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Hydrothermal versus microbial MEthane release From very shallow coastal systems: can differently sourced emISsions direcTly escape intO the atmosphere? (MEFISTO)

Deliverable 1. Pre-survey in Northern Adriatic Sea (May 13, 2024) - *Report of the activity* -

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Finanziato dall'Unione europea NextGenerationEU
Ministero dell'Università e della Ricerca
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1. SUMMARY

MEFISTO preliminary survey of the most relevant bio-concretionned rocky buildups disseminated over the Northern Adriatic Sea (also known as “grébeni” “trezze” or “tegnue”) was carried out by OGS operational unit in May 13, 2024. Two outcrops were investigated during the campaign, one off the Venetian coast, commonly referred to as “Bardelli”, and another belonging to the so-called “Trezze San Pietro e Bardelli” Site of Community Importance, located in the Gulf of Trieste and called “Sudpiastra”. The main objective of the survey was to identify sites with different methane (CH_4) emission magnitudes, corresponding to the stations to be sampled during the successive field campaigns. In fact, coralligenous buildups are often associated with gas seeps, thus leading to interpret such deposits as methane-derived carbonates.

The survey, functional to the implementation of the experimental design, was conducted onboard the Castorino 2 vessel by mean of a remotely operated vehicle (ROV), that provided high-resolution georeferenced seafloor photomosaics, making it possible to mark the position of single CH_4-related bubble streams and to estimate the intensity of each emission point.

This report contains the preliminary observations and the most significant images taken by the ROV during the investigations of the potential emission sites.

2. MEFISTO RESEARCH PROGRAMME AND OBJECTIVES

2.1 General scientific background

Methane (CH_4), accounting for about 30% of the ongoing atmospheric warming, is today recognized as one of the most powerful greenhouse gases (GHGs), being an even stronger absorber of Earth's emitted thermal infrared radiation than carbon dioxide (Simson, 2021). Atmospheric CH_4 concentrations, which increased by only 700 ppb during the millennium before industrialization, are now more than 2.6 times above estimated pre-industrial equilibrium levels, reaching 1857 ppb in 2018 (Saunois et al., 2020). Such an increase is largely the result of anthropogenic emissions related to human activities, including agriculture, production and utilisation of fossil fuel and waste management practices (Ciais et al., 2014). Nevertheless, since the lifetime of CH_4 in the atmosphere barely exceeds 10 years (Prather et al., 2012), the concentrations and therefore the radiative forcing of this potent GHG are thought to be scaled down in a few decades by just stabilising or reducing the anthropogenic emissions (Shindell et al., 2012). Such an approach is considered an effective and realistic way to rapidly mitigate climate change, making it possible to limit the global temperature rise to 1.5-2.0 °C, as targeted by the Paris Agreement (Nisbet et al., 2019).
In order to verify future emission reductions, a precise quantification of the global CH_4 budget is actually needed but, according to the most recent modelling, important uncertainties still affect the calculations, since global emissions were estimated to range between 576 Tg CH_4 / yr and 737 Tg CH_4 / yr (Saunois et al., 2020). The most important source of uncertainty is attributable to natural emissions, accounting for 40% of the global CH4 budget, 1-13% of which is due to the oceans (Kirschke et al., 2013; Saunois et al., 2016). However, while the open ocean CH_4 emissions are relatively well constrained and are driven by variations that are steadily linked to the organic matter cycling, the global marine flux appears to be mostly influenced by shallow near-shore environments (0-50 mbsl), where CH_4 released from the seafloor can escape to the atmosphere before oxidation (Weber et al., 2019). Here, many forcings can severely affect the amount of CH_4 that reaches the air-sea interface, above all water depth, currents, tides, temperature, water column stratification and microbial methane oxidation (Boles and Clark, 2001; Jordan et al., 2022; Mc Ginnis et al., 2006), but due to limited and few data, the actual contribution of coastal areas to atmospheric CH_4 is still quite uncertain (Weber et al., 2019).

2.2 The MEFISTO project

The MEFISTO project aims to reduce the abovementioned uncertainties in the estimates of the natural CH_4 fluxes by providing new data on the emissions from shallow near-shore marine environments, where, rapidly bypassing the water column by bubble transport, this powerful GHG can be directly released into the atmosphere (Weber et al., 2019). The lack of data on CH_4 fluxes in coastal areas has significant implications for the accurate calculation of the atmospheric budget for this gas and the accuracy of this estimate is crucial for the verification of potential emissions reductions associated with the adoption of effective climate change mitigation strategies. The MEFISTO project, combining classical physical, chemical, and molecular methods with innovative hydroacoustic approaches, will help to fill this knowledge gap by focusing on the study of two Italian shallow coastal areas: a seepage zone recently identified in the Gulf of Trieste, centred on the Bardelli outcrop (Northern Adriatic Sea) and the hydrothermal vent area off the Panarea Island (Aeolian Archipelago, Southern Tyrrhenian Sea).

The project has three main purposes: 1) to ascertain possible differences in the water column degassing pathways and fates between microbially sourced and volcanic-related CH_4 emissions; 2) to assess the main physical and biological forcings (i.e., water depth, currents, tides, temperature, water column stratification and microbial community structure and composition) favouring or preventing the release of CH_4 to the atmosphere from the two investigated marine shallow areas; 3) to eventually develop local emission estimates that will contribute to the refinement of the global atmospheric CH_4 budget.

2.3 Grébeni/Trezze/Tegnúe: methane-derived deposits in the Northern Adriatic Sea

The Northern Adriatic Sea is generally characterized by a rather monotonous seabed, consisting mostly of mobile silty-sandy sediments. Nevertheless, numerous submarine rocky substrates of biogenic concretions, called “grébeni” or “trezze” in the Gulf of Trieste and “tegnúe” off the coast of Venice, are irregularly scattered over the soft bottom of this Adriatic Sea sub-basin (Casellato and Stefanon, 2008; Ingrosso et al., 2018; Lipej et al., 2016). Their size ranges from a single small block of 1 m^2 up to a few 1000 m^2, and their height rarely exceeds 4 m. These rocky substrates are suitable for the settlement and development of specific floristic and faunistic assemblages, that are favoured by the accumulation of calcareous incrusting algae, creating complex biostructures commonly referred to as “coralligenous” and giving the colourful underwater landscape a typical appearance (Lipej et al., 2016; Turicchia et al., 2022). For this reason, since 2015, a limited number of biogenic outcrops in the Gulf of Trieste have been legally protected under the European Habitats Directive (92/43/EEC) and included in the European Natura 2000 network as Sites of Community Importance (Decision EU 2015/69 of December 3, 2014) (Bettoso et al., 2023). These sites are generally called “IT3330009 - Trezze San Pietro e Bardelli” (Figure 2.1).

