



Gas in Marine Sediments (GIMS): past, current, and future (contributions from GIMS-14)

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Background

Shallow sediment (< 1000 m below the seafloor) along modern continental margins hosts enormous quantities of low molecular weight hydrocarbons (mostly methane, CH₄) that exist as free (gas) bubbles, clathrates (or gas hydrates), or dissolved in water. The total amount and correct distribution of these hydrocarbons at present-day remain wildly unconstrained, principally because of current complications regarding means to detect, to quantify, and to explain. This problem only magnifies over geologic time, which necessarily forces consideration of past variations in sea level, ocean temperature, and carbon fluxes to and from the seafloor. In any case, gas in marine sediments has become an increasingly fascinating topic across a broad spectrum of geo- and bio-sciences.

The Gas in Marine Sediments (GIMS) conference series (Table 1), initiated in 1990 by the Shallow Gas Group, was intended to stimulate an awareness of shallow gas and gas-related features (e.g., seepages and pockmarks) within the wider community. GIMS meetings, held approximately every 2 years (Table 1), provide an opportunity for scientists and engineers spanning multiple disciplines to share cutting-edge knowledge in a welcoming environment. During early conferences, there was a concerted effort to foster east-west relationships by encouraging the participation of colleagues from the Eastern Bloc. This goal of facilitating interdisciplinary and international cooperation, as well as publishing key and diverse work continues. Here, we introduce the fourteenth conference (GIMS-14), held in Haifa, Israel (October 14–20,

2018), which led to some interesting papers and key ideas. A Web site for the meeting, including the program and other details, can be found at <http://gims14.haifa.ac.il/>.

Rationale for a Haifa meeting

At the end of GIMS-13 in Tromsø, Haifa was proposed and selected as the location for GIMS-14. To an outsider unfamiliar with the history, the Mediterranean coast of northern Israel probably seems about as odd for an international conference on gas in marine sediment as the Norwegian Arctic. However, the choice was strategic. Obviously, the region has a long historical interest in oceanography, where many introductory textbooks begin with the Phoenicians. In the last 15 years, though, the Leon Charney School of Marine Sciences at the University of Haifa has rapidly become a recognized institute for oceanographic studies, and world-class gas fields (e.g., Tamar and Leviathan) were discovered and developed offshore Israel. Indeed, these gas fields have changed the economy and energy usage in Israel considerably.

Like several past meetings in the series, GIMS-14 was relatively small (83 participants) but with a diverse group of individuals spanning 15 country affiliations and a wide range of interests (Fig. 1). Also consistent with past GIMS conferences, about 50% of the participants were students.

Field trips have been an important tradition of GIMS meetings, both to gain camaraderie amongst colleagues and to examine the science of mutual interest. The conference included city tours of Haifa and Jerusalem. More relevant to science, a 1-day field trip, including a cruise, focused on Lake Kinneret (Sea of Galilee), the lowest freshwater lake on Earth at ~ 215 m below sea level (Fig. 2). This water body lies in one of the pull-apart basins of the Dead Sea Transform fault system, and because of climate and hydrography, sediments contain abundant gas (mostly CH₄). Field-trip participants saw a hands-on demonstration of methane emission from gassy

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Table 1 Gas in Marine Sediments (GIMS) conference series

Number	Year	Location	Conference-related publication volume
1	1990	Edinburgh, UK	Cont. Shelf Res., 12(10), 1075–1264, 1992
2	1992	Hirtshals, Denmark	Bull. Geol. Soc. Denmark, 41(1), 3–109, 1994
3	1994	Texel, Netherlands	Mar. Geology, 137(1/2), 1–189, 1997
4	1996	Varna, Bulgaria	
5	1998	Bologna, Italy	Cont. Shelf Res., 22(16), 2265–2442, 2002
6	2000	St.Petersburg, Russia	Geologiya i Geofizika, 43(7), 581–711, 2002
7	2002	Baku, Azerbaijan	Geo-Mar. Lett. 23(3/4), 137–358, 2003
8	2005	Vigo, Spain	Geo-Mar. Lett. 27(2/4), 71–302, 2007
9	2008	Bremen, Germany	Geo-Mar. Lett. 30(3/4), 151–476, 2010
10	2010	Listvyanka, Russia	Geo-Mar. Lett. 32 (5/6), 373–562, 2012
11	2012	Nice, France	Geo-Mar. Lett. 34 (2/3), 85–295, 2014
12	2014	Taipei, Taiwan	
13	2016	Tromsø, Norway	
14	2018	Haifa, Israel	Geo-Mar. Lett., this volume

sediments when weighted lines were sunk into sediment and bubbles emerged.

