E/V Nautilus Mapping and ROV Dives Reveal Hundreds of Vents Along the West Coast of the United States

OCEAN EXPLORATION TRUST

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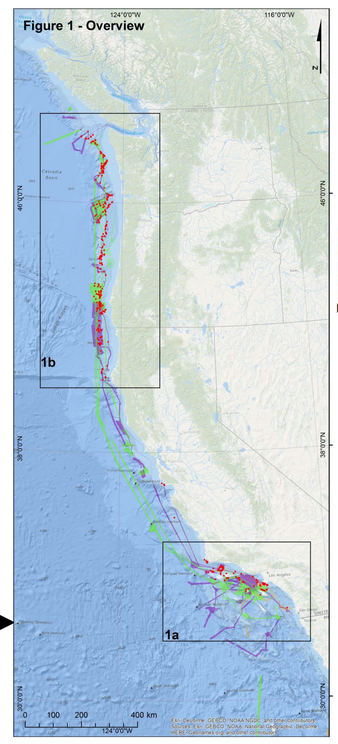
Overview

Examination of water column data collected in the 2016-2017 field seasons along the US west coast revealed hundreds of distinct vertical features, presumably plumes of methane gas released from the seafloor. While seafloor reservoirs of methane are thought to contribute 5-10% of the global discharge, inventories of seafloor methane seeps are poorly constrained due to the lack of data such as the distribution and abundance of seafloor gas plumes. The results of mapping efforts reveal an unexpected number of methane seeps (Fig. 1). ROV dives were then used to provide geological context to the seeps and associated unique biological communities.

Figure 1: US west coast seep sites (red dots) found by E/V Nautilus 2015-2017



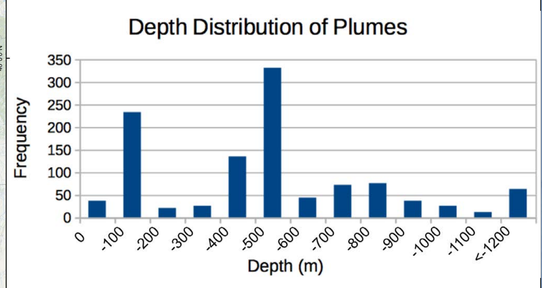


Figure 1c: Histogram showing depth distribution of gas plumes discovered along the coast.

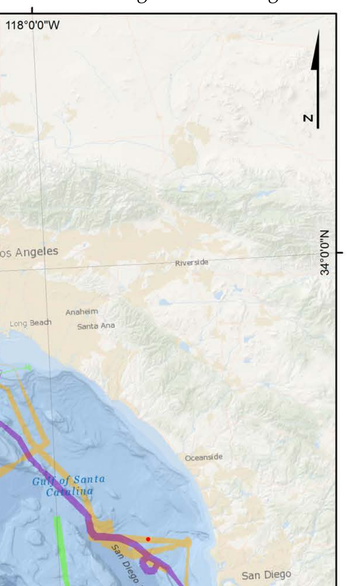


Figure 1b: Gas plumes found off the coast of Washington and Oregon.

Projection: WGS84 Mercator; Data: Ocean Exploration Trust, ESRI basemap

Figure 1a: Highlight of gas plumes found around the Channel Islands.

Sensors and Systems

The Exploration Vessel (E/V) *Nautilus* has mapped more than 80,000 km^2 of seafloor off the west coast of the United States between July 2015 and September 2017. The 30 kHz Kongsberg EM302 multibeam mapping system collects water column data in addition to bathymetry and backscatter. The 1x1^o beam width is fixed to 65^o for seep detection surveys (Fig. 2). Remotely operated vehicles (ROVs) *Hercules* and *Argus* were used to examine and carry specialized equipment to sample the seep sites (Fig. 3).

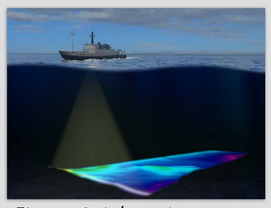


Figure 2 (above): Nautilus is equipped with an EM302 capable of mapping water depths from 10-7000 m

Figure 3 (above): ROV Hercules gathers seep bubbles with a funnel to collect in a gas tight chamber for gas composition analysis.