Up to 4000 outcrops are currently recorded in the Northern Adriatic Sea (Figure 2.1), mostly off the Venetian coast, while in the Gulf of Trieste about 250 have been mapped so far, most of them off the lagoon of Marano and Grado, at a distance of 3 to 10 nautical miles (nm) from the coast and at a depth ranging between 13 and 25 m (Caressa et al., 2001).

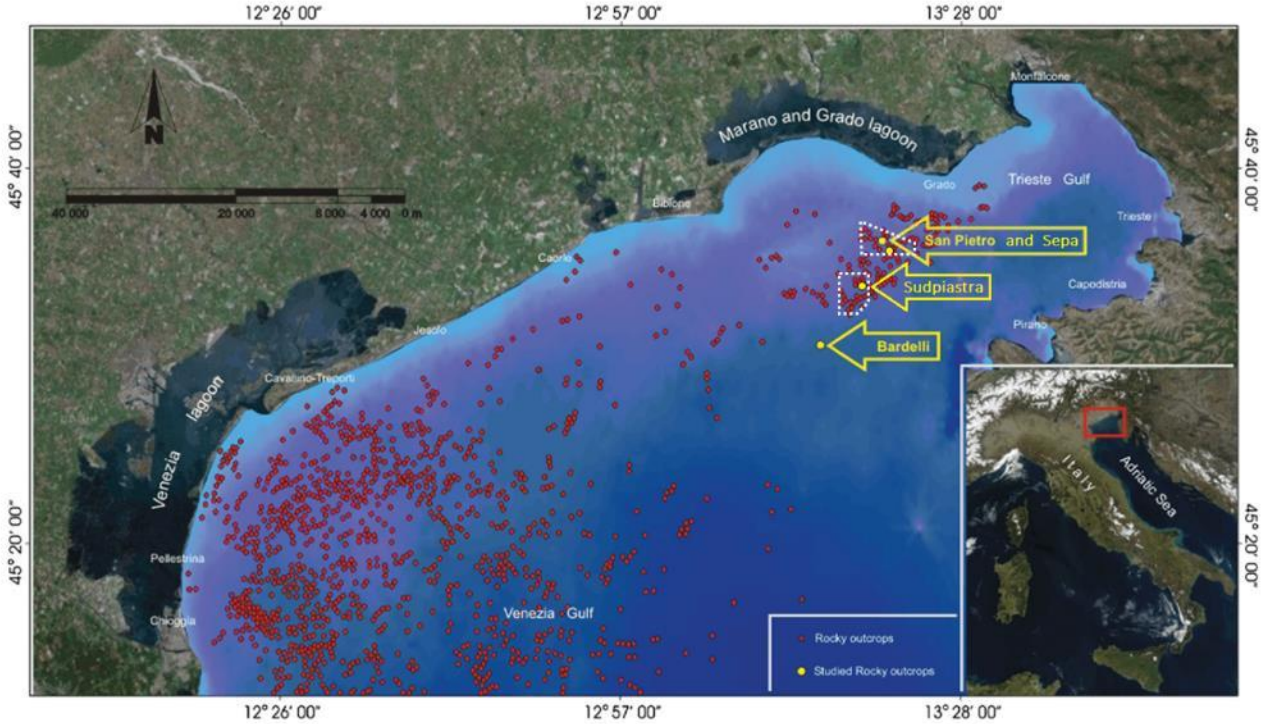

Figure 2.1. Location map of the northern Adriatic Sea rock outcrops (red dots) where the position of trezze San Pietro, Sepa, Sudpiastra and Bardelli is highlighted. Sites of Community Importance in the Gulf of Trieste are are indicated by white dashed polygons (mod. from Gordini et al., 2012).

These coralligenous buildups are often associated with gas seeps, thus leading to interpret such deposits as methane-derived carbonates. In fact, several gas fields were discovered and exploited during the 1960s in the Northern Adriatic Sea, where, particularly in the averagely 22 m deep Gulf of Trieste, gas seeps can produce up to 20 m-high gas flares and intermittent bubbling within the water column (Donda et al., 2019; Gordini et al., 2012). These seep gases, mainly composed of CH_4 and occurring both in deep and shallow Plio-Quaternary successions, are microbial in origin and mostly originate from laterally persistent Late Pleistocene peat layers, which are widely distributed throughout the Northern Adriatic Sea and represent the main source of organic matter feeding the gases (Donda et al., 2019).

2.4 Field research program to accomplish MEFISTO objectives

The field research program included the visual detection of bubble streams generated by leaking gases by mean of a remotely operated vehicle (ROV). The survey was carried out by OGS operational unit in May 13, 2024 using a Blue Robotics BlueROV2 equipped with a 1080p low light camera and multiple 1500 lumen lights (Figure 2.2). The identification of the targeted outcrops (whose geographic position is well known) was supported by the employment of the vessel side-scan sonar and echosounder, which in turn gave also the opportunity to detect (before the ROV deployment) punctual gaseous emissions during the navigation above the rocky buildups.

Figure 2.3. BlueROV2 by Blue Robotics.

Efforts focused on close visual inspection of the selected rock outcrops, particularly their edges, where gas emissions are most likely to be observed.

Two outcrops were investigated during the campaign, one off the Venetian coast, commonly referred to as "Bardelli", and another (belonging to the so-called "Trezze San Pietro e Bardelli" site) located in the Gulf of Trieste and called "Sudpiastra" (Figures 2.1).

The Bardelli outcrop (depth 22.5 m b.s.l.), covering an area of 250x90m, consists of two main groups separated by a flat sandy seafloor. The larger group, formed by smaller rounded shaped blocks separated by sandy to gravelly deposits, is 95x80m wide, while the second, composed of closely spaced rock slabs split by vertical fractures, is 55x38m wide (Gordini et al., 2012). At this site, geological and geophysical data at different scales of resolution indicated gas occurrences within the sedimentary succession, at the sea floor and in the water column (Donda et al., 2015; Donda et al., 2019; Gordini et al., 2012; Gordini et al., 2023), while geochemical analyses showed that the consisted mainly of methane (81-84%; Gordini et al., 2012; Donda et al., 2019).

