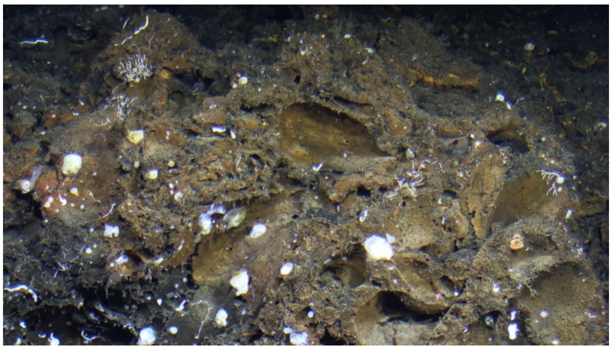


V *Close-up of one of the rocks in* **T** *with a smooth surface in its center, probably deriving from an entrapped gas bubble, colonised by tubeworms, brachiopods and bivalve shells*

W *Volcanic gravel below the 206-m-peak*

X *Smooth surface within a volcanic rock, probably cause by an entrapped gas bubble. Colonized by tubeworms, bryozoans, bivalves*

Y *Rock colleting at the gravel slope*



Z *Close-up of a scoria with large vesicles*

Figure 14. *Images of volcanic features, habitats and prominent megafauna captured during JAGO dive 1304(5) at cone E.*

Preliminary results of the biological community analysis from JAGO video footages

The dominant megafauna elements of the benthic hard substrate community along the steep slope at the shoreline and around the older volcanic cone G were encrusting and erect lithistid sponges and cnidarians. The cnidarian community is divers in gorgonian octocorals with unbranched whip corals as the most common taxa. Together with antipatharians they form ‘gardens’ at some of the sites. Colourful fan-shaped gorgonians were in particularly abundant on the summit of cone G. Beside gorgonians other forms of octocorals, like smaller species of ‘true’ soft corals, were locally present but not as abundant as gorgonians. Actinians (sea anemones) were only represented by smaller species, which, however, were not very prominent.

The most frequently seen stony coral (Scleractinia) is the yellow *Dendrophyllia cornigera*, however, only represented by scattered small colonies. An accumulation of the reef-building scleractinian coral *Lophelia pertusa* was only seen once on a steep wall during the first dive along the slope following the coastline. These slowly-growing corals need a stable and less corrosive environment and are probably therefore absent on habitats that are more strongly affected by recent volcanism, like those around cone G and E. However, small specimens of solitary scleractinian cup corals, probably *Desmophyllum* sp., were already found on some of the collected lava rocks, indicating a quick colonization of recently formed hard substrate by this taxon.

Other sessile taxa are represented by heavily branched hydroid colonies, colonial bryozoans (‘moss animals’), brachiopods, bivalve molluscs and serpulid tubeworms. In particularly the white shells of sessile bivalves, small fragile oysters and the calcium carbonate tube of serpulid tubeworms are very prominent on the dark volcanic rocks. They are good and well-visible indicators for the recruitment progress and grade of re-colonization in areas that were directly affected by the 2011-eruption, like the flanks of cone E. Some of the lava rocks below the crater at the southeastern flank of the cone, which were formed in 2011, were already scarcely colonized by these pioneer species, four and a half years after the eruption. Remains of the 2011 eruption, like fine-grained dark ash, were also found in depressions (trap-sites) on the summit of cone G. Also some of the antipatharian gardens that were documented around 170 m depth at the western slope of cone G are partly buried by the same material, about 1.6 km northwest of the 2011-eruption site.

The deep-sea oyster *Neopycnodonte cochlear*, which can reach a shell size of 20-30 cm and which is considered as a 'living fossil', require a vertical habitat. The giant oysters usually colonize overhanging banks or escarpments protruding from steep walls. During POS494 they were only seen in small patches at the steeper flanks of the canyon that was surveyed during dive 1300(1).

The mobile benthic community is not characterized by a high faunal density and taxon richness. Large molluscs in form of larger snails, for example, were completely absent. Grazers, like the sea urchins *Echinus* sp. and *Cidaris* sp., were present but not very abundant. The same counts for other echinoderms like asteroids (sea stars) and brittle stars. Holothurians (sea cucumbers) and crinoids were not seen at all. Crustaceans are rare too. Larger species of lobsters, crabs and spider crabs were completely absent. Benthic shrimps were seen only once in a small cave during the long transect from the base of cone E to cone G during dive 1303(4). Mobile polychaets are represented by the fireworm *Hermodice carunculata,* which is relatively abundant in shallower waters but not in the surveyed area, and smaller species of bristle worms. The Ascidiacea were represented by small transparent sessile tunicates that were occasionally seen on hard substrate, some smaller ascidians and by the pelagic 'fire-salp' *Pyrosoma* sp. Cephalopods were also not abundant. Single specimens of small octopus were occasionally encountered on the sediment slopes, e.g. during dive 1302(3).

Also the fish community documented during the dives consists of few species only. Above hard substrate it is dominated by the swarming swallowtail seaperch *Anthias anthias*, and the regularly seen solitary blacktail comber *Serranus atricauda*, the occasionally encountered comp grouper *Mycteroperca rubra* and the scorpionfish *Helicolenus dactylopterus*. Single sightings encompass the deepbody boarfish *Antigonia capros*, the moray eel *Muarena helena*, a conger eel, and two different species of unidentified small bottom-dwelling fish (perhaps a lizard fish and a goby). Flat fish are present on the sediment slopes, a sting ray was seen once. Pelagic fish like jack fish and barracudas forage in swarms around the summits of the cones.

The highest faunal densities were found at the steep rocky cliffs between 300 and 400 m depth during the first dive, and on the summit of the old volcano cone G at around 125 m during the third dive.

7.2 Seabed Geological Mapping (M. Anderson, M. Hannington)

Seven of the cones within reach of JAGO were originally targeted for diving. Only three ("E", "F", and "G") were reached during the cruise, but seafloor observations confirm that most of these cones are volcanic in origin. The surrounding seafloor between the cones is incised by deep erosional canyons, exposing extensive deposits of weathered volcaniclastic and bioclastic sedimentary rocks. These surveys revealed a complex history of offshore volcanism and mass wasting.

Geological mapping of the summit region of Volcano "E" was carried out by careful documentation of dive videos, in order to establish the volcanic architecture in the area of hydrothermal venting. Figures 15-17 were prepared from compilations of the data obtained from the dive videos. Figures 18-20 show the corresponding frame grabs of the seafloor features.

Preliminary geological observations from Volcano “E”

Volcano “E” rises from a depth of at least 350 m up to its current minimum depth of 88 m below sea level. The cone was constructed from molten material erupted for a period of five months from October 2011 to March 2012. Extensive degassing at the time of the eruption drastically changed the physical and chemical properties of the water column in the area. Afterwards, the system evolved to the presently observed hydrothermal vents. Careful mapping shows that the summit of Volcano “E” is, in fact, a composite structure with more than one central cleft or vent (Figures 16 and 17). The uppermost part of the volcano is dominated by slightly older lavas, whereas a small high on the southern flank of the summit is covered by less oxidized lavas. Both areas show features of extrusive vents, including fissure-like depressions, lava hornitos, possible coherent dike-like features, and widespread Fe-oxides and bacterial mat.

During our dives, we saw evidence of the first eruptions from 2011, indicated by virtually unweathered lavas, and we found what appears to be the remnants of a feeder dike and eruptive fissure. In 2014, ROV operations with Liropus 2000 documented what appeared to be extensive deposits of Fe-oxide crusts, bacterial mats and low-temperature venting close to the summit of the volcano. But in 2015, the plume of gas and low-pH water shifted to the southeast of the summit area into a shallow depression on the SE flank of the volcano. The JAGO dives by Prof. Santano-Casiano and Dr. Fraile Nuez observed the exact nature of this depression. The floor is bathed in warm water (up to 39 °C in discrete vents) and covered by a thin layer of bright orange Fe-oxides and white bacterial mat. Rock samples collected by JAGO revealed very fresh ash and scoria just beneath the layer of oxides and bacteria, indicating that the depression most likely formed at the end stage of the 10.11-03.12 eruption, possibly as an eruption crater. The older oxidized lavas at the summit of the volcano are already colonized by abundant fishes, shrimps, polychaetes, and algae, but the younger depression is surrounded by fresh lava and still devoid of any large fauna. Warm water was observed emitting through the bottom of the crater over an area of at least 100 meters square, with more focused discharge occurring at discrete vents through small, 5-cm high Fe-oxide chimneys. A thin coating of bacteria occurs on all surfaces around the vents, and the water above the crater is clouded by a persistent “milky white” plume. Despite strong prevailing bottom currents, the plume hangs in the water column at a low height above the depression, sustained by the ongoing diffuse hydrothermal venting. Although the crisis of 2011 was, by all accounts, an isolated event, the new findings show that parts of the volcano are still emitting warm water, presumably heated by the still cooling lava and/or subvolcanic intrusive bodies.

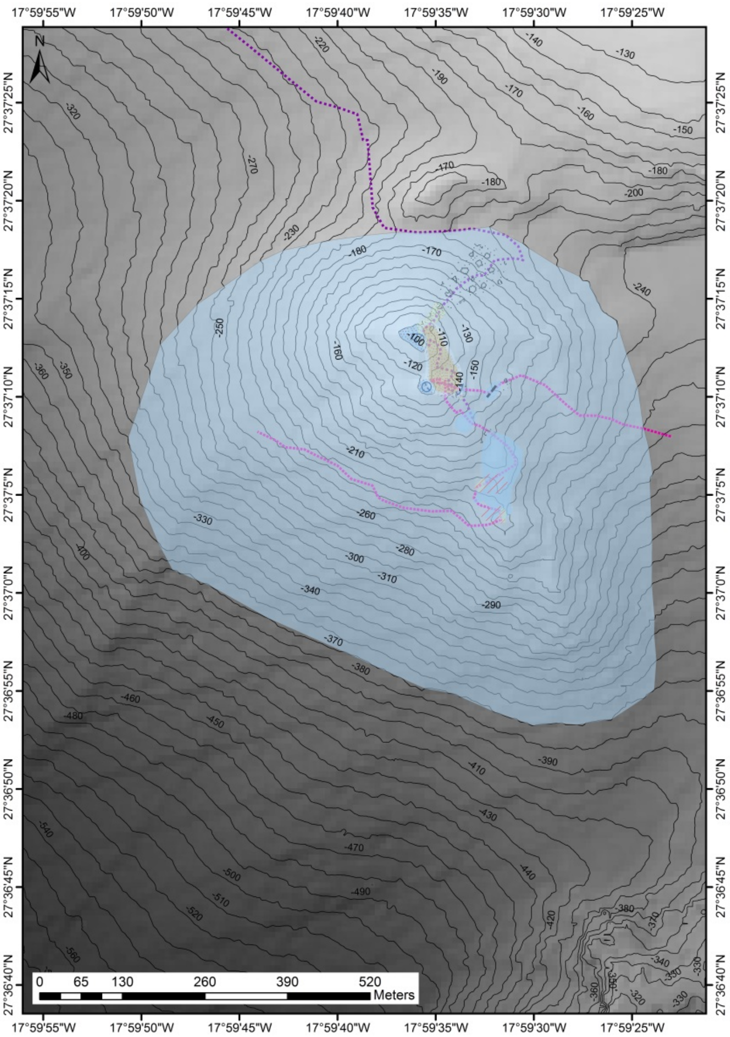


Figure 15. *Map showing the JAGO dive tracks in the summit area (blue) of Volcano "E".*

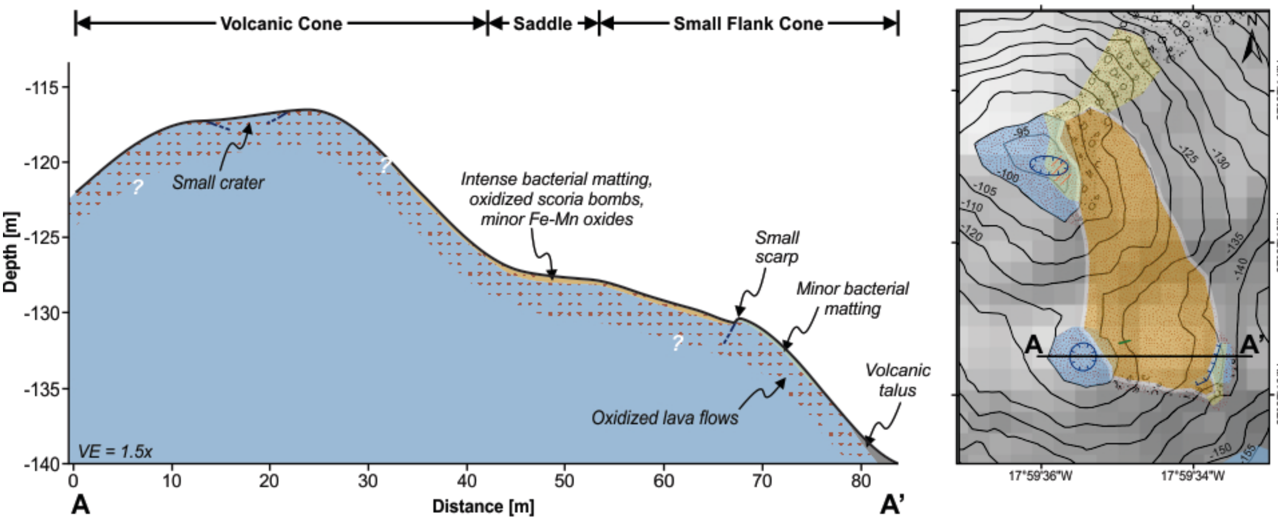


Figure 16. *Schematic cross-section of the south flank of Volcano "E", including the small cone on the southern ridge and the plateau on which the actively venting SE depression is located.*

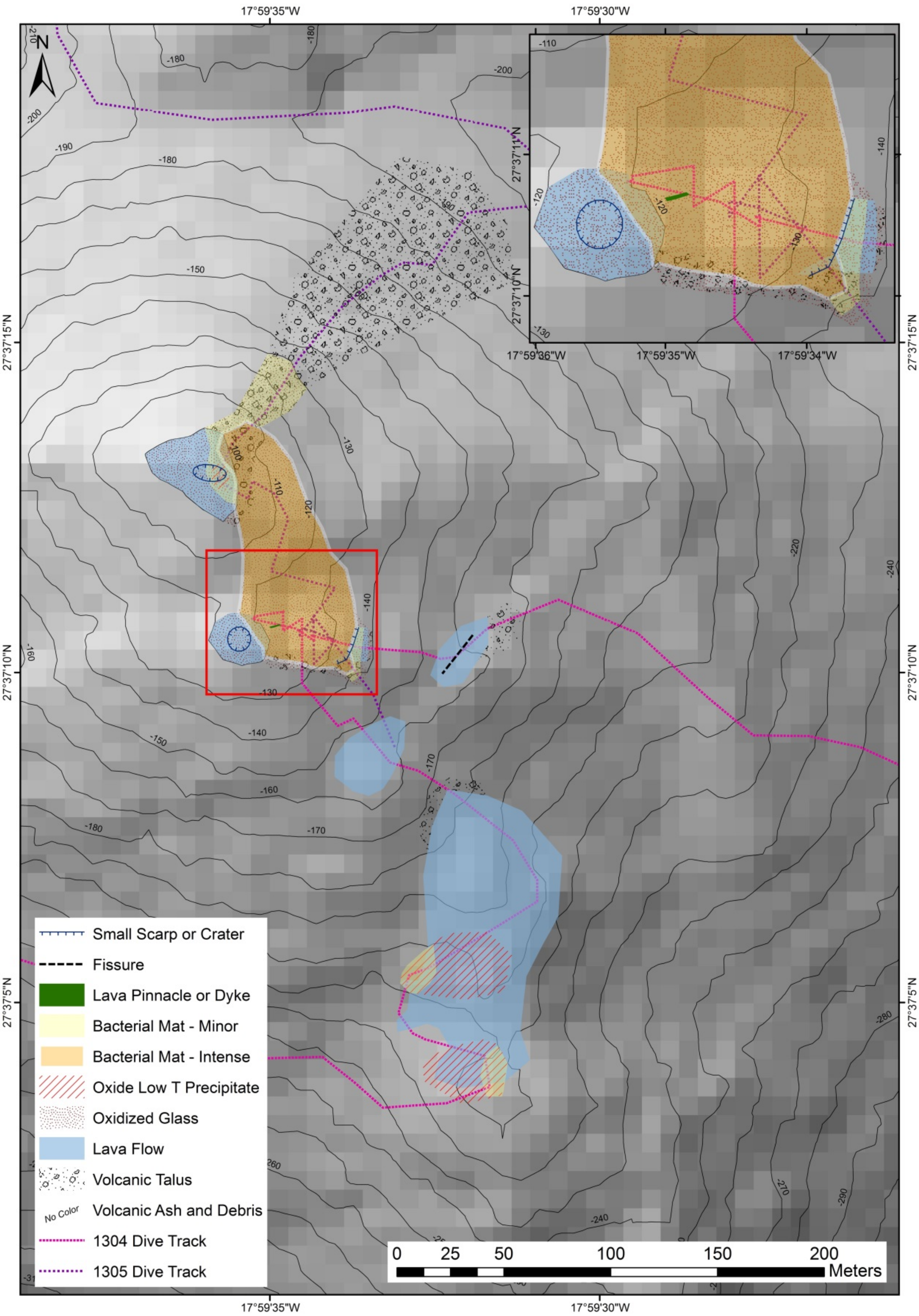


Figure 17. *Map of the main geological features observed at the summit of Volcano "E" during JAGO Dives 1303 and 1304.*

