Occurrence of Methane in Groundwater of South-Central New York State, 2012 —Systematic Evaluation of a Glaciated Region by Hydrogeologic Setting

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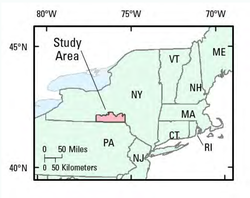
Introduction

A survey of methane in groundwater was undertaken to document methane occurrence on the basis hydrogeologic setting within a glaciated 1,810-square-mile area of south-central New York along the Pennsylvania border.



Sixty-six wells were sampled during the summer of 2012. All wells were at least 1 mile from any known gas well (active, exploratory, or abandoned). Only domestic wells and similar purposed supply wells with well-construction and log information were selected for classification.

The hydrogeologic setting classes were based on:

- topographic position (valley and upland)
- confinement or non-confinement of groundwater by glacial deposits
- well completion in fractured bedrock or sand and gravel, and hydrogeologic subcategories.

Table 1. Hydrogeologic setting classification in the study area, south-central New York.

Tier	Characteristic	Setting								
1	Topographic position	Valley						Upland		
2	Confinement	Confined			Unconfined			Confined		Unconfined
3	Aquifer	Bedrock		Sand and gravel	Bedrock	Sand and gravel		Bedrock	Sand and gravel (none)	Bedrock	Sand and gravel (none)
4	Hydrogeologic subcategories	Upland valley	Lowland valley			Sand and gravel over bedrock	Sand and gravel over confining unit			

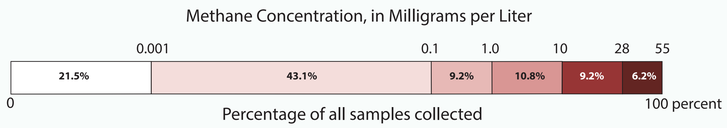
Sampling

Field water-quality characteristics (pH, specific conductance, dissolved oxygen, and temperature) were measured at each well, and samples were collected and analyzed for dissolved gases, including methane and short-chain hydrocarbons. Carbon and hydrogen isotopic ratios of methane were measured in 21 samples that had at least 0.3 milligram per liter (mg/L) methane.

How Much Methane was there?

Results of sampling indicate that occurrence of methane in groundwater of the region is common:

- Greater than or equal to 0.001 mg/L in 78% of samples
- Concentrations of methane ranged over five orders of magnitude
- Methane concentrations at which monitoring or mitigation are indicated (greater than or equal to 10 mg/L) were measured in 15% of the samples.



Was there any Pattern to Methane Occurrence and Hydrogeologic Setting?

Yes. Methane concentrations greater than 0.1, 5, and 10 mg/L were associated with specific hydrogeologic settings. Wells completed in bedrock within valleys and under confined groundwater conditions were most closely associated with the highest methane concentrations. Fifty-seven percent of valley wells had ≥ 0.1 mg/L methane, whereas only 10 percent of upland wells equaled or exceeded that concentration. Twenty-nine percent of valley wells had ≥ 10 mg/L methane, whereas no upland wells did.

Hydrogeologic classification of wells sampled, with each class color coded by percentage of samples with methane concentrations greater than or equal to: A, 0.1 milligram per liter, B, 5 milligrams per liter, and C, 10 milligrams per liter in south-central New York, 2012.
[≥, greater than or equal to; <, less than; mg/L, milligrams per liter; %, percent; (X), number of samples]

Percentage of samples greater than or equal to listed methane concentration

0	>0 to <20	20 to <40	40 to <60	60 to <80	80 to 100

***A.* Methane concentration ≥0.1 mg/L**

Tier	Characteristic	Setting								
1	Topographic position	Valley (35) 57% Primarily thermogenic methane source, with some indication of mixing with microbially derived (carbon-dioxide reduction) methane from subregional groundwater flow system					Upland (30) 10% Primarily microbial (carbon-dioxide reduction) source of methane, with indication of mixing with thermogenic methane or oxidation of microbial methane in some samples			
2	Confinement by glacial deposits	Confined (18) 83%			Unconfined (17) 29%		Confined (13) 23%		Unconfined (17) 0%	
3	Aquifer	Bedrock (15) 87%		Sand and gravel (3) 67%	Bedrock (8) 63%	Sand and gravel (9) 0%	Bedrock (13) 23%	Sand and gravel (0)	Bedrock (17) 0%	Sand and gravel (0)
4	Hydrogeologic subcategories	Upland valley (5) 100%	Lowland valley (10) 80%			Sand and gravel over bedrock (6) 0%	Sand and gravel over confining unit (3) 0%			

