2005 Salt Lake City Annual Meeting (October 16–19, 2005)

Paper No. 69-8

Presentation Time: 10:15 AM-10:30 AM

ARSENIC OCCURANCE IN THE UNCONFINED FRACTURED BEDROCK AQUIFER SYSTEM OF THE NORTH CAROLINA PIEDMONT

PIPPIN, Charles G., Aquifer Protection Section, NCDENR - DWQ, 610 East Center Avenue, Suite 301, Mooresville, NC 28115, chuck.pippin@ncmail.net, REID, Jeffery C., NCDENR, North Carolina Geologic Survey, 1612 Mail Service Center, Raleigh, NC 27699, **WITHERS, Courtney**, Department of Geography and Earth Sciences, University of North Carolina - Charlotte, 9201 University City Boulevard, Charlotte, NC 28223, cwithers@uncc.edu, and ENNIS, Lisa, S&ME Inc, 3118 Spring Forrest Road, Raleigh, NC 27616

A study to assess the distribution of arsenic in North Carolina was initiated in 2000. Data collected from historically and recently sampled domestic water supply wells (DWSW) have been combined to produce a database of over 24,000 groundwater samples, of which ~10,000 samples have been geolocated based on address information. Probability analysis, using indicator kriging, revealed a high probability zone for detectable arsenic in groundwater that trends northeast from Union County to Person County. This zone is spatially correlative with volcanic and volcaniclastic rock bodies of the Carolina Zone (CZ).

Veined and disseminated sulfides have been observed in cores from the CZ. Laboratory analyses of respective sulfide minerals and their host rocks suggest that they are a naturally occurring source of arsenic. In addition, field-based geochemical studies of naturally occurring iron-manganese boulder and fracture coatings, ceramic streak plate experiments, along with additional sampling of DWSW, soils, stream water and stream sediment are being used to understand arsenic fate and transport in the unconfined fractured bedrock aquifer system, characteristic of the CZ.

Our interim conclusions suggest that chemical weathering of the upper bedrock results in the dissolution of arsenic from sulfide bearing minerals and, depending on groundwater chemistry, precipitation onto fracture surfaces. The fraction that is not precipitated is then flushed from the groundwater system via discharge to surface waters where transport through a greater oxidation front (i.e., moving from a groundwater system to a surface water system) forces precipitation of iron and manganese oxyhydroxides with which arsenic is co-precipitated.

Of particular interest to our study is the role DWSW have on the geochemical system. For example, historically elevated arsenic levels have been recorded in Public Water Supply Wells (PWSW) from many areas in the state. These levels typically attenuate over a few years. The limited temporal data we have for DWSW does not indicate similar reductions in arsenic levels. We hypothesize that the greater production volumes of PWSW changes the local geochemistry resulting in either the depletion of the source material or the prevention of conditions favorable for sulfide dissolution.

2005 Salt Lake City Annual Meeting (October 16–19, 2005)
General Information for this Meeting

Session No. 69
Arsenic Occurrence and Fate in Hydrogeologic Systems I
Salt Palace Convention Center: 250 DE
8:00 AM-12:00 PM, Monday, October 17, 2005

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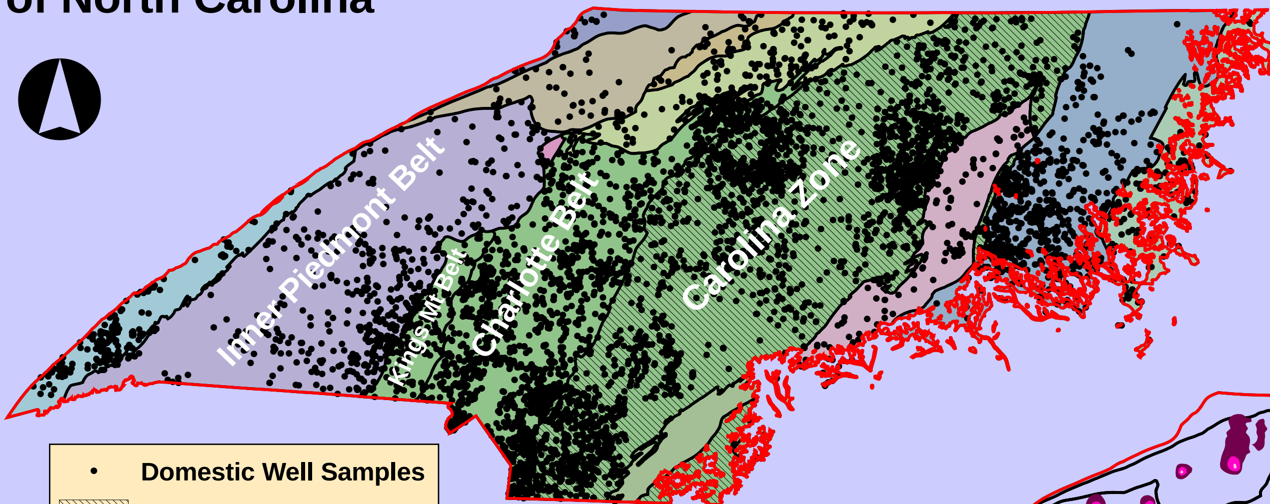
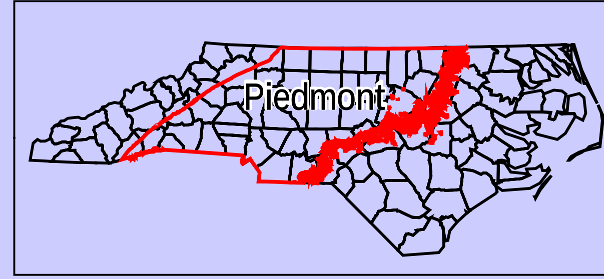
- Charles Pippin, Aquifer Protection Section, NCDENR – DWQ
- Jeffery C. Reid., NCDENR, North Carolina Geologic Survey
- Courtney Withers, Dept. of Geography and Earth Sciences, University of North Carolina – Charlotte
- Lisa Ennis, S&ME Inc.

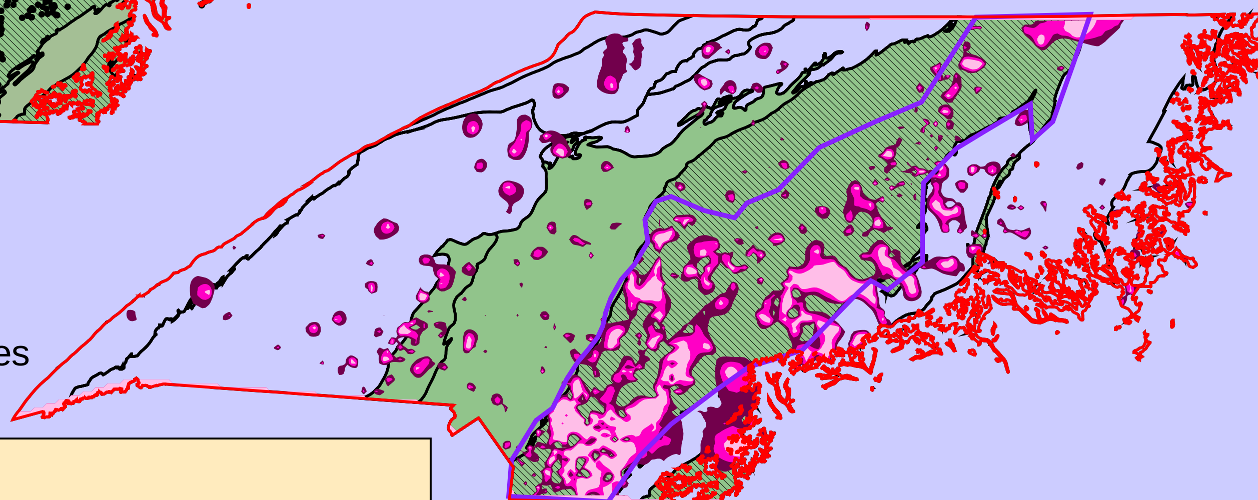
Arsenic in the Piedmont of North Carolina





- Domestic Well Samples
- Carolina Zone
- Carolina Terrane

60 30 0 60 Miles



Legend

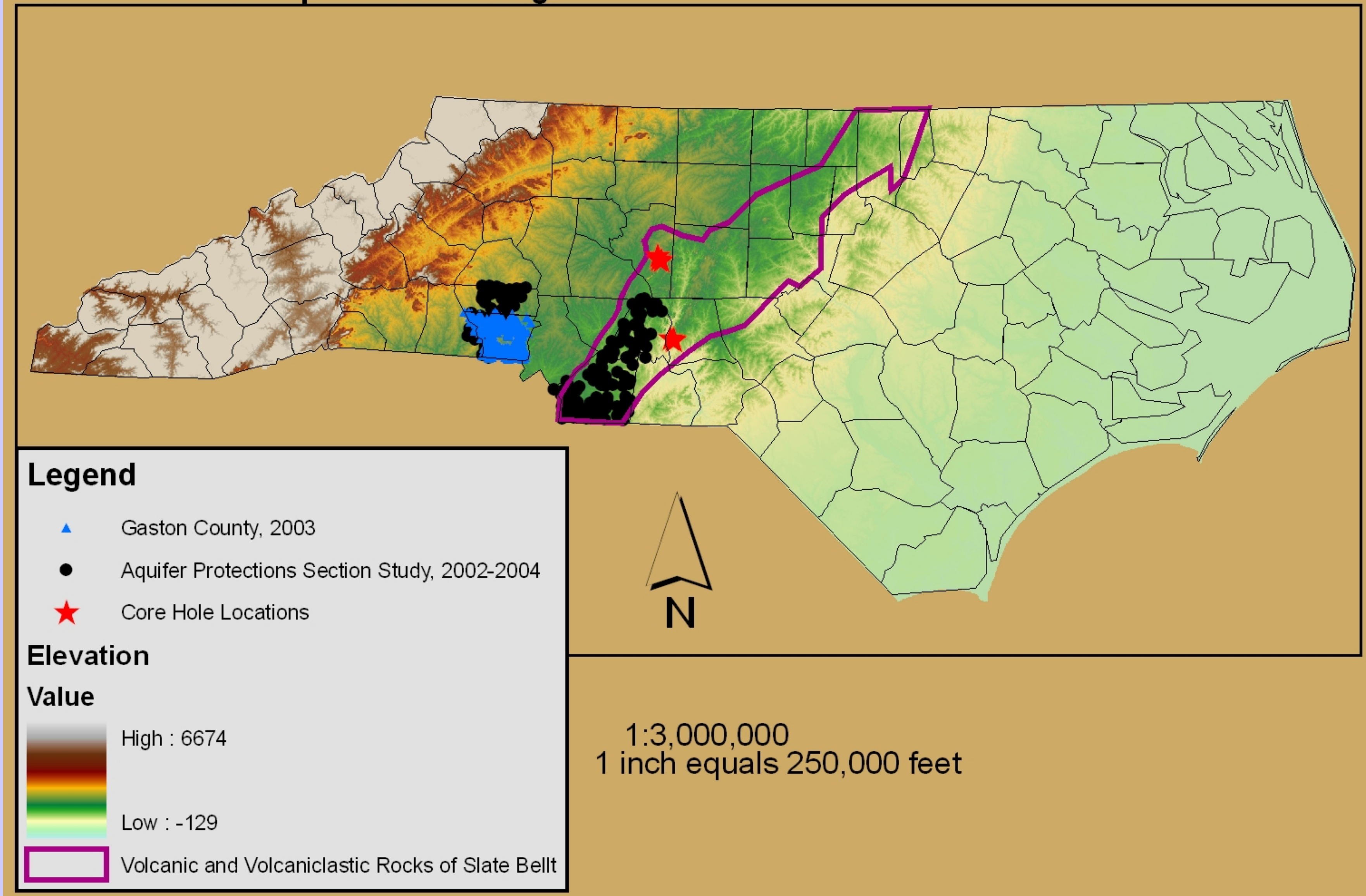
Probability to Exceed 1 ug/L

- 75% Probability
- 50% Probability
- 25% Probability
- Carolina Zone
- Carolina Terrane
- Carolina Zone Volcanic and Volcaniclastic Rocks

