



ARSENIC MOBILIZATION AND TRANSPORT IN:

HYDROGEOCHEMICALLY DYNAMIC RECHARGE ZONES VERSUS STEADY-STATE DEEP WATER-BEARING CONDUITS IN THE LOCKATONG (LF) AND PASSAIC (PF) FORMATION AQUIFERS IN THE NEWARK BASIN, NEW JERSEY

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Problem / Questions

Up to 254 µg/l As occurs in potable wells in the Newark Basin: Lockatong (LF) & Passaic (PF) Formations.

- What are the most biogeochemically significant As mobilization zones in each formation?
 - Do surface excavations enhance As mobilization?

Arsenic Mobilization Hypotheses

LF and PF aquifers are naturally enriched in As: major mobilization zones?

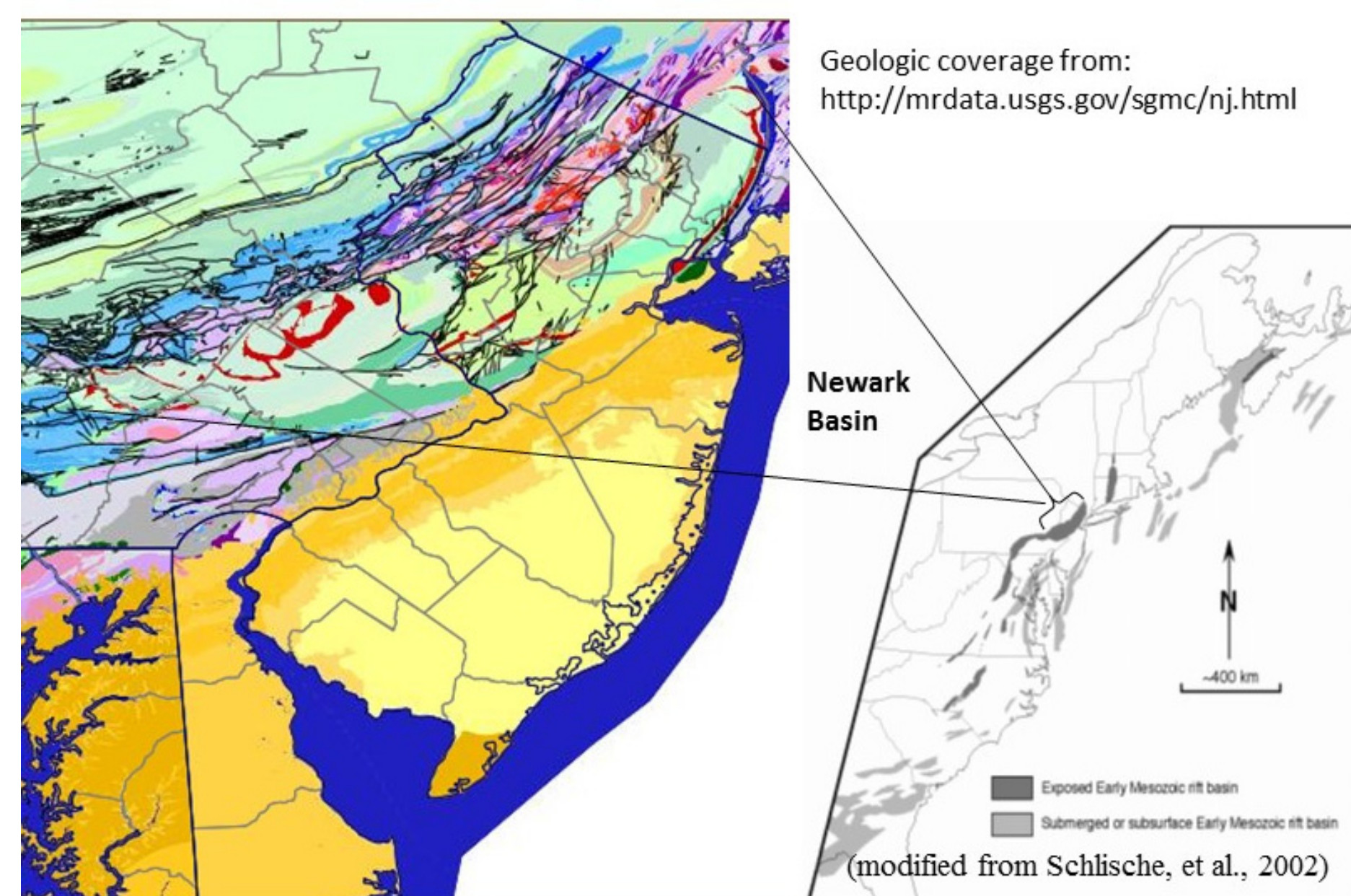
- LF (pyritic black/gray argillite): pyrite oxidation in GW recharge zone?
- LF: sulfide-arsenide substitution in pyrite in deeper water-bearing zone?
- PF (hematite mudstone): adsorption-desorption in GW recharge zone?
- PF: adsorption-desorption in deeper water-bearing zone?

