PREDICTED ARSENIC CONCENTRATIONS IN BASIN-FILL AQUIFERS OF THE SOUTHWEST

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Western Region
(Nevada, Arizona, and Utah)

U.S. Department of the Interior
U.S. Geological Survey

BACKGROUND

In 2001 USEPA revised the arsenic drinking-water standard from 50 to 10 µg/L

Interest in areas within the United States where enriched arsenic concentrations in potable supplies are or may potentially occur

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OBJECTIVE

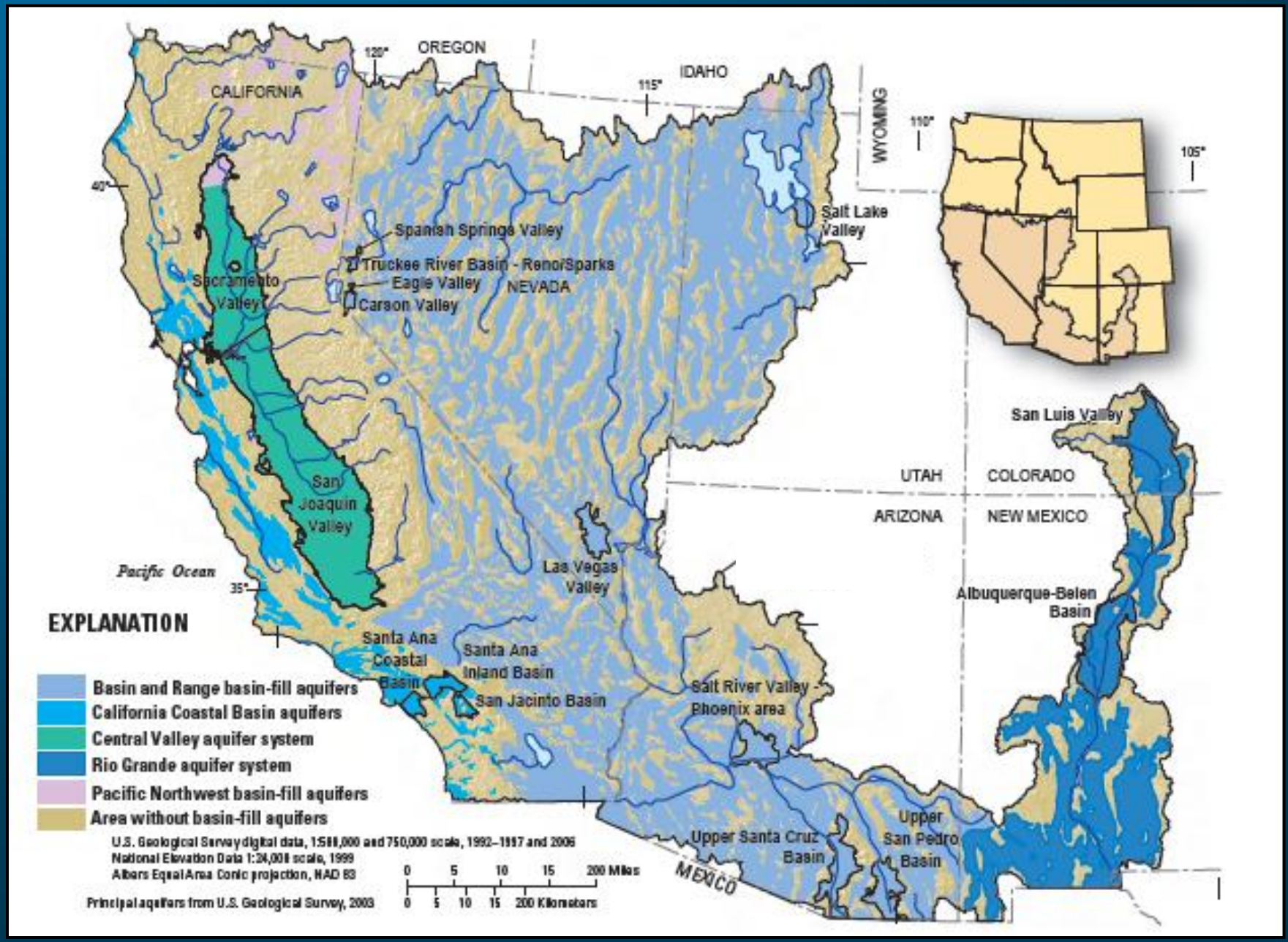
Characterize a spatial context in arsenic concentrations throughout basin-fill aquifers of the Southwest United States

Using the current understanding of arsenic occurrence, geochemistry, and transport mechanisms

Predict arsenic concentrations from areas of known concentration to areas where concentrations are unknown

USGS

Basin-Fill Aquifers



OBJECTIVE

Characterize a spatial context in arsenic concentrations throughout basin-fill aquifers of the Southwest United States

Using the current understanding of arsenic occurrence, geochemistry, and transport mechanisms

Predict arsenic concentrations from areas of known concentration to areas where concentrations are unknown

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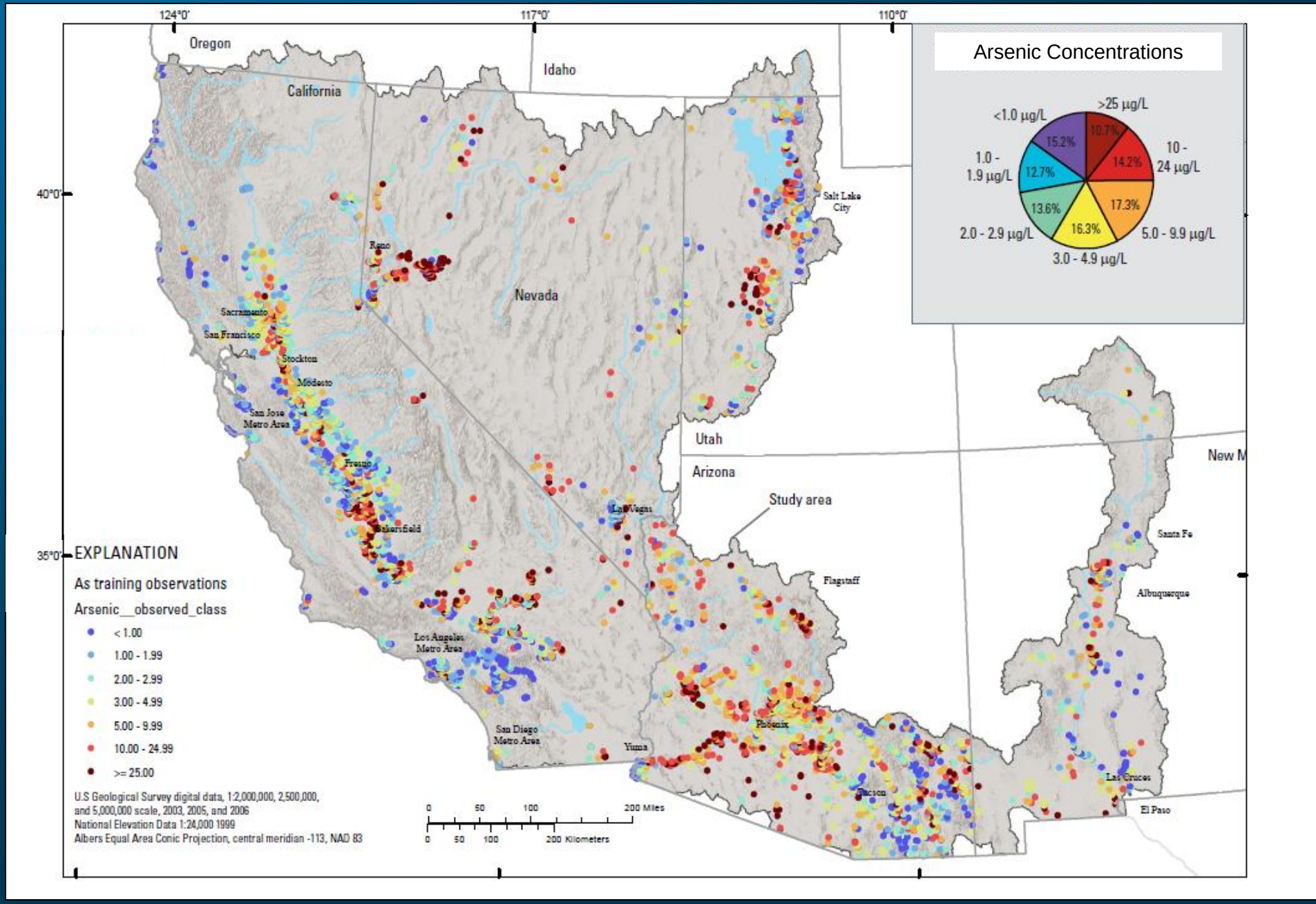
APPROACH

- The ≈191,000 mi^2 basin-fill regional study area was discretized into smaller spatial units (grid cells)
  - 54,854 grid cells (3.5 mi^2/ each)
- Measured arsenic concentrations were available for about 6 percent (10,700 mi^2) of the regional study area
  - One to two observations per grid cell (shallow, deep)
  - Measured arsenic concentrations available for 4,162 wells
  - 7 Categorical Concentration Classes (<1 to ≥25 µg/L)

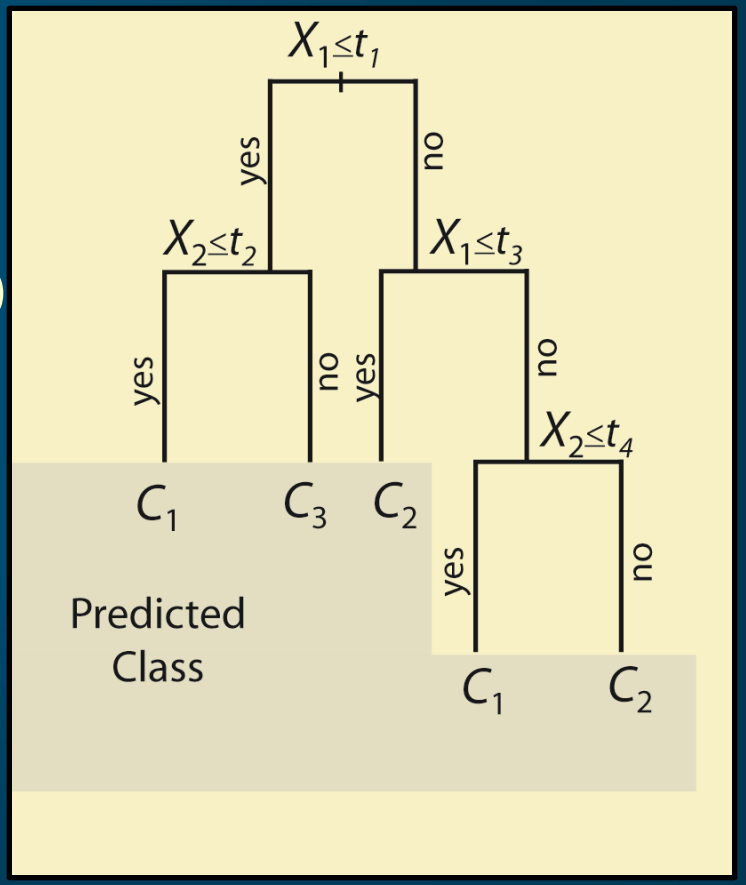
USGS

Measured Arsenic Concentrations



Random Forest Classifier (RFC):
multiple decision tree analyses

- Concentrations assigned to each of 7 concentration classes (C_n)
- Known concentrations used to calibrate using explanatory variables,X_n (53 available)
- Variables randomly selected for each tree (35 for each tree)
- Conditional relations among explanatory variables based on threshold value (t_n) for each
- 1000 individual trees make up the RFC



