Geology of In Situ Leaching Uranium Mining

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New Mexico Bureau of Geology and Mineral Resources
Earth Science for the 21st Century

USGS

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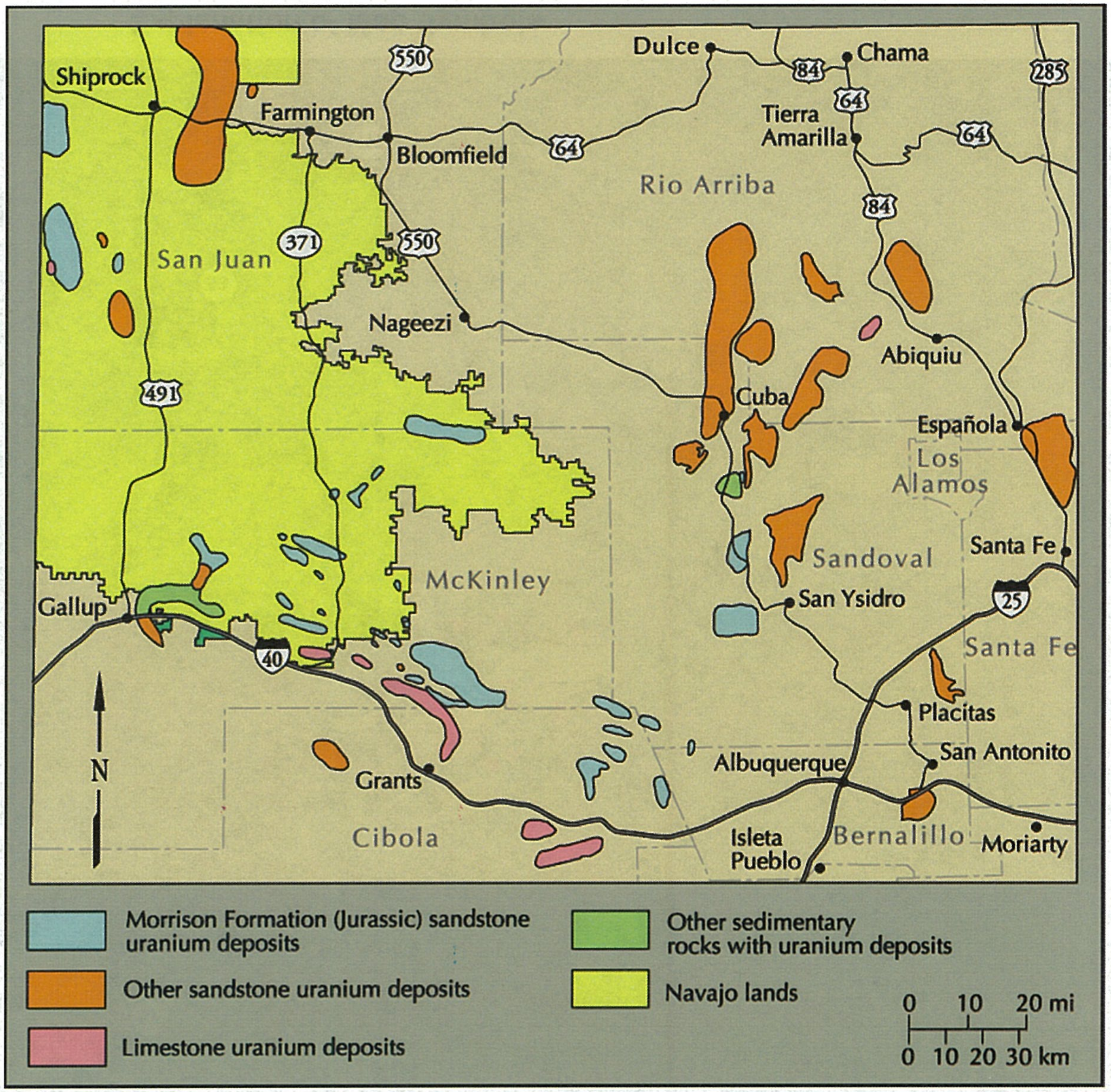
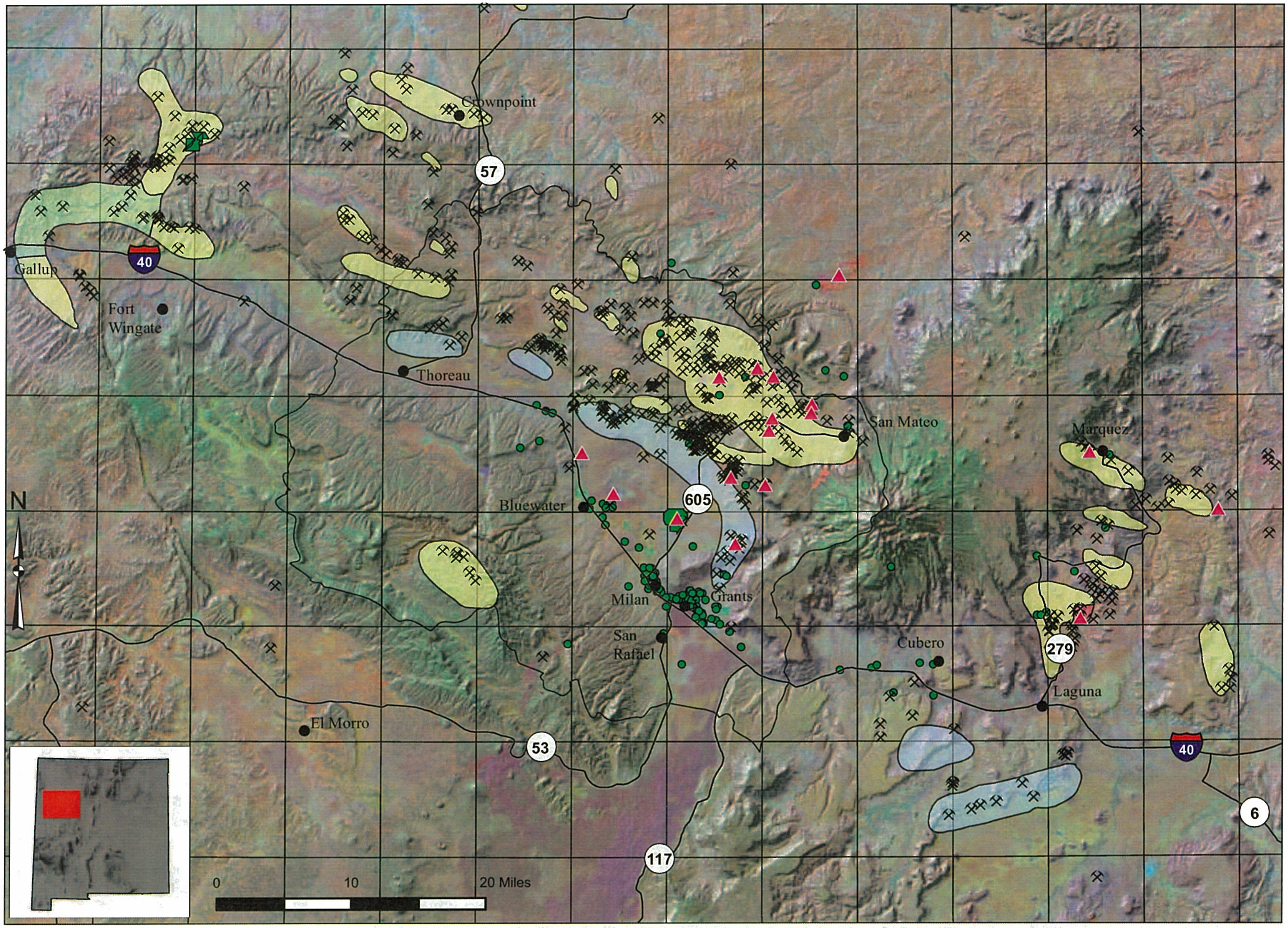
Origin of Uranium