Sudpiastra (20 m b.s.l.) is a locally well-known but less studied outcrop (Bettoso et al., 2023), so that almost no data are available in terms of size, volume geometry and methane emissions. However, the vessel echosounder revealed potential gaseous emissions in correspondence of this study site, making it suitable for the MEFISTO project purposes.

3. NARRATIVE OF THE CAMPAIGN

MEFISTO pre-survey of the trezze in the northern Adriatic Sea was carried out by OGS operational unit in May 13, 2024. The activities were conducted thanks to the logistical support provided by the Castorino 2 vessel and crew.

Monday, May 13, 2024

09:00 - Storing of the equipment on the Castorino 2 vessel and briefing on the daily work plan.
09:40 - Departure from Grado harbour to the work area.
10:50 - Arrival at “Bardelli” outcrop.
10:55 - Vessel positioning.
11:04 - Set up of the ROV.
12:00 - ROV in water for communication and general test of correct functioning.

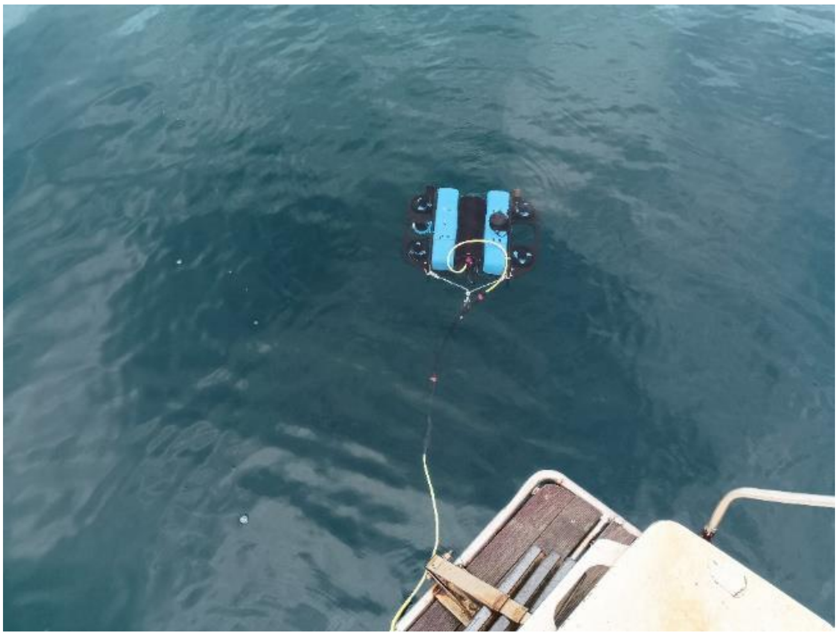

Figure 3.1. Blue Robotics BlueROV2 in water for communication tests.

12:25 - ROV onboard and battery pack change.
12:30 - ROV in water for study site investigation.
14:00 - ROV onboard.
14:25 - Departure to “Sudpiastra outcrop”.
14:35 - Vessel positioning.
15:00 - ROV in water for study site investigation.
16:12 - ROV onboard.

16:20 - Departure to Grado harbour.
17:00 - Arrival at Grado harbour; end of the operations.

4. PRELIMINARY RESULTS

4.1 Bardelli outcrop

The site was extensively explored during the ROV survey. The strong water turbidity prevented the photos and videos taken by the underwater vehicle from being of good quality, so that the outcrop was barely recognisable above 21.5 m b.s.l. (Figure 4.1).

Figure 4.1. Bardelli outcrop pictures taken by the ROV at about 21 m b.s.l. The rocky buildup is hardly distinguishable due to the strong water turbidity.

Slightly better resolution was obtained at greater depths, even though no bubble stream released from the seafloor was detected during the visual inspection of this trezza (Figures 4.2, 4.3 and 4.4). However, isolated microbial mats were observed on the sandy seafloor separating the blocks forming the outcrop, thus confirming that intermittent gas emissions occur in the area (Figure 4.5).

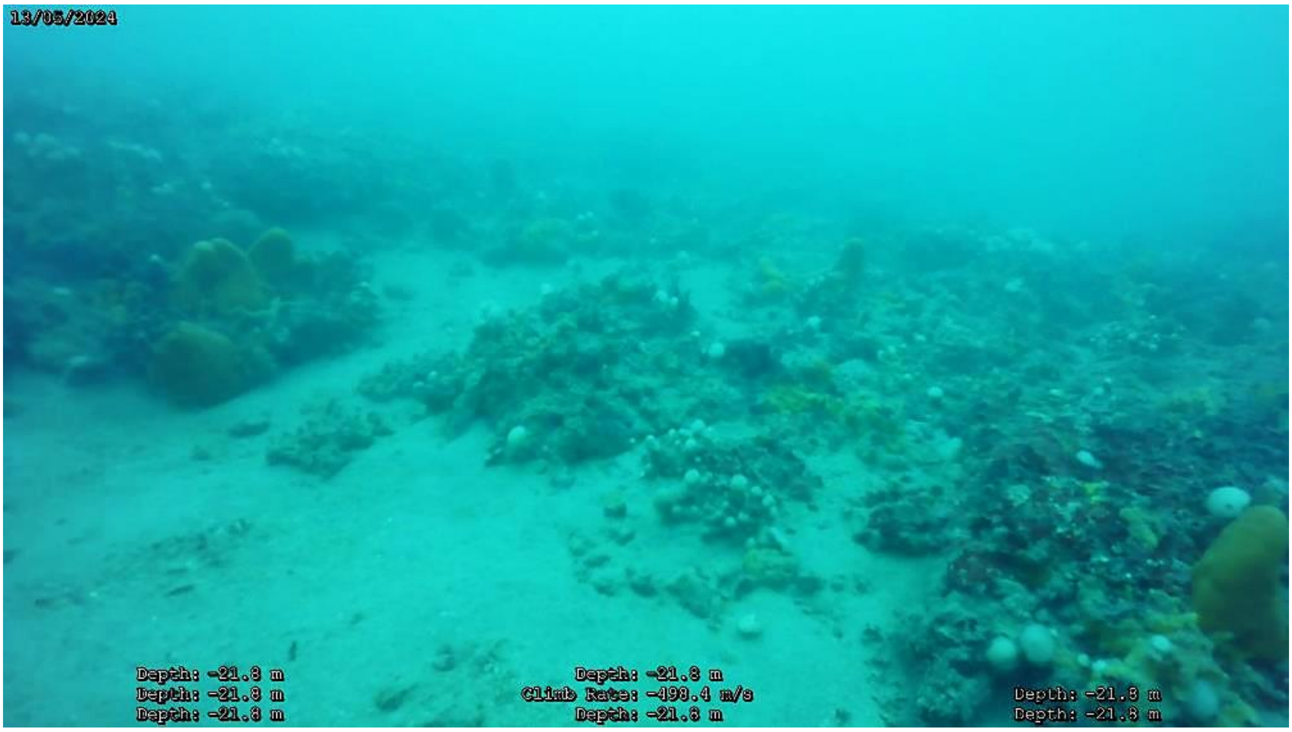

Figure 4.2. Seafloor picture taken at 21.8 m b.s.l. showing a slight better resolution despite the water turbidity.