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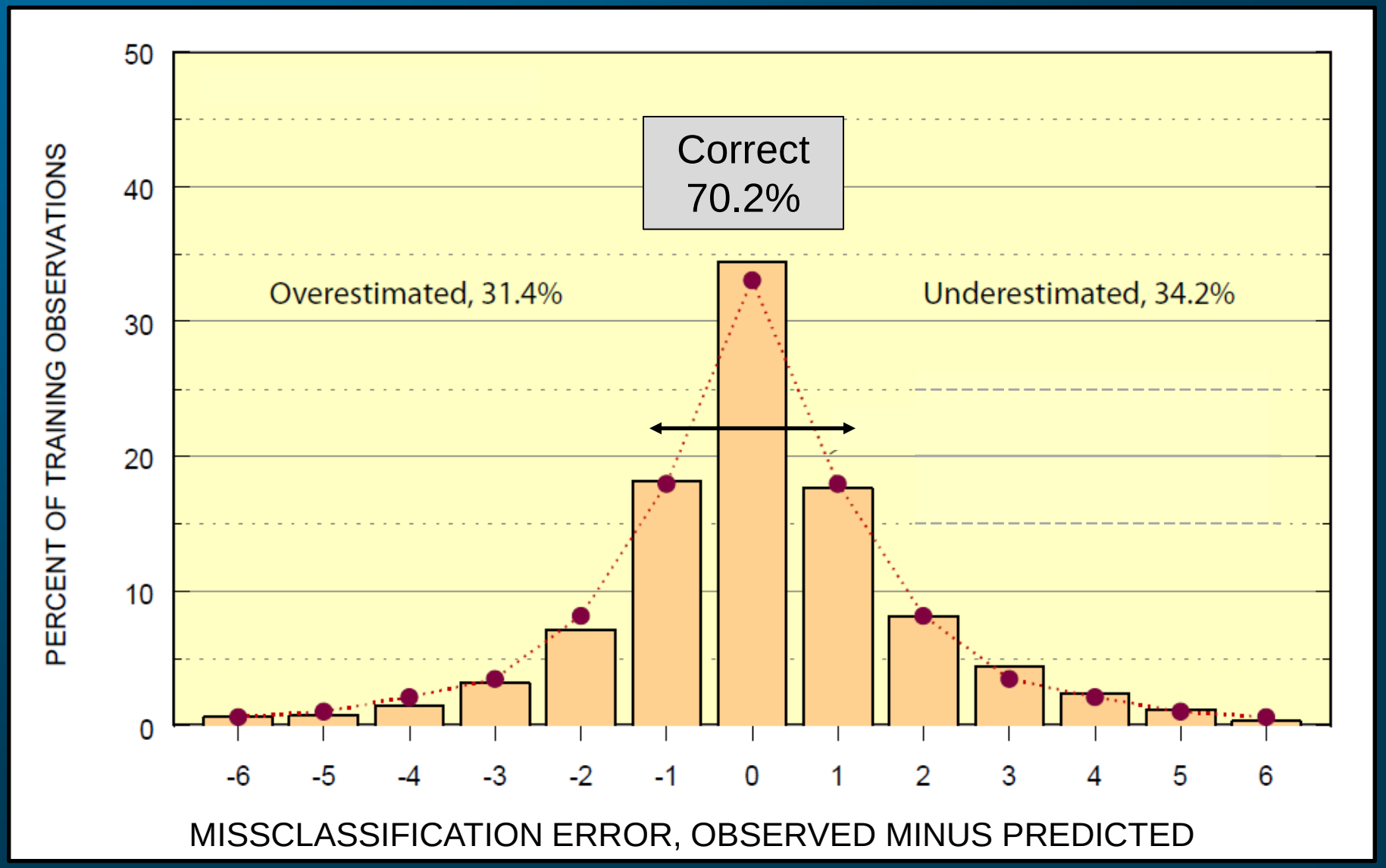
RFC PERFORMANCE

N = 4,162 wells



EXPLANATORY VARIABLES

Prediction RFC

Explanatory variables throughout regional basin-fill study area = 53

- Land use (agricultural, urban, rangland)
- Water use (irrigation, municipal)
- Geology (presence, cell distance from unit)
- Soil characteristics (permeability, composition)
- Flow path (elevation percentile, slope, distance from basin margin)
- Hydroclimate (potential ET, estimated contributory recharge)

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FACTORS IMPORTANT IN THE DISTRIBUTION OF ARSENIC

- Geology surrounding basin
- Position along flow path (residence time)
- Relative contributing recharge
- Basin characteristics (open, closed) – flushing

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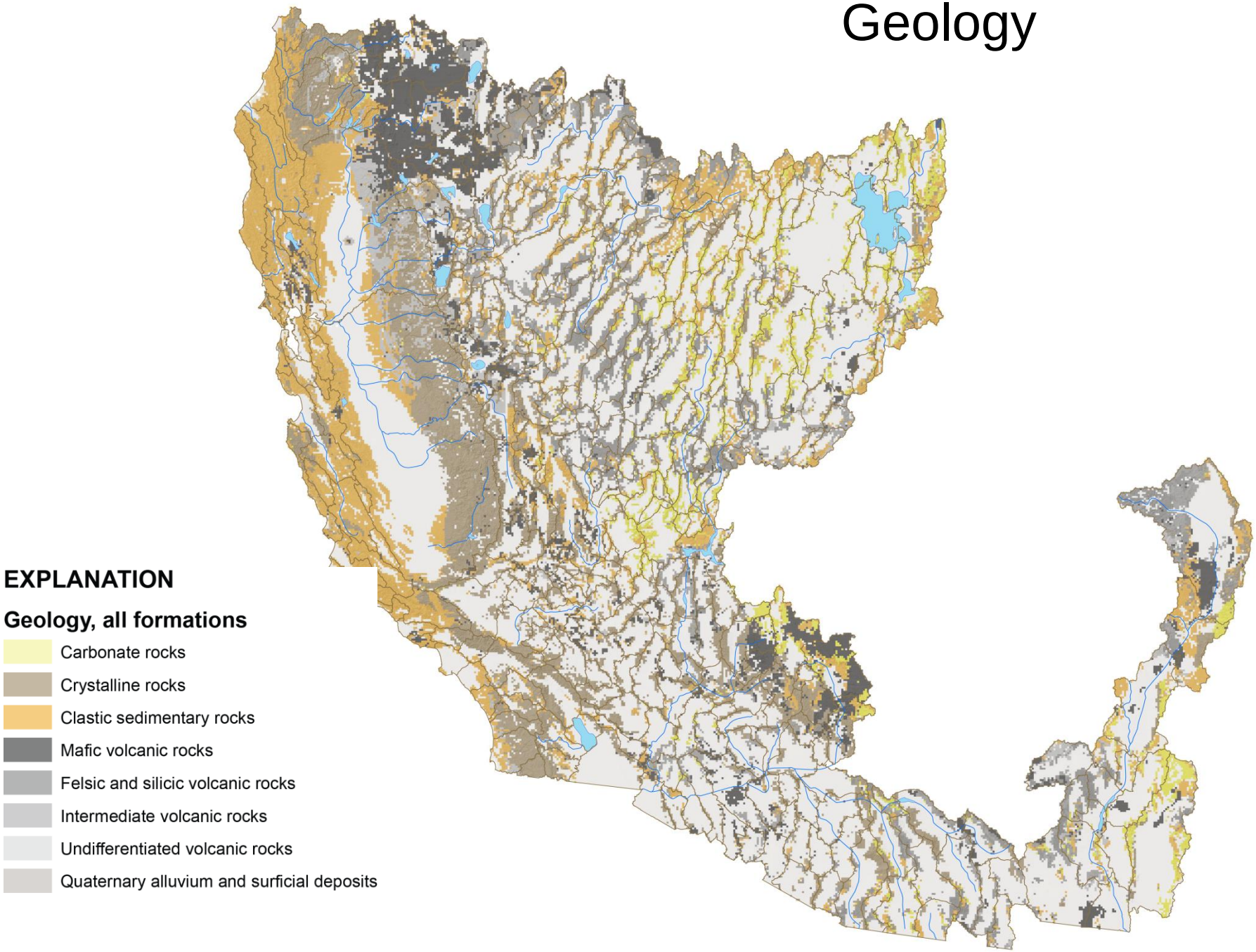
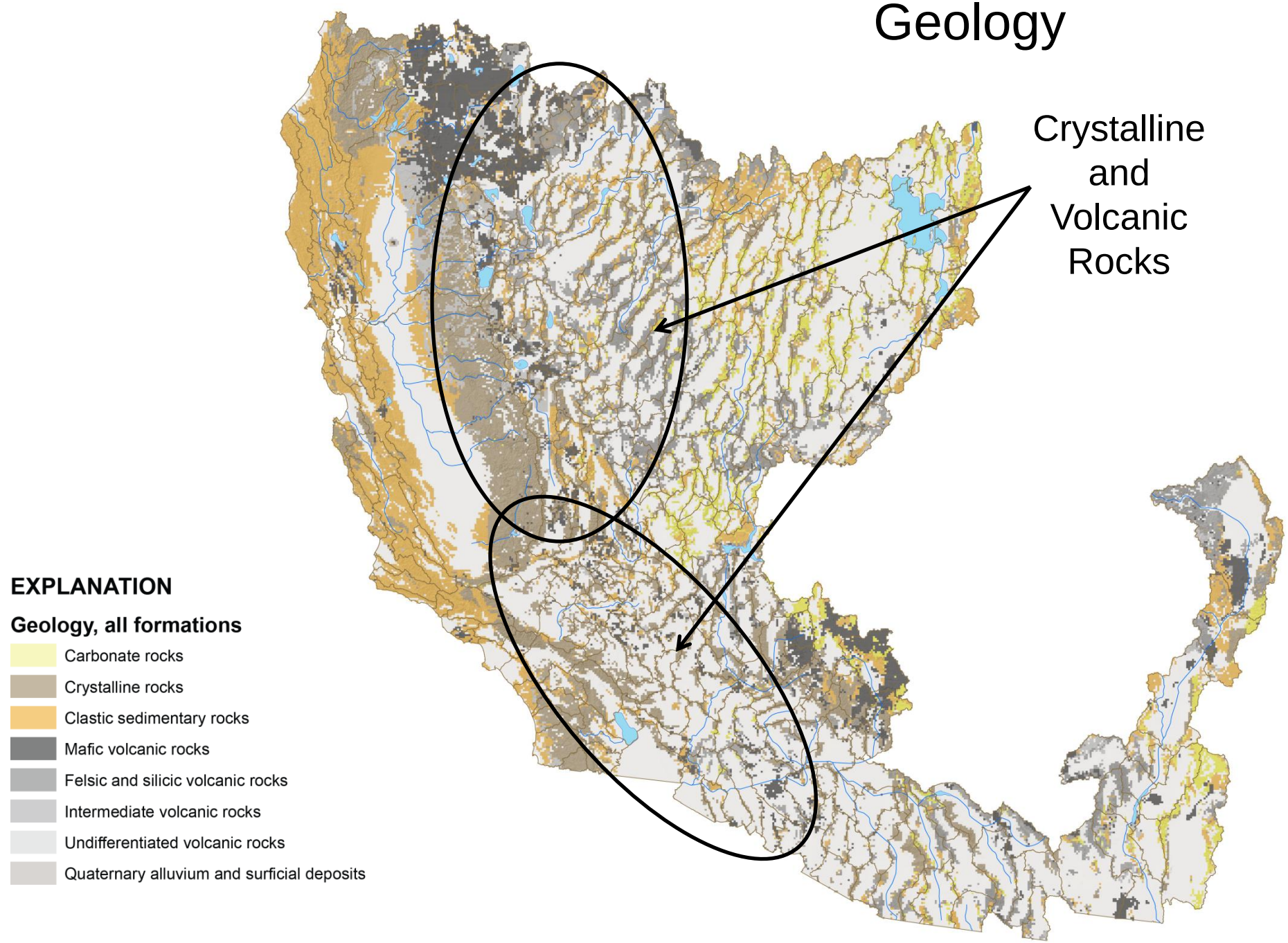
Geology


