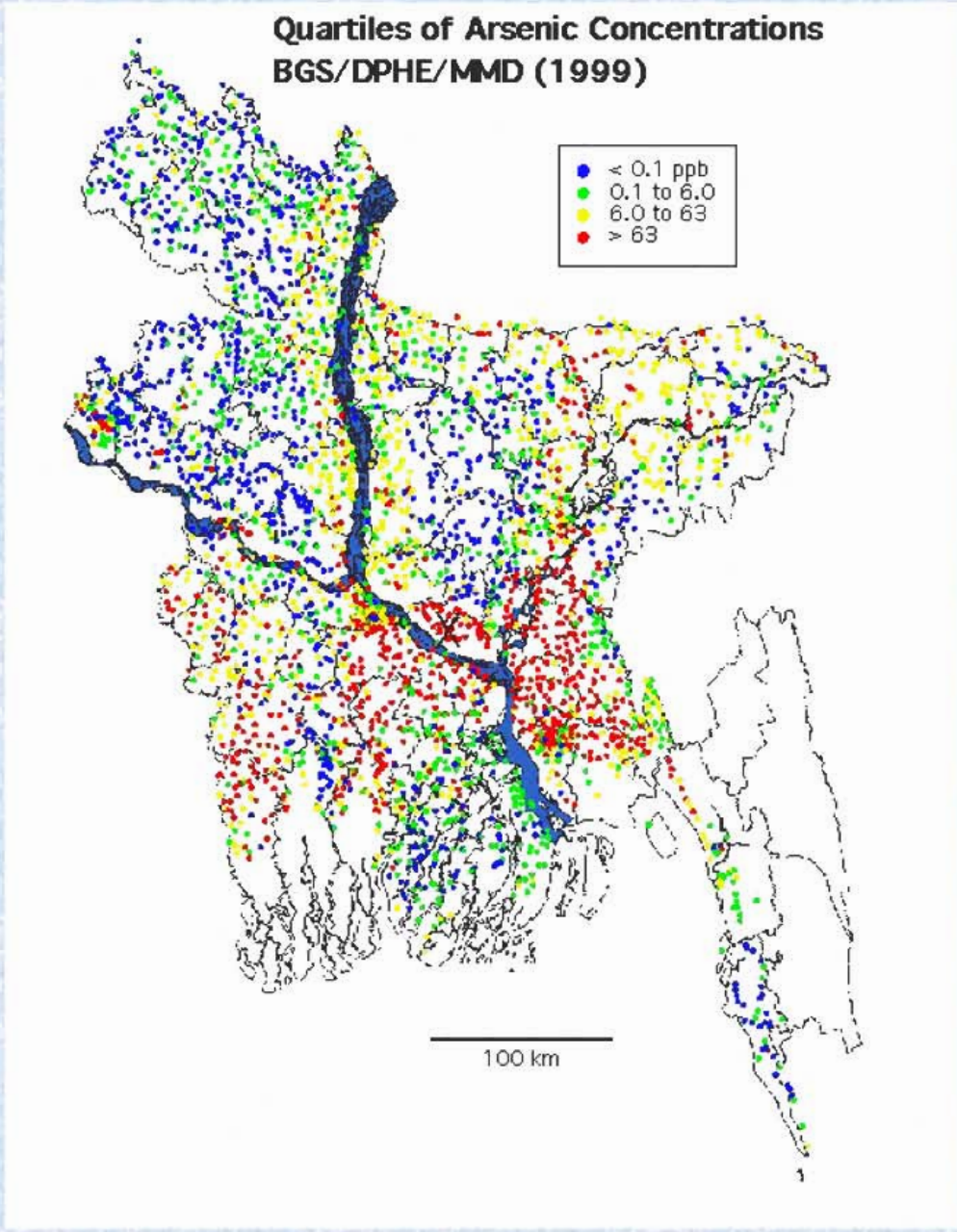
Bangladesh Arsenic Case Study

Cost comparison

Option	Unit Cost ($)	Persons (per unit)	Cost per Person ($)	Cost per arsenicosis case avoided
Deep Tubewell	$500 - 790	250	$2 - 3	$30 - 50
Household Treatment	$5 - 50	5	$3 - 20	$55 - 330
Dug Well	$560 - 620	125	$4.5 - 5	$65 - 70
Pond Sand Filter	$400 - 600	250	$2 - 4	$35 - 65
Rain Water	$100 - 200	5	$20 - 40	$350 - 630
Piped Supply	$30,000	2000	$17	$280

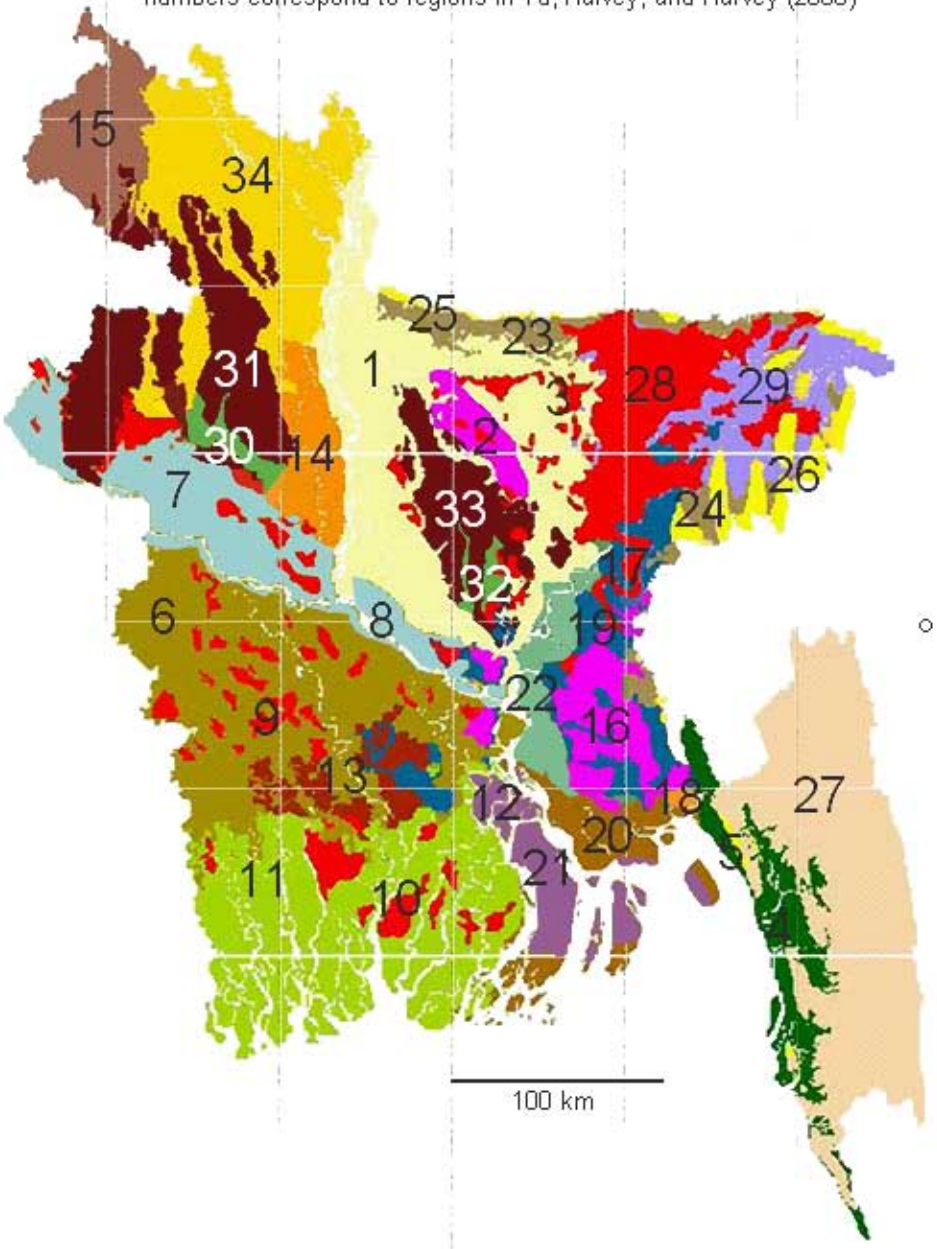
Source: Ahmed (2002)

