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# Spatial distribution of seafloor bio-geological and geochemical processes as proxies of fluid flux regime and evolution of a carbonate/hydrates mound, northern Gulf of Mexico

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ABSTRACT

Woolsey Mound, a carbonate/hydrate complex of cold seeps, vents, and seafloor pockmarks in Mississippi Canyon Block 118, is the site of the Gulf of Mexico Hydrates Research Consortium's (GOMHRC) multi-sensor, multi-disciplinary, permanent seafloor observatory. In preparation for installing the observatory, the site has been studied through geophysical, biological, geological, and geochemical surveys. By integrating high-resolution, swath bathymetry, acoustic imagery, seafloor video, and shallow geological samples in a morpho-bio-geological model, we have identified a complex mound structure consisting of three main crater complexes: southeast, northwest, and southwest. Each crater complex is associated with a distinct fault. The crater complexes exhibit differences in morphology, bathymetric relief, exposed hydrates, fluid venting, sediment accumulation rates, sediment diagenesis, and biological community patterns. Spatial distribution of these attributes suggests that the complexes represent three different fluid flux regimes: the southeast complex seems to be an extinct or quiescent vent; the northwest complex exhibits young, vigorous activity; and the southwest complex is a mature, fully open vent. Geochemical evidence from pore-water gradients corroborates this model suggesting that upward fluid flux waxes and wanes over time and that microbial activity is sensitive to such change. Sulfate and methane concentrations show that microbial activity is patchy in distribution and is typically higher within the northwest and southwest complexes, but is diminished significantly over the southeast complex. Biological community composition corroborates the presence of distinct conditions at the three crater complexes. The fact that three different fluid flux regimes coexist within a single mound complex confirms the dynamic nature of the plumbing system that discharges gases into bottom water. Furthermore, the spatial distribution of bio-geological processes appears to be a valid indicator of multiple fluid flux regimes that coexist at the mound.



## 1. Introduction

Hydrate mounds are unique seafloor sites characterized by an extraordinary variability of bio-geological processes; the vent gas and gas hydrate are intimately associated with complex chemosynthetic communities, whose initiation and stability depend upon hydrocarbon-driven microbial activity in sediments, including microbial hydrocarbon oxidation, reduction of $CO_2$ via methanogenesis, sulfate reduction, and sulfide oxidation (Sassen et al., 1993, 1998, 2004). Microbial processes contribute to the development and stability of chemosynthetic communities by providing required $H_2S$. Anaerobic microbial processes lead to deposition of diagnostic authigenic minerals related to the carbon (carbonate minerals) and sulfur cycles (pyrite, elemental sulfur) that alter the structure of the seafloor. Seafloor cementation promotes the formation of carbonate hard-grounds that provide a hospitable environment for hard-bottom fauna, such as chemosynthetic tubeworms and seep mussels (Sassen et al., 2004). Hydrate mounds, therefore, represent unique sites for understanding the relationships between hydrate formation and dissociation, vent activity, sediment diagenesis, bacterial activity, and faunal distribution.

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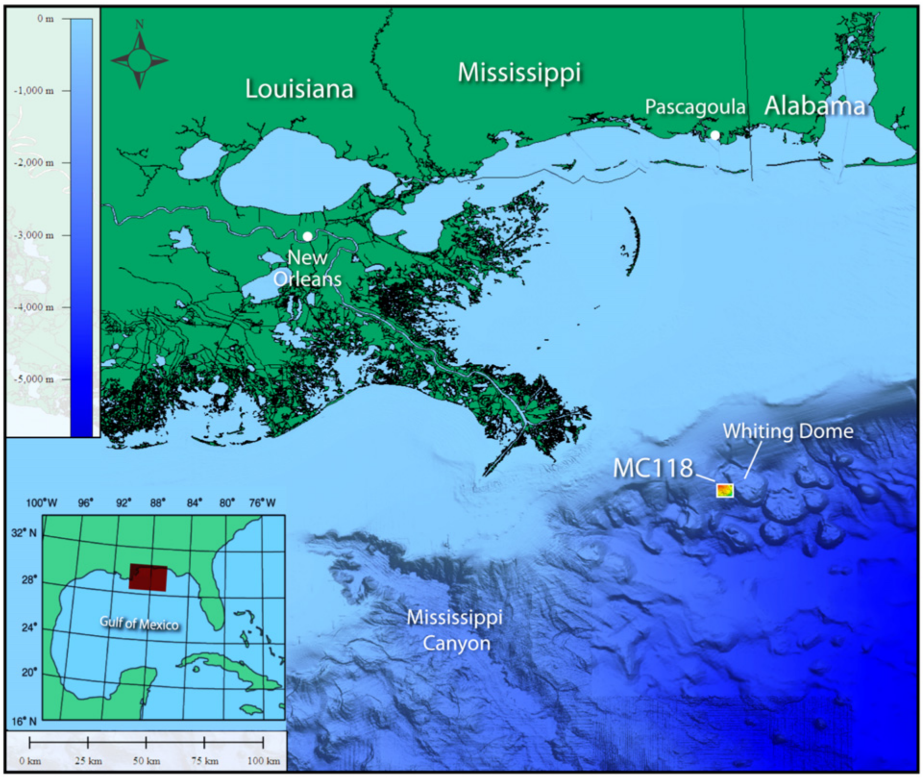


