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Redox Processes and Water Quality of Selected Principal Aquifer Systems:

Implications for Ground-Water Monitoring

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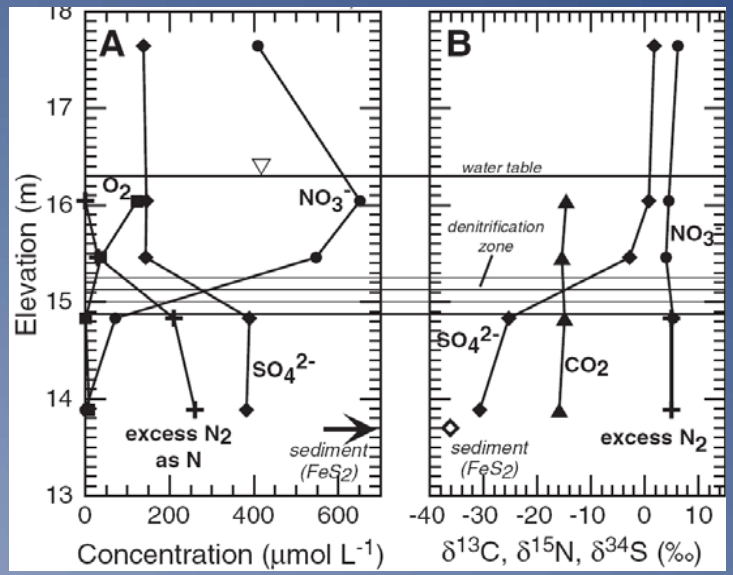
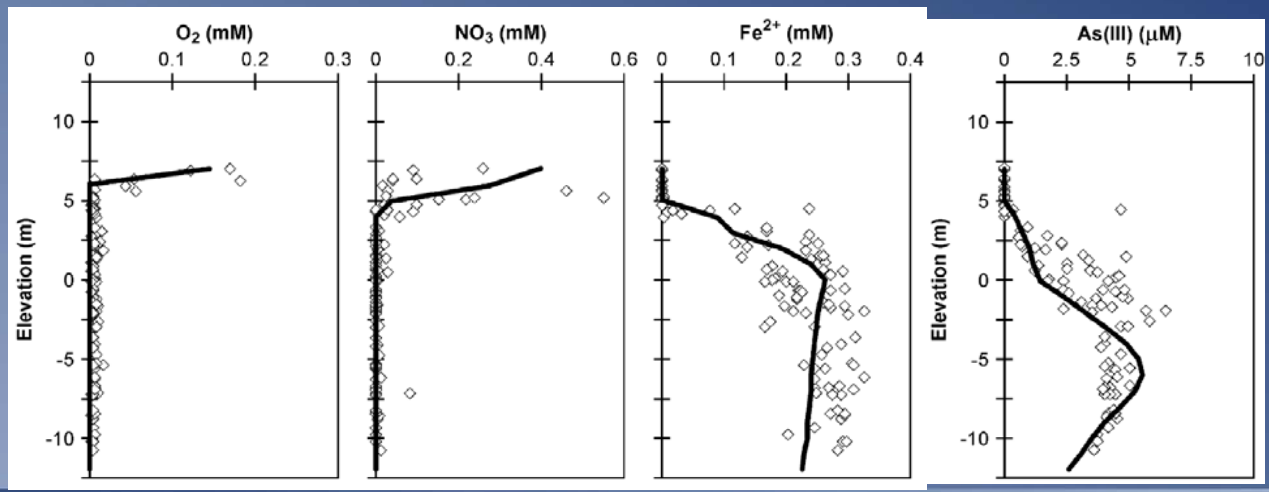
Redox Processes at Small Scales (we know a lot!)



Nitrate
(Böhlke et al., 2007, JEQ)

Arsenic
(Postma et al., 2007, GCA)



