Charleston to Woods Hole R/V Armstrong Transit: Atlantic Margin Upper Slope Fluid Flow Features, Seafloor and Water Column Surveys

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The letter of intent focuses on surveying US Atlantic margin upper slope features that are related to faults, fluid flow, methane seepage, and possibly gas hydrates as a test of the *R/V Armstrong*'s hull-mounted subseafloor, seafloor, and water column imaging systems during the transit from Charleston to Woods Hole in spring 2015. The survey strategy builds on digital data obtained during the NSF-supported community GeoPrisms seismic experiment (ENAM 2014), DOE-supported cruises by the USGS in 2015 on the *R/V Endeavor* and the *R/V Sharp*, and multiple NOAA Ocean Exploration (OER) cruises between 2012 and 2014, with results documented in a 2014 *Nature Geoscience* paper and associated public methane seeps database. In addition, 2013 and 2014 NOPP cruises, the NOAA OER cruises, and the July 2015 *R/V Atlantis* SeepC cruise led by colleague Cindy Van Dover have collected video or chemosynthetic samples at two of the sites.

We have identified three high-priority target areas where focused surveying by the *R/V Armstrong* would answer specific scientific questions being pursued by the Woods Hole scientific community, while also providing the opportunity to test the EM122/EM710 and EK80. While the Knudsen could be used to enhance any of these surveys, this would require slower ship speeds, which would significantly increase the amount of the transit consumed by these surveys.

Particularly with respect to water column imaging, note that the USGS Woods Hole has been at the forefront in defining more than 550 seep sites on the US margin between Cape Hatteras and Georges Bank since 2013. In addition, the USGS has worked for more than 20 years on the Cape Fear and Blake Ridge diapirs that are almost directly offshore of Charleston. The USGS would be pleased to provide further information about transit-over sites that would provide underway tests of the geophysical imaging (seafloor and water column) of the *R/V Armstrong*.

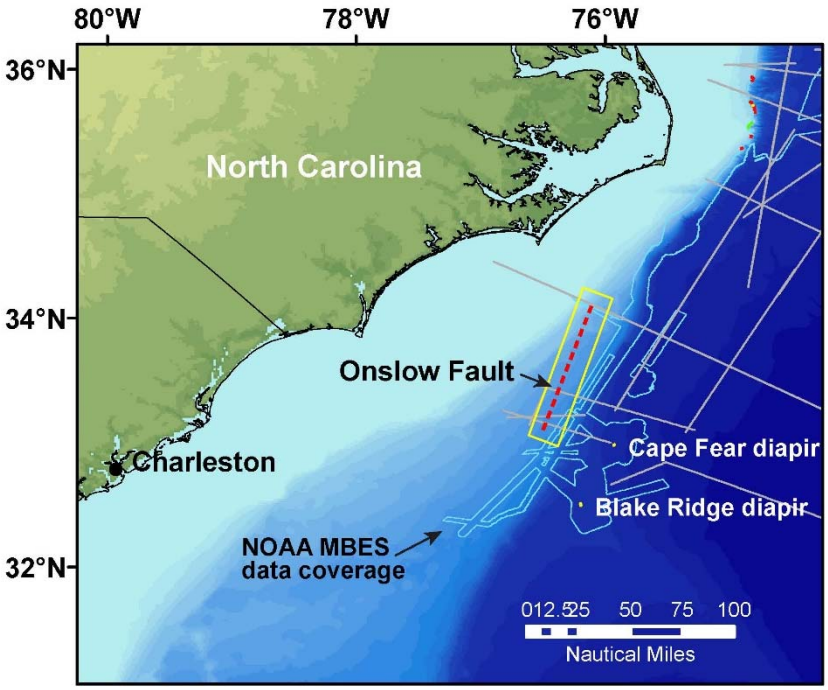
Calibration of the EK80 system: This proposal requests use of the EK80 system for water column imaging, and the system will have to be calibrated before the ship conducts any surveys from which quantitative information like target strength is obtained. The USGS Woods Hole office has experience with calibrating the predecessor to the EK80 system (EK60; the USGS owns an EK80 broadband transceiver and 38 kHz split-beam transducer, but has been using the EK60 while its EK80 was under construction) twice in 2015. However, the calibration experts for these systems are at NOAA. We suggest contacting J. Christopher Taylor (chris.taylor@noaa.gov) at the Beaufort, NC office of NOAA, who has previously calibrated 5-transducer EK60 systems on the *Okeanos Explorer*, or Mike Jech (michael.jech@noaa.gov) at NMFS-Woods Hole, whose engineers have built an automated GUI-driven system for EK60 calibration.