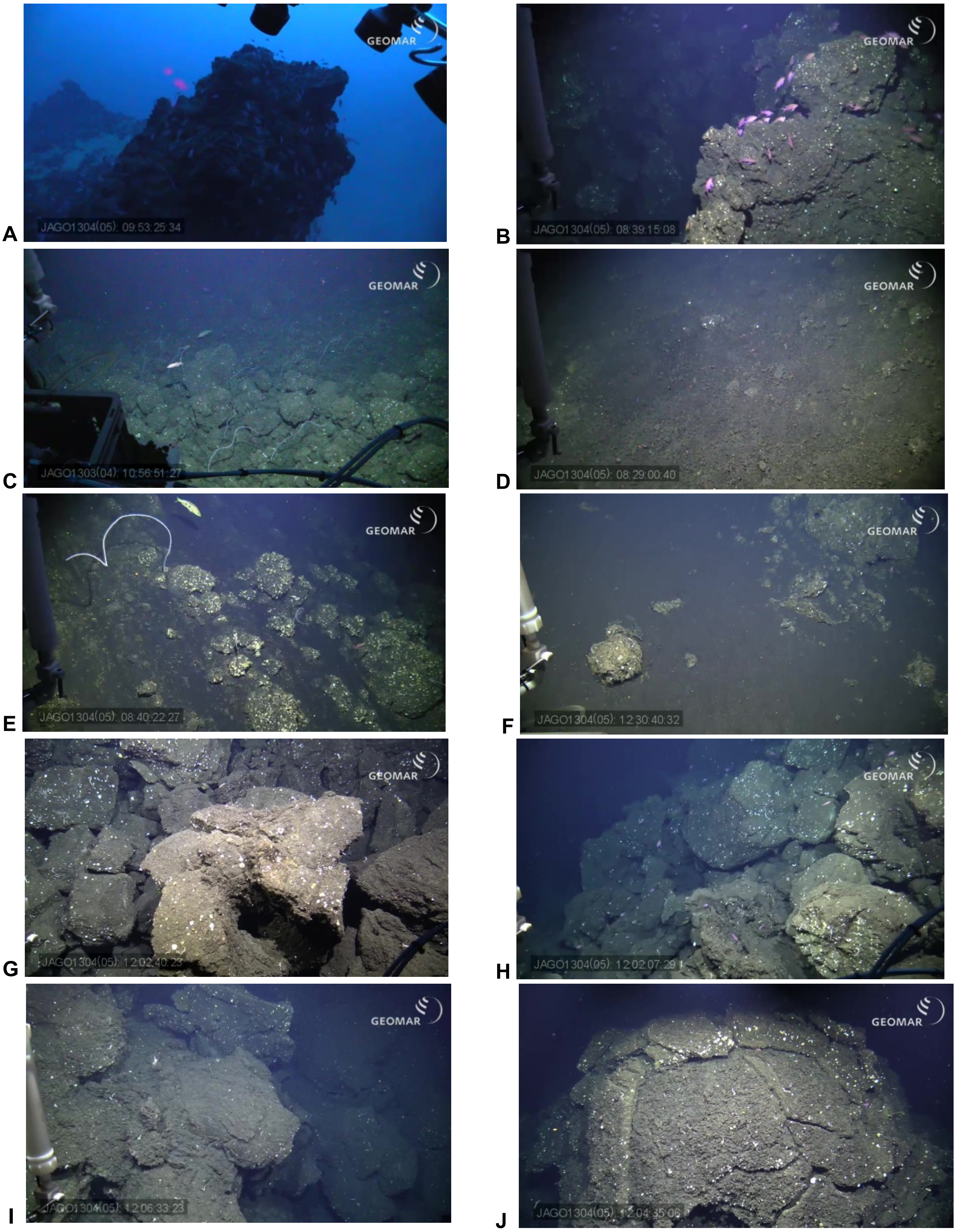


Figure 18. *Video frame-grabs of fresh coherent lava and ash. A) Lava pinnacle looking towards top of small cone (photo location 6). B) Small fissure vent (?) trending NE-SW (photo location 2). C) Volcanic talus (bombs?) on the flank of the main volcano (photo location 17). D) Volcanic ash and debris on flank of small volcanic cone (photo location 1). E) Volcanic ash and large scoria blocks with abundant white shells (photo location 3). F) Black volcanic ash and block next to "pillow mound" (photo location 15). G) Blocky fragments of "pillow mound" (photo location 9). H) Blocks on "pillow mound" showing radial fractures (photo location 8). H) Irregular lava tube on "pillow mound" (photo location 11). J) Large "pillow" with exfoliated outer surface (photo location 10). Rough surfaces and poorly formed pillows likely reflect the high gas content of the melt.*

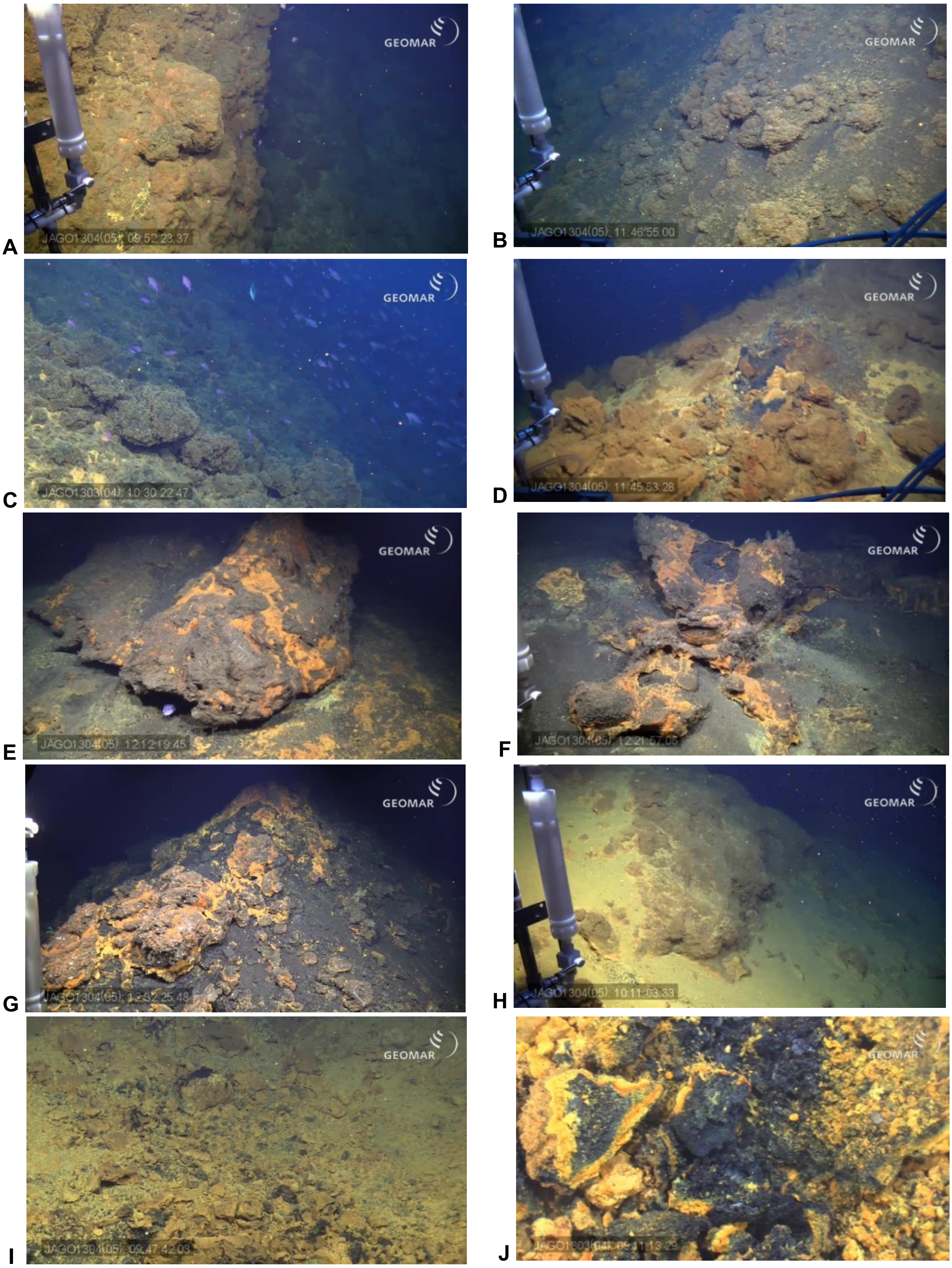


Figure 19. *Video frame grabs of oxidized lava and Fe-oxide deposits. A) Weathered base of lava pinnacle (photo location 5). B) Ash on top of slightly oxidized volcanic talus (photo location 7). C) Old volcanic talus with minor bacterial mat on flank of main cone (photo location 34). D) Top of small volcanic cone with abundant Fe-oxides (photo location 28). E) Toe of lava flow coated by orange Fe-oxides and minor yellow bacterial mat (photo location 12). F) Scoria blocks with orange Fe-oxides and minor yellow bacterial mat (photo location 13). G) Volcanic ridge with abundant orange Fe-oxides (photo location 14). H) Outcrop of older lava flow in area of intense bacterial mat near top of small cone (photo location 26). I) Close-up of oxide in area of intense bacterial mat (photo location 24). J) Coating of Fe-oxide on fresh scoria blocks (photo location 23).*

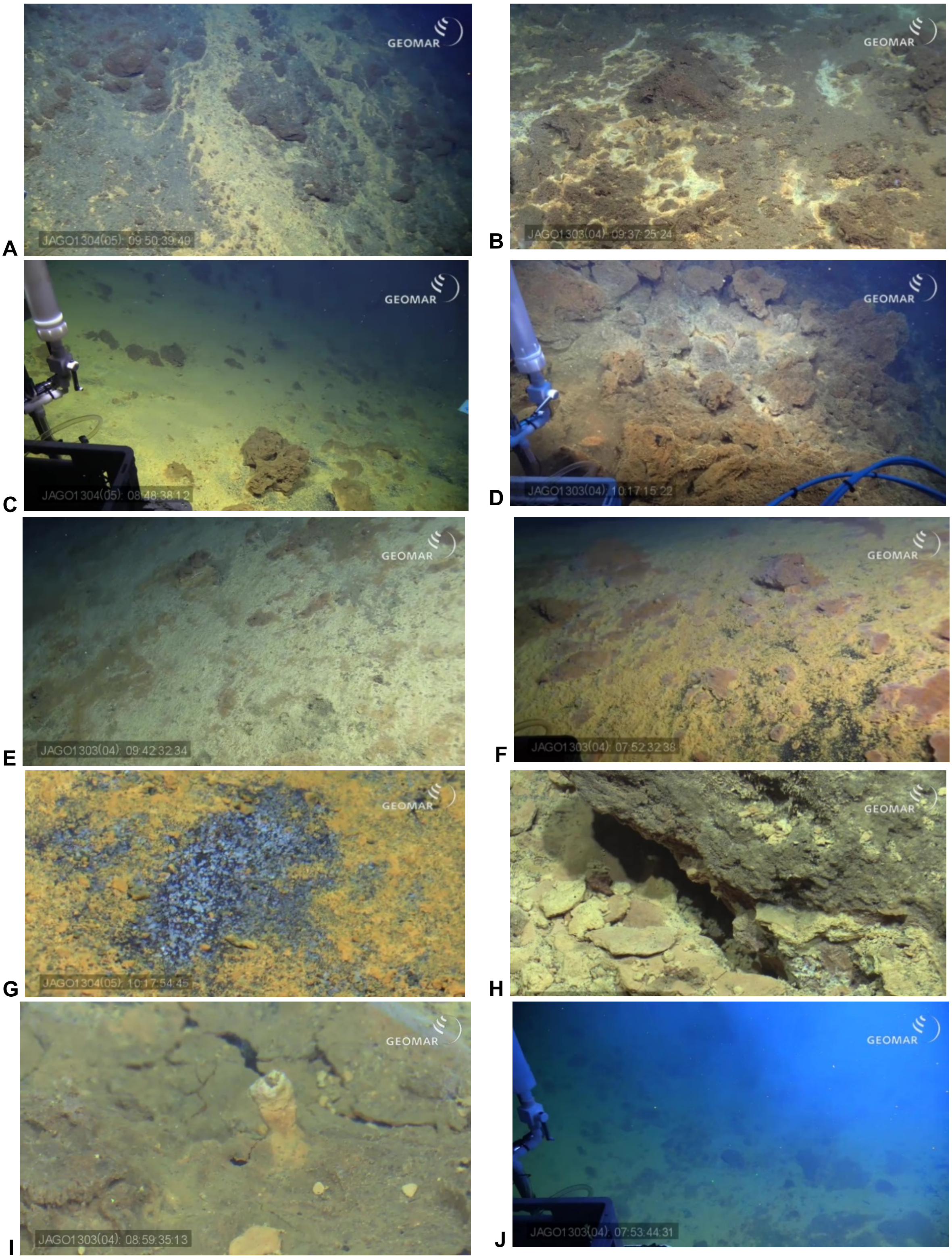


Figure 20. *Video frame grabs of active venting and bacterial mat. A) Discontinuous bacterial mat on slope of small volcanic cone (photo location 25). B) Old oxidized scoria with whitish yellow bacterial mat (location 31). C) Continuous bacterial mat with oxidized scoria (location 18). D) Localized bacteria among rubbly lava near top of main cone (location 33). E) Whitish yellow bacterial mat (location 32). F) More intense bacterial mat (location 29).G) Close-up of Fe-oxide and bacteria on ash (location 27). H) Close-up of bacteria surrounding vent with shimmering water (photo 21). I) Small, <3 cm Fe-oxide "chimney" in area of intense bacterial mat (location 30). J) Milky plume in area of intense bacterial mat (location 19).*

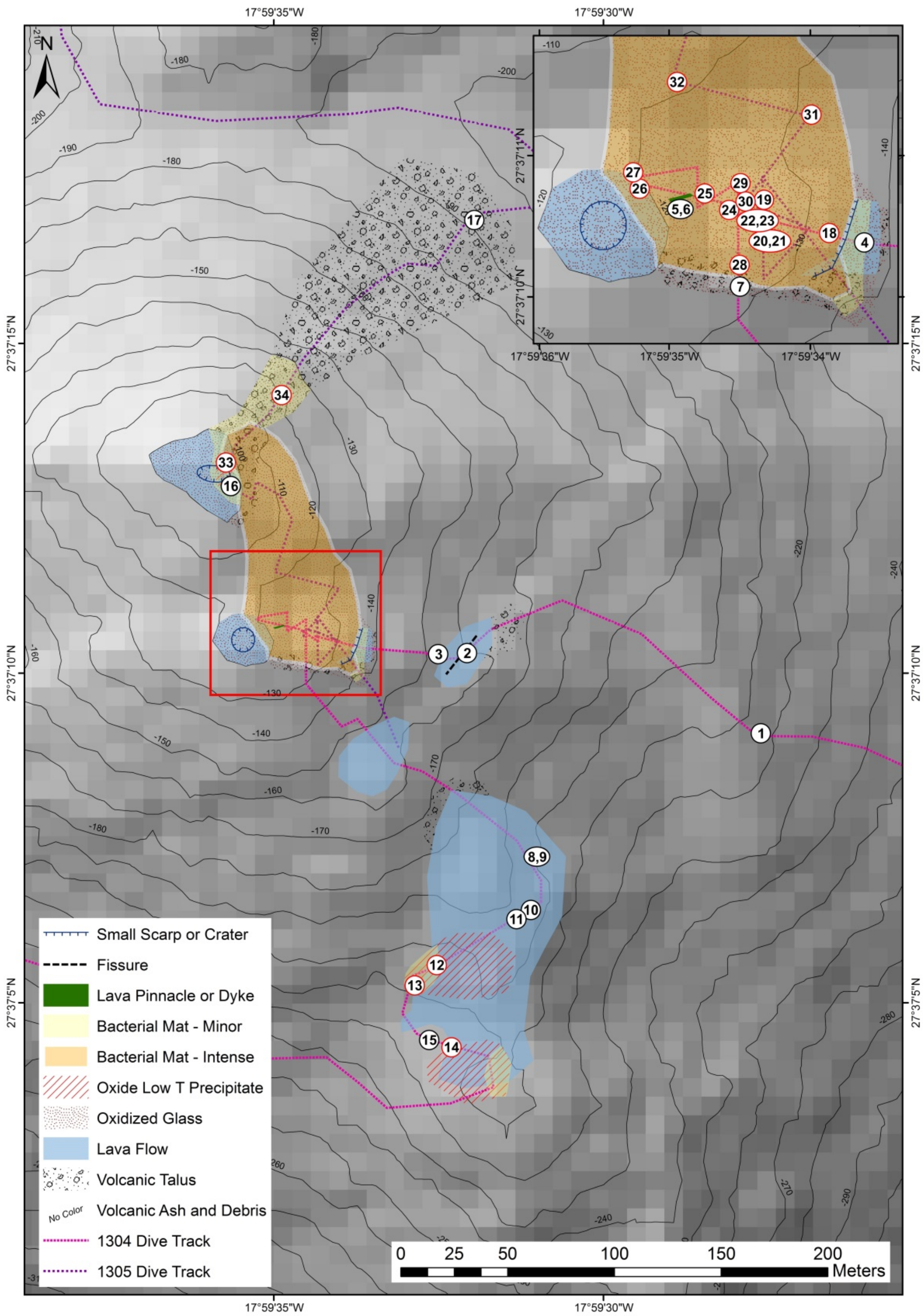


Figure 21. *Locations of video frame grabs in Figures 18, 19, and 20.*

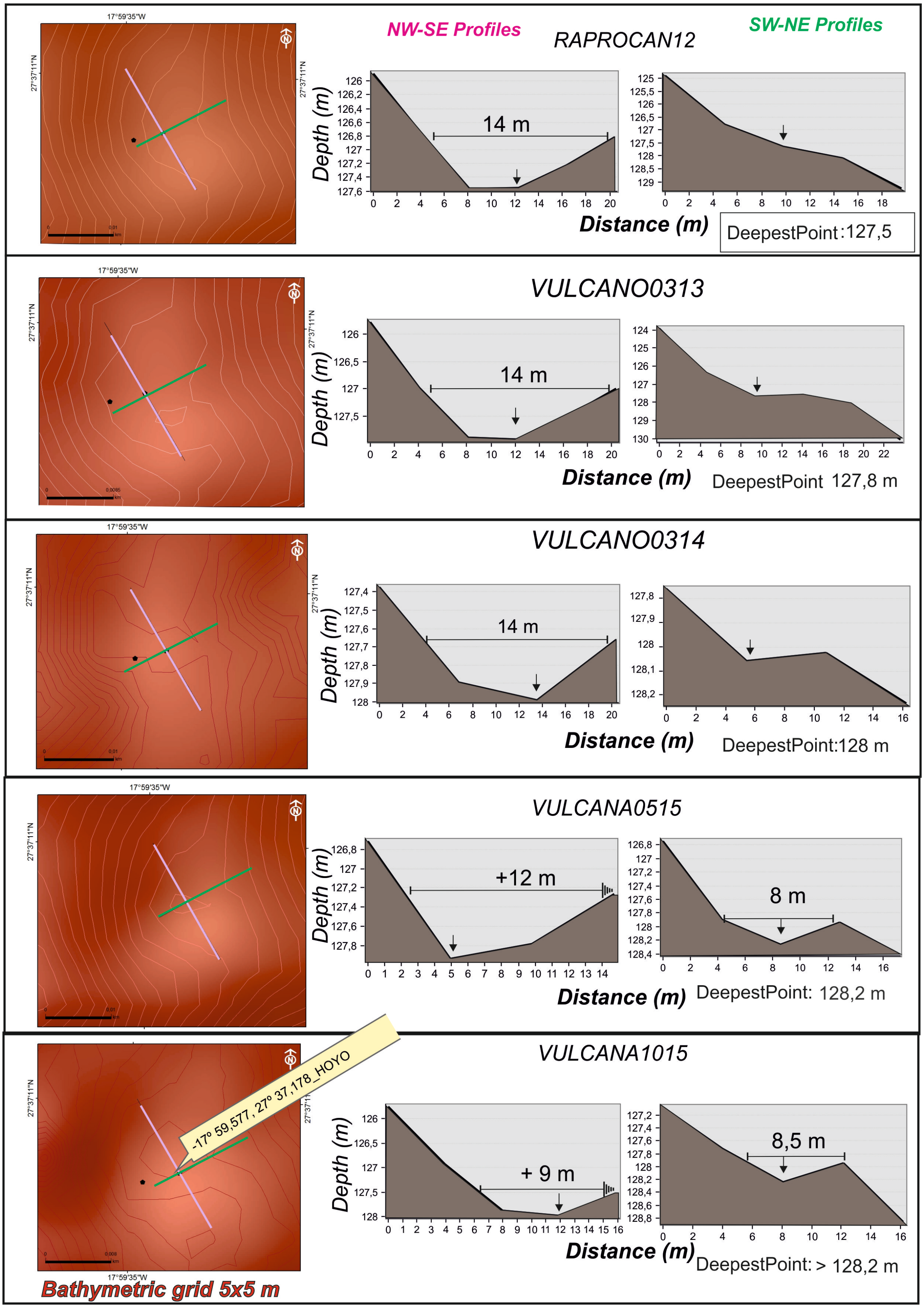


Figure 22. *Cross-sections of the secondary crater on the SE flank of Volcano "E", showing the depth and extent of the depression. Bathymetry from IEO (Instituto Espanol de Oceanografia) collected during repeat surveys of the cone from 2012-2015 (courtesy E. Frailes Nuez).*

7.3 Rock sampling (S. Petersen, S. Lange)

Rock samples and Fe-oxide crusts (scoop samples) were collected on JAGO Dives 1303 and 1304 at Volcano "E". The samples included volcanic lavas, Fe-oxyhydroxides as well as conglomerates consisting of coarse biogenic material (shells, etc) and volcaniclastics. The volcanic rocks comprise very young glassy volcanic rocks coated in Fe-oxyhydroxides as well as rounded volcanic blocks of apparent older age. Descriptions and photographs are provided in the table below.

