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STUDY TITLE: Deepwater Program: Foraminiferal Communities of Bathyal and Abyssal Hydrocarbon Seeps, Northern Gulf of Mexico: A Taxonomic, Ecologic, and Geologic Study

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KEY WORDS: Foraminifera, Gulf of Mexico, hydrocarbon seeps, tubeworms, epibenthic, endobenthic

BACKGROUND: Marine hydrocarbon seeps ("cold seeps"), especially those of the Gulf of Mexico, have been the subject of many studies because, like hydrothermal vents ("hot vents"), they support a complex community of organisms in a chemosynthesis-based ecosystem. The present study relates to a very large group of shelled protists, namely benthic Foraminifera, that live in seep-related substrates. This is frequently the most abundant meiofaunal group in diverse marine habitats. Foraminiferal species respond rapidly to environmental disturbances, and their large extant populations and well-preserved shells make them excellent recorders of present and past marine biodiversity. Some species are capable of inhabiting environments where oxygen is depleted to extremely low levels, or even absent. Hydrocarbon seeps provide a special window to study the Foraminifera of such dysoxic and anoxic environments, and to assess long-term effects of petroleum pollution on foraminiferal communities.

Our preliminary studies of the Foraminifera associated with Gulf of Mexico hydrocarbon seeps, especially those found in or under bacterial (*Beggiatoa*) mats, had indicated the existence of facultative anaerobes within this community. These studies, however, were

too limited in scope for an understanding of spatial and temporal distribution trends, and for an assessment of diversity and abundance anomalies. In particular, the composition of seep foraminiferal communities in the Gulf of Mexico at depths greater than 700 m was wholly unknown at the commencement of the present study.

OBJECTIVES: The principal objectives were as follows:

- Identification and illustration of benthic foraminiferal species present in seafloor sediments and on surfaces of vestimentiferan tubeworms;
- Preparation of a numerical database of species abundances, and computation of species-diversity measures;
- Analysis of foraminiferal community structure in relation to water depth and substrate composition;
- Assessment of the effects of CH_4, H_2S, and liquid petroleum on the survival or proliferation of foraminiferal species in seep environments; and
- Recognition of anoxia-tolerant foraminiferal species (facultative anaerobes or microaerophiles) in seep environments.

DESCRIPTION: The investigation involved a quantitative analysis of foraminiferal assemblages retrieved from various shallow and deep bathyal seepage areas in the northern Gulf of Mexico. Sediment cores and tubeworm clumps were obtained during submersible dives in Alaminos Canyon, De Soto Canyon, Farnella Canyon, Garden Banks, Green Canyon, and Mississippi Canyon in water depths of 245-2918 m. The foraminiferal microhabitats included bacterial (*Beggiatoa*) mats, mussel beds, substrates of tubeworm colonies, and inorganic sediments around points of hydrocarbon seepage and at control sites away from seeps. In addition, a presence-absence census was also conducted for epibenthic species attached to tubeworm surfaces. Scanning electron micrographs were taken of all species for which suitable specimens were found; some digital photomicrographs were also taken, especially of species attached to tubeworms.

SIGNIFICANT CONCLUSIONS:

(1) There are no seep endemics among the 185 identified species of benthic Foraminifera, even among the 21 that were previously unknown in the Gulf of Mexico.

(2) The imprint of water depth on foraminiferal assemblages is clearly detectable because the species are recruited from the surrounding non-seep habitats.

(3) Foraminiferal species of wide-ranging morphologic and taxonomic affinities are able to maintain sizeable populations at sites of hydrocarbon seepage.

(4) The high bacterial productivity at northern Gulf of Mexico hydrocarbon seeps is a major factor in sustaining the foraminiferal populations.

(5) The presence of oil in surface and subsurface sediments has no conspicuous effect on the dominant foraminiferal species of hydrocarbon seeps.

(6) The abundance of *Cibicides wuellerstorfi* in seep sediments is an evidence of post-mortem assemblage mixing; *C. wuellerstorfi* is an elevated-epibenthic species of deep bathyal to abyssal depths, and is intolerant of anoxia or dysoxia.

(7) In the shallower sampling areas, the diversity (species richness) of both calcareous and agglutinated Foraminifera is higher in non-seep than in seep substrates.

(8) Epibenthic species attached to vestimentiferan tubeworms are not affected by the oxygen depletion and H_2S toxicity at the sediment-water interface.

STUDY RESULTS: One hundred eighty-five species of benthic Foraminifera were identified; 122 species were calcareous, 63 agglutinated. An atlas of species illustrations is included in the final report.