Project Overview

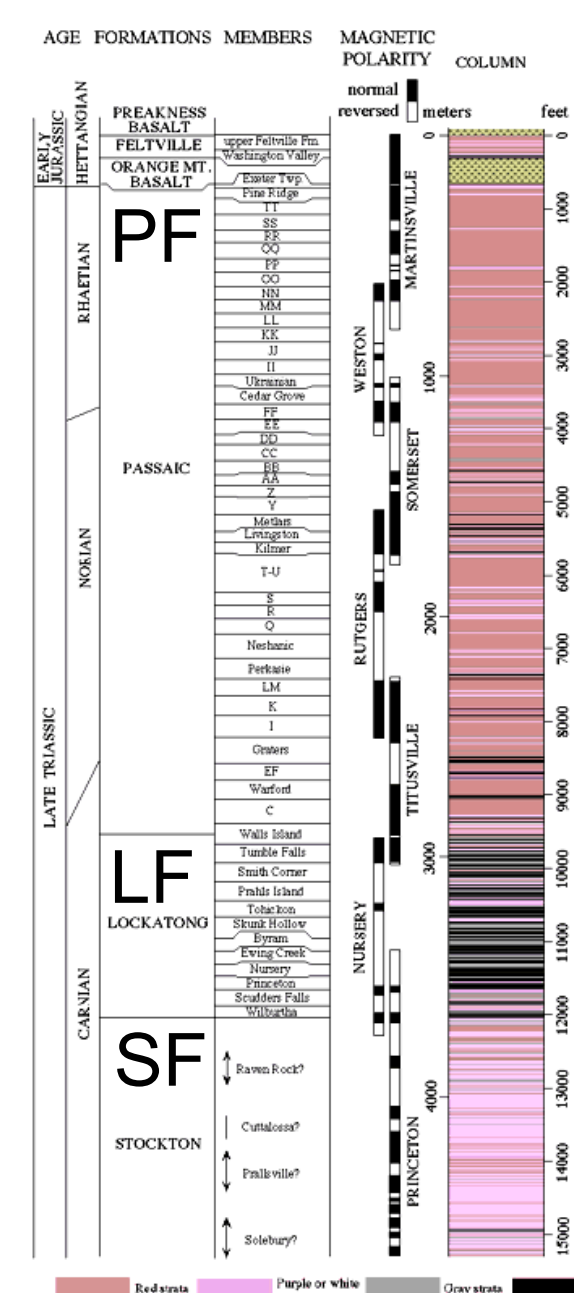
The Newark Basin (NB) is a Mesozoic aged half graben that filled upward with non-marine: (1) fluvial deltaic - Stockton Formation, (2) deep lake - LF, and (3) shallow lake playa - PF, now comprising the 3 major aquifers. Only the LF and PF aquifer matrix are enriched in arsenic and have natural aqueous arsenic issues. These formations strike ~ NE and dip ~ 12 degrees NW and the LF and PF are bedding confined, multi-layered, leaky aquifer systems. Much work to evaluate the sources and mobilization mechanisms of arsenic in the LF and PF aquifers has been conducted (Serfes, 2005; Zhu and others 2008; Serfes and others, 2010).