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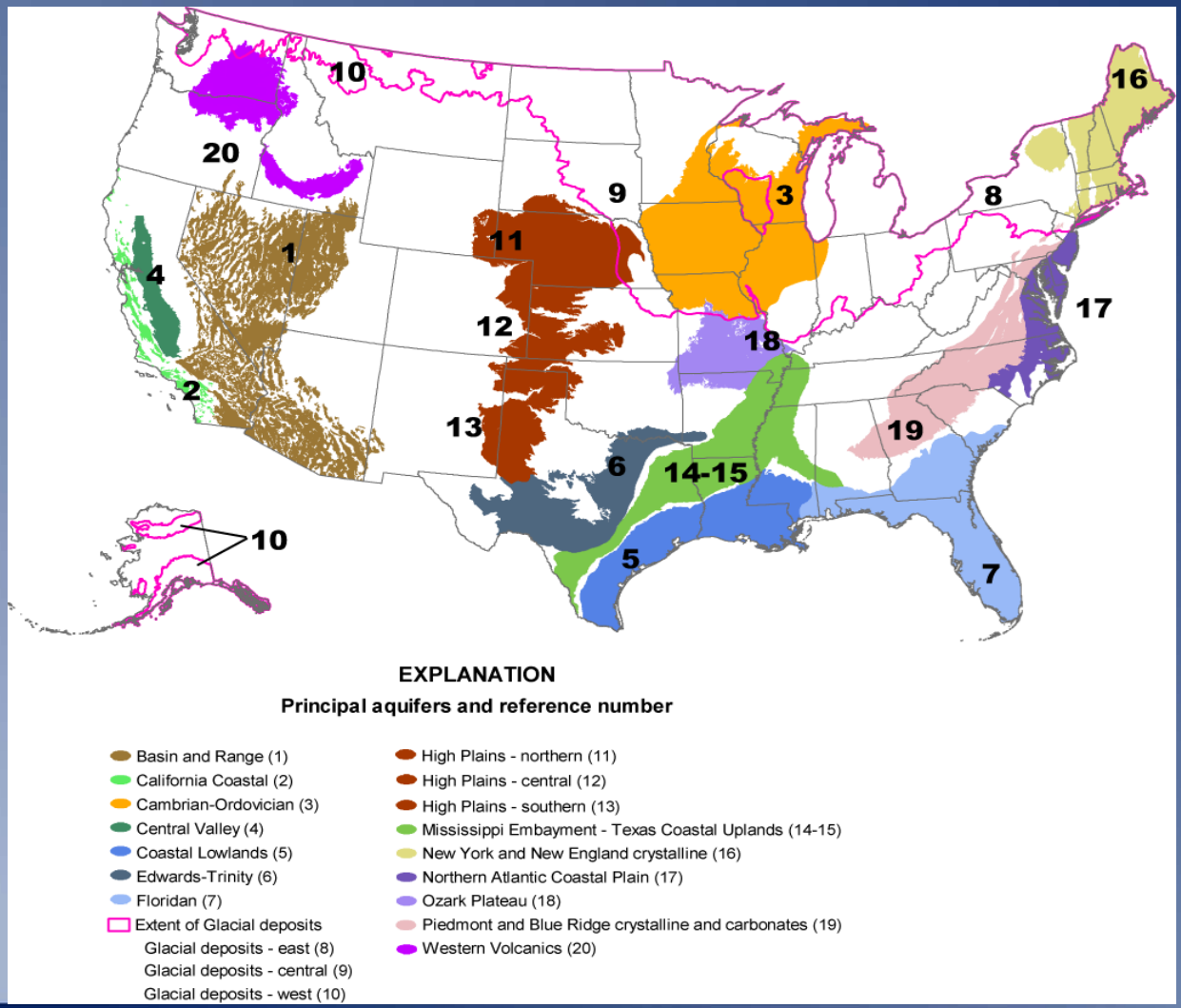
Redox Processes at Large Scales (there's a lot we don't know!)



- How does redox vary between PAs?
- Lack of consistent data across states/ regions (e.g. variable reporting levels, different field & lab techniques)
- Lack of "complete" data at large scale (O_2 data is hard to come by!)

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Objectives

- Use NAWQA datasets to characterize ambient redox conditions in selected Principal Aquifers
- Examine water-quality issues (nitrate, arsenic, VOCs) in the redox framework

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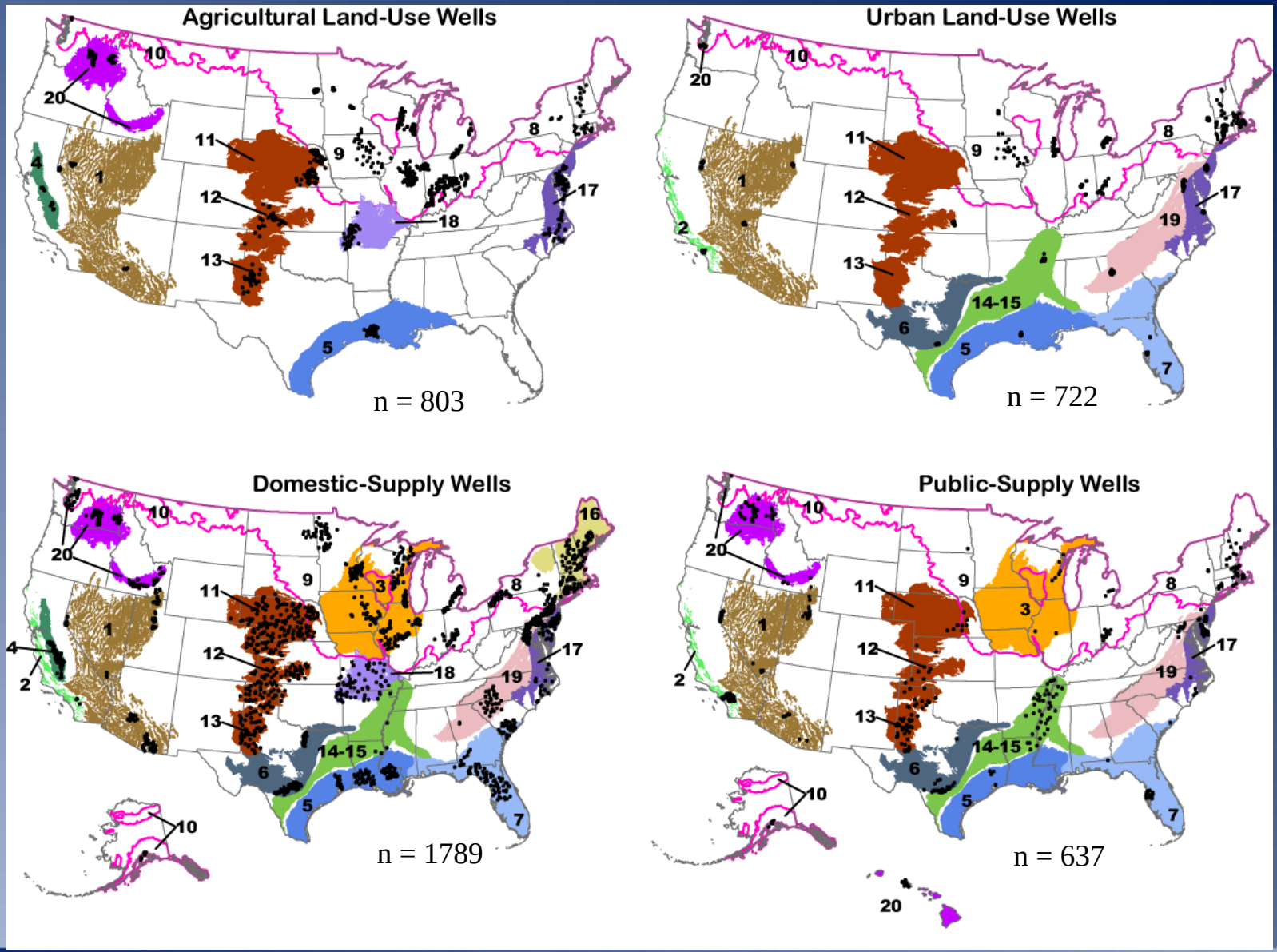
Distribution of Sampled NAWQA Wells



