Deep-Sea Exploration of the US Gulf of Mexico with NOAA Ship *Okeanos Explorer*

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INTRODUCTION

The Gulf of Mexico is an important driver of the US Blue Economy. Industries such as tourism, commercial fishing, oil and gas extraction, and shipping generate trillions of dollars in revenue annually and provide millions of jobs. Many of these industries rely on a healthy Gulf of Mexico ecosystem, but much of it remains poorly known, particularly deepwater habitats. Thus, decision-makers often work with limited information when making important resource management decisions.

From November 2017 to December 2018, NOAA's Office of Ocean Exploration and Research, as part of the Southeast Deep Coral Initiative (SEDCI), worked with regional partners and the scientific community to conduct three expeditions in the Gulf of Mexico, one of which focused on testing emerging technologies. To address knowledge gaps and inform resource managers, NOAA Ship *Okeanos Explorer*'s suite of deepwater mapping systems and the capabilities of ROV *Deep Discoverer* were used to explore deepwater ecosystems of the US EEZ in the Gulf of Mexico.

The expeditions built on previous *Okeanos Explorer* exploration in the Gulf of Mexico in 2011, 2012, and 2014, as well as OER-sponsored projects such as Lophelia II and Pulley Ridge. Drawing on the community of partners OER has developed over the years, as well new ones, over 100 managers and scientists from more than 40 institutions participated in cruise planning via OER's suite of telepresence-enabled collaboration tools. This collaborative approach to ocean exploration continues to be useful and ensures that OER's work is relevant to the broader science and management communities. ROV dive sites were chosen based on numerous criteria, with a particular focus on areas that were likely to contain deep coral and sponge communities, bottomfish habitats, shipwrecks, and a variety of chemosynthetic habitats, including cold seeps, mud volcanoes, and brine pools. In addition to these particular types of locations, dives were preferentially conducted in areas that were under consideration for management actions to ensure bodies such as the Gulf of Mexico Fishery Management Council have the best possible data.

During the 2017 and 2018 Gulf of Mexico expeditions, the at-sea team successfully conducted 32 ROV dives with ROV *Deep Discoverer*, which is operated and maintained by the Global Foundation for Ocean Exploration, and mapped 53,300 km^2 within the US EEZ (Figure 1). ROV dives during this expedition explored the seafloor between 300 m and 3,010 m depth and four dives explored the water column at depths ranging from 300 m to 2,100 m. During the expeditions, 172 biological samples were collected because they were thought to be undescribed species, they represented significant range extensions of known species, or they represented the dominant morphotype of an area. Additionally, 20 rock samples were collected to help characterize the petrology of the Gulf. All samples collected during the expedition will be archived in publicly accessible repositories so they can be used by the marine science community. In addition to exploring the Gulf's geological and biological resources, the expeditions surveyed submerged cultural heritage sites.