Figure 4.3. Seafloor picture taken at 21.8 m b.s.l. showing a slight better resolution despite the water turbidity.

Figure 4.4. Detail of the coralligenous biostructures (photo taken by the ROV at 22 m b.s.l.).

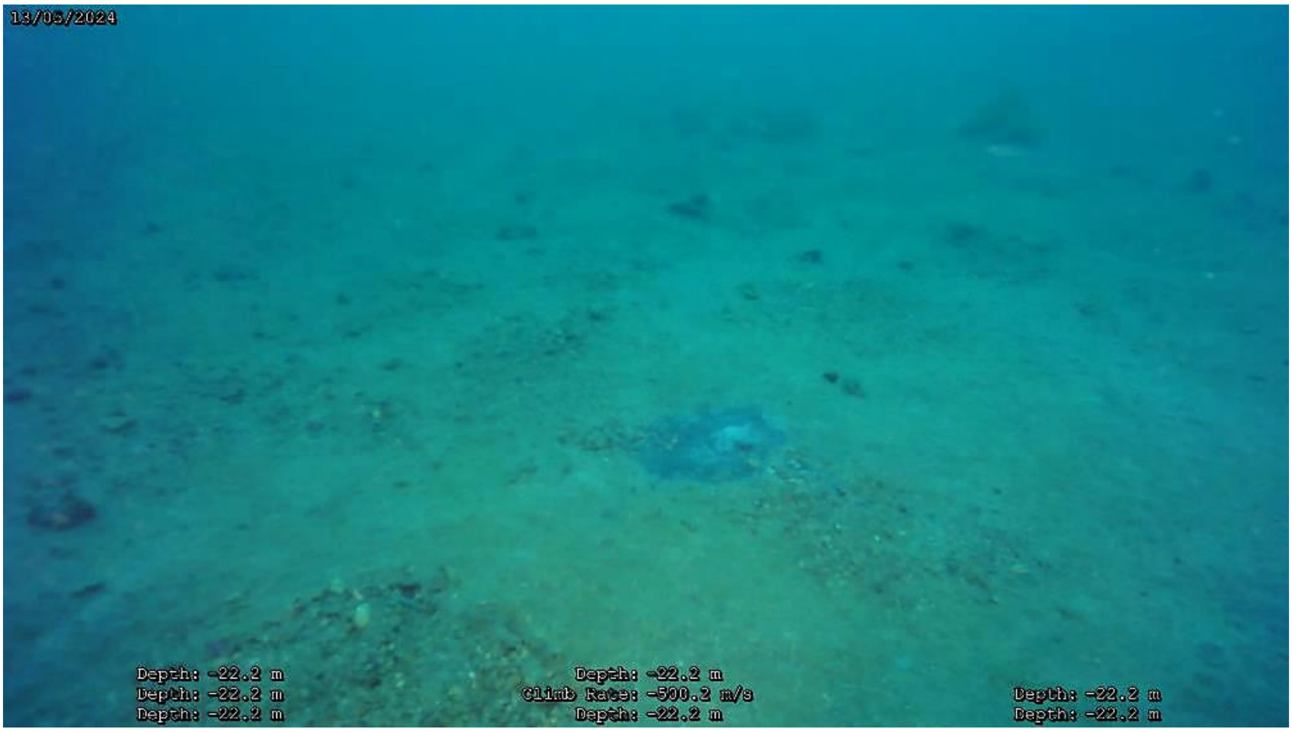

Figure 4.5. Isolated microbial mat on the sandy seafloor separating the blocks forming the “Bardelli” outcrop.

4.2 Sudpiastra outcrop

At this site, active gas seepage was observed during the survey, with several bubble streams frequently (even though intermittently) released from the seafloor, in particular from the gravel-to-sandy patches between the rocky deposits (Figures from 4.6 to 4.13). Seven emission points were observed during the investigation of the area.