Recent concerns about the significance of As mobilization from non-imported backfill to be used in a linear trench excavation transecting the LF and PF have been evaluated. Column leach testing of LF and PF rock particles used EPA Method 1627 (USEPA, 2011; Serfes, 2016). These test results not only provided information addressing the key concern(s), but also indirectly about what the major zones of As mobilization in these aquifers are. The EPA-1627 methodology and an improved biogeochemical model of As mobilization in the NB follows.

Geologic Setting / Stratigraphic Column



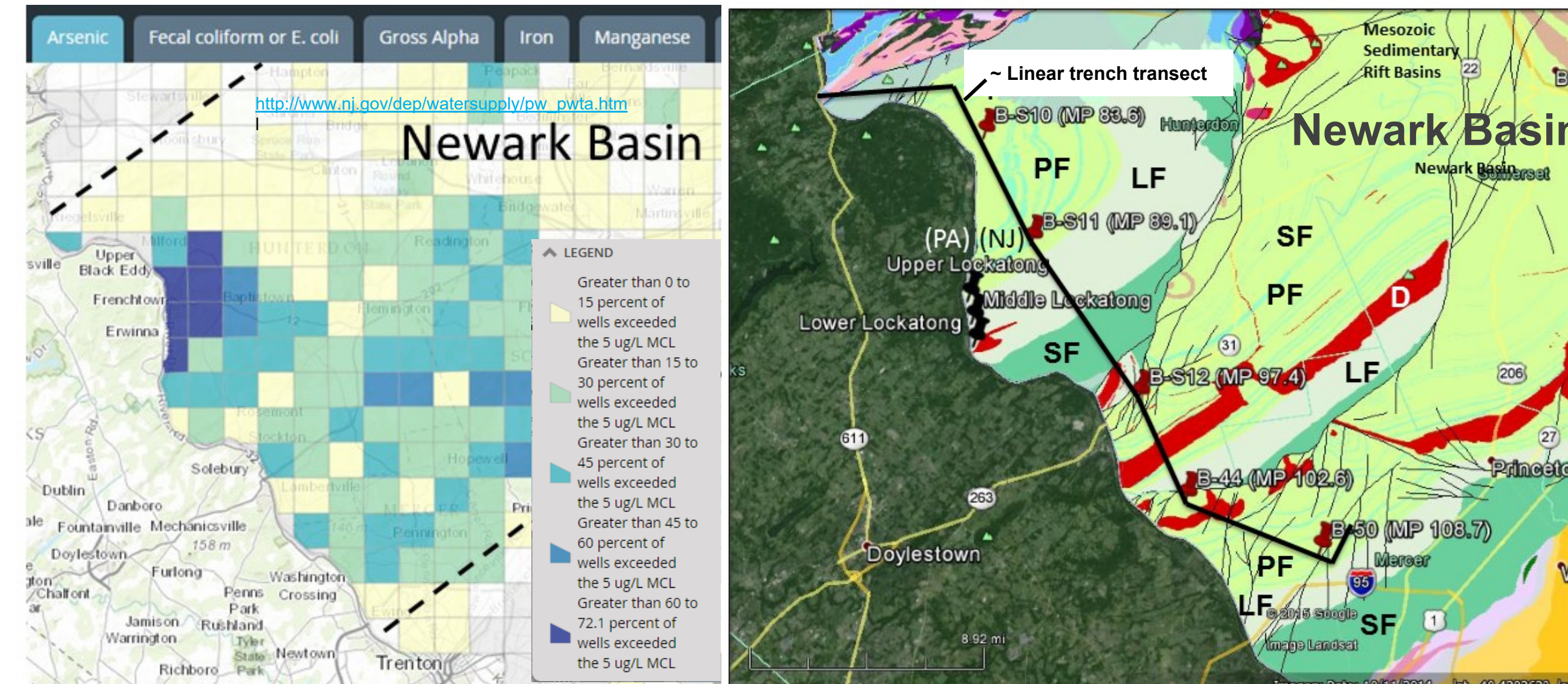
Geologic coverage from:
<http://mrdata.usgs.gov/smgc/nj.html>



As Rich

Stratigraphic column of NB rocks by Olsen and others (1996). Some beds are more As-enriched than others and wells that intersect them, if WBZs, can have unacceptable As concentration. CaCO₃ in LF & PF yield a circum-neutral pH