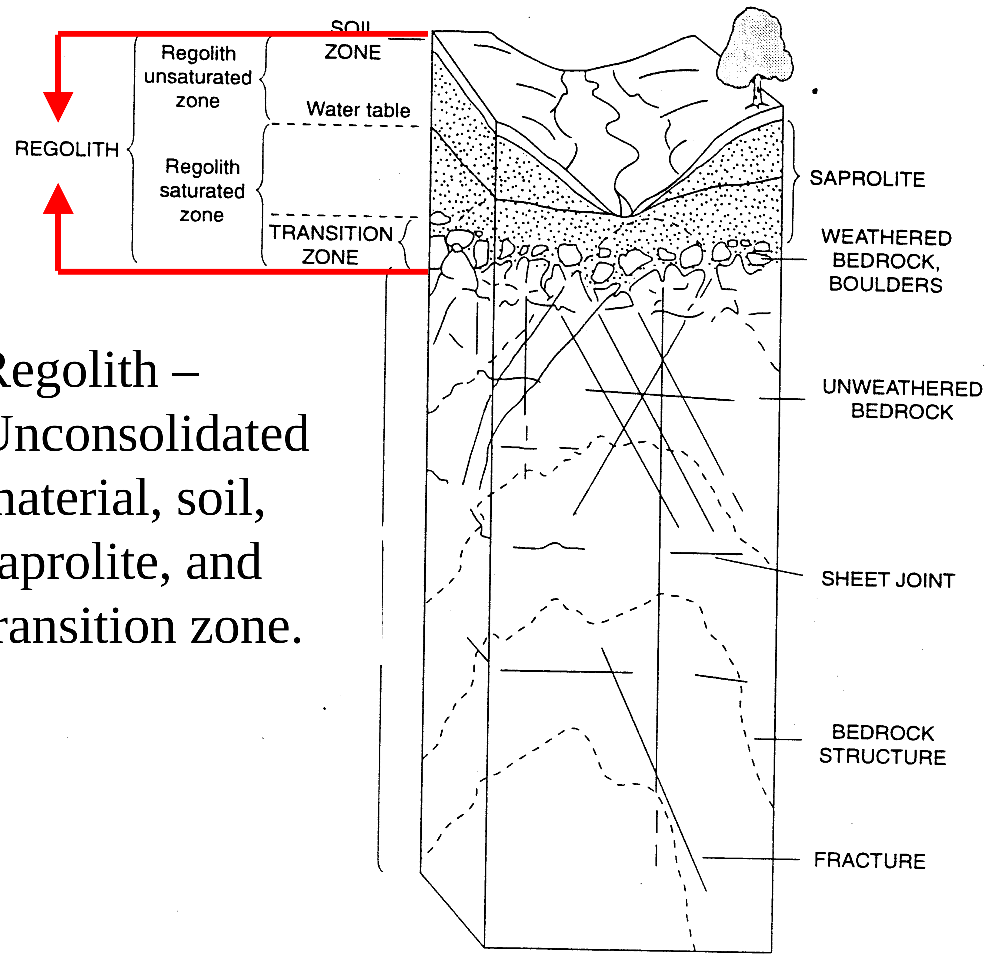
Map prepared by the North Carolina Department of Environment and Natural Resouces, Division of Water Quality, Aquifer Protection Section

High Probability zones are spatially correlative with volcanic and volcaniclastic rocks of the Carolina Zone.

Sample Locations for the Aquifer Protection Section and Gaston County Arsenic Studies and Core Hole Locations from Exploration Drilling.



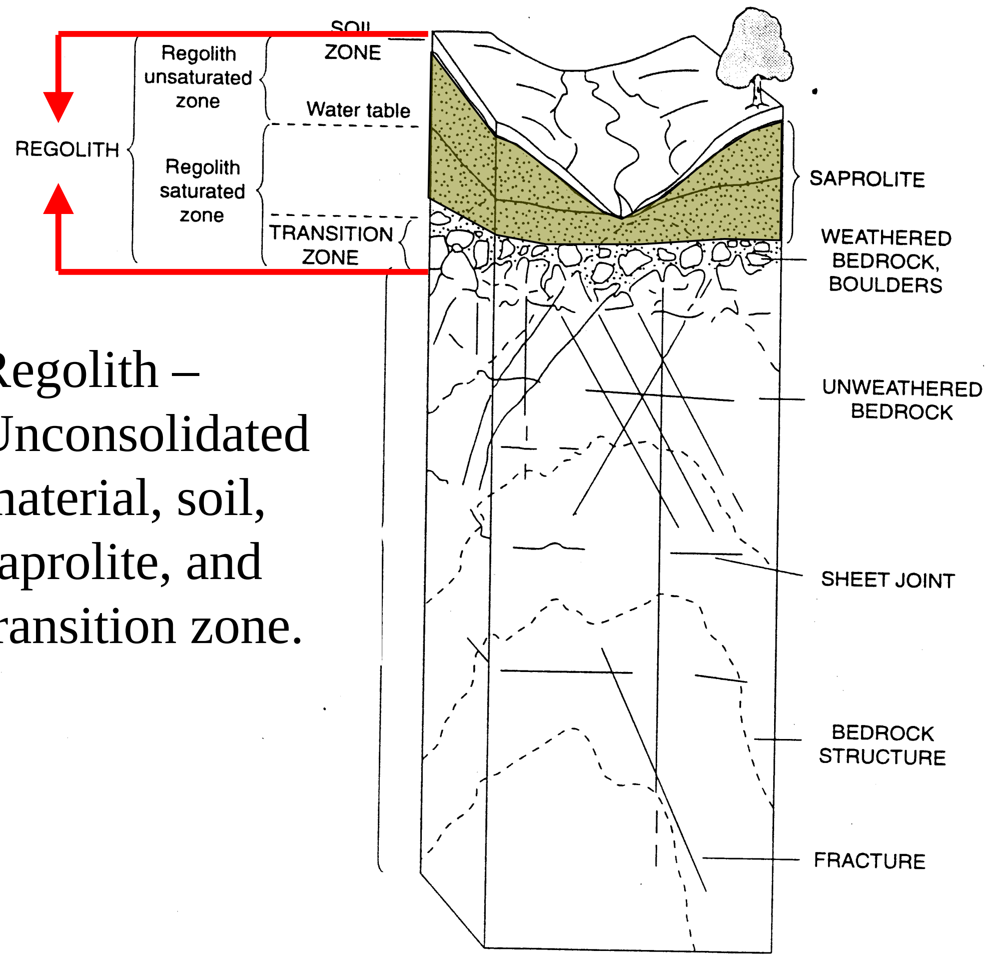
Overview of the Piedmont Aquifer System



Regolith – Unconsolidated material, soil, saprolite, and transition zone.

Figure 2. Principal components of the ground-water system in the Piedmont physiographic province of North Carolina (from Harned and Daniel, 1992).

Overview of the Piedmont Aquifer System



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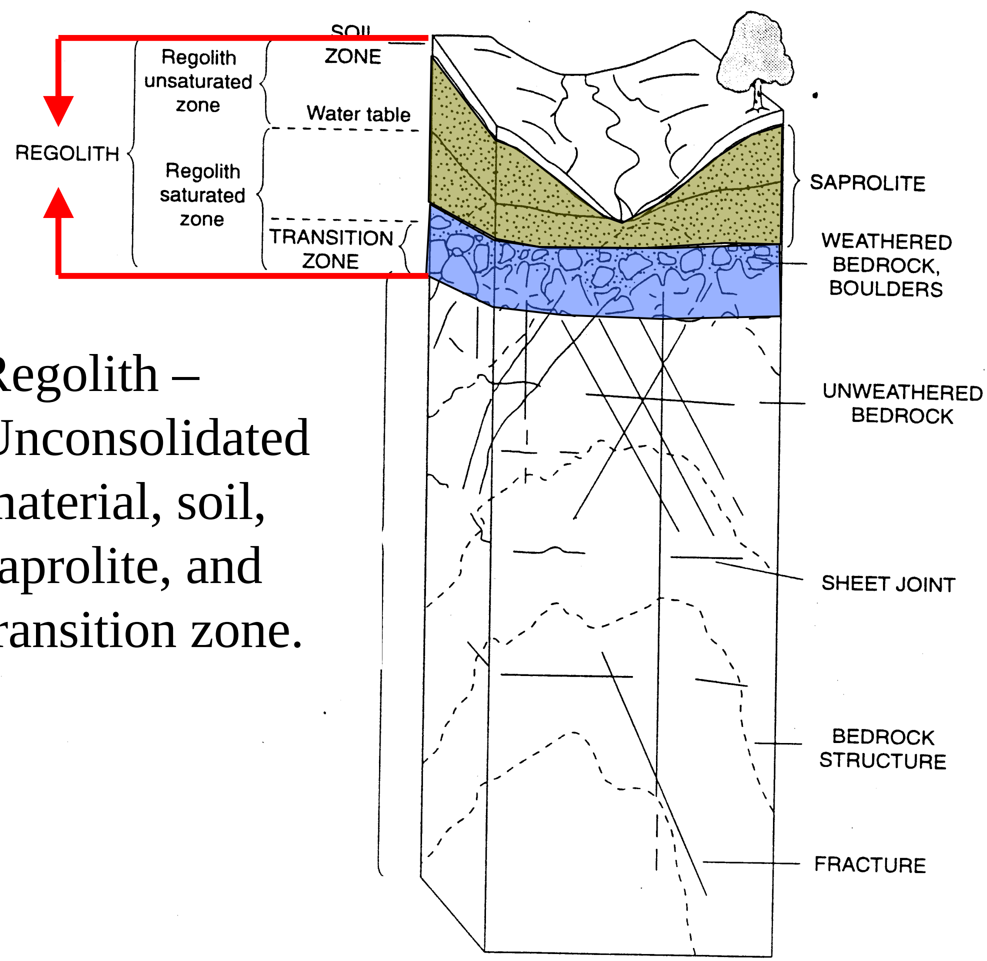

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Transition Zone – Weathering zone between saprolite and bedrock, generally more transmissive than the overlying saprolite zone.