Personnel: The surveys below could be carried out with one WHOI scientist (Lizarralde or his designee) shipboard and one USGS operations/technical staff member to coordinate acquisition of data at USGS targets.

SITE 1: ONSLOW FAULT (WHOI: Lizarralde, Behn)

The Onslow Fault is a 100-km-long SSE-NNW striking fault whose southern tip lies 170 nm east of Charleston. The fault cuts a 5 km thickness of the sedimentary section at upper slope (500-1000 m) water depths between Cape Lookout on the north and Cape Fear on the south. The fault may accommodate all the seaward motion of the uppermost sedimentary section on this part of the margin. The 2014 ENAM multichannel seismic data that cross the fault in several locations reveal -seafloor displacements consistent with continued contemporary motion and some places with trapped fluids/gases. Several types of data could be acquired over the Onslow Fault during the *R/V Armstrong* shakedown/north transit:

- *MBES data:* The Onslow Fault lies on a part of the margin where MBES coverage is sparse. NOAA OER's coverage stops outboard of the fault, and the Extended Continental Shelf/Law of the Sea coverage compiled at UNH CCOM (http://ccom.unh.edu/data/atlantic-bathymetry) starts at the base of the continental slope, far seaward of the fault. The acquisition of *R/V Armstrong* MBES data with the EM710 or EM122 would fill a critical gap in US margin data coverage and provide backscatter data to constrain any seafloor expression of the fault or the distribution of features associated with fluid flow.
- *Water column imaging data:* EK80 data and water column backscatter from the MBES system should be acquired along the fault to locate potential methane gas plumes. Part of the Onslow Fault lies within the depth range where the *2014 Nature Geoscience* paper identified over 300 seeps on the US Atlantic margin north of Cape Hatteras based on EM302 water column backscatter. The fault also obliquely crosses the updip limit of gas hydrate stability on this part of the continental slope (where gas hydrate may be breaking down to the impingement of the warming Gulf Stream) and shows strong indications for fluids and gas at depth.

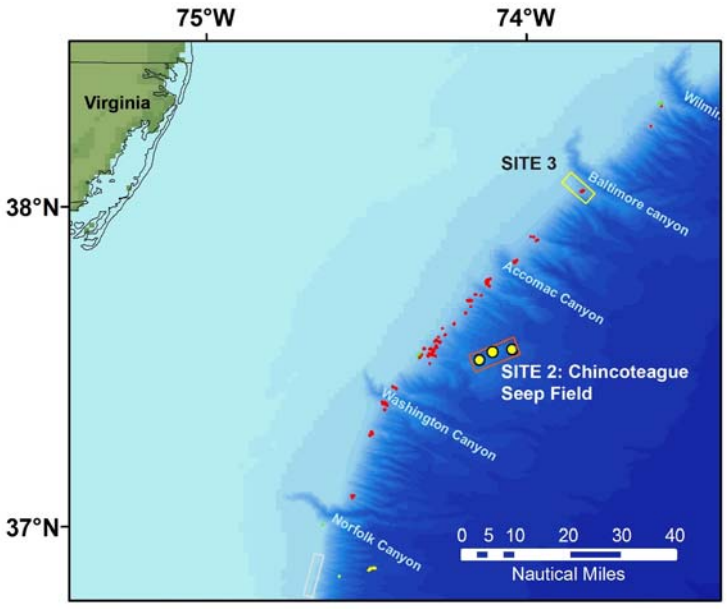


Survey along the strike of the fault: 70 nm or ~9 hours for MBES/EK80 collected at 8 knots. This will provide a several-km-wide swath and backscatter directly along the fault.

SITE 2: "CHINCOTEAGUE" DEEPWATER SEEP FIELD (USGS: Ruppel)

