Exploration and discovery in Gulf of Mexico hypersaline brines Mandy Joye, UGA Marine Sciences, mjoye@uga.edu

Brine volcano, Green Canyon, Gulf of Mexico

Gulf of Mexico – a hydrocarbon basin underlain by salt



https://www.boem.gov/oil-gas-energy/mapping-and-data/map-gallery/northern-gom-deepwater-bathymetry-grid-3d-seismic

Gulf of Mexico





derlain by salt



Joye, Ann. Rev. Earth Planet. Sci.

Key Research Questions/Discoveries

Questions – 1) document variability in microbiology, microbial activity and biogeochemistry between brine pool, brine basin, and mud volcano sites; **explore the fidelity of functional and phylogenetic diversity; assess the regulation of microbial activity** across sites; **determine the primary sources of metabolic energy and cell carbon** to support microbial growth.

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Questions – 1) document variability in microbiology, microbial activity and biogeochemistry between brine pool, brine basin, and mud volcano sites; 2) explore the fidelity of functional and phylogenetic diversity; 3) assess the regulation of microbial activity across sites; 4) determine the primary sources of metabolic energy and cell carbon to support microbial growth.

Discoveries – 1) microbial communities in brines are extremely diverse; halophilic methanogens, halotolerant fermenters, and sulfur oxidizers are common; 2) across brine site types - despite differences in system dynamics and biogeochemistry - some classes of organisms persist (Thermoproteota, Gammaproteobacteria, Epsilonproteobacteria); 3) sulfate reduction and anaerobic oxidation of methane are highest in interfacial samples where normal sediments and brine-influenced sediments intersect; 4) methanogenesis rates peak in core brine samples; 5) chemical priming seems to offset salt-inhibition -- high concentrations of dissolved organic carbon and inorganic phosphorus and nutrients fuel microbial activity and support biomass accumulation; 6) brines are sources of key nutrients and organic carbon to the deep sea.

Finding a needle (mud volcano) in a haystack (complex geology)

Use available (industry) data to identify prospective sites



Towed camera or AUV surveys to confirm





Sample site with ALVIN or JASON



(https://www2.whoi.edu/site/miso/)



Brine lake shoreline



Fig. 2. Alaminos Canyon 601 Brine Lake and mud volcano, a From left to right: the brine lake

Barite crystals in brine

Heart urchins along shore

Sulfur oxidizing Microbial mats

Iron oxides mark recent mud flows

Teske & Joye 2020

<u>AC601</u>



Sediment Geochemistry

Table 1 Geochemical analysis of samples from AC601 brine lake					
	40 m control	3 m control	Upper halocline	Lower halocline	Bottom
Average pH Average	7.5 36	7.4 47	7.3 57	6.7 85	6.8 87
salinity (PSU)					
Geochemical in	nventories (µr	mol cm ⁻²):			
CH₄	0.03	3.6	7.8	18.6	12.8
DIC	30	99	145	166	111
DOC	12	14	21	16	16
H ₂ S	0	47	82	10	8
SO ₄ ²⁻	409	257	107	28	20
PO ₄ ³⁻	0.1	0.1	0.3	0.4	0.4
DON*	0.6	n.d.	7	16	n.d.
TDN	2	4	15	31	24

Crespo-Medina et al., Geobiology, DOI: 10.1111/gbi.12185

<u>AC601</u>



Microbial Activity



Sulfate reduction is limited by sulfate availability

Crespo-Medina et al., Geobiology, DOI: 10.1111/gbi.12185

<u>AC601</u>



Microbial Community Composition



Fig. 5 Bacterial (A) and Archaeal (B) diversity at different sites within AC601 brine lake based on the results of the16S rRNA gene clone libraries.

