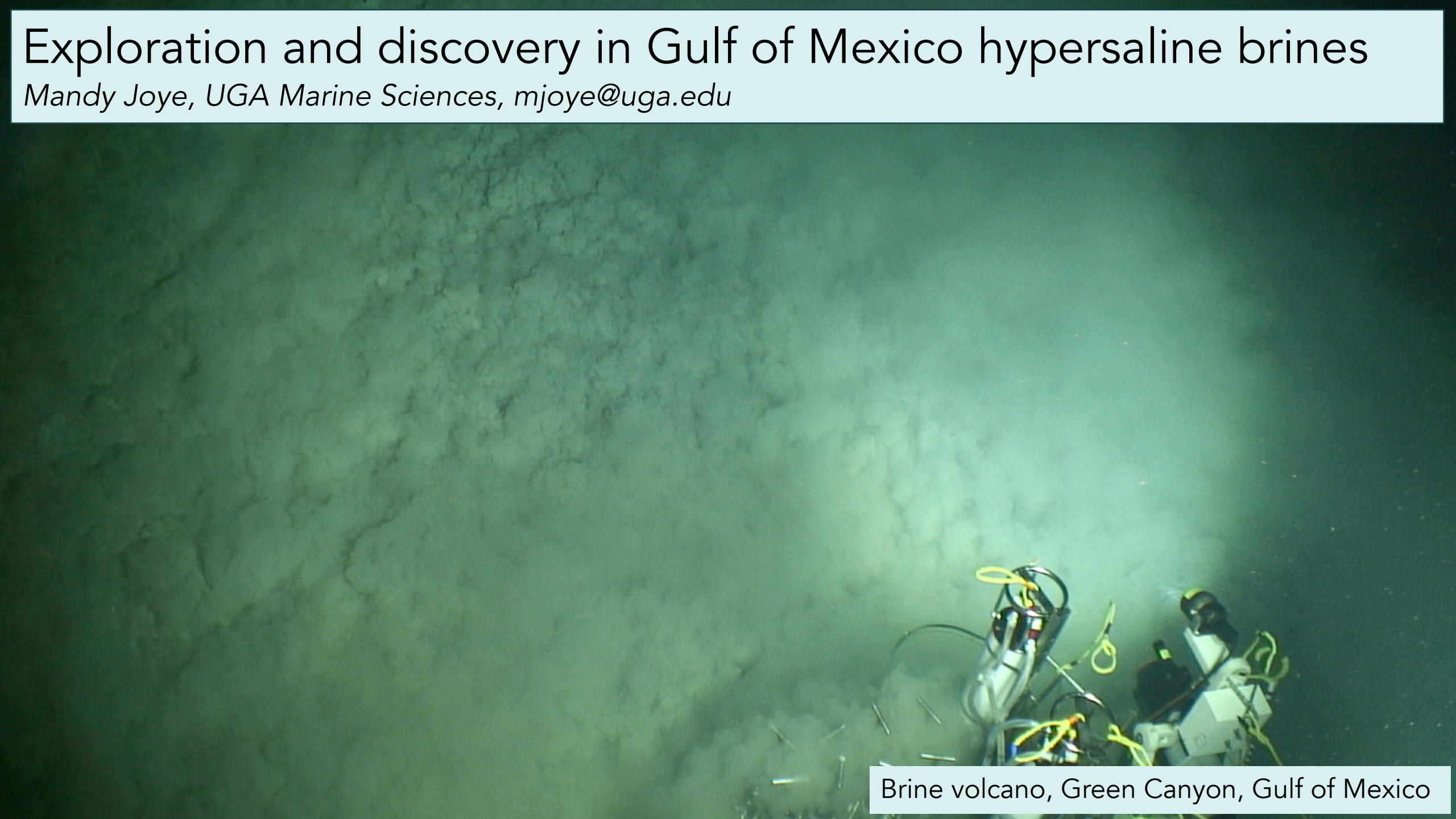
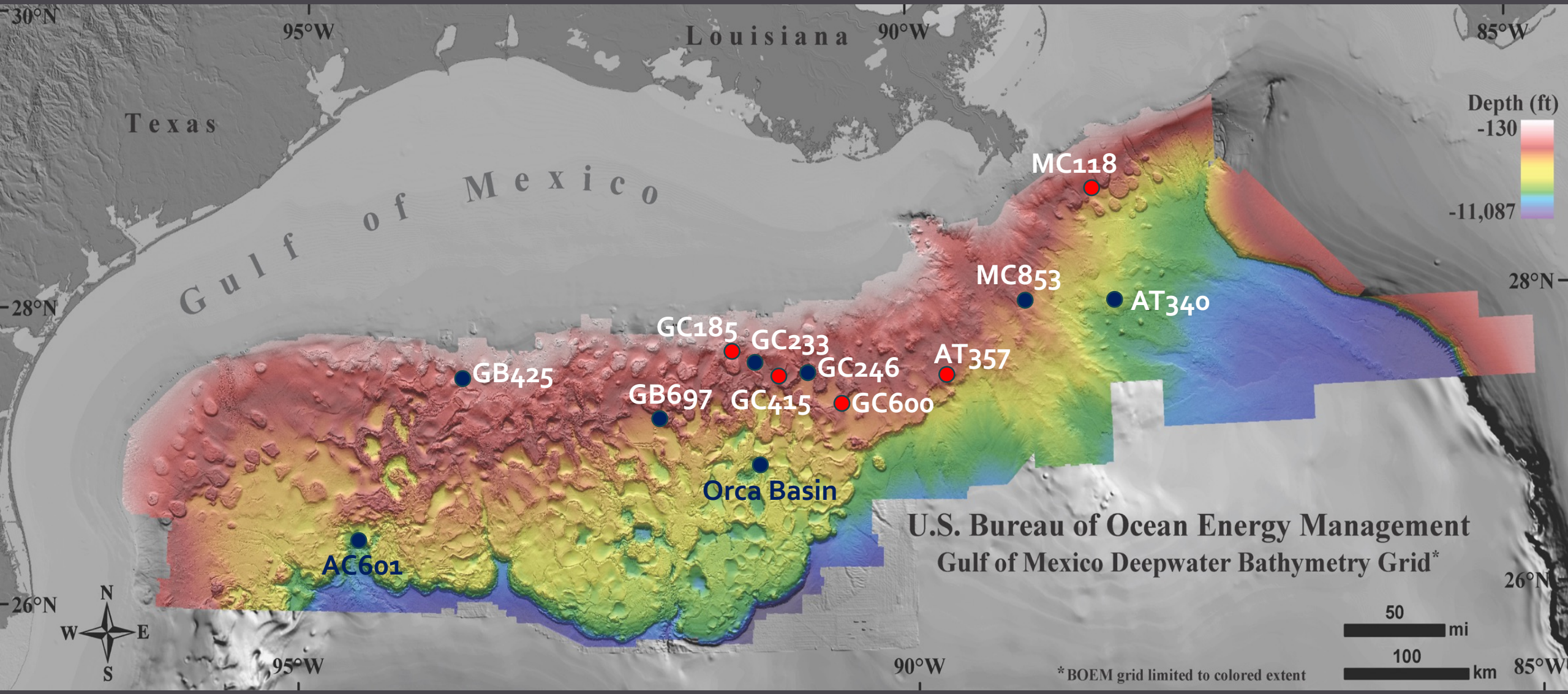
Exploration and discovery in Gulf of Mexico hypersaline brines