EXPLANATION
Geology, all formations
Carbonate rocks
Crystalline rocks
Clastic sedimentary rocks
Mafic volcanic rocks
Felsic and silicic volcanic rocks
Intermediate volcanic rocks
Undifferentiated volcanic rocks
Quaternary alluvium and surficial deposits

Geology


Crystalline and Volcanic Rocks
EXPLANATION
Geology, all formations
Carbonate rocks
Crystalline rocks
Clastic sedimentary rocks
Mafic volcanic rocks
Felsic and silicic volcanic rocks
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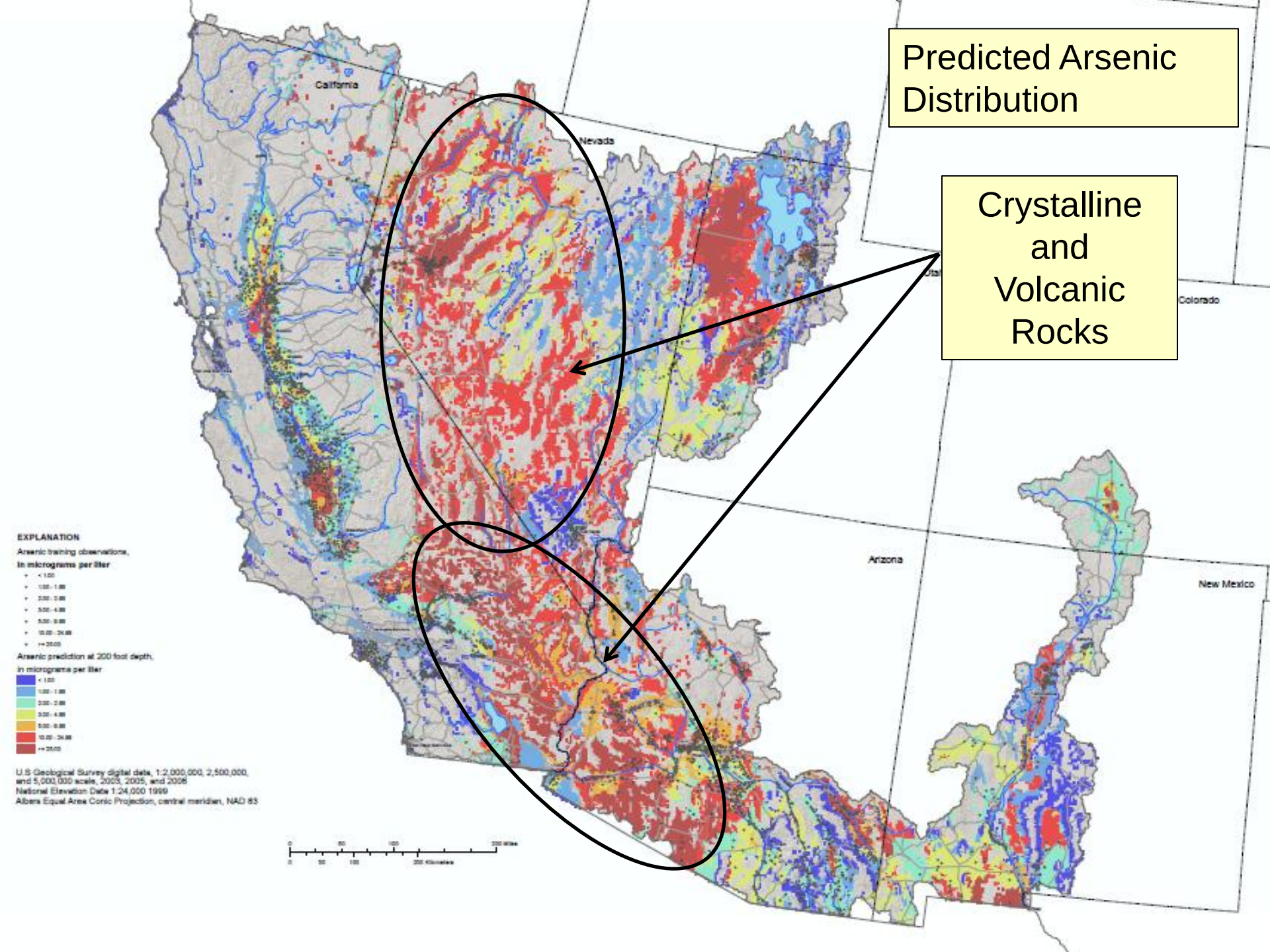
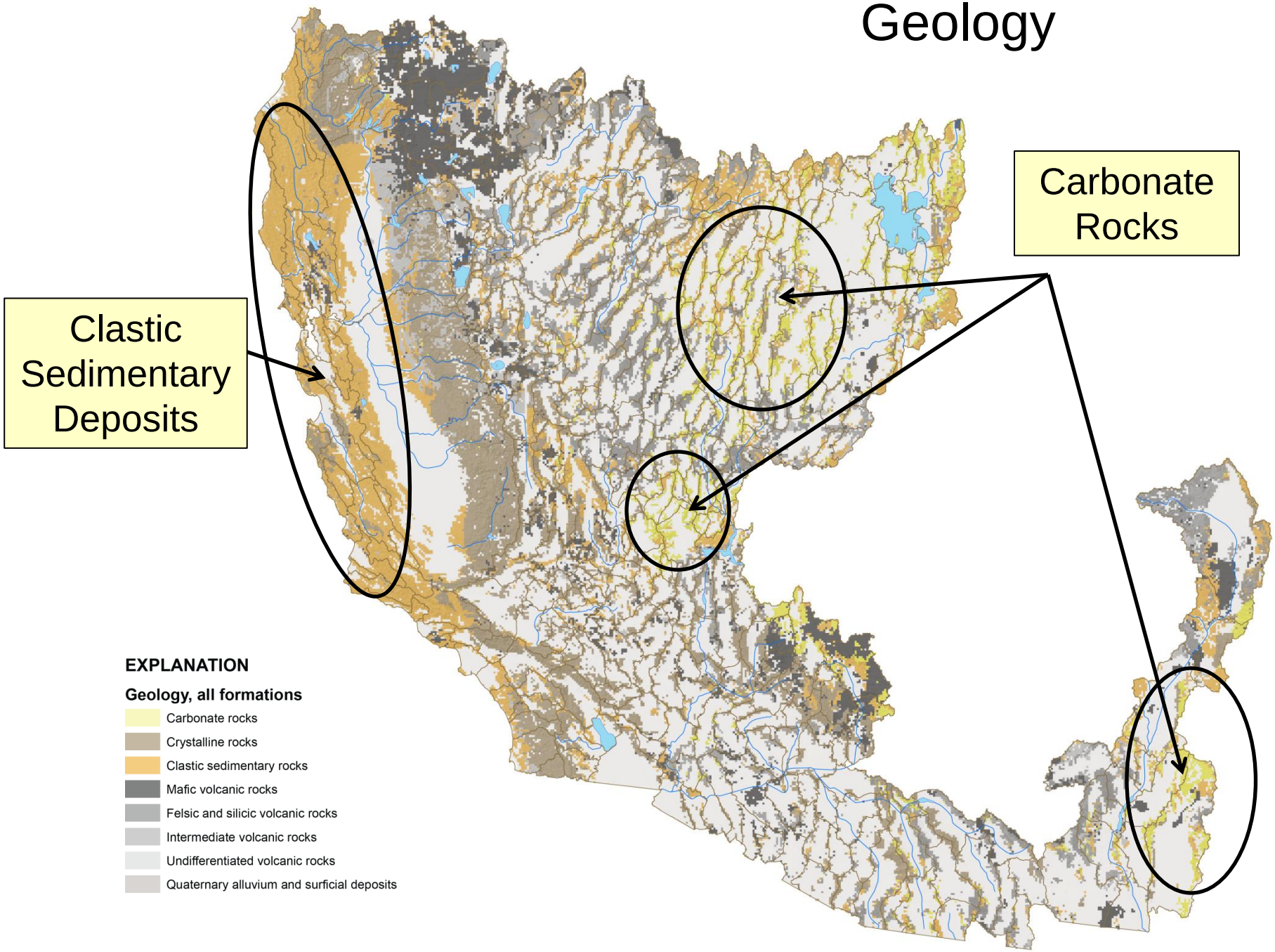

