A shallow mud volcano in the sedimentary basin off the Island of Elba

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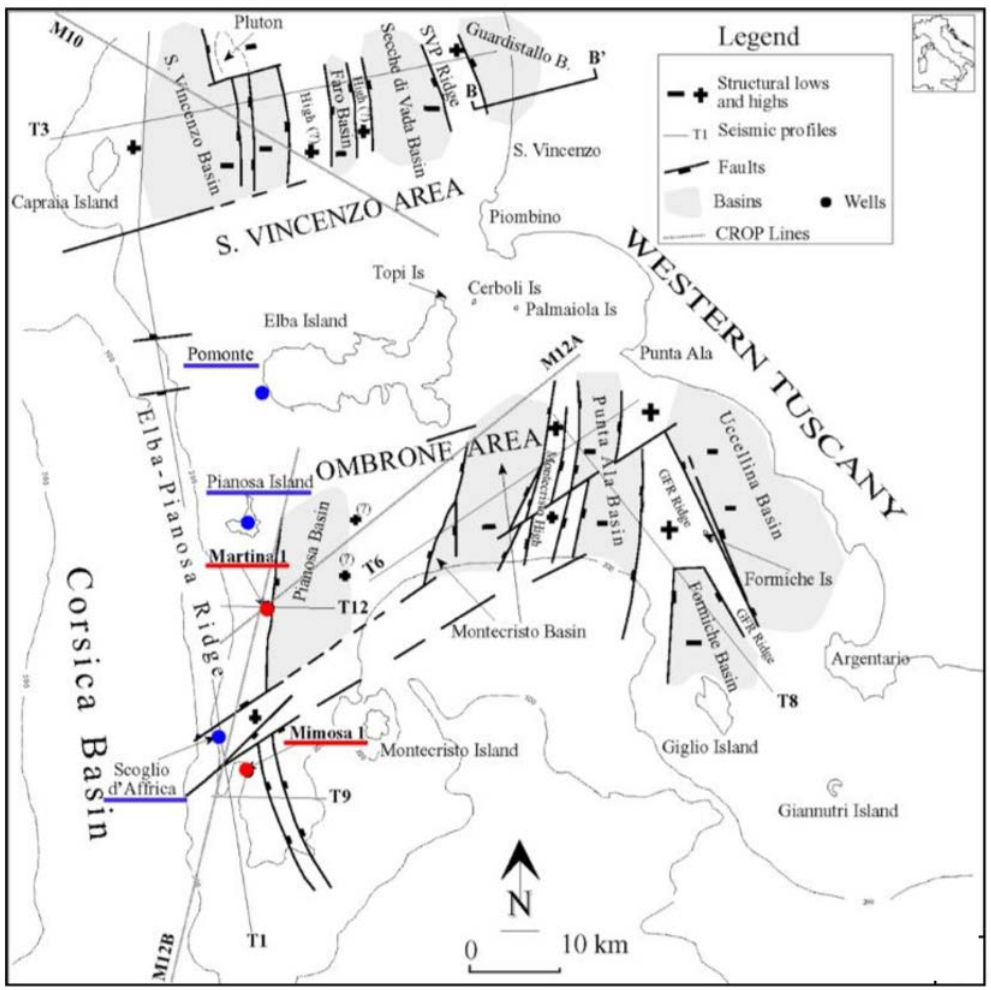
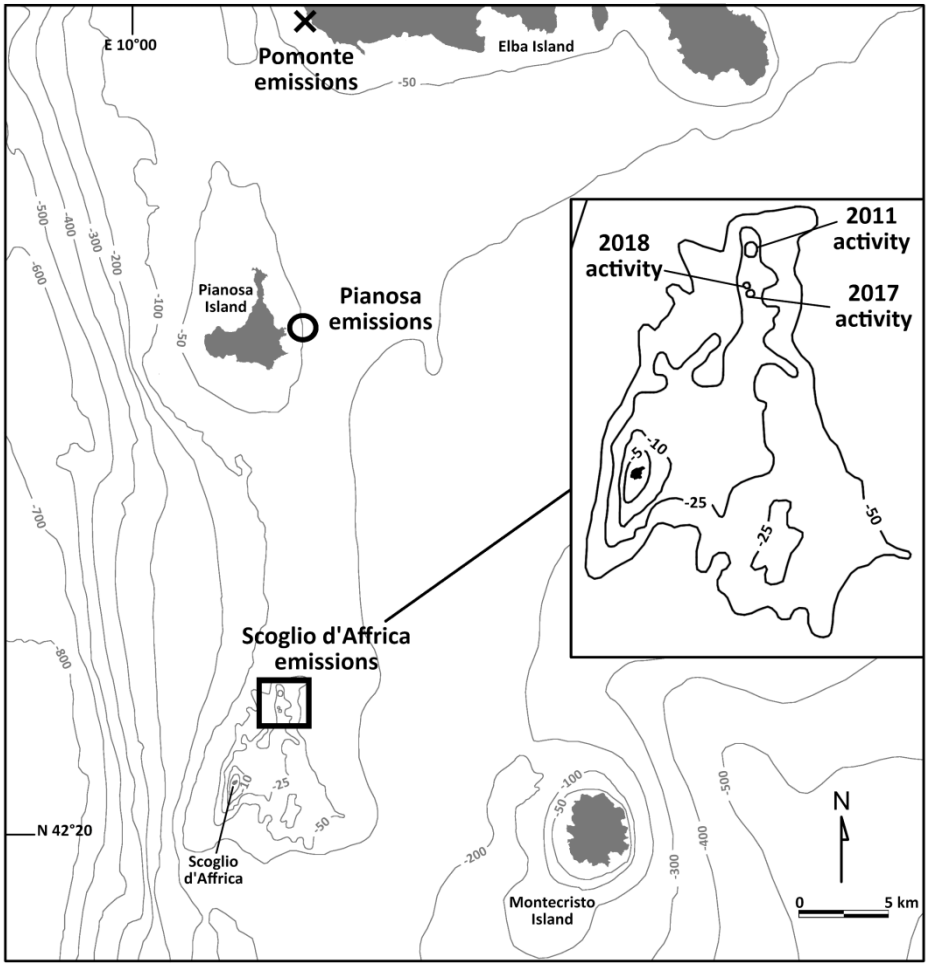
Elba Island