Mandy Joye, UGA Marine Sciences, mjoye@uga.edu



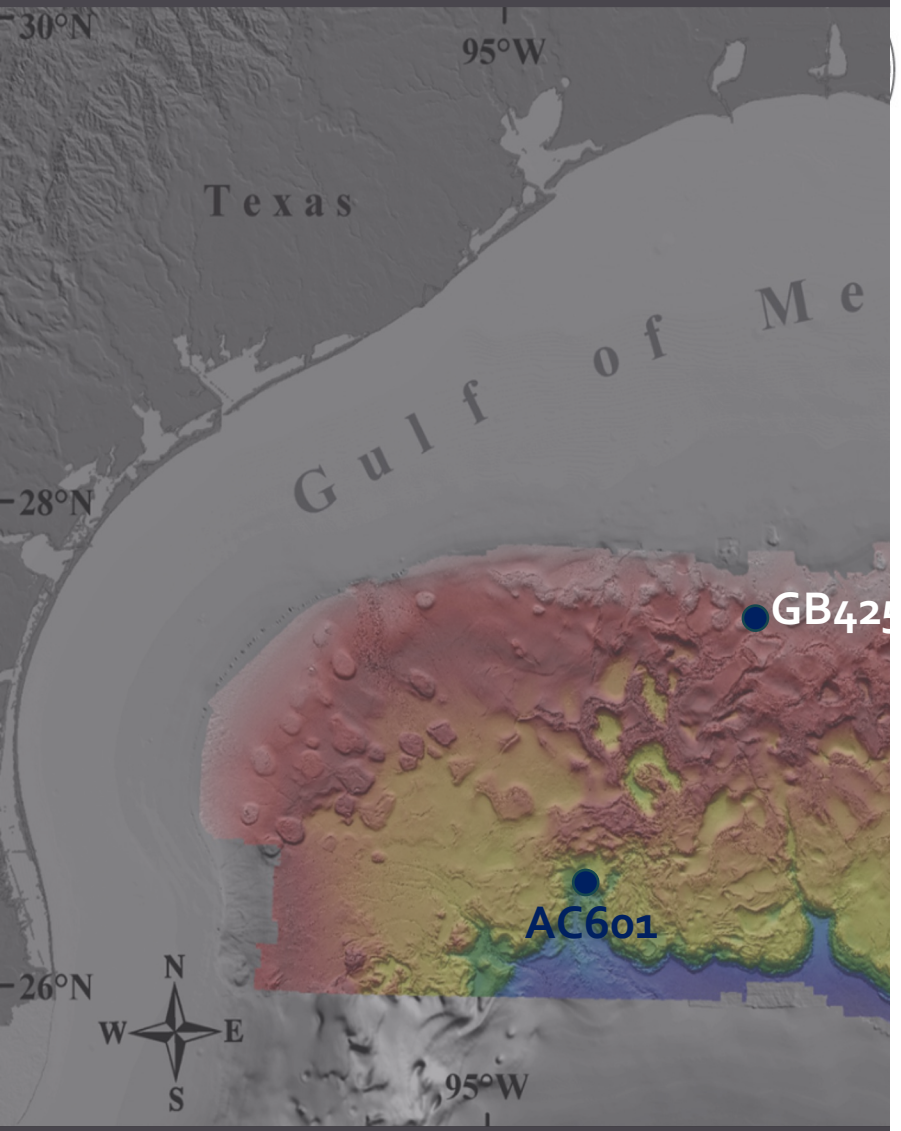
Brine volcano, Green Canyon, Gulf of Mexico

Gulf of Mexico – a hydrocarbon basin underlain by salt

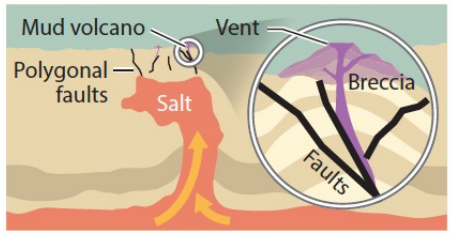


https://www.boem.gov/oil-gas-energy/mapping-and-data/map-gallery/northern-gom-deepwater-bathymetry-grid-3d-seismic