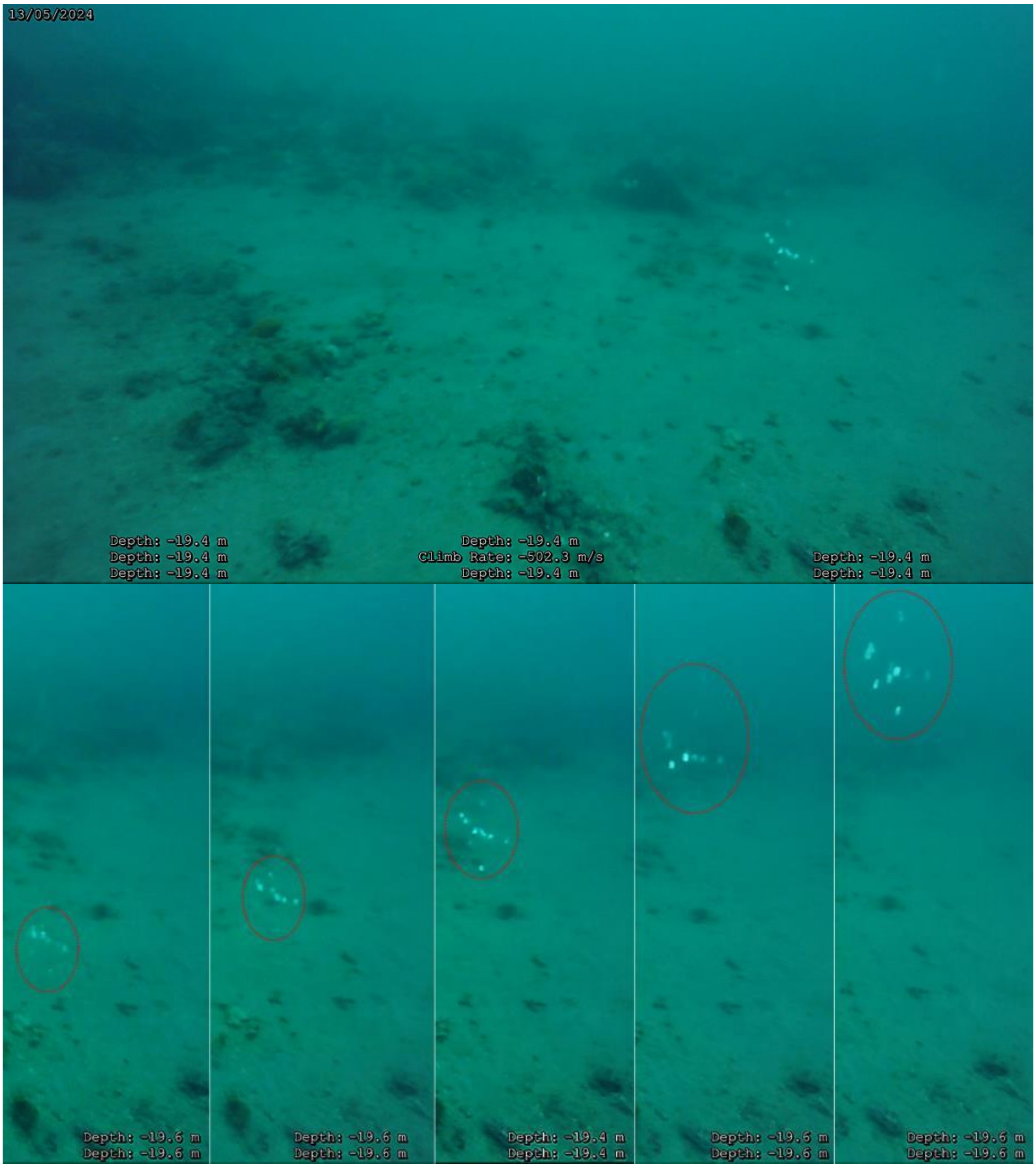

Figure 4.6. a) Bubbles in water column at emission point 1; b) Emission sequence frame by frame.

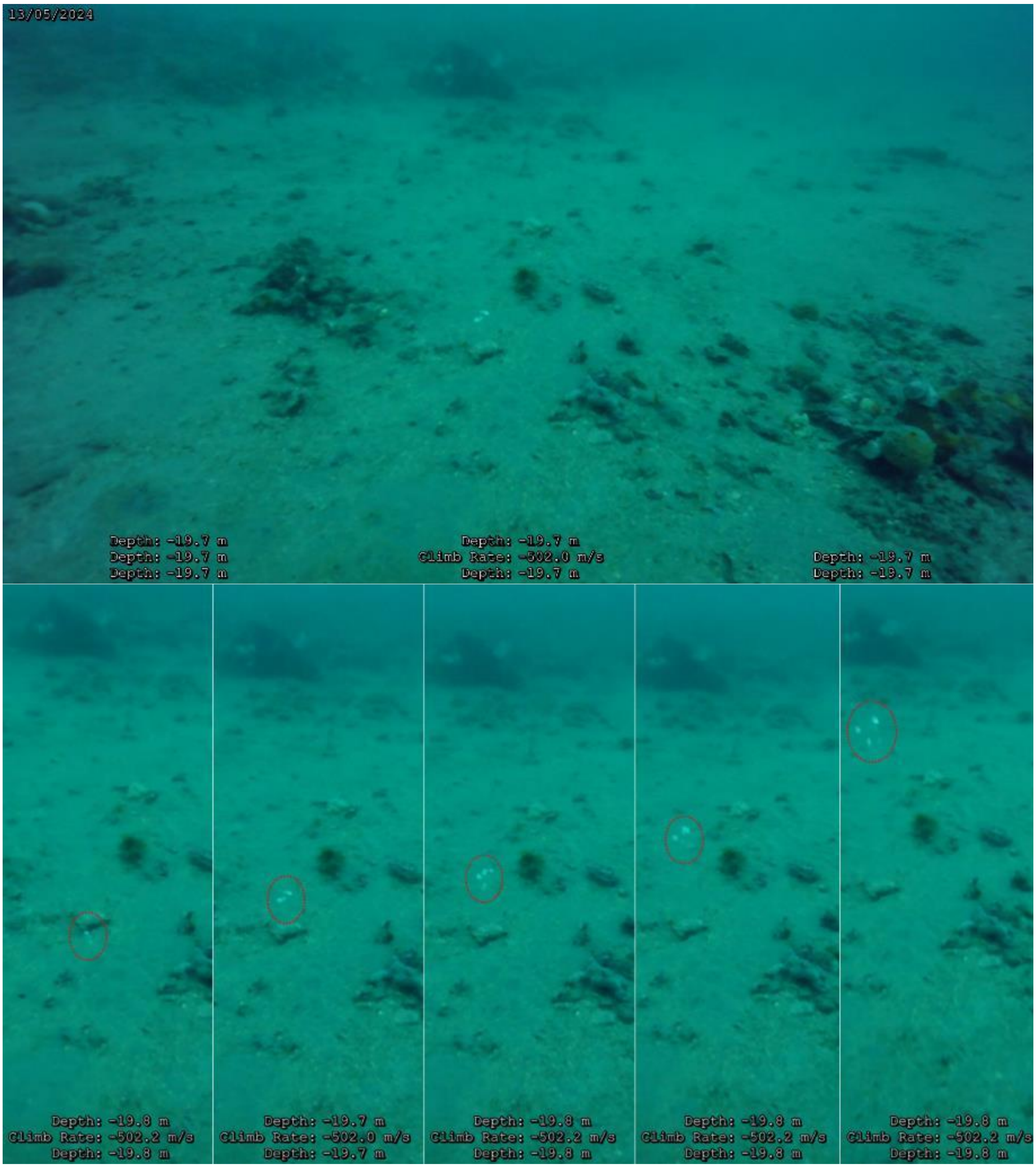

Figure 4.7. a) Bubbles in water column at emission point 2; b) Emission sequence frame by frame.

Figure 4.8. a) Bubbles in water column at emission point 3; b) Emission sequence frame by frame.