The Island of Elba, located in the westernmost portion of the northern Cenozoic Apennine belt, is formed by metamorphic and non-metamorphic units derived from oceanic (i.e. Ligurian Domain) and continental (i.e. the Tuscan Domain) domains stacked toward NE during the Miocene (*Massa et al., 2017*).



Offshore, west of the Island of Elba, magnetic and gravimetric data suggest the occurrence of N-S trending ridges that, for the very high magnetic susceptibility, have been interpreted as serpentinites, associated with other ophiolitic rocks (*Eriksson and Savelli, 1989; Cassano et al., 2001; Caratori Tontini et al., 2004*). Moving towards south in Tuscan domain, along N-S fault, there is clear evidence of off-shore gas seepage (mainly CH_4), which can be related to recent extensional activity.

Scoglio d'Affrica site



Bathymetric map of the area between the island of Elba and Montecristo showing the location of Scoglio d'Affrica emission site, Pomonte seeps and Pianosa emission site. In the inset locations of the Scoglio d'Affrica emission activities detected in 2011 (*HYDRA Institute, 2011; Meister et al. 2018*), 2017 (*Chiocci et al., 2017*) and 2018 are shown.

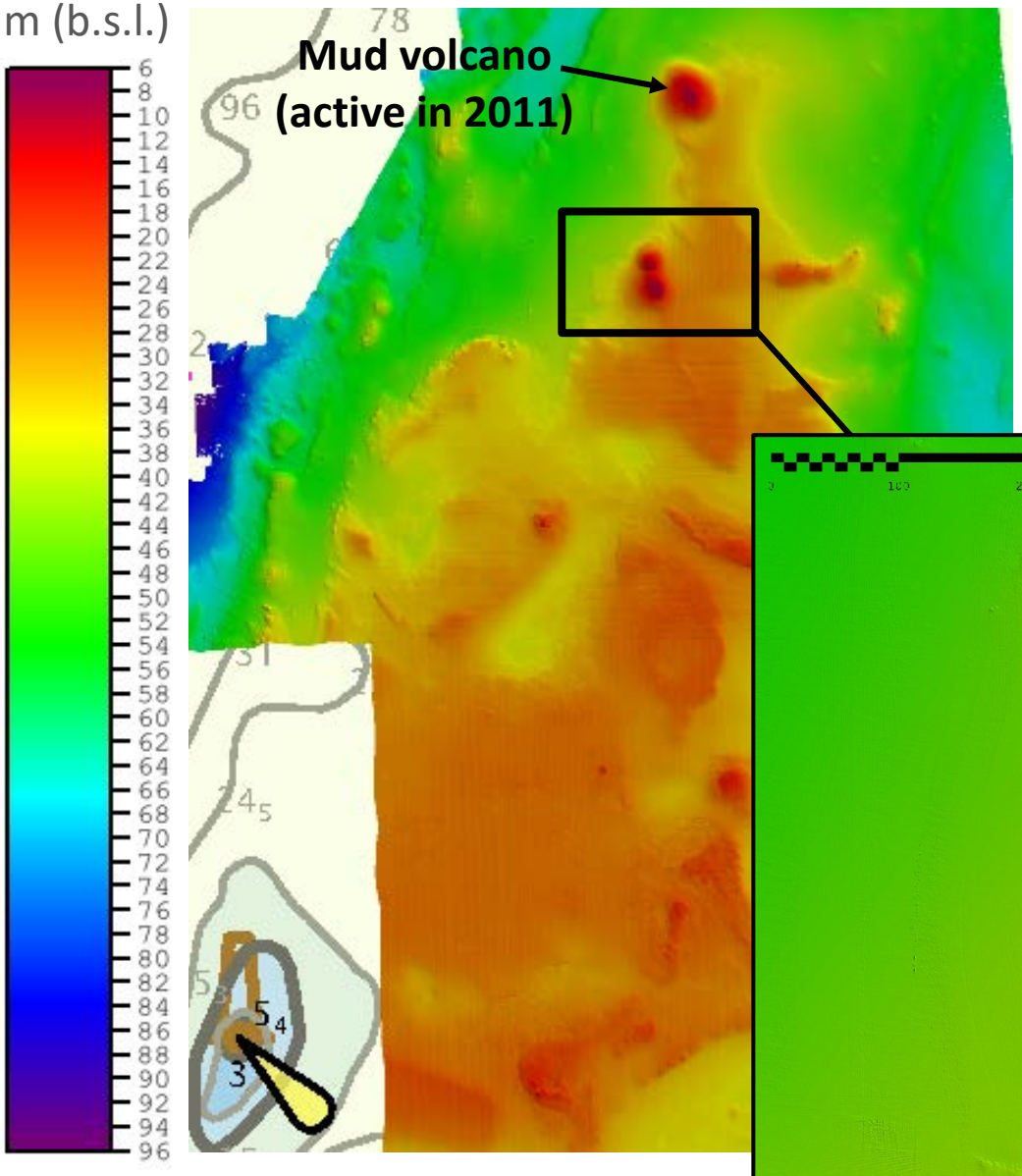
All these areas are characterized by the occurrence of conical-round morphologies at a shallow water depth (from 7 to 12 m) well distinguished from the seafloor which in turn is characterized by the presence of blocks and mud. The gas is emitted as large bubbles (up to 15 cm in diameter) from conical mud mounds or from bubbles of centimeter to millimeter size from sandy-muddy sediment or fissures in the blocks.