**Fig. 1.** Location of Mississippi Canyon block 118 (MC118).

The Woolsey Mound at Mississippi Canyon Block 118 (MC118) is an example of a complex carbonate/hydrate mound fed by an intricate system of faults overlying shallow salt and thereby with access to deeply-buried source rocks for gas and oil (Macelloni et al., 2012). Several submersible missions to the seafloor have identified large gas hydrate exposures, authigenic carbonate deposits, several vents of methane and oil bubbles, and chemosynthetic communities, including ice worms (Sassen and Roberts, 2004; Woolsey et al., 2005). For these compelling reasons, MC118 was chosen, in 2004, by the Gulf of Mexico Hydrates Research Consortium (GOMHRC) as the site for a long-term, gas hydrate monitoring station (McGee, 2006; Lutken et al., 2011a). In order to characterize the site in preparation for installation of station components, and to build the baseline model to which to compare long-term monitoring observations, MC118 has been investigated extensively using a wide range of geophysical, geological, and biogeochemical studies. Field investigations have targeted both the mound's subsurface – i.e., source of hydrocarbon gases (Lapham et al., 2008)), mechanism of fluid transport, and geometry of the shallow plumbing system – and processes ongoing at the mound's surface including hydrates formation and exposure, gas venting, sediment distribution, and faunal occurrence and distribution. Such observations have fostered the opportunity to assess marine gas hydrates formation/dissociation in a complex natural system.

The purposes of this paper are:

1) To present the methodology we adopted to build a conceptual model of the spatial distribution of bio-geological processes on the Mound;
2) To investigate the relationship between the spatial distribution of the bio-geological processes and the hydrocarbon fluid flux regime; and
3) To derive the conceptual model that links the hydrocarbon fluid flux regime, fault activity, and hydrates formation/dissociation with mound formation/evolution.

## 2. Site location

MC118 is located approximately 170 km south of Pascagoula, Mississippi, and 100 km east of the Mississippi Canyon in ~890 m of water (Fig. 1). The site is located on a gently seaward dipping (3° to 4°) portion of the continental slope. A fault-controlled canyon, flanking the Whiting Dome and slump structure to the east, is the only other prominent morphological feature present in the block (Fig. 1).

Near MC118, on the upper slope, there is evidence, particularly from bathymetry, of salt domes in the nearby shallow subsurface (Fig. 1). Exposures of gas hydrates, faulted carbonate hardgrounds and pockmark features consistent with gas and petroleum seepage cover approximately 1 $km^2$ of the seafloor at MC118 (e.g., Sassen et al., 2006; Sleeper et al., 2006). The supply of hydrocarbons (natural gas and petroleum) to the seafloor supports an active biological seep community and microbial chemolithotrophy in the immediate vicinity of active gas–fluid seepage.

## 3. Materials and methods

### 3.1. Multibeam echo-sounder data

A complete high-resolution, high-precision, bathy-morphological survey was executed in 2005 by C&C Technologies (Lafayette, La.) using a HUGIN 3000 Autonomous Underwater Vehicle (AUV). The AUV was equipped with a Simrad EM 2000 multibeam bathymetry system, a dual frequency (120 and 240 kHz) side-scan sonar, and a 2–10 kHz chirp sub-bottom profiler. The Simrad EM 2000 is a high-frequency echo-sounder that simultaneously records high-resolution depth data and co-registered acoustic backscatter. Depth data have been post-processed combining standard and non-standard processing techniques described by Bosman (2004) and Bosman et al. (2009).