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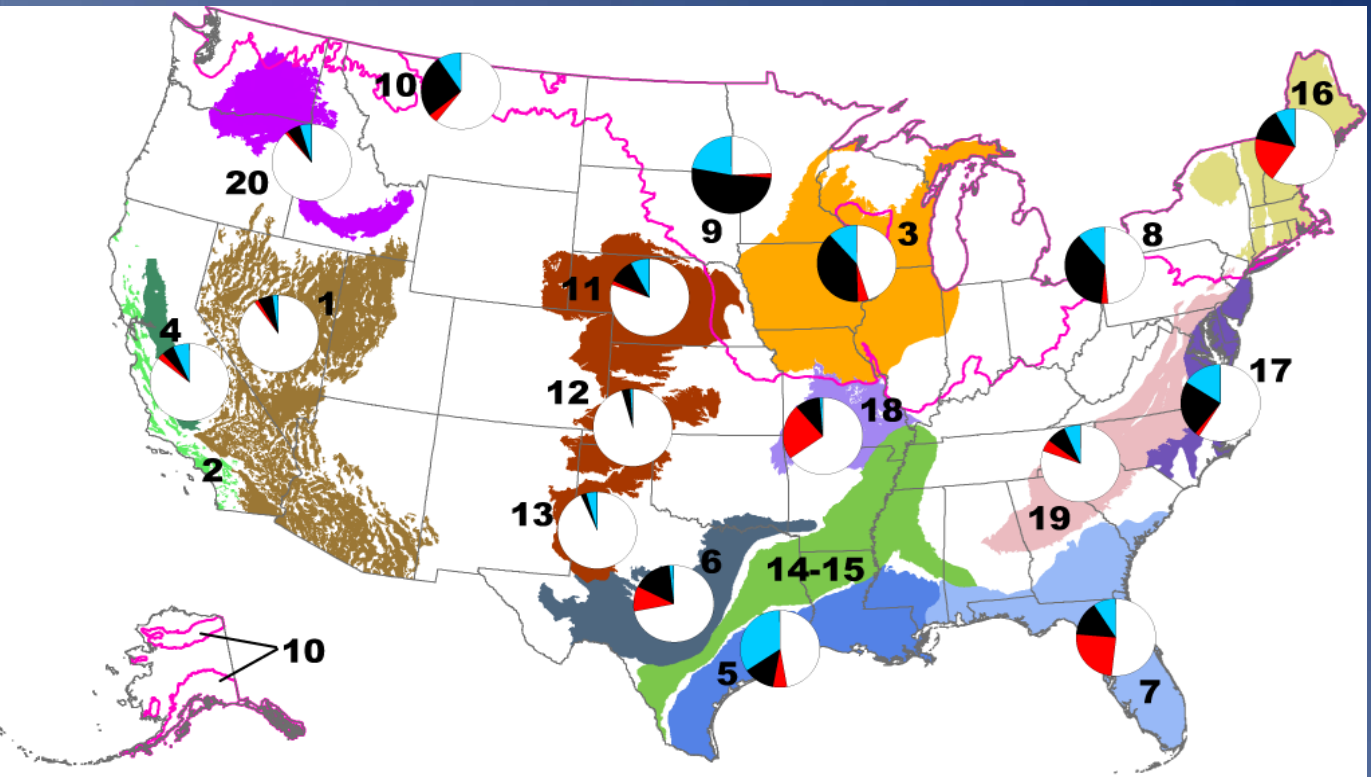
Framework for Identifying Redox Processes

Redox Process	Water-Quality Criteria (mg/L)				
	O_2	NO_3^--N	Mn^{2+}	Fe^{2+}	SO_4^{2-}
Oxic					
O_2 reduction	≥ 0.5	–	< 0.05	< 0.1	–
Suboxic					
–	< 0.5	< 0.5	< 0.05	< 0.1	–
Anoxic					
NO_3^- reduction	< 0.5	≥ 0.5	< 0.05	< 0.1	–
Mn(IV) reduction	< 0.5	< 0.5	≥ 0.05	< 0.1	–
Fe(III)/SO_4^{2-} reduction	< 0.5	< 0.5	–	≥ 0.1	≥ 0.5
Methanogenesis	< 0.5	< 0.5	–	≥ 0.1	< 0.5
Mixed	Criteria for more than one redox process are met.				

