Long-term aspect of 1980's submersible-observed methane venting on the northern Gulf of Mexico upper continental slope, mapping of areal extent and aggregation: R/V Okeanos Explorer EX1203

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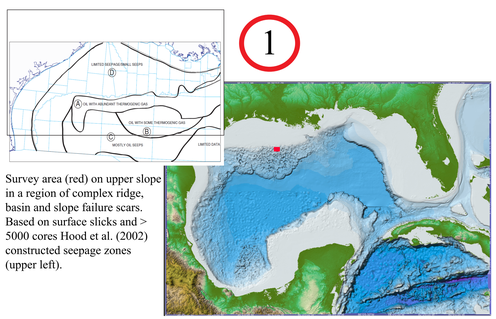
Upper Continental Margin Sites 1

The continental margin of the northern Gulf of Mexico (GoM) is topographically complex due to the interaction of salt-layer migration, slope instability and the shifting location of shelf-edge river deposition (Jackson et al 2010; Stigall and Dugan 2010; Galloway 2001). The full complexity of the ridge and basin systems became more widely apparent with the compilation of a digital terrain model (DTM) by Liu and Bryant (2000). Intensively investigated due to the extensive hydrocarbon reservoirs, it has become increasingly apparent that the GoM margin is a leaking system on a large scale, especially on the upper continental slope (Hood et al. 2002). The survey area considered here centers on four seep sites located in lease blocks Green Canyon 184/5, 233, 234, and 272. These were the primary sites for the first extensive investigations of deepwater chemosynthetic communities in the northern GoM. GC 184/5 is the initial discovery site (Kennicutt et al. 1985) and is often referred to as Bush Hill. GC 233 contains a brine pool with associated biota (Macdonald et al 1990) and is referred to as Brine Pool NR-1. The Bush Hill and Brine Pool NR1 sites remain actively studied. The other two sites have been less often re-sampled. Methane plumes have been observed during submersible observation at all three sites. Methane hydrates have been observed erupting through the seafloor at all sites except Brine Pool NR-1.

1



Survey area (red) on upper slope in a region of complex ridge, basin and slope failure scars. Based on surface slicks and > 5000 cores Hood et al. (2002) constructed seepage zones (upper left).

Methods 2 & 3

Previous Submersible Observation

Direct observation and seep sampling 1989-2009 primarily employed the Johnson SeaLink submersible (JSL) then operated by Harbor Branch Oceanographic Institution. Dive sites were selected on the basis of prior bathymetric and seismic surveys. Topographic highs which coincided with acoustic wipeout zones were targeted. No systematic echosounder surveys were undertaken, but bubble plumes were observed on occasion. Video footage taken on 89 separate dives (78 JSL; 10 Pisces V, and 1 Alvin) now archived at LSU fell within the survey area were examined for evidence of bubble plumes. The examined archive consists of 1,899 5 minute digitized clips.

2012 Acoustic Survey

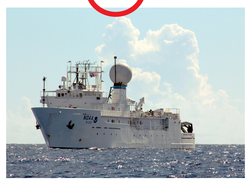
The survey May 6 Through 8, 2012 during cruise EX1203 was carried out by the NOAA Ship Okeanos Explorer. The ship is capable of mapping and carrying out in-water exploration using remotely operated vehicle (ROV). Mapping capability is provided by a multibeam (Kongsberg EM 302, 30 kHz) and a single-beam (Kongsberg EK 60, 18 kHz) system. EM 302 is a swath mapping system providing a swath width of up to 5.5 times water depth capable of providing both seafloor and water column data. EK60 has been widely used in fisheries research . During this survey EM 302 and EK 60 were concurrently used to collect water column data in vicinity of green canyon in water depth ranging from ~ 100 m to ~ 1100 m. The EM 302 was operated in high density equidistant mode forming 432 beams with beam widths of 1 x 0.5 degrees. EK 60 operated with a single beam of 7 degree beam width.