Special issue overview

This special issue of Geo-Marine Letters includes 10 contributions highlighting the diversity of topics presented at GIMS-14. The first group of papers focuses on gas emissions from the seafloor. The distribution of hydrocarbon gasses is examined from the Tatar Strait of the northern Sea of Japan (Yatsuk et al. 2020), indicating a large-scale degassing zone that coincides with a variety of free gas indicators. Römer et al. (2020) examine gas bubble emissions from the Black Sea and show how almost all free gas flares are limited to below depths of 100-m depth. They suggest that these gasses dissolve into the water column at these depths and contribute significantly toward the Black Sea's anoxic character. Chen et al. (2020) describe high-resolution bathymetry of the seafloor of southwestern Taiwan, and a new type of pockmark, comet-shaped depressions, forming from discrete degassing events associated with large earthquakes. Baranov et al.

(2020) examine cold methane seeps from the shelf of the Laptev Sea and report on the shallow water seep fauna of the Siberian Arctic for the first time. Faults determine seep sites, where the community structures are related to extreme oligotrophic conditions local to the area.

The second collection of papers addresses methane-derived authigenic mineralization. Judd et al. (2020) examine methane-derived authigenic carbonates (MDAC) from the UK sector of the Irish Sea. Their results suggest the continual formation of MDACs since the last glacial maximum and that methane release to the atmosphere occurred immediately after the local ice sheet retreat. The foraminiferal record of stable isotopes as related to gas hydrate flows is tackled by Dessandier et al. (2020), who investigate the potential biases of these records due to ontogenetic effects. The controls of greigite preservation are examined using rock-magnetic and transmission electron microscope analyses from cores of the Krishna-Godavari basin of India by Badesab et al. (2020a). They suggested that silica diagenesis and silicate weathering, triggered by paleo-methane seepage, played a key role in crystallizing diagenetically formed iron sulfide (greigite) into a silicate matrix, thus enhancing preservation potential.



Fig. 1 Conference participants at GIMS-14 in front of the eastern Mediterranean and submerged Levantine Basin

Badesab et al. (2020b) further examine the rock magnetic variations of a long core from the same basin. Results suggest that magnetic iron-bearing sulfide intervals, found below a sulfate-methane transition zone, were controlled by microbially mediated diagenesis, related to fossil gas hydrate zones. Downcore variations in rock magnetic variations appear to be controlled by differential loading of detrital magnetic minerals, in addition to hydrate-induced iron sulfide formation during late diagenesis.

The third set of papers discusses shallow gas accumulation in lacustrine sediments. The shallow sediments of Lake Kinneret (Fig. 2) are examined by Liu et al. (2020) who describe the spatial and temporal controls on ebullition using core, chemical, and geophysical techniques. They demonstrate the absence of free gas in sediments of the littoral zone of the lake, where gas content increased toward the profundal zone. They report, for the first time, on the significant role that CH_4 production plays in the long-term ebullition pattern, whereas a short-term variability in ebullition was associated with seasonal lake-level changes. In tandem, Uzchansky et al. (2020) studied the temporal (multiannual) changes to sedimentary free gas content in the same lake system, induced by the lake-level change over the studied period and attributed to changes in CH_4 solubility. In addition, the spatial variability in gas content indicated higher values in deeper locations of the profundal zone and in the shallow zone proximal to the Jordan River inflow (Fig. 2).