The discovered Mud Volcano

In this context, a cold methane seep was discovered in the sedimentary basin off Elba Island, characterized by typical mud volcanoes conditions. Generally, mud volcanoes are the shallow expression of subsurface processes characterized by movements of large masses of sediments and fluids.

A marine mud volcanoes is a window into different depth levels of the submerged geosphere where hydrogen sulfide, methane and other hydrocarbon-rich fluid seepage occurs caused by tectonic activity. Indeed, vertical migration of geogas, especially CH_4 from the reservoir strata to the sea floor occurs along focused, permeable migration pathways, often created by faults and fractures.

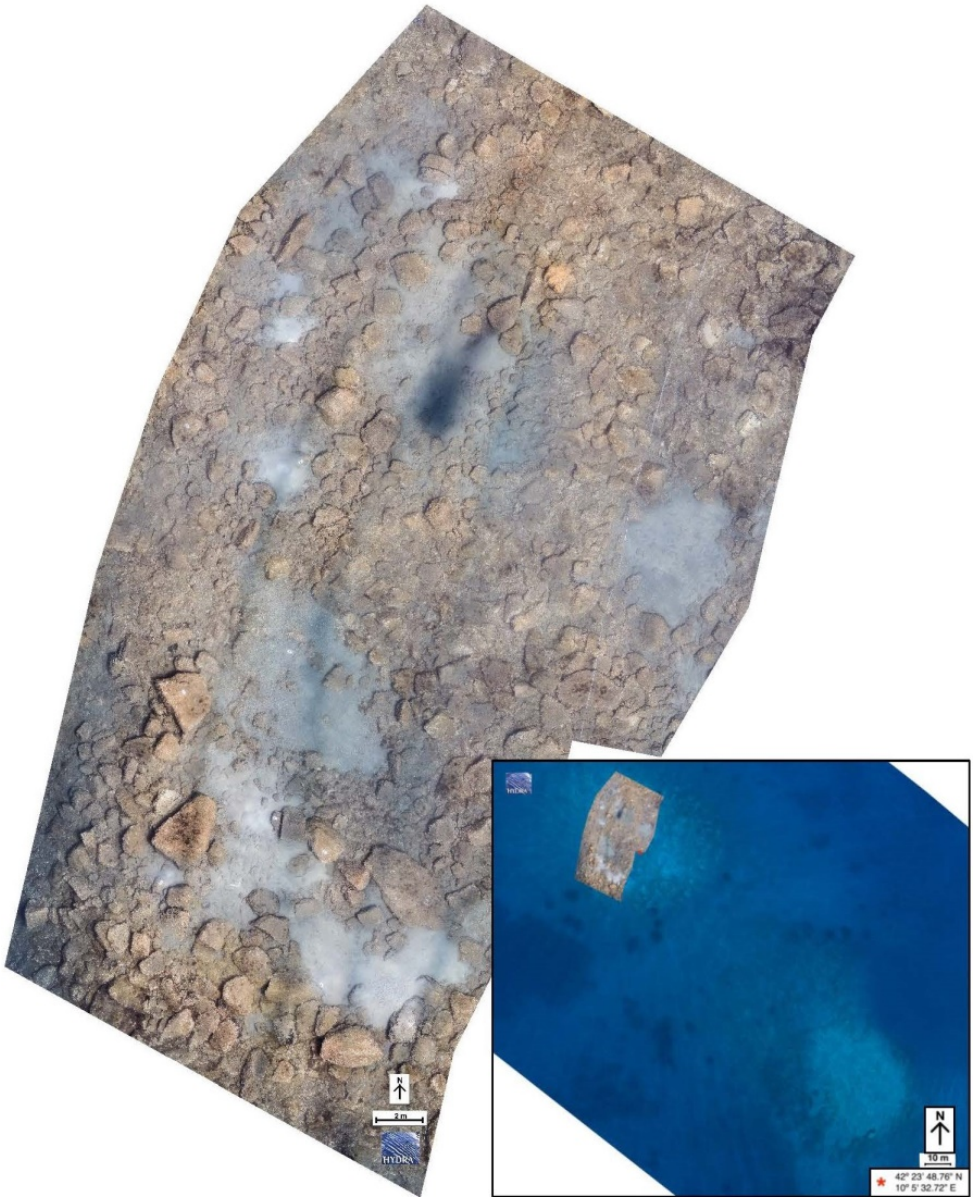
The discovered Mud Volcano: morphology



Bathymetric map of the Scoglio d'Affrica area. The surveying was conducted using multibeam echosounder.

The discovered mud volcano reveals similar cone shape and bathymetry to the other emission sites of the area.