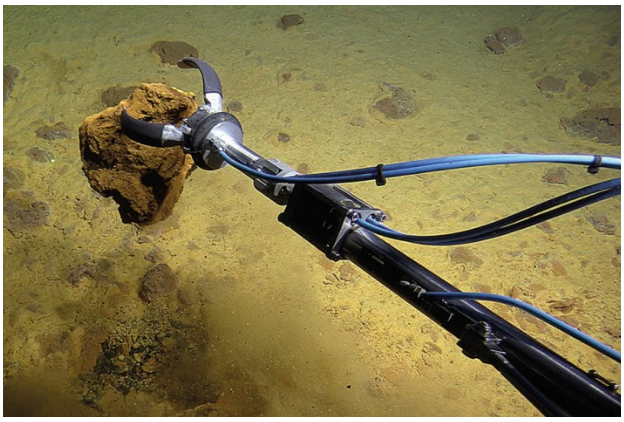
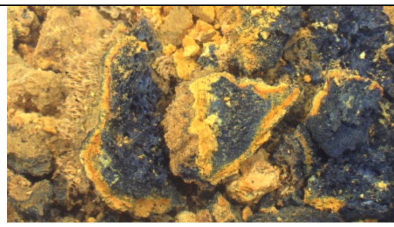
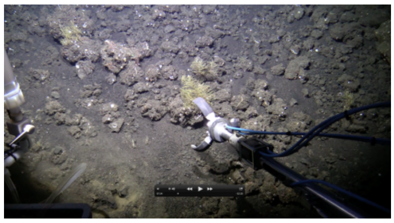
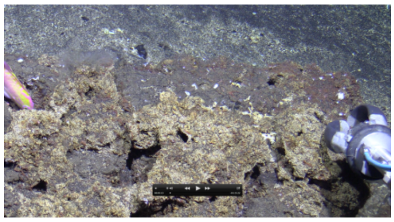
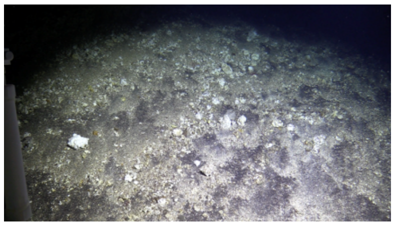


Figure 23A) *Sampling Fe-oxide coated scoria on top of volcano "E".* ***B)*** *Collection of samples from cone "G" and volcano "E".*

Sample ID date/time (UTC)	**Latitude / Longitude depth**	**Description**	**Photos**
POS494 25-1 12.02.2016/ 08:15	27°37.174'N/ 17°59.565'W 130m	From depression Group 1: thin platy Fe-oxyhydroxides flakes and siliceous (?) material sampled with net. More porous yellow material is fluffy and dispersed easily during station work at the seafloor. The fluffy material contributes to the marine snow in the area. 	
POS494 25-2 12.02.2016/ 09:12	27°37.176'N/ 17°59.565'W 130m	From depression Group 2: blocks of fresh glassy lava, very vesicular, coated by mm to cm thick Fe-oxyhydroxide layer and (partially) fibrous microbiology. These blocks are located between the fine-grained Fe-oxyhydroxides of group 1. Are these samples younger than the 2011 eruption?	

Sample ID date/time (UTC)	**Latitude / Longitude depth**	**Description**	**Photos**
			
POS494 25-3 12.02.2016/ 11:01	27°37.283'N/ 17°59.513'W 202m	From NE summit of volcano "E" Group 3: basalt blocks, still vesicular but much denser than group 2; less glassy and dark grey, coated by bryozoan, small oysters, snails, and molluscs indicating older age when compared to type 2 samples. 2011 eruption? 	
POS494 25-4 12.02.2016/ 12:15	27°37.397'N/ 17°59.652'W ca.230m	Between volcano "E" and site "F" Group 4: fine-grained mix of biological material (largely sponge and sea-urchin speculi (?) intermixed with fine-grained (<2mm) volcaniclastic material and Fe-oxyhydroxides; samples resemble pumice in the ROV dive video 	
POS494 25-5 12.02.2016/ 12:27	27°37.411'N/ 17°59.673'W ca.230m	Between volcano "E" and site "F" Group 5: conglomerate with intermixed rounded volcaniclastic material (mm to several cm in size) and shell fragments (also from mm to several cm in size), forming blocks and slabs that are being eroded and contribute to the biogenic lighter-colored sediment on top of the darker ash layers in the area.	

Sample ID date/time (UTC)	**Latitude / Longitude depth**	**Description**	**Photos**
			
POS494 25-6 12.02.2016/ 12:42	27°37.390'N/ 17°59.679'W ca.230m	Between volcano "E" and site "F" Group 6: carbonate bioherm with clam shells and stromatolite-like porous blocks 	
POS494 27-1 13.02.2016/ 12:51	27°37.063'N/ 17°59.534'W 211m	Small knob south of volcano "E" summit Group 1: blocks of fresh glassy lava in a talus pile; very vesicular; similar to group 2 of the previous dive, but showing flow surfaces; video shows pillows and tubes nearby; some samples show thin Fe-oxyhydroxide coating again indicating similarity to group2 of the previous day; younger than 2011 eruption?	

7.4 Water-column measurements (M. Santana-Casiano, E. Fraile Nuez)

In March 2014, a map of "hydrothermal emissions" was created by towing a combination CTD-pH-ORP package from the base to the top of volcano "E", from 3 to 40 m above the seafloor (Santana-Casiano et al., 2016). During POS494-2, water column sampling for discrete pH, total alkalinity (AT) and total dissolved inorganic carbon (CT) were carried out in the maximum anomalies detected in 2014. Additionally, one CTD cast was conducted outside of the volcano's influence. The results from the analysis of the data of the self-contained pH-orp sensor installed on JAGO demonstrated that the submarine volcano of El Hierro is still active with a degasification process that is generating strong physical-chemical anomalies.

The main objective of the plume surveys and water sampling were to identify the type of emissions from the volcano and the diffusion process. During two dives with JAGO and multiple hydrocasts, the maximum physical-chemical anomalies were located in the depression on the SE flank of the volcano (secondary crater). The geomorphology, ongoing hydrothermal activity and fresh volcanic rocks from the crater indicate that it is the youngest feature of the volcano. Diffuse hydrothermal venting is mainly through openings between scoria blocks and through porous ash-covered areas. These areas are extensively covered by white to yellow bacterial mat and orange Fe-oxide crusts. Very rare, small delicate Fe-oxide chimneys were also observed. The entire secondary crater was filled by a white milky cloud, coincident with the previously identified pH anomaly.

Prof. J. M. Santana-Casiano (ULPGC) and Dr. E. Fraile Nuez (IEO) dived in the JAGO 1303 and 1304, respectively, taking samples for pH, total Alkalinity (A_T), total dissolved inorganic Carbon (C_T) and Fe(II). The samples for pH were measured on the ship using an UV-Vis spectrophotometric system. A self-contained pH-ORP sensor (from IEO) mounted on JAGO was also used to measure in situ redox potential and pH. Samples for A_T and C_T are being analysed by Prof. M. González-Dávila and for Fe(II) by C. Santana-González in the QUIMA-IOCAG lab in the ULPGC. Data from the self-contained pH-ORP sensor were processed together with the navigation data from JAGO by Dr. Fraile Nuez. Those data highlight the potential role of the self-contained sensor as a methodology to track this kind of anomalies over the submarine volcanoes.

The physical-chemical sampling with JAGO was carried out during 9, 10, 12 and 13 February (Jago_02, Jago_03, Jago_04 and Jago_05). The following samples were collected:

Dive	pH-orp sensor	Mini-CTD (Geomar)	Niskin	Teflon bottle
Jago_02	1717 measurement	yes	–	–
Jago_03	2055 measurement	yes	2 pH, 1 A_T, 1 C_T	4 pH, 1 A_T, 1 C_T
Jago_04	5689 measurement	no	–	2 pH, 10 Fe(II),
Jago_05	5281 measurement	yes	1 pH, 3 filters of water samples at 0.1, 0.22 and 0.45 µm (GEOMAR)	1 pH, 5 Fe(II)

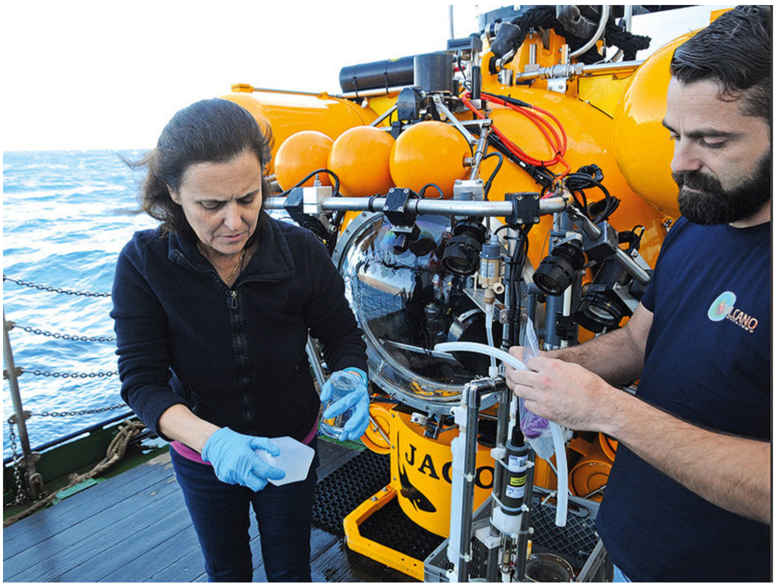


Figure 24. *Prof. J. M. Santana-Casiano (left) and Dr. E. Fraile Nuez (right) collecting samples recovered by the submersible JAGO.*

The locations of water samples collected in the eruption crater were chosen based on in situ temperature measurements (up to 39 °C) recorded by inserting the temperature probe up to 10 cm into the Fe-oxide crusts and ash. Water samples were collected with the specially designed water sampler mounted with an in-line pump. Water samples from the Teflon bottles were collected as close to the vents as possible, at temperatures from 23 °C to 39 °C (6 to 22 °C above ambient), first using a funnel-shaped inlet and then a stainless probe inserted into holes with visible shimmering water. The pH and ORP were measured in situ with the pH-ORP sensor attached to JAGO, employing two different techniques (potentiometric and UV-Vis Spectrophotometric). Close to 15,000 data points were collected with the pH-ORP sensor during 5 dives. A_T (total alkalinity), C_T (total inorganic carbon), and Fe(II) will be measured in the onshore lab at ULPGC and combined with the onboard pH-ORP data and navigation data from JAGO. A minimum pH of 7 was measured in the least diluted sample collected with the stainless probe.

Water samples near the seafloor were also collected during station 27 (JAGO Dive 1304) with the small Niskin mounted on the submersible. The bottle was triggered a few meters above bottom in the eruption crater on Volcano E where a visible "milky" cloud is rising from the eruption crater. This sample was filtered through a 0.45 micron filter (135 ml), 0.22 micron filter (135 ml), and 0.1 micron filter (35 ml), which will be examined in a low-vacuum environmental SEM to characterize the nature of the plume particles.

Water Sample List from JAGO Dives:

JAGO Dive 1300/1 Station17
Location: El Hierro, coastal slope
Date:9-2-2016, Observer: Mark Hannington, Pilot: Jürgen Schauer
No samples. No pH-ORP sensor

JAGO Dive 1301/2 Station18
Location: El Hierro, coastal slope
Date:9-2-2016, Observer: Maarten v. Rouveroy, Pilot: Jürgen Schauer
No samples.
Test pH-ORP sensor

JAGO Dive 1302/3 Station20
Location: El Hierro, cone G
Date:10-2-2016, Observer: Sven Petersen, Pilot: Jürgen Schauer
Samples:
Teflon botlle 1: pH
Teflon botlle 2: pH
Niskin bottle: pH, AT y CT
ORP-pH sensor: Data

JAGO Dive 1303/4 Station25
Location: El Hierro, Submarine Volcano E
Date:12-2-2016, Observer: J. Magdalena Santana-Casiano, Pilot: Jürgen Schauer
Dive duration: start at 7:17, at bottom at 7:30, leave bottom at 14:57, end at 15:14
Samples:
Teflon botlle 1: pH and Fe(II) in hydrothermal fluids
Teflon botlle 2: pH and Fe(II)
Niskin bottle: open, no samples
pH-ORP sensor: Data

JAGO Dive 1304/5 Station27
Location: El Hierro, Submarine Volcano E

Date:13-2-2016, Observer: Eugenio Fraile Nuez, Pilot: Jürgen Schauer
Dive duration: start at 7:45, at bottom at 8:06, leave bottom at 13:45, end at 13:59
Samples:
Teflon botlle 1: pH and Fe(II) in hydrothermal fluids
Teflon botlle 2: no samples
Niskin bottle (milky cloud): pH, Fe(II)
Filter water and filters (35ml, 0.1 μm, 135 ml 0.22 μm, 135 ml 0.45 μm)
ORP-pH sensor: Data

Methods:

pH: The pH on the total scale at a constant temperature of 25ºC ($pH_{T,25}$) was measured spectrophotometrically (Clayton and Byrne, 1993) with m-cresol purple as an indicator (González-Dávila et al., 2003; the dye effect was removed for each pH reading) with an uncertainty of 0.002 units.

A_T and C_T: A VINDTA 3C system (www.MARIANDA.com) was used for both total alkalinity and total dissolved inorganic carbon concentration determination. The titration of certified reference material for oceanic CO_2, CRMs, was used to test the performance of the equipment. Measurements of CRMs were within ±1.0 μmol kg^{-1} of the certified value for both parameters. The computation of other carbonate variables (pCO_2, pH) and values at in situ conditions was done by using the CO2sys.xls v12 program (Lweis and Wallace, 1998) and the set of constants of Mehrbach et al. (1973) as in Dickson and Millero (1987).

TDFe(II): In order to determine the concentration of Fe(II) in seawater the FeLUME system (Waterville Analytical) was selected. The FIA-chemiluminescence technique uses luminol as the reagent (King et al., 1995). Dissolved, colloidal and labile phases of Fe(II) are determined and expressed as TDFe(II).

pH-ORP sensor: pH and ORP data were recorded by a SBE 27 pH and O.R.P. (Redox) sensor combines a pressure-balanced, glass-electrode, Ag/AgCl reference probe and platinum O.R.P. electrode to provide in-situ measurements at depths to 1200 m. The replaceable pH probe is permanently sealed and is supplied with a soaker bottle attachment that prevents the reference electrode from drying out during storage. The sensor is a modular and self-contained package. Data were post-processed using Matlab software using a combination of data: navigation data and temperature and salinity self-contained micro-CTD from JAGO. All data are interpolated every 2 seconds.

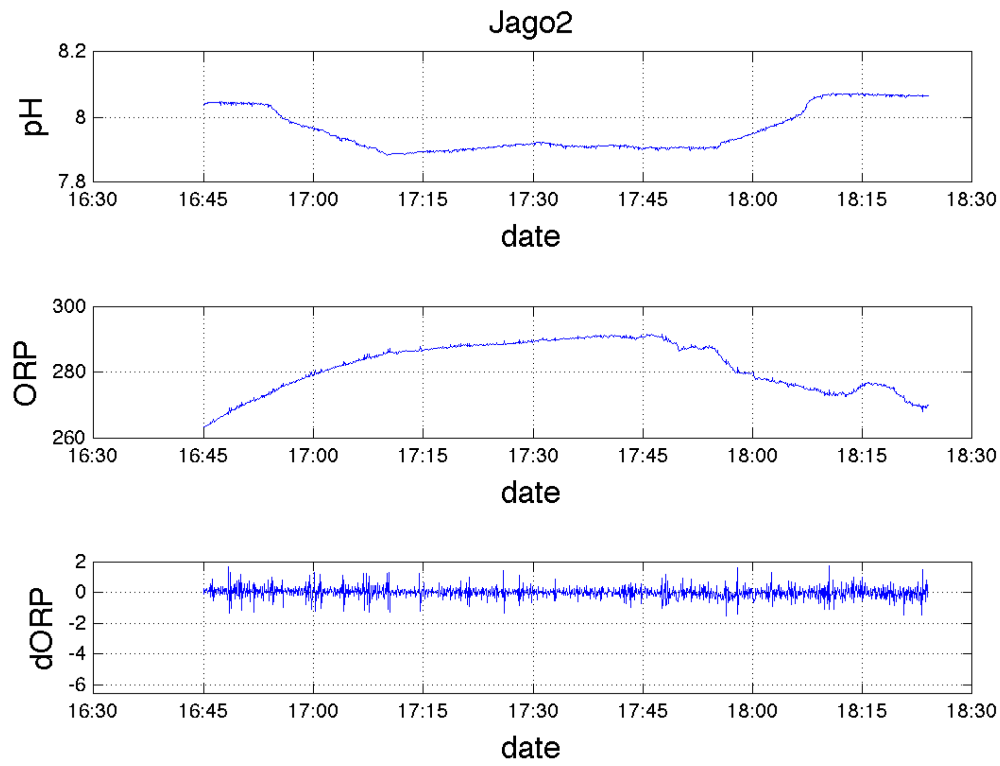


Figure 25. *pH, ORP and dORP for continuous pH-orp self-container sensor on board Jago. Dive 1301/2 Station 18*