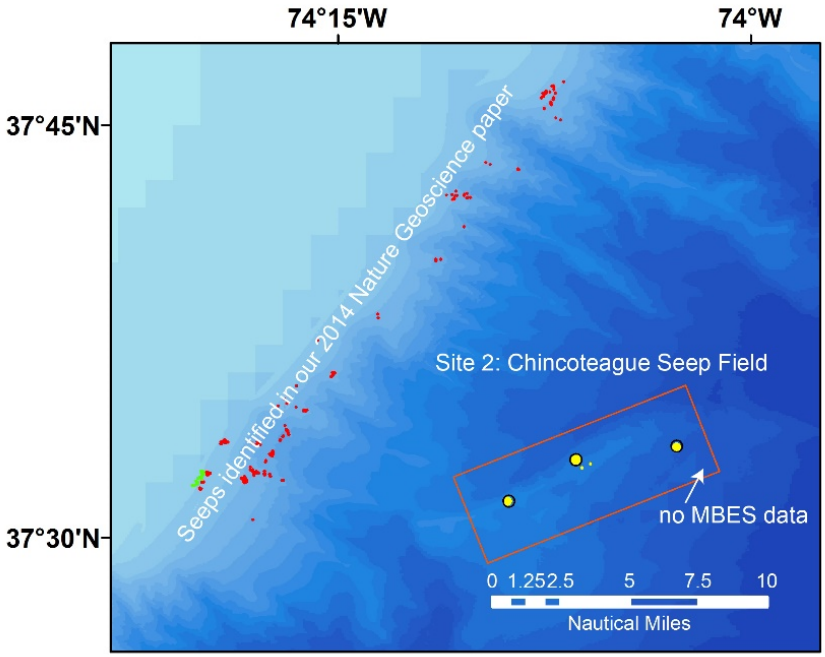
The Chincoteague Deepwater Seep Field is the informal name given to spectacular methane seeps whose plumes rise hundreds of meters into the water column along a sediment ridge that deepens from 950 to 1250 m to the NNW ~110 nm offshore Chincoteague Island. In the August 2014 *Nature Geoscience* paper, the USGS and coworkers identified only two distinct seeps there based on *Okeanos* EM302 water column backscatter data. Another large plume was found by A. Skarke on Cindy Van Dover's *R/V Atlantis* SeepC cruise in July 2015, and the USGS in September 2015 discovered new seeps that extended the field to ~5 nm long (see map). USGS multichannel seismic data acquired in April 2015 image fractures in underlying Eocene rock channeling gas all of the way to the seafloor, an unusual observation.

- *MBES data:* The area has been swath mapped by the Okeanos EM302, but it is suggested that the *R/V Armstrong* re-map the area using its EM710 to provide a comparison with the raw EM302 MBES data available from NGDC and a test of EM710 capabilities at these water depths (including seafloor backscatter). The EM122 would also be suitable at these water depths, but data from the EM710 is preferred unless WHOI has an interest in comparing EM122 to EM710 data here.
- *Water column imaging data:* EK80 data and water column backscatter from the MBES system should be acquired to image known methane plumes. The USGS has EK60 38 kHz data over the known seeps from September 2015 for comparison with the new *Armstrong* data and older data over the main seeps from April 2015. Older multifrequency EK60 data from NOAA OER varied in quality due to calibration issues. The *Armstrong* surveys will be the first complete multifrequency EK80 survey of this area and are likely to reveal new seeps from the deepwater Eocene fractured rock.
- *Knudsen surveys:* NOT SUGGESTED. The USGS acquired dense Edgetech subbottom data over seep field in September 2015, and Knudsen data from the *R/V Armstrong*'s system are therefore not required unless WHOI marine operations would benefit from comparison of USGS towed Edgetech chirp vs hull-mounted Knudsen data.



<u>Survey a 7 x 3.5 nm box bounding the seep field (4-5 hours):</u> At 8 knots and average water depth of 1000 m, this box can be mapped in a few hours (2 swaths with overlap).Such mapping would also fill in a bathymetric data gap in US continental slope coverage at the southeast corner of the survey area. Due to the narrow cones of the EK80 transducers, another

pass through the box and directly over the seeps is suggested to acquire high-quality plume data. The Gulf Stream is not a factor in this area.



Closeup of Site 2 (Chincoteague) in the red survey box. The large yellow circles are new seeps found by the USGS (westerly ones) and by Skarke (easterly) aboard the R/V Atlantis SeepC cruise in 2015. The small yellow dots and the red/green dots on the upper slope are from our 2014 *Nature Geoscience* northern Atlantic margin database of plumes, mapped with water column backscatter from the NOAA OER EM302.

BALTIMORE CANYON PROMONTORY SEEP FIELD (USGS: Ruppel)

