nature geoscience

SUPPLEMENTARY INFORMATION

DOI: 10.1038/NGEO2232

Widespread methane leakage from the seafloor on the northern US Atlantic margin

A. Skarke[1], C. Ruppel[2], M. Kodis[3], D. Brothers[4], and E. Lobecker[5]

[1]Dept of Geosciences, Mississippi State University, Mississippi State, MS 39762; [2]U.S. Geological Survey, Woods Hole, MA 02543; [3]Dept. of Geological Sciences, Brown University, Providence, RI 02912; [4]U.S. Geological Survey, Santa Cruz, CA 95060; [5]Earth Resources Technology, Inc., Laurel, MD 20707.

Northern US Atlantic Margin Water Column Backscatter Plume Database

The Excel database contains the latitude and longitude (WGS84 coordinates) of the base of the water column gas plumes, water depth from multibeam bathymetric data, the *Okeanos Explorer* cruise number (e.g., 1101 means cruise EX1101, the first cruise in 2011), the line number designator for the multibeam data, UTC date and time of the observations, a subjective quality factor (see Supplementary Figure 1) that ranges from 1 (best) to 5 (poorest), notes (where applicable), and geographic location when the plume occurs near named seafloor features. Data are sorted by latitude from north to south. This database also includes the locations of plumes previously identified over the Blake Ridge and Cape Fear diapirs[1]. The original multibeam data for these surveys is available from: http://www.ngdc.noaa.gov/mgg/bathymetry/multibeam.html.

Header for Table S1 in the associated Excel database.

Seep Number	Latitude (N)	Longitude (W)	DEPTH	DEPTH	EX CRUISE ID	LINE	DATE (UTC)	TIME (UTC)	Quality Factor	NOTES	GENERAL LOCATION
	WGS84	WGS84	(mbsl-negative)	(mbsl-positive)	Year-Number				1 = best		
1	40.5698	-69.8706	-58.6	58.6	1204	337	06/13/12	1:04:42	4		
2	40.5696	-69.8735	-58.3	58.33	1204	337	06/13/12	1:05:31	1		
3	40.5696	-69.8805	-57.7	57.72	1204	337	06/13/12	1:07:32	1		
4	40.5695	-69.8836	-57.8	57.81	1204	337	06/13/12	1:08:27	2		
5	40.5693	-69.8686	-58.4	58.42	1204	337	06/13/12	1:04:06	4		
6	40.5692	-69.8863	-58.3	58.33	1204	337	06/13/12	1:09:14	3		
7	40.5691	-69.9074	-57.9	57.9	1204	337	06/13/12	1:15:18	1		
8	40.5691	-69.8838	-58.1	58.07	1204	337	06/13/12	1:08:30	2		

9	40.5685	-69.9247	-57.8	57.81	1204	337	06/13/12	1:20:21	1	
10	40.5677	-69.9608	-56.6	56.58	1204	337	06/13/12	1:30:59	2	
11	40.5676	-70.2165	-53.9	53.85	1204	338	06/13/12	2:48:03	3	
12	40.5674	-70.2146	-54.0	54.02	1204	338	06/13/12	2:49:01	4	
13	40.5673	-69.9843	-55.9	55.87	1204	337	06/13/12	1:37:52	1	
14	40.5672	-69.9866	-55.6	55.61	1204	337	06/13/12	1:38:33	1	
15	40.4212	-67.6731	-501.1	501.13	1204	287	06/11/12	18:57:20	1	Lydonia Canyon
16	40.2442	-68.1842	-281.4	281.43	1204	253	06/10/12	19:30:22	4	Oceanographer Canyon
17	40.2441	-68.1865	-276.5	276.45	1204	253	06/10/12	19:29:34	4	Oceanographer Canyon
18	40.2437	-68.1863	-280.0	280.01	1204	253	06/10/12	19:29:38	4	Oceanographer Canyon

Table S2. Videotaped clips and seep characteristics.[1]