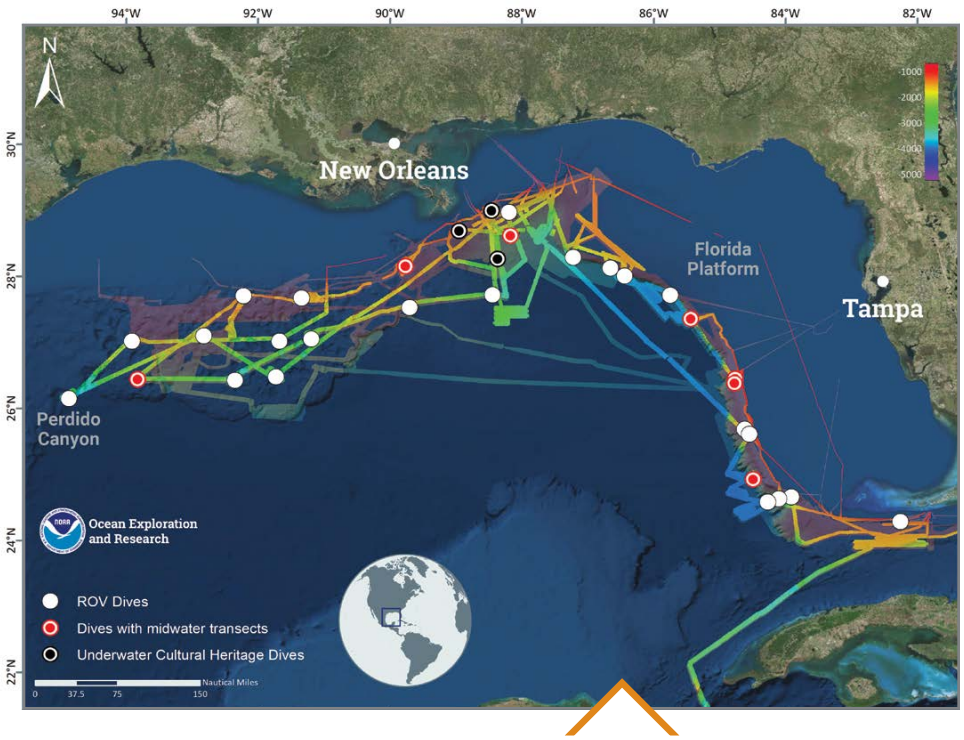

Figure 1. Map of the Gulf of Mexico showing cumulative color-coded multibeam sonar bathymetry collected during all NOAA Ship *Okeanos Explorer* expeditions, including the three most recent expeditions.

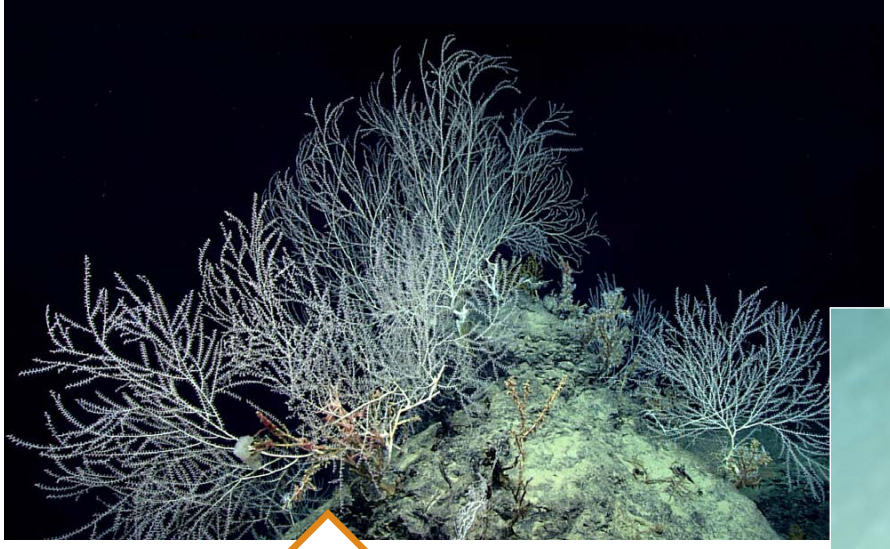

Figure 2. While diving on Escarpment Canyon Ridge at the southwest edge of the Florida Escarpment, a very high density of bamboo corals and glass sponges were observed at approximately 2,300 m depth. To date, these high-density communities are among the deepest recorded in the Gulf of Mexico.

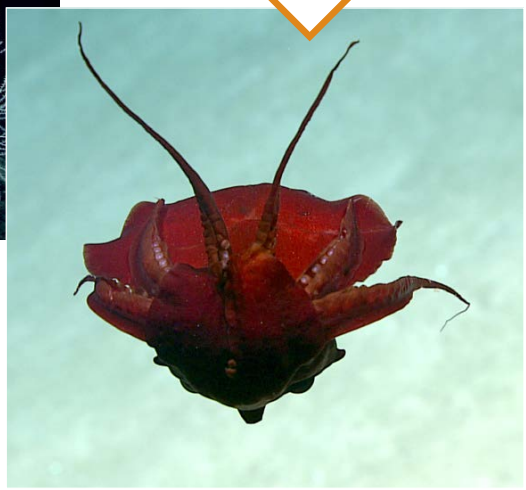

Figure 3. This unidentified squid (possibly *Discoteuthis discus* in the family Cycloteuthidae) exhibited behavior seen in this picture that was described as "probably the most bizarre squid I've ever seen" by cephalopod expert Michael Vecchione from NOAA's National Marine Fisheries Service.

BIOLOGICAL HIGHLIGHTS

During the two ROV expeditions, the team documented a rich diversity of habitats and organisms. *Deep Discoverer* documented at least 22 previously unknown chemosynthetic communities across the northern Gulf. These communities thrive on chemical energy and hydrocarbons that naturally seep into the water. These natural cold seeps are also an important source of exposed rock that can provide habitats for coral and sponge communities. Additionally, at least 14 high-density and high-diversity coral (Figure 2) and sponge communities were located, including one at approximately 2,600 m depth, the deepest known in the Gulf of Mexico.