Extent of Contamination and Health Effects

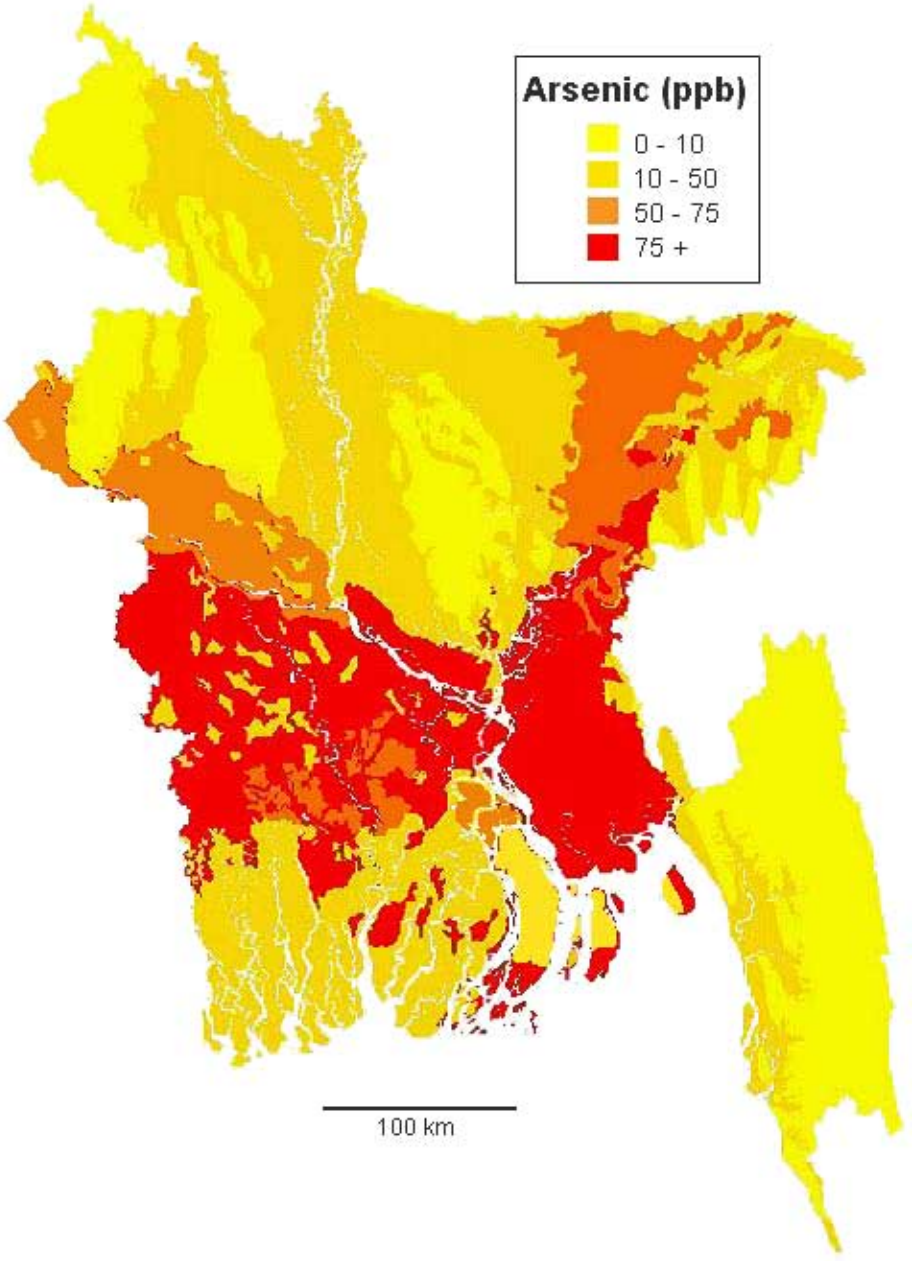

Quartiles of Arsenic Concentrations
BGS/DPHE/MMD (1999)
< 0.1 ppb
0.1 to 6.0
6.0 to 63
> 63
100 km

Geologic/Geomorphic Regions

numbers correspond to regions in Yu, Harvey, and Harvey (2000)

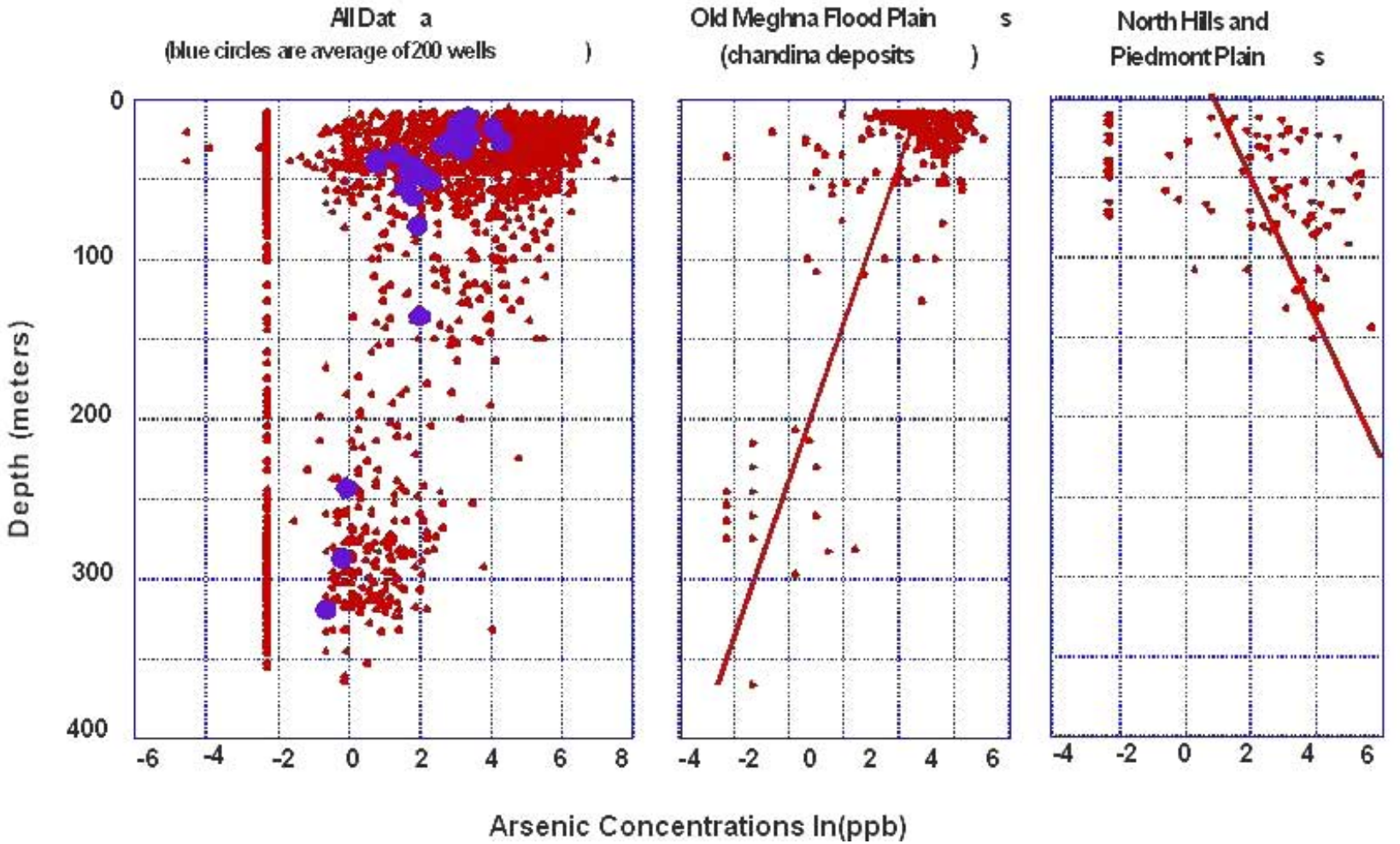


Mean Arsenic Concentrations in each Geologic/Geomorphic Region



Groundwater Arsenic Concentrations Versus Depth

(from British Geologic Survey Regional/Special Surveys)



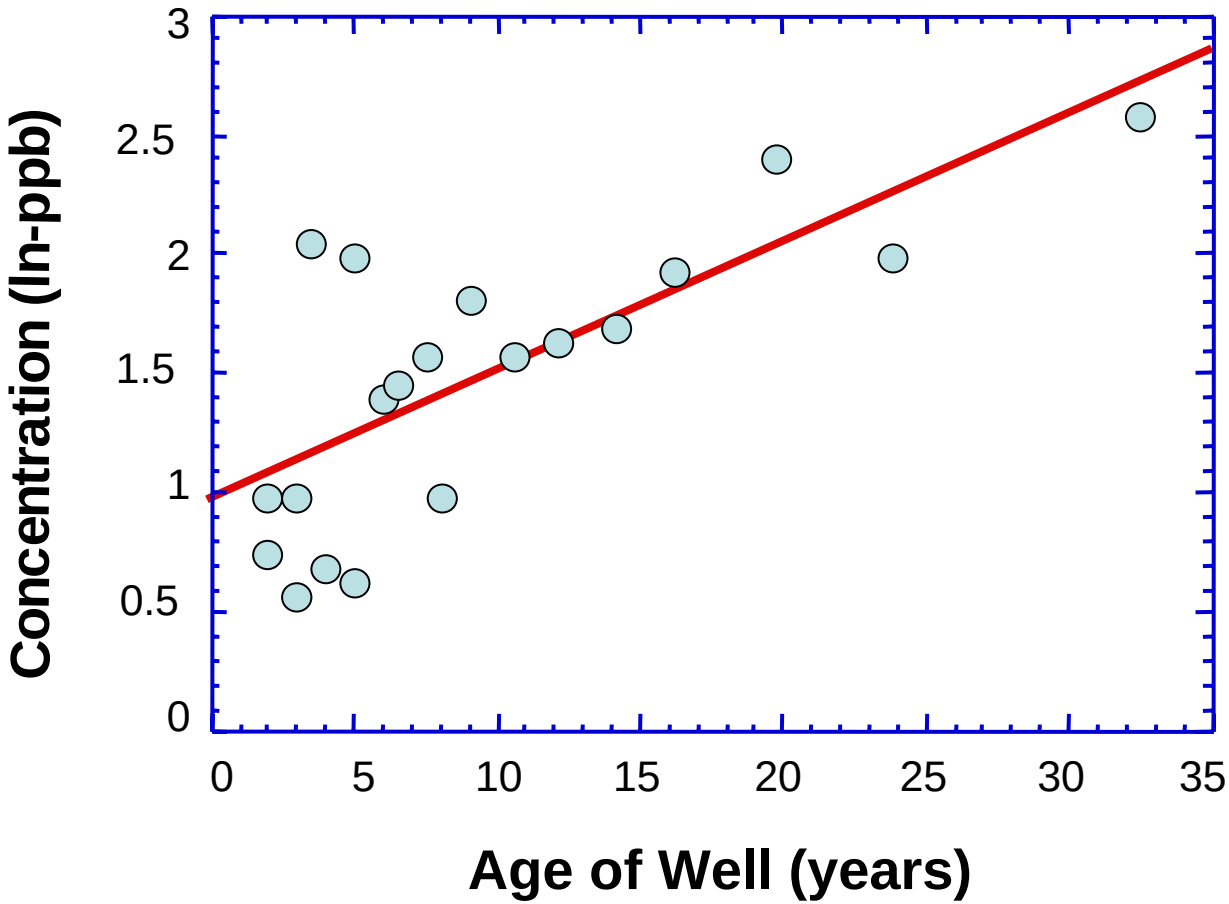
Predicted National Rates of Arsenicosis and Cancer

	Present Conditions	150m Wells Remedy
Arsenicosis West Bengal Data our model fit	1,860,000 people (1%)	690,000 people (0.57%)
Skin Cancer Taiwan Data our fit	125,000 people (0.1%)	37,000 people (0.04%)
Internal Cancers Taiwan Data NRC model fit	3,000 people/yr	800 people/yr

The 150m well remedy:

- **Replaces 30% of the nations wells**
- **That is 800,000 wells at a cost of $500/well**
- **Total cost of $395,000,000**
- **$340 per reduction in arsenicosis prevalence**

Groundwater Arsenic Concentration vs. Age of Well



Each point represents an average of ~200 wells.
Wells were sampled in 1997-1999.