The discovered Mud Volcano: morphology

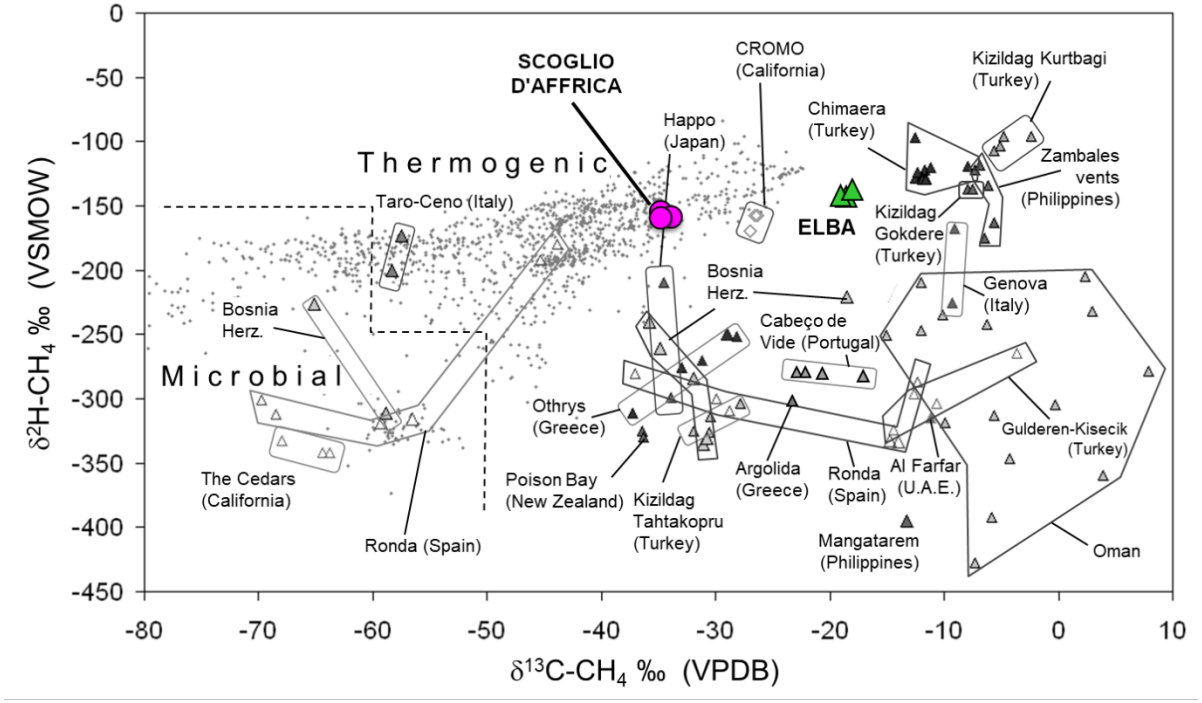


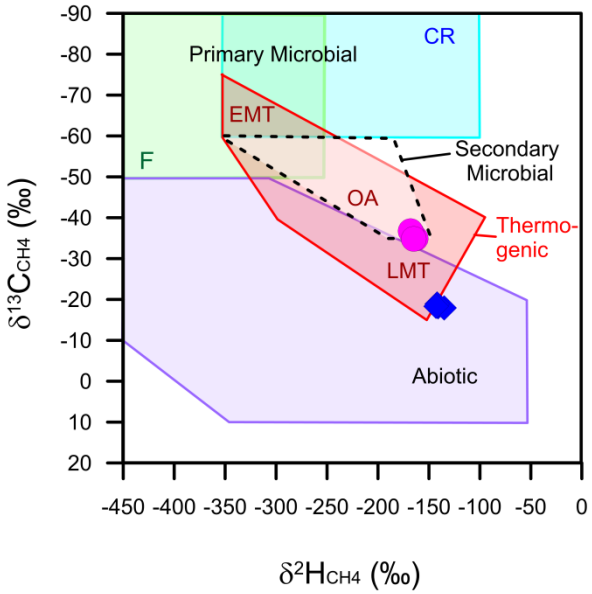
The conical shapes highlighted by the high resolution multibeam survey are very similar to the typical acustic backscatter signature of other mud volcanoes, thus confirming the possibilities of classify this site as mud volcano.

Indeed, already during the scuba diving survey that allowed sampling gas, rock and sediment, it was clearly observed and documented as a mud volcano.

The discovered Mud Volcano: geochemistry

The sampled gas chemistry is typical of mud volcanoes, with methane as the prevalent gas component (>95 vol%) and minor gases that include carbon dioxide, nitrogen and trace amounts of helium. The combined stable C and H isotope composition of CH_4 ($\delta^{13}C$ and $\delta^{2}H$) highlights a thermogenic origin of fluids discharged from mud volcano, contrary to likely abiotic origin gas found in the Pomonte seep and linked to serpentinized ultramafic rock systems.





Moreover, the samples collected on this mud volcano are extremely depleted in ^{3}He and their $^{3}He/^{4}He$ ratios are typical for a geological setting in which radiogenic crustal helium is strongly predominant. On the contrary, the Pomonte ophiolitic gas seeps (*Sciarra et al., 2019*) show a mantle-derived ^{3}He-rich component estimated in the range between 10 and 15%.