Figure 4.10. a) Bubbles in water column at emission point 4; b) Emission sequence frame by frame.

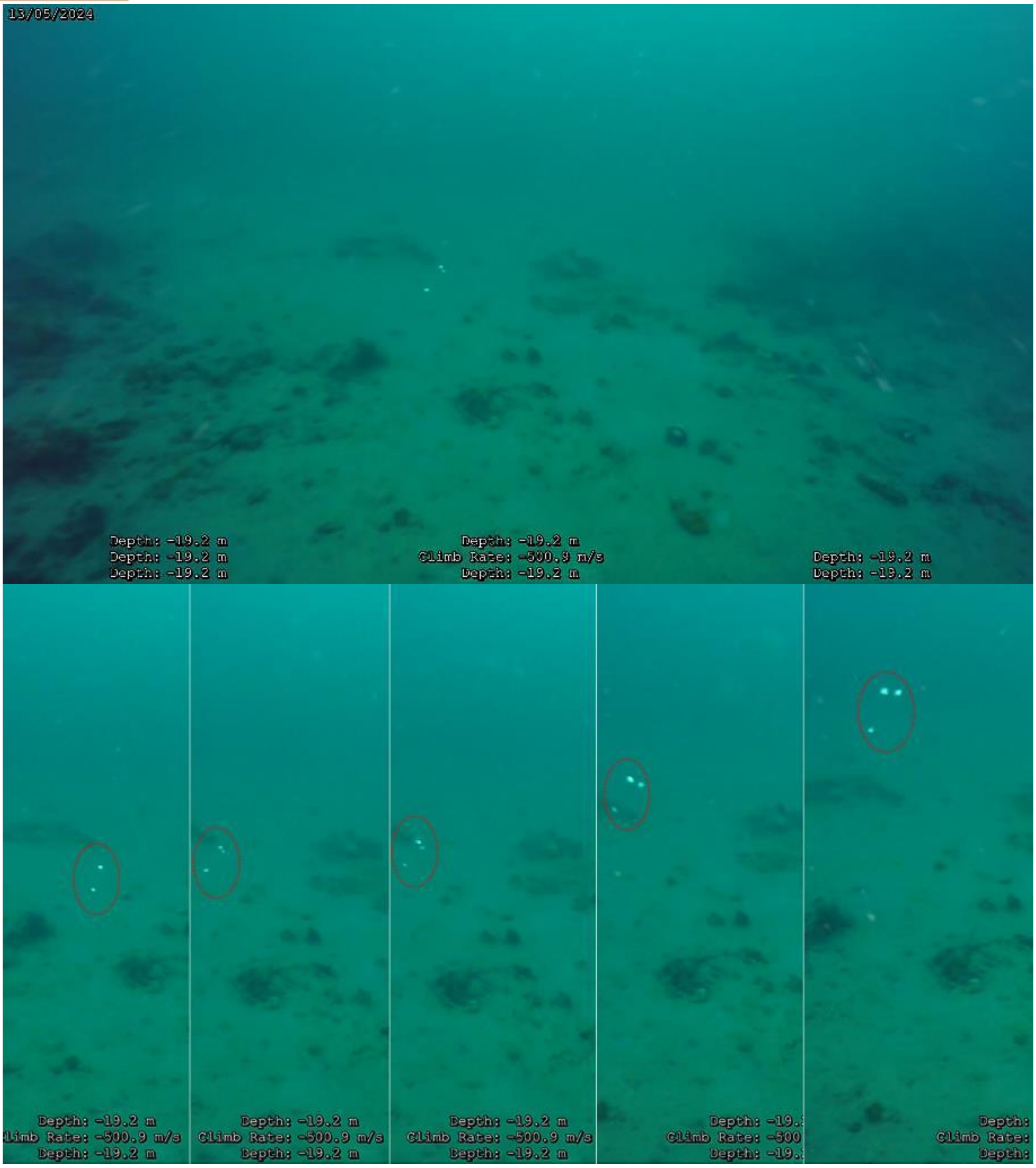

Figure 4.11. a) Bubbles in water column at emission point 5; b) Emission sequence frame by frame.