????

Big Basic Questions:

Why are dissolved arsenic levels so high?

- **Where does it come from? -- Little solid phase arsenic**
- **Why isn't it flushed away? -- Flow + Little retardation**

Why are arsenic concentrations so variable on small scales?

Important Questions for Decision Making:

Will arsenic concentrations change?

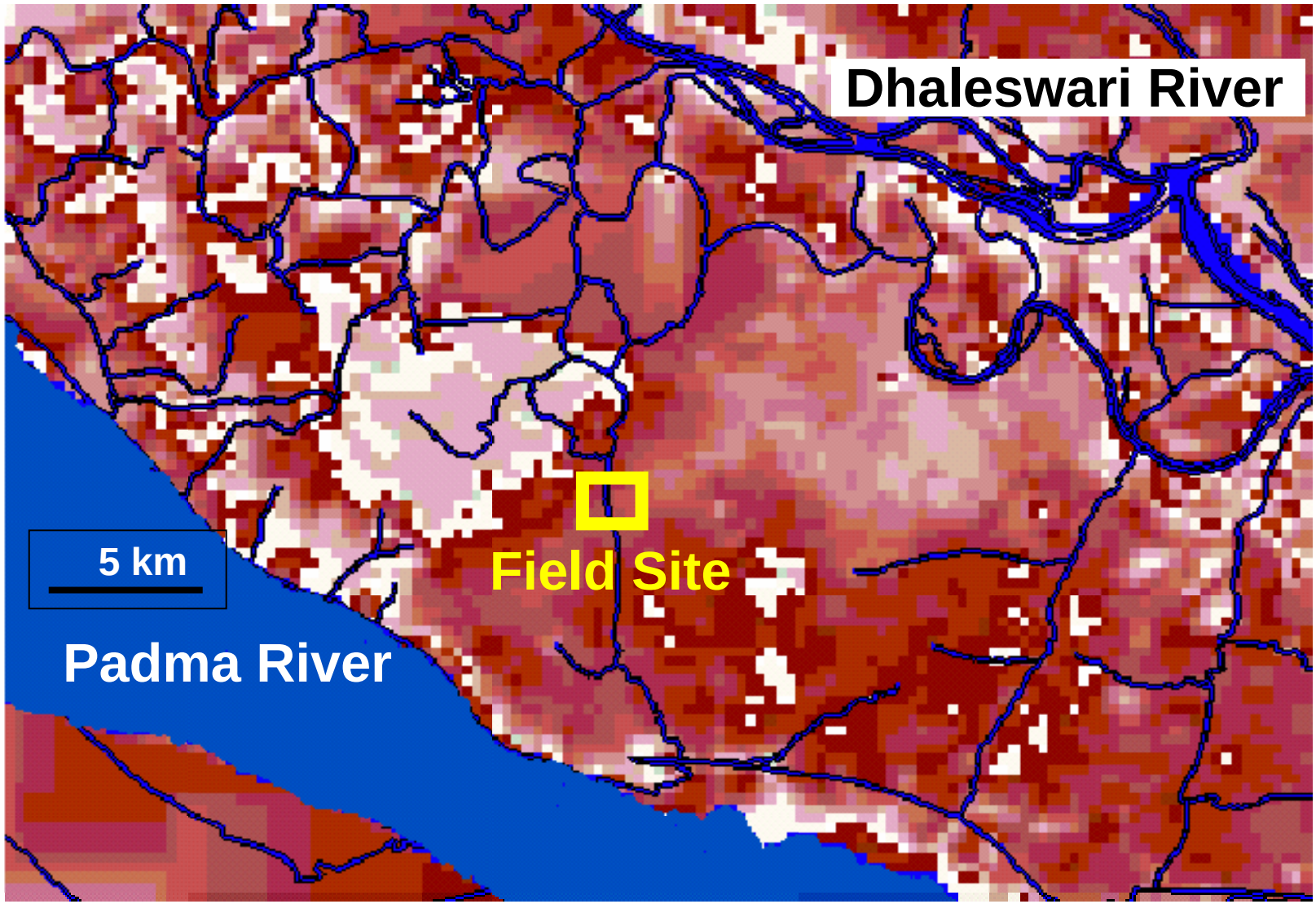
Can deep aquifers provide a long-term solution?

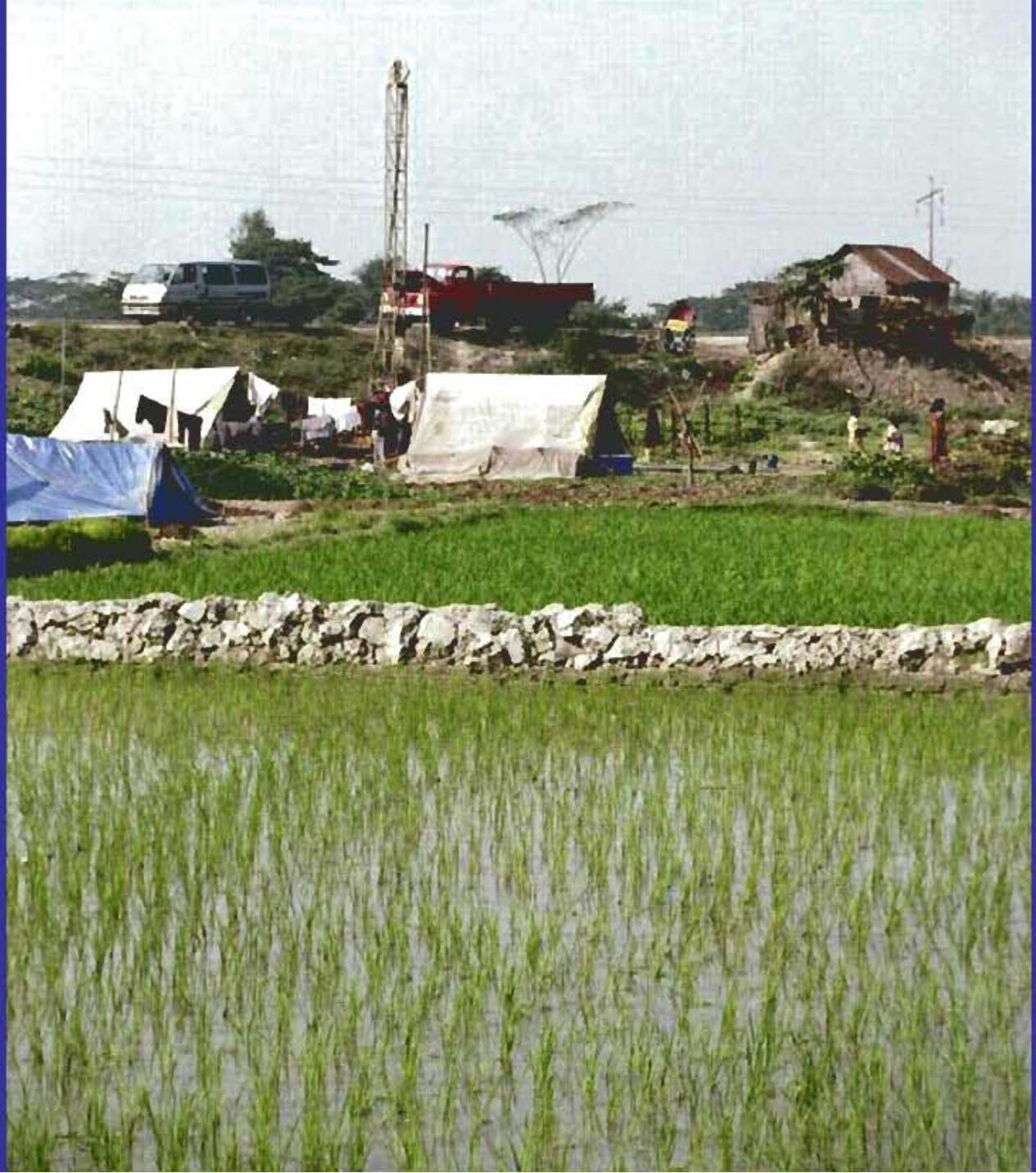
Key Scientific Questions:

What is the solid state of arsenic?

How do shifts in water chemistry affect arsenic mobility?

