Shale Energy and Water Impacts: A Review of Recently Published Research

Presented by

Dave Yoxtheimer, P.G.

Marcellus Center for Outreach and Research
Penn State University

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Source: Energy Information Administration based on data from various published studies.
Updated: May 9, 2011

Well Site in Operation

Shale Gas Development Water Use

Source: Chesapeake Energy

- **~100,000 gall of water used during drilling**
- **3 to 7 million gall of water used during hydraulic fracturing**
- **Approximately 8-10% of injected fluids return as flowback water**

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Potential Water Quality Impact Pathways

- Methane migration into groundwater/surface water due to faulty well construction
- Direct spill of fluids to ground surface via leaking pipes, impoundments, spills or a blowout
- Effluent from treatment facility (largely a non-issue with new treatment standards)
- Erosion and sedimentation from pads and roads
- Fracturing fluid migration (??)

Study of Groundwater Quality Before and After Drilling

- Study: *The Impact of Marcellus Gas Drilling on Rural Drinking Water Supplies, Center for Rural PA, October 2011*
- PSU Researchers collected pre- and post-drilling water sample from private wells
- Collected and analyzed nearly 230 samples within 1,000 feet and within 1 mile of Marcellus wells
- No significant before/after changes in water quality
  - ~40% of wells fail at least one drinking water standard and background methane found in ~24% of the wells.

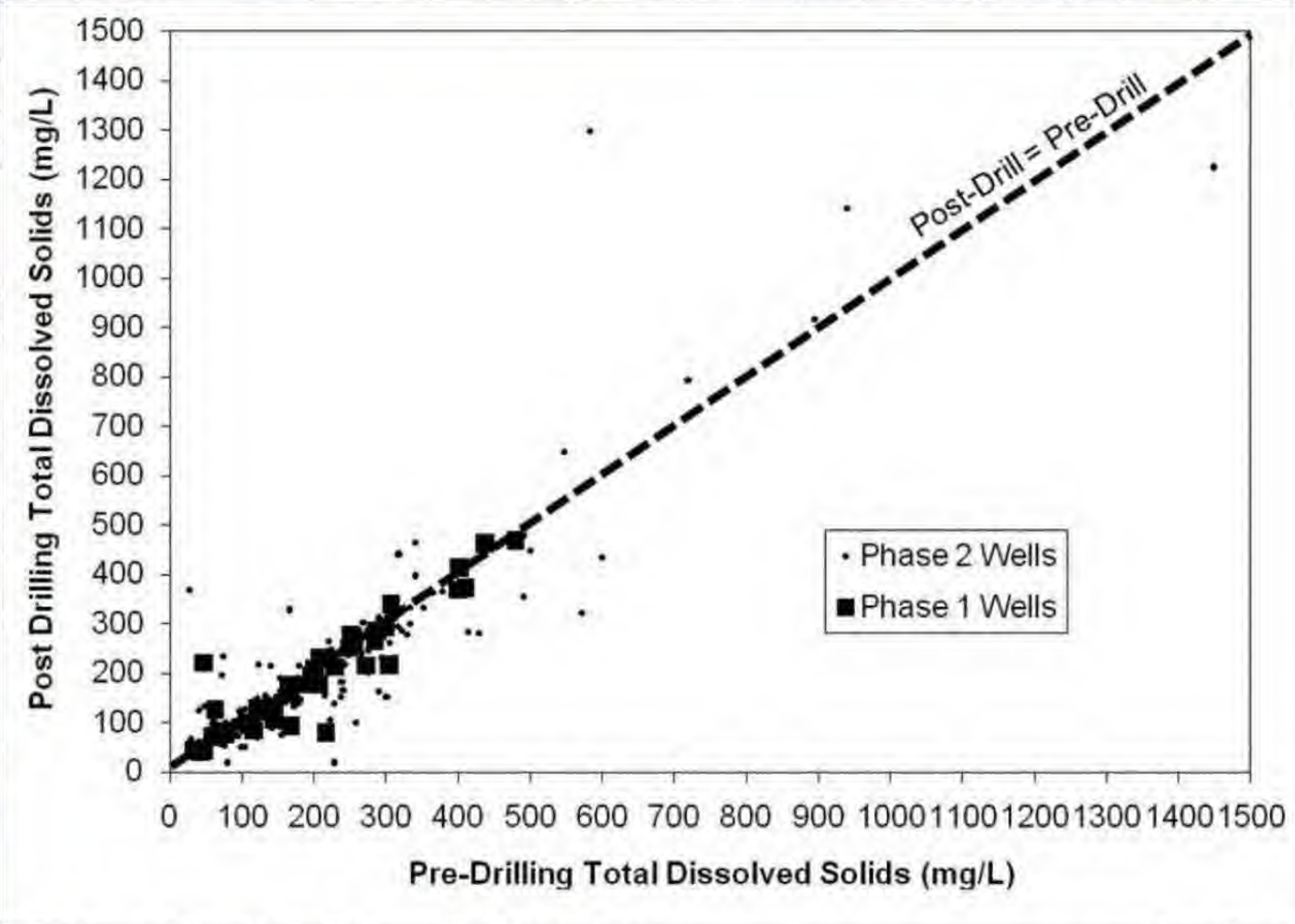
Groundwater Quality in PA

Table 1. Water quality parameters measured in Phase 1 water wells in comparison to Pennsylvania drinking water standards and to typical concentrations in Pennsylvania water wells and Marcellus wastewaters. All concentrations are reported in units of mg/L except pH.

Parameter	Drinking Water Standard[1]	Approximate Median Concentration in Typical Pennsylvania Groundwater[2]	Approximate Median Concentration in Typical Marcellus Wastewater[3]
pH	6.5 to 8.5	7.50	6.60
Total Dissolved Solids	< 500	163.0	67,300
Total Suspended Solids	-	1.0	99.0
Barium	< 2.0	0.070	686
Iron	< 0.30	0.20	39
Manganese	< 0.05	0.01	2.63
Sodium	-	6.87	18,000
Hardness	-	86.1	17,700
Strontium	-	0.26	1,080
Chloride	< 250	5.3	41,850
Sulfate	< 250	18.0	2.4 to 106
Nitrate-Nitrogen	< 10	0.50	0.1 to 1.2
Bromide	-	0.016	445
Dissolved Organic Carbon	-	<1.0	62.8
Dissolved Methane		No data available	No data available
Oil & Grease	-	<5.0	6.3

[1] Pennsylvania Department of Environmental Protection. 2006. [2] Pennsylvania State University. 2011; Davis et al., 2004; and Thurman. 1985. [3] Hayes. 2009.