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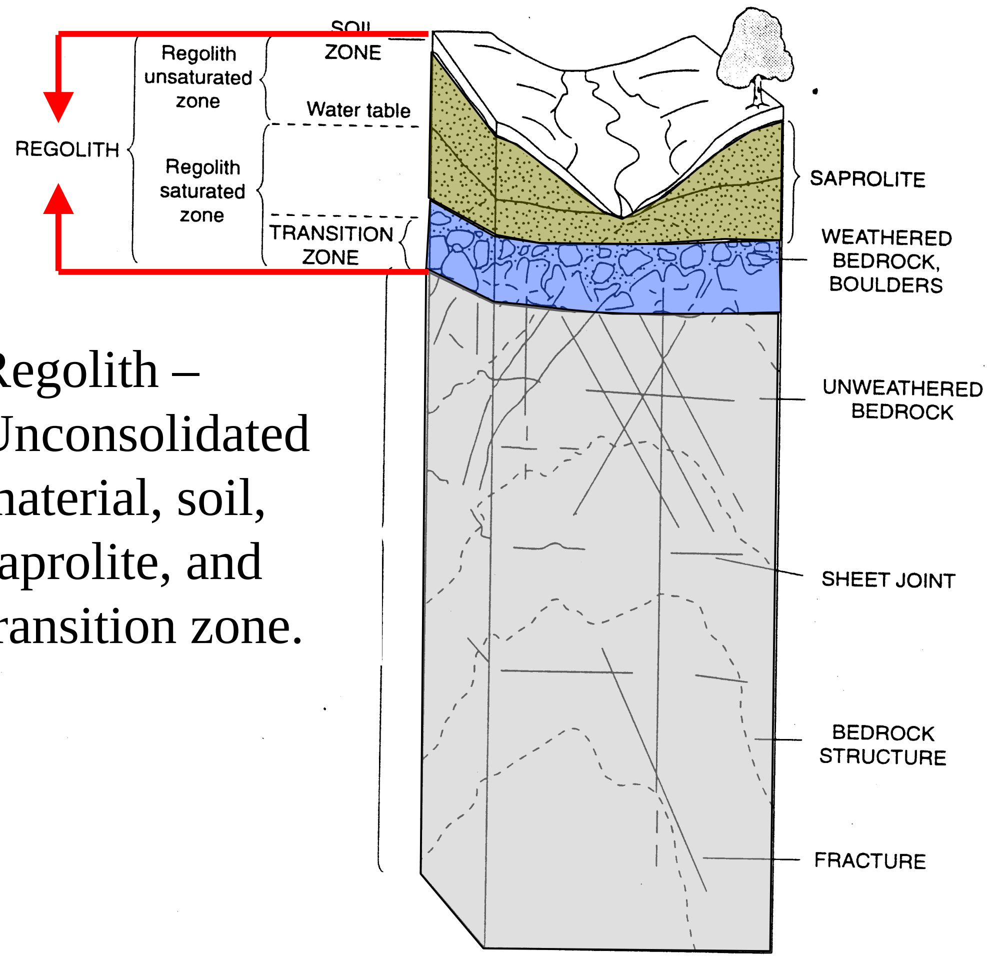

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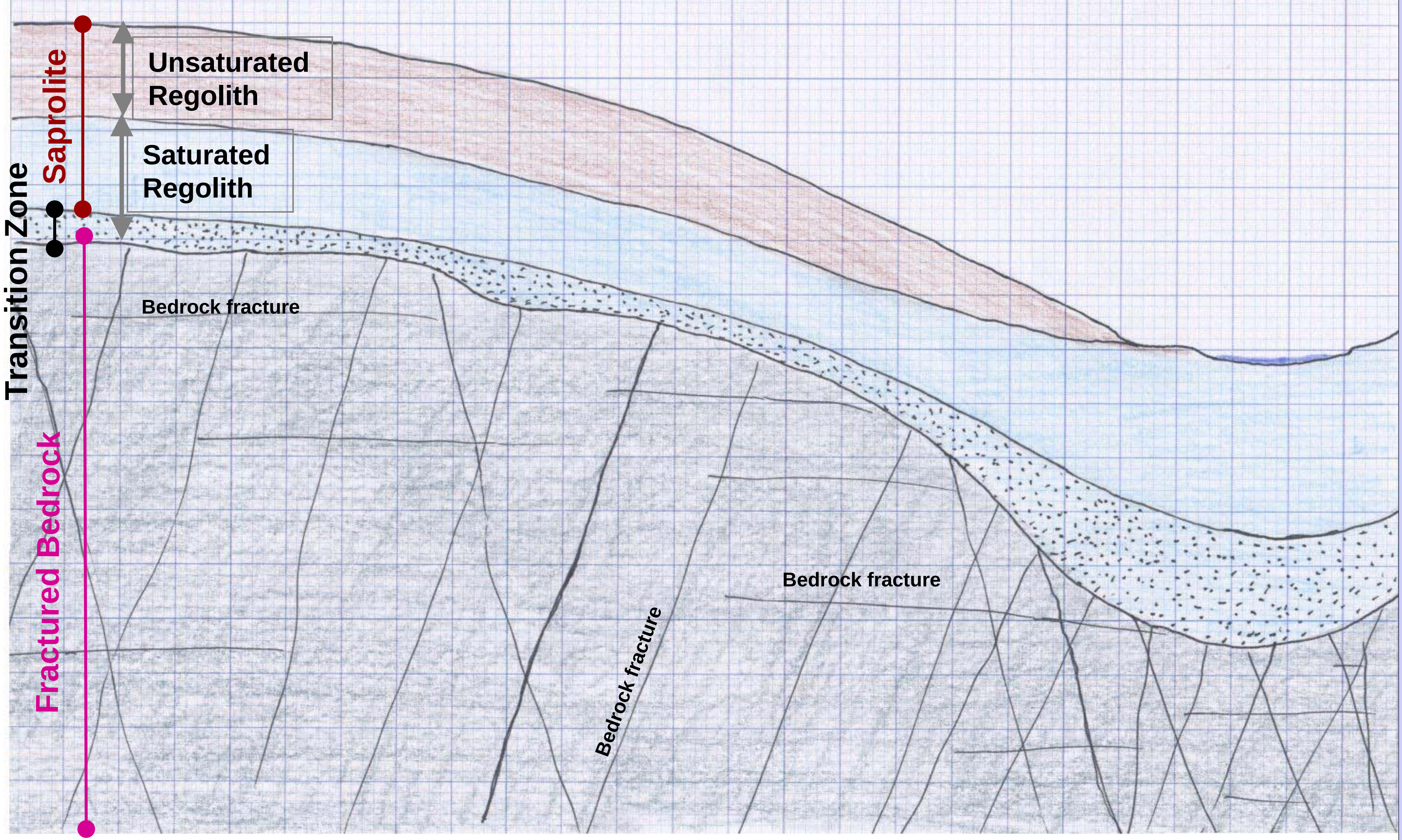
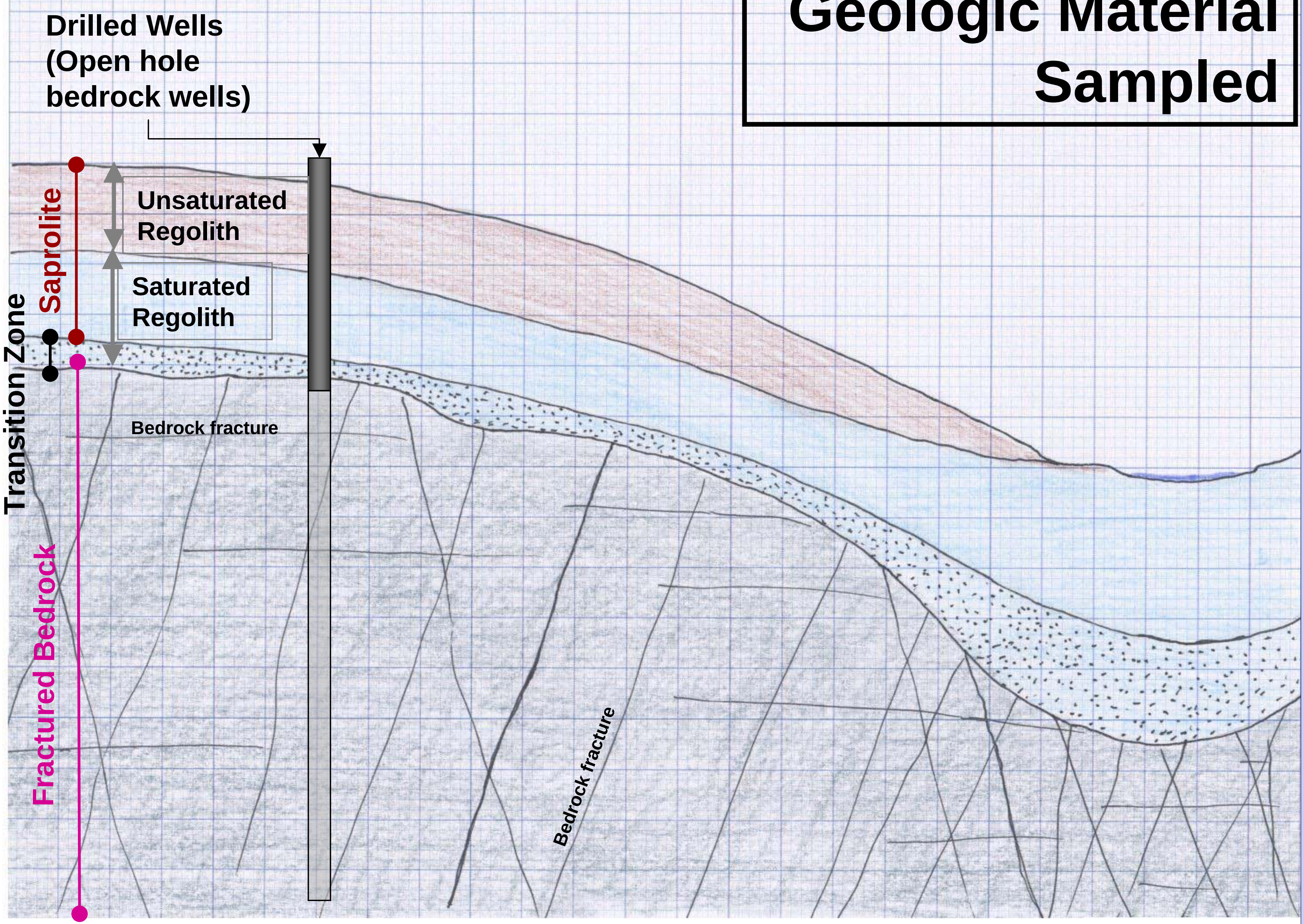
Fractured Bedrock – Igneous or metamorphic rocks. Groundwater is transmitted to discharge areas or wells *via* fracture network. Highly transmissive, but little storage. Connectivity to overlying regolith determines available water.

