



U.S. Department of Energy  
Office of Civilian Radioactive Waste Management



# Geochemical Mapping of the Groundwater System, Yucca Mountain Area

Presented to:

**U.S. Nuclear Waste Technical Review Board Panel  
on the Natural System**

Presented by:

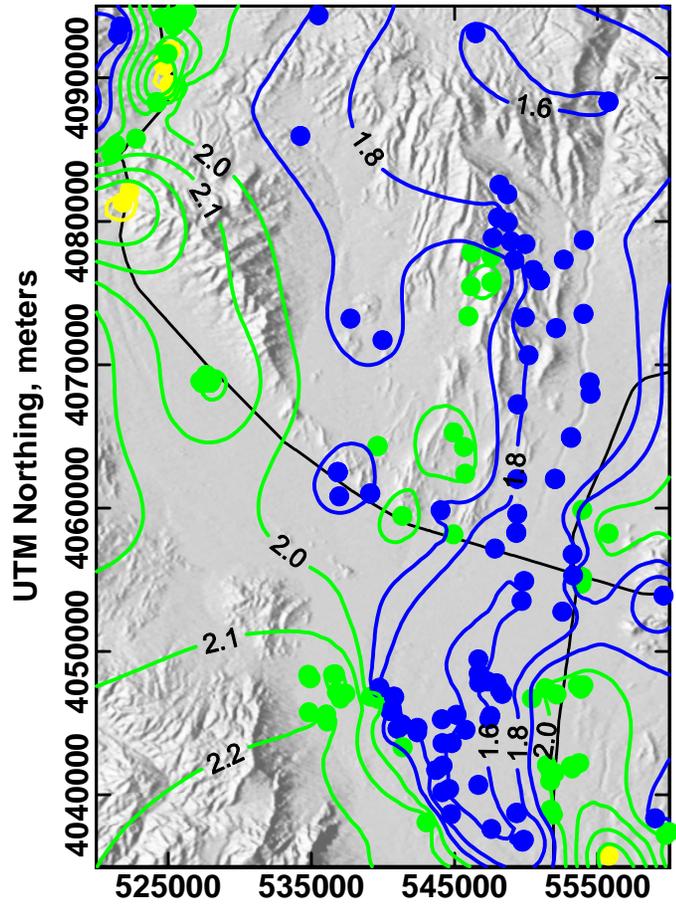
**Gary L. Patterson  
U.S. Geological Survey**

**March 9-10, 2004  
Las Vegas, Nevada**

# Objectives

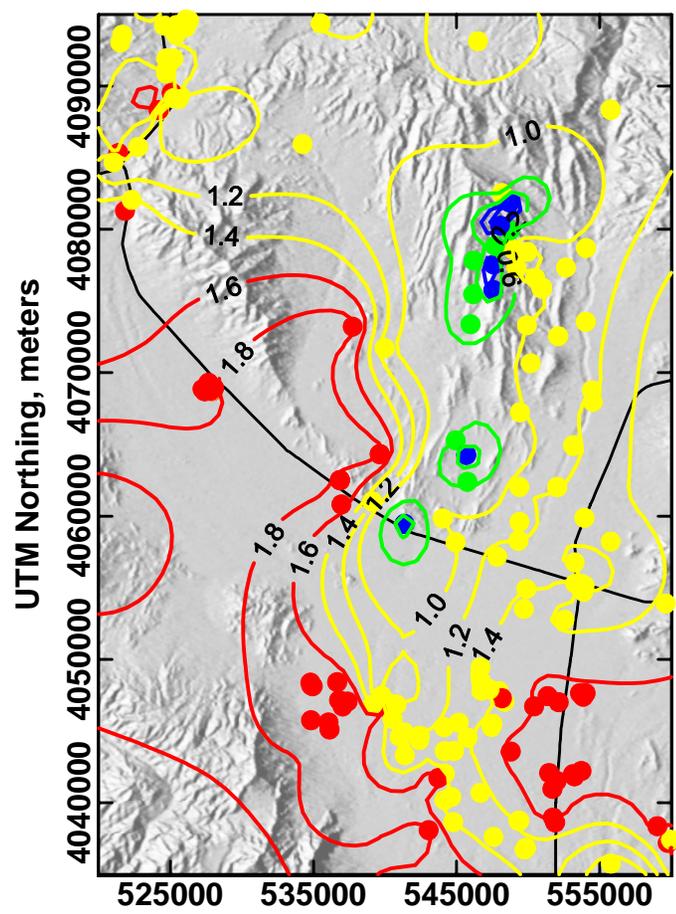
- **Use major and minor dissolved ions, stable isotopes, radiogenic isotopes, and both inorganic and organic carbon-14 age estimates to determine flow domains, flow paths, identify discharge sites, and estimate flow rates**
- **Independently validate flow paths generated by saturated zone (SZ) flow and transport models**
- **Independently constrain flow rates generated by SZ flow and transport models**