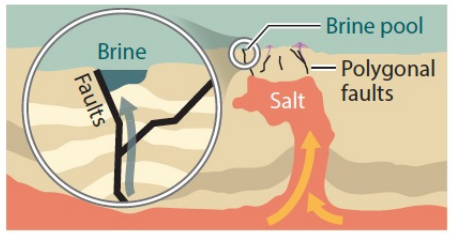
Gulf of Mexico



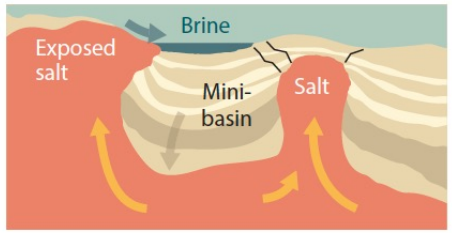
YOUNG
MUD-PRONE
RAPID FLUX



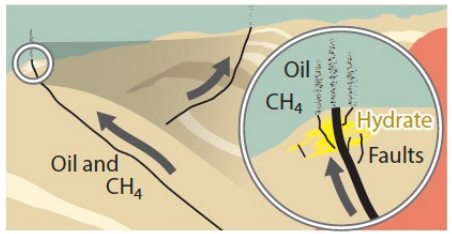
Mud volcanoes



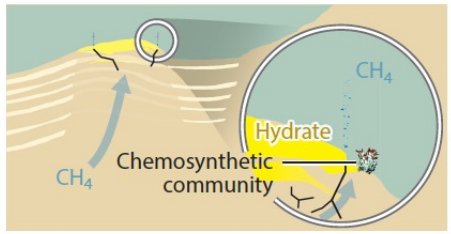
Brine pools



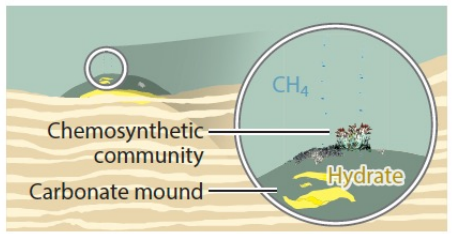
Brine basins



Oil/gas seeps



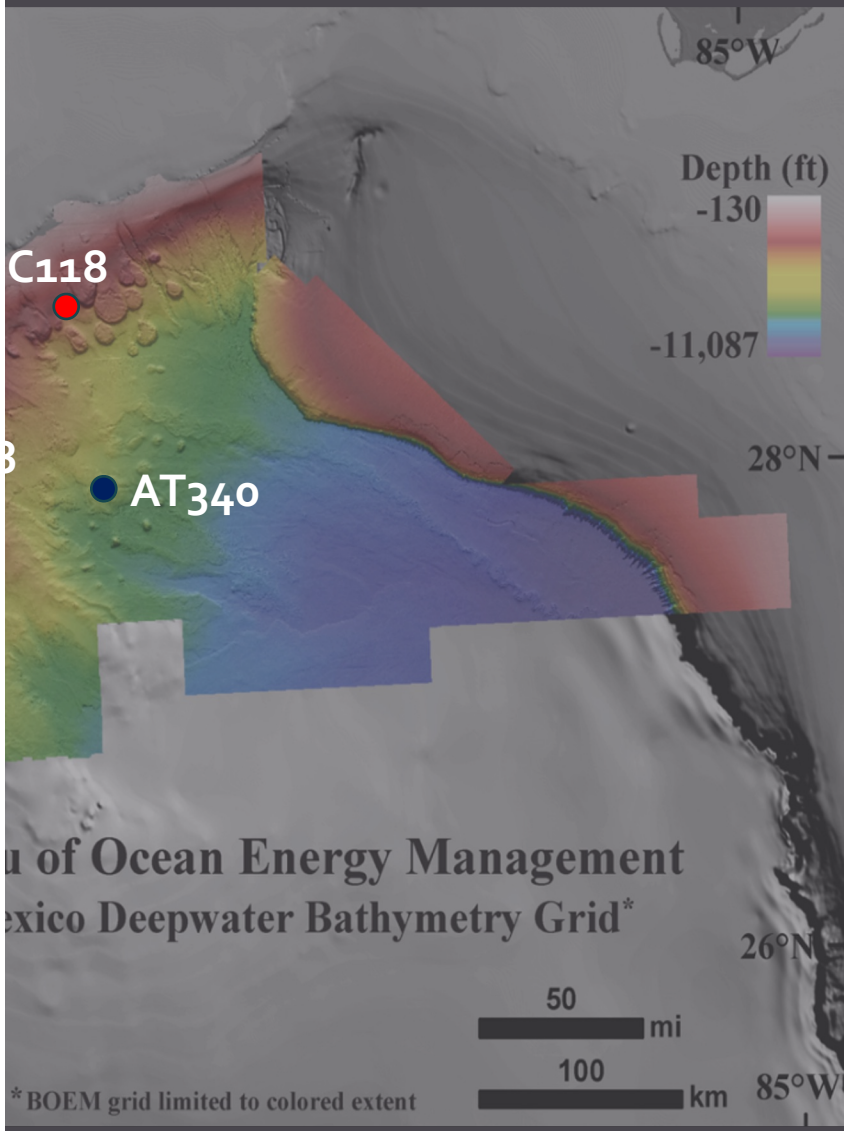
Exposed hydrate



Authigenic carbonate

OLD
MINERAL-PRONE
SLOW FLUX

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.

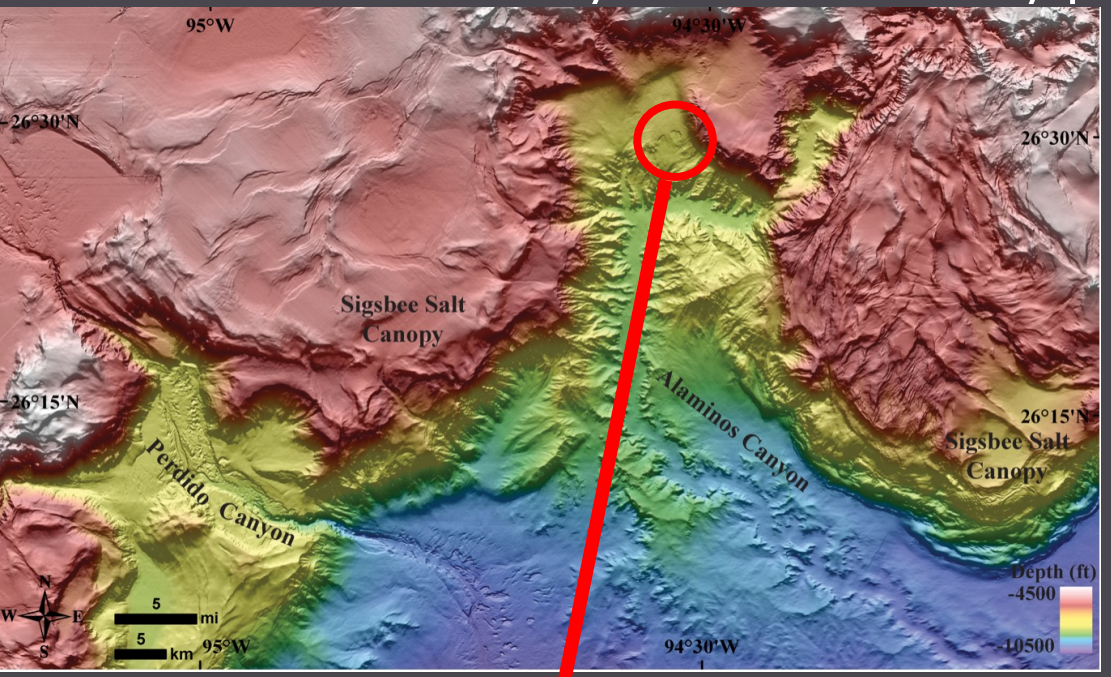
Key Research Questions/Discoveries

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.

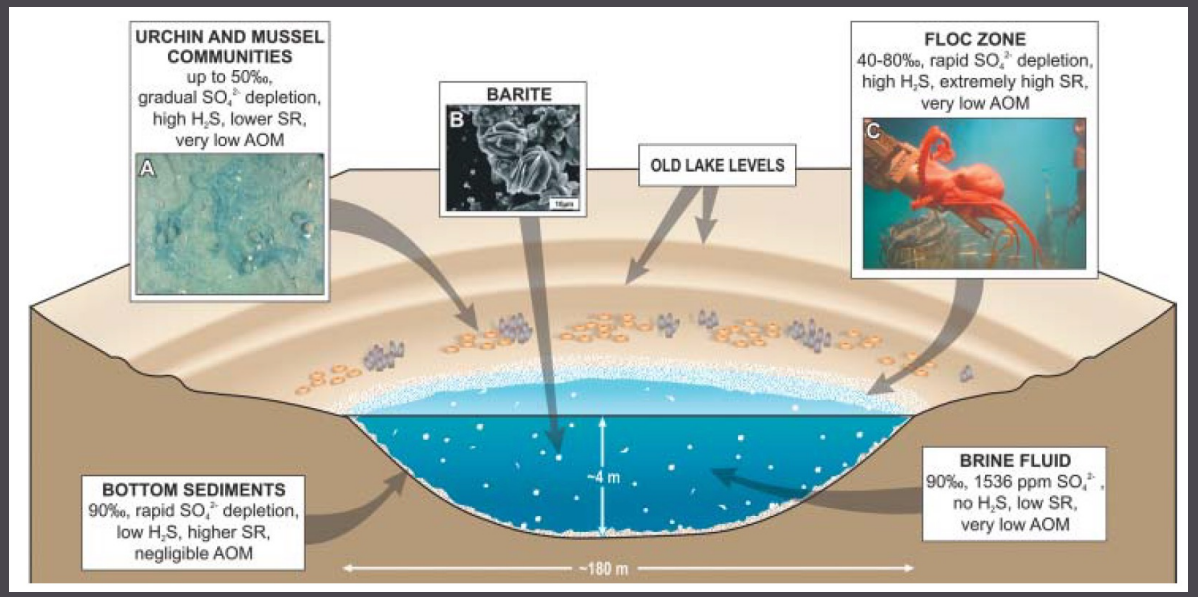
Discoveries – 1) **microbial communities in brines are extremely diverse**; halophilic methanogens, halotolerant fermenters, and sulfur oxidizers are common; 2) across brine site types - despite differences in system dynamics and biogeochemistry - **some classes of organisms persist** (Thermoproteota, 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)

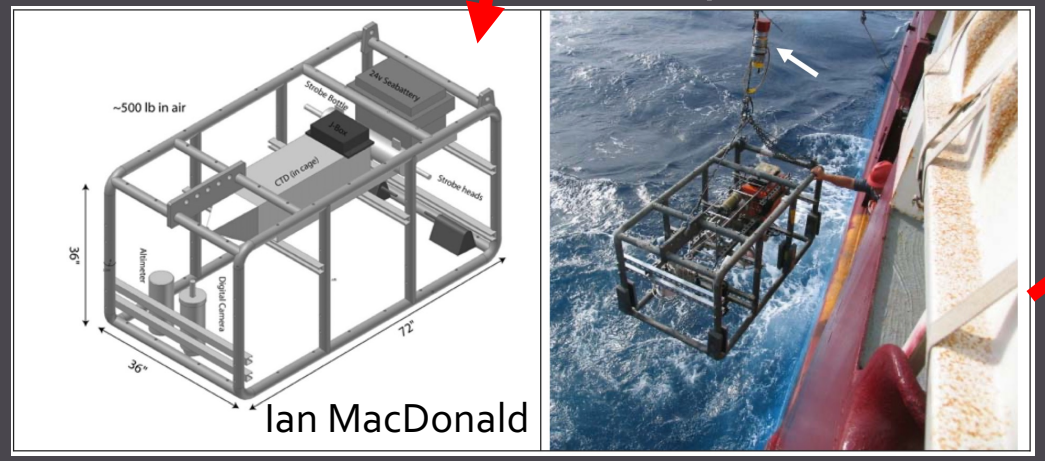
Use available (industry) data to identify prospective sites