Private Well TDS Pre- and Post-Drilling

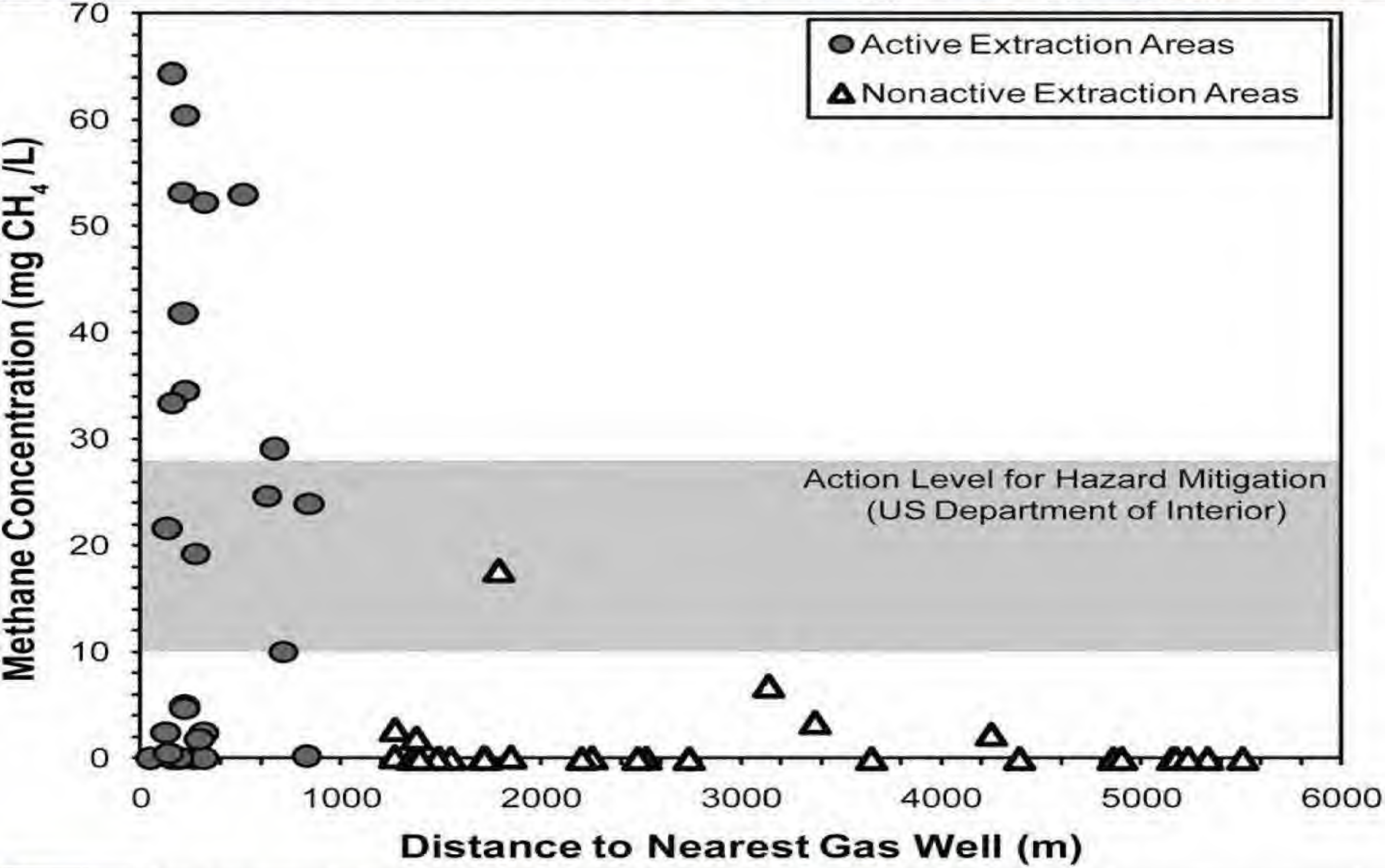


The Impact of Marcellus Gas Drilling on Rural Drinking Water Supplies, Center for Rural PA, October 2011

Studies of Methane in Groundwater in NE PA

- Study: *Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing, Osborn et al, 2011*
- Duke University researchers found methane concentrations were detected generally in 51 of 60 drinking-water wells (85%)
- More thermogenic methane signals closer to active Marcellus drilling and production
- Concluded that methane on average 17X higher in groundwater wells in areas of active extractions (< 1 km) vs. areas where no extraction occurring
- There were known methane migration issues associated with 18 private wells in the study area per PaDEP investigations