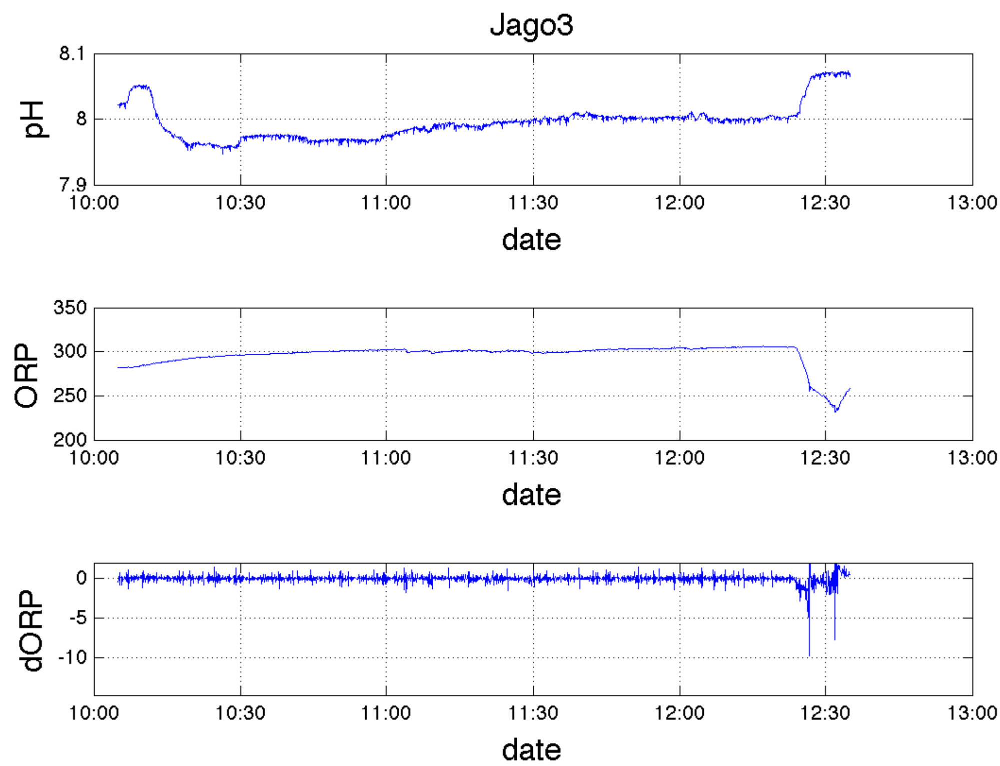


Figure 26. *pH, ORP and dORP for continuous pH-orp self-container sensor on board Jago. Dive 1302/3 Station 20*

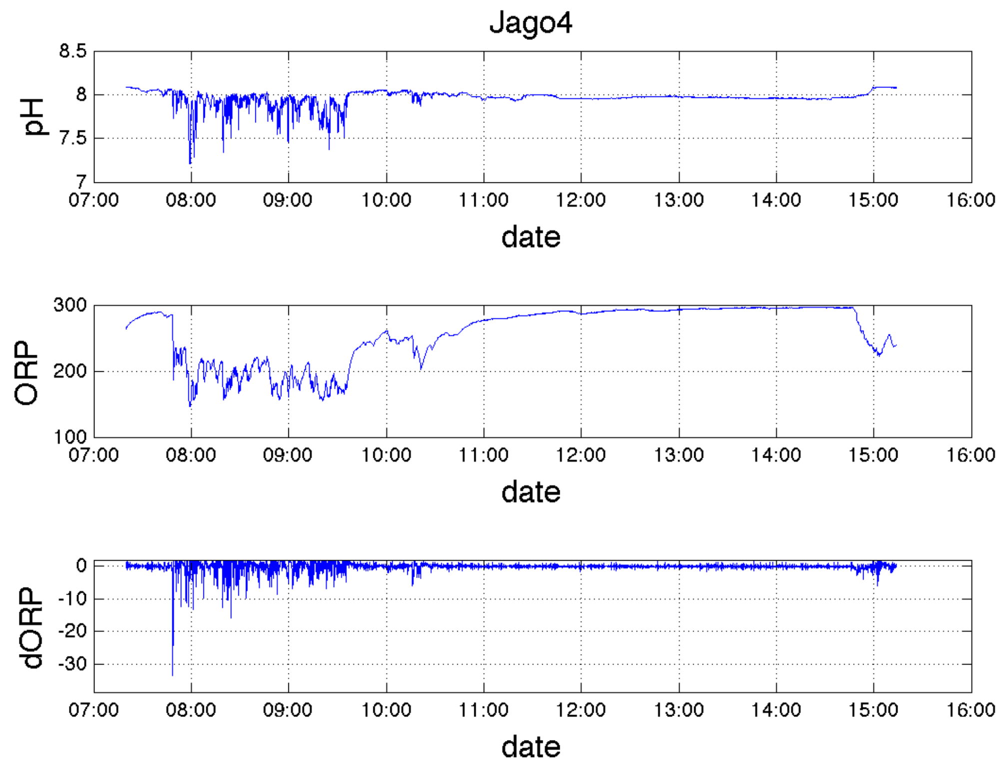


Figure 27. *pH, ORP and dORP for continuous pH-orp self-container sensor on board Jago. Dive 1303/4 Station 25*

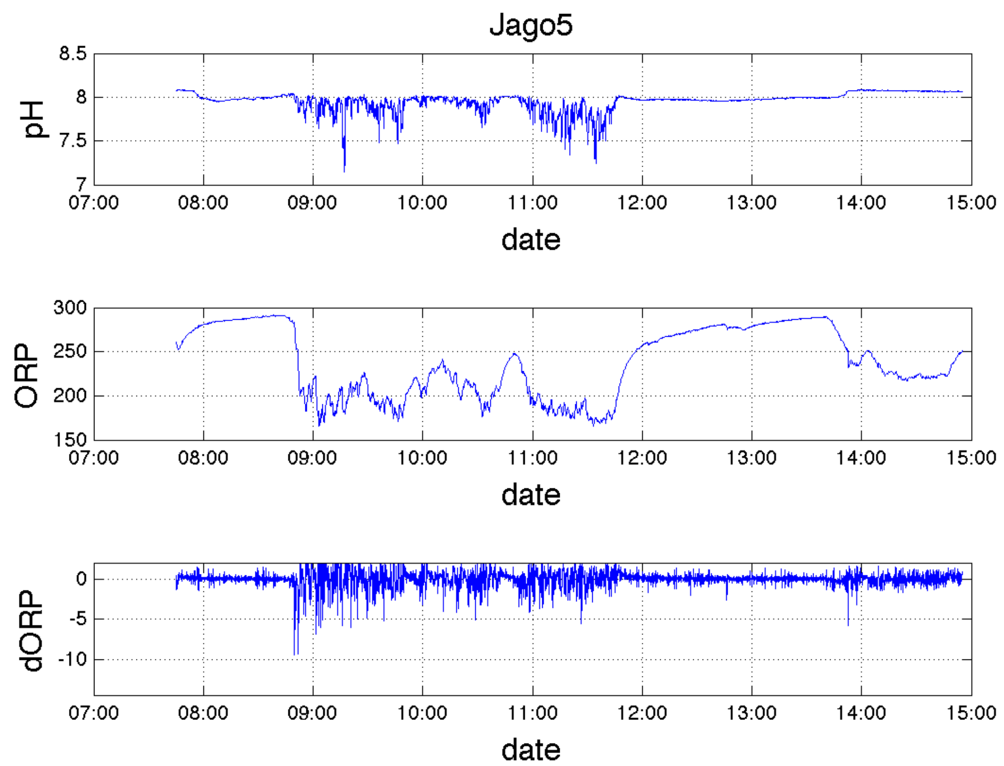


Figure 28. *pH, ORP and dORP for continuous pH-orp self-container sensor on board Jago. Dive 1303/4 Station 25*

7.5 CTD and "camera tow" (M. Santana-Casiano, E. Fraile Nuez, S. Petersen)

CTD-Rosette Niskin bottles
Date:11-2-2016, Towyo_01
Sampling: 12 Niskin bottles for pH, AT and CT and GoPro imaging

CTD	Physical parameters (GEOMAR)	JAGO "GoPro" Cameras	Niskin
Towyo_01	24 Hz, CTD sensors	Continuous video	12 pH, 12 A_T, 12 C_T

A shallow water CTD deployment was made over the summit of volcano "E" on February 11. The purpose was to sample the plume from diffuse venting over the top of the cone and the secondary eruption crater on the SE side of the summit where a distinctive temperature anomaly was recorded in 2015. 11 bottles were triggered in a random profile across the summit and in the crater. A 12th and final bottle was triggered away from the volcano at 200 m water depth for background.

During the CTD Station, an experiment was performed by attaching 2 GoPro cameras in a pressure housing from JAGO on the CTD frame. One camera was set for normal daylight conditions, and the other was set for low-light conditions. Both cameras prove a wide-angle view. Continuous video of the bottom was obtained from heights varying between 1 and 5 m above bottom. Because of the shallow water depth (200 to 80 m), ambient light was sufficient to illuminate the top of the cone, revealing both the overall shape of the volcano summit and also the large areas of bacterial mat.

7.6 Multibeam mapping (M. Klischies, S. Petersen, S. Lange, I. Yeo)

Data acquisition and processing: The system installed on-board R/V POSEIDON is a SeaBeam 3100 multi-beam system (by L-3 Communications ELAC Nautik GmbH), nominally operating up to 3000 m water depth using the 50 kHz frequency band, with a maximum swath angle of 140°, a beam width of 1.5° x 2°, and a maximum reception of 386 beams in the multi-ping mode (two swaths of 193 beams each). Figure 29 shows the system set up during cruise POS494-2. The weather and wave conditions limited the mapping course headings to 40-45° and 220-225° (see ship tracks in Figure 30 and 31). In order to enhance the beam coverage, the average cruise speed was between 2.0 to 2.5 kn over ground, and the average swath angle was set to 60° in deeper waters and approximately 100° in shallower areas. The system is connected to the motion sensors via the ship's sonar system network and, as much as possible, automatically corrects for vessel motions and surface sound velocity. The system was operated and monitored with HydroStar on-board. Post-processing was conducted with *MBsystems* and *Fledermaus*, on shore. The data set covers about 400 km^2 south of El Hierro island, and maps the South Rift and adjacent areas south of the island (Figure 32). The mapped seafloor shows a mean slope of 10°, from shallow waters near the coastline to abyssal plains in water depths of more than 3000 m.

In total, 21 profiles were mapped. After the 11th profile, a sound velocity profile was finally recorded during a CTD cast at 18°04'30"W, 27°35'20"N, to a maximum water depth of 2150 m, and before gridding the data were recalculated in MBsystems using the sound velocity profile. The mapped water depths ranged from 88 m at the top of main target area (site E) to abyssal areas with depths exceeding 2500 m. Due to heavy weather conditions, the data quality was generally poor, especially in the deeper water, and data collected while drifting over the dive targets may have been affected by communication with the submersible.

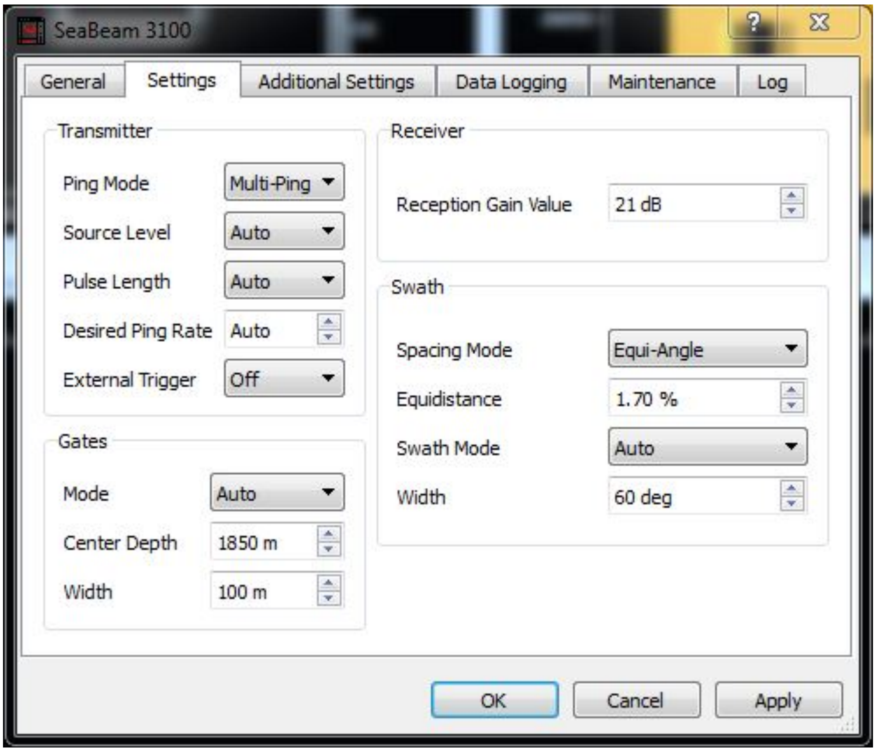


Figure 29. *Screenshot of SeaBeam 3100 system setup during cruise POS494.*

Preliminary observations from multibeam mapping

The new multibeam data collected during POS494, extend coverage approximately 10 km south and west of the existing multibeam surveys. These data show that the down-slope channels and structures on the submarine flanks of the island are mostly erosional, whereas the South Rift has a constructional character mostly lacking erosional features.

El Hierro's southern tip extends as a submarine ridge more than 27 km offshore. Submersible dives focussed on the shallowest part of this volcanic ridge, about two kilometres southwest of the harbour of La Restinga (see Figure 4). In proximity to the island, the ridge crest strikes more or less North-South, is in general shallower than 1500 m water depth, and forms a 3 km wide plateau in 1000 m water depth. As shown in Fig. 5c-d, the ridge has never been mapped south of 27°30'N, where it has a mean water depth of 1500 m and trends SE-NW, with a strike of around 025-205°. Structures that suggest frequent land sliding and mass wasting, e.g. down-slope oriented channels, dominate the submarine flanks of El Hierro (Figures 32 and 33). The south extending ridge has a rough topography, and volcanic edifices with a characteristic cone shape top the 3 km wide plateau. Erosional features are less apparent on the ridge, when compared to the island's flanks, suggesting a relative younger age.

At least a dozen young volcanic cones, similar to those in the volcanic field surrounding La Restinga, occur on the submarine flank of El Hierro on or close to the offshore South Rift Zone. These cones appear to be aligned along a series of an echelon NW-SE trending lineaments that correspond closely to structures mapped on land.

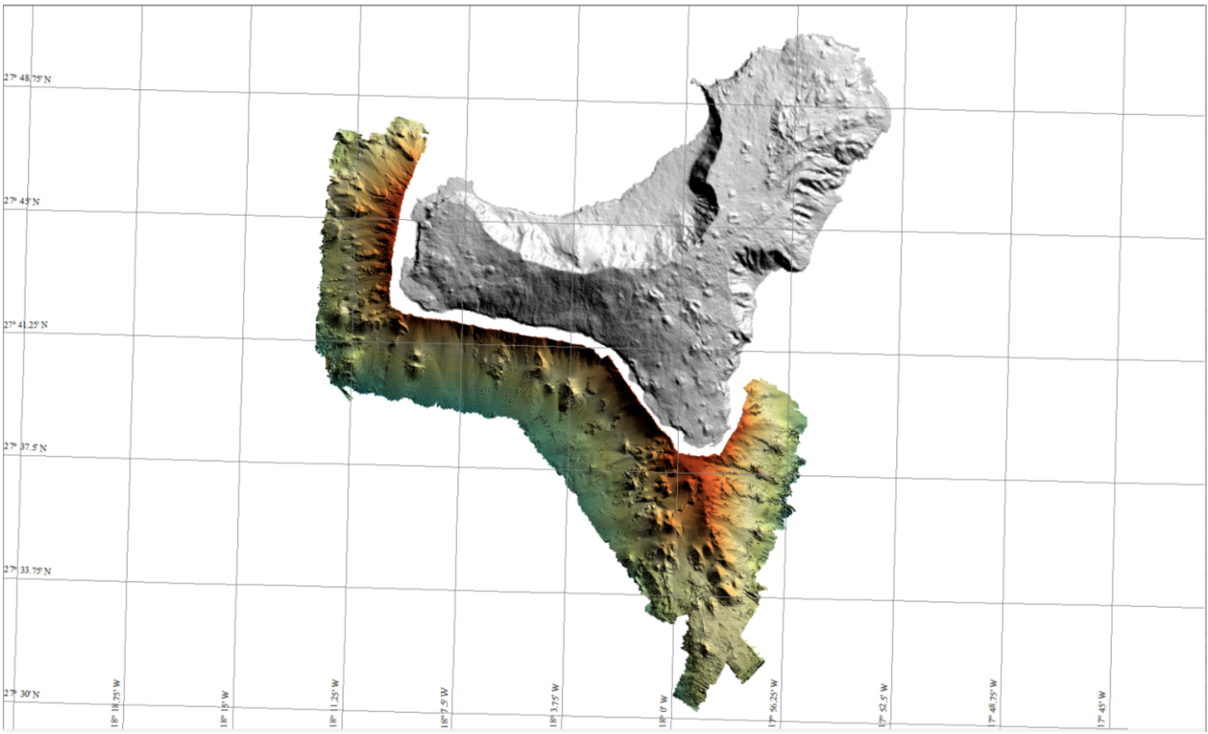


Figure 30. *Available ship-based bathymetry provided by IEO, gridded at 10 m resolution. The nighttime multibeam surveys extend this mapping approximately 10 km to the south and west.*

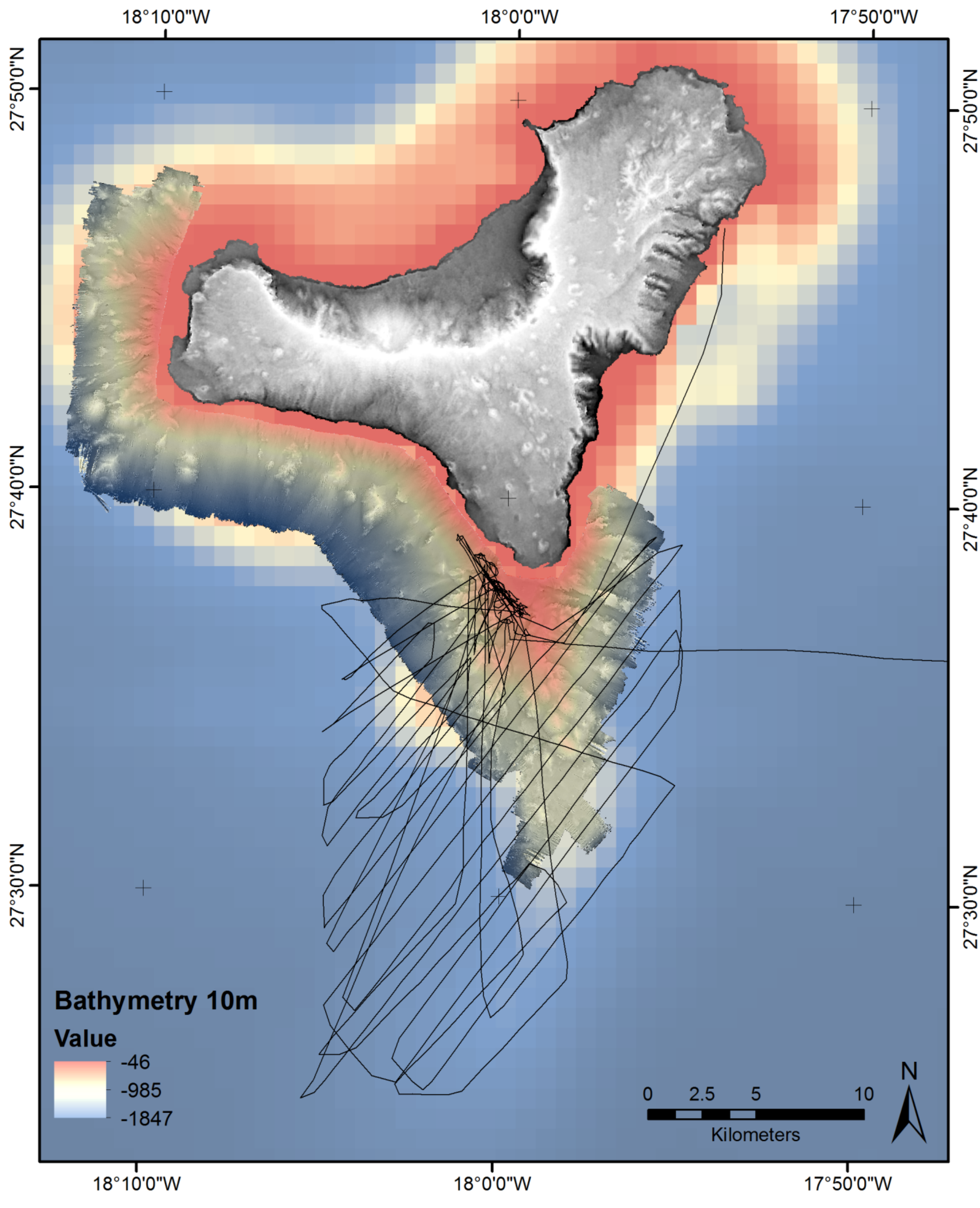


Figure 31. *Shiptracks for multibeam mapping profiles with SRTM 30 min bathymetry (water depth in meters) in the background, together with the topography of the island (in greyscale) and available ship-based bathymetry from Figure 30. The NE-SW-trending, parallel lines correspond to the nighttime mapping campaigns; tracks at the main target areas (around 18°0'0"W, 27°37'30"N) belong to the drifting ship during the dives of the submersible JAGO. Approximate scale: 1:250,000.*

