Fracture Characteristics and Groundwater Arsenic in Bedrock Wells of Manchester, Maine

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Introduction

High density sampling of domestic wells in the greater Augusta area, Maine, has identified that approximately 40% of wells installed to the calc and calc-silicate meta-sedimentary rock, Sangerville and Waterville Formations, contain > 10 µg/L arsenic (As). The survey reveals a high degree of spatial heterogeneity of ground water As distribution at local scales of ⩽ 100 m, because domestic boreholes are typically supplied by water with distinct chemistry from complicated inter-connected fracture network. This was investigated by geophysical logging and fracture water sampling in two existing private wells installed to Silurian pelite-sandstone/limestone units in Manchester, Maine.

Study Area

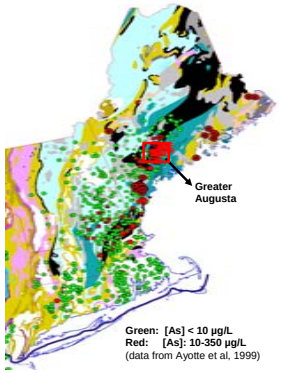
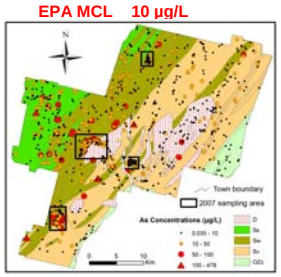


Fig. 1 Groundwater arsenic plotted on bedrock geology map of New England



D - Biotite-muscovite granite
Ss - Biotite granofels with minor schist
Sw - Schist and granofels +/- marble
Sv - Biotite granofels and schist, minor calc-silicate
OZc - Mixed metavolcanics

31% of 790 groundwater samples > 10 µg/L;
5% > 50µg/L; maximum 478µg/L

Fig. 2 Groundwater arsenic plotted on simplified bedrock geology map in the greater Augusta area, Maine

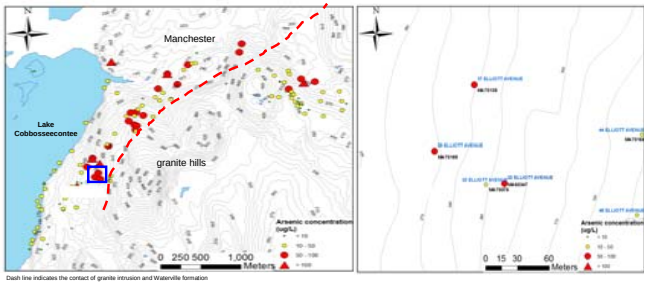
Stepwise logistic model test

All the parameters included: well type, well depth, temperature, pH, DO, bedrock unit, alkalinity, major elements, trace elements, elevation, soil [As]

The final logistic model included: well type, pH, DO, bedrock unit and soil [As]

glm(formula = prob ~ Type + pH + DO + Bedrock + Soil [As], family = binomial)

	Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	-10.73432	1.38757	-7.736	1.03e-14 ***
Type-dug	**0.75394**	0.54144	1.392	0.1638
PH	**1.14476**	0.16252	7.044	1.87e-12 ***
DO	**-0.10532**	0.05232	-2.013	0.0441 *
Bedrock-OZ	**-0.29692**	0.74166	-0.400	0.6889
Bedrock-Ss+Sw	**1.02680**	0.42076	2.440	0.0147 *
Bedrock-Sv	**0.77492**	0.42611	1.819	0.0690 .
Soil [As]	**0.02453**	0.01207	2.032	0.0421 *



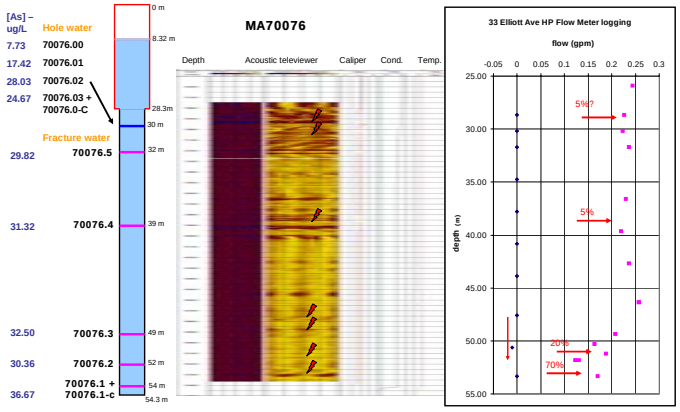
Dash line indicates the contact of granite intrusion and Waterville formation