- Uranium is a naturally occurring element.
- It is easily oxidized and therefore very mobile. Uranium occurs ***naturally*** in groundwaters and most economic uranium ores have been deposited from such waters.
- It would not be unusual for groundwaters to have *naturally* elevated dissolved uranium concentrations.
- Uranium naturally occurs in soils and water; therefore it has the potential to be taken up by plants, animals and humans.
- New Mexico has the second highest known uranium reserves of any state in the U.S.
- Northwest New Mexico is “Uranium Country.”
- Main deposits are in Jurassic Morrison Formation; other uranium deposits are found in Cretaceous Dakota Sandstone, Triassic Chinle Group, Jurassic Todilto Limestone, and other Cretaceous and Tertiary units.

Main NM Uranium Resources

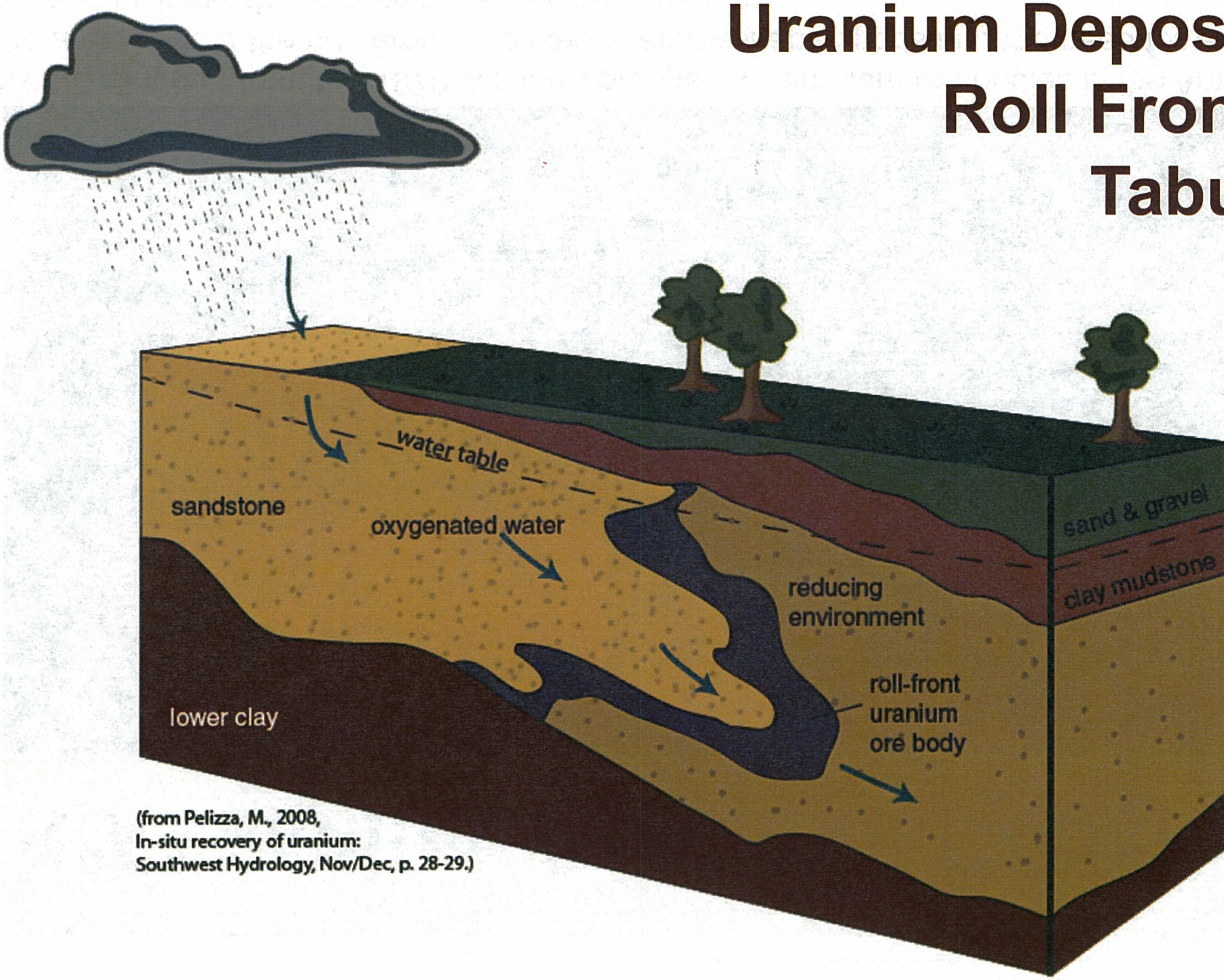




Explanation of Map Symbols

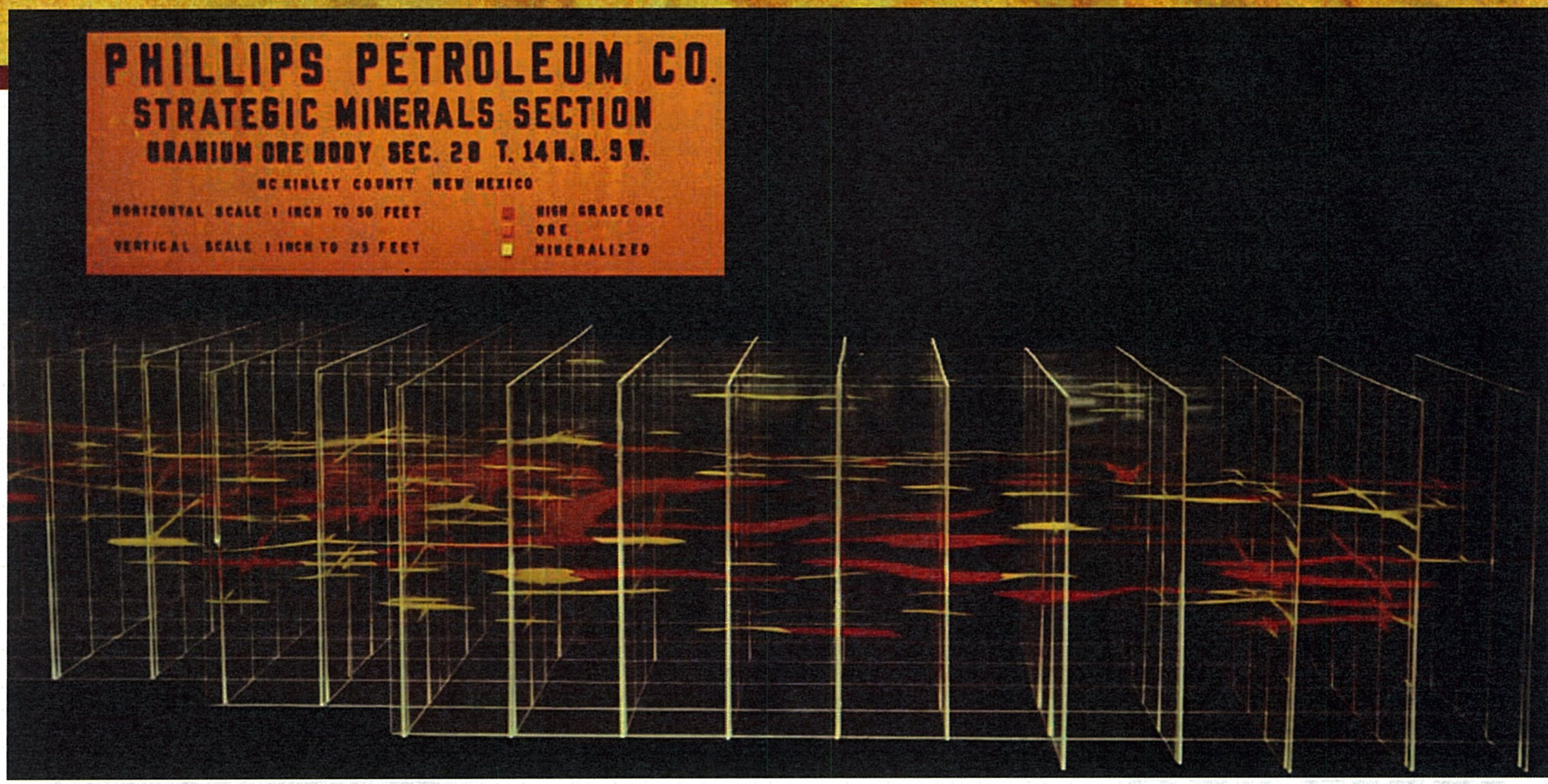
Symbol		**Uranium Deposits**
Active Mines & Mills		Sandstone
Active & Requested Mine Permits		Igneous
Other Superfund Sites Related to Mining/Industry		Limestone