As in Wells / Geology / Trench Transect



Left: NJ Private Well Testing Act data shows density of potable wells > 5 µg/l As, NJ MCL (2x2 mile cells with at least 10 PWs per). (Note: As percentiles in 20 shallow monitor wells in area: 25th = 0.5 µg/l, median = 1.4 µg/l and 75th = 2.5 µg/l)

Procedure: EPA Method 1627

Step 1

Selected Representative Samples

3-LF from outcrops (microbial active), and, 3-PF from rock core borings (locations mapped above)
LF whole As: 5 – 15 mg/kg
PF whole As: <5 - 8 mg/kg

Step 2

Preparation of Samples for Kinetic Testing using 2-inch columns

Crushed 2 kg to method specific particle size distribution (PSD) range: < 0.25 mm to ~ 10 mm
Note: 6-inch columns also used with scaled up PSD: (As in leachate < 2-inch)

Step 3

Controlled Simulation of Field Weathering Conditions

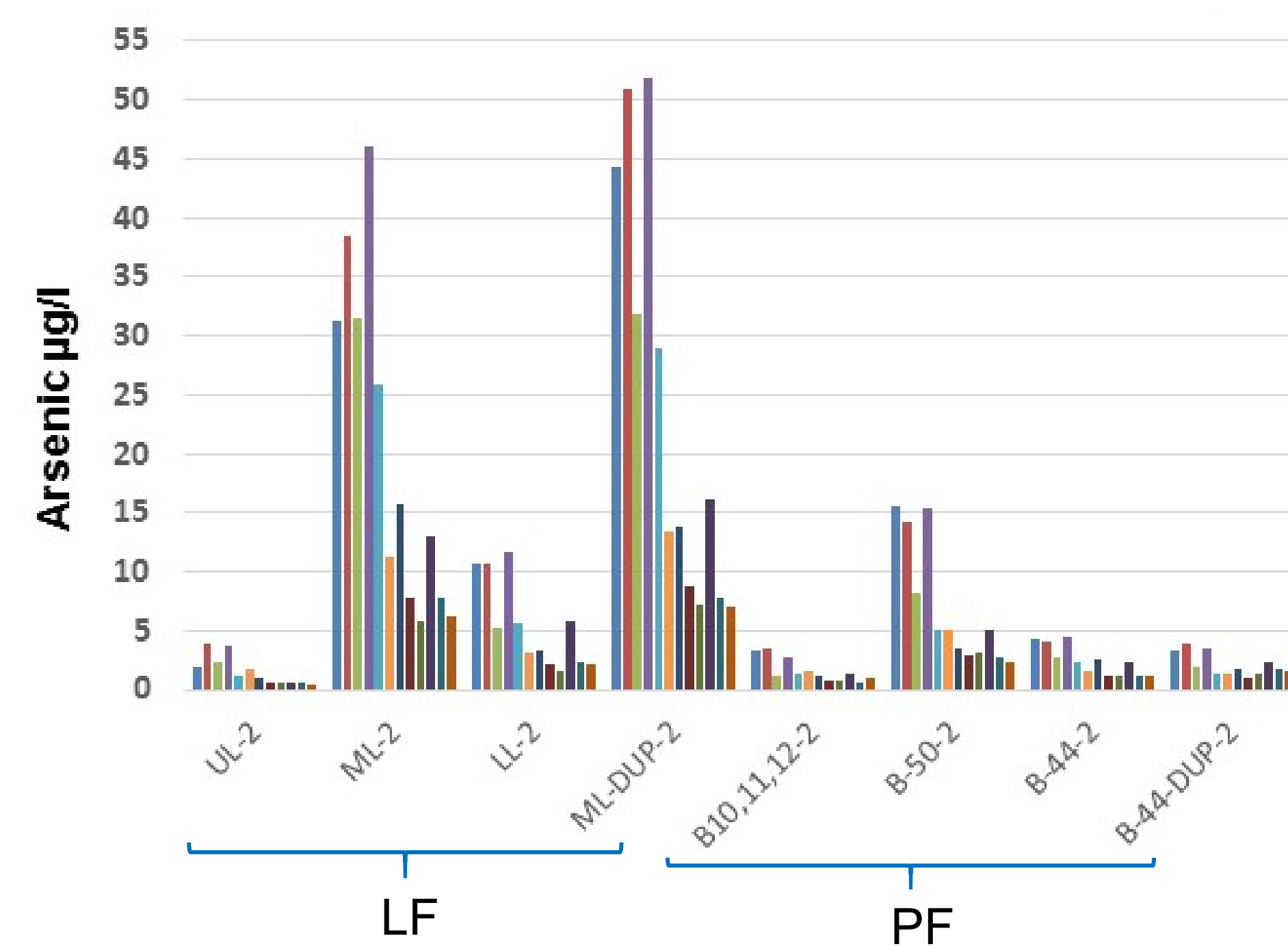
Trench assumptions: (1) humid with intermittent saturations, (2) CO₂ rich Columns: humidified air 6-days (1 Lpm, 10% CO₂), 24-hour saturation/week, over 12-weeks