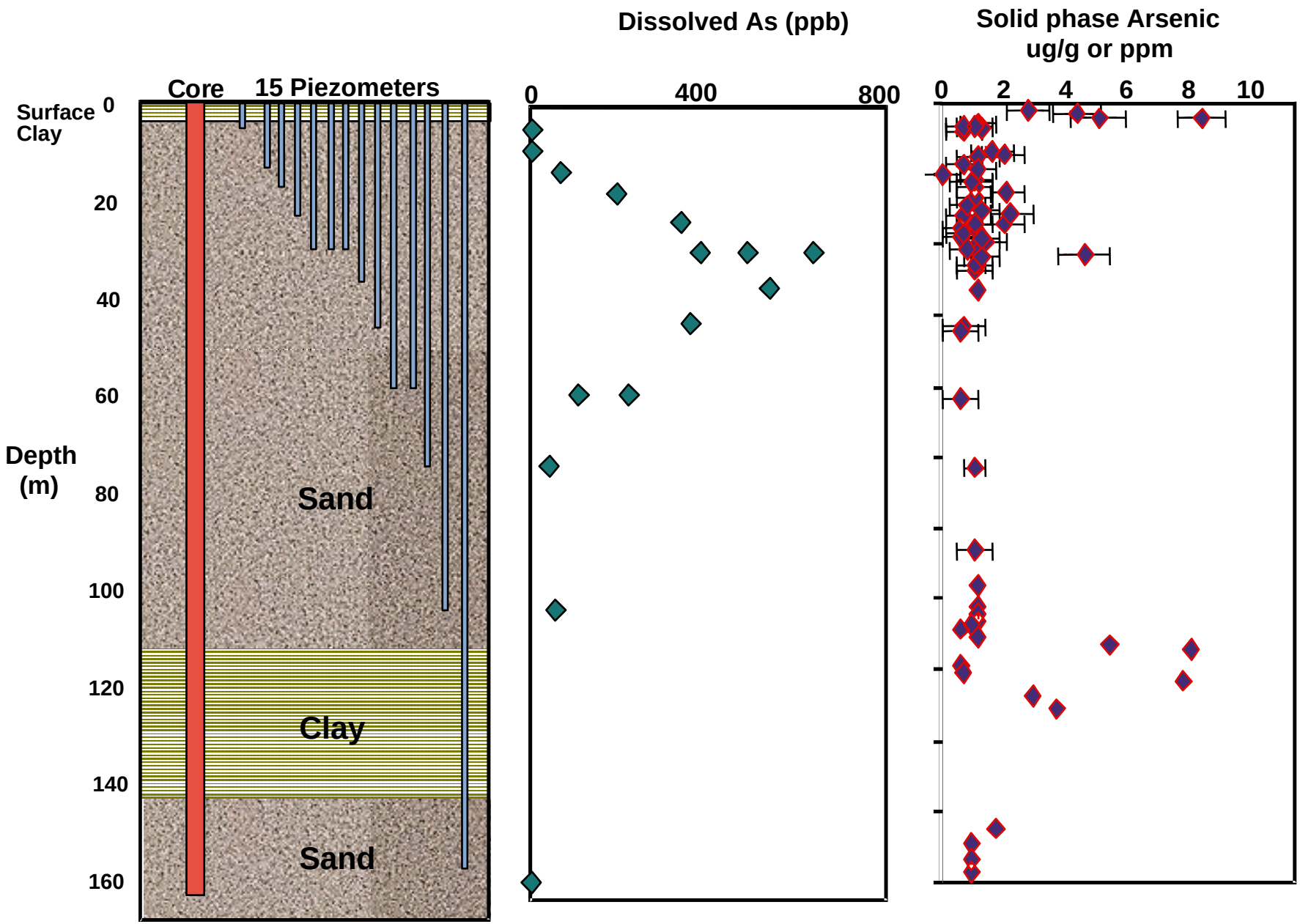
MIT/BUET Field Site

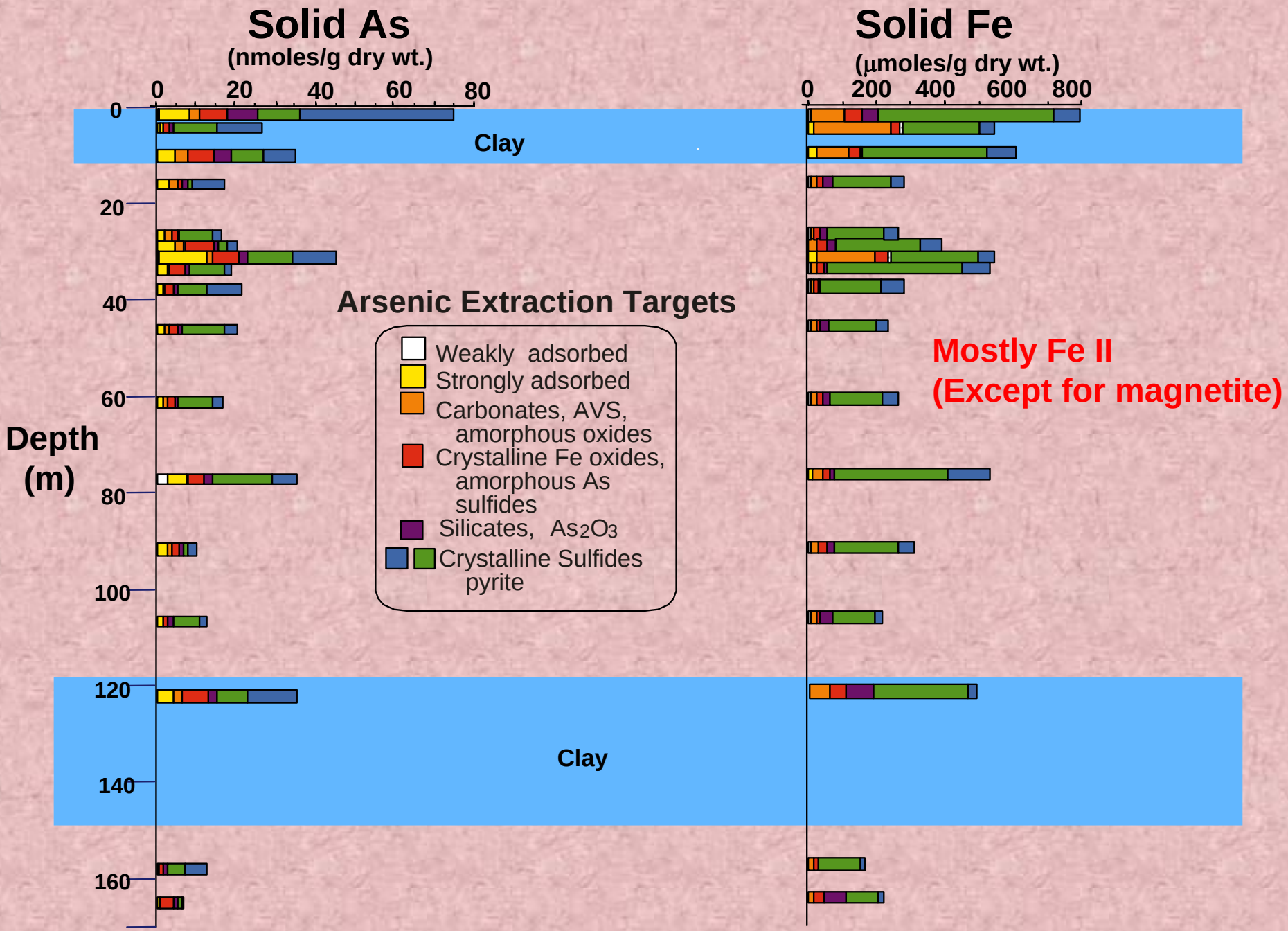

Dhaleswari River
Field Site
5 km
Padma River



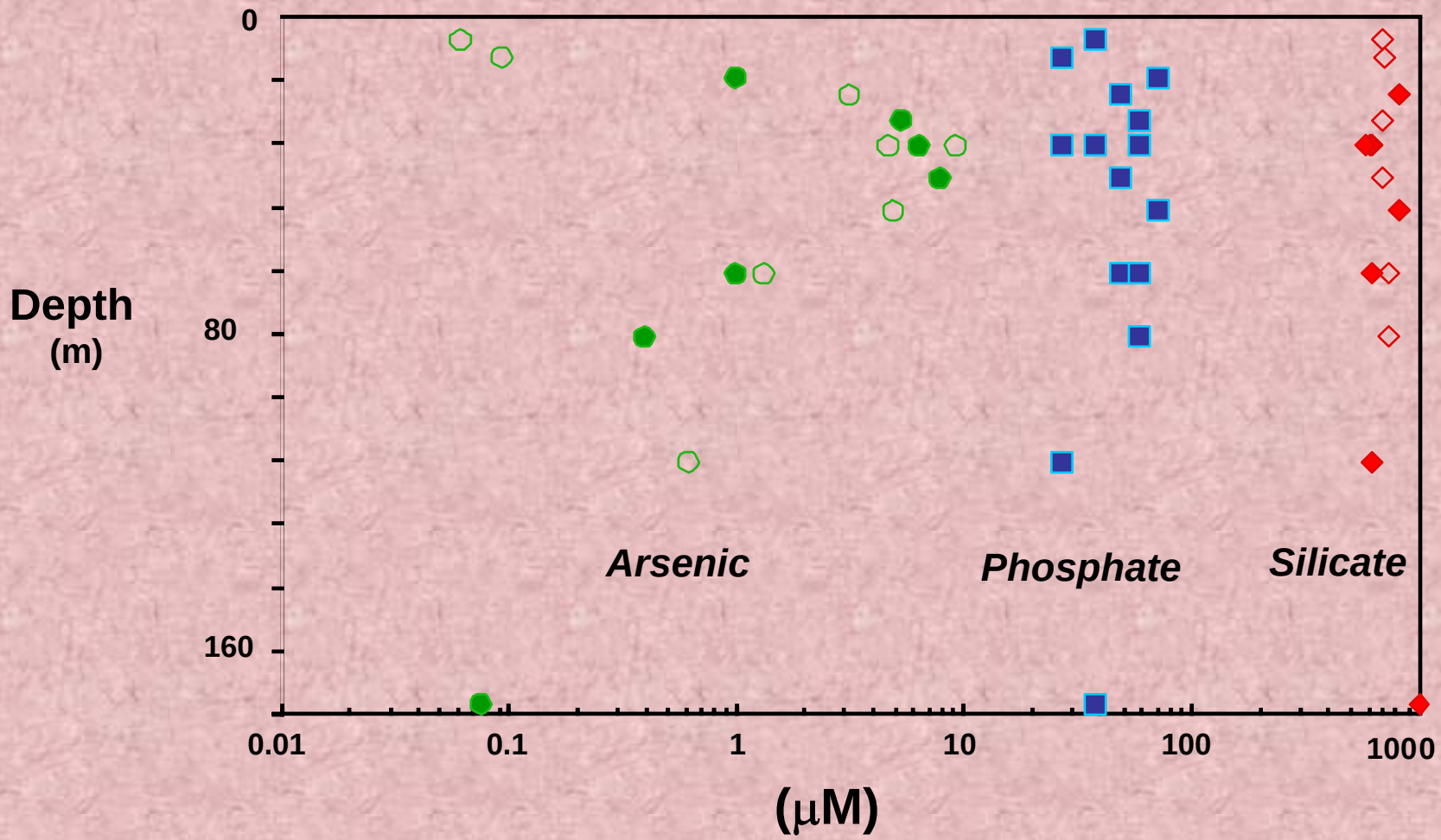
Biogeochemistry

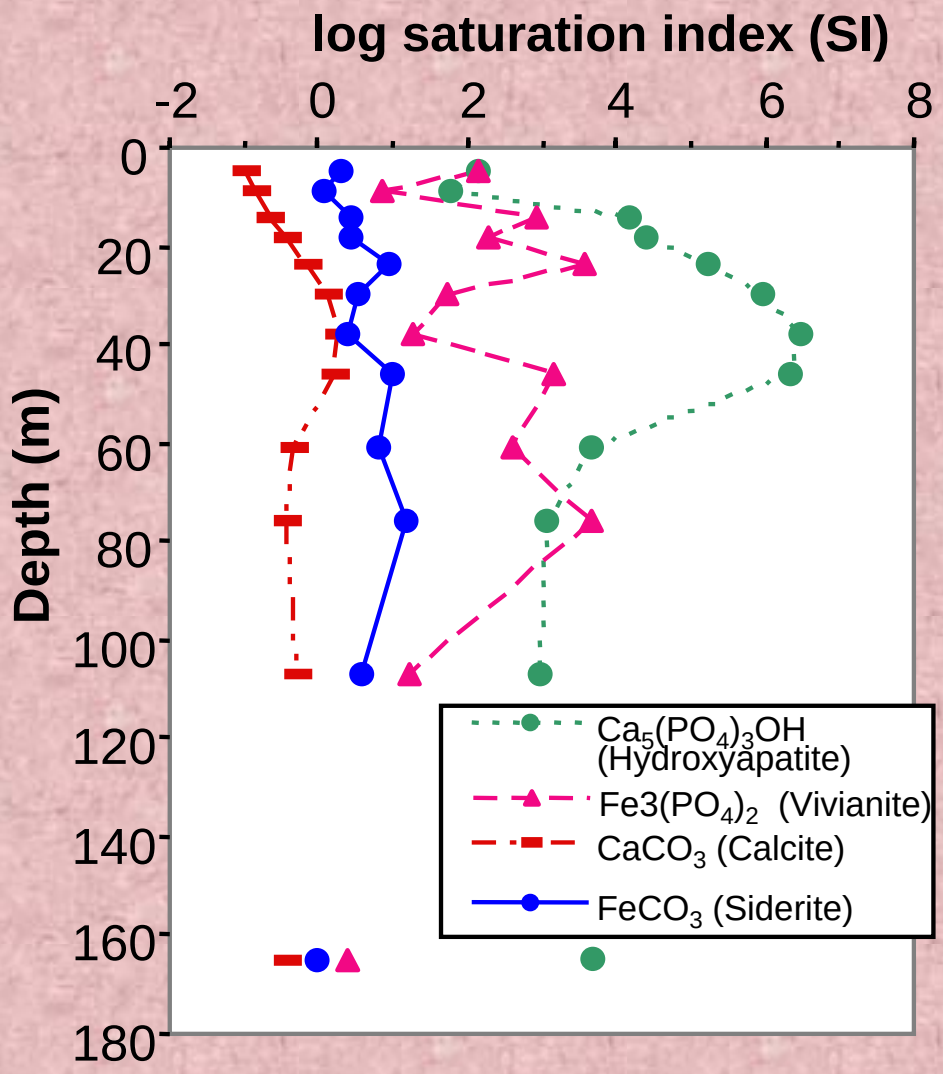
Arsenic Profile

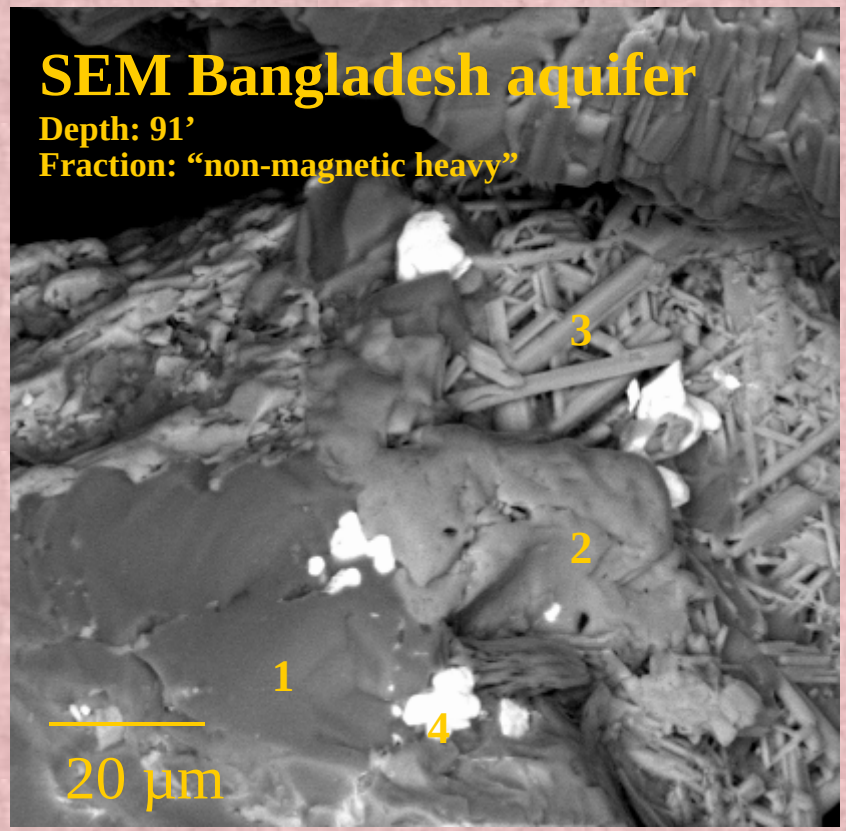



Solid As
(nmoles/g dry wt.)
0
20
40
60
80
Solid Fe
(μmoles/g dry wt.)
0
200
400
600
800
Clay
Depth (m)
0
20
40
60
80
100
120
140
160
Arsenic Extraction Targets
Weakly adsorbed
Strongly adsorbed
Carbonates, AVS, amorphous oxides
Crystalline Fe oxides, amorphous As sulfides
Silicates, As2O3
Crystalline Sulfides pyrite
Mostly Fe II
(Except for magnetite)
Clay