The initial bathymetric and water column data processing was carried out onboard using CARIS HIPS and QPS Fledermaus water column tool. Further data processing was carried out at Louisiana State University and NOAA Office of Ocean Exploration and Research (Silver Spring, MD) where the digital terrain model (DTM) of the area was created. The water column data from EM 302 and EK 60 were processed using QPS Fledermaus water column tool. The gaseous seeps in the water column data were identified based on peculiar linear elongated shape of the water column targets. The presumed gas seep locations were then overlaid with the DTM generated from EM 302 with EK 60 water column curtains to visualize seafloor bathymetry, seafloor backscatter, and water column targets.

2

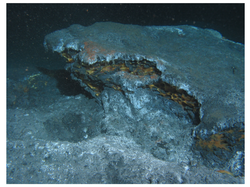
The Johnson SeaLink submersible has been extensively used in the exploration of GoM seeps shallower than 1000m depth. The great field of view increased the likelihood of observing bubble plums which could then be recorded in video images as early as 1989.

3

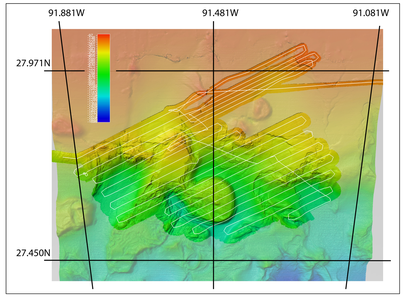


The NOAA vessel Okeanos Explorer carried out an extended mission in the Gulf of Mexico in 2012 which included multibeam and single beam surverying of the upper slope in the Green Canyon area.

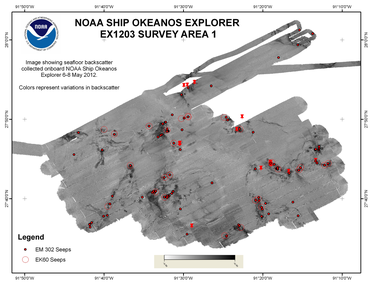
4



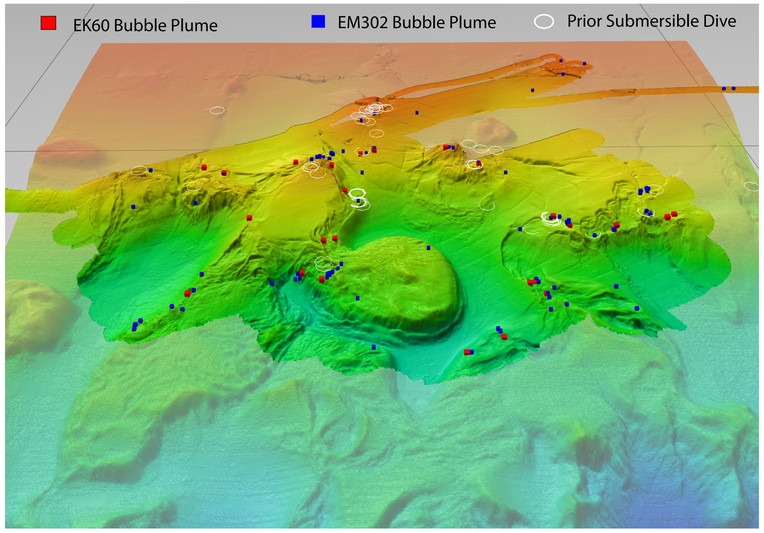
Methane bubble plumes sometimes are associated with decomposing hydrates erupting through the seafloor as seen in this Johnson SeaLink Image. Courtesy of C. Young.



7 Survey tracklines at 2km spacing.



9 Backscatter and bubble Plumes



8 DTM Projection showing aggregation of existing plumes along basins surrounding minibasins. Larger area (subdued color) from NOAA Coastal Relief Model.