National Priority List Superfund Site		Other Sedimentary

Uranium Deposits: Roll Front & Tabular



(from Pelizza, M., 2008,
In-situ recovery of uranium:
Southwest Hydrology, Nov/Dec, p. 28-29.)

NM Uranium Plays are Complex



This 3-D diagram from the 1970's shows prospective uranium ore bodies in the Ambrosia Lake area — note the numerous, isolated channel-shaped pods and the need for extensive drilling to distinguish ore from non-ore concentrations.

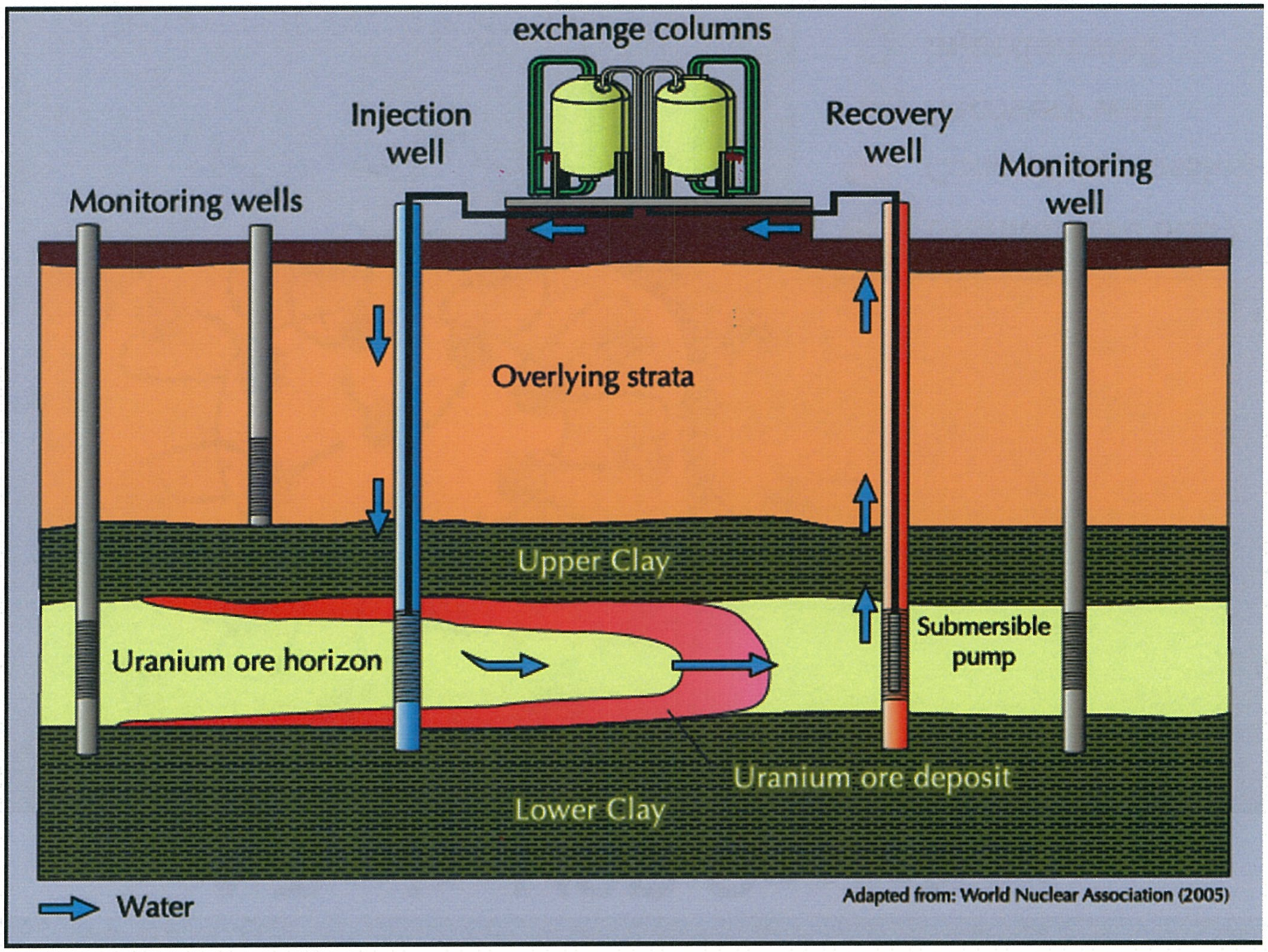
In-Situ Recovery (ISR)/ In-Situ Leach (ISL)