Water Column Data Analysis

The initial processing used the QPS Midwater tool to locate the seeps and determine their size and location. This was achieved using a number of different modes: the single fan, stacked fan (10-20 pings) to improve detection of faint seep returns in noisy environments, and stacked range mode for a chronological view (Figure 5). Each line of data was viewed in playback mode. When a seep was detected, the locus of the seep at the seafloor (bottom pick) and maximum height above the seafloor (rise) was geo-picked and saved (Figure 4). Geospatial distribution was reviewed during processing in 3D scenes (example to right) to relate the seeps to the multibeam bathymetry and backscatter.

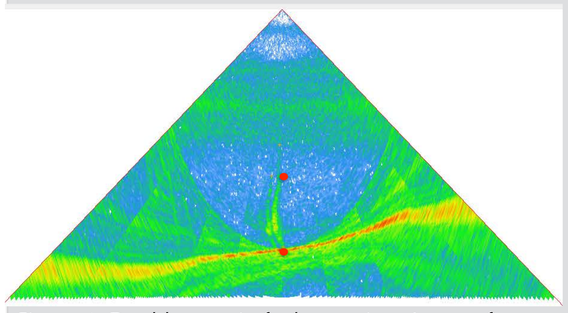


Figure 4 Double seep in fanbeam view. Locus of seep and rise of one seep marked with red circles.

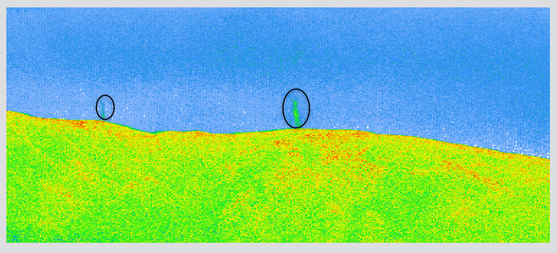
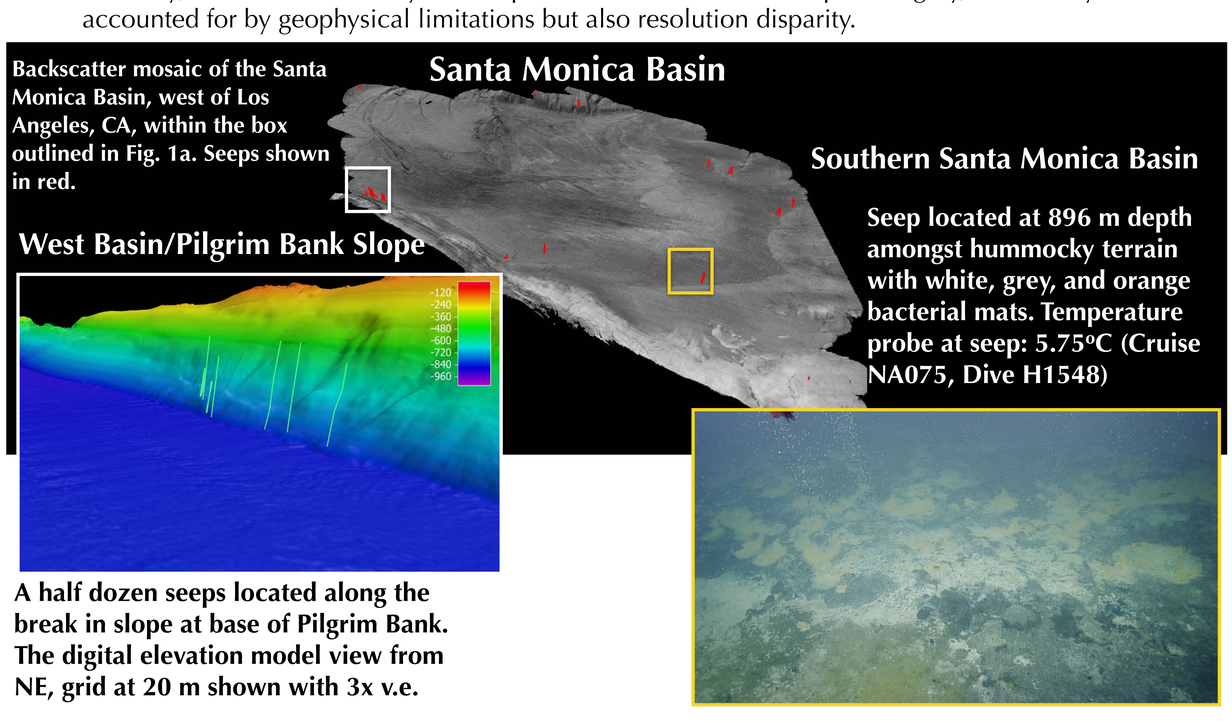