UTM Easting, meters  
**Log Na, mg/L**

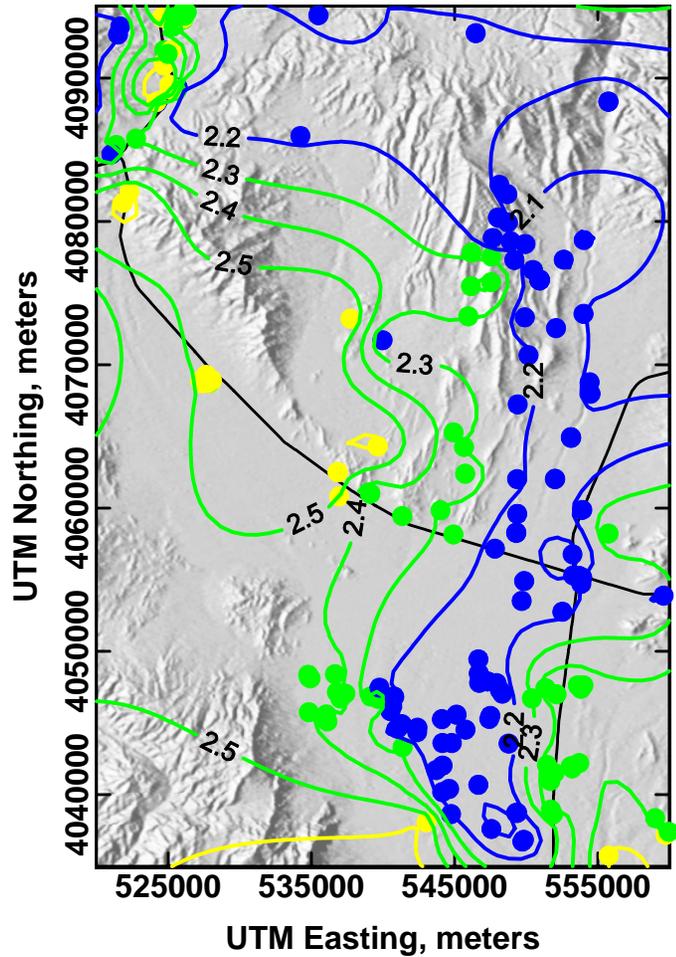
- 1.50 to 1.90
- 1.90 to 2.30
- 2.30 to 2.70
- 2.70 to 3.10



UTM Easting, meters  
**Log Ca, mg/L**

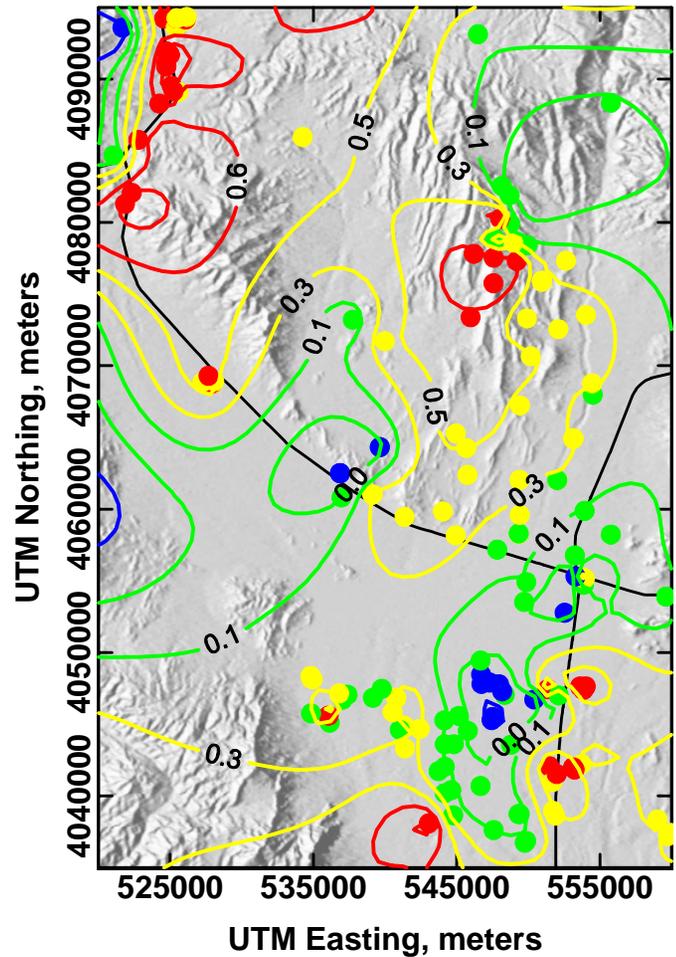
- -0.60 to 0.13
- 0.13 to 0.81
- 0.81 to 1.50
- 1.50 to 2.18