Conference thoughts and future considerations

Since the first GIMS conference, which mostly focused on shallow gas in sediment on continental shelves, topics have progressively broadened in scope and significance. This evolution has occurred in part by the inclusion of gas hydrates and emissions from regions containing these compounds. GIMS-14 very much followed this avenue. Of overlapping interest are shallow gas hydrates in the Arctic. They can also relate to other “shallow gas” features in this region, including pockmarks and seafloor venting.

Indeed, gas in shallow marine sediment ultimately relates to global carbon cycling, an idea discussed amongst participants at GIMS-14. Methane generally forms from burial and decomposition of solid organic carbon. In many places, through advection and diffusion, this CH_4 returns to the ocean through seafloor venting, where much is subsequently oxidized to CO_2 or consumed by anaerobic oxidation of CH_4 and production of HCO_3^- .

The fate of CH_4 emissions from shallow sediment extended in several directions at GIMS-14. It included potential changes in CH_4 fluxes caused by deglaciation, natural or

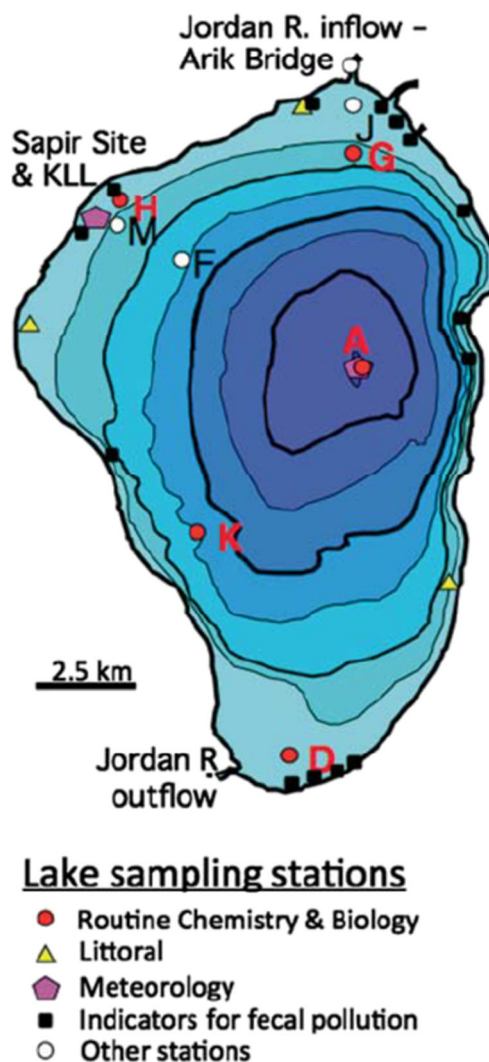


Fig. 2 Bathymetry of Lake Kinneret (black bold contour lines at 10 m increments) with various sampling stations for routine analyses shown (adopted from Sukenik et al. 2014)

anthropogenic, as well as implications. This subject was discussed within the context of historical data and modern evidence.

Another important subject covered by the conference, the one not addressed sufficiently in the literature, is CH_4 ebullition from the freshwater (non-marine) systems (lakes, rivers, and reservoirs). These may present a substantial source of atmospheric CH_4 . It is obvious that those interested in sedimentary gas should expand their horizons to lakes.

Finally, one topic that we universally agreed upon is the poor but common usage of “biogenic gas,” a blanket term that ignores the specific origins of the phenomenon. We, as representatives of the delegates from GIMS-14, propose the use of the term “microbial gas” for CH_4 produced in shallow sediment through microbial activity.

Many discussions and debates transpired across talks, open sessions, meals, and field trips during GIMS-14. Importantly,

the core aspects and special nature of GIMS remain wonderfully intact. These meetings persist as a place for colleagues to meet, to share, and to discuss a common interest in an open and welcoming environment, one particularly good for communication between senior and junior scientists and engineers. Barring any unusual global turmoil, GIMS-15 will take place in Cadiz, Spain during October 2020 (<http://gims15.com/>). Cadiz again was selected for intriguing reasons, and the meeting should follow tradition—a relatively small group of participants sharing a wide range of results and ideas in an engaging atmosphere.

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