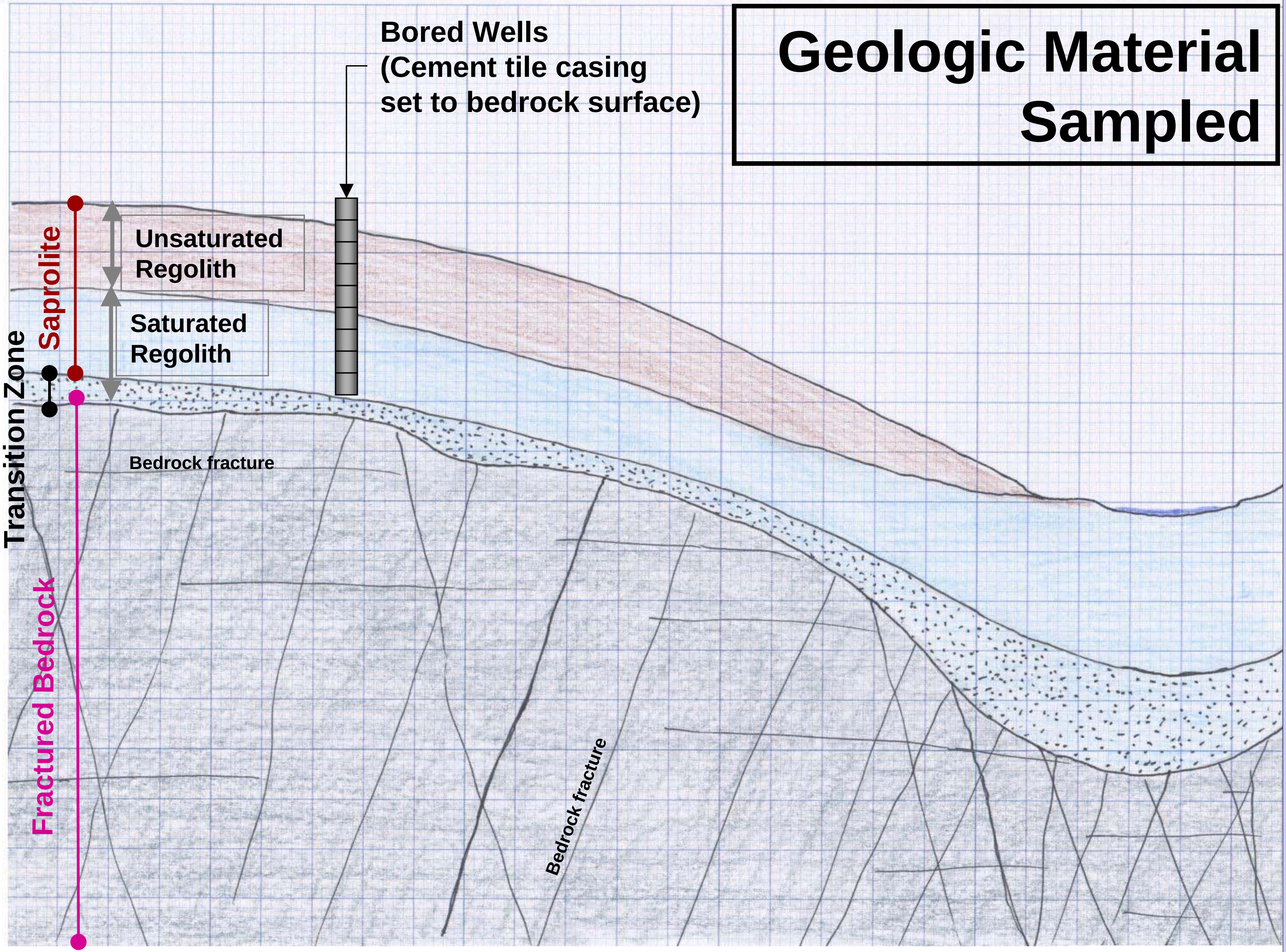
Geologic Material Sampled

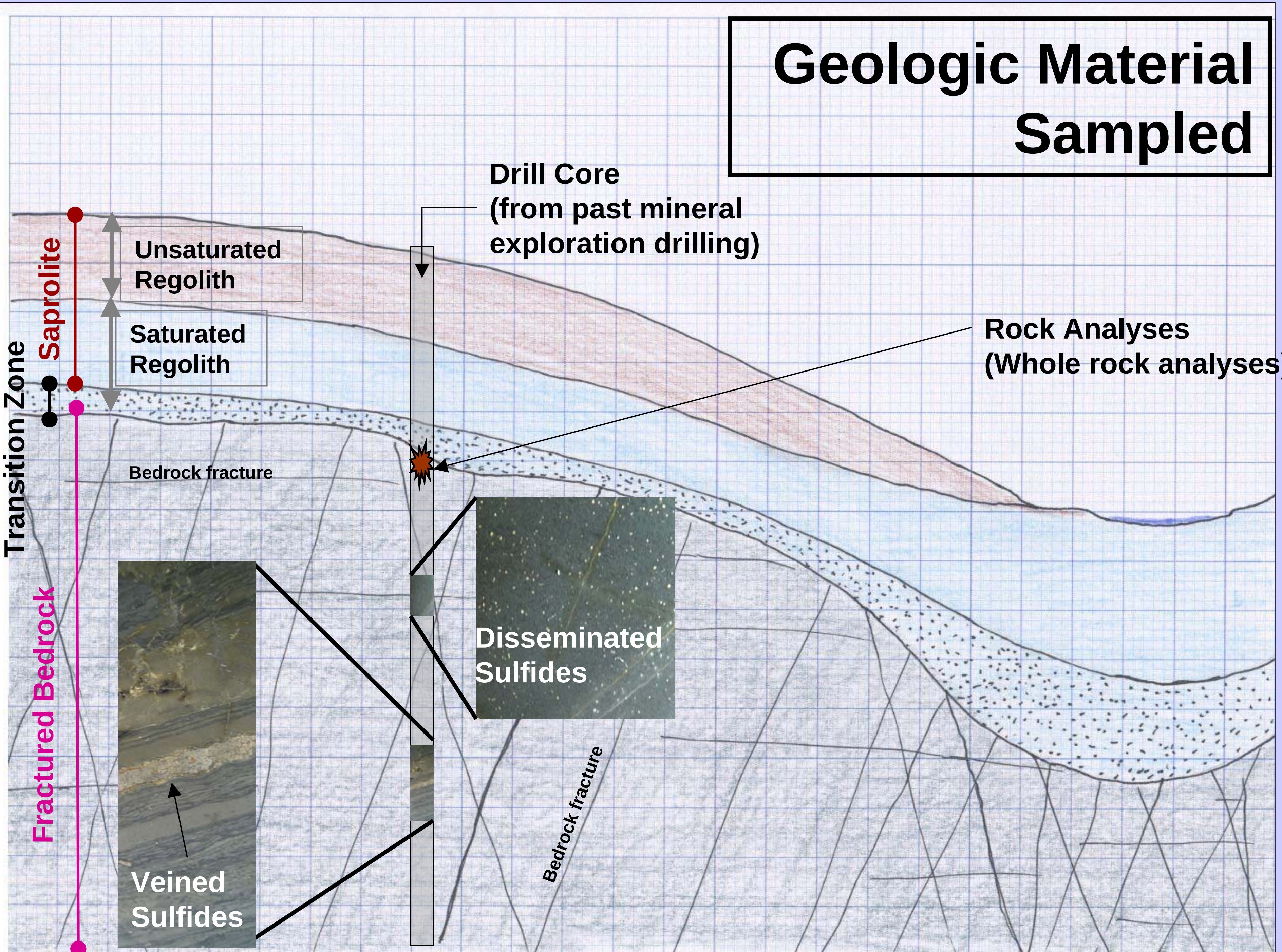


Geologic Material Sampled

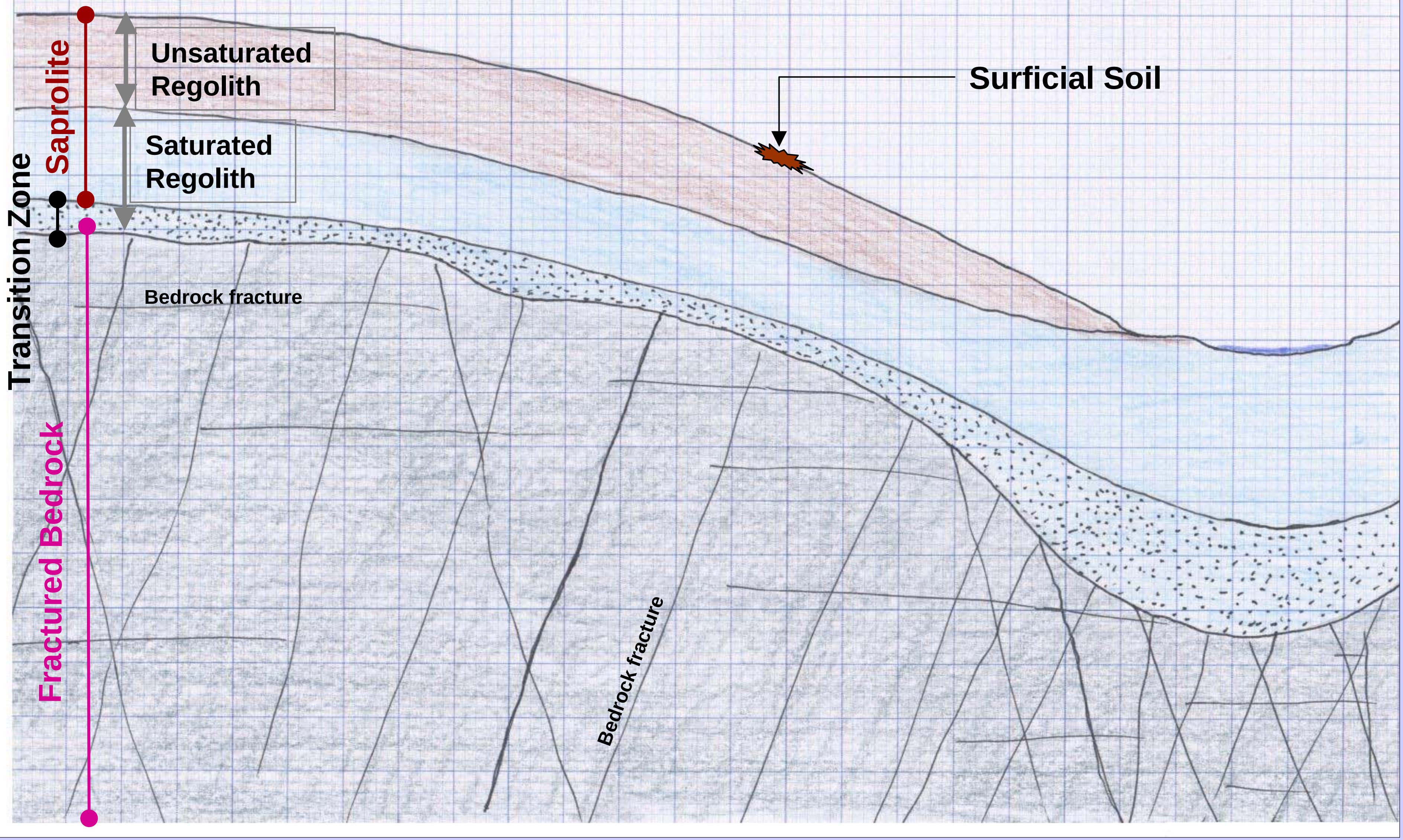


Geologic Material Sampled

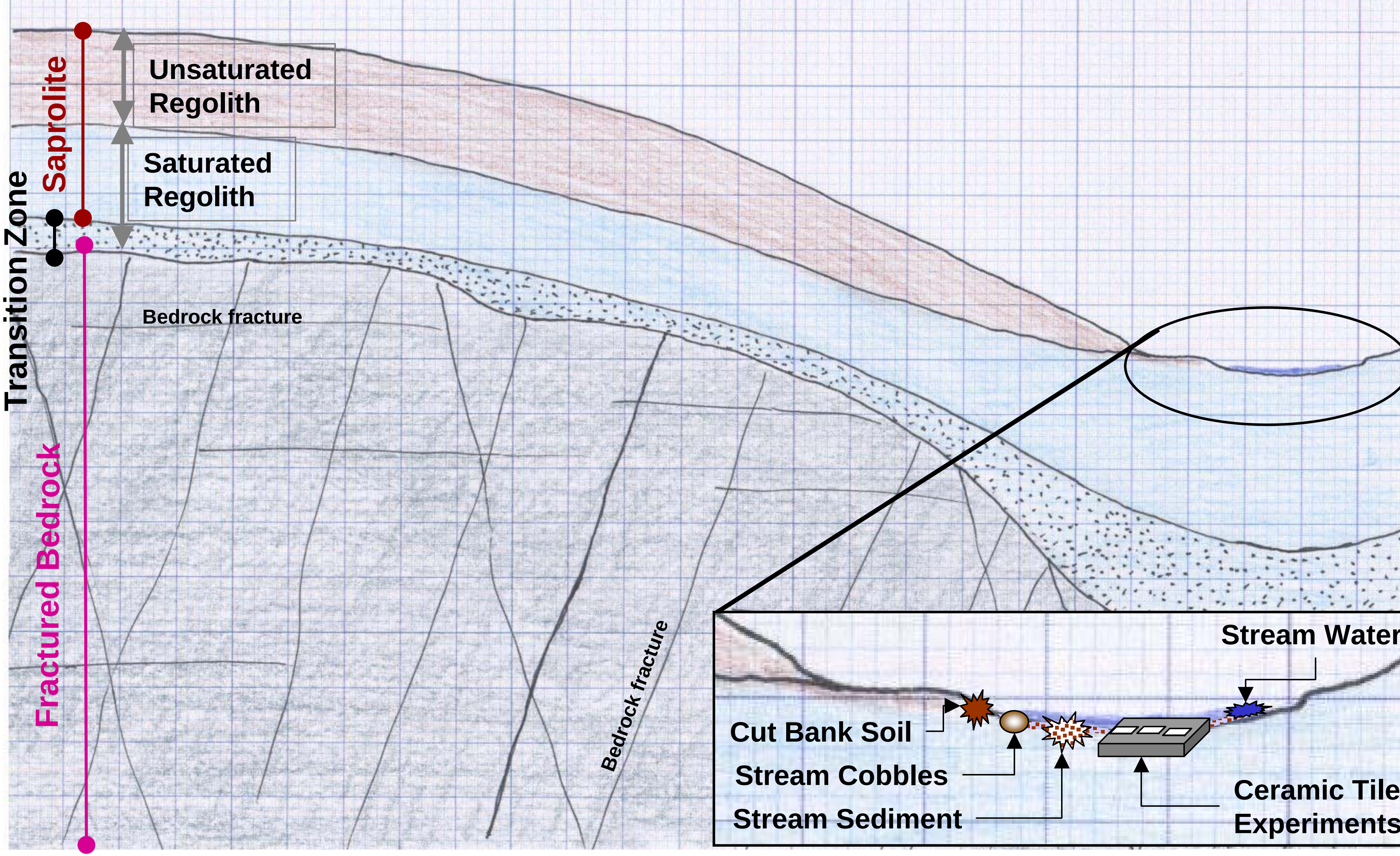



Geologic Material Sampled
Drill Core
(from past mineral exploration drilling)
Unsaturated Regolith
Saturated Regolith
Saprolite
Transition Zone
Fractured Bedrock
Rock Analyses
(Whole rock analyses)
Bedrock fracture
Bedrock fracture
Disseminated Sulfides
Veined Sulfides