Sample site with ALVIN or JASON



Towed camera or AUV surveys to confirm



Ian MacDonald

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

AC601

Brine lake shoreline

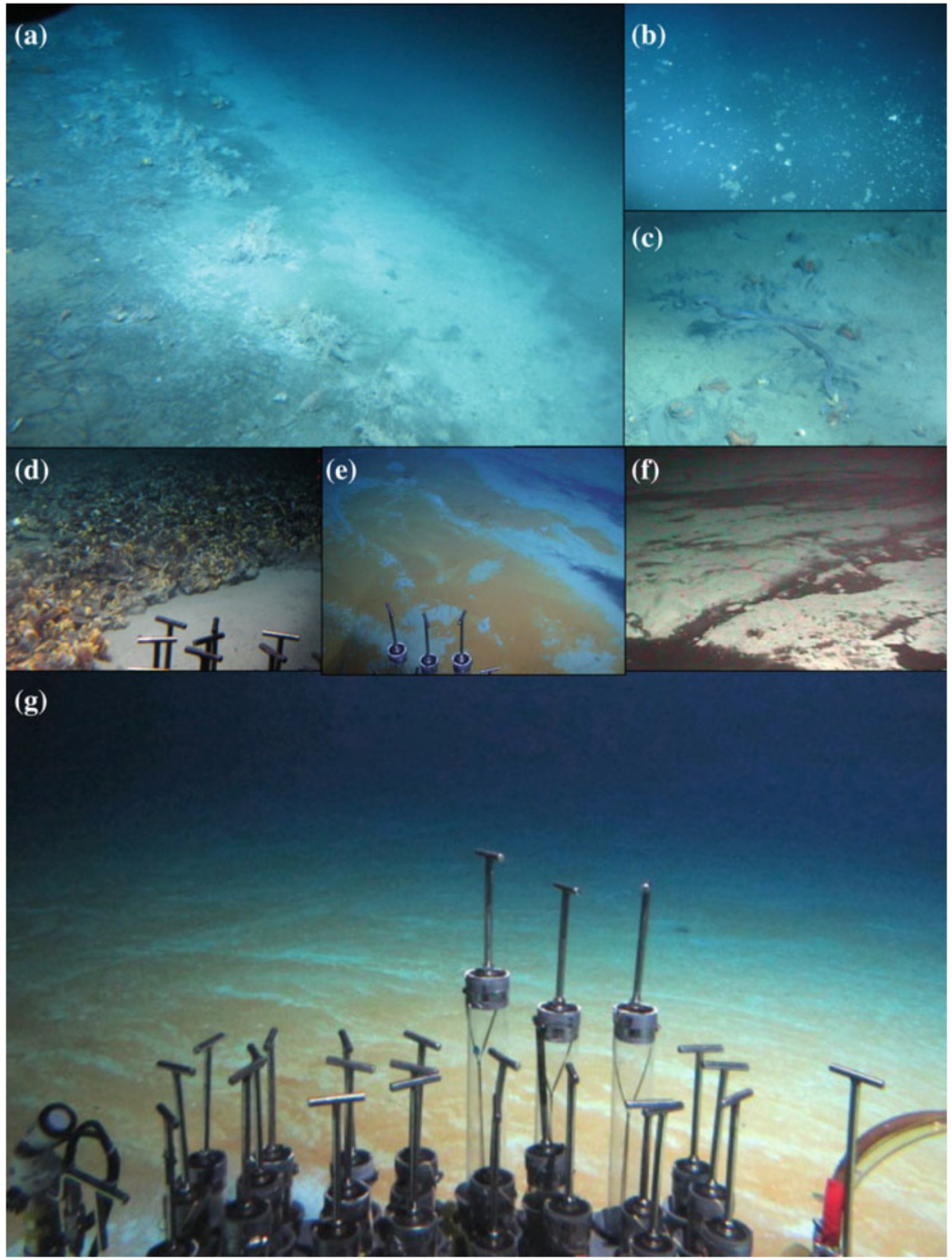


Fig. 2 Alaminos Canyon 601 Brine Lake and mud volcano. a From left to right: the brine lake