Methane in Groundwater in NE PA



Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing, Osborn et al, 2011

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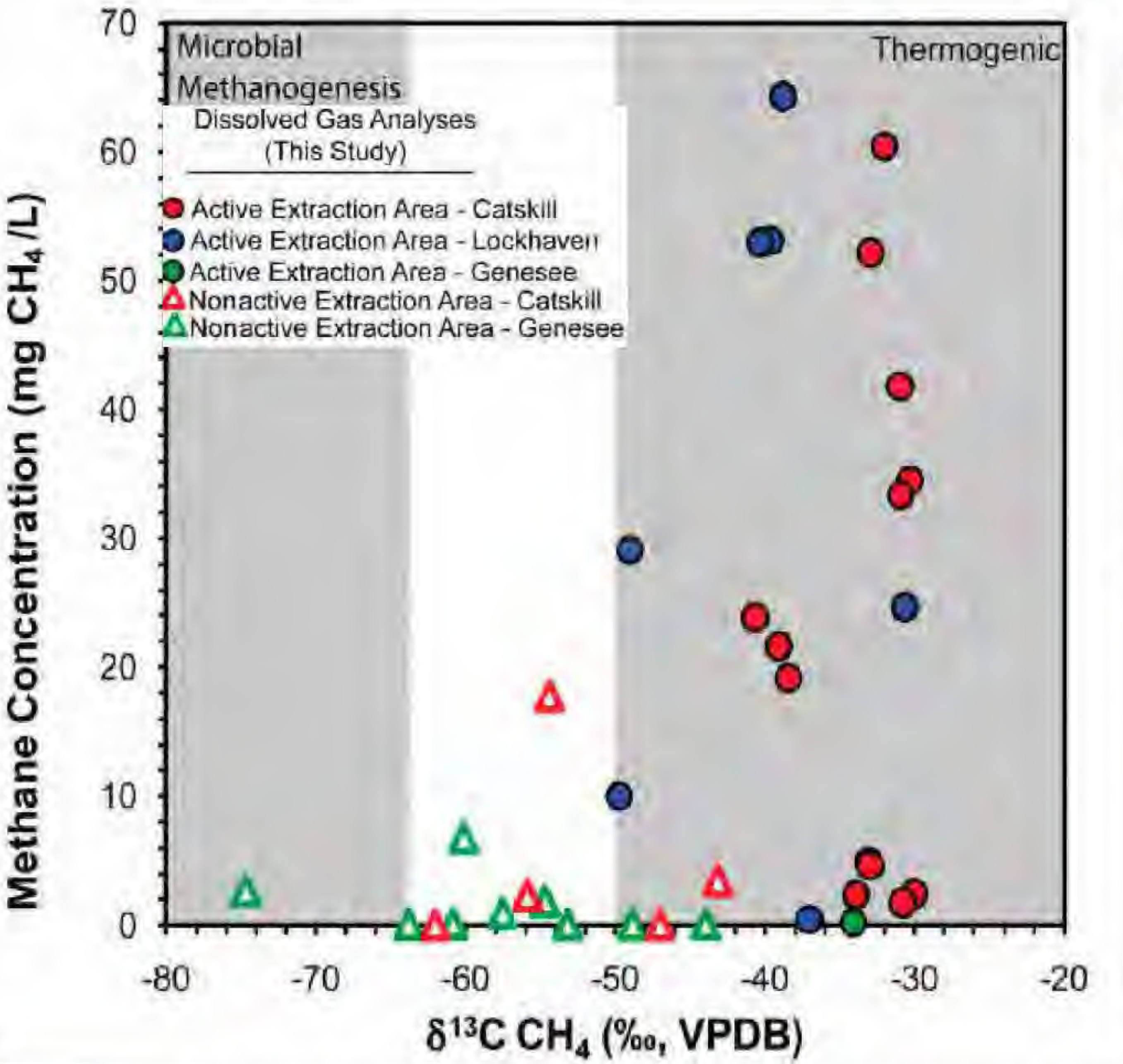
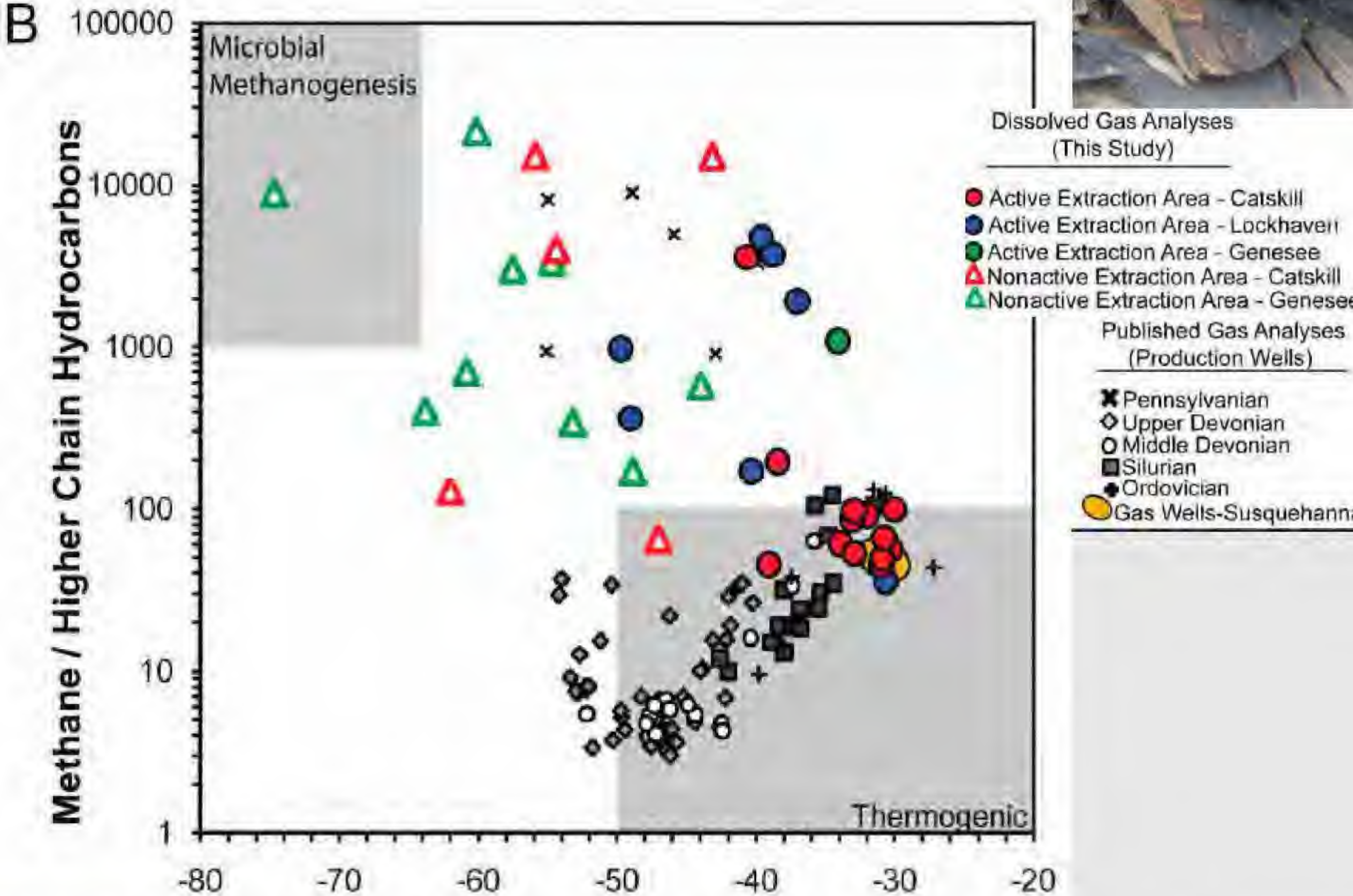


- δ13C in the methane becomes more like the thermogenic signature as gas concentration increases
- Grey areas are typical δ 13C values for biogenic and thermogenic (Osborn and McIntosh (2010)

Isotope standard = VDPB (Vienna Pee Dee Belemnite)

Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing, Osborn et al, 2011



Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing, Osborn et al, 2011

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Additional Methane in Groundwater Study

- Study: *Methane in Pennsylvania Water Wells Unrelated to Marcellus Shale Fracturing, Molofsky, et al (2012)*
- 1,713 pre-drilling samples collected by industry with methane detected in 78% of samples
- Found a topographic relationship with methane detections in groundwater rather than proximity to active drilling areas
- 51% of samples collected in valleys, but 88% of samples with >7 ppm methane occur in valleys

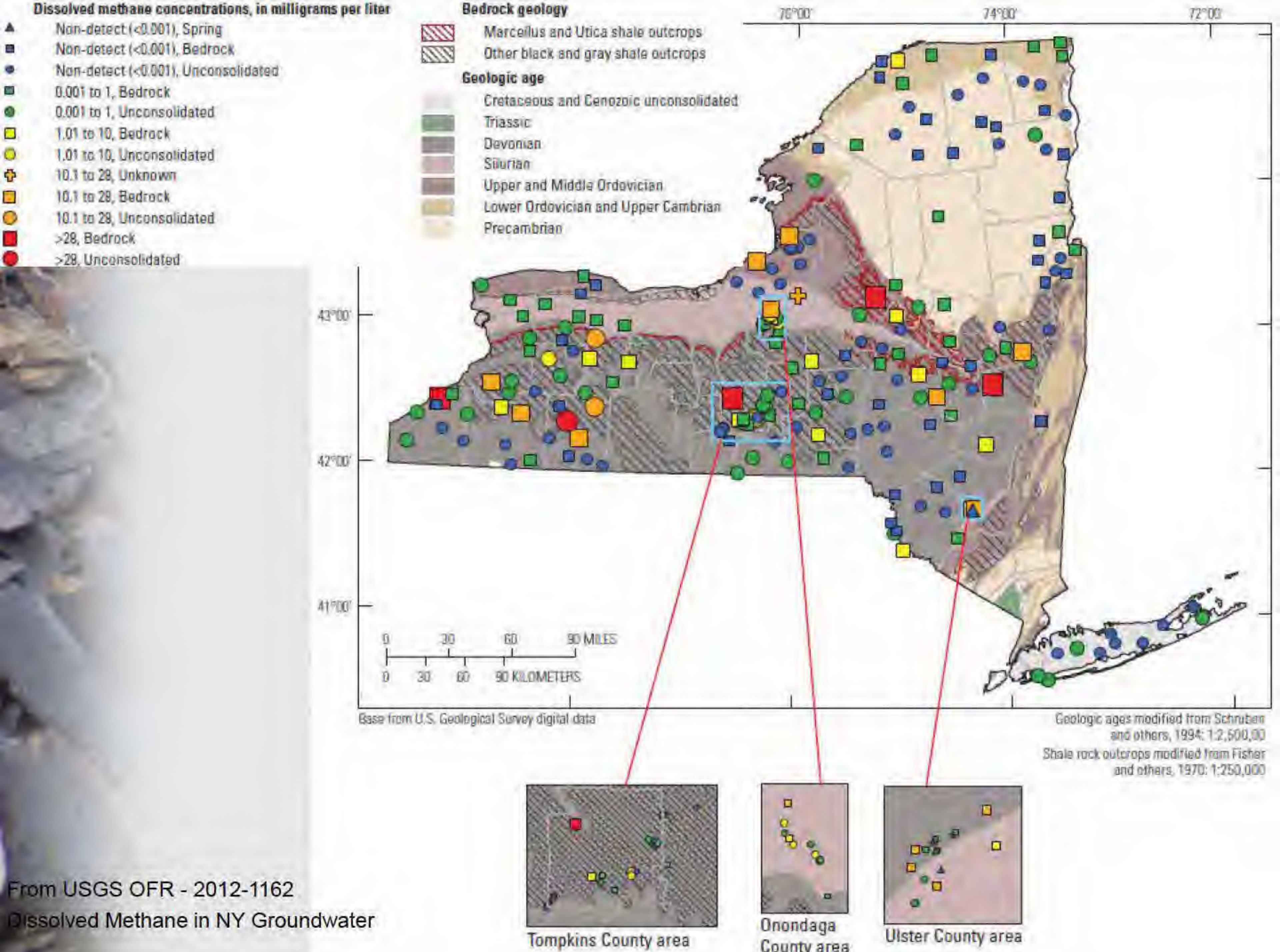
Gas Happens!

Photograph by Matthew Conheady (www.nyfalls.com)