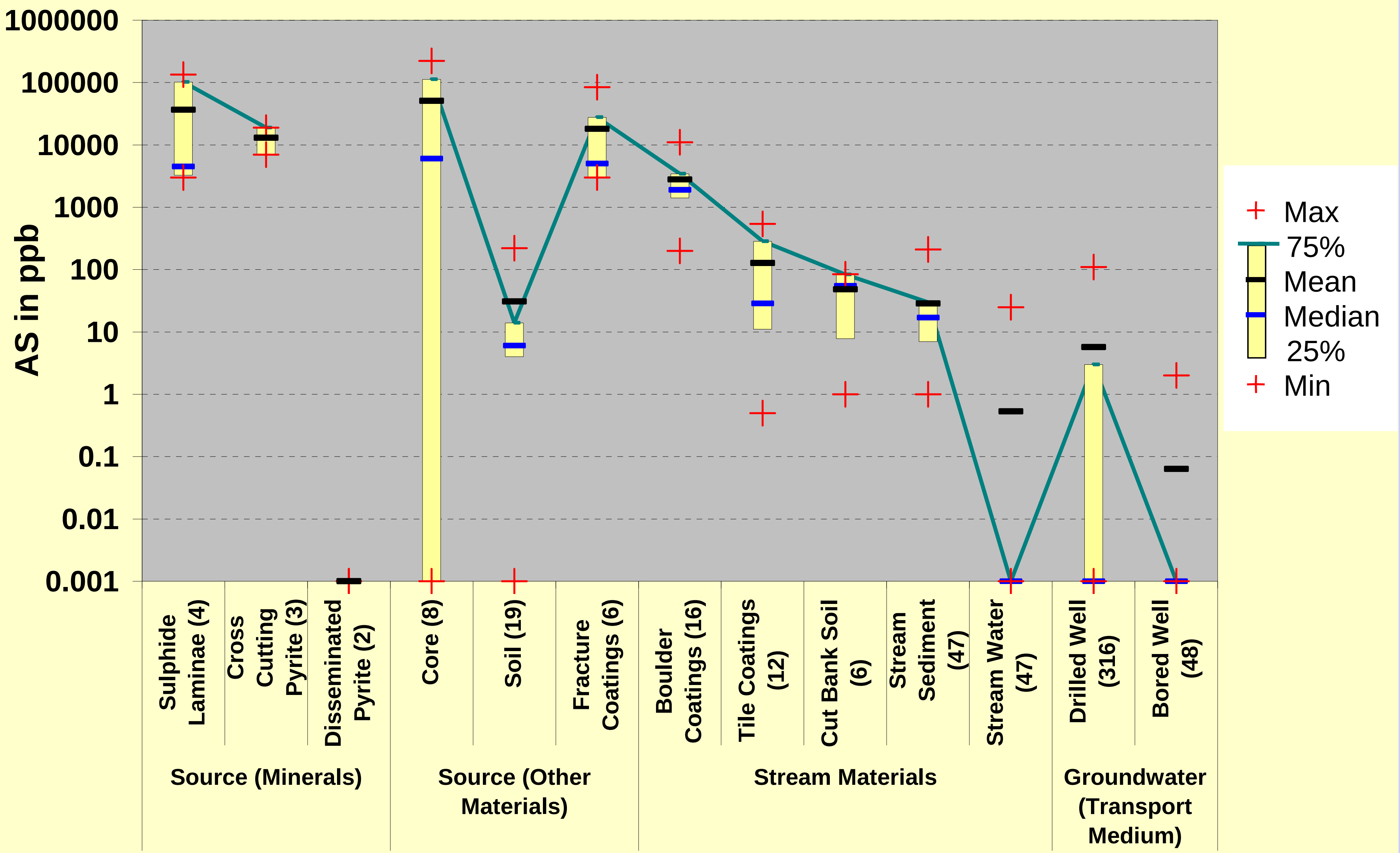
Geologic Material Sampled

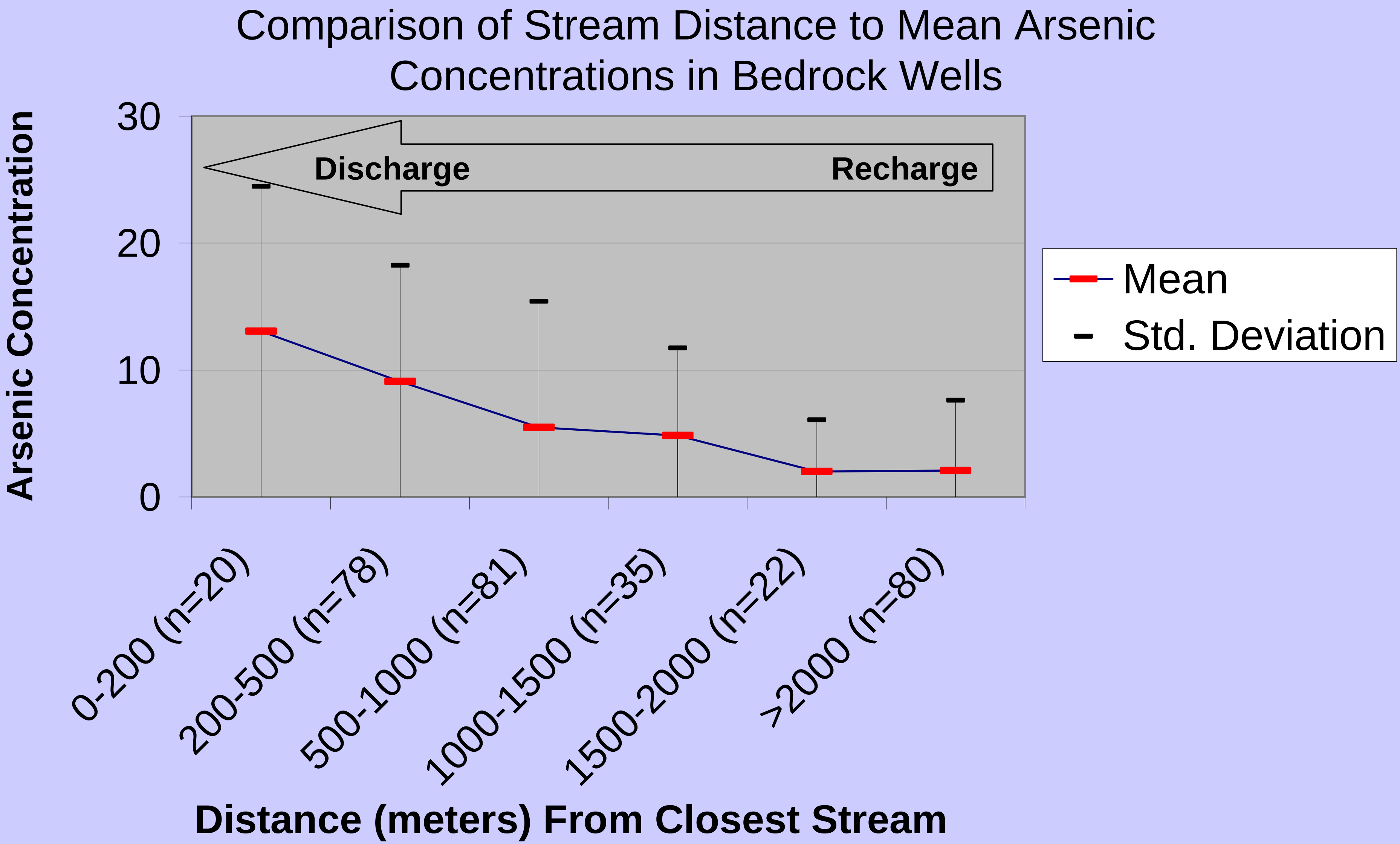


Geologic Material Sampled



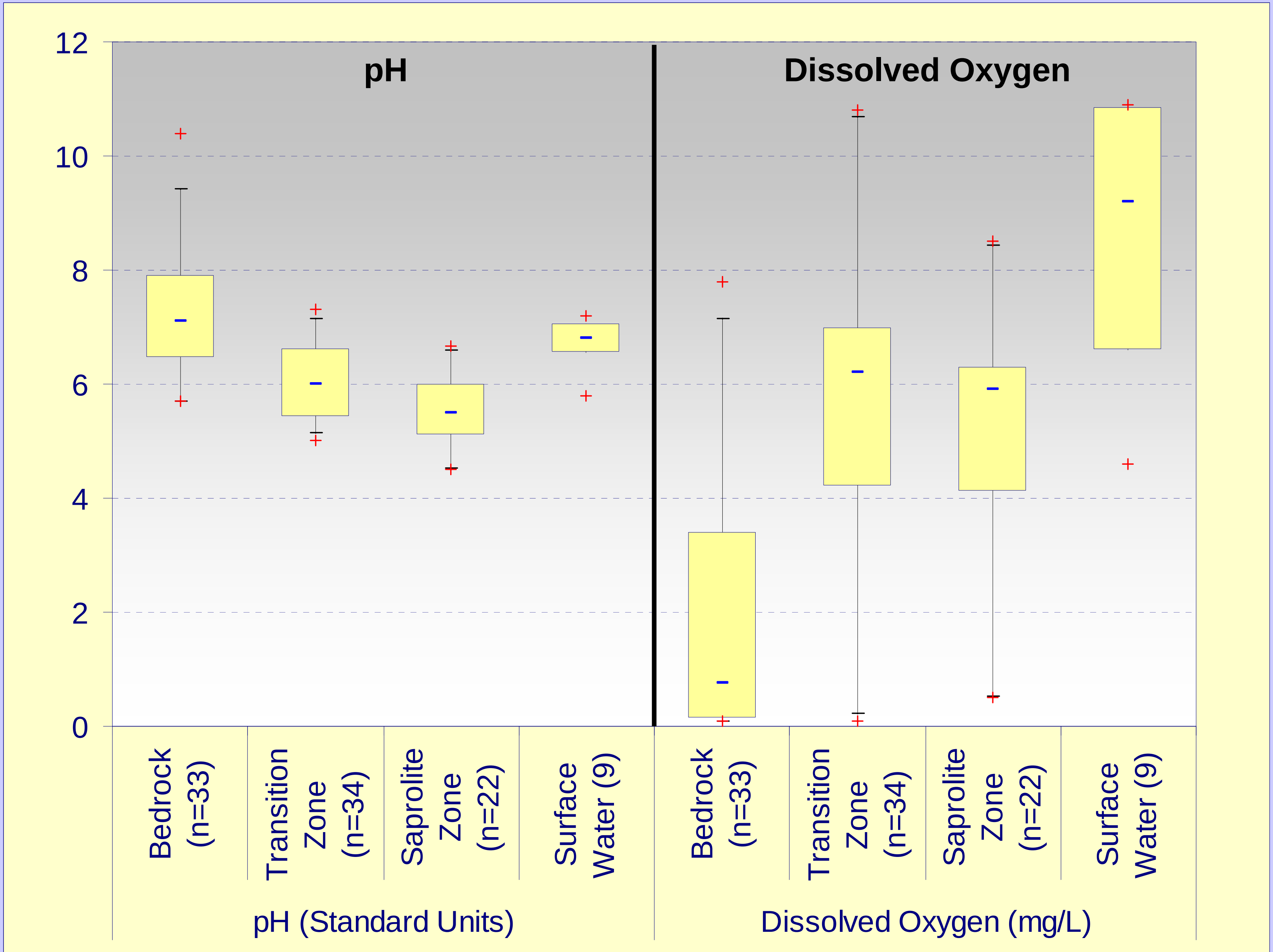
Box Plots of Arsenic Concentrations in Sampled Geologic Media



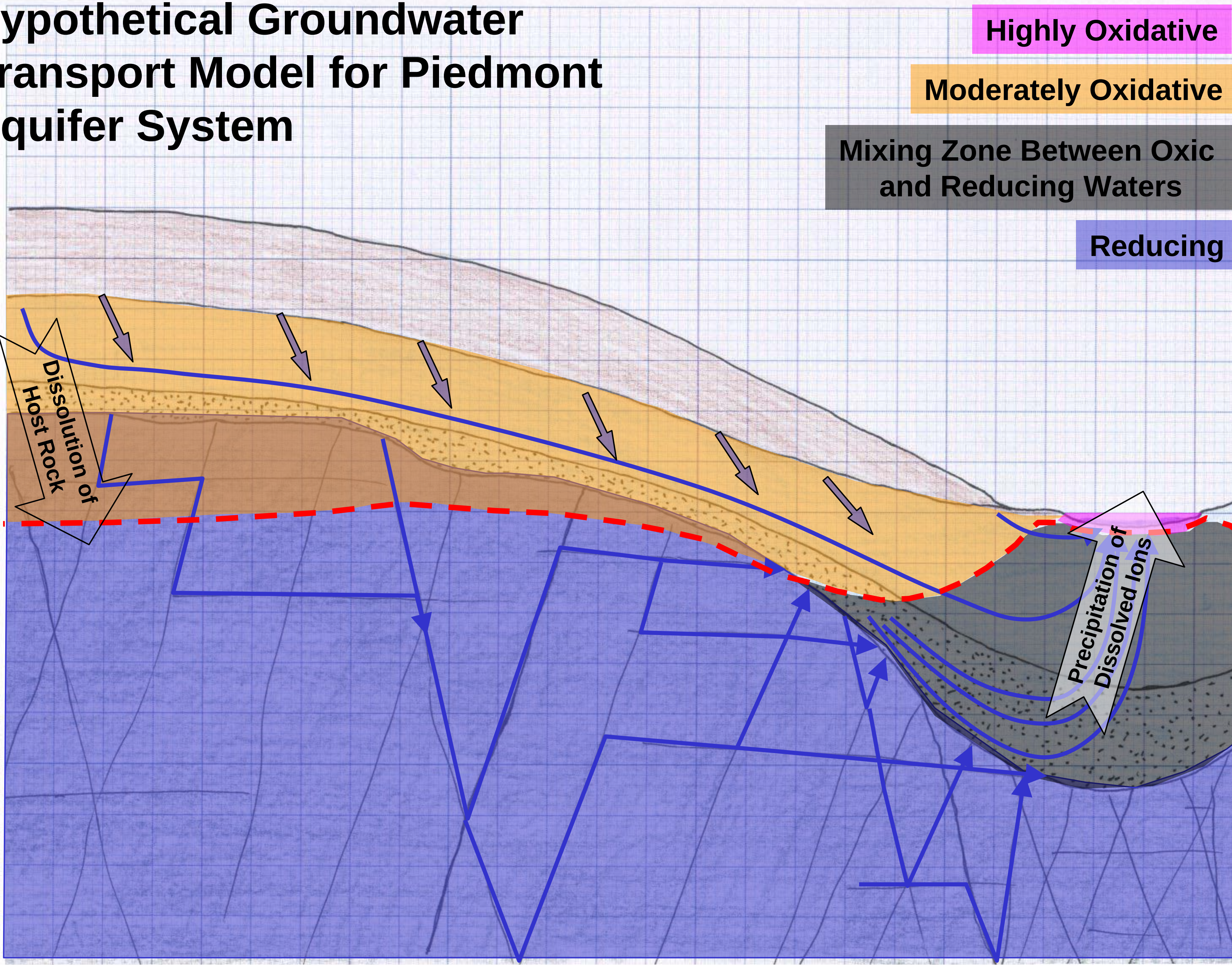


Comparison of Stream Distance to Mean Arsenic Concentrations in Bedrock Wells
Arsenic Concentration
30
20
10
0
Discharge
Recharge
Mean
Std. Deviation
0-200 (n=20)
200-500 (n=78)
500-1000 (n=81)
1000-1500 (n=35)