Competing Anions

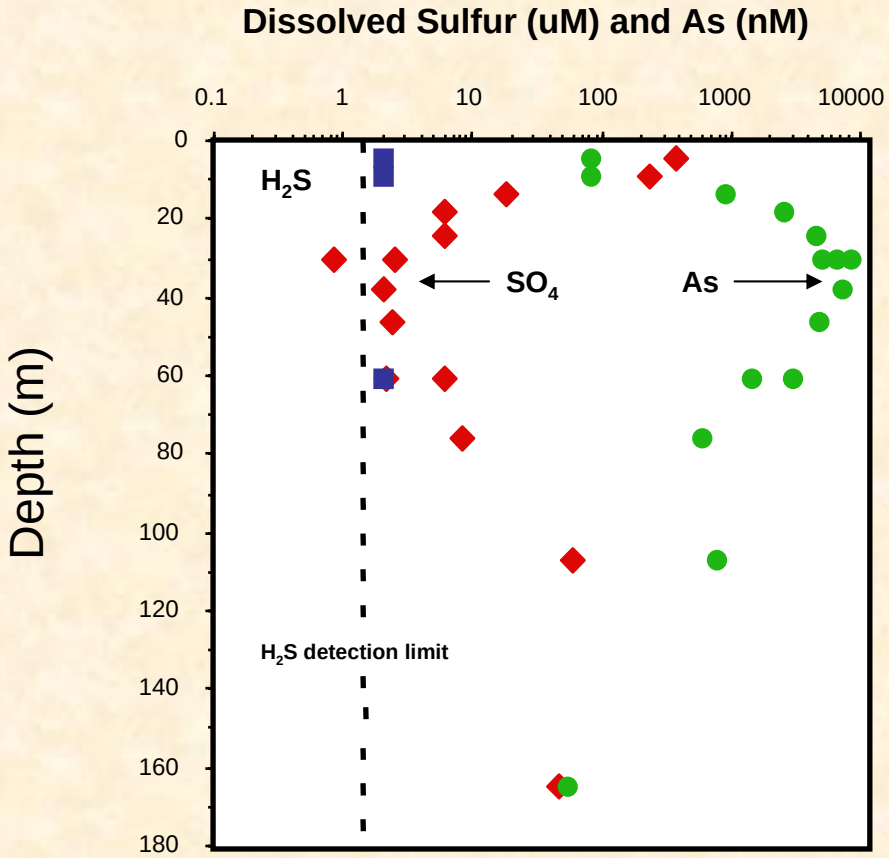


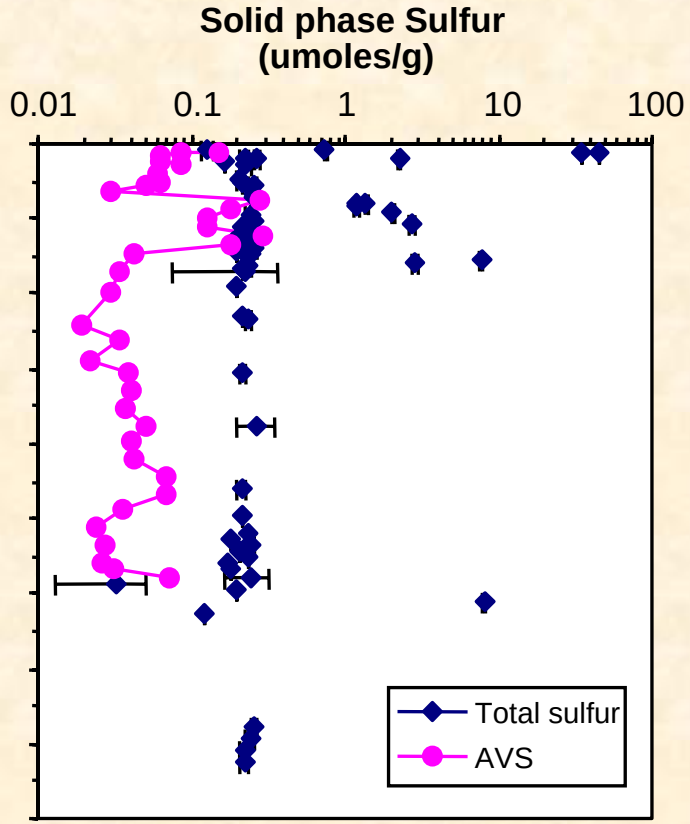




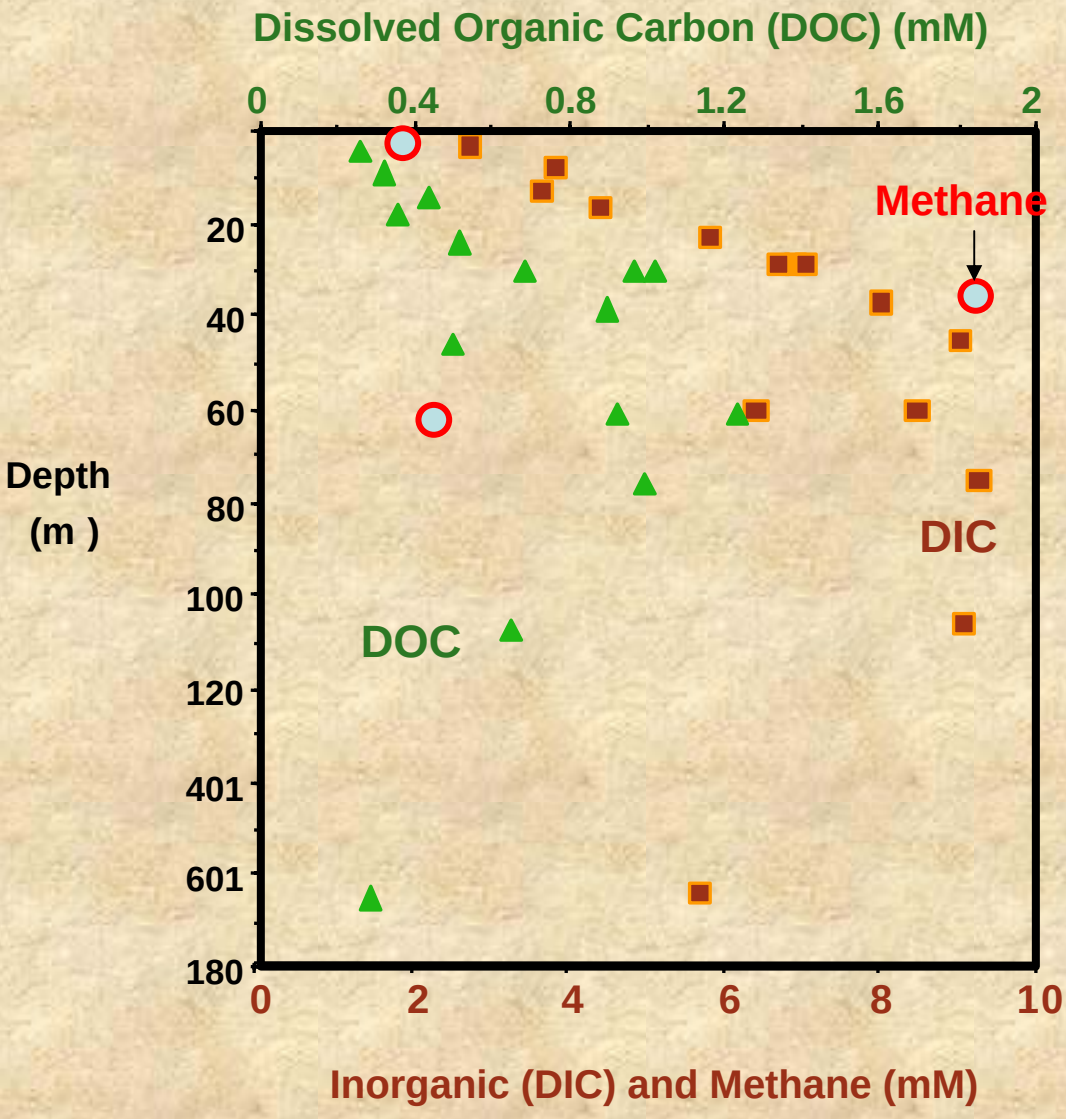
1. quartz (SiO_2)
2. Ca-phosphate
3. rutile (TiO_2)
4. REE-phosphate

