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Mapping Gas Seeps with the Deepwater Multibeam Echosounder on Okeanos Explorer

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By Thomas C. Weber, Larry Mayer, Jonathan Beaudoin, Kevin Jerram, Mashkoor Malik, Bill Shedd, and Glen Rice

The Gulf of Mexico has long been known to contain large reservoirs of oil and gas. Some of these hydrocarbons make their way up through faults to the seabed surface (Roberts and Carney, 1997), providing an energy source for chemosynthetic communities (Fisher et al., 2007). Methane bubbles at these sites are sometimes released into the seawater where they dissolve or, occasionally, rise to the sea surface and into the atmosphere (MacDonald et al., 2002). Detecting the presence of gas seeps and mapping their locations are critical steps toward refining our understanding of the complex geological and biological processes occurring in the deep Gulf of Mexico, as well as our understanding of background conditions in light of events such as the Deepwater Horizon spill.

Gas bubbles in seawater are acoustically strong targets because they respond like simple harmonic oscillators with a strong resonance when excited by acoustic waves. We exploited this behavior to map gas seeps in the northern Gulf of Mexico using a multibeam echosounder during a cruise aboard the NOAA Ship *Okeanos Explorer* in the late summer of 2011. Multibeam echosounders insonify a large swath (typically an across-track fan that is four to six times the water depth) of the ocean on each ping (Figure 1), making large-scale mapping of a region a realistic possibility. These echosounders are traditionally designed with a focus on mapping the seafloor, and several manufacturers now routinely provide a capability for collecting acoustic backscatter data that can also be used for "midwater" mapping. Gas seeps have been mapped previously with multibeam echosounders (e.g., Nikolovska et al., 2008; Gardner et al., 2009), but we did not know how well the 30 kHz system (a Kongsberg EM302) on *Okeanos Explorer* would perform for our work in the Gulf of Mexico (Figure 2).

Initial results from the multibeam echosounder are quite promising. We observed hundreds of seeps—some repeatedly—in our survey area. We identified seeps mainly from their "continuous" returns, which were quite narrow in comparison to their vertical extent (e.g., Figure 1). Typically, the acoustic backscatter anomalies that we associated with these seeps were not observed shallower than 500 m, a depth that coincides with the methane hydrate stability zone (Milkov and Sassen, 2000). Given the depth and temperature of the deep Gulf of Mexico, it is likely that methane bubbles rising from the seafloor form methane hydrates, inhibiting gas transfer into the methane-undersaturated ocean during bubble ascent.

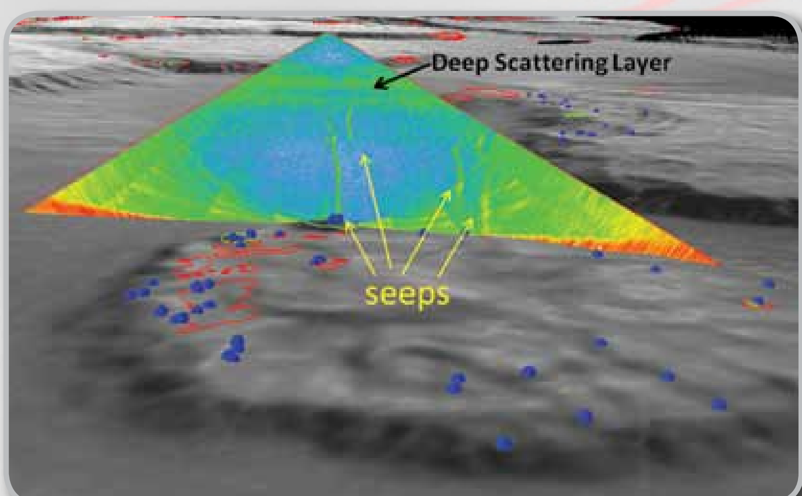

Figure 1. Backscatter data in the shape of a fan collected from a single ping of the 30 kHz multibeam echosounder, along with gas seep targets extracted from hundreds of pings during a survey over Dauphin Dome in the northern Gulf of Mexico.