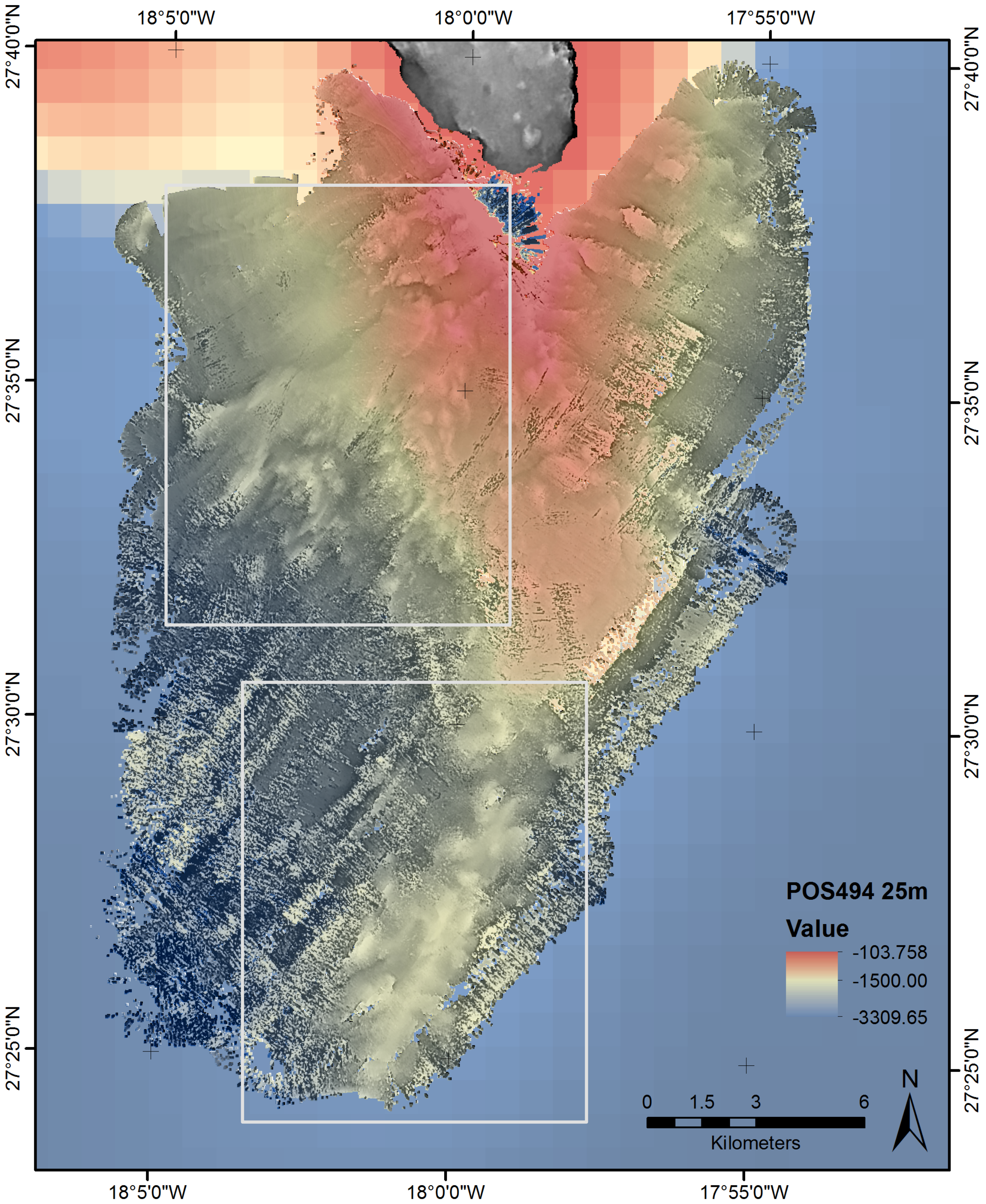


Figure 32. *Map showing bathymetric data acquired during POS494 (water depth in meters), gridded in 25 m resolution, and illuminated by a diffuse light source (terrain texture shader by Leland Brown). Outlined areas indicate locations of maps in Figure 33. Map scale is ca. 1:150,000. The data shows a high density and quality only in water depths shallower than 1500 m. Where the mapping course was along the slope, the quality is degraded.*

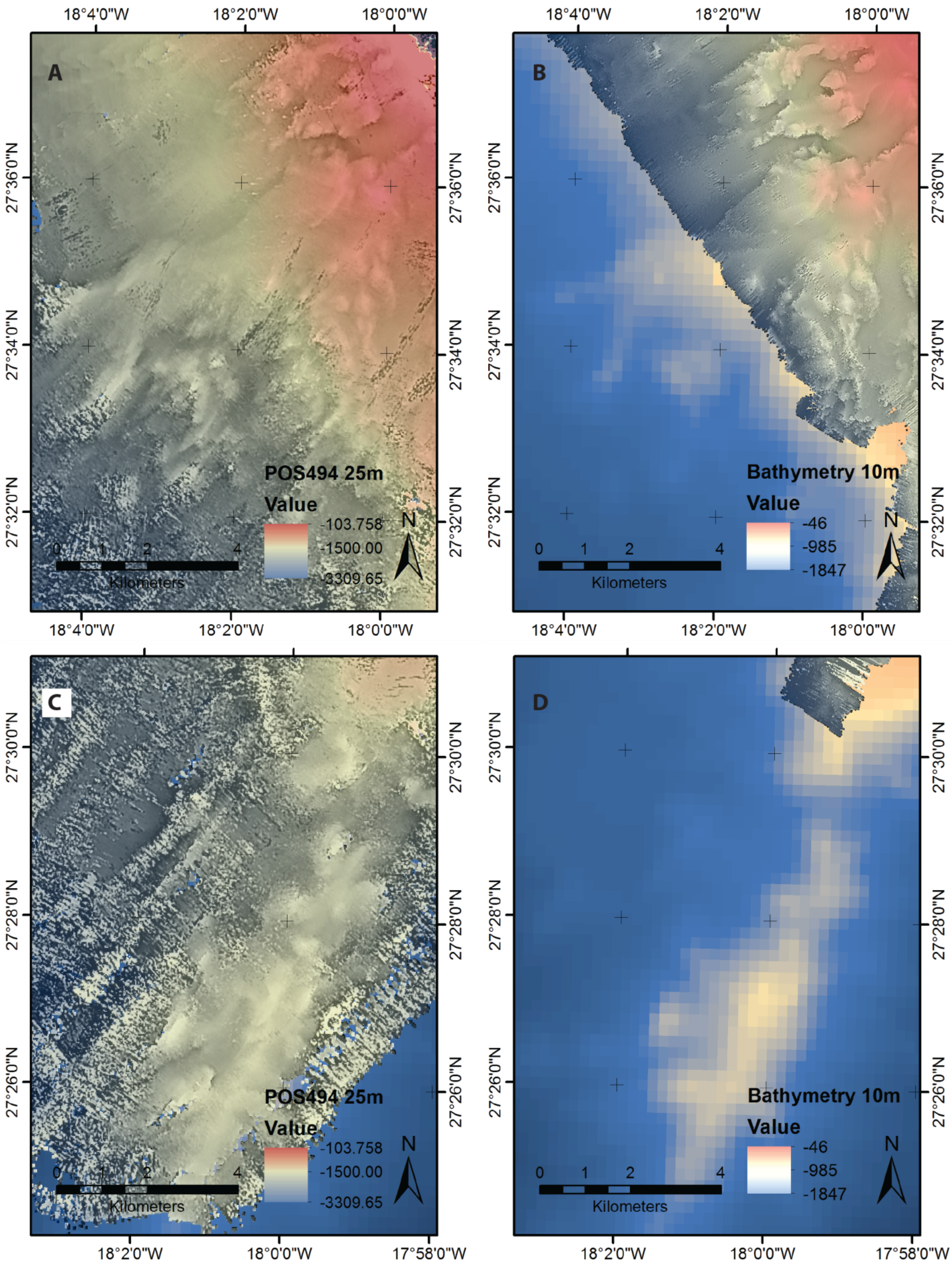


Figure 33. *Comparisons of new multibeam data from the ELAC3100 system on POSEIDON and pre-existing data in the study area. A and C) Close-ups of bathymetry in meters of water depths from POS494. B and D) Data from IEO acquired in 2011 plus public data available from GeoMapApp in the background. Scale is about 1:100,000. The new POS494 data show that the down-slope channels and structures on the submarine flanks of the island (A) are mostly erosional features, whereas the southern ridge (C) has a constructional character mostly lacking erosional features.*

7.7 Onshore geological mapping (M. Anderson)

Geological mapping was also carried out at the same time as the JAGO diving on POS494-2 to elucidate the probable volcanic features of the offshore South Rift zone; in particular the controls on effusive and explosive eruptions in relation to the regional stress field. In order to achieve this objective, a geological map is being created to cover the subaerial portion of the southern rift zone that will be combined with a similar map of the submarine area. The first steps toward creating this onshore-offshore geological map have been undertaken in association with the POS494 expedition.

Detailed geological mapping and photography of volcanic features on the island were carried out from 3-13 Feb 2016. Field work focused on the southern rift zone near the town of La Restinga, plus two days in the western rift zone with the media team. Standard field mapping methods were used to map the different lava flows, volcaniclastic units, and volcanic cones. Geological units were mapped onto satellite base maps at a scale of 1:10,000, and observations were recorded in field notes. Volcanic features were photographed using a digital SLR camera with locations carefully recorded. Accurate positioning was provided by a Garmin eTrex 20 GPS, in UTM grid WGS87 zone 28N. At all locations, observed lava morphologies were compared with satellite imagery to define contacts and geological units. ~110 line kilometers with 120 waypoints were covered on foot (Figure 34), and more than 1200 photos were taken. 245 of the best photographs were digitally post-processed and linked to the satellite imagery. The field maps will be digitalized and overlain on a digital elevation model, then combined with interpreted geology from the offshore bathymetry and JAGO dive videos. To the best of our knowledge, this type of “seamless” onshore-offshore mapping has not been attempted before.

The main volcanic features observed onshore were multiple generations of pahoehoe and aa lava flows, for which relative ages could be inferred from cross-cutting/overlapping relationships, degree of weathering (oxidation of glass), as well as lichen and vegetation coverage. Volcanic cones, including scoria cones and larger spatter cones, with and without central craters, were mapped, as well as smaller volcanic vents/hornitos (Figure 35). Many of these features were also observed during the JAGO dives on Volcano “E”. Large scoria cones near the coast that were partially eroded into the ocean, and those crossed by road cuts, give a view of the likely interiors of the offhsore cones, revealing feeder dikes and eruption sequences marked by lava flows and volcaniclastic successions of variable thickness (Figure 35 G-H). Loose sand- to gravel-sized volcaniclastic deposits occur around the base of several scoria cones extending for 100s of meters, partially to completely covering coherent lava flows. Few dikes or other structures are exposed in this part of the island, likely obscured by recent volcanism; however, the orientation of fissures and scoria cone rows were measured directly from satellite imagery, providing evidence for the regional stress field. The latter correspond closely to the NW-SE alignment of the volcanic cones mapped offshore.

A number of volcanic features observed at Volcano “E” are also seen on the volcanic centers mapped onshore. In particular, features indicative of relative ages of flow units observed in JAGO dives are very similar to those observed among onshore lava flows (degree of weathering, oxidation of glass, sediment or “organic” cover). The onshore cones reveal what is likely to be the internal structure of Volcano “E”. In particular some of the features observed at the seafloor may be analogous to the smaller volcanic vents/hornitos or dikes observed on land. Some important differences between the volcanic geomorphology onshore and offshore are the presence of pillow-like structures on Volcano “E” and the lack of fluidal flow texture typical of pahoehoe flows on land.

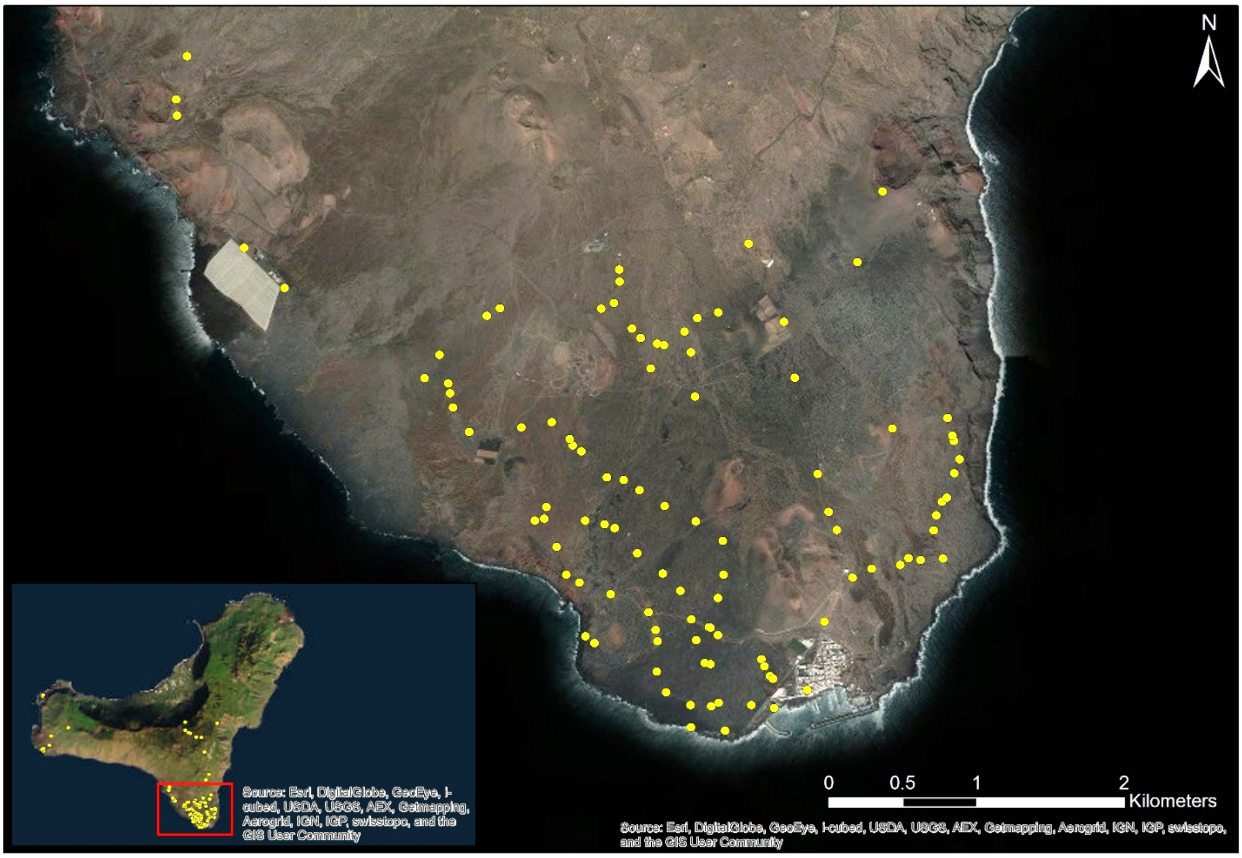


Figure 34. *Satellite image of the southern rift zone of El Hierro, Canary Islands, with waypoints indicated by yellow circles. Additional waypoints outside of the southern rift zone are shown in the inset satellite image of the entire island of El Hierro. Note: Not all areas visited for mapping purposes are marked by a waypoint.*

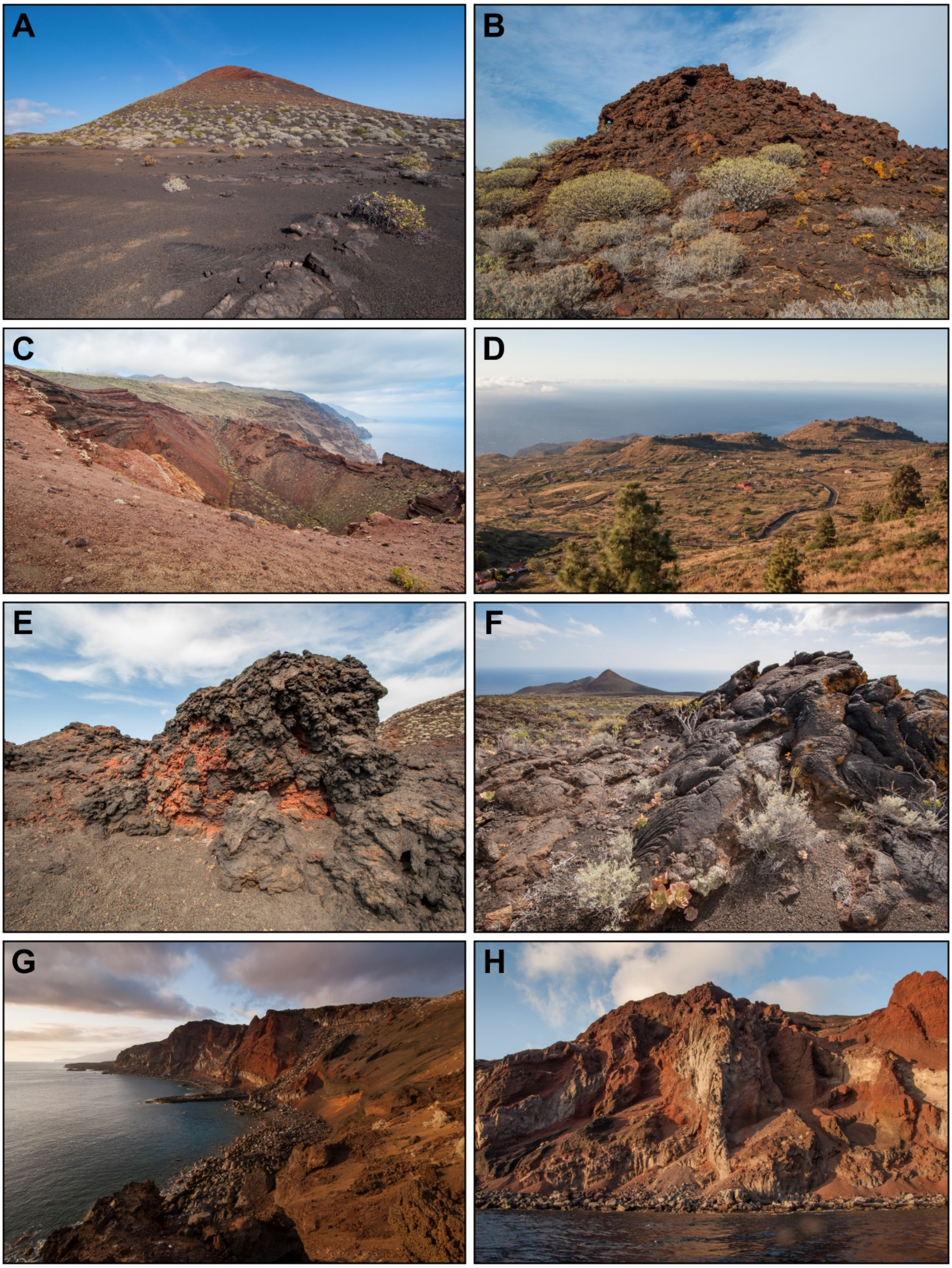


Figure 35. *Volcanic cones at El Hierro: (A) large 200-m wide scoria cone surrounded by volcaniclastic material partially covering pahoehoe flows, (B) large 0-m tall spatter cone, (C) large 350-m wide crater with laminar flows visible in the crater wall, (D) older vegetated and cratered scoria cones, (E) 2-m tall hornito, (F) small 1-m tall eruptive vent with pahoehoe flows, (G) 280-m tall eroded scoria cone along the coast immediately adjacent to the JACO dive site. (H) central feeder dike of 280-m tall eroded scoria cone.*

8. Media Coverage (Maike Nicolai)

With different teams investigating various aspects of El Hierro's volcanic activity at the same time and research vessel POSEIDON and submersible JAGO operating close to the coast, the POS494 cruise and HIERROSeis 2016 campaign offered ideal opportunities for media activities.