Sulfur Chemistry

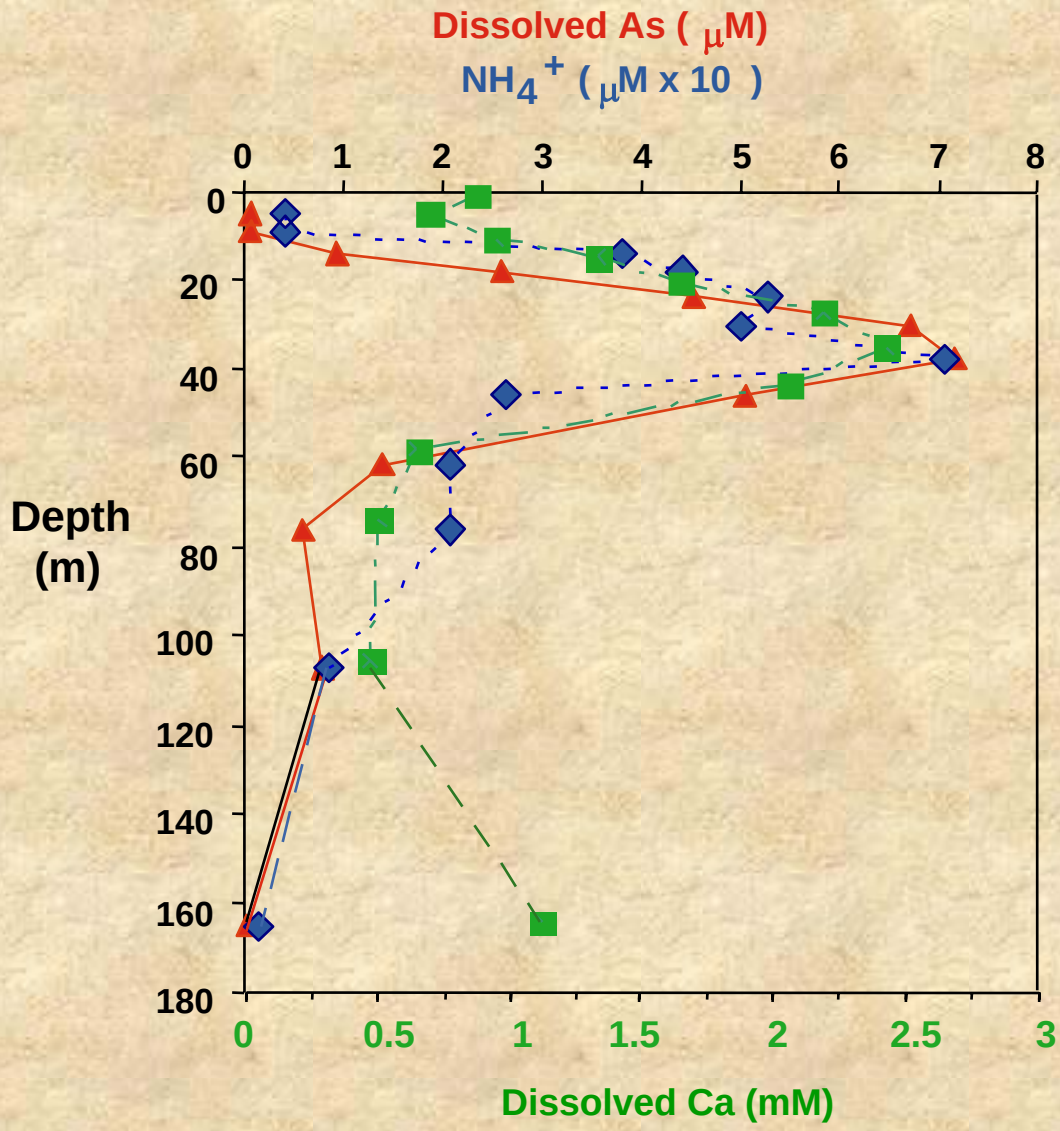




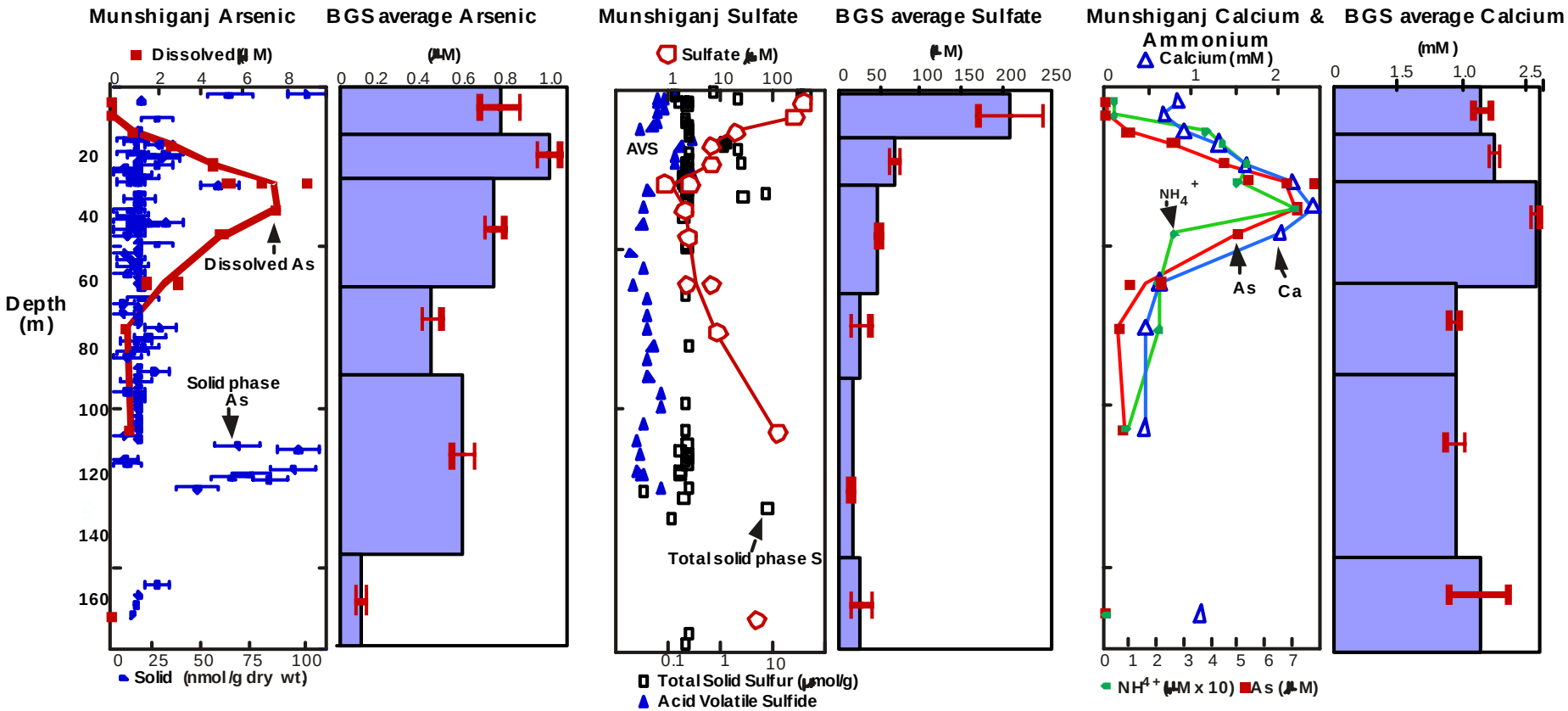
Dissolved Carbon



Arsenic, Ammonium and Calcium

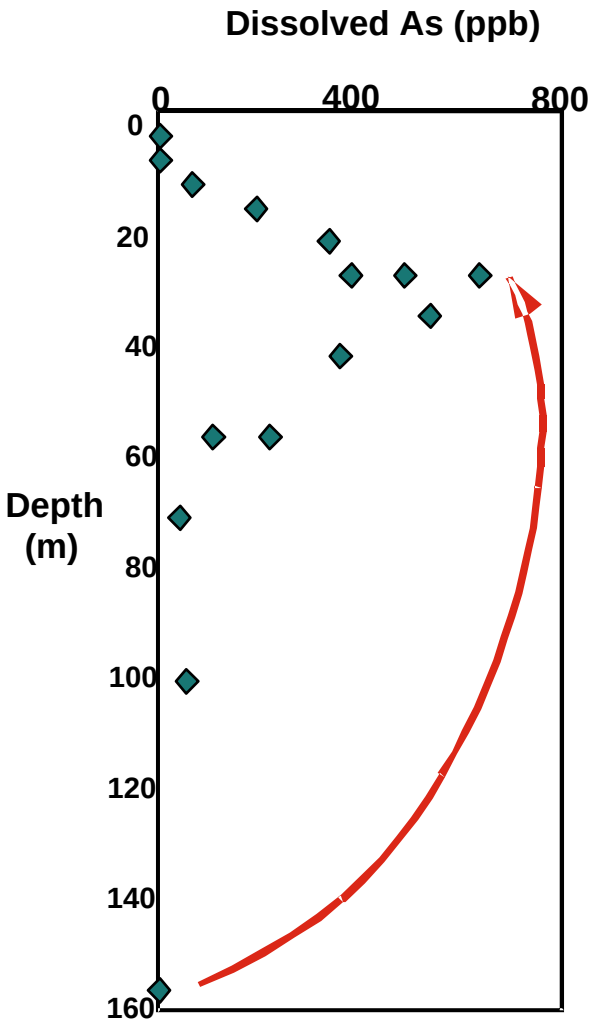


Comparison of MIT field site to BGS national data set

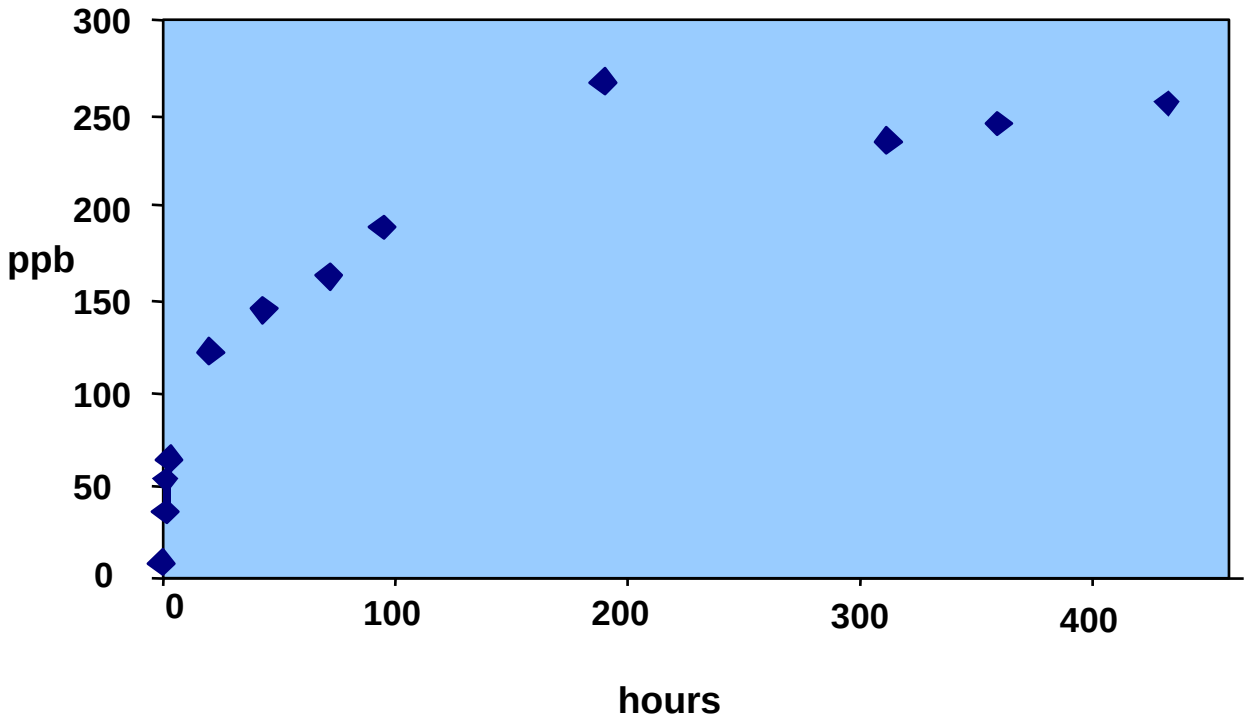


Arsenic in Withdrawn Water

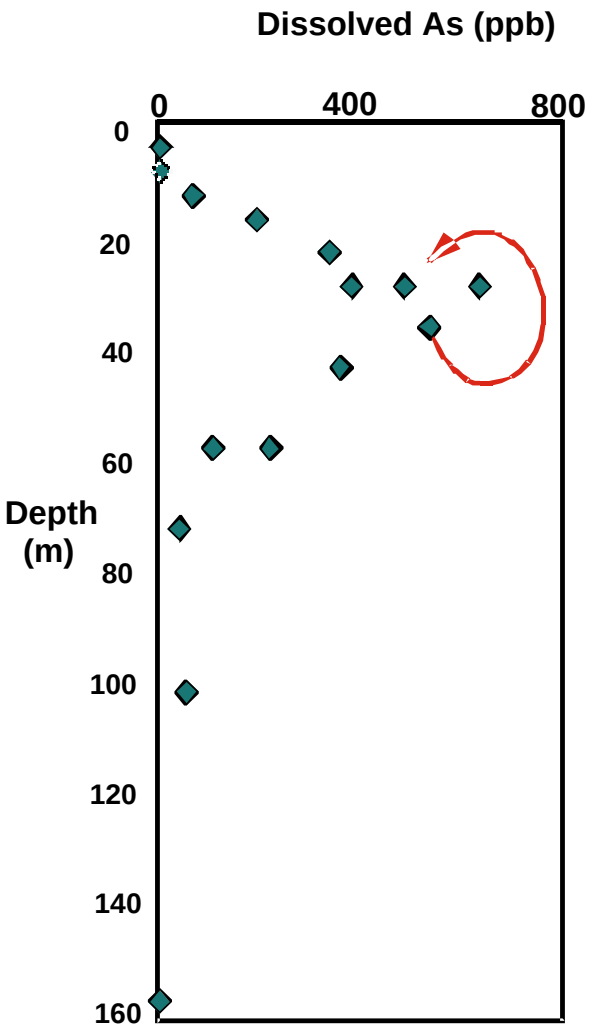
after Injection of Low-Arsenic Groundwater Water