1500-2000 (n=22)
>2000 (n=80)
Distance (meters) From Closest Stream

pH and Dissolved Oxygen Data from Four Hydrogeologic Characterization Sites Located in the NC Piedmont.

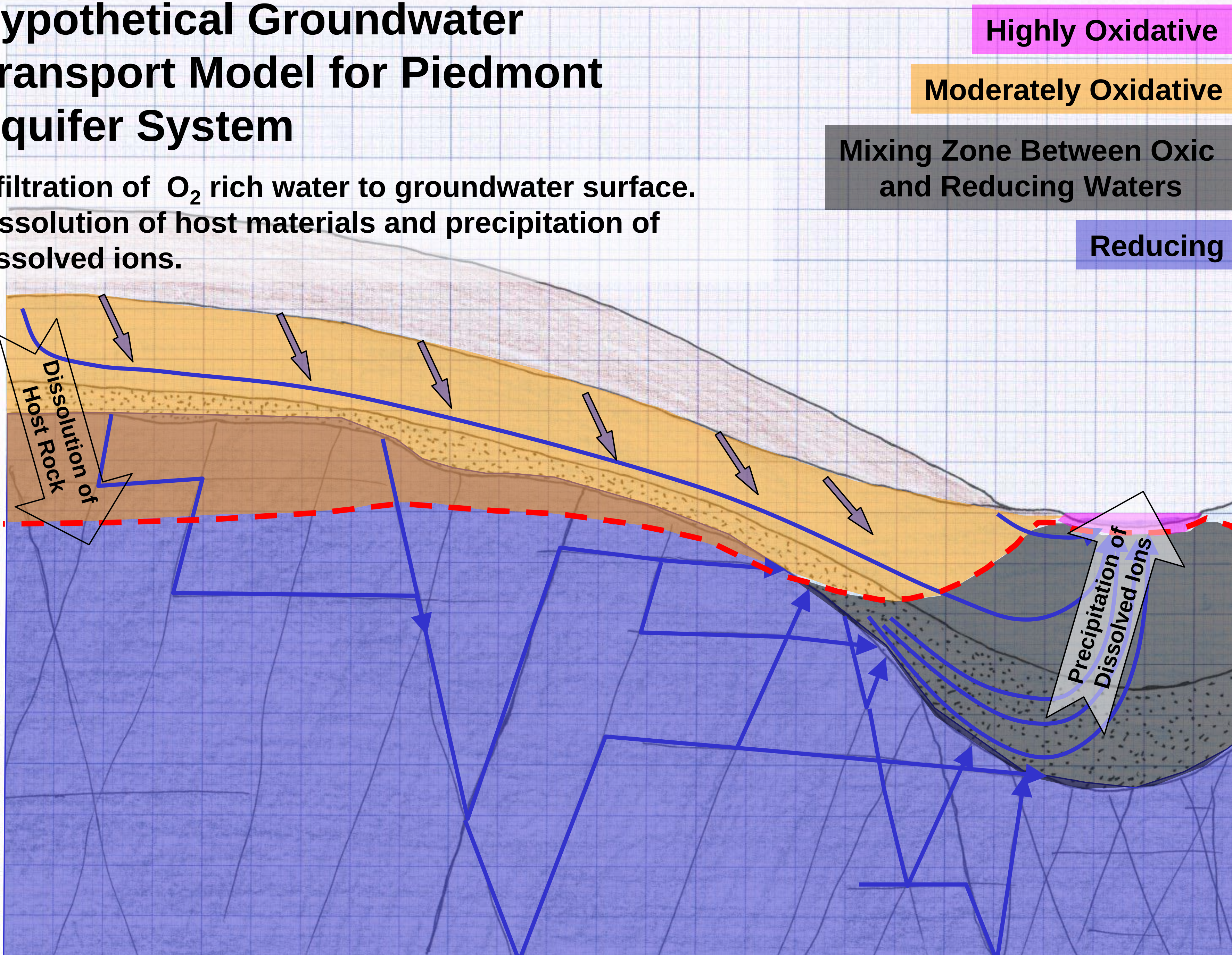


Hypothetical Groundwater Transport Model for Piedmont Aquifer System



Hypothetical Groundwater Transport Model for Piedmont Aquifer System

Infiltration of O_2 rich water to groundwater surface. Dissolution of host materials and precipitation of dissolved ions.