Initial study of the physical specimens collected has yielded potentially dozens of substantial species range expansions and several likely new species. Previously unobserved behaviors in known species (e.g., squid defensive posture [Figure 3], octopus aggressive behavior, several sea stars feeding on sponges) were documented. Highlights also include the first record of the crinoid family Hyocrinidae (a probable new species) in the tropical western Atlantic and a likely new and locally abundant species in the crinoid family Thalassometridae, the first-ever in situ observation of the rare sea star *Remaster palmatus* (family Korethrasteridae), and the first documentation of several species of sea stars feeding, including one on a black coral.

GEOLOGICAL HIGHLIGHTS

These expeditions explored a wide variety of deep-sea geological settings, including carbonate shelves, escarpments, cold seeps (Figure 4), mud volcanoes, asphalt seeps, brine pools, and sedimented plains and slopes. ROV *Deep Discoverer* was used to explore the seafloor from the remote Perdido Canyon, which is on the border of the US EEZ and just over 200 nm from the southernmost tip of Texas, to Pourtales Terrace, which is just 50 nm southwest of Key West, Florida (Figure 1).

During the 15 dives over salt domes in the western Gulf, we observed methane seeps (some with visible methane hydrate), asphalt seeps, and brine rivers, with most locations supporting well-developed chemosynthetic communities, including bacterial mats. Many of these chemosynthetic

Figure 4. High-viscosity oil (black tubules) seeping from the seafloor among white bacterial mats forms asphalt when the extrusions solidify. The long tubules are bent to the left due to the current.

sites were surrounded or interspersed with asphaltic or authigenic carbonate outcrops that hosted coral and sponge-based communities. These exposures and their communities are like oases in broad expanses of sediment.

The rocks and sediments collected will be analyzed for chemical composition and age to increase understanding of how these features formed. The rock samples were primarily collected from exposed siliciclastic and carbonate rock outcrops, but also included authigenic carbonate rock, asphalt, a fossilized coral, and a fossilized burrow cast or bone.

Twelve dives were conducted on the West Florida Escarpment, the steep western slope of the Florida Platform, to better understand its geological composition and origins. Some of the dive sites featured exposed carbonate formations with amphitheater-like features and steep cliff faces often encrusted with ferromanganese deposits. Carbonate deposits were usually exposed only on very steep slopes. Gentler slopes were either completely covered by sediment or had only very small exposed surfaces. The expeditions also explored previously unmapped and unexplored sinkholes on the Pourtales Terrace, the deep shelf south of the Florida Keys.

ARCHAEOLOGY HIGHLIGHTS

ROVs were used to explore five suspected cultural heritage sites in the Gulf. Bureau of Ocean Energy Management archaeologists identified one of the wrecks as an early nineteenth-century copper-clad merchant vessel. Visible artifacts included glass bottles, ceramic and porcelain vessels, remnants of a suction bilge pump with cast-iron flywheels, an anchor, and a cast iron stove. Draft marks on the bow indicated that at least four vertical meters of hull were buried in the seafloor, so the full nature and extent of the cargo could not be determined. Working with BOEM archaeologists, *Deep Discoverer* ran a series of video transects along and across the wreck's forepart to supply the imagery required for making a three-dimensional digital reconstruction.

Expedition archaeologists and scientists also conducted the first exploration of the sunken tug boat *New Hope* (Figure 5). In 1965, the US Coast Guard performed a daring helicopter rescue to save the vessel's crew during Tropical Storm Debbie. All lives were saved. Information collected during the dive confirmed the identity of the wreck, and could help support an application for the *New Hope* shipwreck to be added to the National Register of Historic Places.