Working in 1,200–2,500 m water depth, we were able to most reliably detect seeps over a swath width that was approximately twice the water depth; outside of this detection window, reverberation from the seafloor tended to mask most of the seeps. Given this seep detection capability

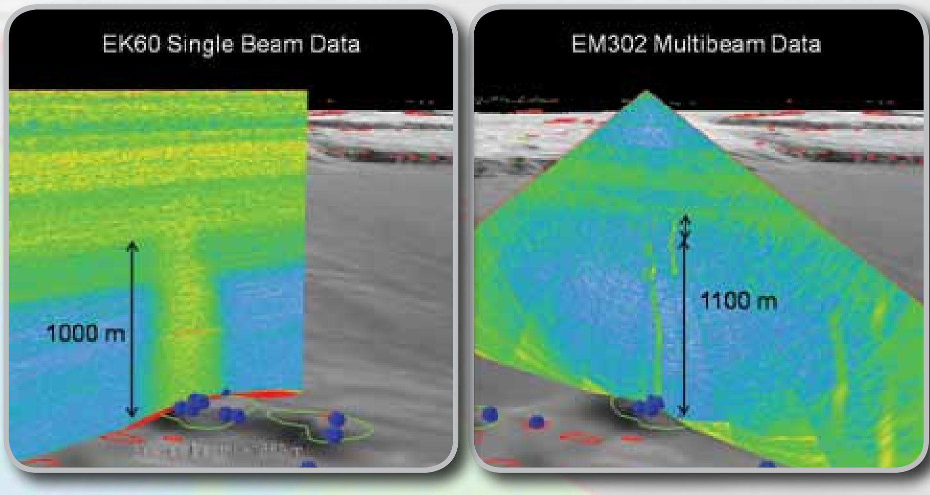

Figure 2. A contrast in backscatter: a seep simultaneously mapped with the both an 18 kHz single-beam echo sounder (left) and the 30 kHz multibeam echosounder (right). The echogram shown for the single-beam echosounder is constructed from hundreds of pings as the ship travels over the seeps. The data from the multibeam echosounder are from a single ping.

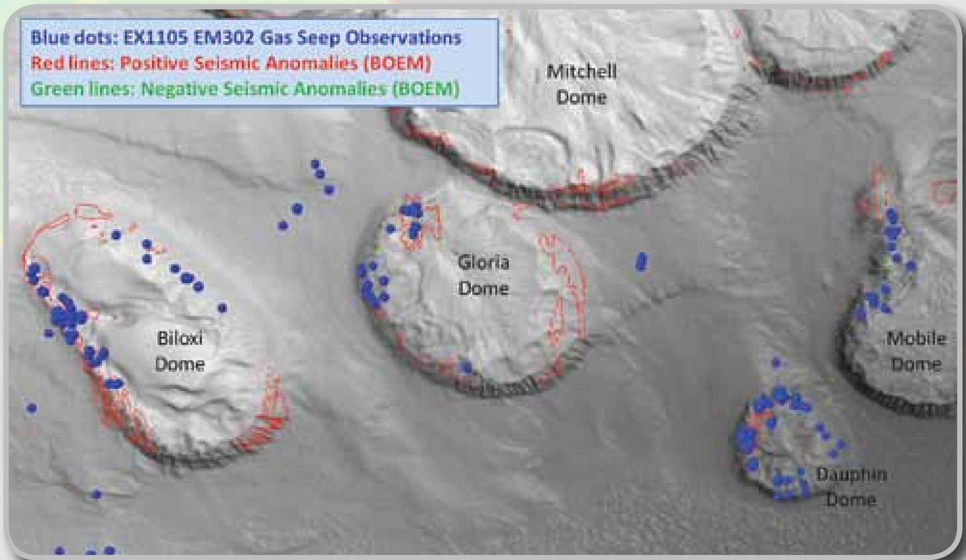

Figure 3. Seeps (blue dots) mapped with the multibeam echosounder overlaid on bathymetry (gray scale) along with seismic anomalies provided by the Bureau of Ocean Energy Management.

and assuming a water depth of 1,500 m and a speed of 10 kts, it is possible to survey more than 50 km^2 of seafloor each hour for potential seep locations.

Most of the seep-like structures we observed acoustically with the multibeam echosounder were on the edges of salt domes, which are common in the Gulf of Mexico's oil and gas province. Often, the seep observations were within suspected "hardground" anomalies mapped using three-dimensional seismic data (http://www.boemre.gov/offshore/mapping/SeismicWaterBottomAnomalies.htm). These positive anomalies possibly indicate past carbonate or hydrate structures, whereas negative seismic anomalies possibly indicate young, high-flux gas seeps or hydrate formations at or just below the seabed interface. However, as Figure 3 shows, we also observed seeps on the edges of salt domes where there were no seismic anomalies (e.g., the eastern edge of Dauphin Dome) and sometimes did not observe seeps where positive seismic anomalies existed (e.g., the eastern side of Gloria Dome). Together, the seismic anomaly maps and the multibeam echosounder water-column detection of seeps offer clues regarding which areas were historically active but are now inactive, which areas have been active long enough to form carbonate hardgrounds, and which areas may be locations of newer events that have not yet formed carbonate structures substantial enough to be detected as seismic anomalies.