Zweites Deutsches Fernsehen, Norddeutscher Rundfunk and Westdeutscher Rundfunk indicated interest before the start of the expedition and land-based work, but were not able to send their own teams to El Hierro. Also, GEOMAR wanted to use the opportunity to document research conducted in the framework of a cooperation initiated with the University of Las Palmas de Gran Canaria (ULPGC) and the Plataforma Oceánica de Canarias (PLOCAN) in 2014. The freelance filmmaker Maarten van Rouveroy was assigned to cover all aspects of the scientific work using topside and underwater cameras as well as a drone for aerial shots. Maike Nicolai, press officer at GEOMAR, was responsible for photographing. The media team was based on land and used a boat shuttle to visit POSEIDON daily.

To address local media, a short briefing was held on board POSEIDON at Valverde harbour during the crew change on February 7. Two TV teams and four freelance journalists attended and received first-hand information from the participants of the two legs of the expedition.

After the cruise, a press release in Spanish, English and German was distributed by GEOMAR, ULPGC and the VOLCANO project. Mostly Spanish media picked up the topic, and Eugenio Fraile Nuez and Magdalena Santana-Casiano answered interview requests.

A ten-minute video in English with subtitles in German and Spanish produced by Maarten van Rouveroy was published on the GEOMAR Youtube channel at March 9. Prior to this, material had been sent to various European TV distribution services such as APTN Horizons, ENEX, Eurovision/EBU, Journeyman Pictures, Green TV, Storyful and the Spanish agency EFE.

A complete list of the media coverage that could be tracked to April 26, 2016, is included in the Appendix. The list has to be incomplete – especially lacking printed articles from outside Germany and TV coverage – because professional media monitoring could only been carried out for German printed media. Nevertheless, the overall coverage is much higher than normally achieved for GEOMAR expeditions. Some reports are still in preparation and most likely there will be more media interest as soon as data and samples are analysed and scientific publications available.

9. Acknowledgements

The Master and crew of POSEIDON are to be commended for ensuring that we achieved our scientific objectives safely and under very difficult and challenging seas. Diving operations were carried out on very short notice each day as rapidly changing weather conditions were assessed. Once a decision to proceed was made by all concerned, the ship handling, deck operations, and dive boat operations were performed perfectly and without any incident. The skill of the deck handling crew made this successful program possible. Other activities, including multibeam and CTD/camera surveys were also performed in very difficult weather. Despite high winds, all operations were completed efficiently and successfully. The result is that a unique dataset was obtained in just a few short days and nights.

Accommodations and meals were superior, and logistical support for the scientific crew flawless. The treatment of the science visitors by the ship's crew was patient, friendly and cordial, especially with our Spanish guests, media team and English-speaking chief scientist. The working relationship with Captain Günther and his crew was, as expected from previous cruises, excellent. This was an important international cooperation project with PLOCAN, ULGC and IOE, and the Captain and crew of POSEIDON were perfect hosts. With the help of our Spanish colleagues, special attention was paid to the provisions of the local marine reserve.

We particularly wish to thank Dr. Dietrich Lange (chief scientist of POS494-1) for his assistance in preparing the cruise proposal and the documentation for the diplomatic clearance, and for generously sharing shiptime needed to achieve our objectives. We also thank our partners at PLOCAN (Platforma Oceania de Canarias)/ ULPGC (University of Las Palmas de Gran Canaria) and the Spanish Institute of Oceanography (IEO, Instituto Espanol de Oceanografia) for assistance with logistics and communication with federal and local authorities.

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11. Station list

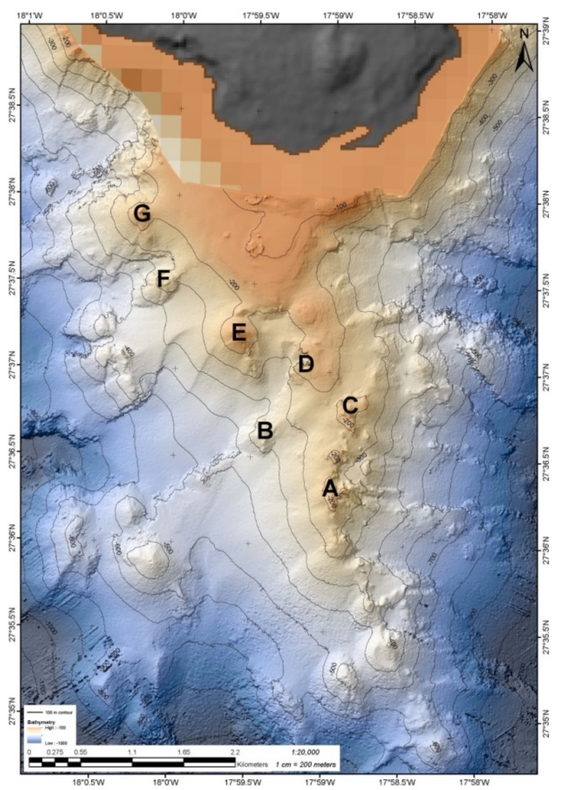


Figure 36. *Key to station list. Letters refer to individual volcanic cones originally chosen for dive targets.*

		Start					End				
Station	Gear	Date	Time	Latitude	Longitude	Depth (m)	Date	Time	Latitude	Longitude	Depth (m)
POS494/15	Multibeam	07.02.16	18:31	27°25.00'N	18°05.00'W	3399	08.02.16	09:51	27°39.00'N	17°55.01'W	1877
POS494/16	Multibeam	08.02.16	15:38	27°28.49'N	18°04.70'W	3066	09.02.16	06:30	27°37.50'N	18°00.50'W	565
POS494/17	Jago dive	09.02.16	10:05	27°38.29'N	18°00.31'W	393	09.02.16	13:17	27°38.57'N	18°00.93'W	512
POS494/18	Jago dive	09.02.16	16:29	27°38.57'N	18°00.71'W	408	09.02.16	18:13	27°38.54'N	18°00.85'W	501
POS494/19	Multibeam	09.02.16	20:47	27°26.92'N	18°04.09'W	2990	10.02.16	06:38	27°28.52'N	17°59.28'W	1702
POS494/20	Jago dive	10.02.16	10:01	27°37.83'N	18°00.06'W	238	10.02.16	12:32	27°37.76'N	18°00.28'W	237
POS494/21	CTD	10.02.16	15:51	27°35.36'N	18°04.54'W	2151	10.02.16	17:12	27°35.35'N	18°04.47'W	2151
POS494/22	Multibeam	10.02.16	21:34	27°27.04'N	17°59.97'W	1515	11.02.16	04:24	27°37.00'N	18°05.00'W	2009
POS494/23	CTD	11.02.16	16:03	27°37.22'N	17°59.60'W	87	11.02.16	17:11	27°37.13'N	17°59.54'W	0,6
POS494/24	Multibeam	11.02.16	19:21	27°35.00'N	18°00.00'W	892	12.02.16	05:47	27°34.00'N	18°05.00'W	2411
POS494/25	Jago dive	12.02.16	07:16	27°37.19'N	17°59.65'W	126	12.02.16	15:05	27°37.69'N	18°00.49'W	385
POS494/26	Multibeam	12.02.16	19:28	27°30.00'N	18°01.00'W	2285	13.02.16	04:51	27°28.00'N	17°58.00'W	2482
POS494/27	Jago dive	13.02.16	07:44	27°37.31'N	17°59.51'W	206	13.02.16	14:01	27°36.93'N	17°59.76'W	419

12. Dive Reports

Dive summary

JAGO – Dive 1300 (01) – St17

POS494-2 (POSEIDON)

Date: 09.02.2016

Observer: Mark Hannington

Pilot: Jürgen Schauer

Station: POS494 / 17

Location: El Hierro, Submarine Canyon north-west of Cone G

Dive duration:

Submerged: 10:09
At bottom: 10:25
Leave bottom: 12:52
At surface: 13:17

Dive objectives:

1. Inspect exposures of canyon walls north-west of cone G.
2. Determine whether the seafloor topography is mainly from the failure of the La Restinga shoreline or partly offshore constructional volcanism.

Samples, measures, media:

Samples (type, depth)
None (restricted sampling area in marine reserve)

Measures
JAGO CTD: yes
IOE/ULPGC pH-ORP sensor: yes

Video / Photo / GoPro
Digi HD video, GoPro jpgs (front window from outside + inside JAGO)

Dive summary:

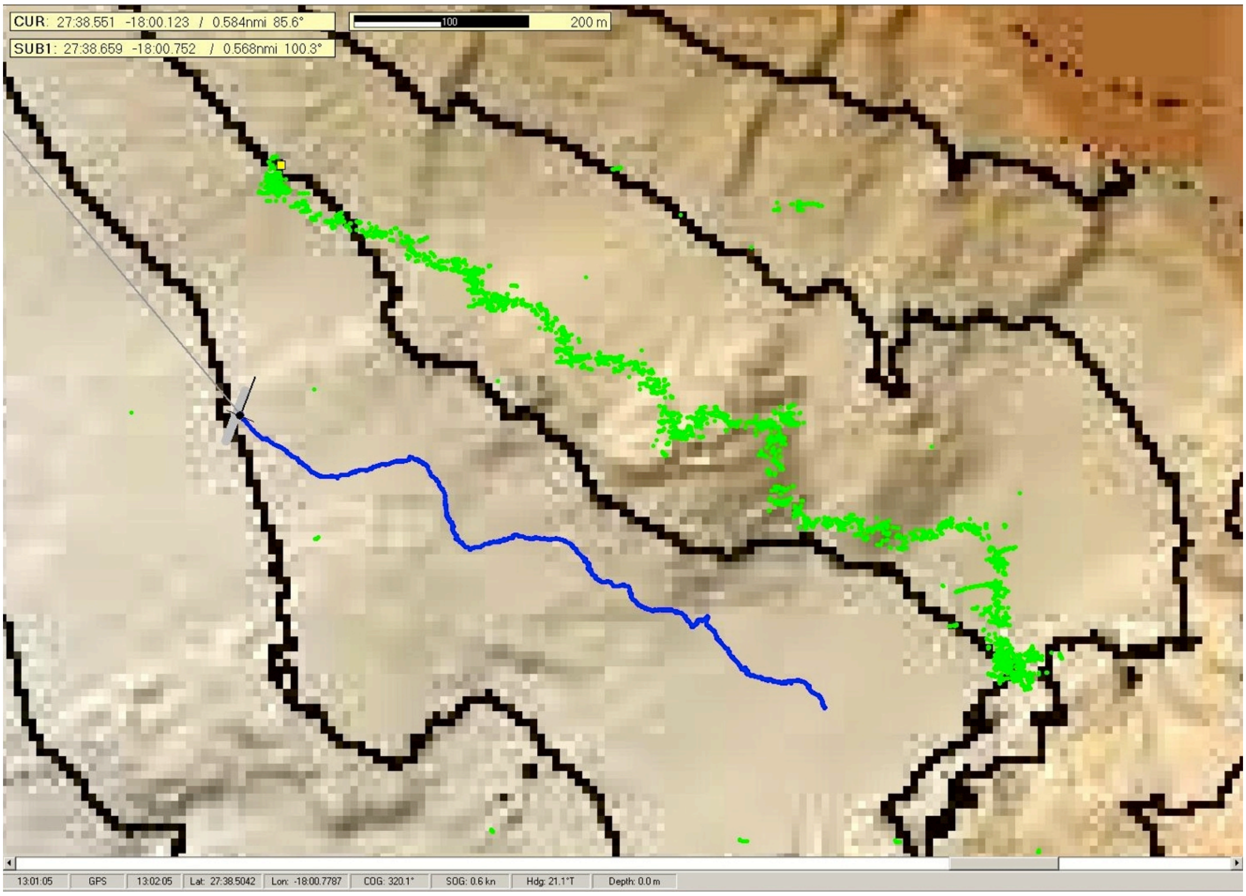
The objective of the dive was to inspect the irregular relief on the eastern and western sides of the canyon formed by the collapse of the volcanic edifice on the La Restinga shoreline. The JAGO landed on the north flank of cone G at 247 m, adjacent to the canyon, and followed the east wall of the canyon down to a depth of close to 400 m. The east wall of the canyon is dominated by very steep escarpments (near-vertical steps of 30-40 m) of stratified volcaniclastic sediments, mainly ash with few blocks. These features appear to be the eroded remnants of a cone flank, very similar to those exposed on shore, with bedding at a moderate to steep but consistent dip to the SW. The central part of the canyon was traversed at a depth close to 400 m and consists of volcaniclastic scree slopes with dark grey to locally white ash, pumice, and rare blocks. At the west wall of the canyon, the erosional remnants form linear ridges of bedded volcaniclastics, 10-20 m in height. However on several slopes, there was clear evidence of older coherent lava (old tubes, ropy lava, and local sheet-like surfaces) on top of stratified ash layers, suggesting that the western side of the canyon is partly a low-relief constructional feature rather than the eroded remnants of a scoria cone.

Conclusion: Many of the low-relief features on the flank of the La Restinga peninsula are not only products of mass wasting (i.e., material shed from onshore collapse features) but include volcanic constructional landforms. These include cones that are partly shaped by landslides and partly buried by material from the failed volcanic edifice on the La Restinga shoreline.

Detailed dive log:

Time UTC	Depth (m)	Long DD:MM.mmm	Lat DD:MM.mmm	Observations (biology, geology, microbiology slope angle, bottom current, visibility)
10:03	0			In the water (depth of 363 m)
10:09	0			Start of dive
10:15	93 m			Descending
10:18	150 m			“ “
10:22	200 m			“ “
10:25	247 m			Encountered a vertical outcropping of ash, 20-30 m high, covered in white sponges and a number of whip corals. Mainly bedded volcaniclastics. Heading 173 °
10:32	278 m	27°38.249N	18°00.225E	Descended wall 30-40 m high to scree slope at 288 m. Sandy grey to black (salt and pepper) sediment at the base with few blocks.
10:34	290 m			Settling on plateau of sandy sediment to retrieve temperature probe.
10:44	304 m			Moving NNE with large cliffs of bedded volcaniclastics to the right. Beds are dipping 30-35° to the west. No or minimal current.
10:46	314 m	27°38.286N	18°00.257E	~30 m drop in front of the submersible
10:51	341 m			Descended to sandy bottom (black and grey) with minor current ripples.
10:55	347 m	27°38.340N	18°00.250E	Travelling along wall covered with white sponges. Bedded volcaniclastics dipping shallowly to SW.
11:03	358 m			Another 20 m drop in 6-10 m steps of outcropping ash beds (50 cm – 1 m thick).
11:13	382 m	27°38.352N	18°00.283E	Still at east side of the canyon.
11:26	377 m			Turning to the west to cross the canyon floor (mid-water).
11:37	396 m	27°38.433N	18°00.369E	Heading across canyon (mid-water), with the canyon floor at 420 m depth.

11:44	395 m	27°38.434N	18°00.409E	Heading 246°. Bottom of canyon slowly coming up from 435 m.
11:49	395 m	27°38.470N	18°00.433E	Approaching west side of canyon. Bottom at a depth of 20 m below JAGO. Sharp ridges of bedded volcaniclastic.
11:56	394 m	27°38.630N	18°00.413E	Wall of bedded volcaniclastics dipping 20-25°, most probably the eroded flanks of another volcanic cone.
12:02	396 m	27°38.500N	18°00.470E	Onto a scree slope of mixed ash (black, grey, white, red) and rare blocks. Older material with sponges and coral already on the blocks.
12:10	395 m			Heading west across the erosional remnants of a former cone with spines and ridges of bedded volcaniclastic material.
12:13	391 m			Shallowly-dipping scree slope (sand and gravel) with rare 30-40 cm blocks.
12:15	389 m	27°38.532N	18°00.520E	Gentle scree slope (sand and gravel) with rare 30-40 cm blocks and local streaks of white pumice fragments.
12:27	380 m			Gentle scree slope (sand and gravel) between ridges and spines of bedded volcaniclastics.
12:29	378 m			Gentle scree slope (and gravel) with more white streaks of pumice gravel.
12:35	377 m	27°38.599N	18°00.637E	More coherent outcrops with very localized ropy surfaces (possible lava flows).
12:39	375 m			Several possible lava tubes (striking 210°); generally old with abundant coral.
12:43	378 m	27°38.599N	18°00.660E	Sand and gravel on flat coherent surface (possible lava flow).
12:50	377 m			Sand and gravel on a ledge with larger blocks of coherent lava. Terminating dive.
13:15	0			Back at the surface
	0			Back on deck



Screenshot of JAGO’s dive track (green) along La Restinga southwestern shore line between 300 and 400 m contour; yellow dot last position before lift off bottom.

Dive summary

JAGO – Dive 1301 (02)

POS494-2 (POSEIDON) – St 18

Date: 09.02.2016

Observer: Maarten van Rouveroy

Pilot: Jürgen Schauer

Station: POS494 / 18

Location: El Hierro, Submarine Canyon north-west of Cone G

Dive duration:

Start descent: 16:40
At bottom: 17:09
Leave bottom: 17:53
At surface: 18:13

Dive objectives:

1. Short media dive for documentation of procedures from within JAGO during launch, descent, bottom landing at >300 m, and ascent.