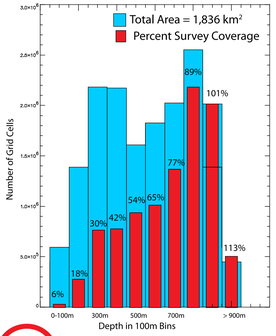
Results 4,5,6,7 & 8

Submersible Observations

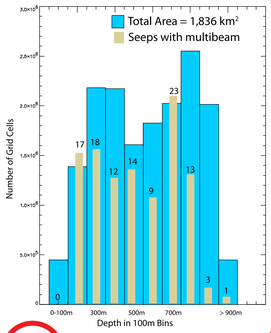
Various seep-associated features were observed in the 89 dives within the survey area made as early as 1989. Most prevalent were carbonate hardbottoms deposited during long-term anaerobic microbial oxidation of methane. Shallower than 400m these hardgrounds were populated by heterotrophic sessile organisms. Below that depth chemosynthetic seep communities became prevalent. Actual bubble plumes were only observed infrequently (11 dives). At the seafloor these flows ranged from modest bubble release through normal sediment to flows through liquid muds strong enough to displace sediment into the water column).

EX1203 Survey

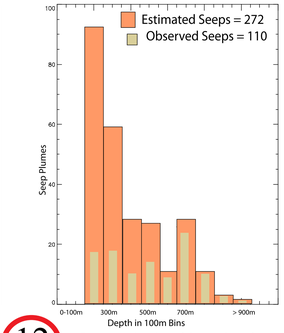
The narrow-beam EK60 detected 27 plumes, and the wide-beam EM302 detected 110. The spatial match between areas with sub-observed plumes from previous years was good but incomplete (Figure $$). The plumes deeper than the slope break were clustered in areas of high slope and high backscatter leaving the minibasin floors essentially void of seeps. The clustering on the shallower shelf edge was more problematic due to the relative lack of relief, but faulting appeared to be the cause of seafloor features.



10 Due to a fixed swath width of 2km and approximately 1000m of vertical relief, depths in the survey area were not equally surveyed by the 100° multibeam angle best suited for bubble plume detection. A histogram of depths in the survey area is compared to the percent of that area actually scanned.



11 Due to aggregation of bubble plumes, the number detected in each depth range is not a simple function of sampling effort. A histogram of depth ranges is overlain with a histogram of plumes detected in multibeam scans; n=110.



12 A first approximation of the number of plumes that might have been detected with 100% coverage can be made by simple multiplication. The estimation is that the 110 observed plumes were a sample of an actual population of 272.

1st Estimation of Plume Population Size n=272 plumes

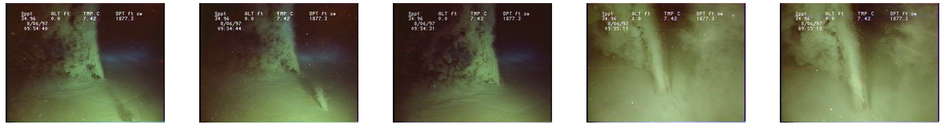
9,10,11 & 12

A swath width of 2km at the sea surface produces multibeam data suitable for mapping bathymetry across the entire swath even at depths as shallow as 200m. Plumes, however are detectable in a narrower acoustic fan of only 100° (50° either side of the vertical) as shown in figure $$. Full swath coverage only becomes 100% for bottoms greater than 800m depth. At 500m fully half the bottom fall outside of the narrower fan. Spatial statistics offers several approaches to estimating such as establishing bottom characteristics associated with plumes such as slope and backscatter strength (Figure $$). An initial and very simple approach is to estimate subpopulation size within each depth band based on the proportion samples. Doing so produces an initial estimate of 272 plumes of which 110 were detected.

Conclusions

1. Use of multibeam survey provides an effective means of detecting bubble plumes coming from bottom. These are novel data unlike bathymetry which is well surveyed but held as proprietary by the offshore industry.
2. Plumes have persisted in the same general locations since the initiation of submersible observation in the late 1980's.
3. As presumed during early submersible observations seeps are generally absent from minibasin floors.
4. While no estimate of flux rate was made, the possibility of 272 plumes in a 2000km2 area would indicate considerable methane flux.

5 Methane bubbles from firm mud bottom forming hydrate when collected.



6 Methane bubbles from fluid mud bottom carrying sediment into the water column.

Acknowledgements

The operations of the Okeanos Explorer are supported by the NOAA Ocean Exploration Program. Prior submersible dives were supported by that program and the Environmental Studies Program of BOEM. Crews and technicians of the NOAA Vessel Okeanos Explorer, R/V Seward Johnson, and R/V Edwin Link were critical to the success of this project.

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