Spatial patterns indicate common controls on ambient redox conditions at national/PA scale

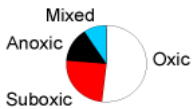


EXPLANATION

Principal aquifers and reference number

- Basin and Range (1)
- California Coastal (2)
- Cambrian-Ordovician (3)
- Central Valley (4)
- Coastal Lowlands (5)
- Edwards-Trinity (6)
- Floridan (7)
- Extent of Glacial deposits
  - Glacial deposits - east (8)
  - Glacial deposits - central (9)
  - Glacial deposits - west (10)
- High Plains - northern (11)
- High Plains - central (12)
- High Plains - southern (13)
- Mississippi Embayment - Texas Coastal Uplands (14-15)
- New York and New England crystalline (16)
- Northern Atlantic Coastal Plain (17)
- Ozark Plateau (18)
- Piedmont and Blue Ridge crystalline and carbonates (19)
- Western Volcanics (20)

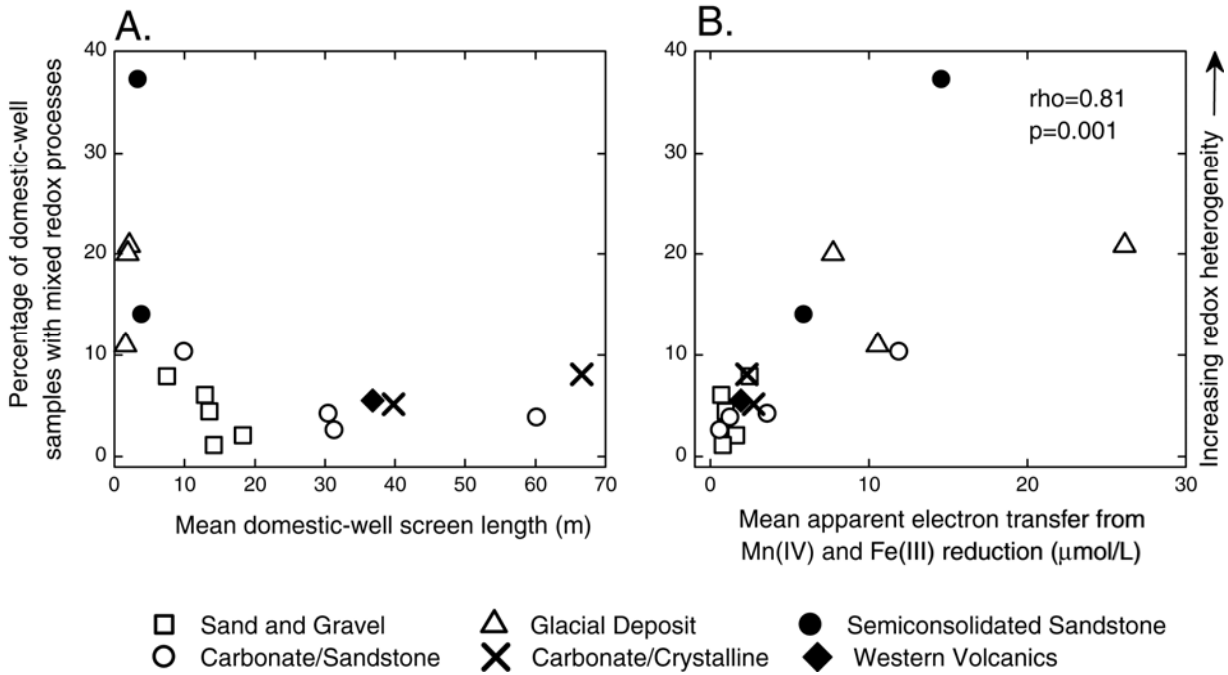
Redox state of aquifer, as percentage of samples



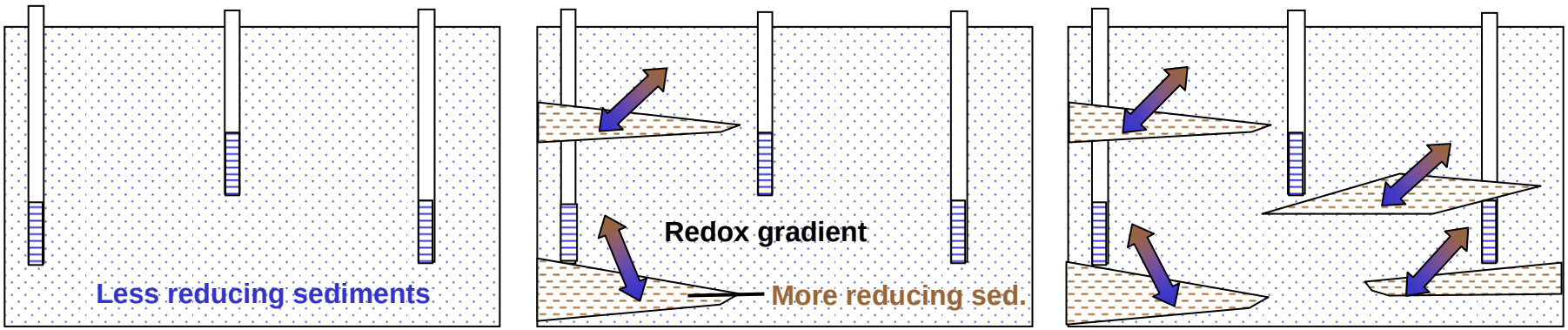
Based on domestic-well data (n=1692)