- How does ISR/ISL work?
  - Oxidizing fluids (lixivants) are pumped down injector wells
    - Hydrogen peroxide, carbon dioxide &/or oxygen
    - Weak acids or bases ("complexing agents") may be used to keep uranium in solution at low (pH 2-3) or high pH depending on the composition of the ore body. U.S. operations generally use alkaline solutions. These include sodium bicarbonate-carbonate & ammonium carbonate.
  - Injected fluids move through the ore body dissolving uranium
  - Recovery wells pump more water out of the ground than was pumped down
    - Creates a cone of depression that minimizes the chance of off-site escape of oxidizing fluids
  - Outside of this zone is a ring of monitoring wells to detect any fluids escaping the area
  - Injected fluids move through the ore body dissolving uranium
  - Recovery wells pump more water out of the ground than was pumped down
    - Creates a cone of depression that minimizes the chance of off-site escape of oxidizing fluids

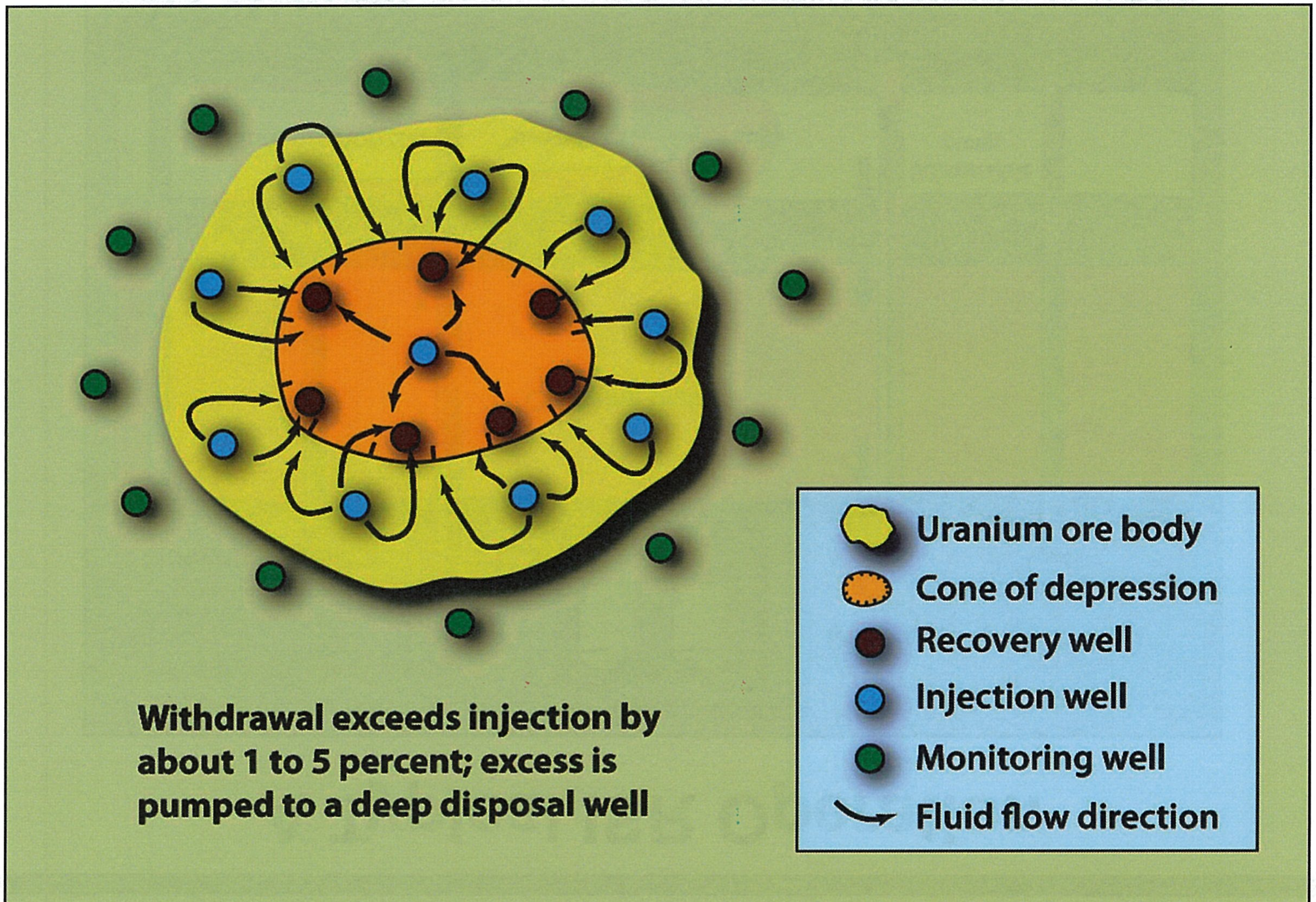
In-Situ Recovery (ISR)/ In-Situ Leach (ISL)