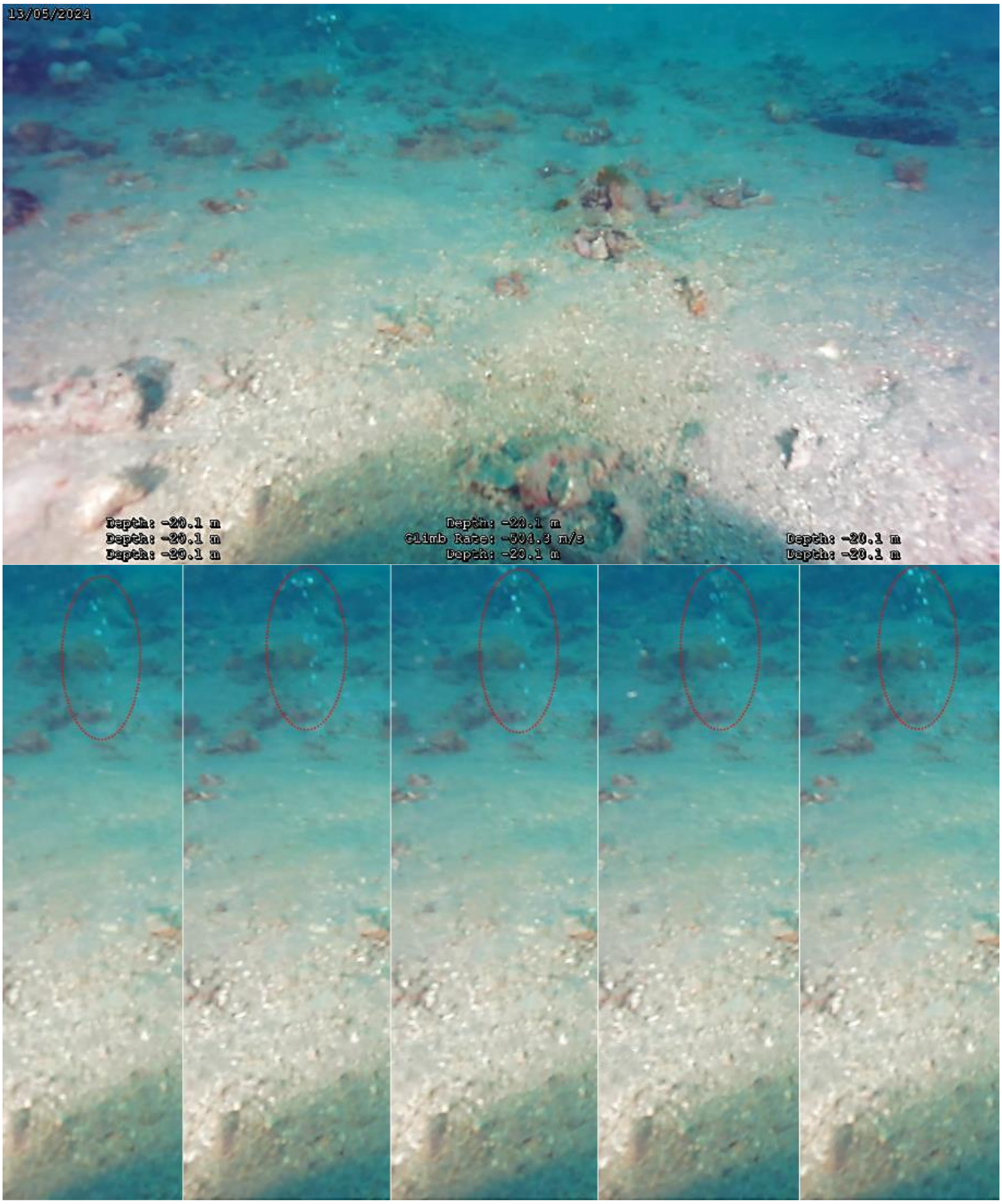

Figure 4.12. a) Bubbles in water column at emission point 6; b) Emission sequence frame by frame.

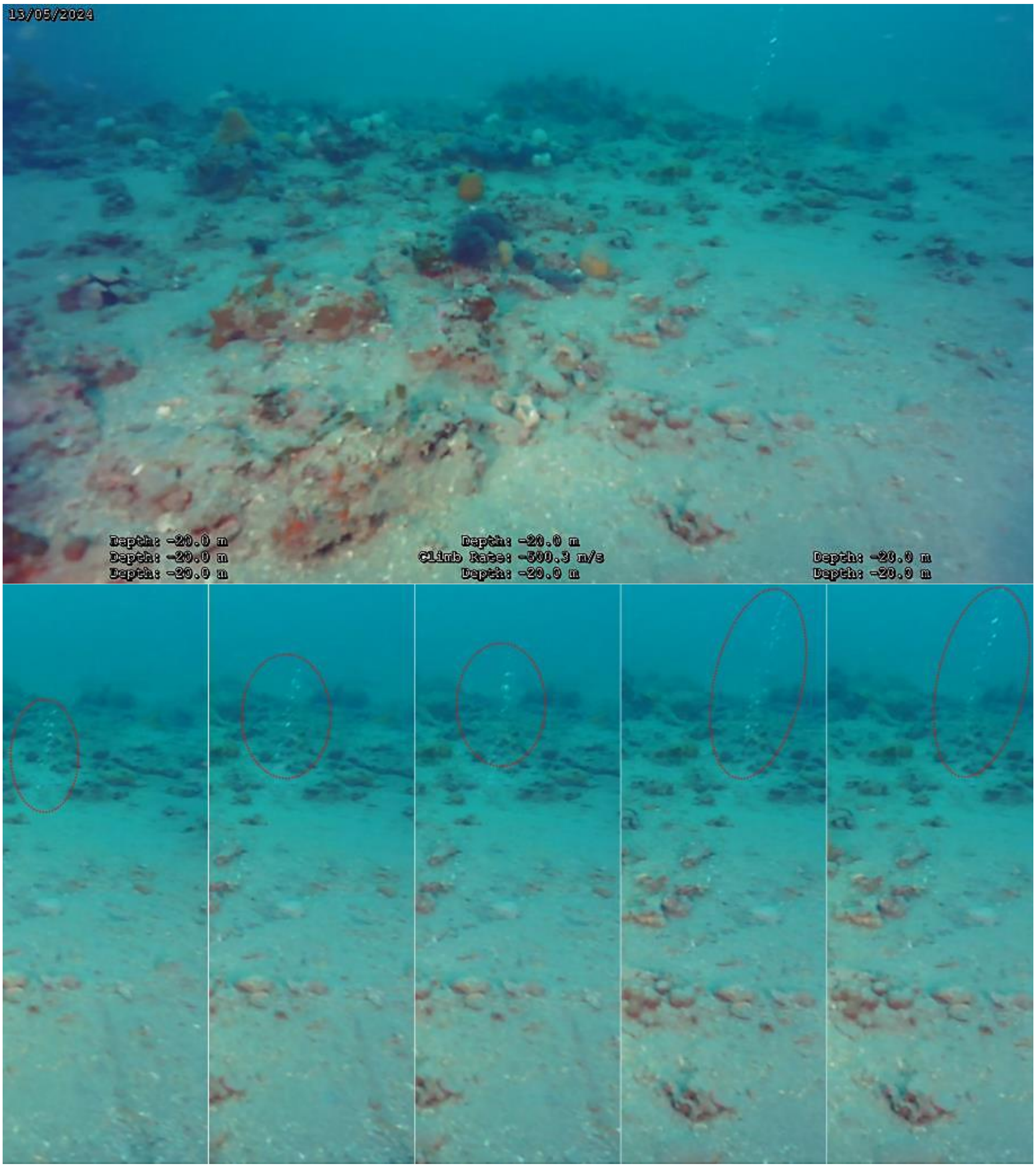

Figure 4.13. a) Bubbles in water column at emission point 7; b) Emission sequence frame by frame.

The seafloor was characterized by the presence of numerous pockmarks (Figure 4.14) and microbial mats (Figure 4.15 and 4.16).