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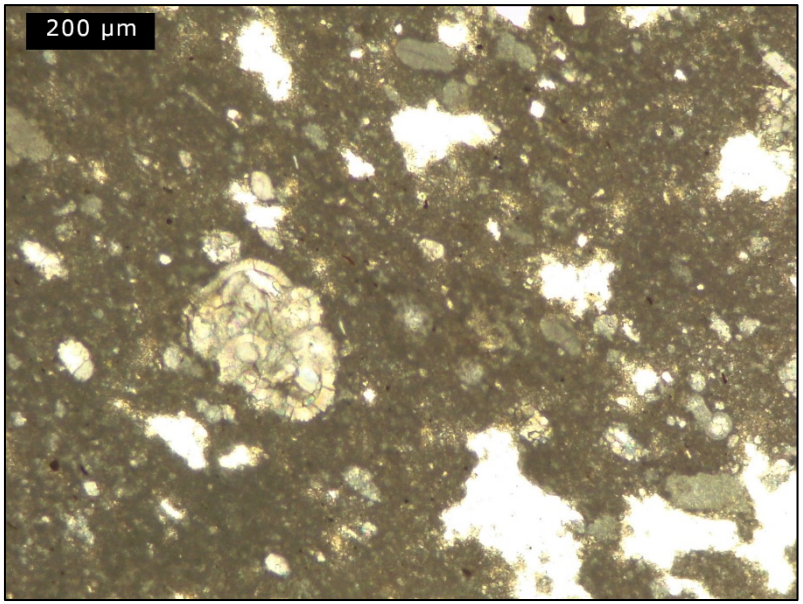
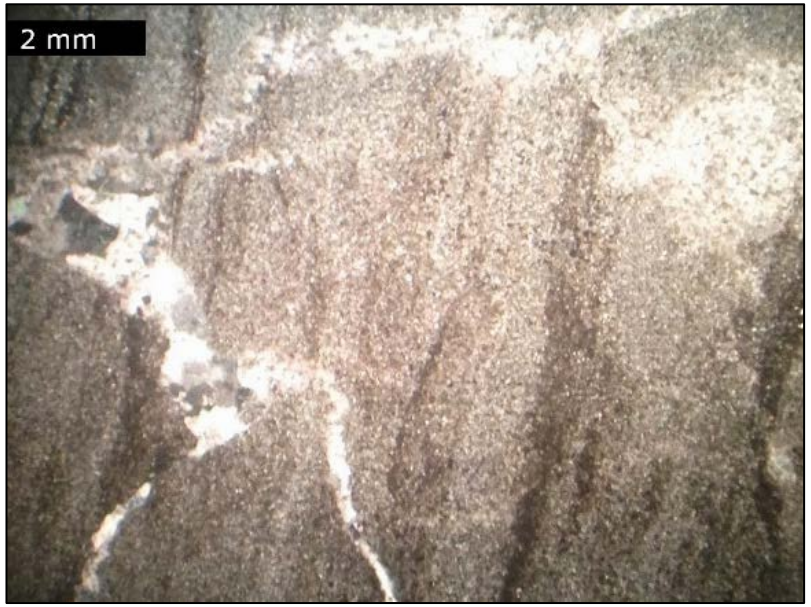
The discovered Mud Volcano: petrography

Petrological data highlight the presence of siltites and marly mudstones characterized by different origin than those found on neighboring islets (shallow