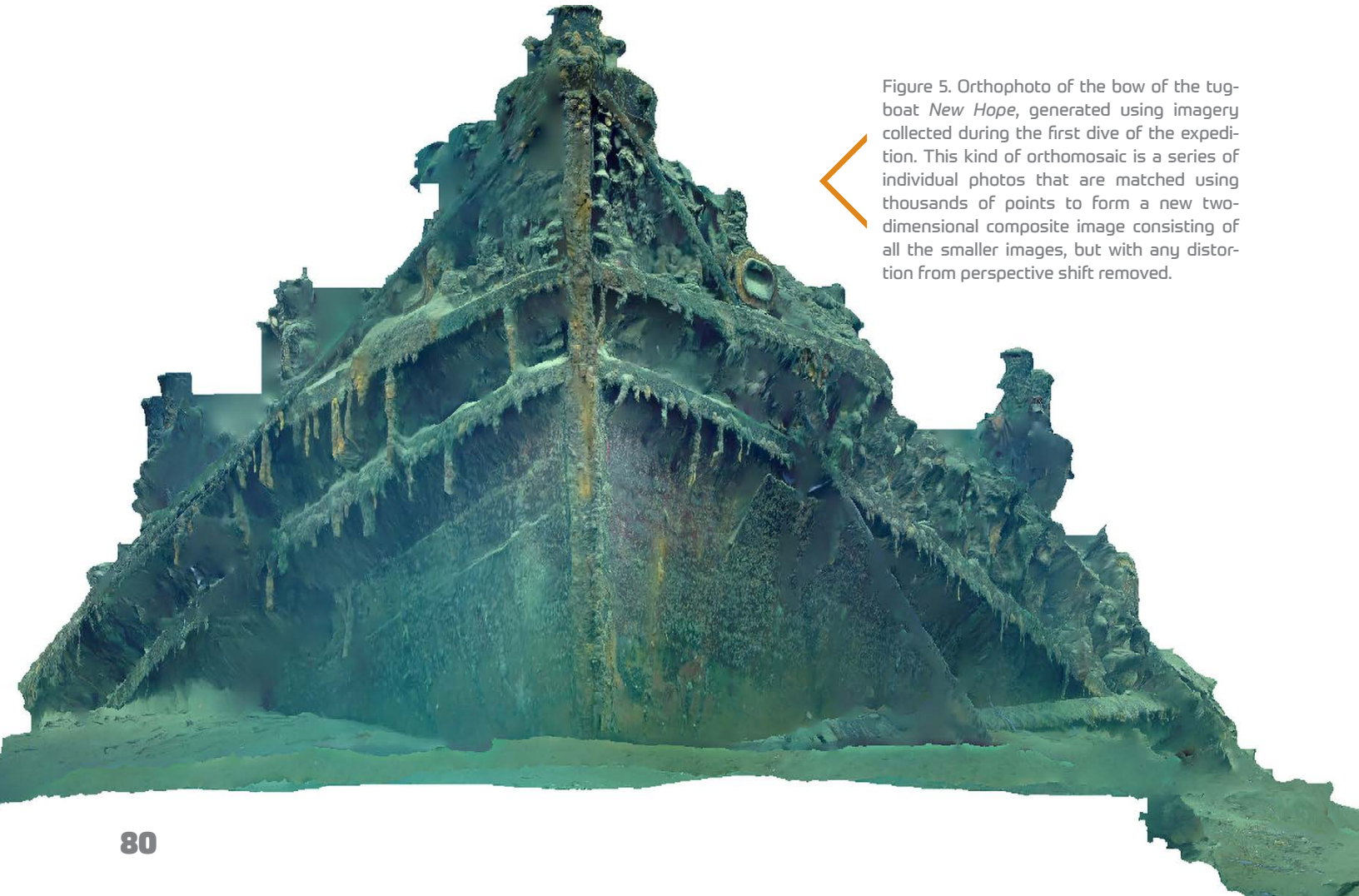

Figure 5. Orthophoto of the bow of the tugboat *New Hope*, generated using imagery collected during the first dive of the expedition. This kind of orthomosaic is a series of individual photos that are matched using thousands of points to form a new two-dimensional composite image consisting of all the smaller images, but with any distortion from perspective shift removed.