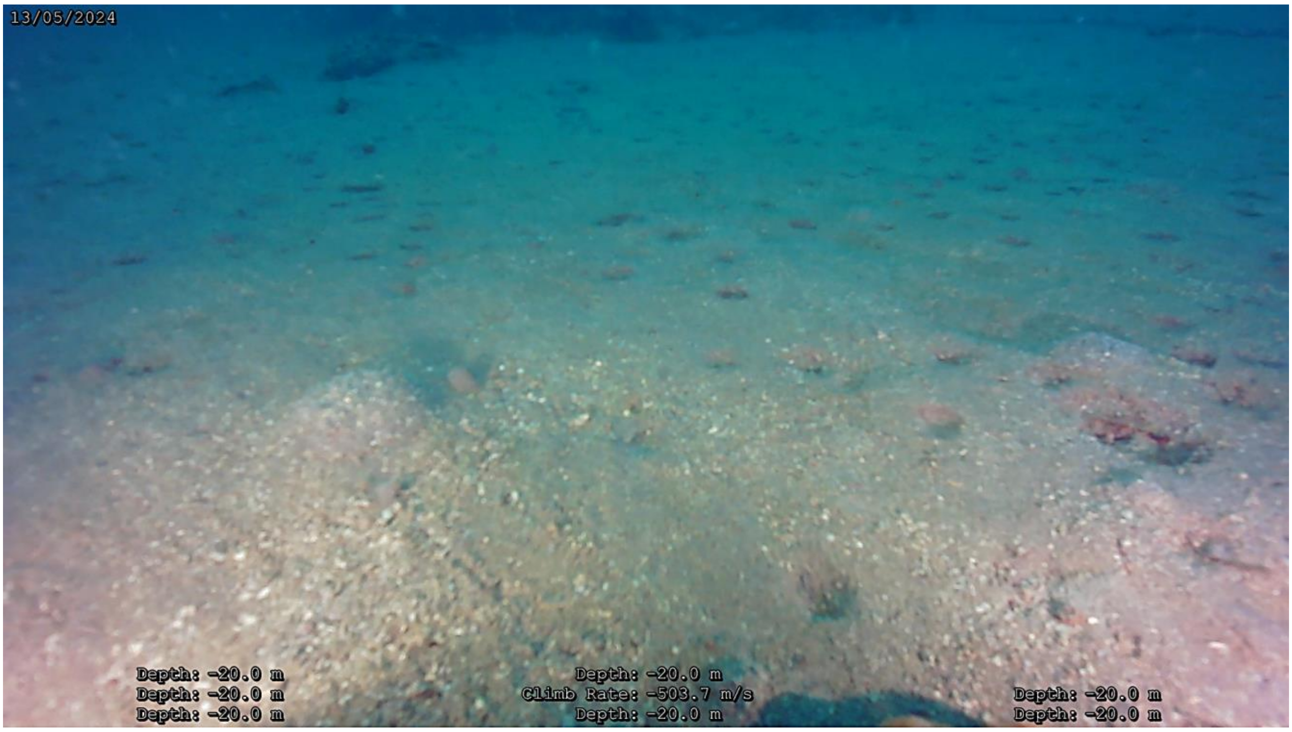

Figure 4.14. Pockmarks at the seafloor of the trezza Sudpiastra.

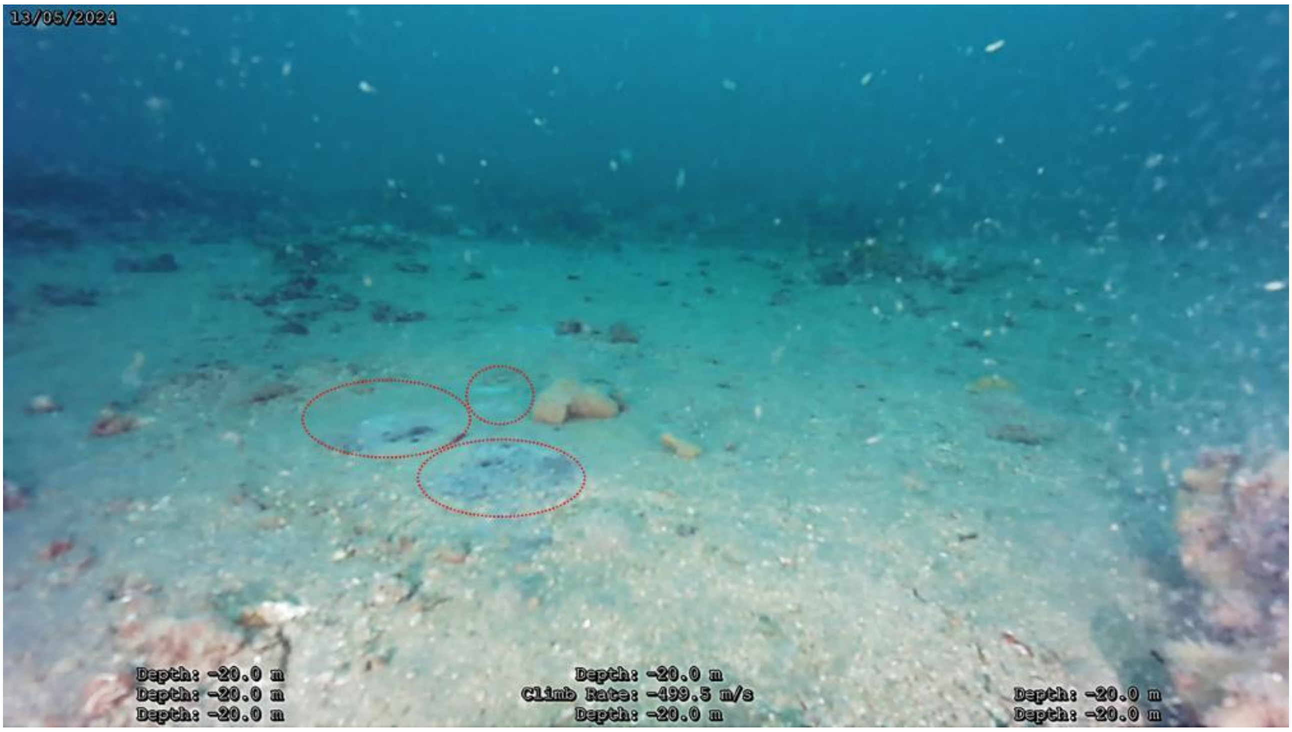

Figure 4.15. Isolated microbial mats on the sandy seafloor separating the blocks forming the Sudpiastra outcrop.

Figure 4.15. Isolated microbial mats on the sandy seafloor separating the blocks forming the Sudpiastra outcrop.

5. ACKNOWLEDGEMENTS

The MEFISTO research team would like to acknowledge the European Union that financially supported the project through the "Fund for the National Research Programme and Research Projects of Significant National Interest (PRIN)" in the framework of the NRRP - Nex Generation EU Mission 4 "Education and Research". Thanks goes to Captain Stefano Caressa for the logistical support provided by the Castorino 2 vessel and crew during the activities conducted at sea.

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