- How does ISR/ISL work (cont.)?
  - Outside of this zone is a ring of monitoring wells to detect any fluids escaping the area
  - Fluids are pumped out and passed through uranium-specific ion-exchange pellets to remove uranium from solution
    - Fluid chemistries are checked, refreshed and sent back down hole to start the process again.
  - Reducing agents or other methods are used to bring groundwater back to original conditions after mining. They include: hydrogen sulfide & sodium sulfide, bioremediation, groundwater sweep and pump & treat mechanisms.

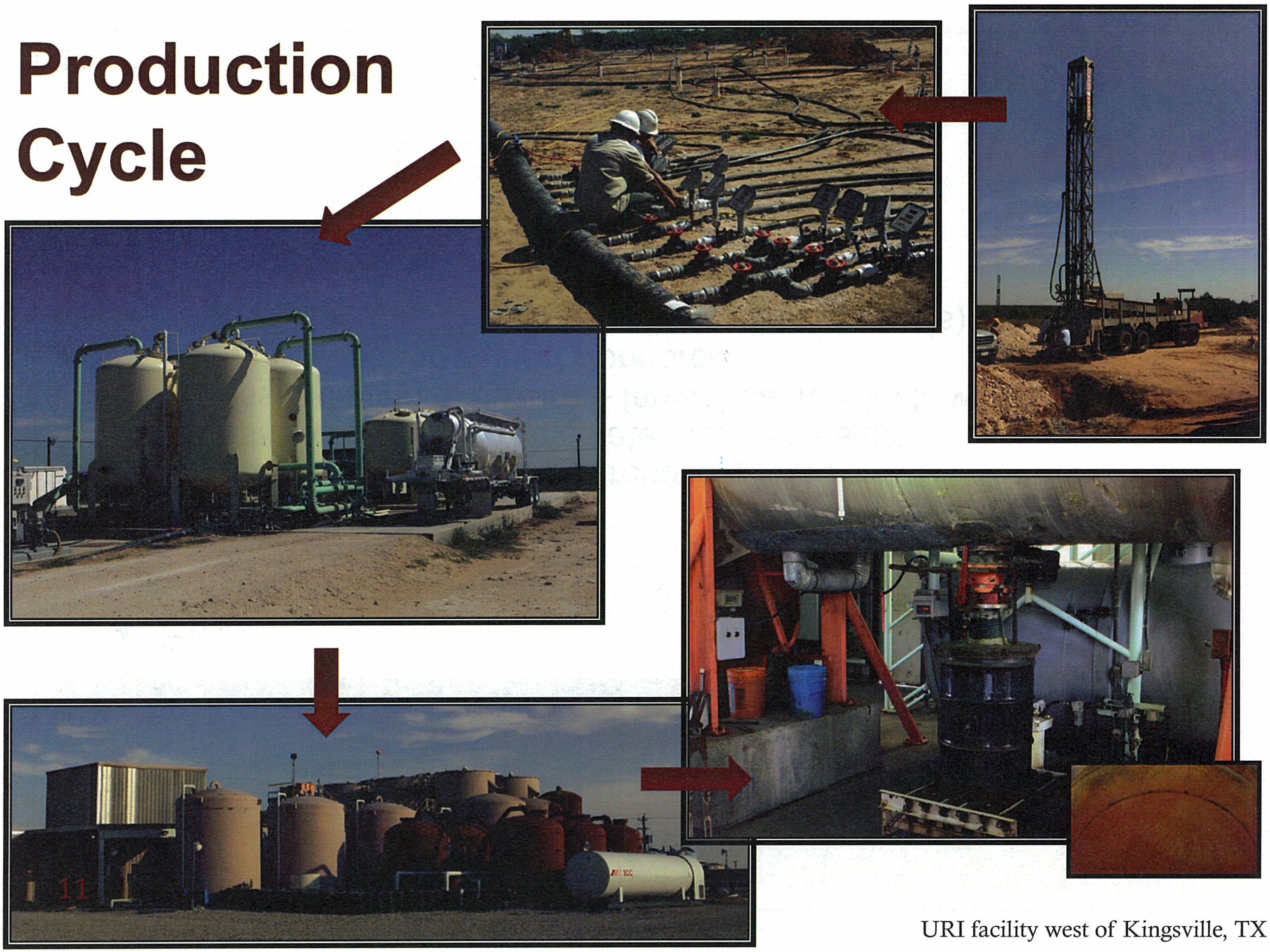
A Typical ISR Operation



A Typical ISR Operation



Production Cycle



URI facility west of Kingsville, TX

In-Situ Recovery (ISR)

- Pros:
  - Minimal surface impact
  - Minor waste rock
  - Short-term site usage
  - Inexpensive startup; high recovery rates
  - Less expensive to remediate than mine sites
  - Less radiation exposure – fewer health risks to workforce
  - Smaller, higher-trained workforce
  - No milling operations (no tailings piles or ponds)

In-Situ Recovery (ISR)

- Cons:
  - Possible local contamination of aquifers
  - Ground water quality may be diminished due to heavy metal contamination
  - Waters have to be pumped and monitored, even after active extraction has stopped
  - Returning the aquifer to original conditions is difficult
    - Inhomogeneities within the unit
    - Chemical reactions downhole changes the unit's porosity & permeability
  - Remediation is based on models; more full-scale tests are needed
  - Waste water disposal required (usually deep injection)
  - Possible radon and radium exposure issues and surface contamination around wells (these can be minimized with proper operation)

ISR in Other States:

- ISR is currently being done in:
  - Wyoming
  - Texas
  - Nebraska
- No ISR operation has been able to bring pore waters back to their original (baseline) composition for **all** analytes
  - Uranium & selenium most common, but calcium, carbonate and other analytes are also found to be elevated in operations in WY, TX, NE and NM.
- The State of Wyoming (through the University of Wyoming) issued an RFP in 2011 for $1.6 million to study ISR technologies and remediation.

What's next?

USGS
science for a changing world