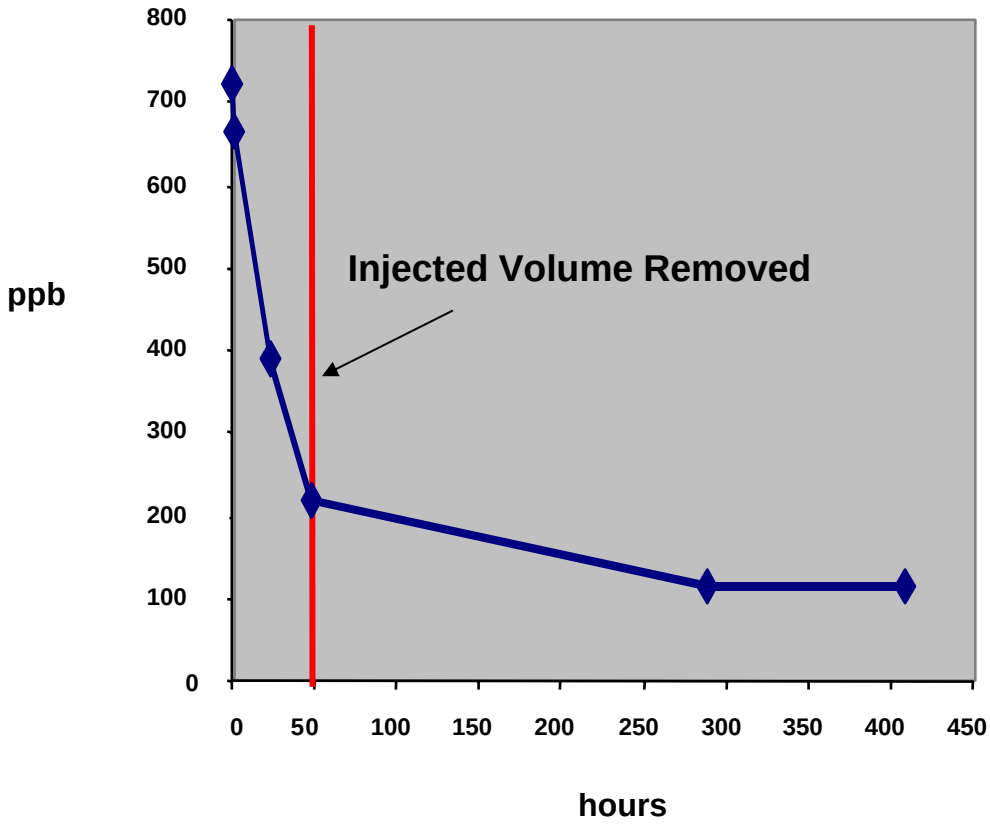
Original Value = 700 ppb



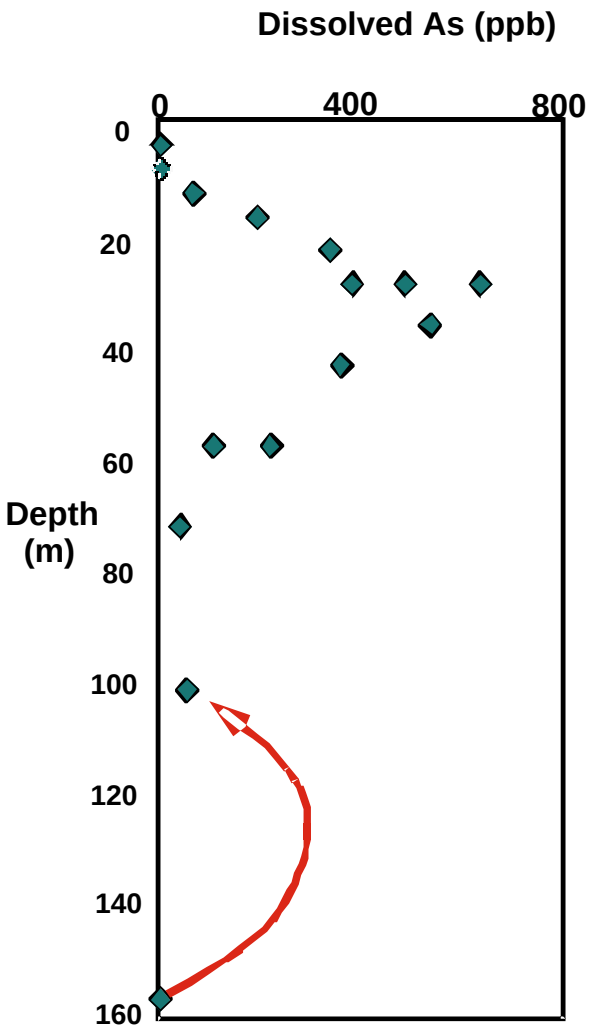
Arsenic in Withdrawn Water after Injection of Nitrate



Injectate: Nitrate Added to High-Arsenic Groundwater

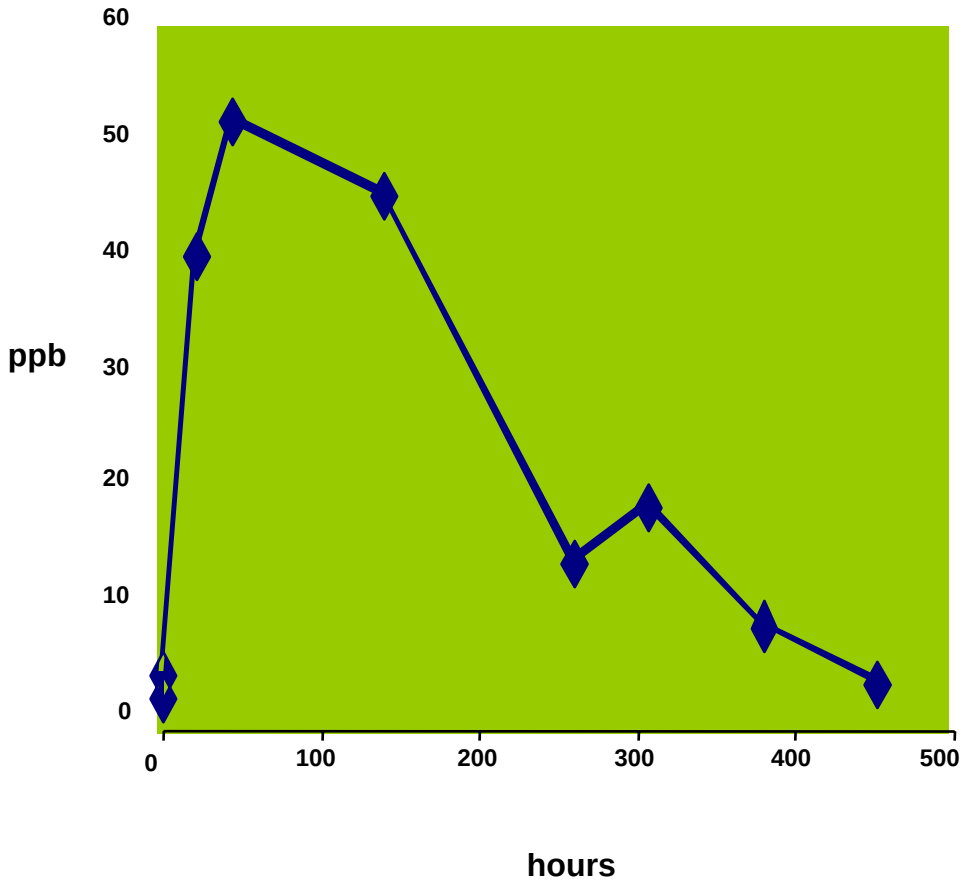


Arsenic in Withdrawn Water after Injection of Molasses

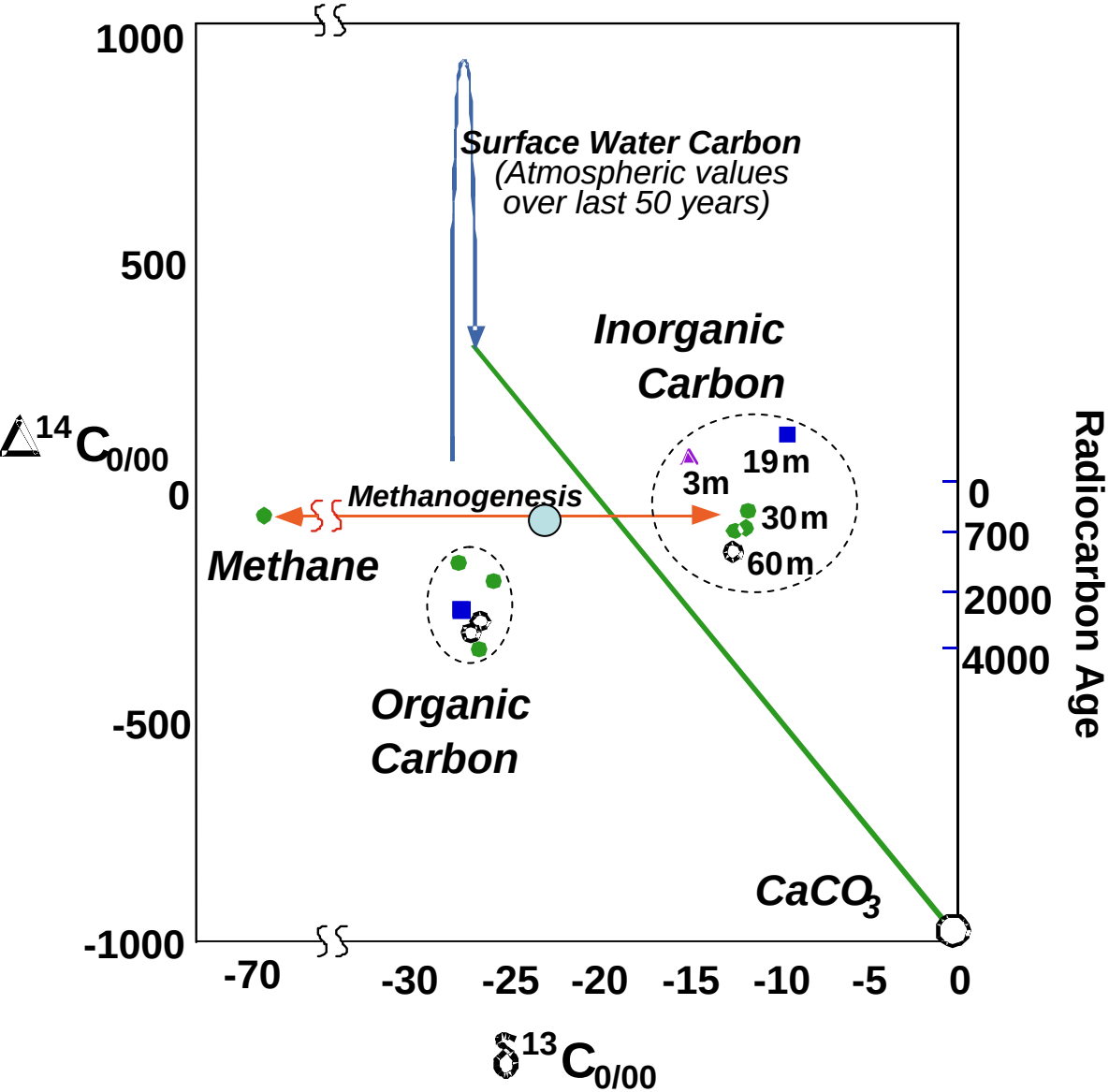


Injectate: Molasses Added to Low-Arsenic Groundwater

Original Value = 120 ppb



Carbon Isotopes



- Inflow of young carbon
- Young carbon drives biochemistry
- Mixture of young and old carbon is not the result of pore water mixing, but mobilization of old organic carbon