Crespo-Medina et al., Geobiology, DOI: 10.1111/gbi.12185

Comparison across brines

Archaea





Marine Group I (Thermoproteota) dominate most brines;

Halophilic methanogens are also very common

-Legend-

Archaea;Euryarchaeota;Halobacteria Archaea;Euryarchaeota;Methanobacteria Archaea;Euryarchaeota;Methanomicrobia Archaea;Euryarchaeota;Thermoplasmata Archaea;Euryarchaeota;Class_NA Archaea;Thaumarchaeota;Group_C3 Archaea;Thaumarchaeota;Marine_Benthic_Group_A Archaea;Thaumarchaeota;Marine_Benthic_Group_B Archaea;Thaumarchaeota;Marine_Group_I * Archaea;Thaumarchaeota;Marine_Group_I * Archaea;Thaumarchaeota;Marine_Group_I *

Comparison across brines





-Legend-Bacteria;Acidobacteria;Acidobacteriia Bacteria;Acidobacteria;Holophagae Bacteria:Acidobacteria:class NA Bacteria;Acidobacteria;empty_class Bacteria:Actinobacteria:Acidimicrobiia Bacteria:Actinobacteria:Actinobacteria Bacteria:Actinobacteria:Coriobacterija Bacteria:Actinobacteria:Nitriliruptoria Bacteria:Actinobacteria:Rubrobacteria Bacteria;Actinobacteria;Thermoleophilia Bacteria; Actinobacteria; class NA Bacteria:Armatimonadetes:class NA Bacteria:Bacteroidetes:Bacteroidia Bacteria;Bacteroidetes;Cytophagia Bacteria:Bacteroidetes:Flavobacteria Bacteria:Bacteroidetes:Flavobacterija Bacteria;Bacteroidetes;Sphingobacteriia Bacteria:Bacteroidetes:class NA Bacteria;Bacteroidetes;empty_class Bacteria;Caldiserica;Caldisericia Bacteria;Chlorobi;Chlorobia acteria;Chloroflexi;Anaerolineae Bacteria:Chloroflexi:Caldilineae Bacteria:Chloroflexi:Chloroflexi Bacteria:Chloroflexi:Dehalococcoidia Bacteria;Chloroflexi;Ktedonobacteria Bacteria;Chloroflexi;Thermomicrobia Bacteria;Chloroflexi;class NA Bacteria:Cvanobacteria:class NA Bacteria:Cvanobacteria:empty class Bacteria:Deferribacteres:Deferribacteres Bacteria:Deinococcus-Thermus:Deinococci Bacteria:Elusimicrobia:class NA Bacteria:Fibrobacteres:Fibrobacteria Bacteria;Firmicutes;Bacilli Bacteria;Firmicutes;Clostridia Bacteria:Firmicutes:Ervsipelotrichia Bacteria:Firmicutes:Negativicutes Bacteria:Firmicutes:class NA Bacteria: Fusobacteria: Fusobacterija acteria;Gemmatimonadetes;Gemmatimonadetes acteria;Ignavibacteria;Ignavibacteria Bacteria:Lentisphaerae:Lentisphaeria Bacteria:Lentisphaerae:Oligosphaeria acteria:Lentisphaerae:class NA Bacteria:Planctomycetes:Planctomycetacia Bacteria;Planctomycetes;class_NA Bacteria:Proteobacteria:Alphaproteobacteria Bacteria;Proteobacteria;Betaproteobacteria Bacteria;Proteobacteria;Deltaproteobacteria Bacteria:Proteobacteria:Epsilonproteobacteria Bacteria:Proteobacteria:Gammaproteobacteria Bacteria;Proteobacteria;Zetaproteobacteria Bacteria:Proteobacteria:class NA Bacteria:Spirochaetae:Spirochaetes Bacteria;Spirochaetes;class NA Bacteria;Synergistetes;Synergistia Bacteria;Tenericutes;Mollicutes Bacteria;Thermotogae;Thermotogae Bacteria;Verrucomicrobia;Opitutae Bacteria:Verrucomicrobia:Spartobacteri Bacteria:Verrucomicrobia:Verrucomicrobia Bacteria:Verrucomicrobia:class NA

Diverse bacterial communities in **Gulf of Mexico** brines

Sulfur oxidizers, fermenters, and heterotrophs dominate these communities

(brines are enriched In DOC, but sulfate Is limiting)

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EXPLORATION

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