Well networks not representative of entire PAs

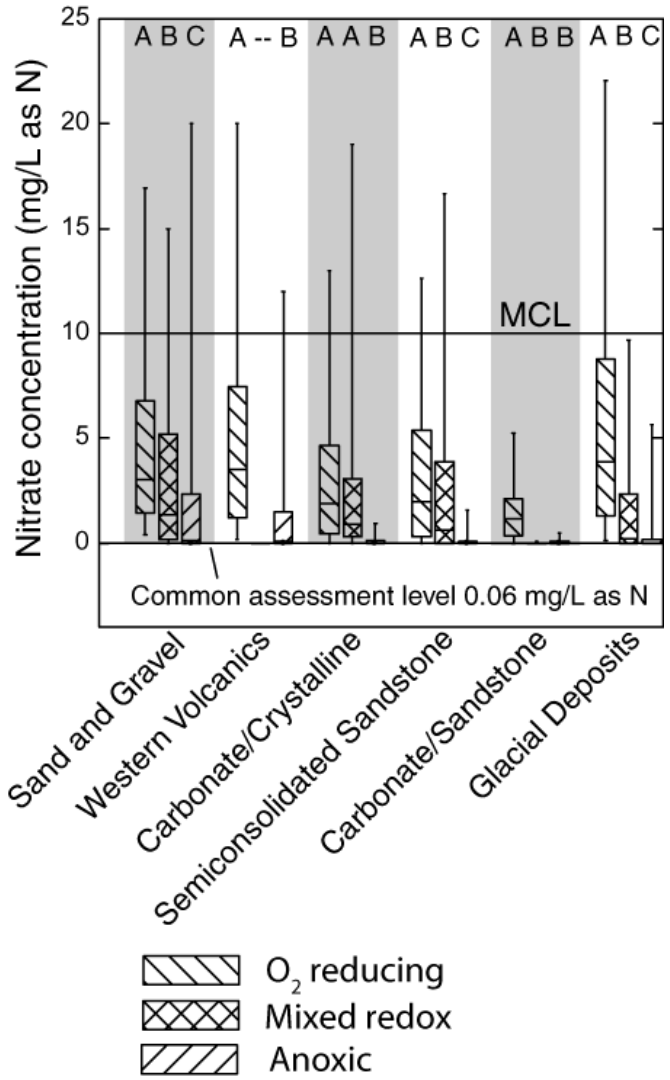
Mixed Redox GW Samples

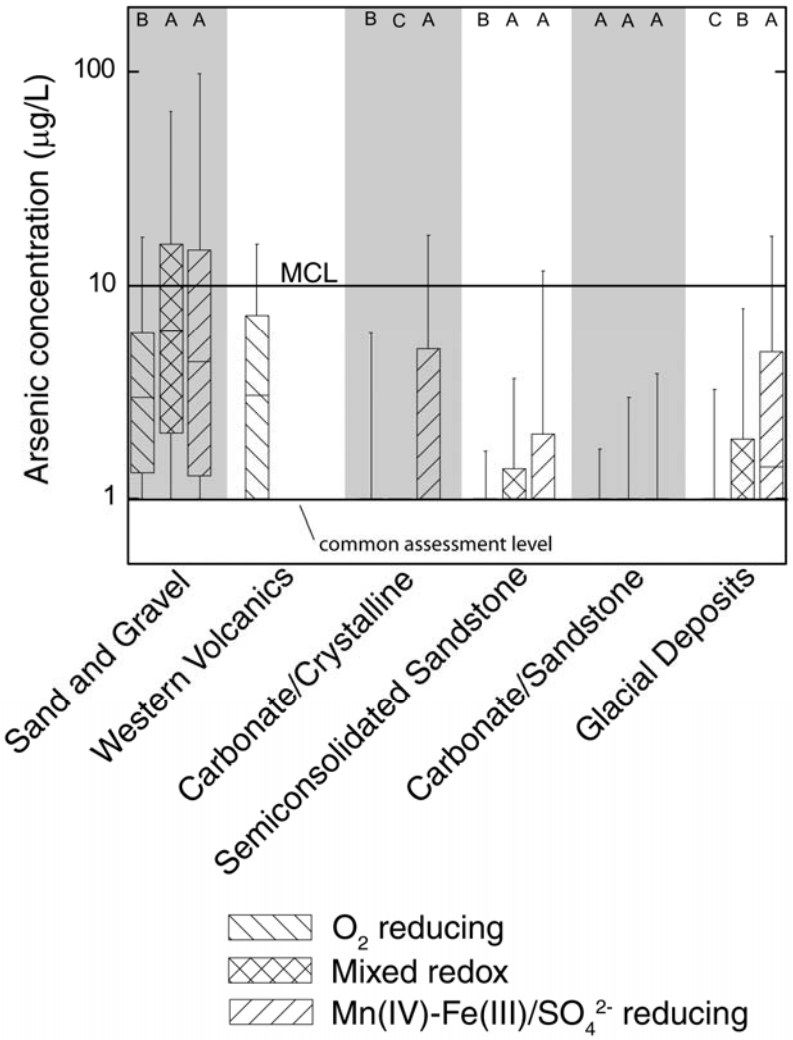


Mixed redox diagnoses may reflect inherent spatial heterogeneity of redox processes in the aquifers

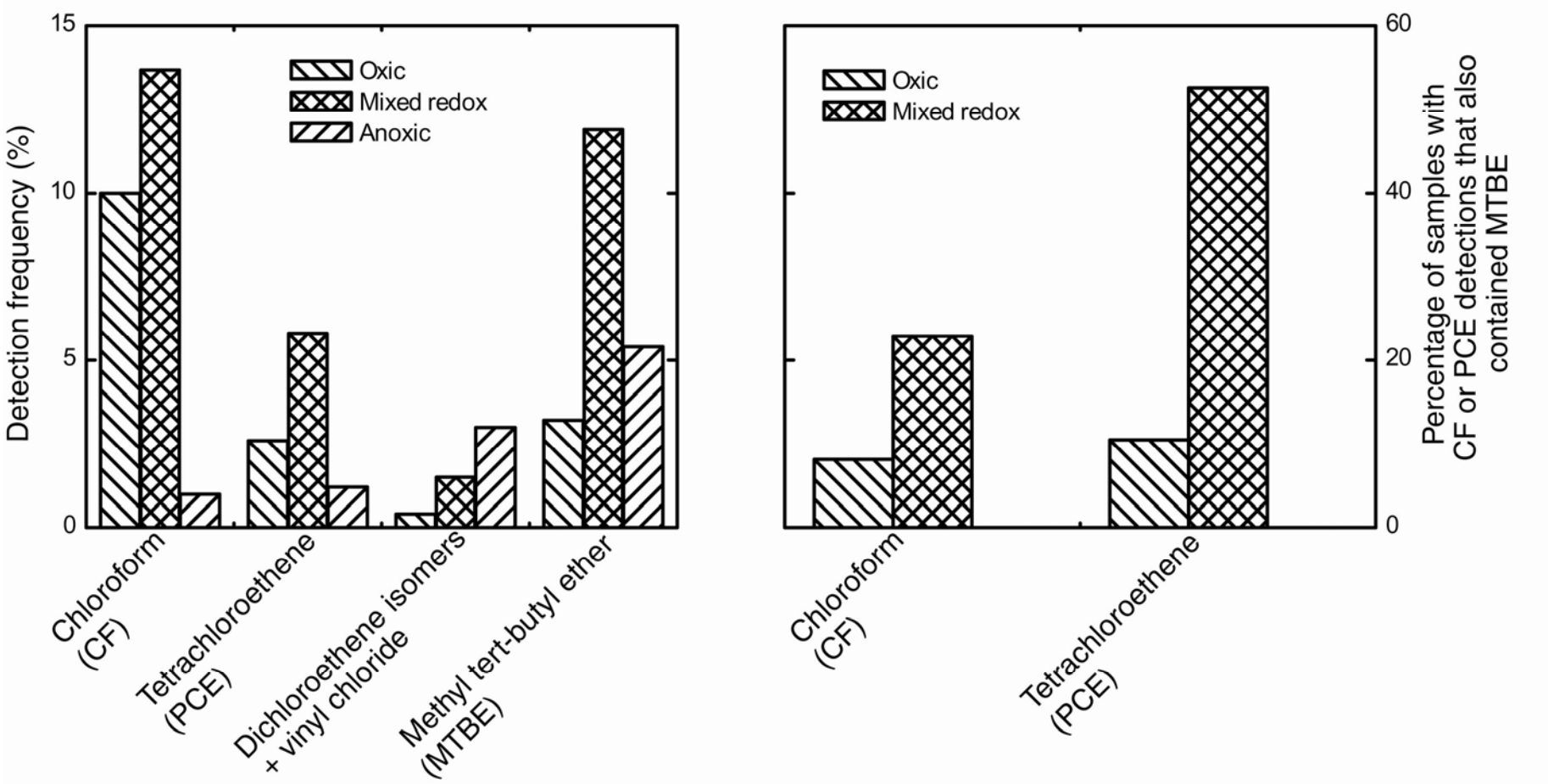


Redox Controls on Nitrate and Arsenic





Redox and VOCs



data from all well types except agri. monitoring wells

Next Steps

Produce companion analysis of public supply well data set

Extend analysis to other PA's using other USGS data sets

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Lack of DO data a problem!

- **Have queried USGS NWIS data base to get additional data to extend redox comparison to other PA's.**
- **Colorado example:**
- # samples in initial retrieval = **6,457**
- # samples after dropping samples with no data for
  - **O_2 = 552**
  - **NO_3, Mn, Fe, or SO_4 = 386**
  - **Aquifer code = 353**
- # samples after retaining only most recent sample for wells with multiple samples = **200**

This is less than 3% of starting number!