From USGS OFR - 2012-1162 Dissolved Methane in NY Groundwater

USGS Study of Methane in Groundwater New York State

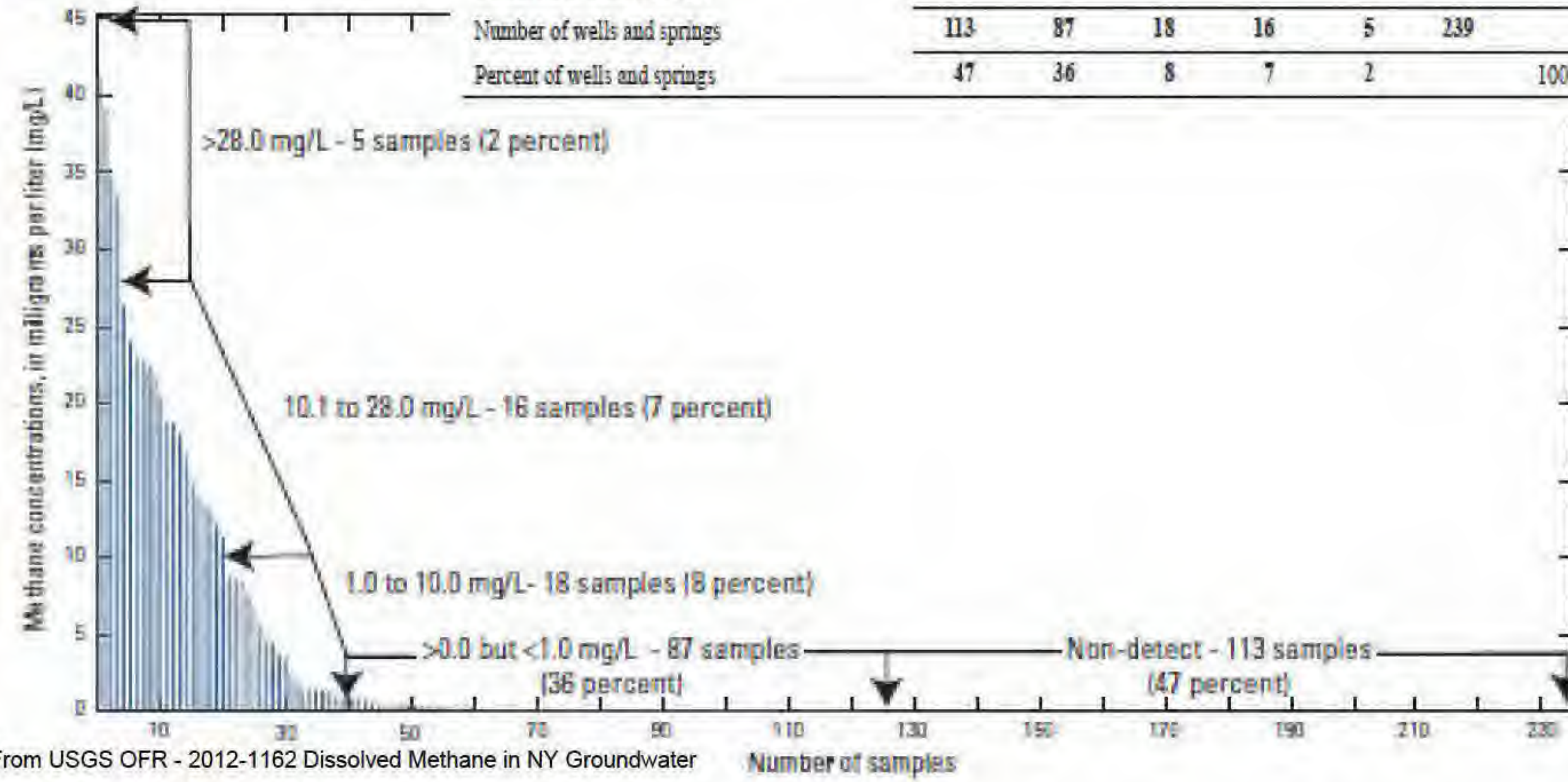
- Study: *Dissolved Methane in New York Groundwater, USGS OFR - 2012-1162*
- 239 groundwater samples collected with methane detected in 53% of samples
- 91% of wells have methane detected at <10 ppm (Office of Surface Mining action level)
- <1% of samples have methane detected at >28 ppm



From USGS OFR - 2012-1162
Dissolved Methane in NY Groundwater

Methane concentrations in NY groundwater

Geologic age of water-bearing formation	Number of wells by methane concentration (in milligrams per liter)						
	Non-detect	< 1.0	1.0–10.0	10.1–28.0	> 28.0	Number of wells	Percent of wells
Pleistocene & Upper Cretaceous (glacial) deposits	75	45	5	3	1	129	54
Devonian	14	19	10	7	3	53	22
Silurian	2	8	1	2	0	13	5
Upper and Middle Ordovician	3	5	1	3	1	13	5
Lower Ordovician & Upper Cambrian	7	6	1	0	0	14	6
Precambrian	9	4	0	0	0	13	5
Unknown & other (springs)	3	0	0	1	0	4	2
Number of wells and springs	113	87	18	16	5	239	
Percent of wells and springs	47	36	8	7	2		100