Supplementary Video Clip	Cruise	Dive date (mon/day/y)	Start time of original video (UTC)	Dive number during cruise	Seep Number and Location	Seafloor depth (m)	Notes
Skarke_Clip1.mov	EX1302	05/23/2013	18:28:49	6	467 (Virginia)	1475	Location approximate (no real-time ROV position information); Multiple, closely-spaced bubble emissions from bare seafloor adjacent to mussel mound; slower, single-bubble seeps also within frame; no laser scale; Figure 2d
Skarke_Clip2.mov	EX1302	05/31/2013	22:07:02	10	261 (Virginia)	450	At least 9 distinct bubble streams at edge of seafloor carbonate cap; no laser scale and no video at base of gas plumes; Figure 2b
Skarke_Clip3.mov	EX1302	06/04/2013	16:48:30	14	79 (Veatch Canyon)	1410	At least 3 bubble emission sites with different rates of seepage within field of dead mussels; no laser scale
Skarke_Clip4.mov	EX1304L1	07/12/2013	17:23:13	4	77 (unnamed New England canyon)	1400	Multiple bubble emission sites from ~30 cm seam in mud in front of gas hydrate forming below carbonate overhang
Skarke_Clip5.mov	EX1304L1	07/12/2013	18:58:31	4	77 (unnamed New England canyon)	1400	At least 15 emission points from ~0.25 m^2 bare seafloor that is surrounded by bacterial mats/seafloor hydrate "film"; emission rates vary, with some too fast to measure and others measured at 0.5 to 1 bubble/second; the few measurements made on all videos (including Skarke_Clip4.mov above) from this dive yield bubble diameters of 3.1 to 4.2 mm, with some possibly larger. Different location than Skarke_Clip4.mov
Skarke_Clip6.mov	EX1304L1	07/21/2013	18:48:34	13	84 (Veatch Canyon)	1425	Single bubble emission from bare seafloor; few measurements made in all videos from this dive yield bubble diameters of 2.3 to 3.2 mm; where measurable, rates for all videos examined for this dive varied from 0.5 to 2 bubbles/second

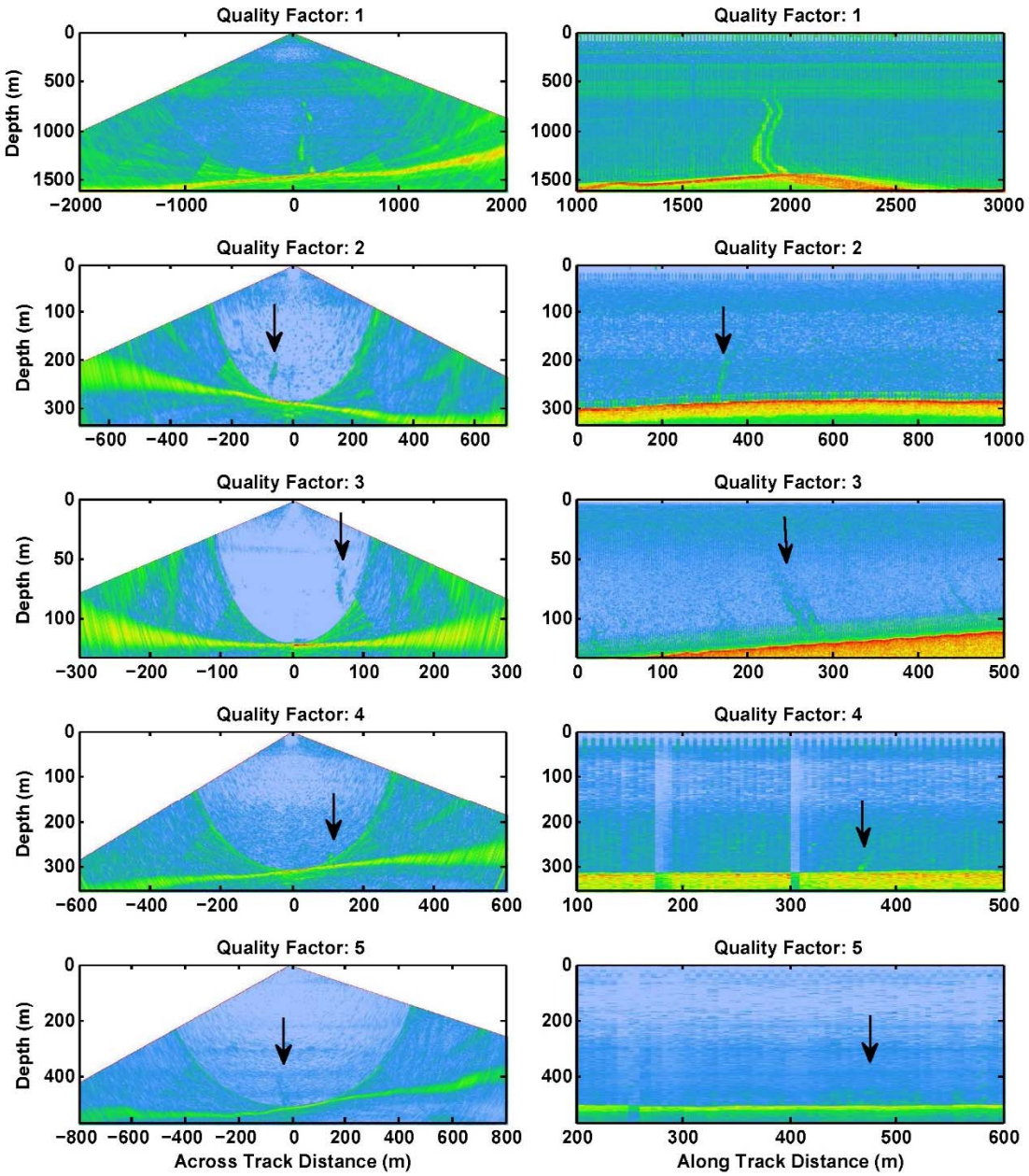
[1]Six distinct seep areas in five clusters were explored during ROV dives in May through July 2013. No video clip is provided here from a dive on July 11, 2013, which explored seeps #74 and #75 in an unnamed canyon on the New England margin at ~1100 m water depth.