Step 4

Leachate Collection and Analysis

Volume in-out, pH, alkalinity, acidity
Filtered leachate (0.45 micron) samples sent to certified laboratory for analysis: As, Ca, Mg, SO₄²⁻, Fe and Mn

12-Week Test Results: (2-Inch Columns)



All leachate:

- Circum-neutral pH (6.5-8.5): (CaCO₃ in LF & PF)
- Ambient dissolved O₂

LF Samples:

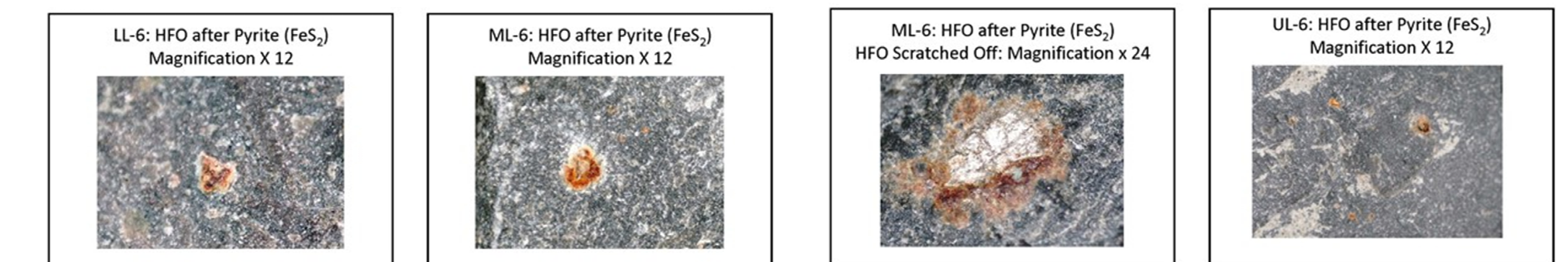
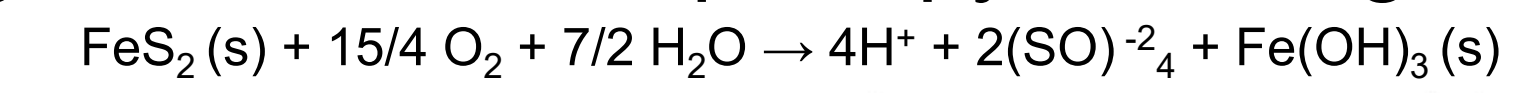
- ML-DUP-2 has highest As leachate concentrations
 - Pyrite oxidizes, HFO forms
 - Maximum acidity of 3 mg/l as CaCO₃
 - Therefore no ARD

PF Samples:

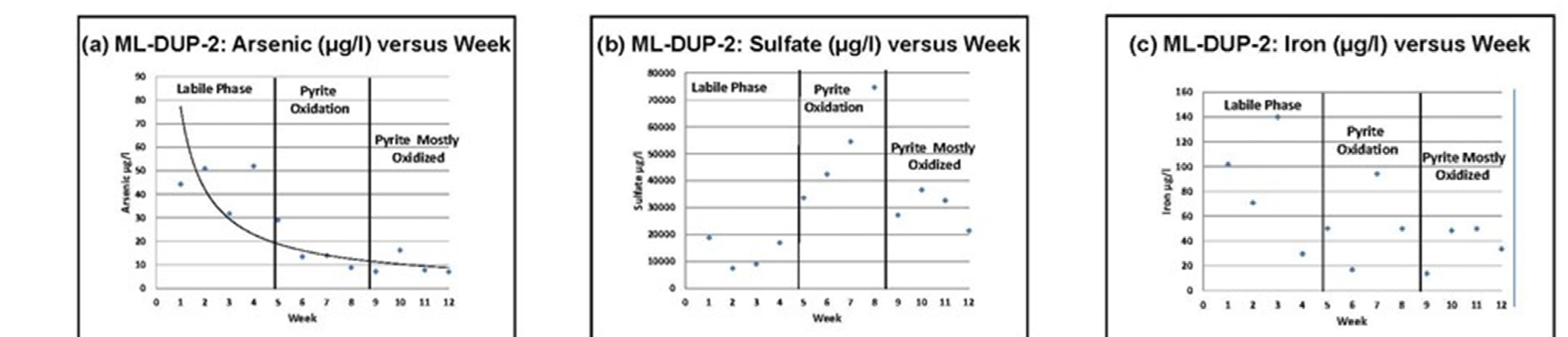
- B-50-2 has highest As concentrations

FeS₂ / As, SO₄⁻² & Fe in Leachate

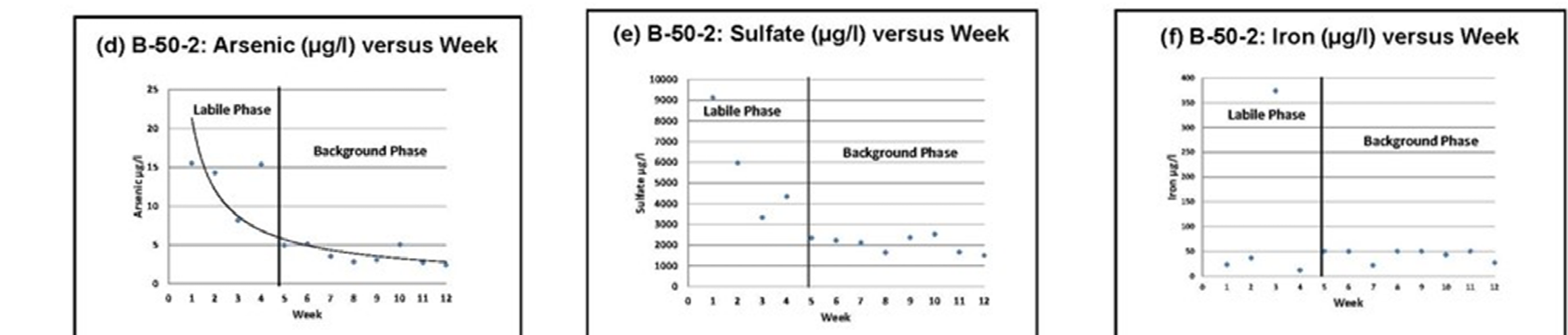
Lockatong Formation Samples: pyrite in argillite was oxidized



Middle Lockatong Formation Sample (ML-DUP-2): Leachate has highest dissolved As concentrations



Passaic Formation (B-50-2): highest dissolved As concentrations



Labile phase: freshly broken rough surfaces very reactive (active weathering)
Pyrite oxidation phase: FeS₂ oxidizes, HFO forms (As sequestered, trapped)
Background Phase: LF and PF non-imported fill becomes less reactive.