Samples, measures, media:

Samples (type, depth)
None (restricted sampling area in marine reserve)

Measures
JAGO CTD: yes
IOE/ULPGC pH-ORP sensor: yes

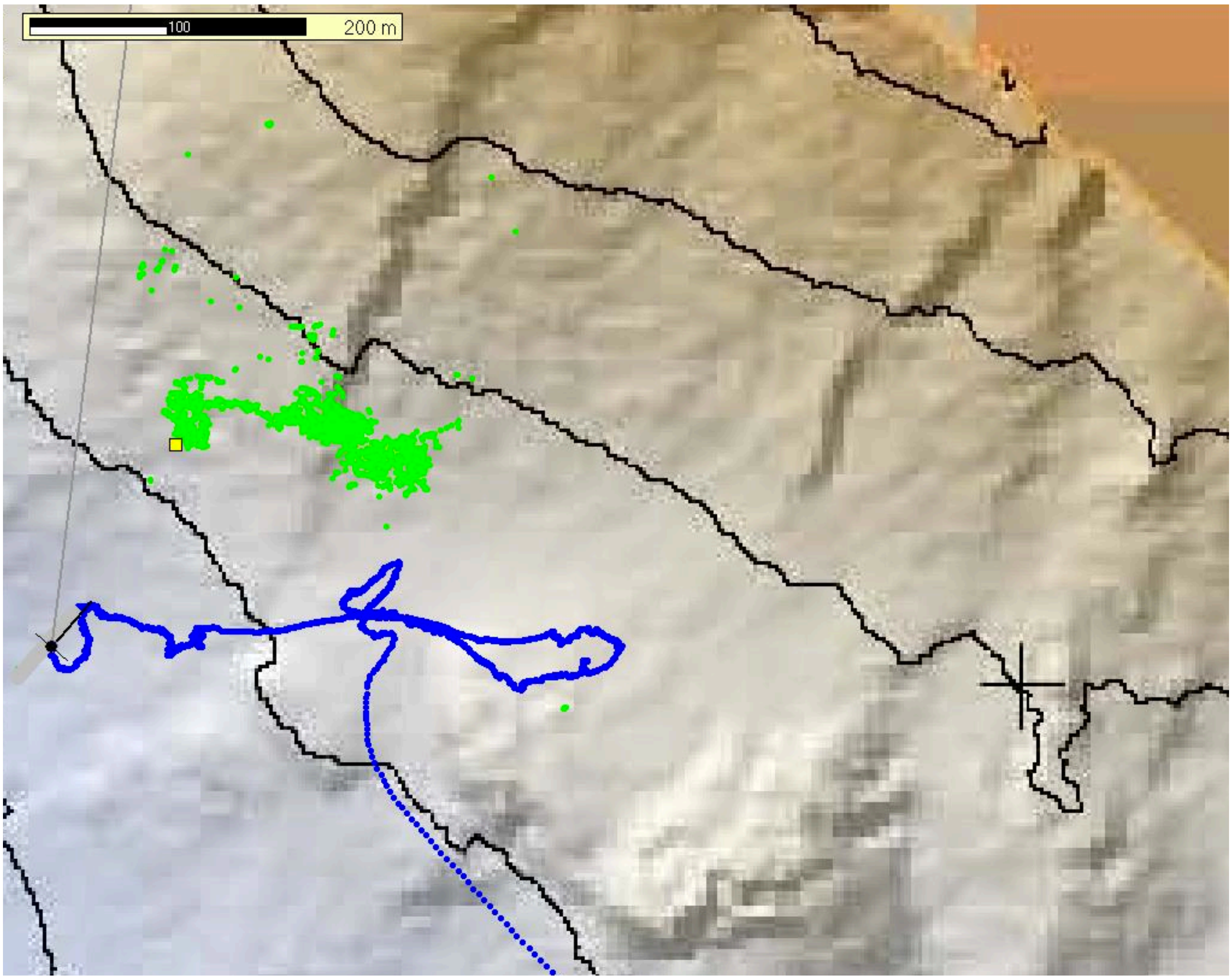
Video / Photo / GoPro
Media camera, GoPro (front window from outside – mp4, inside jpgs)

Dive summary:

The objective of the dive was to document for media presentation the procedures inside JAGO during diving and while hovering above or resting at the bottom. 16 min video footage of the sea floor on the western side of the canyon. Volcanic outcrop ridge with some benthic growth (mainly sponges, single specimens of bushy black corals, deep-water oysters Neopycnodonte sp.)

Detailed dive log:

Time UTC	Depth (m)	Long DD:MM.mmm	Lat DD:MM.mmm	Observations (biology, geology, microbiology slope angle, bottom current, visibility)
	0			In the water
16:40	0			Start of dive
17:09	365 m			Touch down on west side of the canyon related to the collapse of the volcanic edifice on the La Restinga shoreline.
17:36	365			
17:53	365	27°38.641N	18°00.781E	Off bottom
18:13	0			At the surface
18:25	0			Back on deck



Screenshot of JAGO's dive track (green) at La Restinga southwestern shore between 300 and 400 m contour lines; yellow dot last position before lift off bottom.

Dive summary

JAGO – Dive 1302 (03)

POS494-2 (POSEIDON) – St 20

Date: 10.02.2016

Observer: Sven Petersen / GEOMAR

Pilot: Jürgen Schauer

Station: POS494 / 20

Location: El Hierro, Cone G

Dive duration:

Start descent: 10:05
At bottom: 10:20
Leave bottom: 12:23
At surface: 12:32

Dive objectives:

1. Inspect flanks and cone of apparently older cone "G"; identify the nature of the cone (volcanic?)

Samples, measures, media:

<u>Samples</u> (type, depth)
NISKIN water sample at the summit (123 m depth)

<u>Measures</u>
JAGO CTD: no
IOE/ULPGC pH-ORP sensor: yes

<u>Video / Photo / GoPro</u>
Digi HD video, GoPro (front window from outside – mp4)

Dive summary:

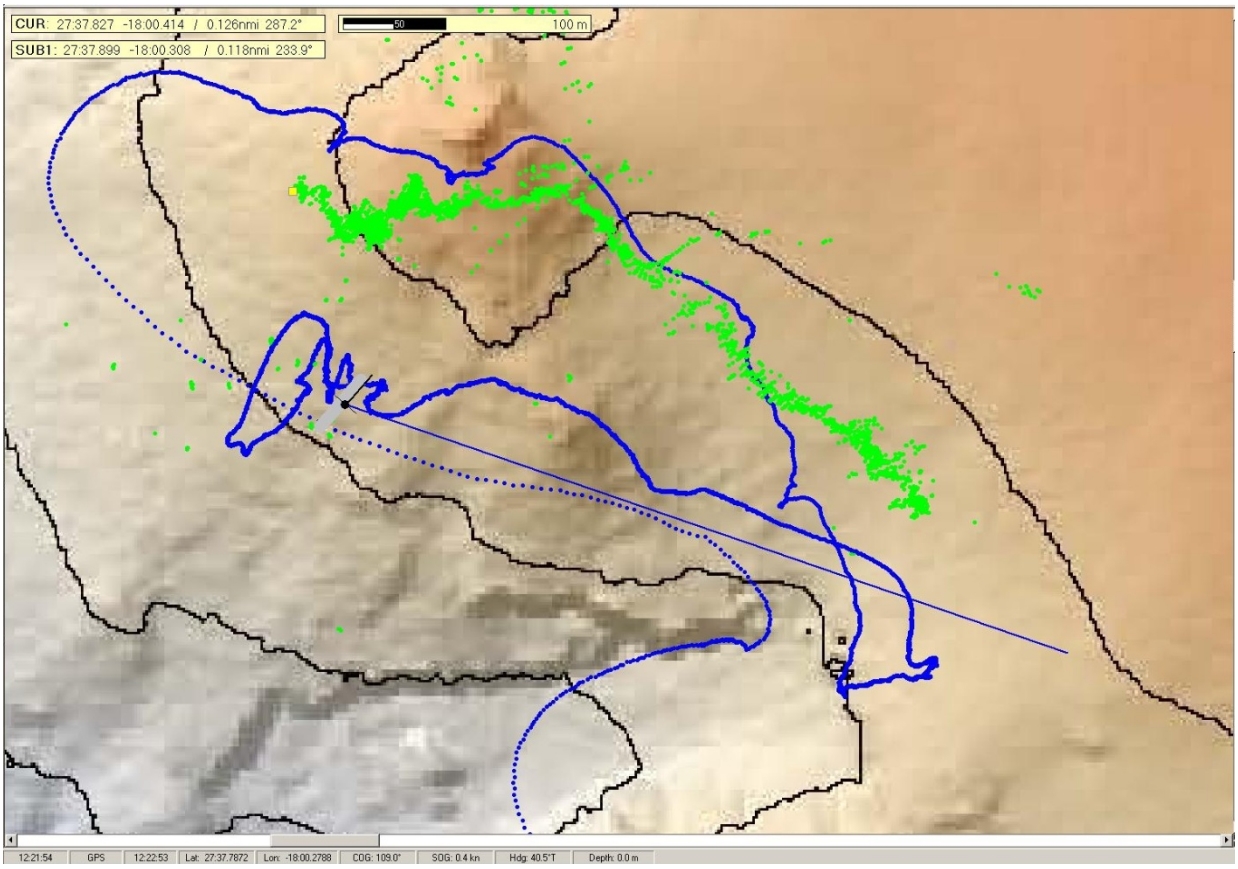
The objective of the dive was to establish the nature of cone "G". The flanks of the cone consist of partially desintegrating carbonate blocks, thereby forming the omnipresent light-colored coarse sediment on the flanks, that are covered to various degrees by fine-grained dark sediment, likely ash from the 2011 eruption. This is evident from the very top of the cone (depth of 123 m) where small plateaus are covered with this fine sediment. Areas covered in dark sediment show little life. In areas where the carbonate substrate is only covered by a thin layer of ash whip corals become more abundant. The carbonate blocks are encrusted by a thick layer of fauna and show abundant mobile life forms as well.

Detailed dive log:

Time UTC	Depth (m)	Long DD:MM.mmm	Lat DD:MM.mmm	Observations (biology, geology, microbiology slope angle, bottom current, visibility)
10:05	0			Start of dive, submerging
10:20	207 m	27°37.760N	17°59.960E	Touch down ca. 800 m southeast of the cone G on sandy SW facing slope, hdg 320 towards the top of the cone
10:25	209 m	27°37.763N	17°59.986E	sandy slope with anundant light grey coarse material and minor black ash (salt and pepper), still going downslope, limited current movement, little benthic fauna (!) dominated by small corals; few red shrimp
10:30	212 m	27°37.777N	18°00.009E	still on sandy slope moving NW, slope is rising now towards the NW; few burrows, little fauna, increasing number of boulders, coarse sand is several cm thick
10:35	209 m	27°37.795N	18°00.044E	coarse material seems to consist of mussel fragments (=old?) with fine volcaniclastic material; small octopus in sight;
10:36	206 m			same, but ripple marks (NE-SW) become more abundant and the abundance of dark fines is increasing
10:42	199 m			ca. 200 m SE of the target, more burrows, still in salt and pepper sediment
10:46	193 m			steeper slope ahead; few dark grey boulders; boulders have darker surface but where broken show a conglomeratic texture with light grey old shell-fragments (?); its is unclear, if all are boulders; some blocks seem to be in place (=larger blocks or outcrop covered in sediment); it is obvious that light coarse material is erosional to those blocks forming fans downslope; blocks commonly show corals and other organisms attached
10:50	185 m	27°37.888N	18°00.140E	still in salt and pepper sediment. few more corals that seem to be attached to hardground below a thin sediment layer
10:53	183 m			over the last few minutes the sediment color is changing to black or dark grey sand; light material is diminishing; ripple marks are abundant; few corals, commonly in groups
10:55	182 m			Large whip corals appear and are attached to small hard pieces penetrating through the dark sediment

Time UTC	Depth (m)	Long DD:MM.mmm	Lat DD:MM.mmm	Observations (biology, geology, microbiology slope angle, bottom current, visibility)
10:57	181 m	27°37.895N	18°00.178E	ripple marks have changed orientation to NE/SW; exposure of small cliff (in situ?) with shell fragments; abundant corals
10:58	181 m			back in black sediment
11:00	172 m			steep slope to the west, large number of corals on coarse light grey (carbonate?) hardground; abundant holes in the light grey rocks; turning west to go upslope (obvious mismatch with bathymetric map used for navigation)
11:02	170 m	27°37.892N	18°00.211E	very large outcrop of carbonate (?) with abundant fish and corals; little dark sediment dusting on top; large cracks in the outcrop
11:04	160 m	27°37.891N	18°00.238E	reached large, steep-sided (almost vertical) block with fractures and cracks; clear biogenic carbonate
11:05	158 m			reached small plateau where dark sediment (ash?) is covering the coarse outcrop
11:08	150m			small fault scarp followed by towering vertical wall; abundand fauna with anemones (?), blue sponges; abundant fish; strong current
11:10	147 m			plateau with dark sediment covering conglomerate; very abundant fauna
11:15	144 m	27°37.897N	18°00.154E	local summit, large conglomerate blocks covered in fauna
11:16	144 m			this was not the summit!; another steep, vertical wall ahead; very strong currents
11:17	147 m			large overhang, JAGO is drawn into the wall by currents
11:21	141 m			local summit with irregular conglomerate block covered in fauna; very steep flanks
11:22	140 m			thick encrusted fishing ropes hanging from next conlomerate block – testifying to the speed of faunal growth on surfaces; large overhang – that we touched gently! strong currents
11:24	140 m	27°37.895N	18°00.248E	morey in crack of the conglomerate; green and red algea(?)
11:31	136 m			at the next vertical wall (conglomerate) going up; several fishing ropes
11:37	126 m	27°37.870N	18°00.265E	finally approaching the very top of the cone
11:41	123 m	27°37.879N	18°00.262E	At top of cone, strong current, forest of whip corals and purple gorgonians; small plateau at the top filled with dark grey

Time UTC	Depth (m)	Long DD:MM.mmm	Lat DD:MM.mmm	Observations (biology, geology, microbiology slope angle, bottom current, visibility)
				sediment (ash?); abundant fish incl. barracuda;
11:58	127 m			after having a problem with sampling gear we were able to take a Niskin water sample
12:01	130 m	27°37.882N	18°00.261E	leaving top; turning west to go around the top to recovery position; the summit turns out to be 15 m high pinnacle; several fishing ropes visible during descent
12:08	160 m			reaching bottom; dark grey to black sediment with abundant whip corals attached to coarse shell fragments and conglomerate boulders protruding through black sand
12:10	164 m			heading NW to recovery position over dark grey to black sediment with ripple marks and few light colored coarse sediment patches (with corals)
12:14	165 m			outcrop of light colored porous (erosion?) crusts covered in fine dark sediment
12:17	163 m	27°37.889N	18°00.291E	conglomerates show bedding roughly parallel to the slope; larger outcrop with very abundant corals
12:21	163 m			preparing ascent; final view of the shell fragments in the crusty material, several holes
12:23	163 m	27°37.902N	18°00.307E	Off bottom
12:32	0			At the surface



Screenshot of JAGO's dive track (green) at the old volcano cone G; yellow dot last position before lift off bottom.

NOTE: the summit of the cone was found to be shifted by 150 m to the southwest on the bathymetric chart.

Dive summary

JAGO – Dive 1303 (04)

POS494-2 (POSEIDON) – St 25

Date: 12.02.2016

Observer: J. Magdalena Santana-Casiano (ULPGC)

Pilot: Jürgen Schauer

Station: POS494 / 25

Location: El Hierro, Submarine Volcano, cone E

Dive duration:

Submerged: 07:17
At bottom: 07:30
Leave bottom: 14:47
At surface: 15:05

Dive objectives:

1. Inspect the anomalies of cone E.
2. To take samples of water and solid.

Samples, measures, media:

Samples (type, depth)
Rocks, partly with FE-oxide crusts
Water samples for measurements of pH, A_T (Total alkalinity), C_T (Total dissolved inorganic carbon), Fe(II)

The pH was measured on board using the potentiometric and UV-Vis spectrophotometric techniques.
AT and CT will be measured in the QUIMA lab at the ULPGC using a VINDTA system by Prof. González-Dávila
Fe(II) will be measured in the QUIMA lab, ULPGC

Measures
JAGO CTD: no
IOE/ULPGC pH-ORP sensor: yes

Video / Photo / GoPro
Digi HD video, GoPro (mp4-video front window from outside), GoPro jpgs inside

Dive summary:

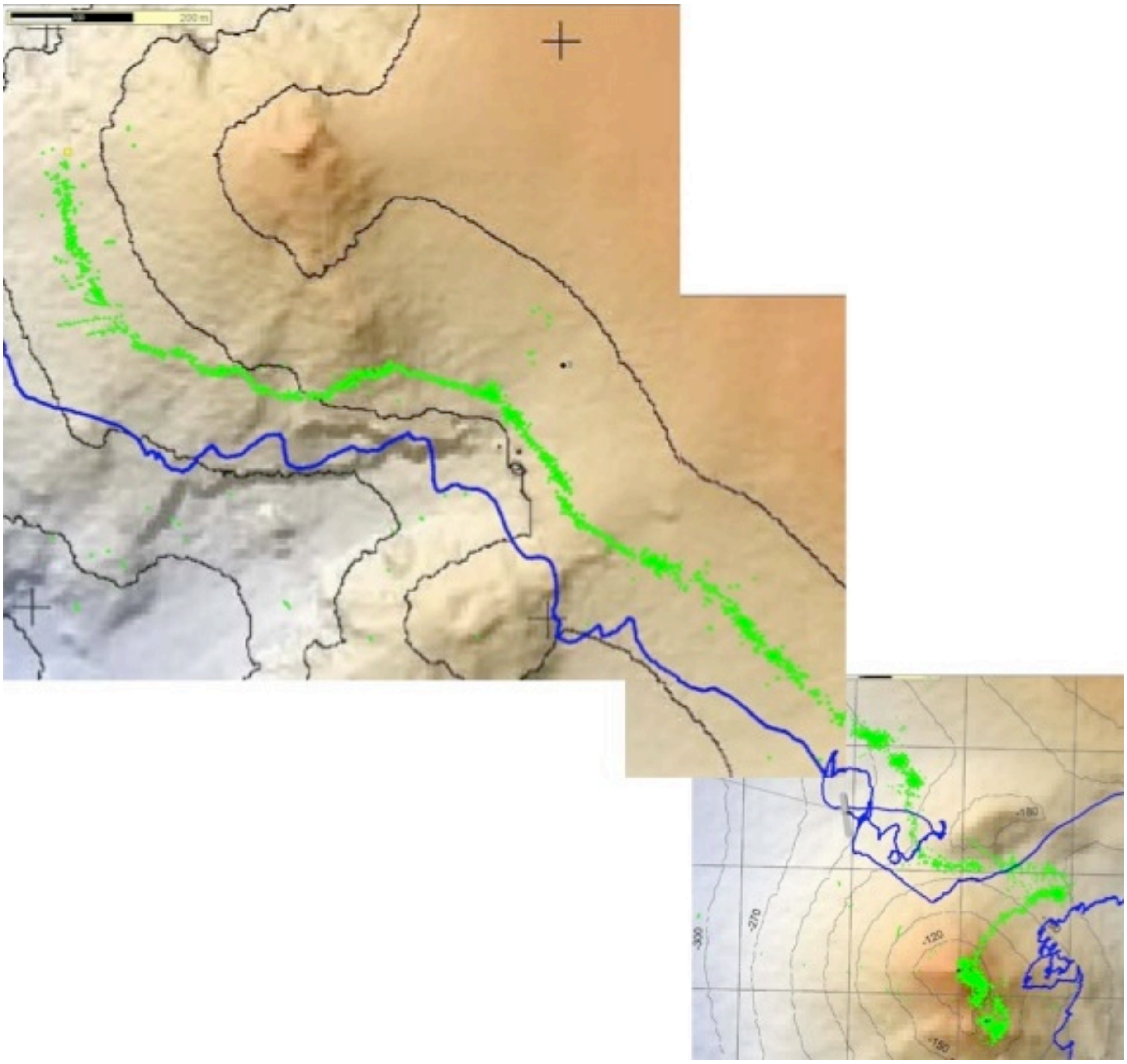
The objective of the dive was to inspect the submarine volcano of El Hierro, south of La Restinga. In the first part, we visited the anomalies found in the previous VULCANO cruises at Latitude 27º 37.178 N, Longitude 17º 59.577 W. (Parcel P-24). Water samples were taken for pH, AT, CT and Fe(II). The pH was measured on board and an anomalous value of 7.4 was obtained. Rock samples were also taken and the temperature 20 cm inside the sediment at the sea floor and in the surrounded water was measured. In the second part, we moved to the top of the main cone and also took water samples and rocks in the area (Parcel N-20). The recovery of the JAGO took place close to the cone structure G. From cone E to cone G northwest of E we moved along the 200 m bathymetric contour, some rocks were sampled along the track.