Figure 5 Stacked view of beams helps identify seeps chronologically (X axis is time starting on left and Y is range from top). Two seeps are visible here (black ovals).

- Over 1100 clusters of seeps were identified through our detection methods, from Washington to California off the US west coast.
- Most mapping efforts (defined here as area mapped) were concentrated along the Cascadia Margin and the Southern California region, and the majority of seeps were found in these locations.
- The majority of seeps were identified along the 500 m depth contour, which coincides with the upper limit of methane hydrate stability, but also represents greatest mapping effort depth zone apart from <-1200 m. Low mapping efforts in the 200-400m depth range (and in the central California region) may account for low seep discoveries.
- There were often fields of seeps found in the 100 m depth zone, but further research is required to identify the cause (perhaps increased water column resolution or higher seep concentrations/more diffuse vent sites).
- Similarly, there were relatively few seeps found in the <1200 m depth category, which may be accounted for by geophysical limitations but also resolution disparity.



Astoria Canyon

Located off the Cascadia Margin, seeps detected at the mouth of the canyon (850 m) and at the head of the canyon (495 m) were studied. Methane hydrate was observed at the 850 m depth site (below right).

Redondo Knoll

Redondo Knoll is 14 km across and rises 350 m above the seafloor 7 miles from the mouth of the Redondo Canyon. The knoll has seeps around the perimeter at 850-900 m depth, particularly on the NW side. The seep site is within the regional oxygen minimum zone and contains no vent fauna, just white, orange, and yellow microbial mats (Figure 6)

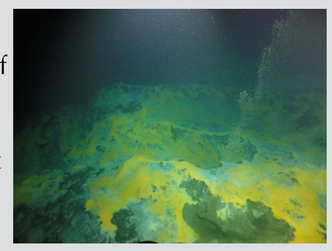
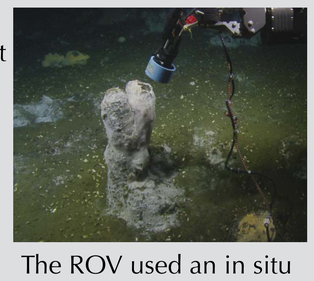


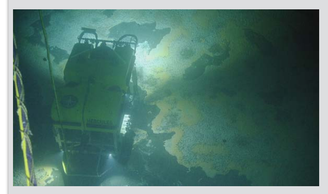
Fig 6. A spray of bubbles emanates from the Redondo Knoll seep. (Image courtesy of GoPro camera provided by Daniel Fornari, WHOI)

Point Dume

Located 5 miles off the Malibu, California coast at 700-750 m depth, this 1.3 km long diffuse flow site is within an oxygen minimum zone. Aside from orange, yellow, and white microbial mats, this site is devoid of typical seep fauna.



The ROV used an in situ sensor to measure eH at the chimneys. The dark sulfidic sediments are beneath a thin crust covered in white microbes. No advective flow or methane bubbles were observed.



Significance & Conclusions

The results of mapping efforts reveal an unexpected number of methane seeps. ROV dives were then used to provide geological context to the seeps and associated unique biological communities. Altogether these findings contribute significantly to our baseline inventory of seeps along the continental margins of the United States. The presence of unexpectedly large numbers of methane seeps on the US Pacific, Gulf and Atlantic margins may influence the management of human extraction activities on the margin seabed. In future work, we hope to gain insight from this data through analysis of seep location in relation to backscatter, slope, depth, and geological setting, with the goal of more automated detection. We also hope to analyze the spatial distribution of seep clusters and what factors constitute a grouping.

Acknowledgements

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