Fig. 3 Arsenic concentrations plotted on topographic map of study site

Arsenic Source

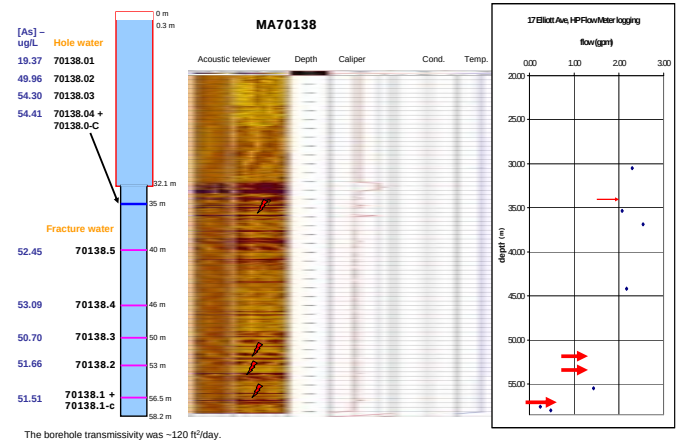
Fig.4 Fe-S rich meta-sedimentary rocks (left: Sv outcrop) and weathered pyrite crystals (right: Sw outcrop)

Geophysical Logging



The borehole transmissivity was 2.5-3.3 ft²/day.

Fig. 5 Geophysical logging and fracture water sampling in MA70076



The borehole transmissivity was ~120 ft²/day.

Fig. 6 Geophysical logging and fracture water sampling in MA70138

Cubitainer Experiment

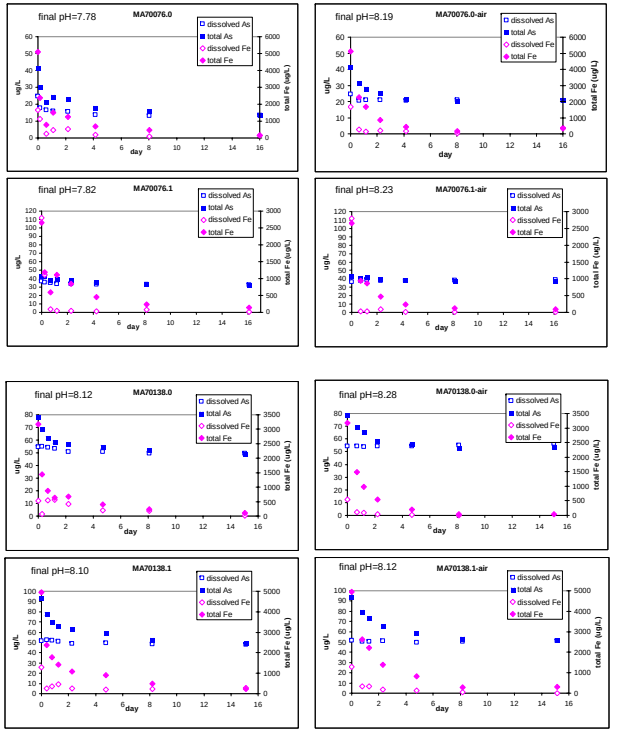


Fig. 7 total and dissolved arsenic and iron concentrations vs. time

Summary

(1) In a single bedrock well, arsenic concentration of hole water is determined by mixing of water with distinct arsenic concentrations from fractures at various depths with variable flow rates.

(2) The bore hole water arsenic concentration reflects the weighted average of arsenic concentrations of fracture water, subjected to modification of redox reactions in the bore hole.

(3) Arsenic precipitates with iron particles quickly in the first couple of days; dissolved arsenic tends to be stabilized in a few hours after coming out of fractures and sitting in the bore hole.

Acknowledgement

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