Table S3. Methane flux estimates for the northern USAM seeps using different assumptions.

	Bubble diameter (mm)	BWT case (1=observed; 2=observed +1° C)	Emission sites per plume	Bubbles per second per emission site	mol/yr methane ($x10^6$) emissions	Mg/yr methane emissions
All seeps (Base Case)	3[1]	1	5	1	2.39	38.3
All seeps	4	1	5	1	5.66	90.8
All seeps	5[2]	1	5	1	11.1	177
All seeps	3	1	5	0.5	1.19	19.1
All seeps	3	2	5	1	2.34	37.6
All seeps	3	1	2	1	0.95	15.3
All seeps, with raw emissions divided by seep quality factor (from 1 for strong to 5 for very weak) representing seep strength	3	1	5	1	2.08	33.3
All seeps, but diffuse ones generate 3 x more methane than discrete seeps	3	1	5	1	3.97	63.7
Seeps < 180 mbsl	3	1	5	1	0.28	4.49
Seeps between 180 and 600 mbsl	3	1	5	1	1.60	25.6

[1]From limited ROV videotape, we estimate that 3 mm is the approximate size of measurable bubbles at some of the seep sites visited in 2013.
[2]On the Makran margin, the average bubble diameter reported through careful analysis of a range of seafloor seeps is ~5.2 mm^2.

Supplementary Figure 1. Example water column anomalies identified in coincident across track (left) and along track (right) 30 kHz echogram profiles of water column backscatter data. Horizontal axes in meters. Each anomaly is assigned a subjective quality factor of 1 (highest) through 5 (lowest), which correspond to the level of confidence that the detected water column anomaly is a gas plume. These quality factors also correspond to the strength of the plumes, which can in turn be related to gas flux.



Supplementary References

1. Brothers, L. L. *et al.* Evidence for extensive methane venting on the southeastern U.S. Atlantic margin. *Geology* **G34217.1**, (2013).
2. Römer, M., Sahling, H., Pape, T., Bohrmann, G. & Spieß, V. Quantification of gas bubble emissions from submarine hydrocarbon seeps at the Makran continental margin (offshore Pakistan). *Journal of Geophysical Research: Oceans* **117**, C10015, (2012).