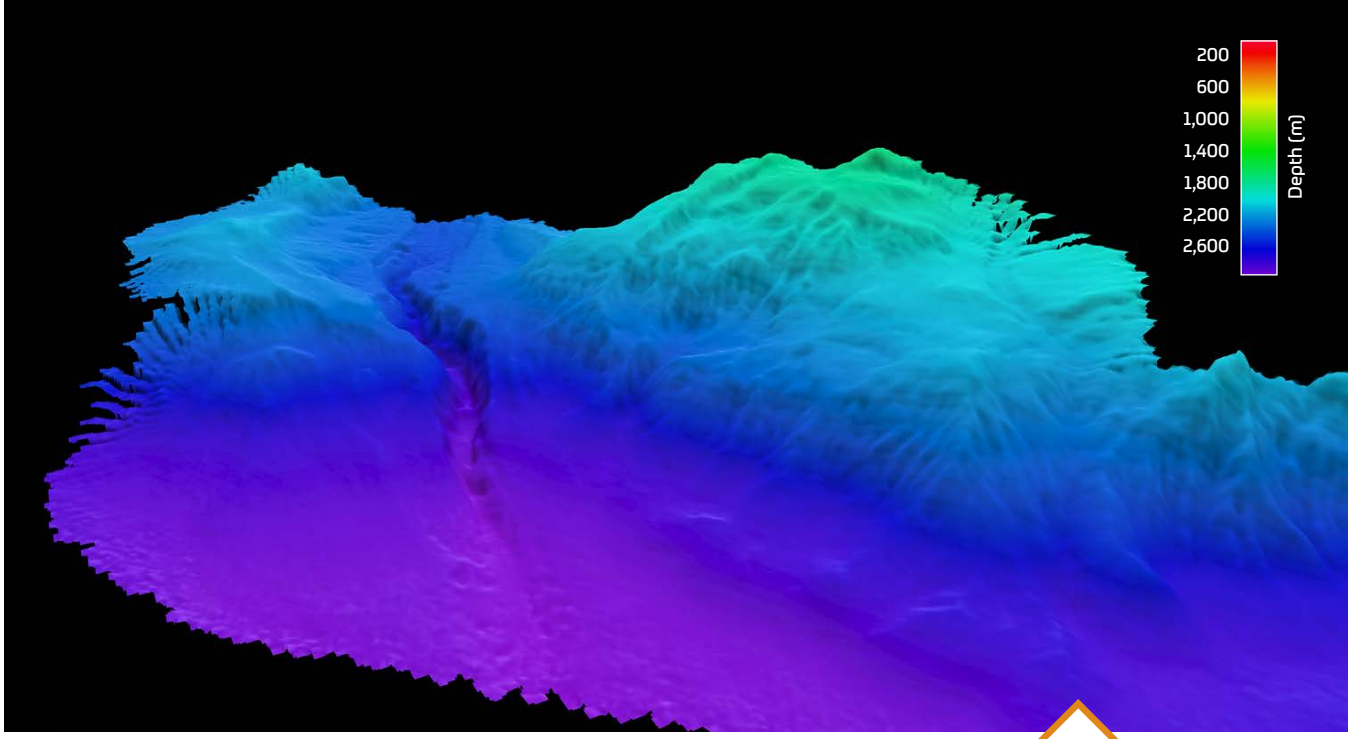

Figure 6. Perdido Canyon was identified as a high priority by the scientific community as an unexplored area of the Gulf of Mexico. The onboard team was able to map this canyon and provide publicly available high-resolution multibeam bathymetry for the first time.

MAPPING HIGHLIGHTS

During the three expeditions, areas where high-resolution mapping data are not available publicly were targeted, such as portions of Perdido Canyon in the far western Gulf (Figure 6), Pourtales Terrace, and the West Florida Escarpment. Multibeam mapping operations also revealed sonar anomalies likely to be gas seeps, one at Whiting Dome and another at Walker Ridge 488, both offshore of the mouth of the Mississippi River. Nighttime operations acquired high-resolution mapping data over potential ROV dive sites chosen to support dive planning.

The science team used seafloor backscatter data to target areas likely to be hard ground during subsequent ROV dives. In addition to identifying potential gas seeps, water column mapping data were used to image part of an oil platform. By identifying the exact location of the cables in the water column, the team was able to successfully plan and execute an ROV archaeology dive within close proximity to the oil platform.

SUPPORTING MANAGEMENT

One of the primary goals of the expeditions was to explore areas that are a priority for resource managers. To that end, seven proposed Habitat Areas of Particular Concern (HAPCs) that are under consideration by the Gulf of Mexico Fishery Management Council were surveyed. Four of the sites host high-density coral and sponge communities and one has extensive chemosynthetic communities. In addition to informing Council resource managers, the expeditions explored eight sites that are included in some of the Flower Garden Banks National Marine Sanctuary proposed expansion zones. High-diversity and high-density coral and sponge communities were discovered at two areas, including a spectacular *Madrepora oculata* coral garden. Chemosynthetic communities located at sites of brine rivers and asphalt seeps were observed in five of the areas under consideration for inclusion into the Sanctuary.

SUMMARY

Because of its proximity to the US mainland and its extensive exploitation by industry, the Gulf of Mexico is often regarded as well explored. However, the many new findings of the 2017–2018 *Okeanos Explorer* Gulf of Mexico expeditions highlight that there is still much to be discovered and learned about this important body of water. Over half of the ROV dives documented species potentially new to science or behaviors that had never been previously observed. In addition to exploratory information gathering, these expeditions acquired data in priority areas identified by the resource management and scientific communities. Specifically, the expeditions explored the habitats of deep-sea corals and sponges, as well as those of midwater and chemosynthetic communities—several of which are in areas that have been proposed as new marine managed areas. Marine cultural heritage sites were also explored. Information obtained during these expeditions will help inform management about the diverse and rich communities living in the deep waters of the Gulf of Mexico that help support the region's Blue Economy.