Conceptual Model / Conclusions

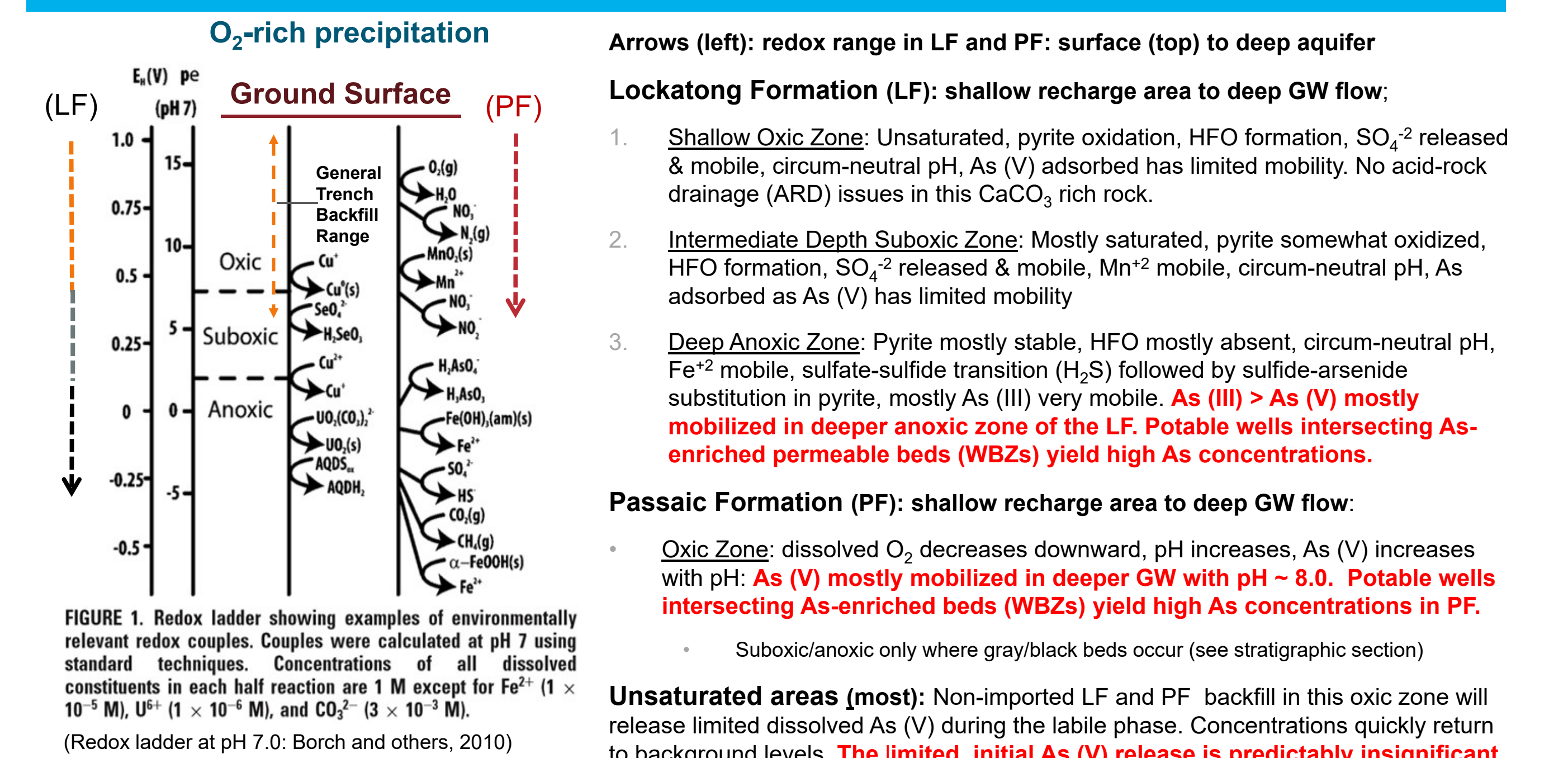


FIGURE 1. Redox ladder showing examples of environmentally relevant redox couples. Couples were calculated at pH 7 using standard techniques. Concentrations of all dissolved constituents in each half reaction are 1 M except for Fe²⁺ (1 × 10⁻⁵ M), U⁶⁺ (1 × 10⁻⁶ M), and CO₂⁻² (3 × 10⁻³ M). (Redox ladder at pH 7.0: Borch and others, 2010)

Unsaturated areas (most): Non-imported LF and PF backfill in this oxic zone will release limited dissolved As (V) during the labile phase. Concentrations quickly return to background levels. **The limited initial As (V) release is predictably insignificant to downgradient groundwater quality in both LF and PF (adsorption-dilution).**

References

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