Barite crystals in brine

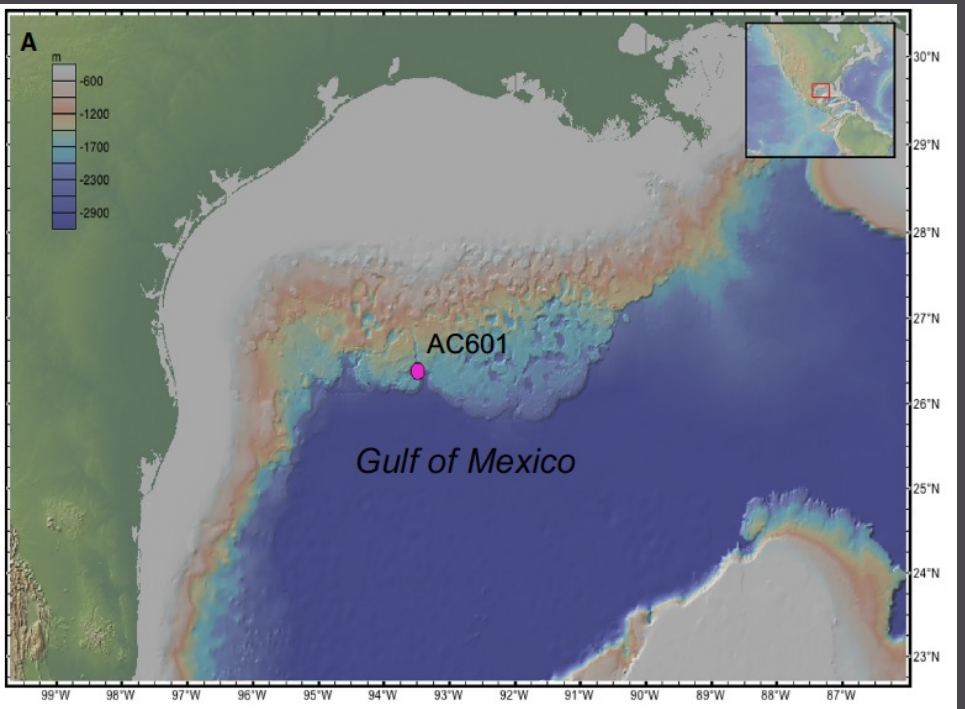
Heart urchins along shore

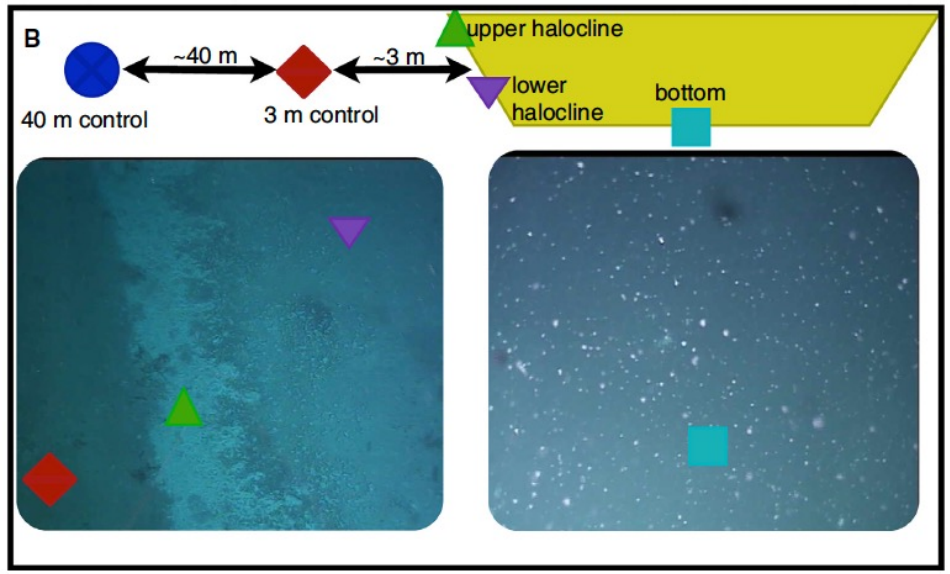
Sulfur oxidizing Microbial mats

Iron oxides mark recent mud flows

Teske & Joye 2020

AC601





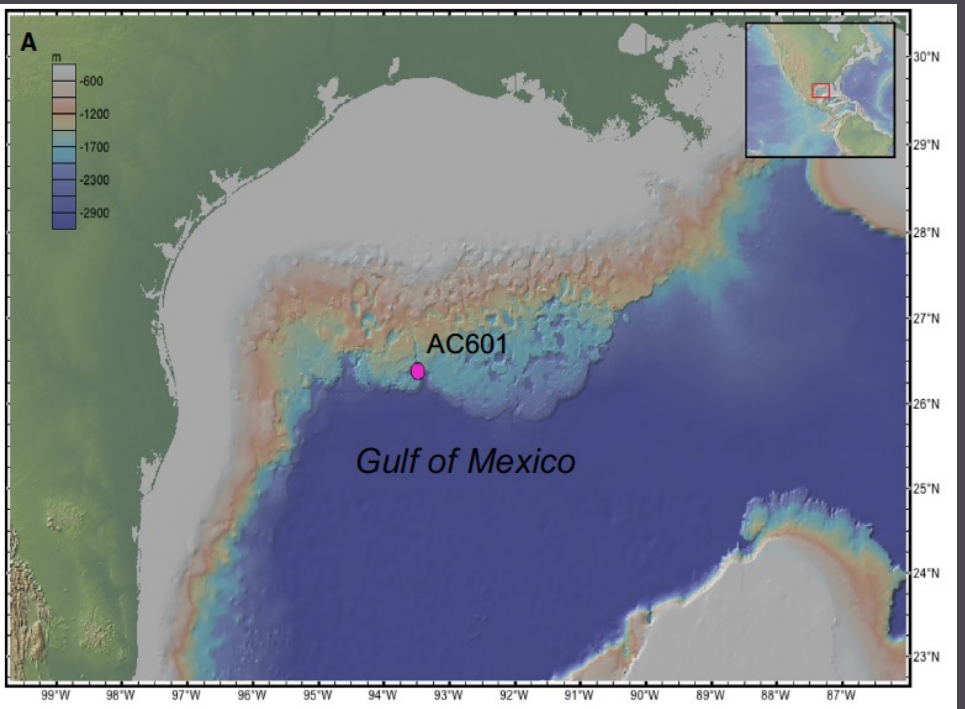
Sediment Geochemistry

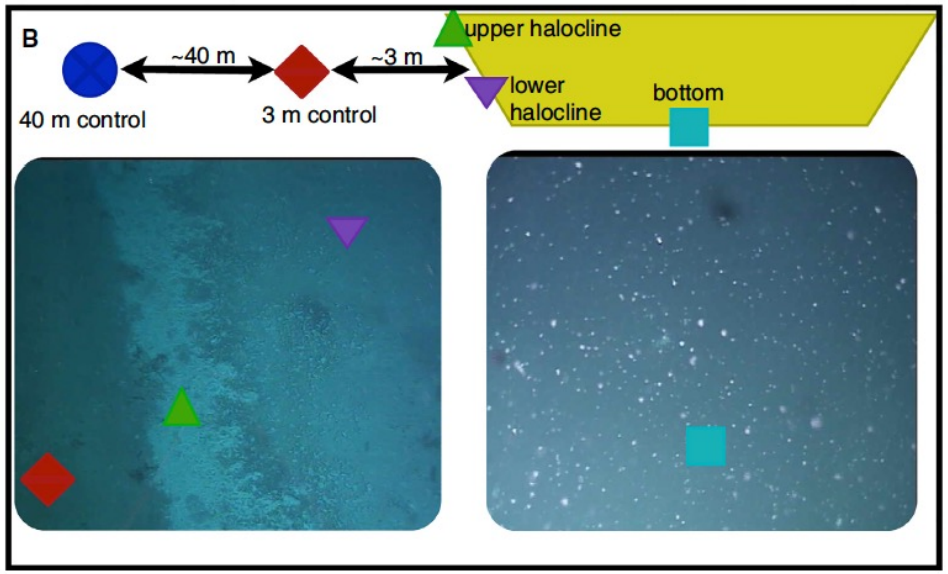
Table 1 Geochemical analysis of samples from AC601 brine lake

	40 m control	3 m control	Upper halocline	Lower halocline	Bottom
Average pH	7.5	7.4	7.3	6.7	6.8
Average salinity (PSU)	36	47	57	85	87
Geochemical inventories (μmol cm^{-2}):					
CH_4	0.03	3.6	7.8	18.6	12.8
DIC	30	99	145	166	111
DOC	12	14	21	16	16
H_2S	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

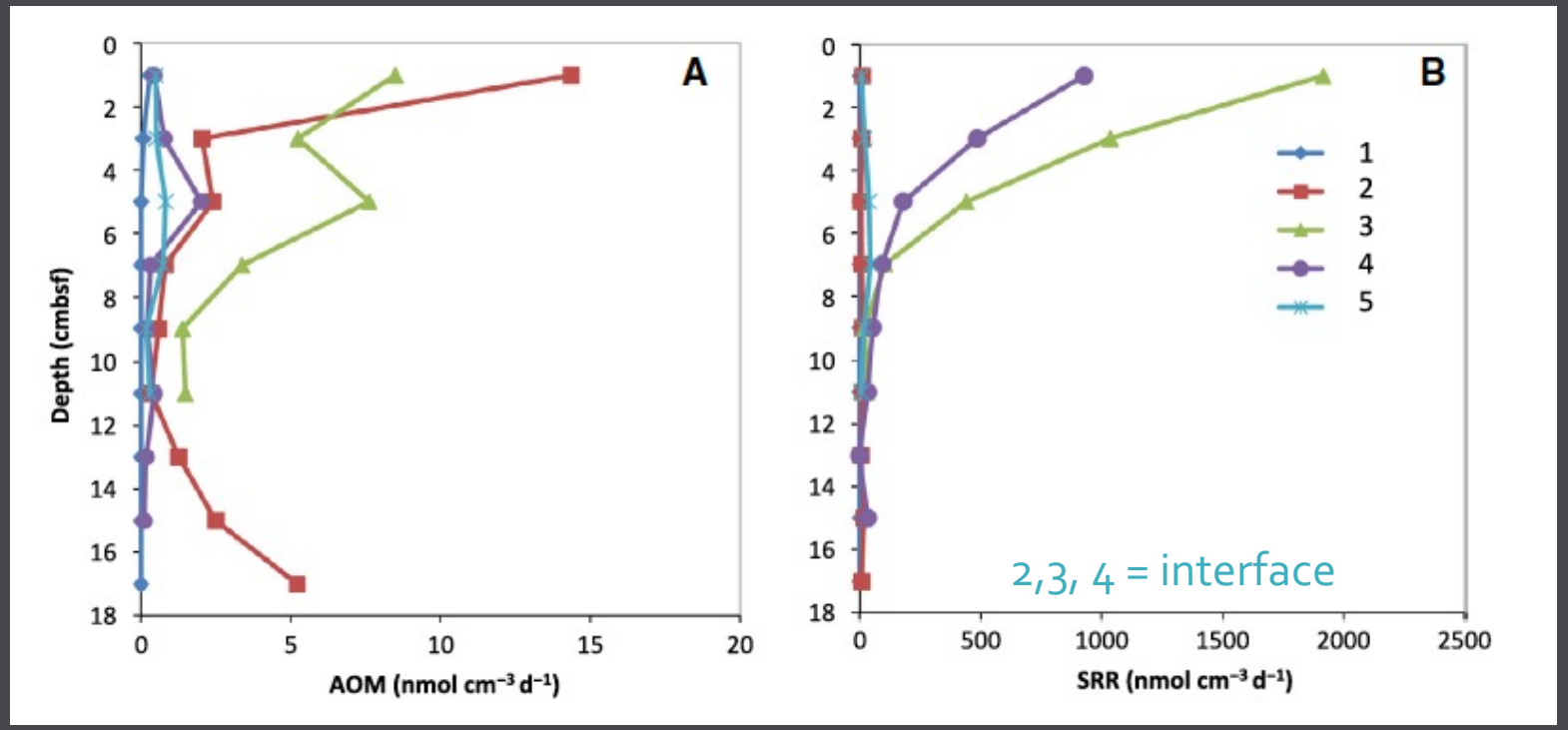
Crespo-Medina et al., Geobiology, DOI: 10.1111/gbi.12185