Predicted Arsenic Distribution
Crystalline and Volcanic Rocks
California
Nevada
Colorado
Arizona
New Mexico
EXPLANATION
Arsenic training observations,
in micrograms per liter
Arsenic prediction at 200 foot depth,
in micrograms per liter
U.S Geological Survey digital data, 1:2,000,000, 2,500,000, and 5,000,000 scale, 2003, 2005, and 2006
National Elevation Data 1:24,000 1999
Albers Equal Area Conic Projection, central meridian, NAD 83

Geology


Carbonate Rocks
Clastic Sedimentary Deposits
EXPLANATION
Geology, all formations
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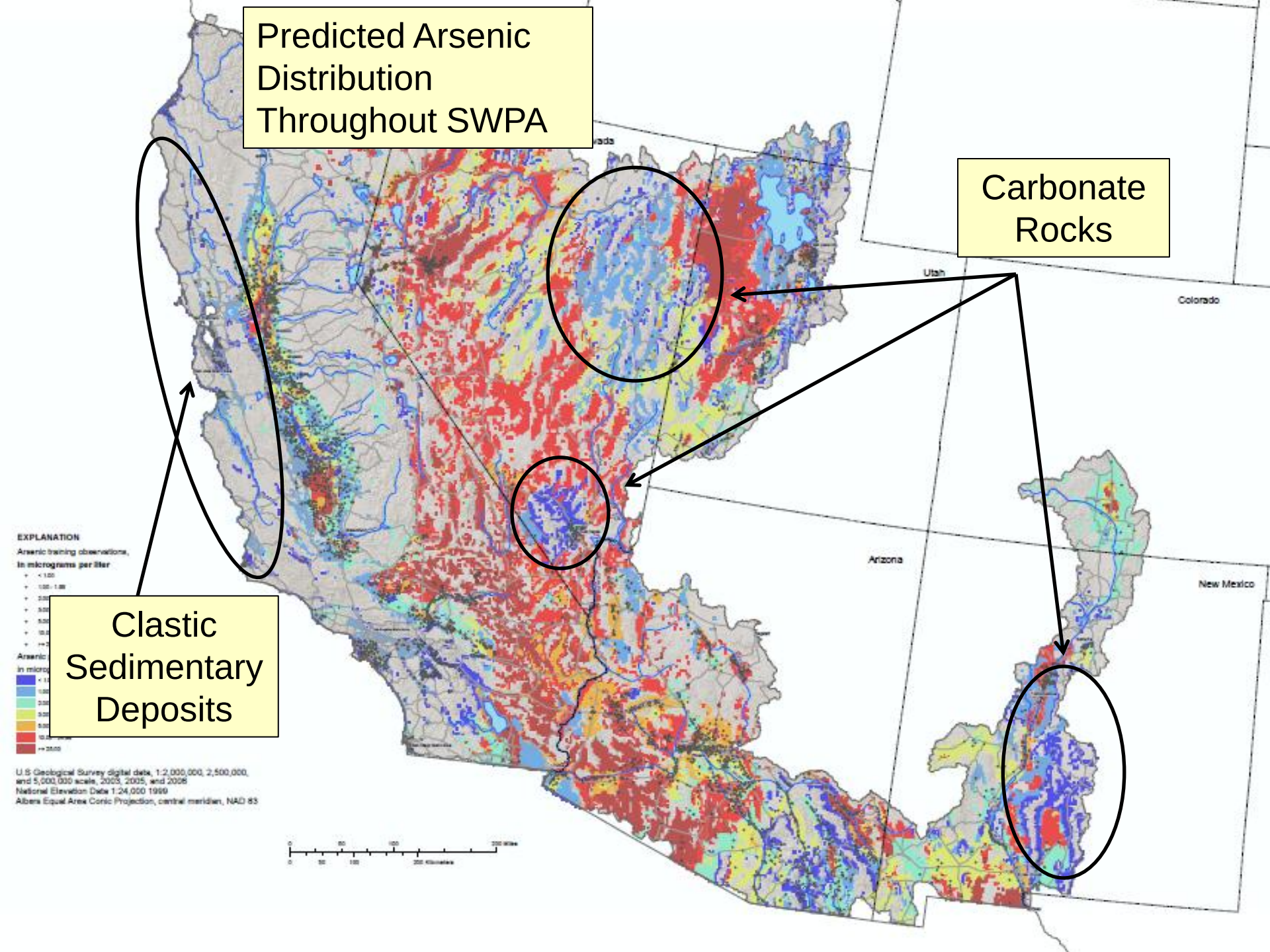
Predicted Arsenic Distribution Throughout SWPA
Carbonate Rocks
Clastic Sedimentary Deposits
Utah
Colorado
Arizona
New Mexico
EXPLANATION
Arsenic training observations,
in micrograms per liter
U.S Geological Survey digital data, 1:2,000,000, 2,500,000, and 5,000,000 scale, 2003, 2005, and 2006
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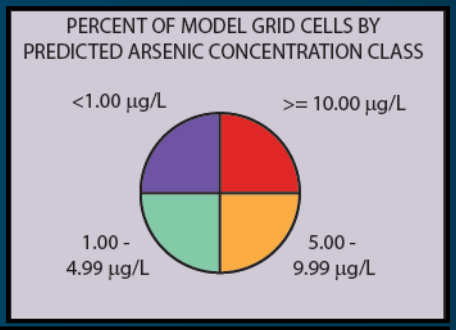
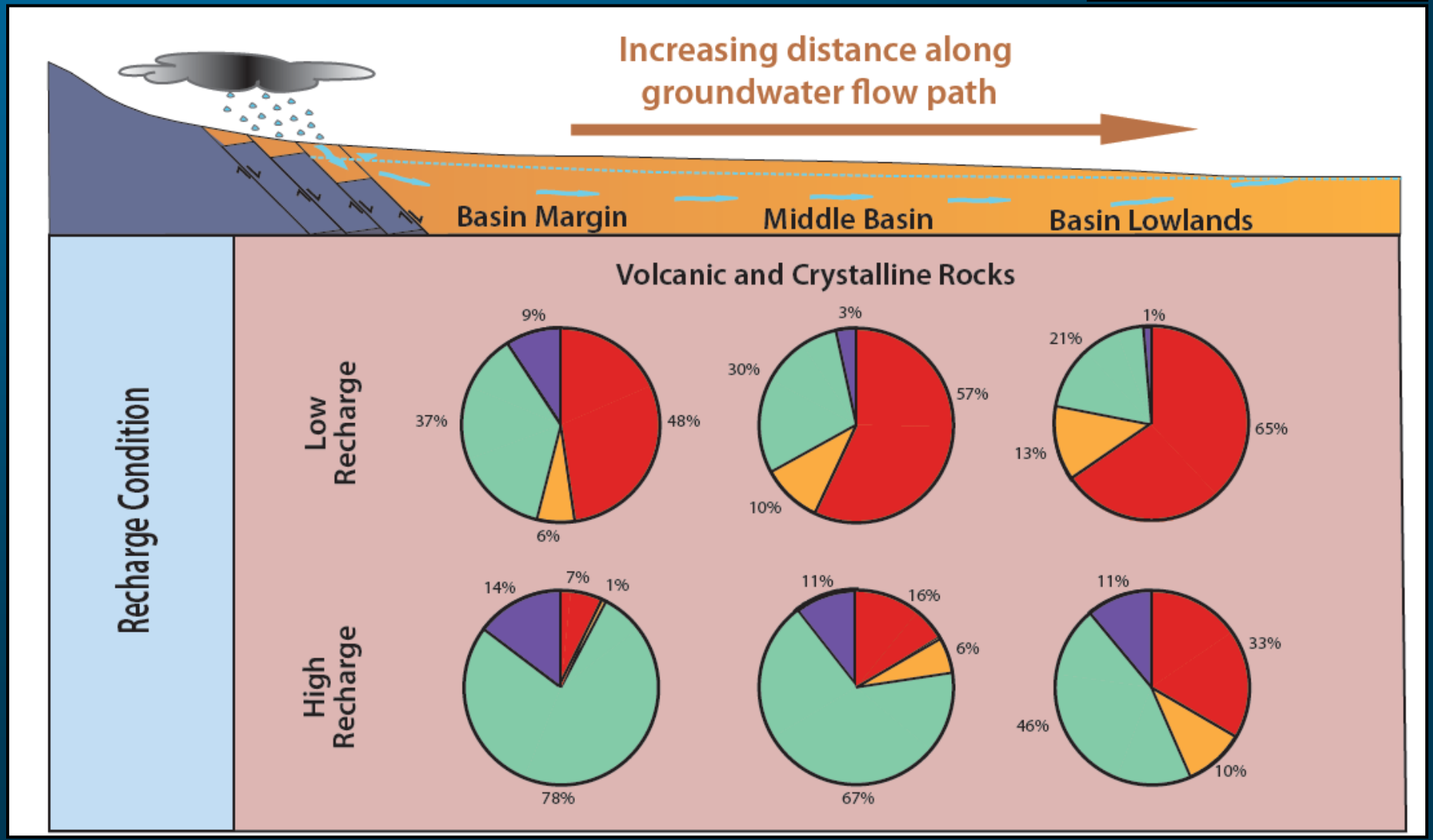
FACTORS IMPORTANT IN THE DISTRIBUTION OF ARSENIC THROUGHOUT SWPA

- Geology surrounding basin
- Position along flow path (residence time)
- Relative contributing recharge
- Basin characteristics (open, closed) – flushing effects