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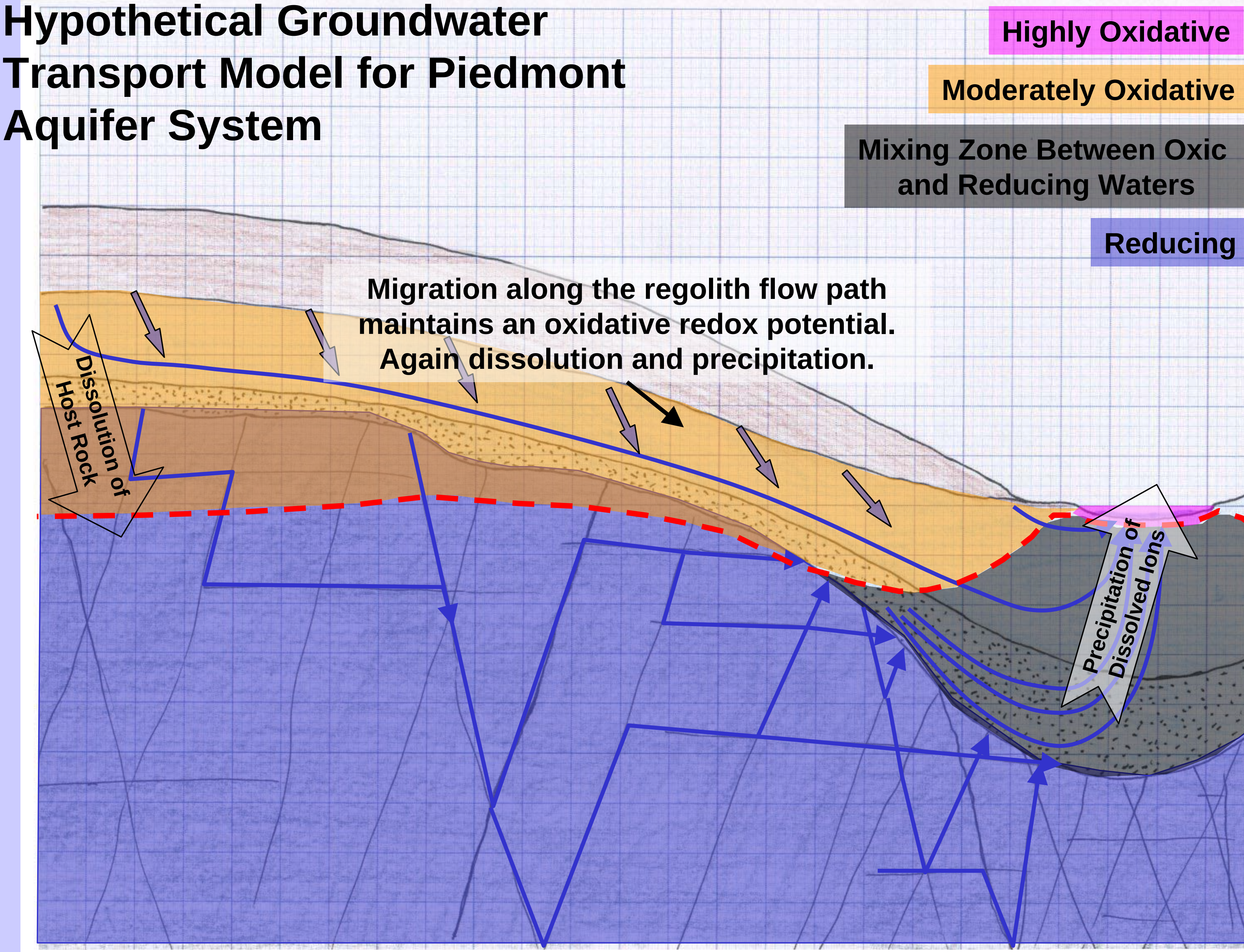

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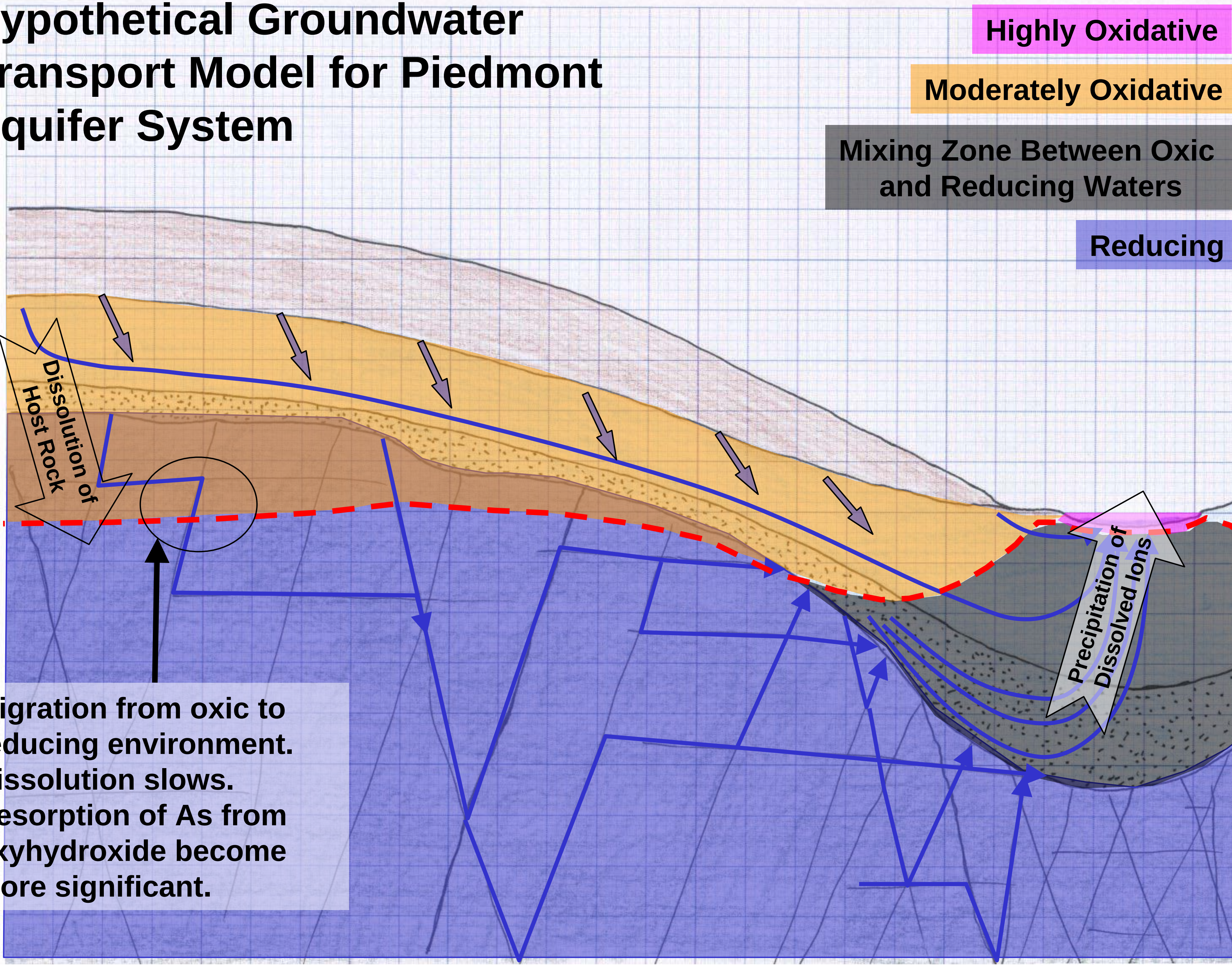

Migration from oxic to reducing environment. Dissolution slows. Desorption of As from oxyhydroxide become more significant.

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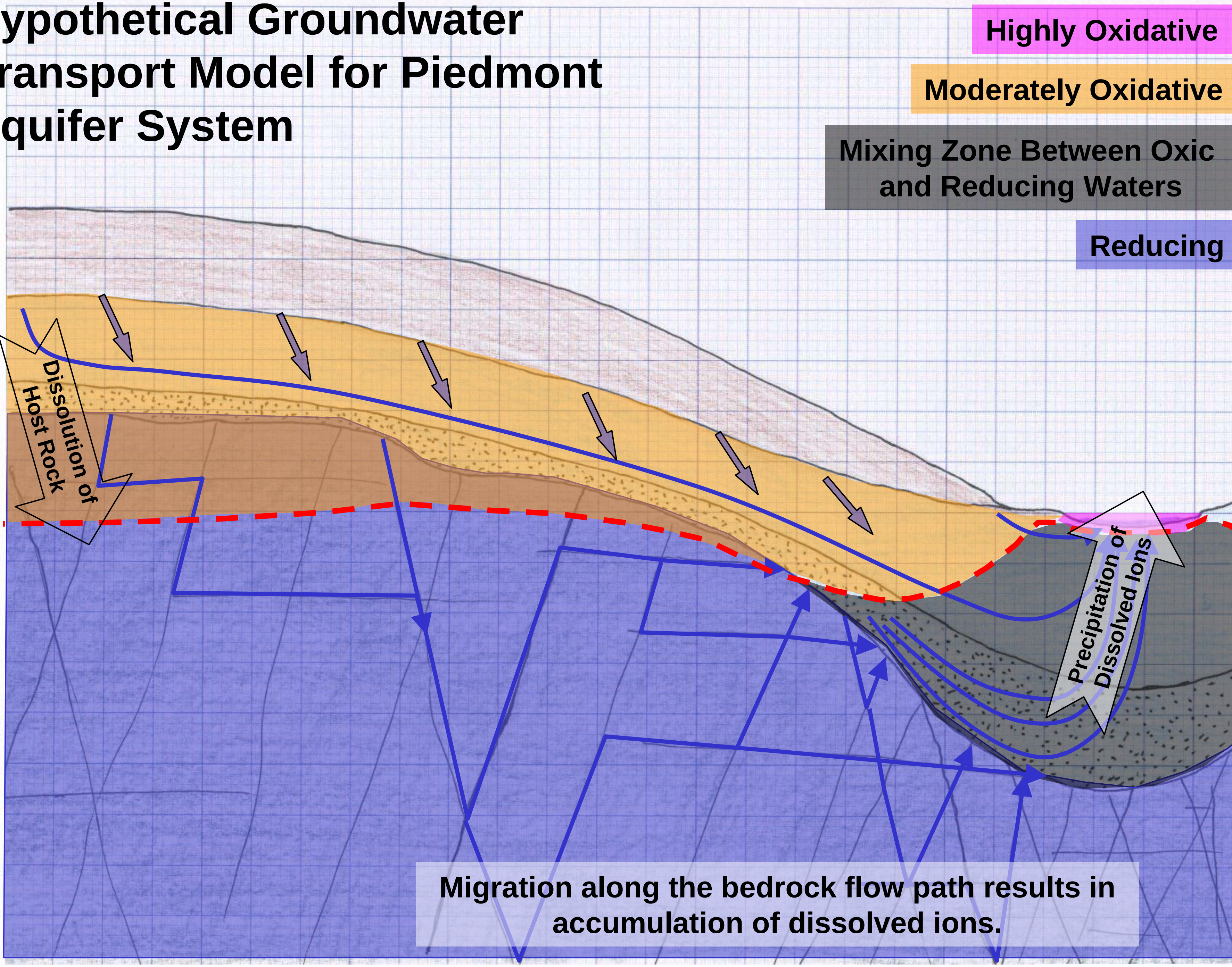