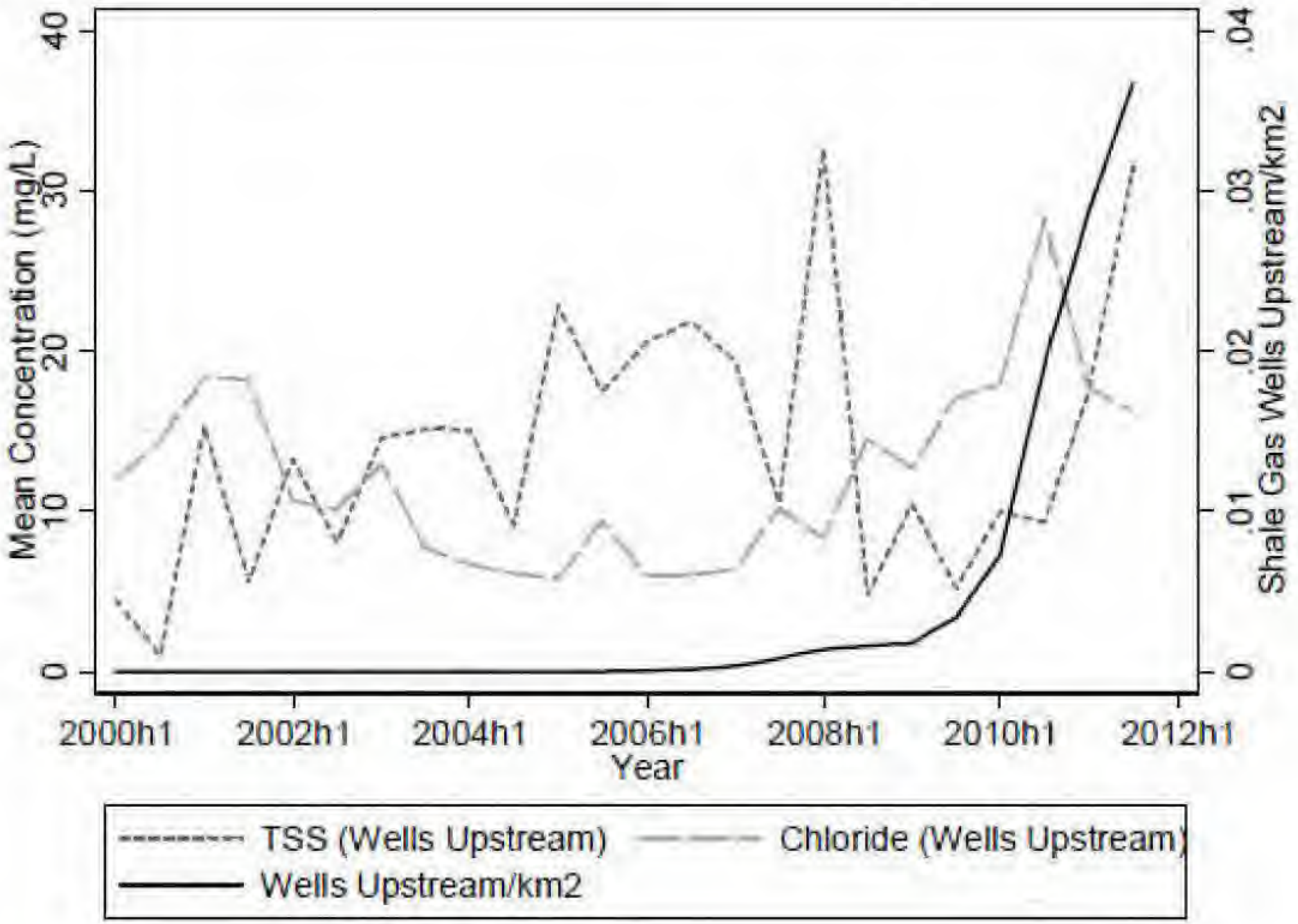


From USGS OFR - 2012-1162 Dissolved Methane in NY Groundwater

Potential Surface Water Quality Impacts

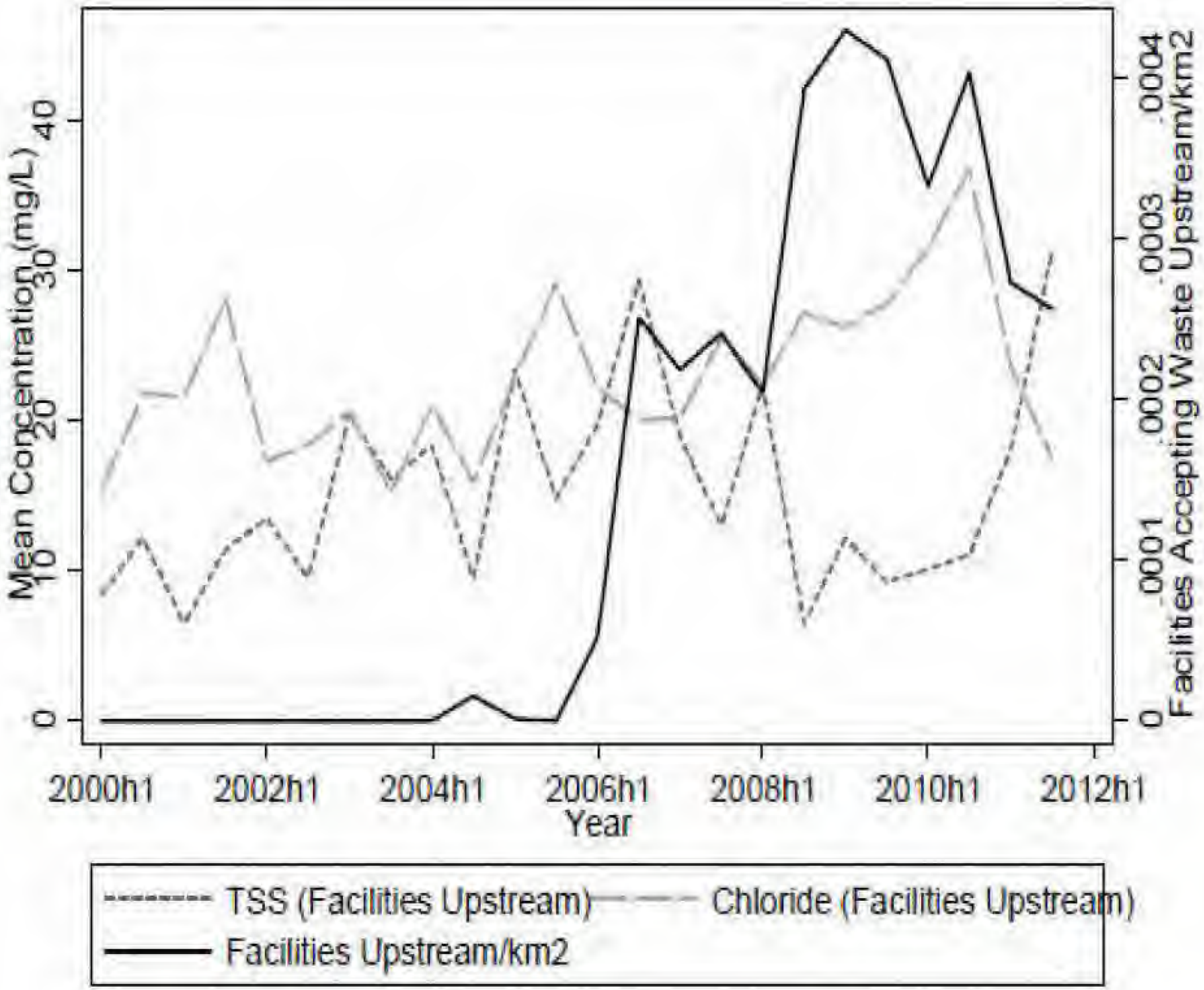
- Study: *Shale gas development impacts on surface water quality in Pennsylvania, Olmstead, et.al. (2012)*
- Created a GIS model to estimate surface water impacts from shale energy development in PA
- The treatment of shale gas waste by treatment plants in a watershed potentially raises downstream chloride concentrations, but not total suspended sediment concentrations
- The presence of shale gas wells in a watershed potentially raises downstream total suspended sediment concentrations, but not chloride concentrations.

Figure S1. Average contaminant concentrations and density of upstream shale gas wells for monitors with at least one upstream well in their watershed (2000-2011)



Shale gas development impacts on surface water quality in Pennsylvania, Olmstead, et.al. (2012)