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Take Home Messages

- Spatial patterns in redox at the Principal Aquifer scale reflect the influence of climate, geology, and hydrology
- Mixed redox ground-water samples provide information on redox heterogeneity that can be related to the occurrence of selected contaminants
- Relatively inexpensive and easy to measure redox parameters such as DO, NO_3, Fe, Mn, and SO_4 should be included in routine water-quality monitoring programs whenever possible
- **Require sampling of these parameters in the National Ground Water Monitoring Network!**

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Reference for this Talk

- P.B. McMahon, and F.H. Chapelle, 2008, Redox Processes and Water Quality of Selected Principal Aquifer Systems, Ground Water 46 (2) , 259–271

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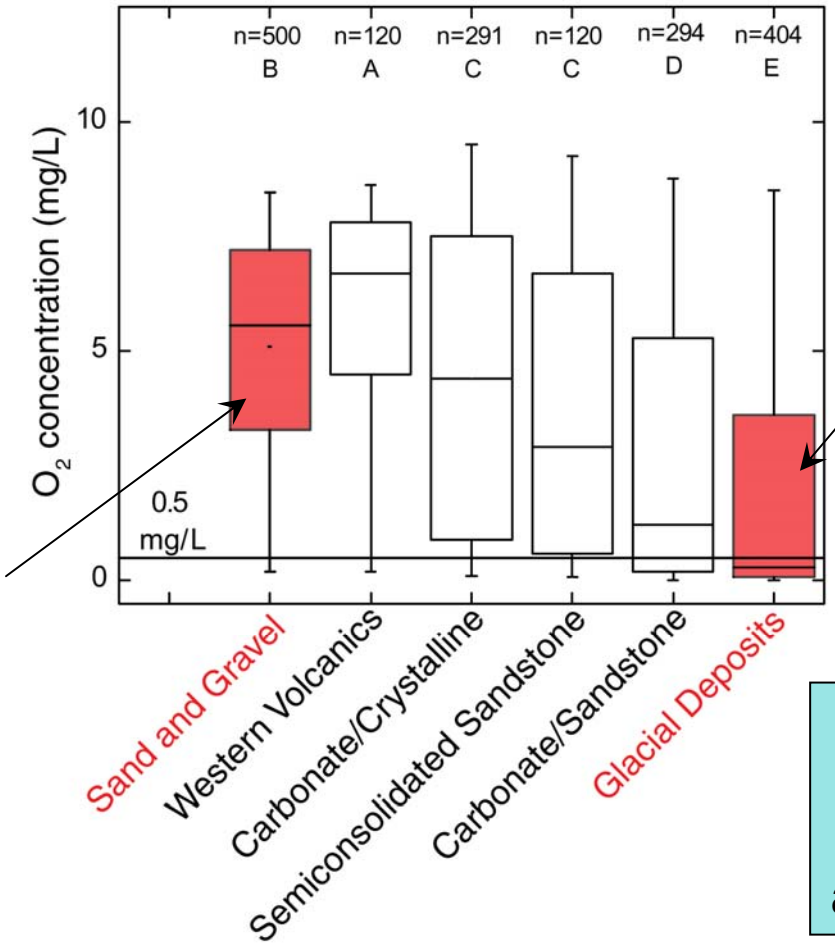
Geologic Controls on Redox



Can transition from O_2 reducing to methanogenic conditions along meter-scale flowpaths

O_2 can persist for 1000s of years along kilometer-scale flow paths

Sediment source and depositional environment influence e-acceptor/donor availability