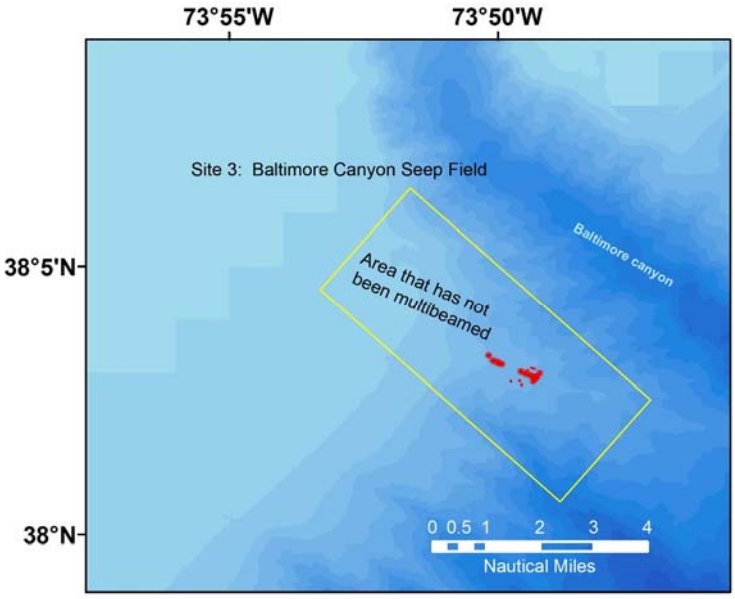
The Baltimore Canyon seep field is located on the south side of the canyon near where it enters the shelf. In 2013, the seep field was rediscovered and sampled for chemosynthetic organisms by NOAA OER and NOPP, respectively. It was extensively sampled by Van Dover during two Alvin dives on the SeepC cruise in July 2015 and surveyed at least 3 times with the USGS EK60 for seep plume ephemerality and episodicity in April and September 2015. The *Nature Geoscience* database derived from NOAA OER water column backscatter found ~15 seeps in this area, and the USGS data have revealed a previously-unmapped seep field updip from the main promontory.

- *MBES data:* The area has only been partially mapped by NOAA, whose data do not extend across the uppermost slope to the shelf break. WHOI may also have EM122 data in this box from the 2015 SeepC *R/V Atlantis* cruise, although the water depths here are not ideal for that instrument. On the *R/V Armstrong*, the EM710 should be used to map from the shelf break (nominal 150-180 m) to at least 600 m water depth on the south side of the canyon as a test of the shallower water capabilities (bathymetry/seafloor backscatter) of the instrument and its performance across changing bathymetry and sweeps. The seep field

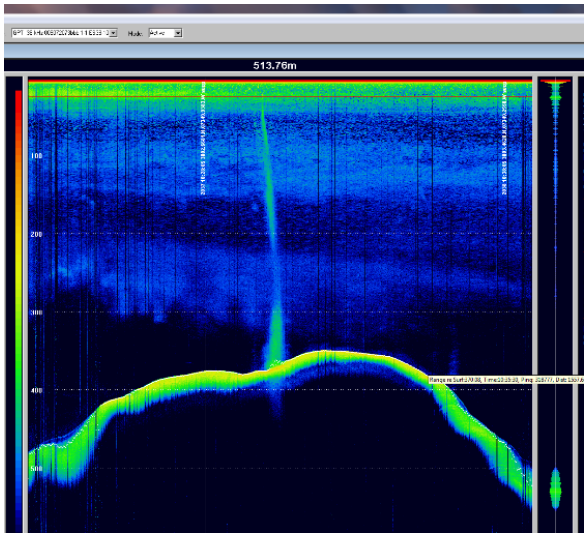
seafloor has substantial carbonate edifices in some places, and the seafloor backscatter data will be critical for mapping methane plumes into seafloor features.

- *Water column imaging data:* Seep field (~350-550 m water depth) EM710 water column backscatter and coincident EK80 data should be used to identify the seep sites active at the time of the surveys. The USGS has done repeated EK60 surveys over the seep field this year, and in September 2015 imaged several plumes continuing through the water column nearly to the sea surface. The *Armstrong* data will provide another component of the methane emissions time series in this seep field. As with the Chincoteague seep, the *Armstrong* surveys will be the first complete multifrequency EK80 survey of this area.
- *Knudsen surveys:* NOT SUGGESTED. Edgetech Chirp acquired in this area by the USGS in 2015 merely reveal gas-charged seafloor with no stratigraphic definition.

Survey a 5.5 x 2.5 nm box bounding the seep field (3-4 hours): At 8 knots and average water depth of 400 m, this box can be mapped in a few hours (possibly up to 3 swaths with overlap). A focused EK80 survey over the seep field could re-occupy USGS survey lines from earlier in 2015 and would require an additional hour. This survey is not strictly necessary. However, this is the best site of those we have proposed to test the full capabilities of the EK80 for water column imaging of methane plumes given the sheer number of seeps.



Left: Closeup of Site 3. Red symbols are seeps published in the Nature Geoscience paper supplemented by new seeps discovered by the USGS in April 2015. The shallow part of the box has no multibeam data.



Right: USGS raw EK60, 38kHz imagery collected in September 2015 on the *R/V Sharp*, showing a plume in the Baltimore Canyon seep field extending nearly to the ocean's surface.