Log HCO<sub>3</sub>, mg/L

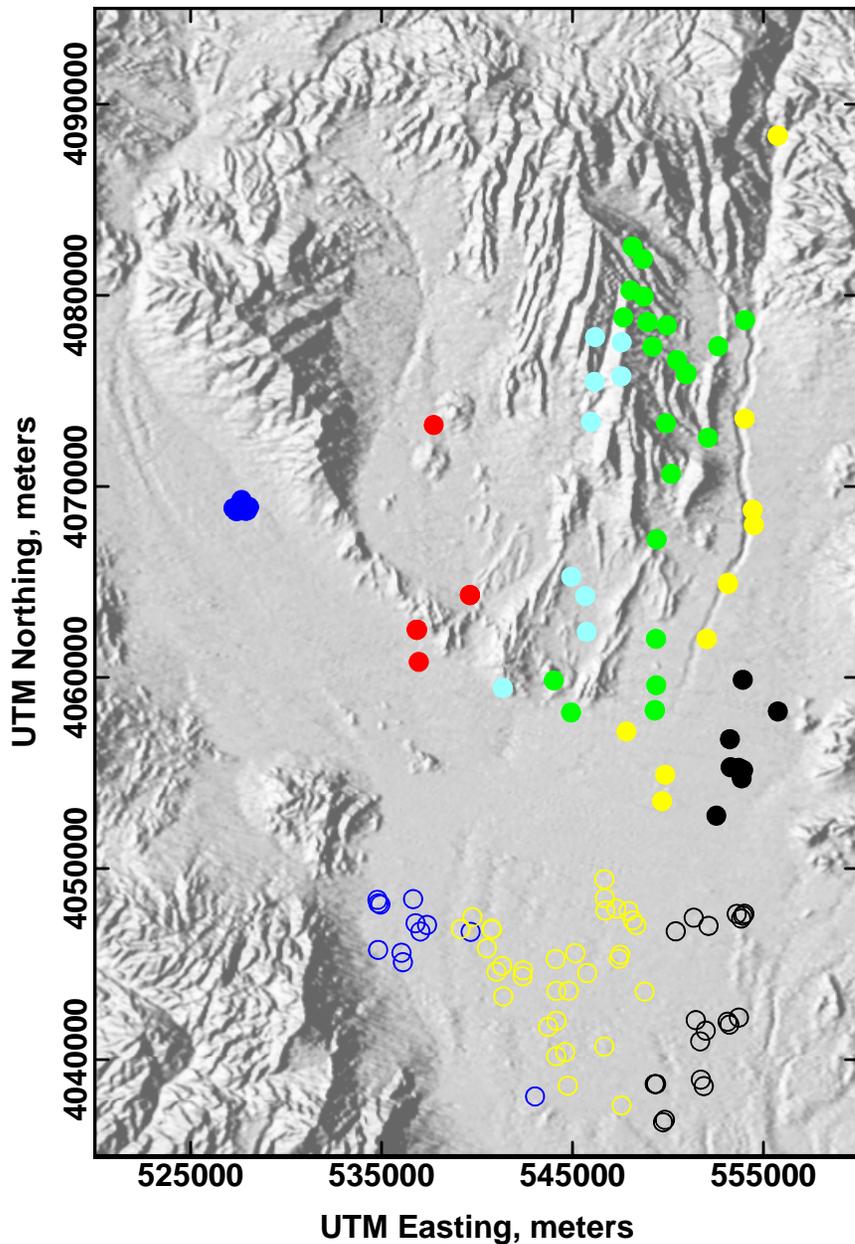
- 2.00 to 2.25
- 2.25 to 2.50
- 2.50 to 2.75
- 2.75 to 3.00