marine organogenic limestones); therefore, the possibility that the fragments of rock blocks, found in the mud volcano area, derive form erosional processes of the islet is discarded.





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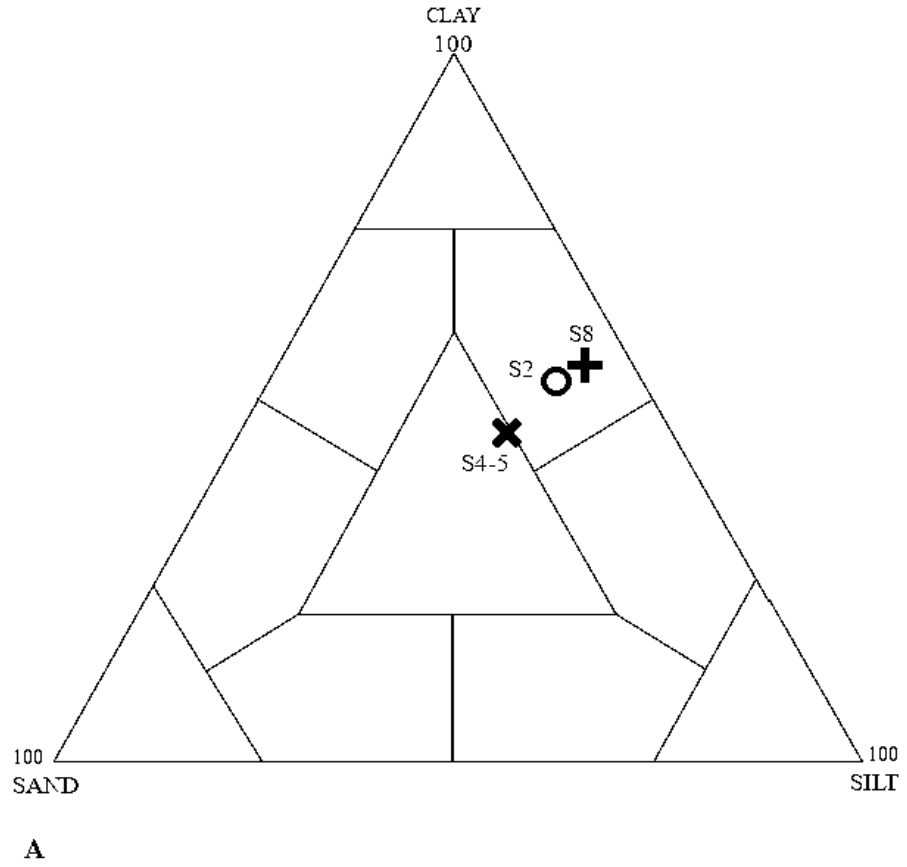
The discovered Mud Volcano: grain size of sea bed