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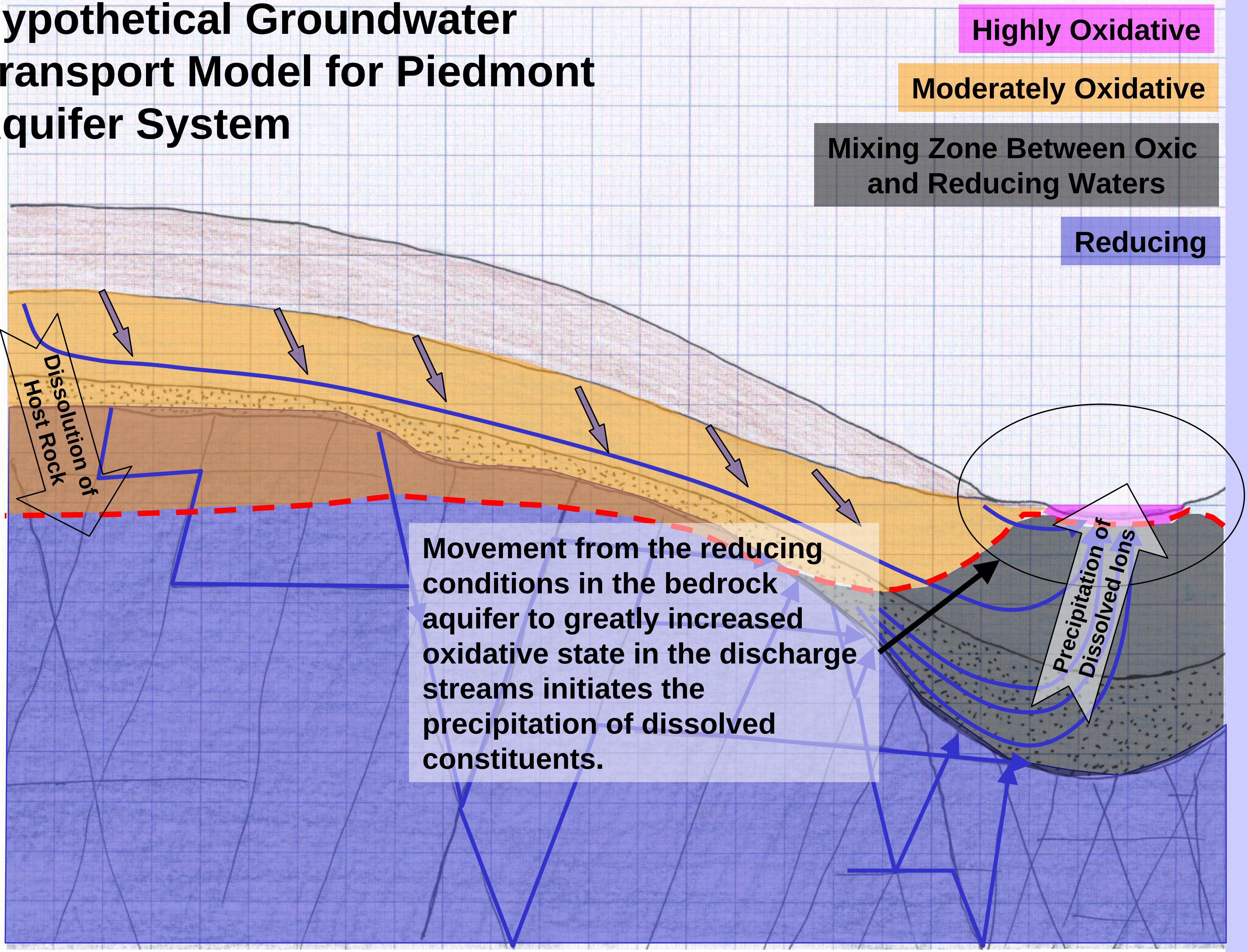
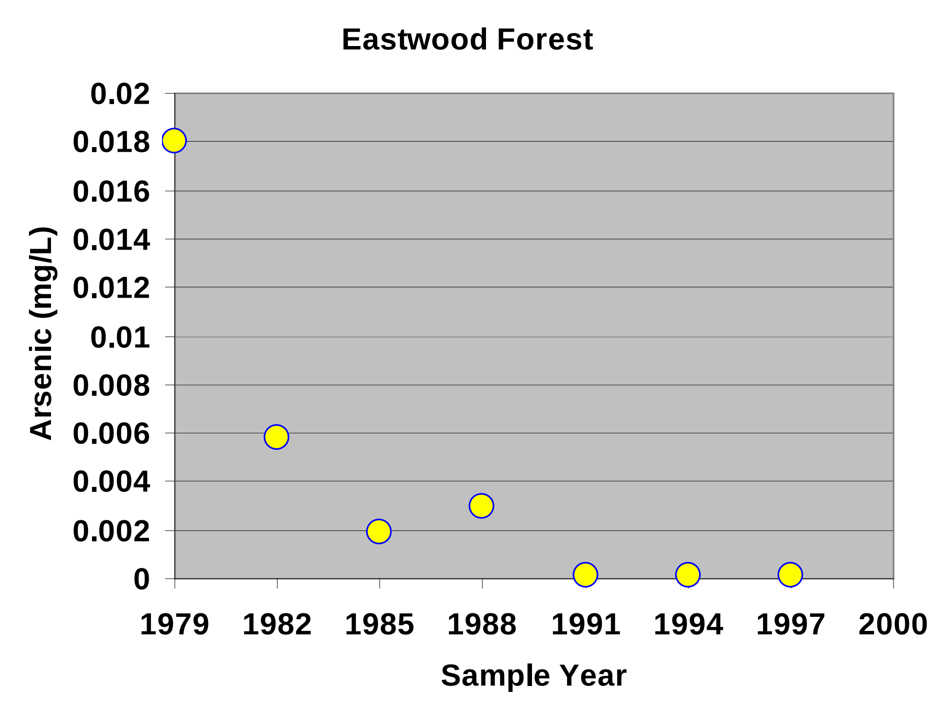
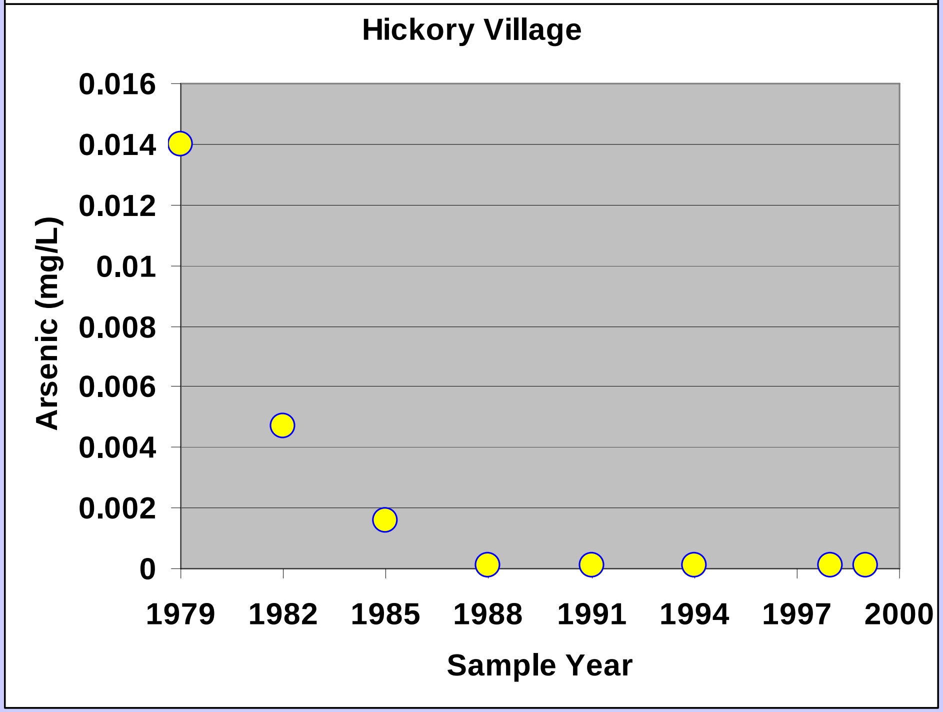




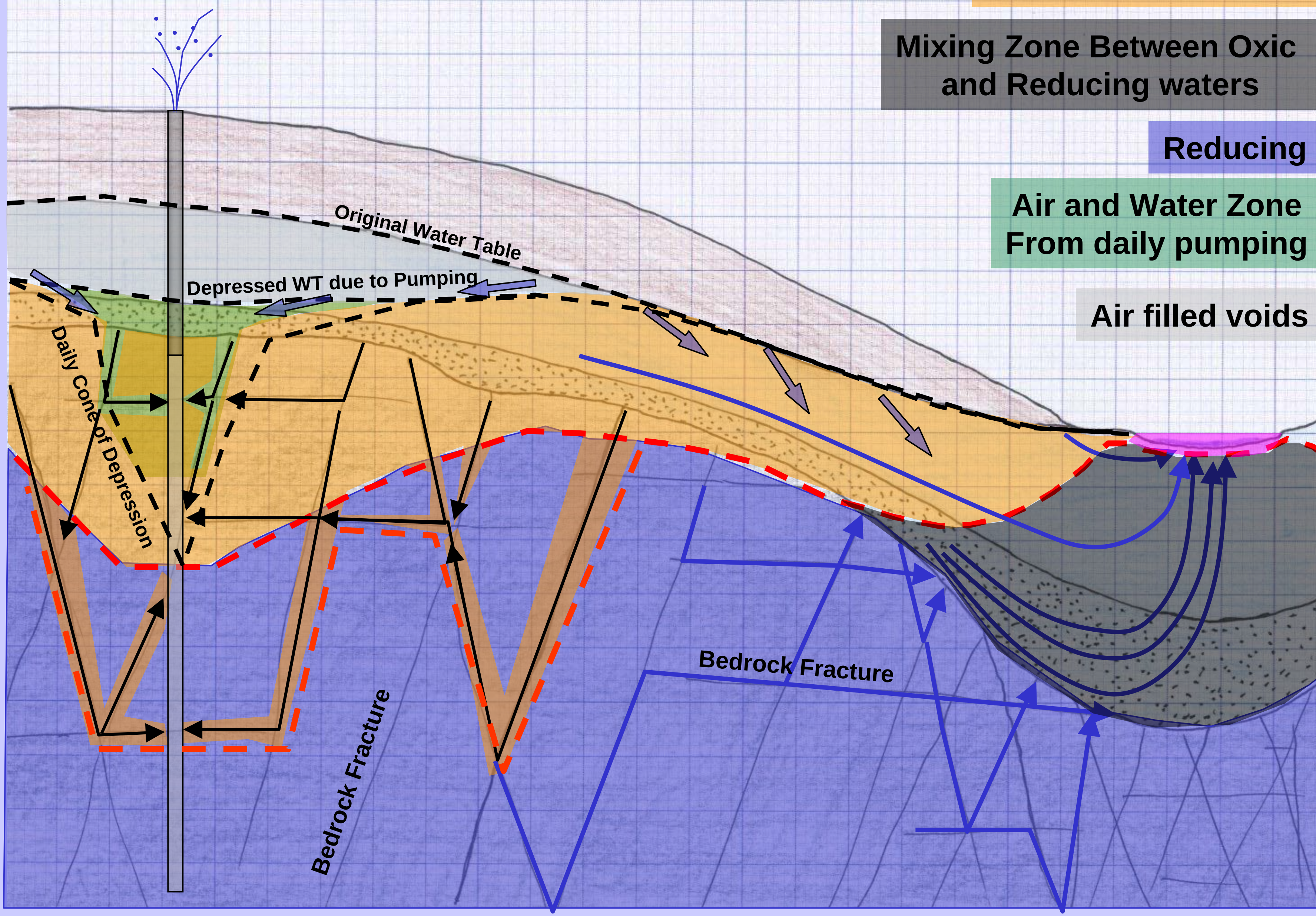


Public Supply Well Data

The Eastwood Forest system for example pumps over 500,000 gallons per month and Hickory Village over 300,000 gallons per month.

By contrast a domestic supply well serving a 4-person household uses approximately 7,750 gallons per month.

Hypothetical Aquifer Response to Public Supply Well Pumping



Conclusions

- Hot spots identified.
- Arsenic appears immobile in regolith; however, arsenic accumulates along groundwater flow paths through bedrock.
- Sulfide mineralization in bedrock is the primary source; however, dissolution, adsorption and desorption are key processes in transport.
- Conceptual groundwater transport model has been developed for the piedmont.
- Model could explain differences between arsenic occurrence in domestic and public water supply wells.

Contacts

Charles G. Pippin, Aquifer Protection Section, NCDENR	chuck.pippin@ncmail.net
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