Annotated Bibliography of Environmentally Relevant Investigations of Uranium Mining and Milling in the Grants Mineral Belt, Northwestern New Mexico

By James K. Otton

USGS Open-File Report 2011–1140

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

What's next?

- Very few studies that could provide baseline hydrologic and water-quality conditions prior to 1950' s when uranium mining and milling began
  - Waring, G.A., and Andrews, D.A., 1935, Ground-water resources of northwestern New Mexico
  - Morgan, A.M., 1938, Ground water conditions in a portion of the Rio San Jose–Bluewater Valley near Grants, New Mexico
  - Halpenny, L.C., and Whitcomb, H.A., 1949a, Water-supply investigation at Baca School, near Prewitt, McKinley County, New Mexico
  - Halpenny, L.C., and Whitcomb, H.A., 1949b, Water-supply investigation at Thoreau, McKinley County, New Mexico
  - Murray, C.R., 1945, Preliminary conclusions on ground-water conditions in the Bluewater area, Valencia County, New Mexico
- Studies since 1950 have mostly been done either at a broad regional or site specific scales

Way Forward....

- **If ISR is going to occur in New Mexico, then the state needs:**
  - A thorough understanding of the geology, hydrology and geochemistry. These units are **not** homogeneous, and we have to understand how channels, faults and fractures affect regional fluid flow.
    - Delineate and map major aquifer units requiring protection as well as potential deep-waste injection zones.
    - Model directions and rates of fluid movement in all units in the vicinity of potential uranium production.
    - Determine aquifer compartmentalization through field and aeromagnetic studies.
  - More studies concentrating on the remediation of well fields to bring the ore zones back to baseline chemistries.
  - Long-term monitoring of well fields to assess pore waters.
  - Design regulations prior to mining to protect aquifers and to make certain that the chance of accidents/mistakes are minimalized.
  - Conduct small-scale ISL tests
  - Develop new and cost-effective methodologies to enhance removal of uranium and associated materials from water (both to improve ISL recovery and **to enhance environmental remediation**)
  - Apply results to rural water supply issues in New Mexico and other areas