USGS

Arsenic, Flow Path, and Recharge





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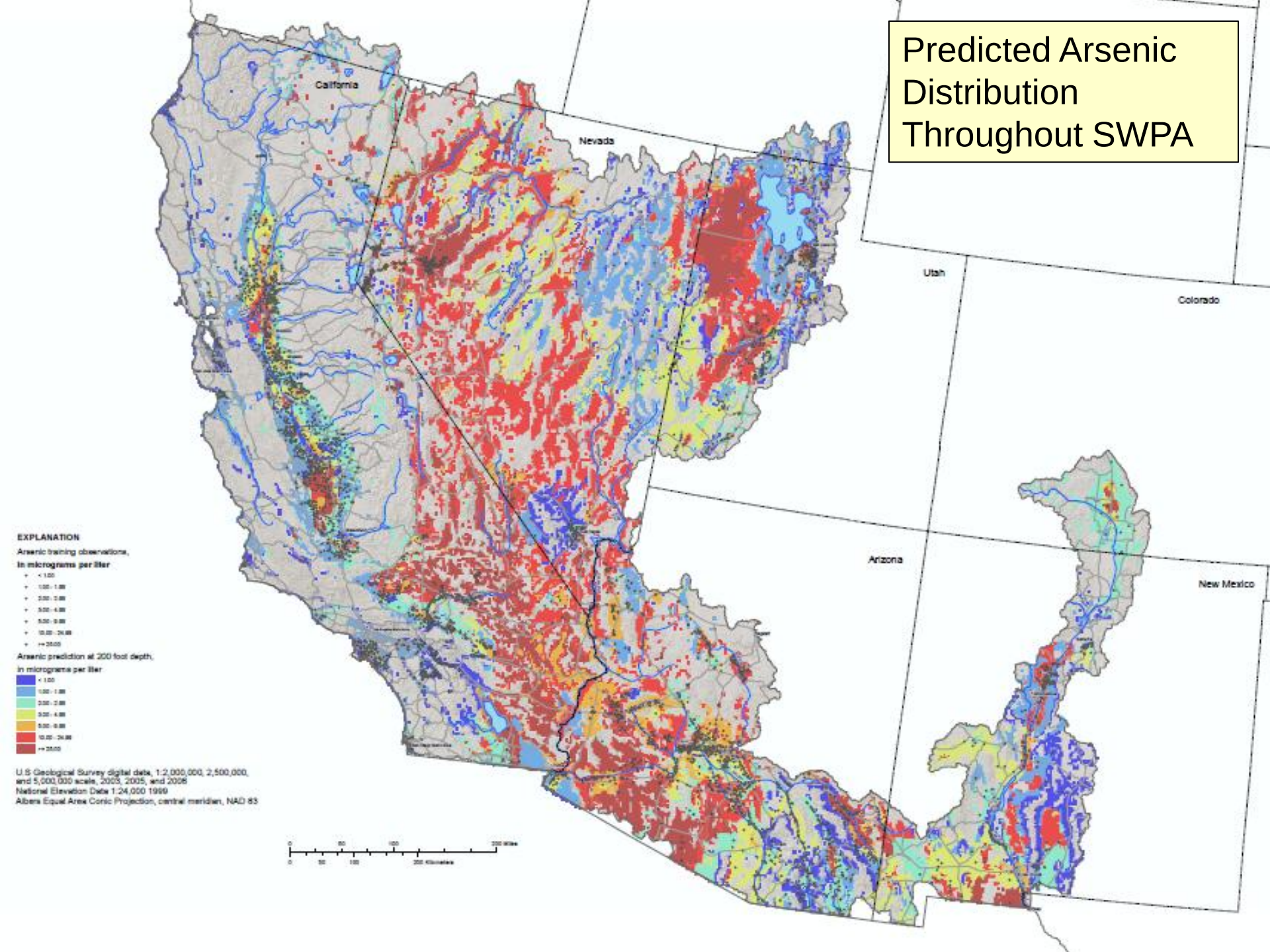
Predicted Arsenic Distribution Throughout SWPA
California
Nevada
Utah
Colorado
Arizona
New Mexico
EXPLANATION
Arsenic training observations,
in micrograms per liter
Arsenic prediction at 200 foot depth,
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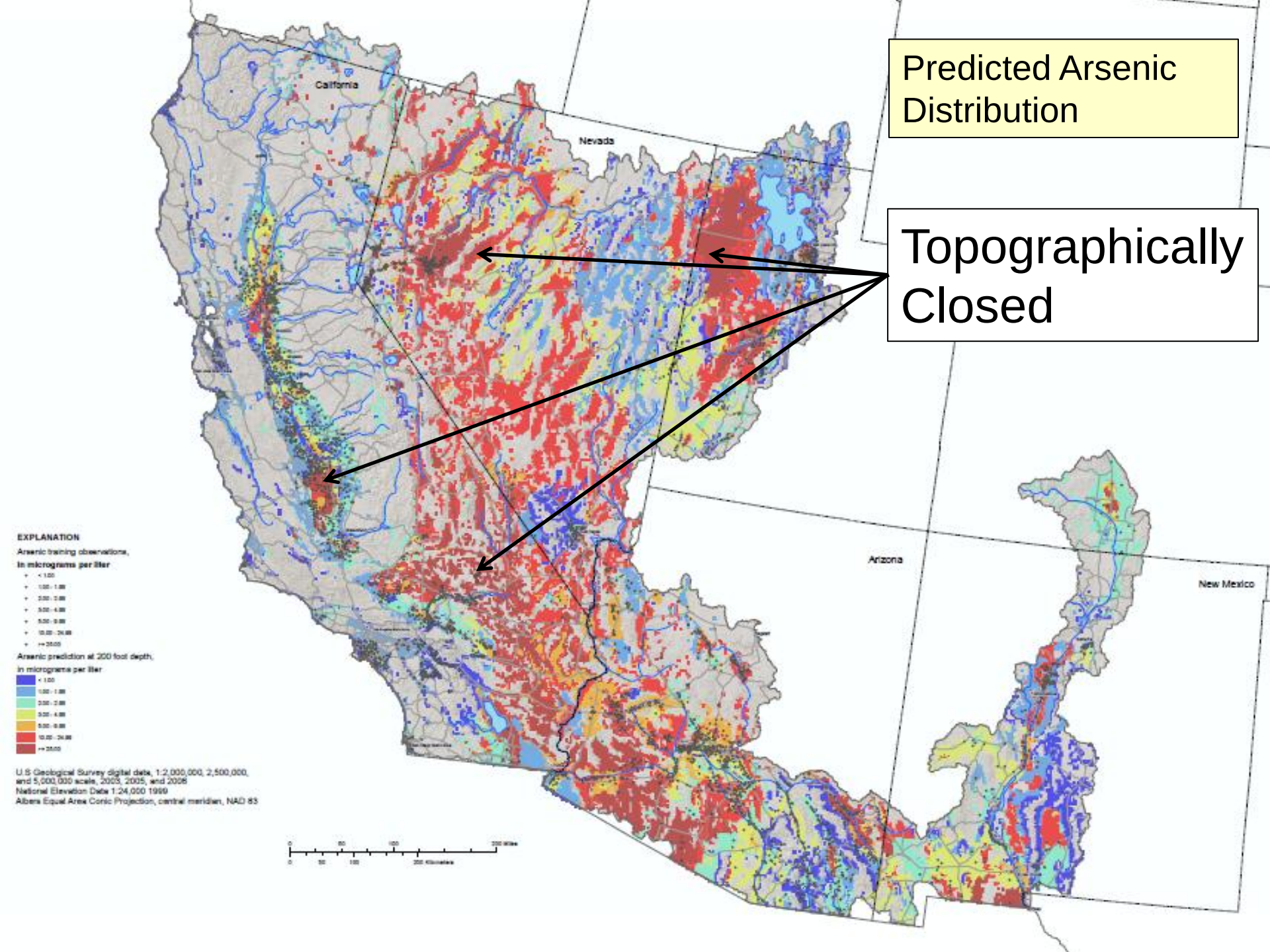
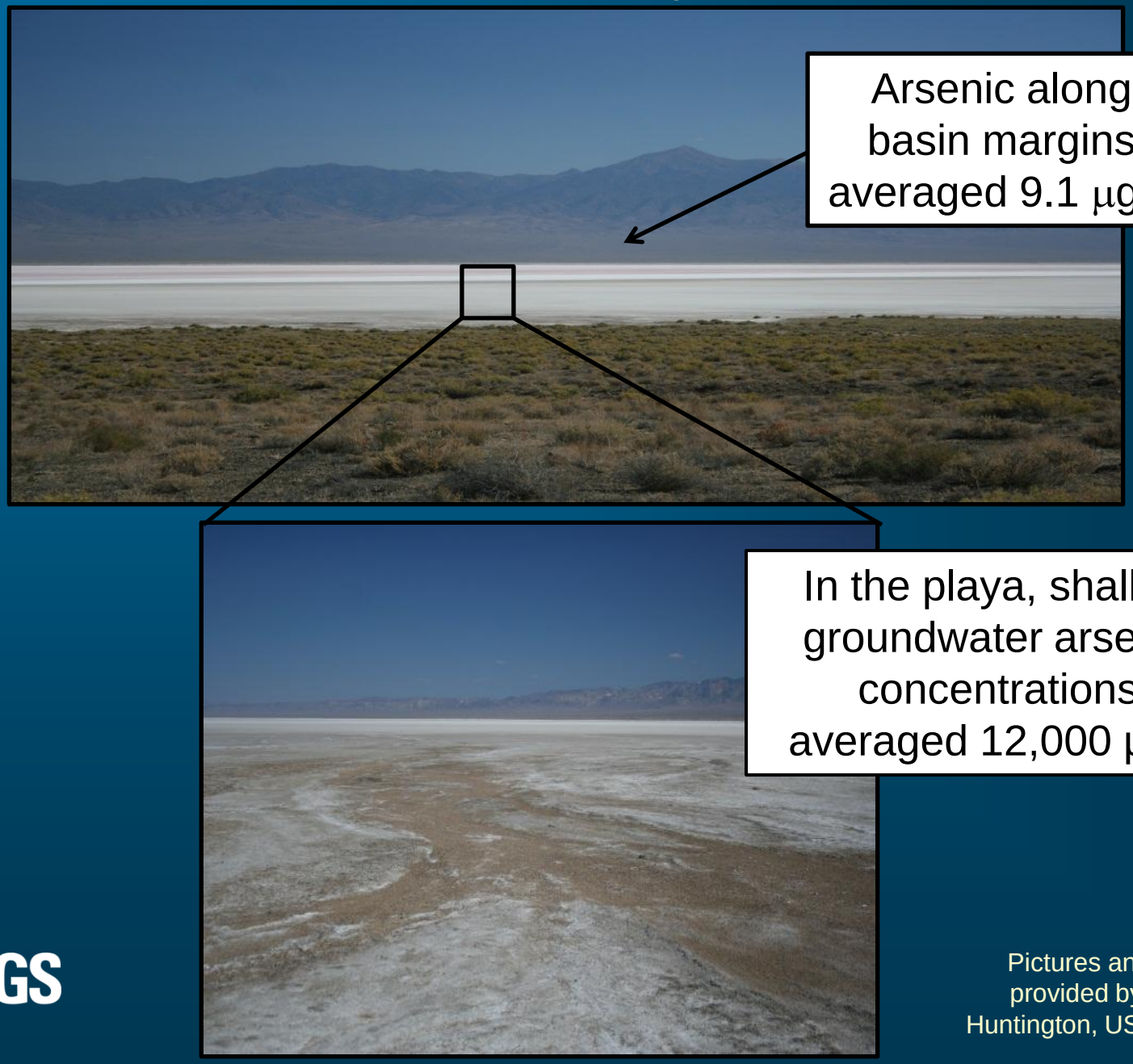
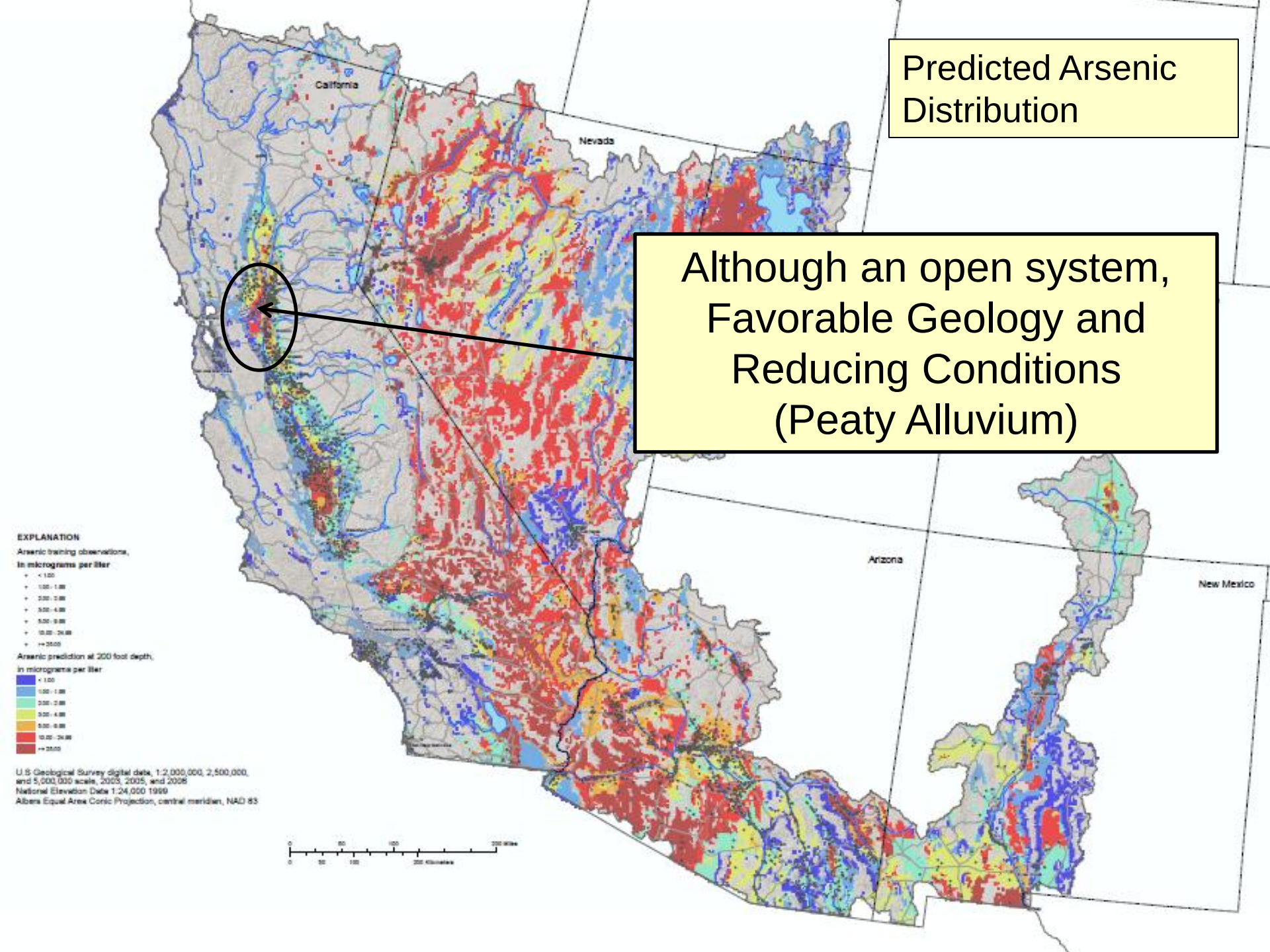