***B.* Methane concentration ≥5 mg/L**

Tier	Characteristic	Setting								
1	Topographic position	Valley (35) 34%					Upland (30) 3%			
2	Confinement by glacial deposits	Confined (18) 56%			Unconfined (17) 12%		Confined (13) 8%		Unconfined (17) 0%	
3	Aquifer	Bedrock (15) 60%		Sand and gravel (3) 33%	Bedrock (8) 25%	Sand and gravel (9) 0%	Bedrock (13) 8%	Sand and gravel (no wells)	Bedrock (17) 0%	Sand and gravel (no wells)
4	Hydrogeologic subcategories	Upland valley (5) 40%	Lowland valley (10) 70%			Sand and gravel over bedrock (6) 0%	Sand and gravel over confining unit (3) 0%			

***C.* Methane concentration ≥10 mg/L**

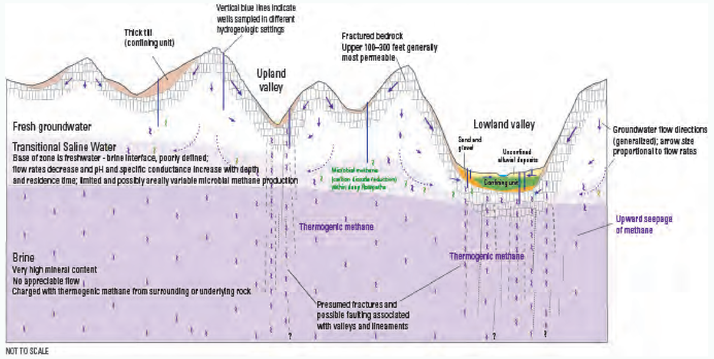
Tier	Characteristic	Setting								
1	Topographic position	Valley (35) 29%					Upland (30) 0%			
2	Confinement by glacial deposits	Confined (18) 50%			Unconfined (17) 6%		Confined (13) 0%		Unconfined (17) 0%	
3	Aquifer	Bedrock (15) 53%		Sand and gravel (3) 33%	Bedrock (8) 13%	Sand and gravel (9) 0%	Bedrock (13) 0%	Sand and gravel (0)	Bedrock (17) 0%	Sand and gravel (0)
4	Hydrogeologic subcategories	Upland valley (5) 40% (1 ≥28 mg/L)	Lowland valley (10) 60% (3 ≥28 mg/L)			Sand and gravel over bedrock (6) 0%	Sand and gravel over confining unit (3) 0%			

What is the origin of the Methane?

The origin of methane, as indicated by isotopic signatures, differed between the major hydrogeologic settings. Methane in valley wells was predominantly thermogenic in origin with some mixed-origin methane. Methane from four upland well samples indicated a microbial origin .

- **Thermogenic methane** is generated by heat and pressure on deeply buried organic-rich rocks.
- **Microbial methane** is produced by bacteria that utilize carbon dioxide (carbon-dioxide reduction) or organic matter in bedrock in highly reducing environments (no oxygen) within the groundwater flow system (long residence time groundwater).
- **Mixed source methane** is most likely where regional groundwater converges at valleys (see conceptual model).

Conceptual Model of Methane Occurrence within the Hydrogeologic System



Conceptual diagram of thermogenic and microbial methane occurence at water wells in south-central New York. Wells are shown in different hydrogeologic settings and in relation to the (fresh) groundwater flow system and the transition to underlying brine. The symbol (~) indicates the likely presence of methane, and the color (green or purple) indicates methane source. No symbol indicates trace or absent methane in groundwater samples.

Previous and current work in the northern Appalachian Basin indicates that the groundwater flow system (fresh water) sits atop relatively stagnant brine, charged with methane, from local or underlying organic-rich bedrock, separated by a transitional zone of saline water.

Thermogenic methane in valley wells (completed in bedrock or confined by glacial deposits) is likely the result of close vertical proximity to underlying methane-bearing saline groundwater and brine and possibly enhanced bedrock fracture permeability beneath valleys that provides an avenue for upward gas migration.

Microbial methane is produced by bacteria in highly reducing (anoxic) environments within the subregional groundwater flow system (long residence time groundwater) primarily in upland areas.

This characterization of groundwater methane shows the importance of subsurface information (hydrogeology, well construction) in understanding methane occurrence and provides an initial conceptual framework that can be utilized in the investigation of stray gas in south–central New York.