AC601





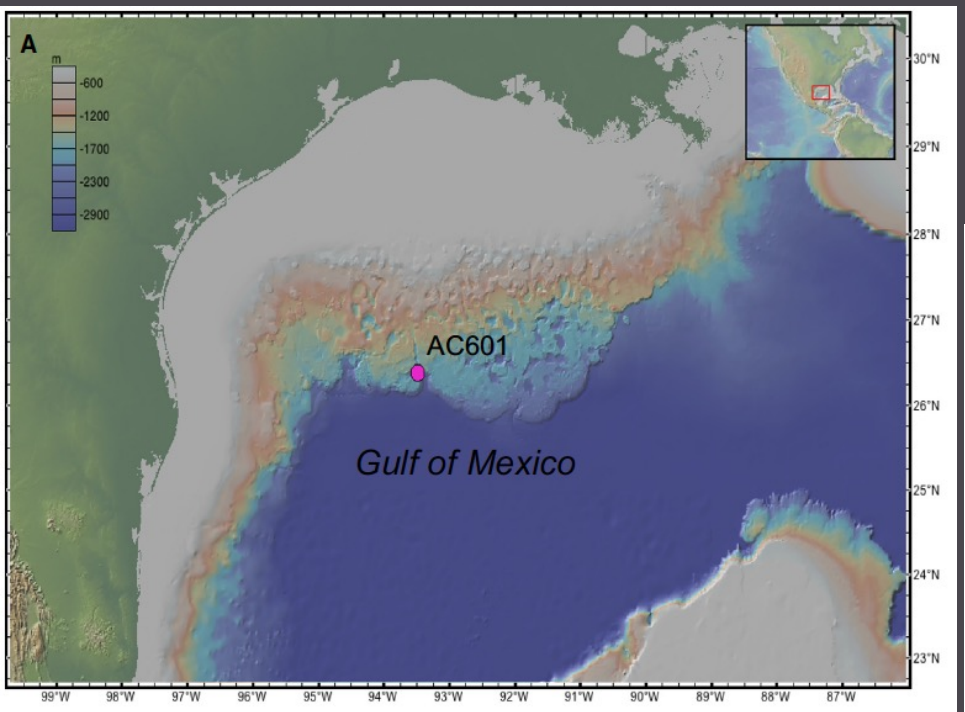
Microbial Activity

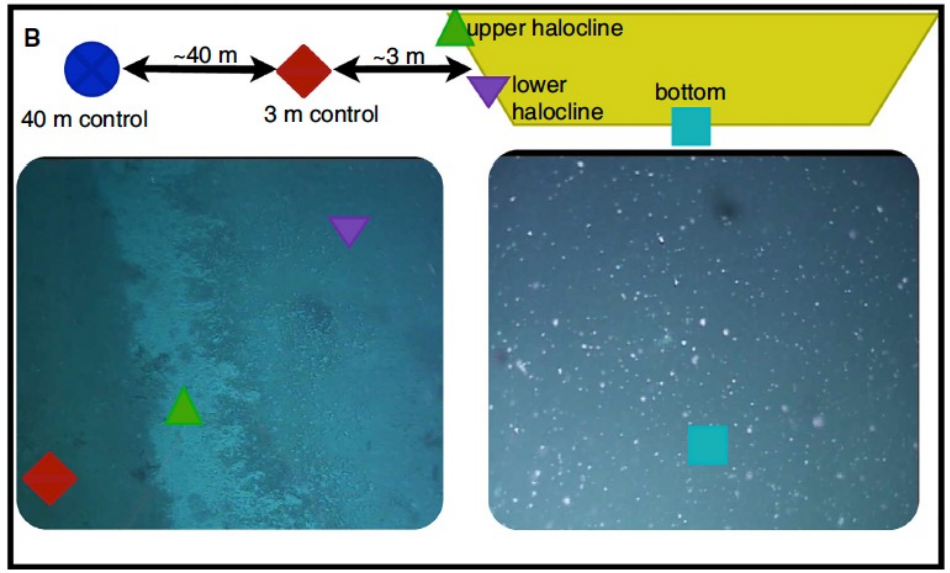


Sulfate reduction is limited by sulfate availability

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

AC601





Microbial Community Composition