Predicted Arsenic Distribution
Topographically Closed
California
Nevada
Arizona
New Mexico
EXPLANATION
Arsenic training observations,
in micrograms per liter
Arsenic prediction at 200 foot depth,
in micrograms per liter
U.S Geological Survey digital data, 1:2,000,000, 2,500,000, and 5,000,000 scale, 2003, 2005, and 2006
National Elevation Data 1:24,000 1999
Albers Equal Area Conic Projection, central meridian, NAD 83

Arsenic in Dixie Valley, Nevada



USGS

Pictures and data provided by Jena Huntington, USGS, 2010


Predicted Arsenic Distribution
Although an open system, Favorable Geology and Reducing Conditions (Peaty Alluvium)
California
Nevada
Arizona
New Mexico
EXPLANATION
Arsenic training observations,
in micrograms per liter
Arsenic prediction at 200 foot depth,
in micrograms per liter
U.S Geological Survey digital data, 1:2,000,000, 2,500,000, and 5,000,000 scale, 2003, 2005, and 2006
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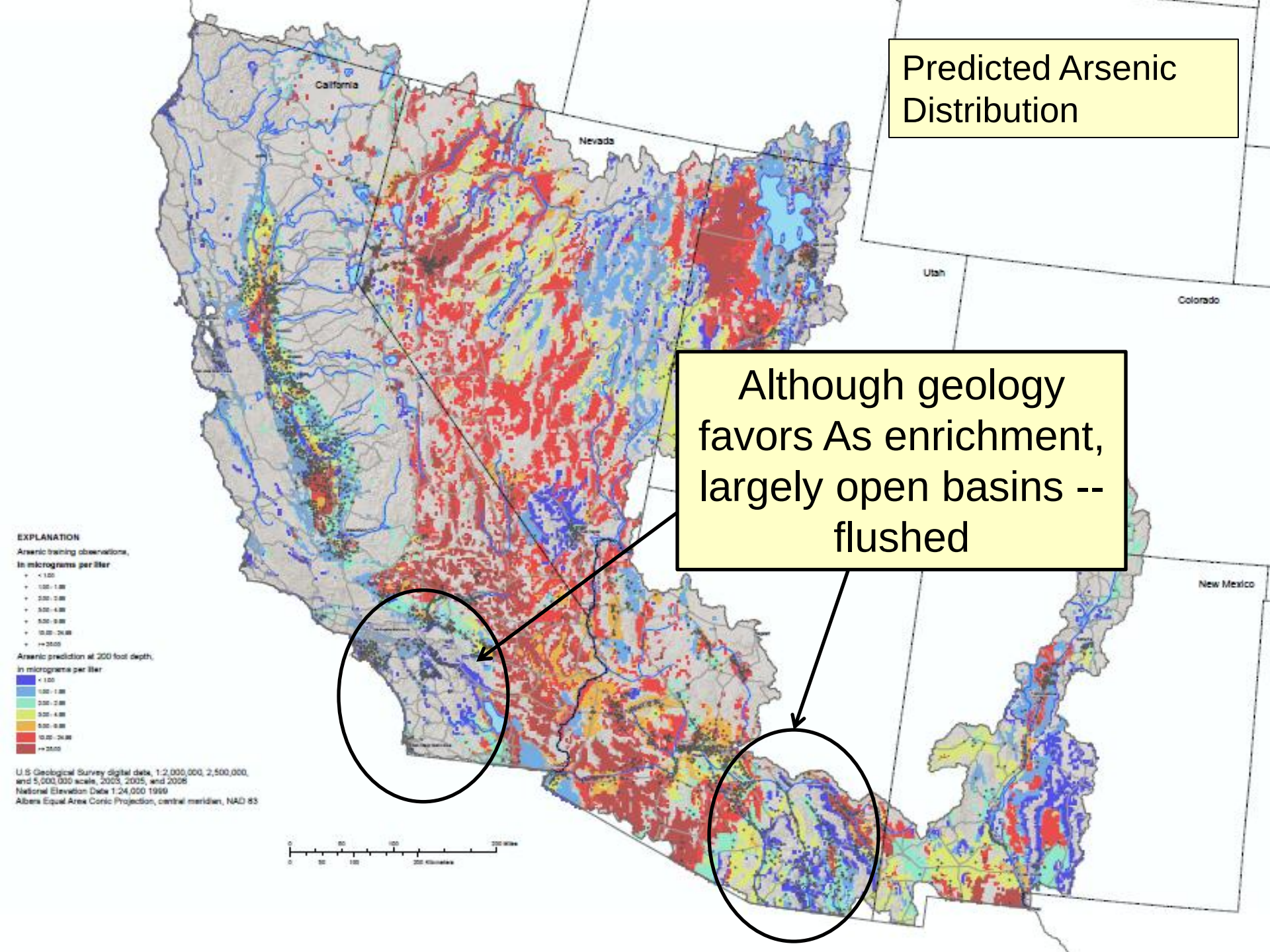
Predicted Arsenic Distribution
Although geology favors As enrichment, largely open basins -- flushed
California
Nevada
Utah
Colorado
New Mexico
EXPLANATION
Arsenic training observations,
in micrograms per liter
Arsenic prediction at 200 foot depth,
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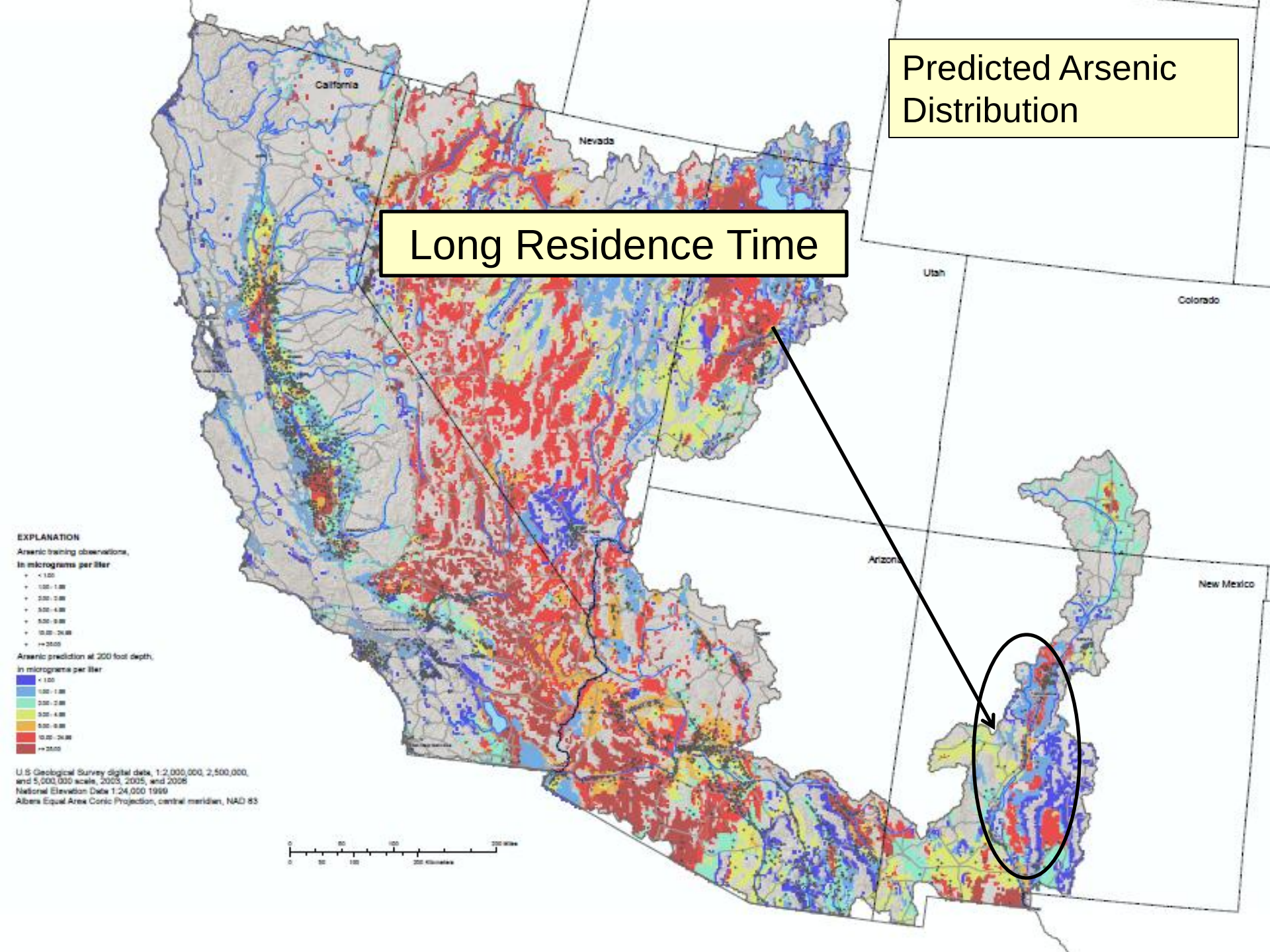
Predicted Arsenic Distribution
Long Residence Time
California
Nevada
Utah
Colorado
Arizona
New Mexico
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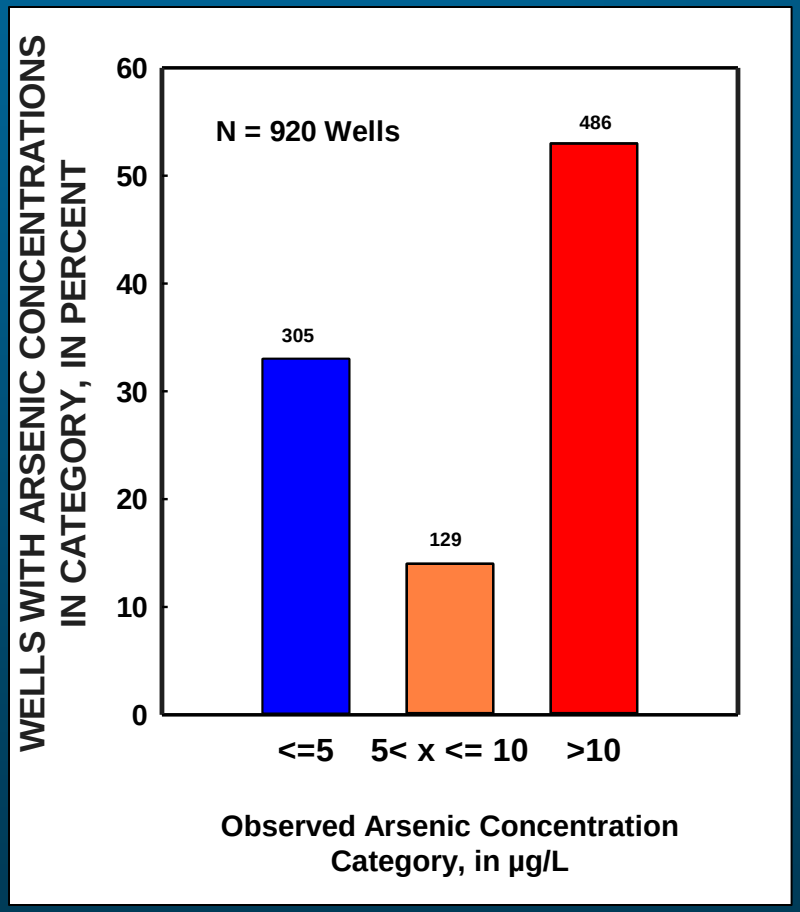
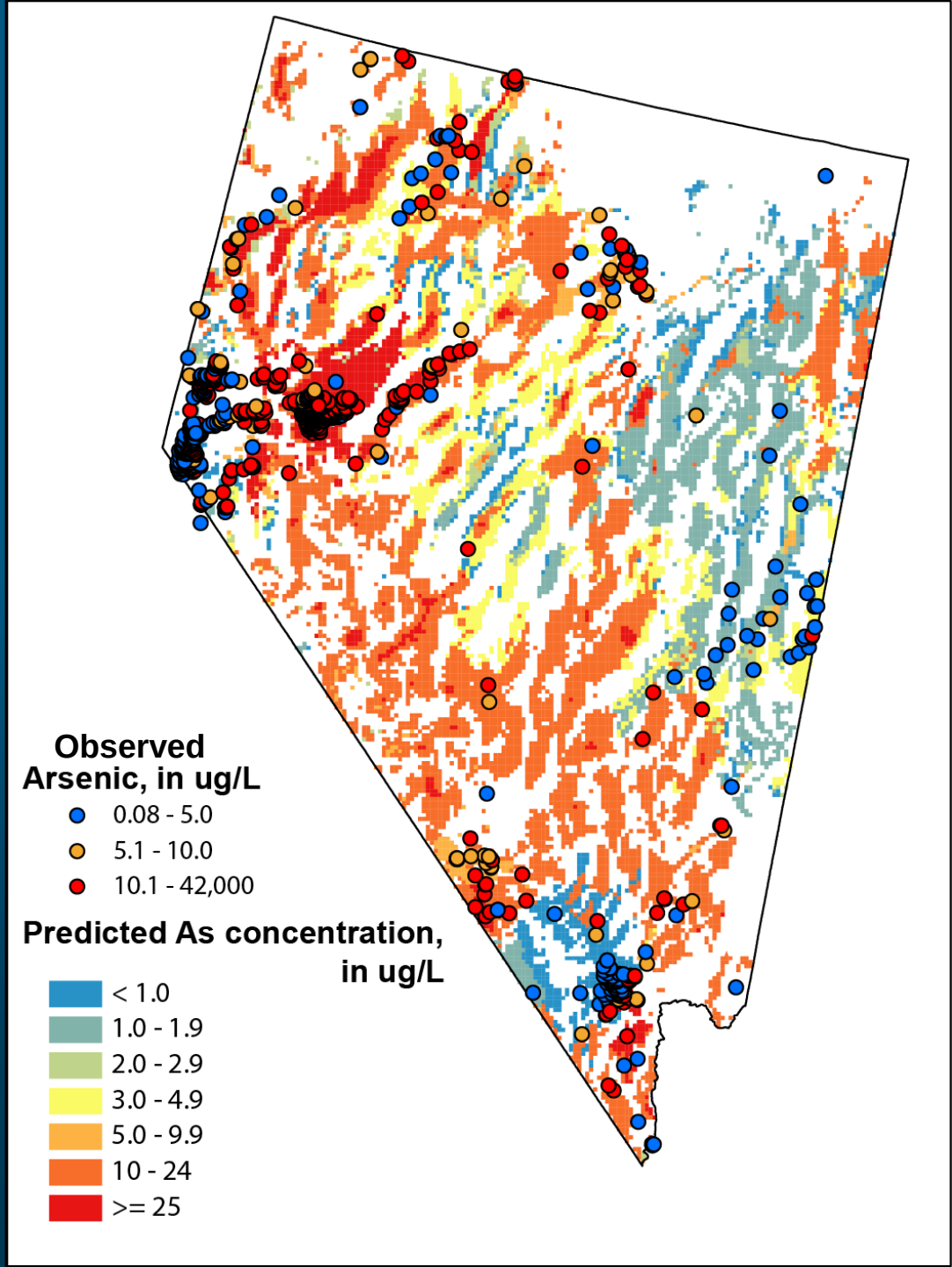
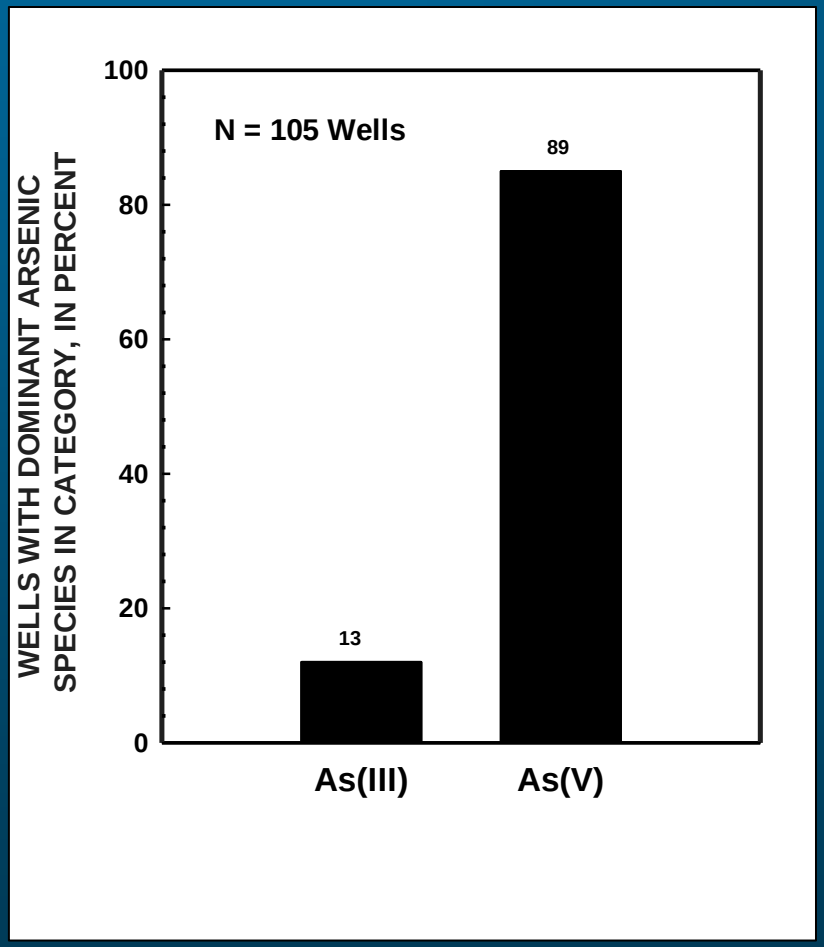
Observed and Predicted Arsenic Distribution Throughout the State of Nevada