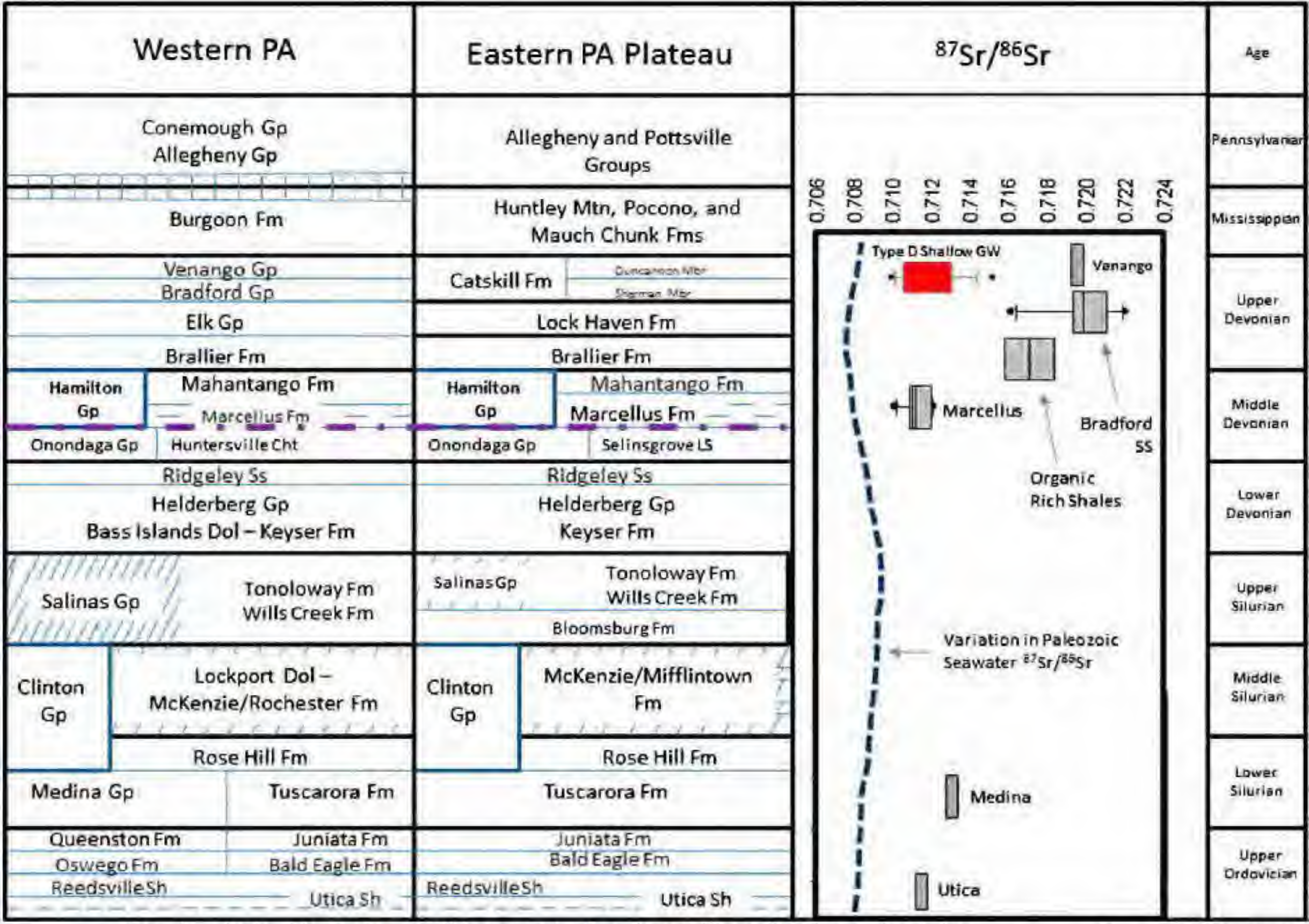
Figure S2. Average contaminant concentrations and density of upstream treatment facilities accepting shale gas waste for monitors with at least one accepting facility in their watershed (2000-2011)



Shale gas development impacts on surface water quality in Pennsylvania, Olmstead, et.al. (2012)

Possible Deep Migration Pathways in Groundwater in NE PA

- Study: *Geochemical evidence for possible natural migration of Marcellus Formation brine to shallow aquifers in Pennsylvania, Warner, et. al., (2012)*
- Present geochemical evidence from northeastern Pennsylvania showing that pathways unrelated to recent drilling activities
- Isotopic ratios (87Sr/86Sr, 2H/H, 18O/16O, and 228Ra/226Ra) suggest that mixing relationships between shallow ground water and a deep formation brine causes groundwater salinization in some locations



Geochemical evidence for possible natural migration of Marcellus Formation brine to shallow aquifers in Pennsylvania, Warner, et. al., (2012)

Naturally Occurring Radioactive Materials (NORMs) (Rowan et al. 2011)