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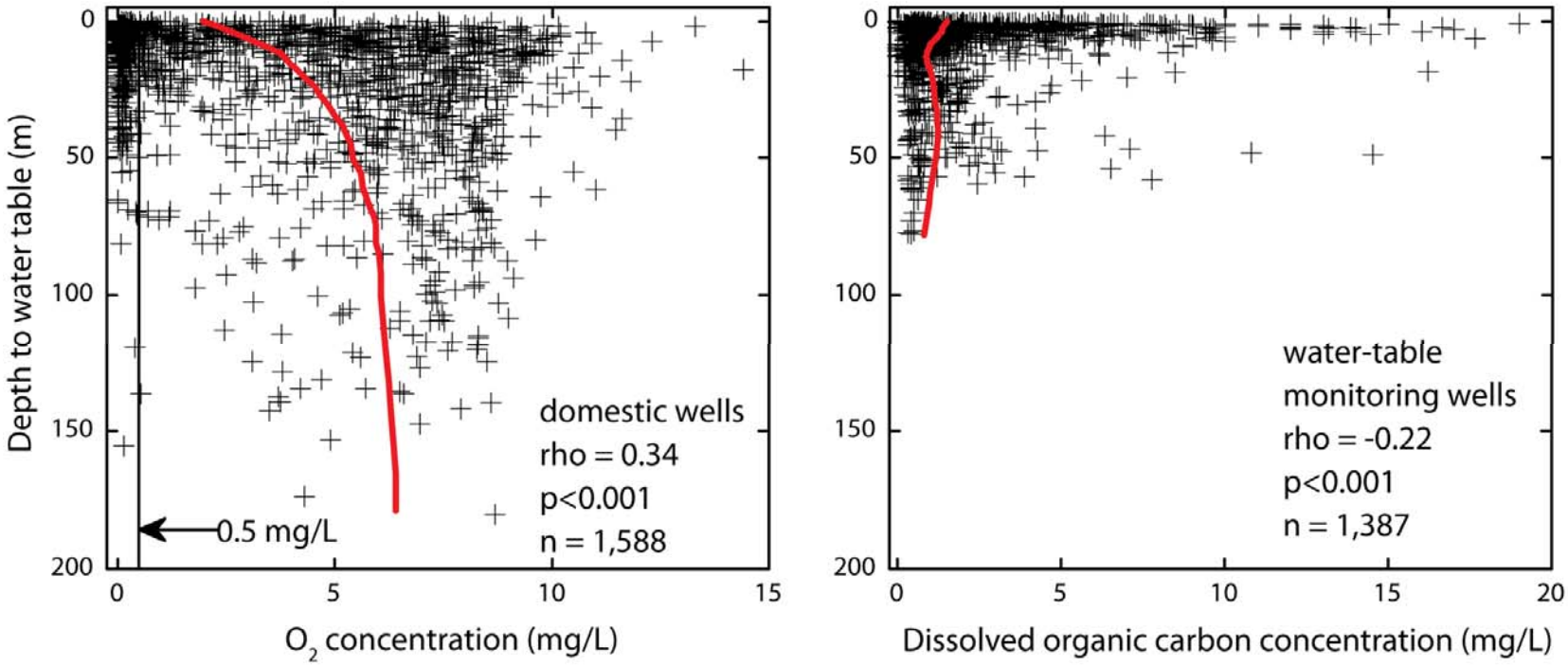
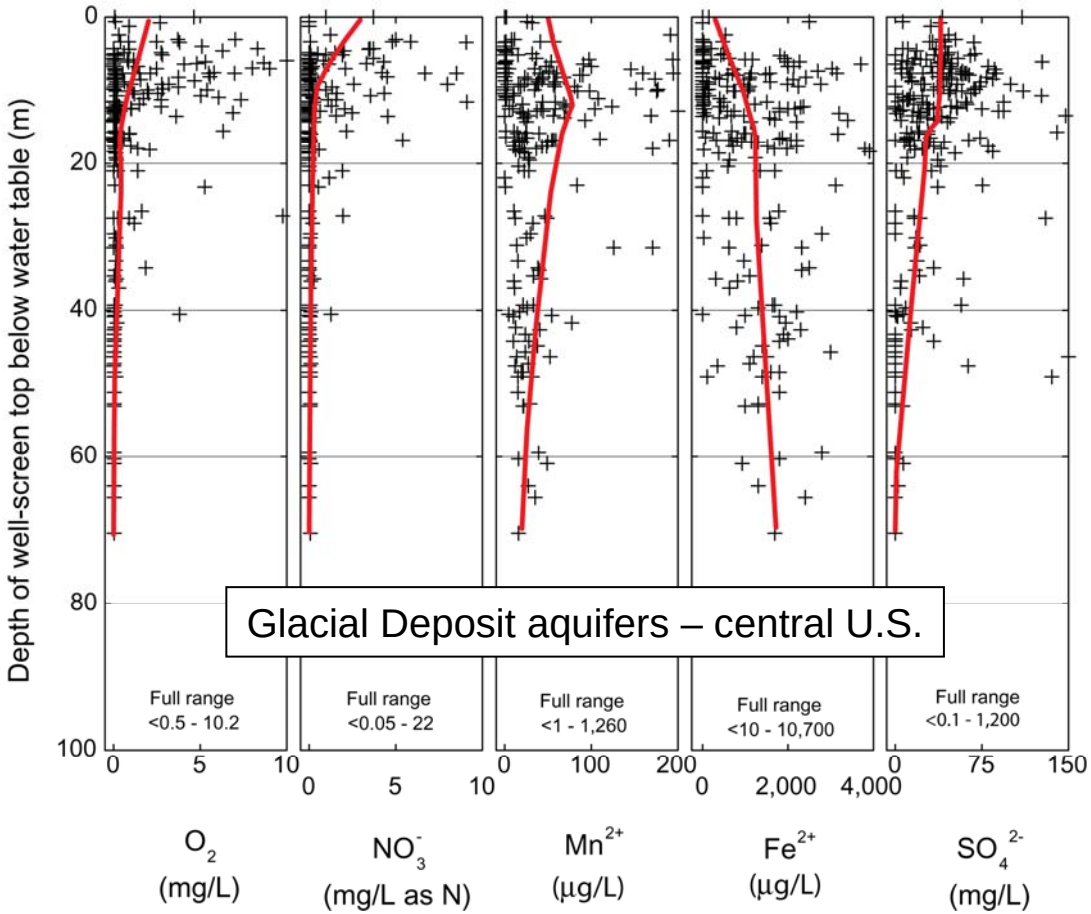
Climatic Controls on Redox



Soil development, vegetation, and recharge influence e- acceptor/donor availability

Hydrologic Controls on Redox



Water residence time influences reaction progress

Anthropogenic factors also influence e-acceptor/donor availability and water residence time