The “extruded” sediment (samples S2, S4, S5 and S8) is characterized by a wide range of grain sizes, including mud



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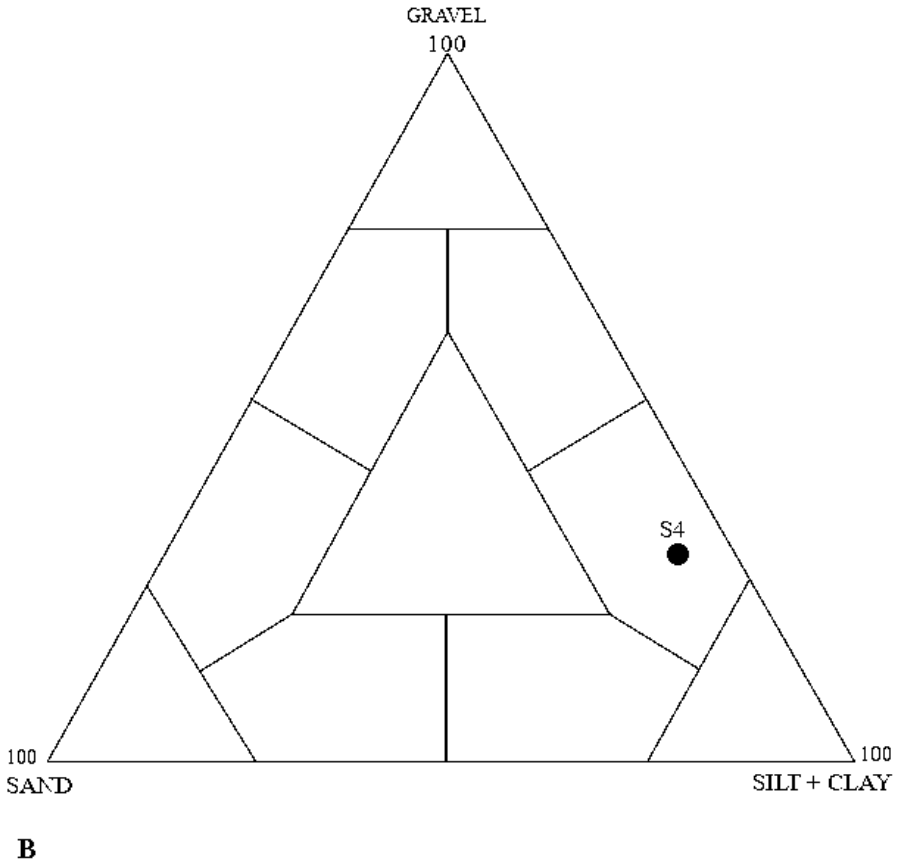

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Conclusions

- The conical shapes is highlighted by the high resolution multibeam survey and the typical acustic backscatter signature of other mud volcanoes confirming to classify this site as mud volcano.
- Chemical composition of extruded gas is enriched in methane with minor amounts of carbon dioxide, nitrogen and trace of helium. Isotopic composition point to a predominant thermogenic origin of methane.
- On the basis of morphological, sedimentary, petrographic and geochemical characteristics of the solid materials and the fluids expelled from the Scoglio d'Affrica site, these seeps can be classified as a mud volcano.

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