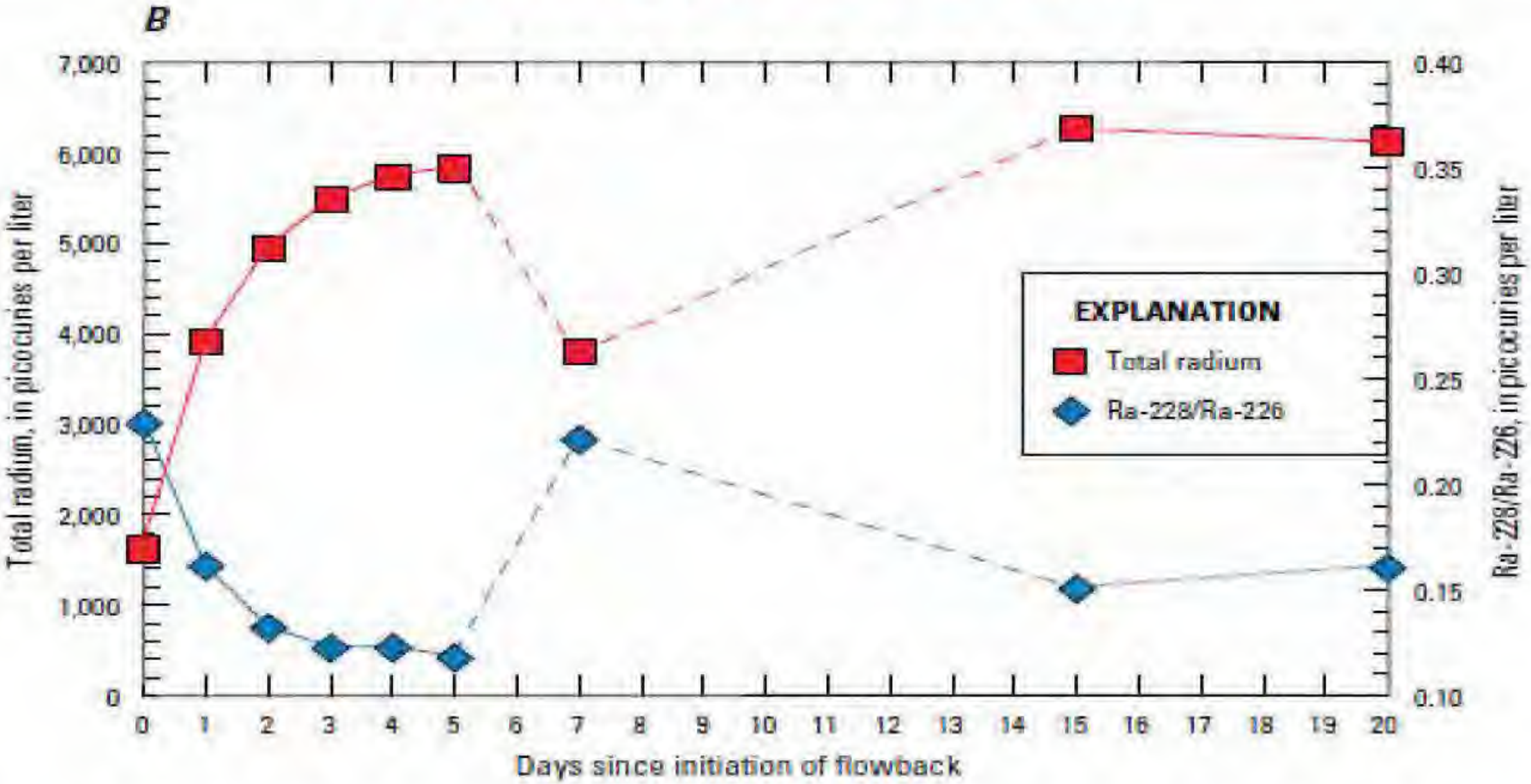


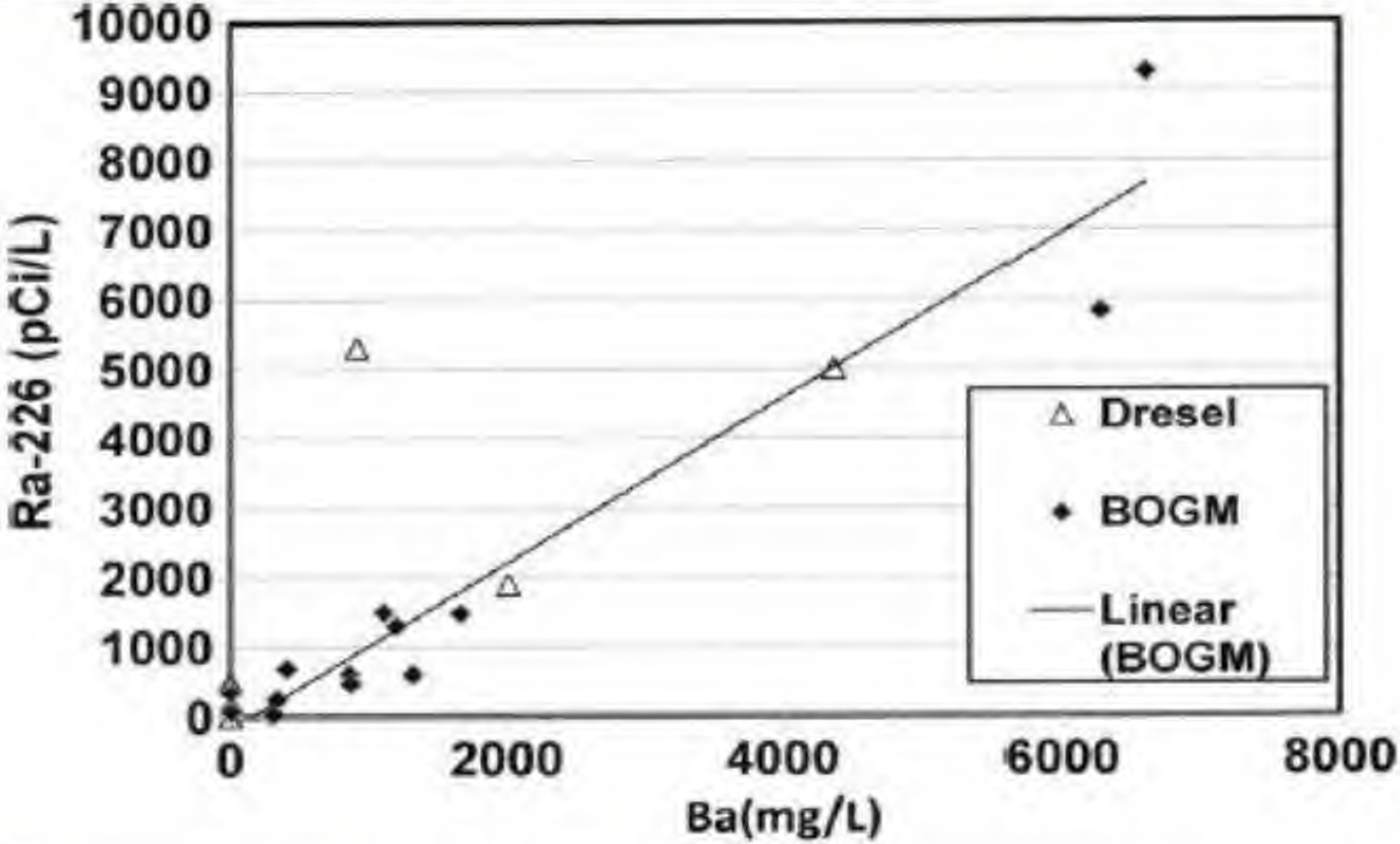
Figure 6. (*A*) Total radium activity and total dissolved solids related to time since initiation of flowback for well no. 11, Washington County, Pa. (*B*) Total radium activity (left axis, squares) and Ra-228/Ra-226 (right axis, diamonds) related to time since initiation of flowback for well no. 132, Greene County, Pa.

Rowan, E.L., Engle, M.A., Kirby, C.S., and Kraemer, T.F., 2011, Radium content of oil- and gas-field produced waters in the northern Appalachian Basin (USA)—Summary and discussion of data: U.S. Geological Survey Scientific Investigations Report 2011–5135, 31 p.
(Available online at http://pubs.usgs.gov/sir/2011/5135/)

Characterization of Produced Fluids

- Study: *Haluszczak, L.O., et al. Geochemical evaluation of flowback brine from Marcellus gas wells in Pennsylvania, USA. Appl. Geochem. (2012),http://dx.doi.org/10.1016/j.apgeochem.2012.10.002*
- The chemistry of the later flowback water is similar to brines produced from conventional Ordovician to Devonian oil and gas wells.
- The Cl–Br relations indicate that the late flowback waters developed from a highly saline brine evaporated from seawater into the stage of halite precipitation, and then diluted and mixed with seawater, fresh water and injected fluids.

Correlation of Barium and Radium-226 in Flowback



Haluszczak, L.O., et al. (2012)

Thank you!

Questions?

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