Potential Agency/University* Partnerships

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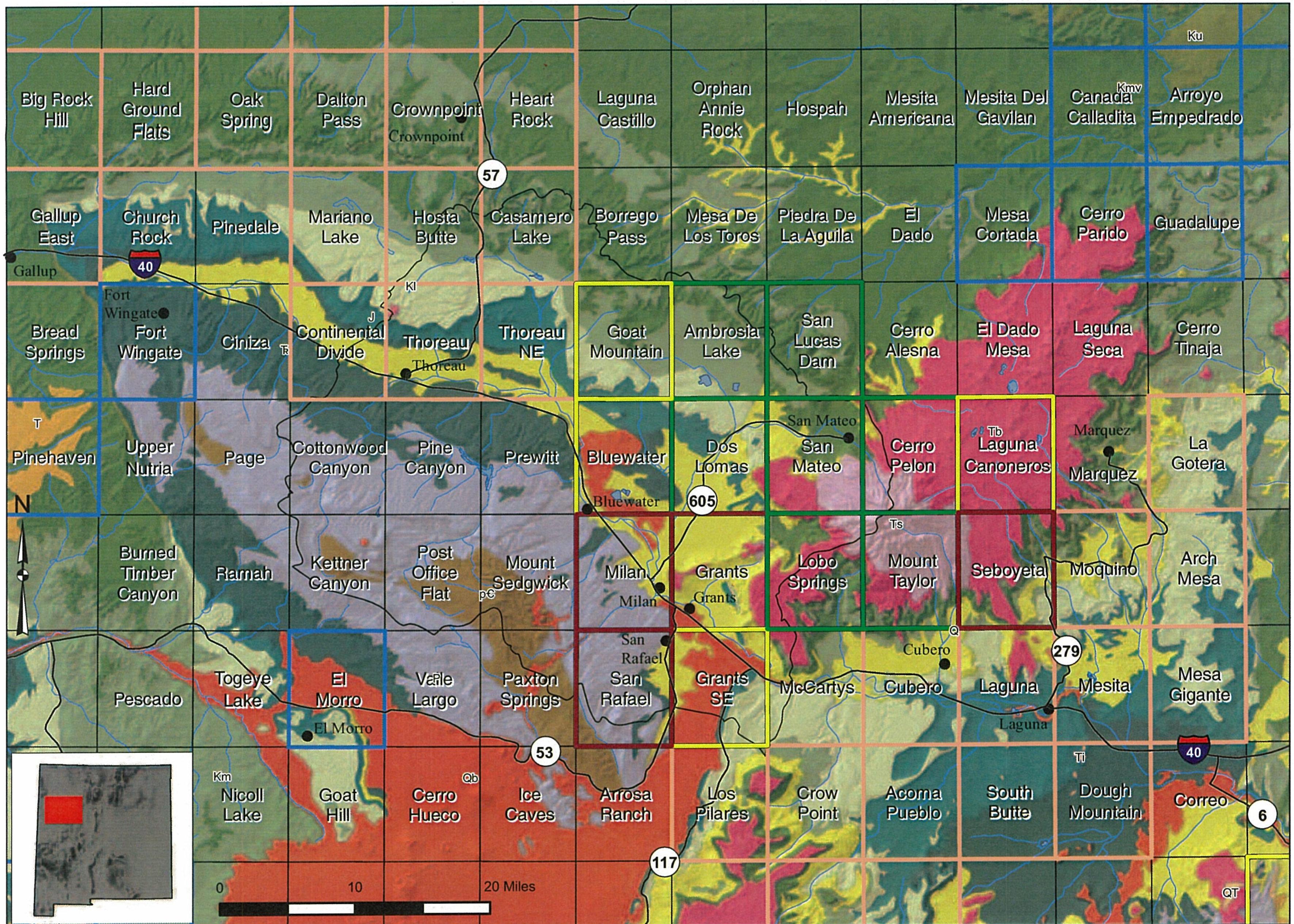
- Geologic mapping
- Geophysics
- Groundwater and surface water networks and monitoring
- Water-quality modeling
- Groundwater flow modeling
- Legacy groundwater, surface water, water quality, and mine databases
- GIS

*And other research universities and national labs



Explanation of Map Symbols

General NM Geology

- Q - Quaternary sediments
- Qb - Quaternary basaltic volcanic rocks
- QT - Quaternary-Tertiary sediments
- T - Tertiary sedimentary rocks
- Tb - Tertiary basaltic volcanic rocks
- Ts - Tertiary silicic volcanic rocks
- Ti - Tertiary intrusive rocks
- Ku - Cretaceous sedimentary rocks above Kmv
- Kmv - Cretaceous Mesaverde group (incl gallup ss and Crevasse can. fm.)
- Km - Cretaceous Mancos shale
- Kl - Cretaceous sedimentary rocks below Km
- J - Jurrassic sedimentary rocks
- Ŧ - Triassic sedimentary rocks
- P - Permian sedimentary rocks
- p€ - Precambrian rocks undifferentiated

Quadrangle Mapping Progress

- Statemap Proposed
- Statemap In Progress
- Statemap Complete
- NMBGMR
- USGS