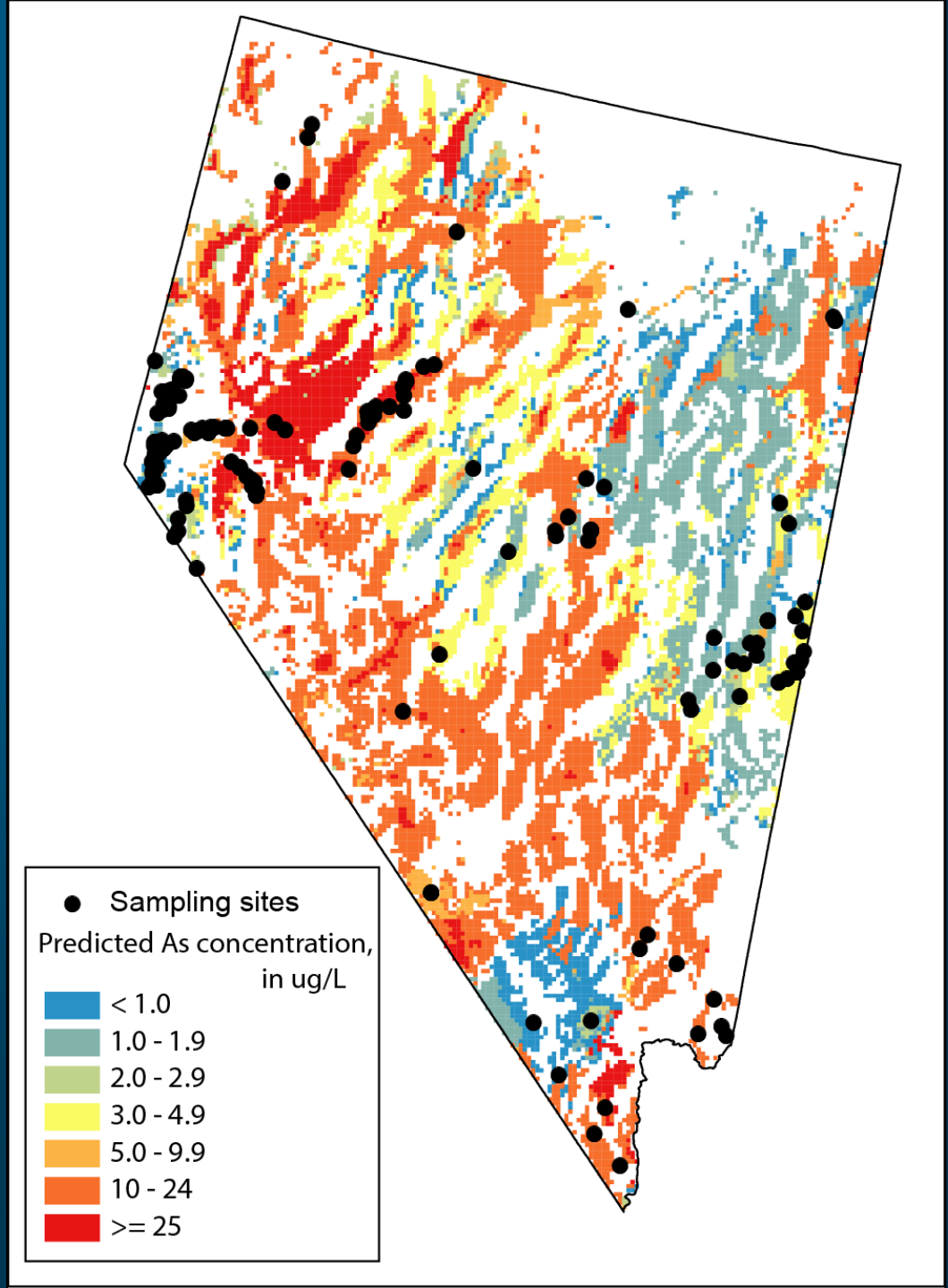
Sites where arsenic speciation has been characterized

(in collaboration with NBMG)



N=3 wells with <LRL for all species

USGS



Within the 191, 000 mi^2 area representing the Southwest basin-fill aquifers

Wells located in areas:

-- surrounded by volcanic rocks

-- with relatively low recharge conditions

-- down gradient areas along a flow path (long residence)

-- topographically low lying areas (particularly closed)

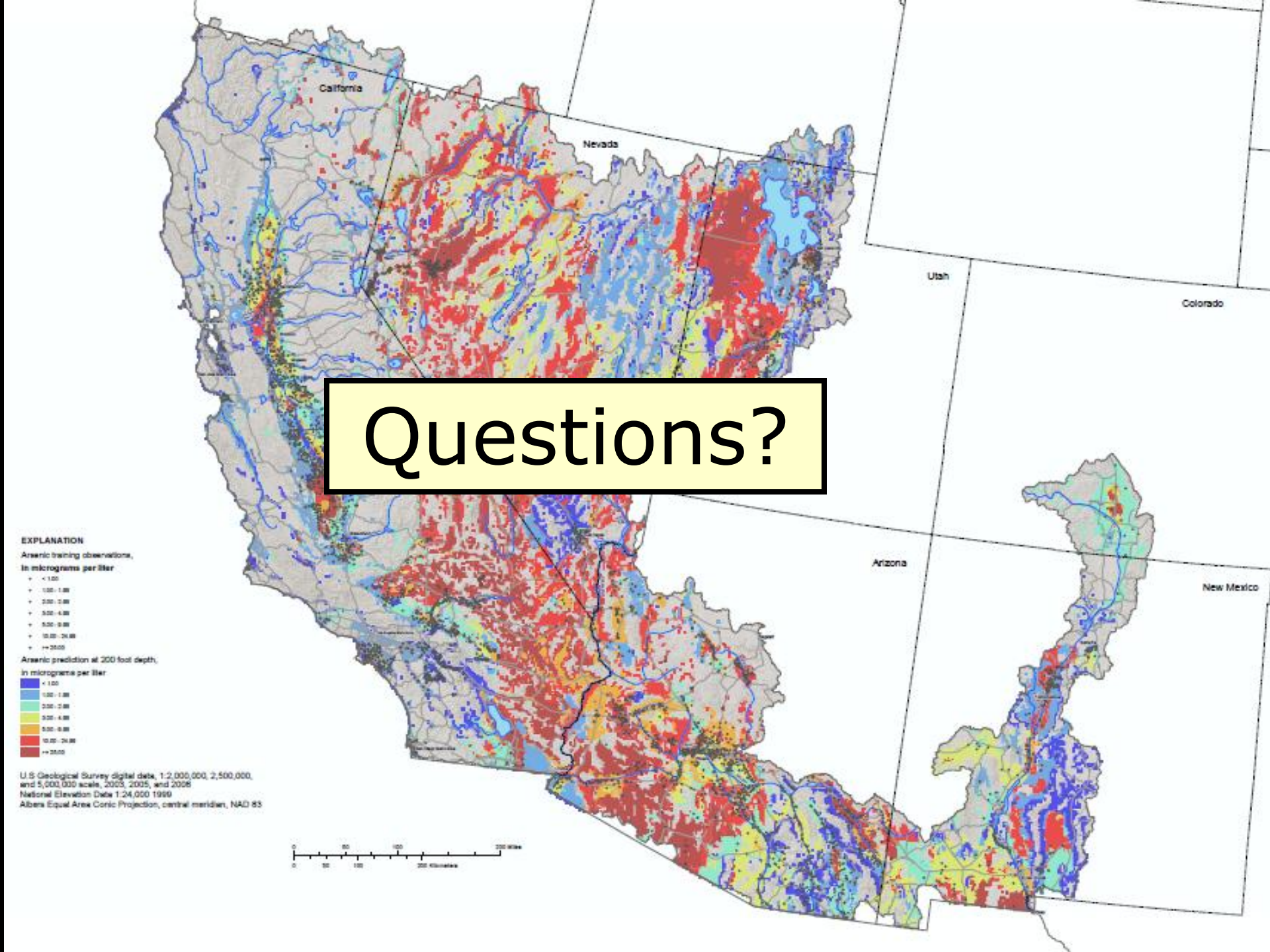
will likely have relatively high arsenic concentrations

USGS

Areas Where Arsenic is Predicted to Exceed Current Drinking-Water Standard

- About 43 percent (≈ 81,400 mi^2) of the regional study area
  - Primarily in the Basin and Range basin-fill aquifers
  - Within Nevada 53 percent of 920 wells have arsenic concentrations >10 µg/L
  - Most of the arsenic in Nevada wells for which speciation has been evaluated occurs as As(V)

USGS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Questions?
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