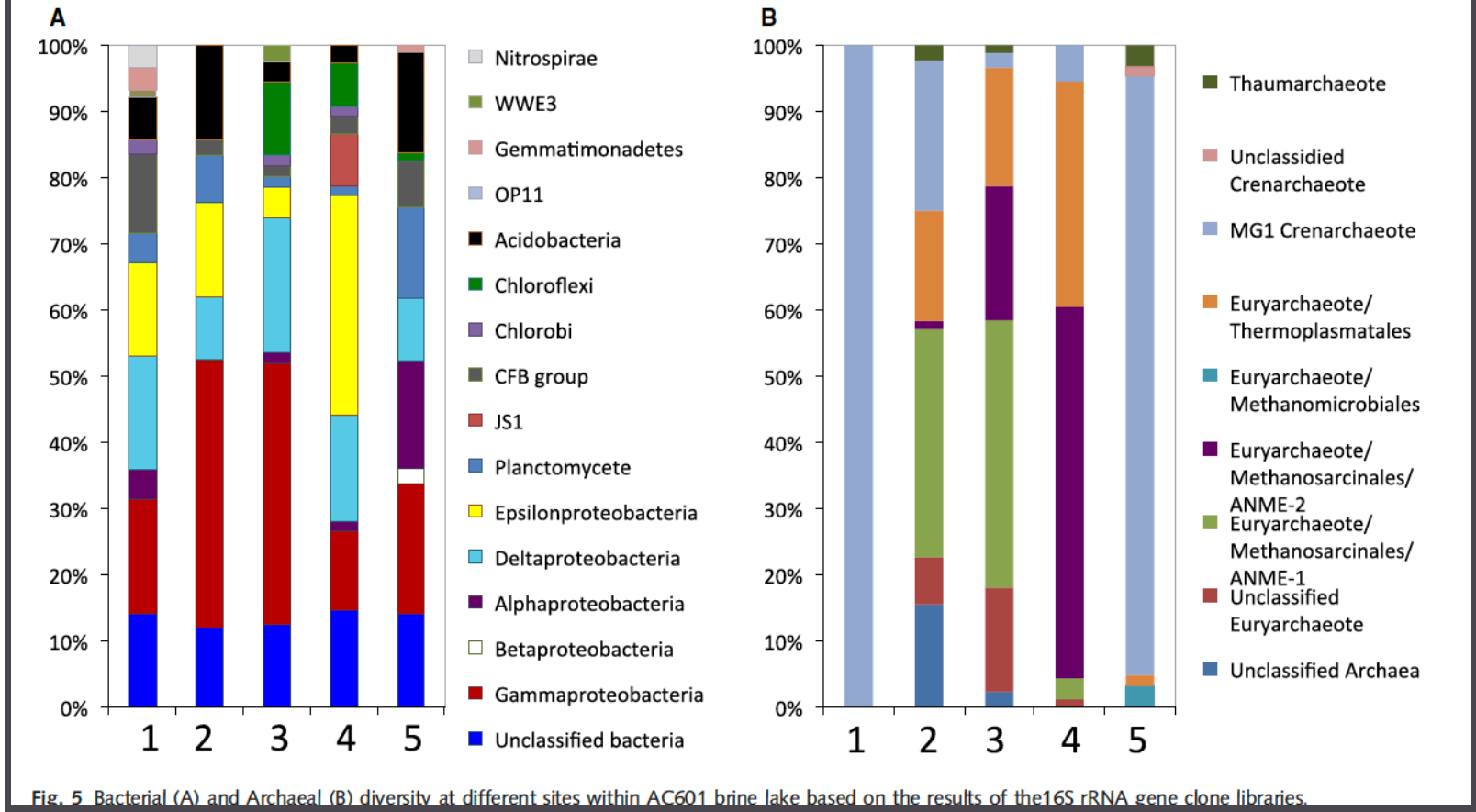
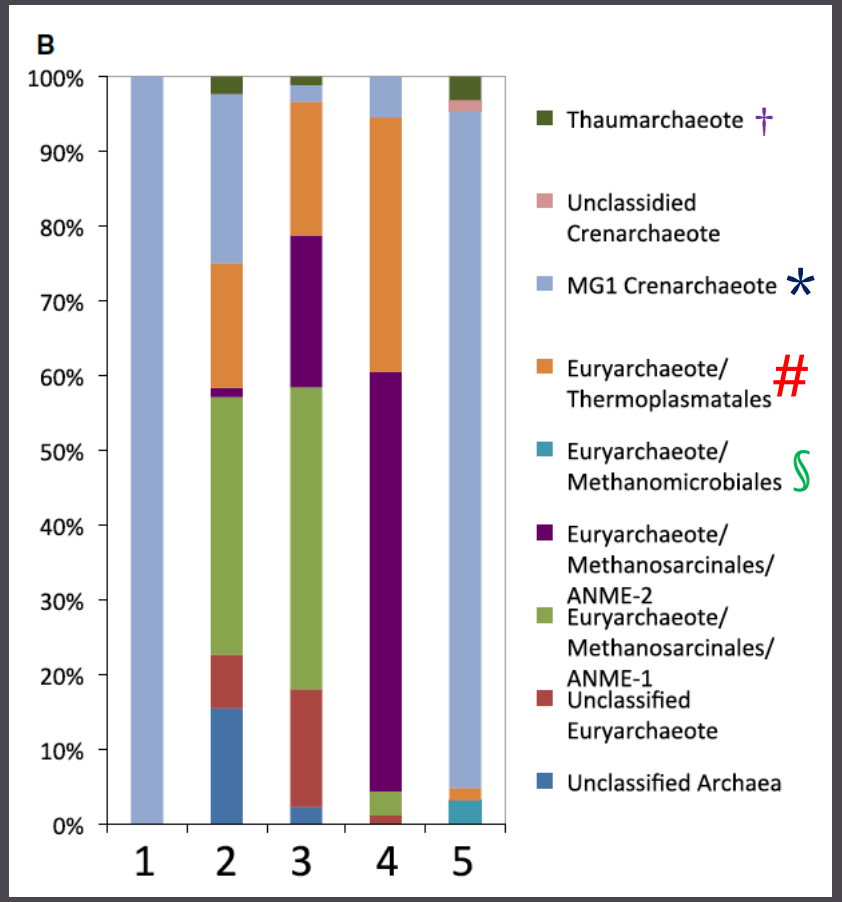


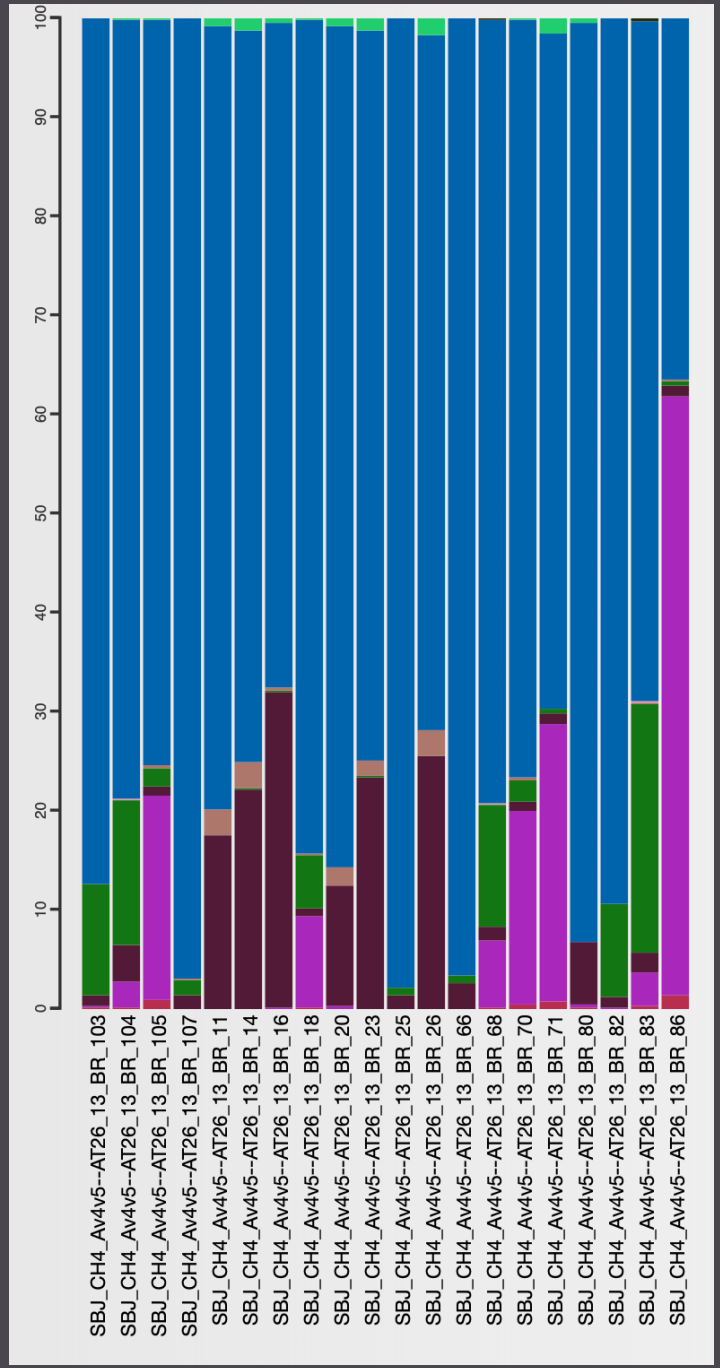
Fig. 5 Bacterial (A) and Archaeal (B) diversity at different sites within AC601 brine lake based on the results of the16S rRNA gene clone libraries.