Conclusion: The volcano continues in its degasification stage

Detailed dive log:

Time UTC	Depth (m)	Long DD:MM.mmm	Lat DD:MM.mmm	Observations (biology, geology, microbiology slope angle, bottom current, visibility)
07:17	0			Deployed into the water
07:20	0			Start descent
07:30	152.5	27°37.148N	17°59.552E	Approaching the sea floor, volcanic rocks
07:36	152.5			Moving close to the sea floor, colonized rock and fish. Important amount of particulate material in suspension, milky suspension
07:48	121.2			Moving along the sea floor which is covered by a light orange-yellow dusty / soft layer. No evident benthic fauna in the area. Volcanic rocks. Milky suspension in the water column
07:54	129.7			Parcel P-24. In the area of anomalies, depression
07:54	129.7			The sea floor is covered with a yellow-orange layer, probably precipitates of iron and bacteria
07:55	129.7			Observing diffuse emission from a small vent, small hole
07:57	129.7	27°37.169N	17°59.572E	We observed a group of micro chimneys
	129.7			We observed milky cloud / suspension in the water column
07:57	129.7			Trying to find a good position for sampling the yellow-orange Fe-oxide layer which we scrape off the sea floor
08:09	129.7			Hole, diffuse emission
08:12	129.7			Temperature 20 cm inside the sediment
				T1= 38.35ºC
				T2= 37.65ºC
				T3 = 37.80ºC
07:20	129.7			Collection of the yellow-orange sediment layer
08:18	129.7			Temperature of the surrounding water Tw = 20.04ºC
08:29	129.7			small holes
08:36	129.7			Water samples collected:
				Niskin for pH, AT and CT
				Teflon bottle1 for pH and Fe(II)
08:46	129.7			Solid samples: 2 volcanic rocks coated with Fe-oxides

08:51	129.7			Deployment of GEOMAR JAGO R/V POSEIDON 494 2/2016 marker #12
08:53	129.7			Small chimney observed
09:06	129.7	27°37.178N	17°59.576E	Temperature 20 cm inside the sediment at the volcanic depression T= 37.60ºC
				Temperature in the surrounding water column (above sea floor) Tw = 19.90ºC
09:12	129.7			Solid samples: Black and Fe-oxide-coated volcanic rocks
09:19	129.7			Small chimney observed
09:45				Moving towards the top of the main cone E
09:52	90	27°37.215N	17°59.588E	On top of cone, many fishes
09:54	90			Concrete block (anchor weight for instrument mooring from one of the previous Vulcano-cruises)
10:02		27°37.211N	17°59.589E	Big purple-pink "worms" = bearded fireworms (marine polychaete, *Hermodice carunculata* family Amphinomidae)
10:07	90			Parcel N-20. On top of the volcano, main cone
				The panorama changed drastically. We observed a volcanic rocky area
				Strong current on the top of the volcano. We moved to a more protected area
10:41	90			Water samples in a-volcanic rocky área:
				Teflon bottle-2 for pH and Fe(II)
10:59	104			Tw = 19.0 ºC
11:04				Solid sample: colonized volcanic rocks
11:10	202.4	27°37.283N	17°59.509E	Moving towards NW, along 200 m contour line, heading towards cones F and G
11:14	202.5			Solid sample: volcanic rocks
11:24				Cave with shrimps
13:15	227			Solid sample: conglomerate and volcanic rocks
15:05				Back at the surface



Screenshot of JAGO's dive track (green), starting at the underwater volcano cone E (southeast) and ending west of volcano cone G (northwest), distance covered about 2.5 km

Dive summary

JAGO – Dive 1304 (05)

POS494-2 (POSEIDON) – St 27

Date: 13.02.2016

Observer: Eugenio Fraile Nuez (IEO)

Pilot: Jürgen Schauer

Station: POS494 / 27

Location: El Hierro, Submarine Volcano

Dive duration:

Submerged: 07:45
At bottom: 08:06
Leave bottom: 13:45
At surface: 13:59

Dive objectives:

1. Inspect the anomalies of cone E.
2. Samples of water and solid.

Samples, measures, media:

Samples (type, depth)
Water (hydrothermal fluids from a chimney and open water milky cloud)
Rocks (sampled at one location)

Measures
JAGO CTD: yes
IEO/ULPGC pH-ORP sensor: yes

Video / Photo / GoPro
Digi HD video, GoPro video (front window from outside, inside)

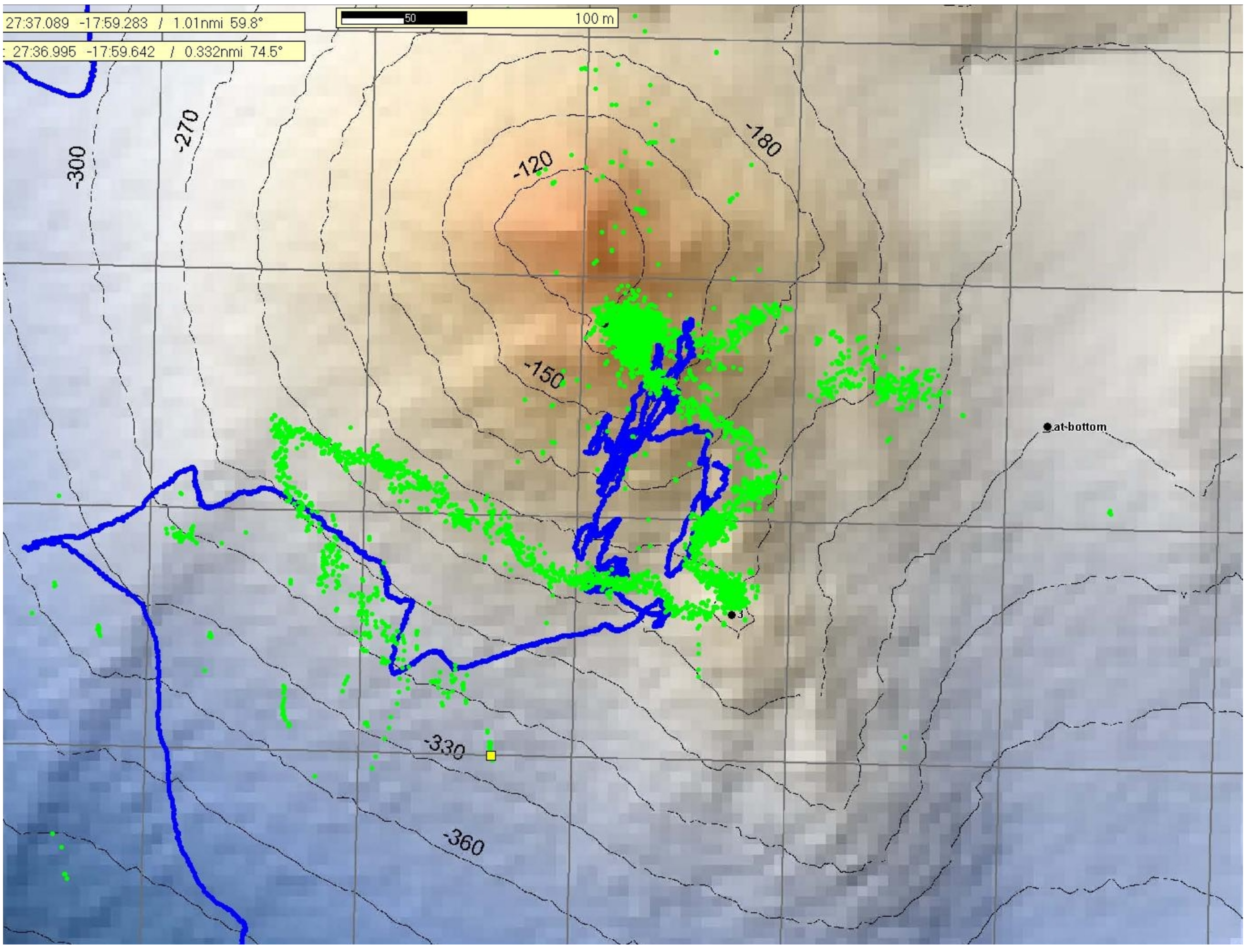
Dive summary:

The objective of the dive was to inspect the submarine volcano at the El Hierro Island (cone E). The JAGO landed on the northeast flank of cone E at 272 m depth. From that position, we approached the east side of the cone southward to position P-24, where a depression area with an active degassing process is present. This area is a depression of 10-20 m diameter with the presence of several chimneys expulsing hydrothermal fluids of low-temperature (around 39.5°C). The minimum pH found in the area was 7.01, 1 unit less than the expected pH for this depth (127 m). With the pH-ORP data recorded by the IEO-ULPGC sensor attached to JAGO's lower front, we will delimitate with more accuracy the exactly degassing area over this P-24 parcel. After we finished the observation of P-24, JAGO approached to O-24. This area presents also a high physical-chemical anomalies recorded by Vulcano project. Due to the strong current in the area, it was impossible for JAGO to reach this area in order to take samples. In any case, we could record several video images from the area, characterized by a combination of two dykes. After that and in order to complete our dive at the submarine volcano, we approached parcel T-34. This area, around 210 meters depth, was characterized by volcanic tubes and pillow lavas and of high concentration of iron-oxide crusts covering the rocks.

Detailed dive log:

Time UTC	Depth (m)	Long DD:MM.mmm	Lat DD:MM.mmm	Observations (biology, geology, microbiology slope angle, bottom current, visibility)
07:45	0			JAGO at the surface. Dive starts.
08:06	272	27°37.136N	17°59.388E	JAGO lands over the seabed
08:23	232			Parcel X-26 to point 1 (depression, parcel P-24)
08:45	127	27°37.173N	17°59.561E	JAGO over the point 1 (depression, parcel P-24)
08:47	127			Found marker #12 (labeled GEOMAR P494)
08:51	129.7	27°37.176N	17°59.573E	Deeper close at the depression, parcel P-24
08:54	129.7	27°37.176N	17°59.572E	Closing the Niskin bottle (milky cloud)
09:39	128.3			Taking the first teflon bottle (at the main exit of a chimney)
09:47	129			Moving to point 2 (parcel O-24)
09:59	118			Low visibility, strong current, getting approach parcel O-24
10:04	123			Strong current, movement of material over the seabed
10:30	128	27°37.181N	17°59.587E	vent area, parcel P-24
11:02	129	27°37.182N	17°59.580E	Parcel P-24, measuring temperature of the sediment T=31.77°C
11:07	129			Sediment temperature (20 cm below sediment surface): T=33.67°C and T=33.80°C ; T of seawater Tsw=18.02°C
11:13	129			Found a little chimney, T=39.37°C and Tsw=19.03°C
11:34	129			Temperature just over the surface of the sediment, Tos=34.33°C
11:46	127			Moving to parcel T-34
12:13	206			Area with high concentration of Fe-oxide
12:14	206	27°37.090N	17°59.548E	Taking a picture of the area
12:32	208			In parcel T-34
12:40	212			T=14.84°C and Tsw=14.22°C
12:50	211			Taking several rock samples
13:45	250	27°37.137N	17°59.735E	Start ascent to surface
14:05	0			JAGO at surface
15:05	0			JAGO on deck Poseidon

Parcel e.g. P-24 refers to the grid overlay A1, A2, A3, etc of the bathymetric chart used for orientation inside JAGO



Screenshot of JAGO's dive track (green), starting east of the underwater volcano cone E (black dot) and ending southwest of the cone between 240 and 270 m contour lines.

13. Appendix

- JAGO QUIMADATA
- List of Media Coverage

					botle pH	botle AT	botle CT	pH	AT (µmol/	CT	S	botle Fe(II)	T Fe(II)
JAGO Dive 1302/3 Station20	JAGO03	10/02/2016		Niskin	1	1A	1A	8.038	2417.46	2140.7	36.84		
					2			8.0442					
				Teflon 1	3			8.0794					
				Teflon 1	4			8.0296					
				Teflon 2	5			8.0082					
				Teflon 2	6			8.0173					
CTD-Rosette Niskin bottles		11/02/2016	CONE E	RosetteNiskin	1	2A	2A	8.033	2427.67	2121.3			
					2	3A	3A	8.0574	2427.63	2117.8			
					3	4A	4A	8.0686	2429.06	2121.4			
					4	5A	5A	8.0695	2430.23	2120.2			
					5	6A	6A	8.0766	2429.4	2119.5			
					6	7A	7A	8.0728	2429.52	2118.1			
					7	8A	8A	8.0733	2432.66	2119.9			
					8	9A	9A	8.072	2401.36	2120.7			
					9	10A	10A	8.07	2427.03	2119.9			
					10	11A	11A	8.0588	2431.5	2120.9			
					11	12A	12A	8.072	2427.44	2119.5			
					12	13A	13A	8.0688	2428.28	2124.3			
JAGO Dive 1303/4 Station25	JAGO04	12/02/2016	CONE E	Niskin	1	14A	14A	8.0445	2429.59	2121.4			
				Teflon1	2			7.4031				1A	192.13
				Teflon1	2			7.4078				1B	180.82
				Teflon2	3			7.9731				3A	706.4
				Teflon2	3			7.9697					
JAGO Dive 1304/5 Station27	JAGO05	13/02/2016	Milky cloud	Niskin	1			7.9607				6A	138.72
					1			7.9656					
			CONE E	Teflon1	2			7.0103				5A	5162.32
				Teflon1	3			7.0529					
				Teflon2	No open								

PARAMETER		**UNITS**
Salinity	S	
pH	pH	
Total Alkalinity	AT	µmol/Kg
Total dissolved inorganic carbon	CT	µmol/Kg
Total dissolved Fe(II)	T Fe(II)	nM
Salinity	S	

MEDIA COVERAGE POSEIDON CRUISE POS494 AND HIERROSEIS
(pdf versions of the articles listed here are availabe at http://tinyurl.com/elhierro-coverage)

Date	Medium	Title	Type	Video	Youtube Hits to April 26
07/01/2016	La Cernidera	Un submarino alemán para investigar el volcán submarino	online		
29/01/2016	Earth System Knowledge Platform	Mit Tauchboot JAGO zum Unterwasservulkan	online	1	
29/01/2016	Earth System Knowledge Platform	Reading the landscape	online	1	
05/02/2016	Cabildo El Hierro	Un instituto alemán estudia el comportamiento volcánico de los fondos de El Hierro con sismógrafos submarinos	press release		
05/02/2016	Diario De Avisos	El buque oceanográfico Poseidón estudia el comportamiento volcánico de El Hierro	online		
05/02/2016	El Dia	Buque oceanográfico alemán estudia el comportamiento volcánico de El Hierro	online		
05/02/2016	El Diario	Un instituto alemán estudia el comportamiento volcánico de los fondos de El Hierro con sismógrafos submarinos	online		
05/02/2016	La Vanguardia	Buque oceanográfico estudia el comportamiento volcánico de El Hierro	online		
05/02/2016	La Opinion	Científicos canarios y alemanes inician un muestreo en el volcán herreño	online		
06/02/2016	Canarias 7	Un instituto alemán estudia el comportamiento volcánico de los fondos de El Hierro	online		
06/02/2016	El Dia	La ULPGC participa en una campaña oceanográfica en la zona del Volcán de El Hierro	online		
06/02/2016	El Periodico de Canarias	Un instituto alemán estudia el comportamiento volcánico de los fondos de El Hierro con sismógrafos submarinos	online		
07/02/2016	TV Canarias	Poseidon El Hierro	tv, online	1	
08/02/2016	20 Minutos	Dos científicos descenderán al volcán de El Hierro a bordo de un submarino tripulado	online		
08/02/2016	100TEK	Una expedición descenderá en un submarino al volcán de El Hierro	online		
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08/02/2016	EFE Verde	Científicos españoles descenderán en un submarino al volcán de El Hierro	news agency		
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19/02/2016	TV Canarias	Volcan Submarino	tv, online	1	
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23/02/2016	20 Minutos	El volcán de El Hierro sigue emitiendo agua a 39 grados cuatro años después	online		
23/02/2016	ActualiCat	El volcà d'El Hierro segueix emetent aigua a 39 graus quatre anys després	online		
23/02/2016	Canarias 7	El volcán de El Hierro sigue emitien años después	online		
23/02/2016	Diario De Nautica	El sumergible JAGO explora el volcán submarino de El Hierro	online		
23/02/2016	Landeszeitung (sh:z)	Kieler Tauchboot am Insel-Vulkan im Einsatz	print		
23/02/2016	Universidad de Las Palmas de Gran Canaria	Una expedición hispano-germana, con presencia de la ULPGC, ofrece nuevos datos sobre este proceso eruptivo de El Hierro	press release		
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07/03/2016	EFE Verde Youtube	El volcán de El Hierro sigue emitiendo agua a 39 grados cuatro años después	online	1	245
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08/03/2016	Signs of the Times	El volcán de El Hierro sigue emitiendo agua a 39 grados cuatro años después	online	1	
09/03/2016	GEOMAR Youtube Channel	Diving El Hierro's Submarine Volcano	video	1	1158
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09/03/2016	AOL ON	Diving El Hierro's Submarine Volcano	online	1	
09/03/2016	Huffington Post	Diving El Hierro's Submarine Volcano	online	1	
10/03/2016	Nauteo	Video: Deutsches Team taucht zu Unterwasser-Vulkan	online	1	
10/03/2016	Earth System Knowledge Platform	Video: Submarine volcano at El Hierro	online	1	
10/03/2016	Earth System Knowledge Platform	Video: Auf Tauchfahrt zum Unterwasservulkan	online	1	
11/03/2016	Green TV Youtube channel	Diving El Hierro's Submarine Volcano	online	1	37
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