No species found in this study is endemic to seeps, but 21 species were previously unknown in the Gulf of Mexico. The imprint of water depth on foraminiferal assemblages is clearly detectable because the species are recruited from the surrounding non-seep habitats. The two major surface-sample groups (clusters) recognized by numerical data analysis are separated by bathymetry. The shallower-water group contains all samples (seep and non-seep) from depths of 245-1081 m; the deeper-water (deepest-bathyal) group contains all samples from 1848-2918 m. Foraminiferal species of wide-ranging morphologic and taxonomic affinities are able to maintain sizeable populations at sites of hydrocarbon seepage; the high bacterial productivity at the seeps is a major factor in the sustenance of these populations. The most conspicuous dominants at seep-influenced substrates (bacterial mats) in the shallower cluster are endobenthic species, especially *Bolivina* spp.; these are possibly facultative anaerobes. The pattern is not as clear in the deepest-bathyal group, because some epibenthic species (e.g., *Nuttallides decorata*) are present among the dominants. In the shallower areas, the diversity (species richness) of both calcareous and agglutinated Foraminifera is higher in non-seep than in seep substrates. This distinction too is not clear in the deepest-bathyal areas. The diversity at some sites may have been elevated by post-mortem mixing of species from different microhabitats. Fifteen sessile, epibenthic Foraminifera colonize surfaces of vestimentiferan tubeworms (and possibly other elevated microhabitats) at hydrocarbon seeps, centimeters to decimeters above the sediment-water interface. These attachment points are sufficiently above locations of gas escape in the seafloor to provide the species with an oxic microhabitat with little or no H_2S. Eight of these species have been found exclusively on tubeworms in this study.

STUDY PRODUCTS:

Sen Gupta, B.K., E. Platon, and M. Lobegeier. 2002. Benthic Foraminifera of Gulf of Mexico cold seeps. First International Paleontological Congress, Sydney, Abstracts. p. 142-143.

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Sen Gupta, B.K., M.K. Lobegeier, and L.E. Smith. 2009. Foraminiferal communities of bathyal hydrocarbon seeps, northern Gulf of Mexico: A taxonomic, ecologic, and geologic study. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2009-013, 380 pp.

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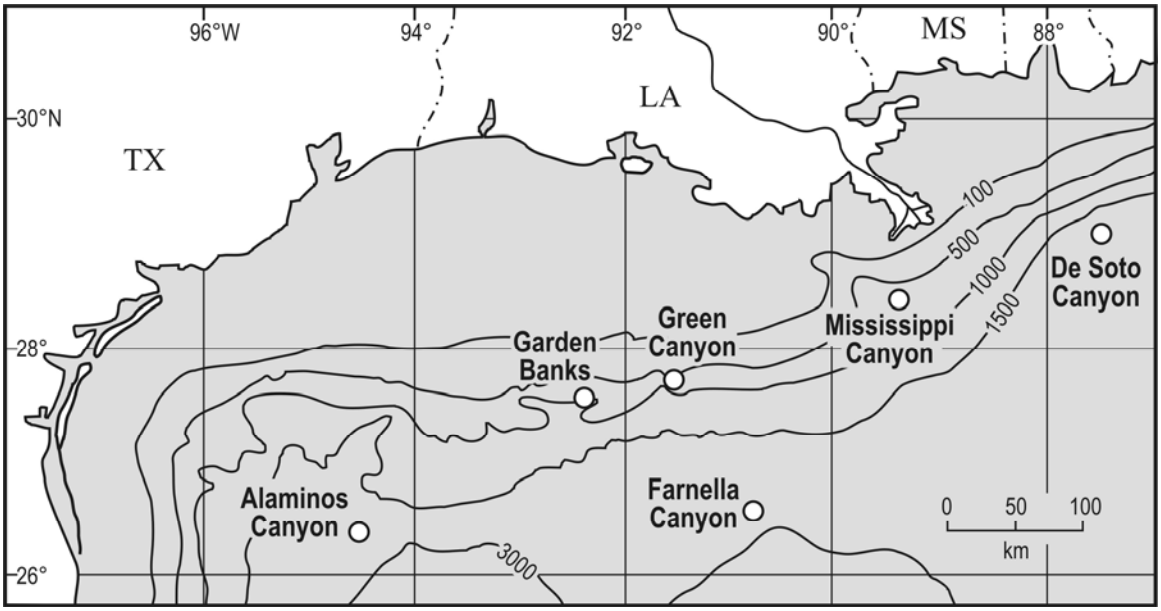

Figure 1. Sampling sites.