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

Comparison across brines

Archaea





Marine Group I (Thermoproteota) dominate most brines;

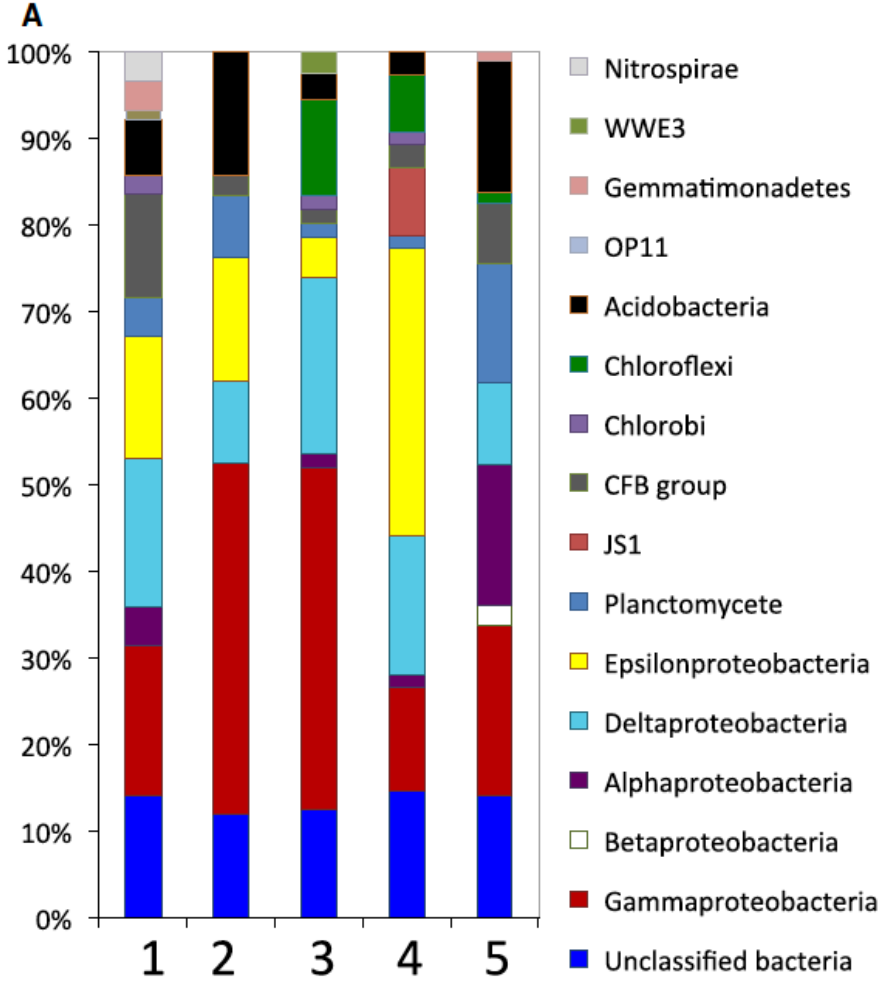
Halophilic methanogens are also very common

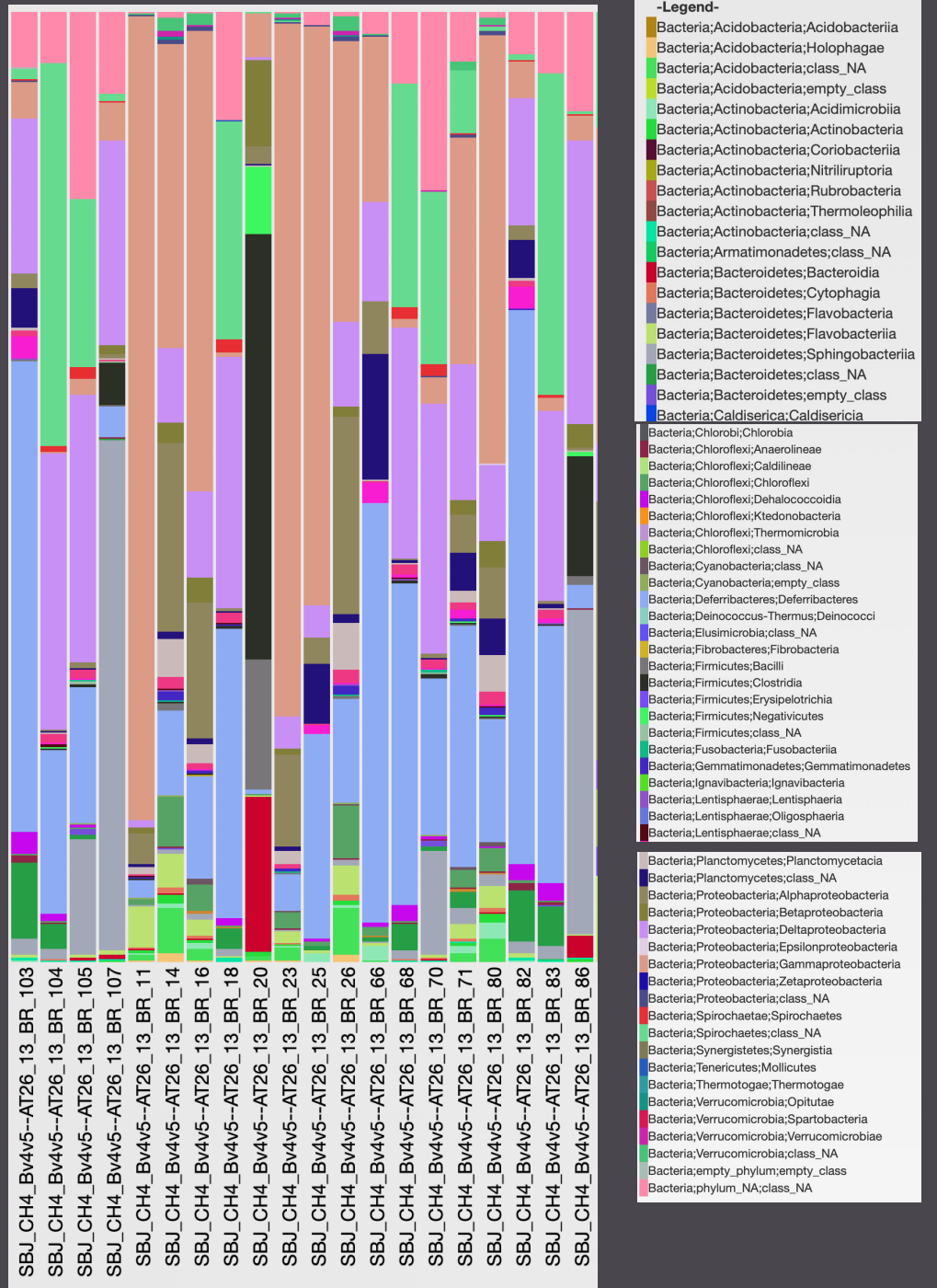
-Legend-

- 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;Miscellaneous_Crenarchaeotic_Group
- Archaea;Thaumarchaeota;class_NA †
- Archaea;Thaumarchaeota;empty_class
- Archaea;Thaumarchaeota;terrestrial_group

Comparison across brines

Bacteria





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)

Acknowledgements

R/V Atlantis' ship's crew
ALVIN group

AT18-02, AT 26-13

Collaborators

Ian MacDonald
Joe Montoya
Andreas Teske

Trainees

Melitza Crespo-Medina
Lindsey Fields
Lisa Nigro
Andy Montgomery
Mary-Kate Rogener
Matt Saxton
Guang-Chao Zhuang

Research Staff

Kim Hunter
Vladimir Samarkin
Ryan Sibert
Antje Vossmeyer

The results presented today were funded by the National Science Foundation (EF-08-01741), the Bureau of Ocean & Energy Management (1435-01-03-CT-72323) and the NOAA Office of Ocean Exploration.