Log F, mg/L

- -0.3 to -0.05
- -0.05 to 0.25
- 0.25 to 0.55
- 0.55 to 0.85



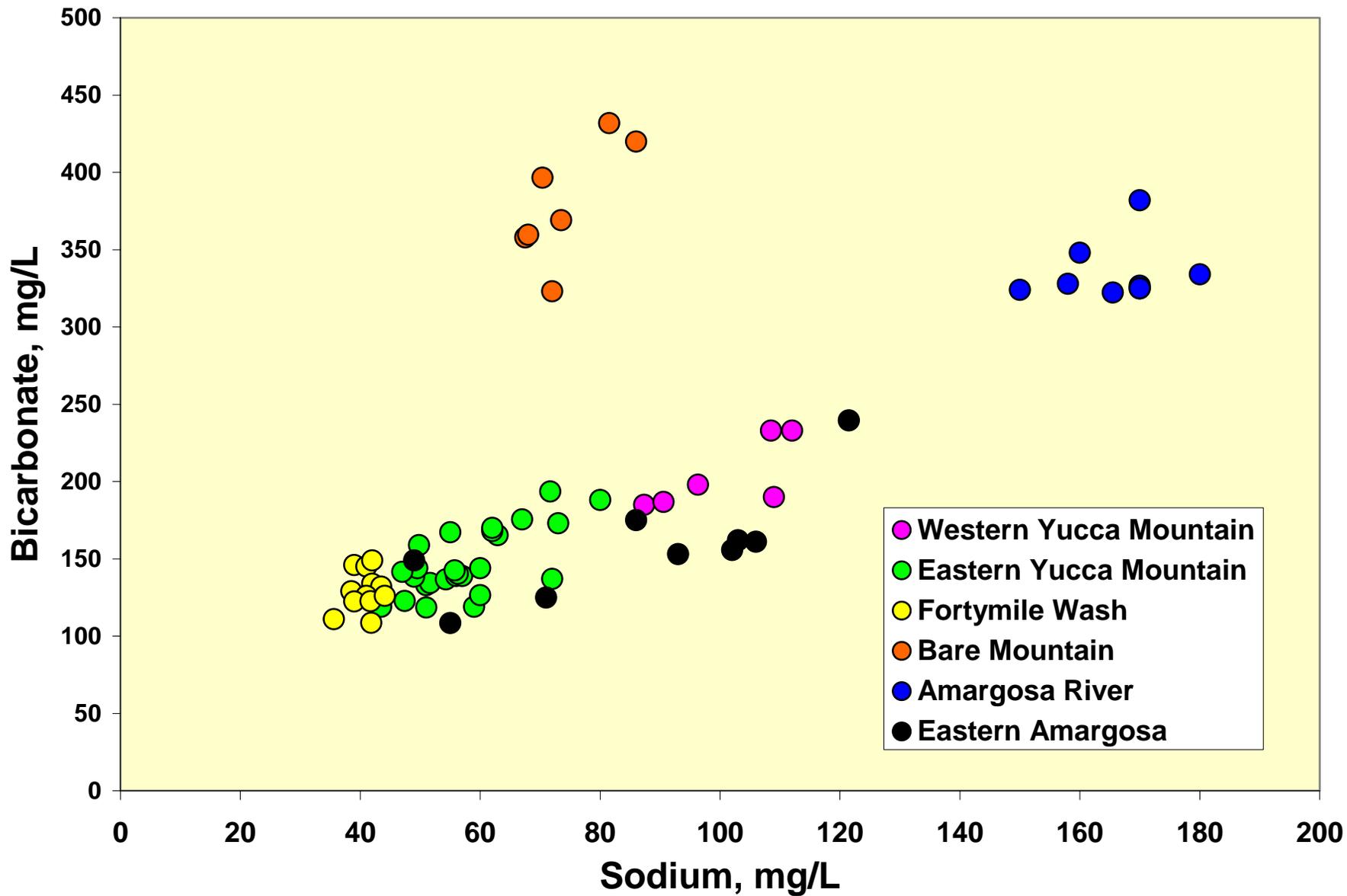


## Hydrochemical Facies

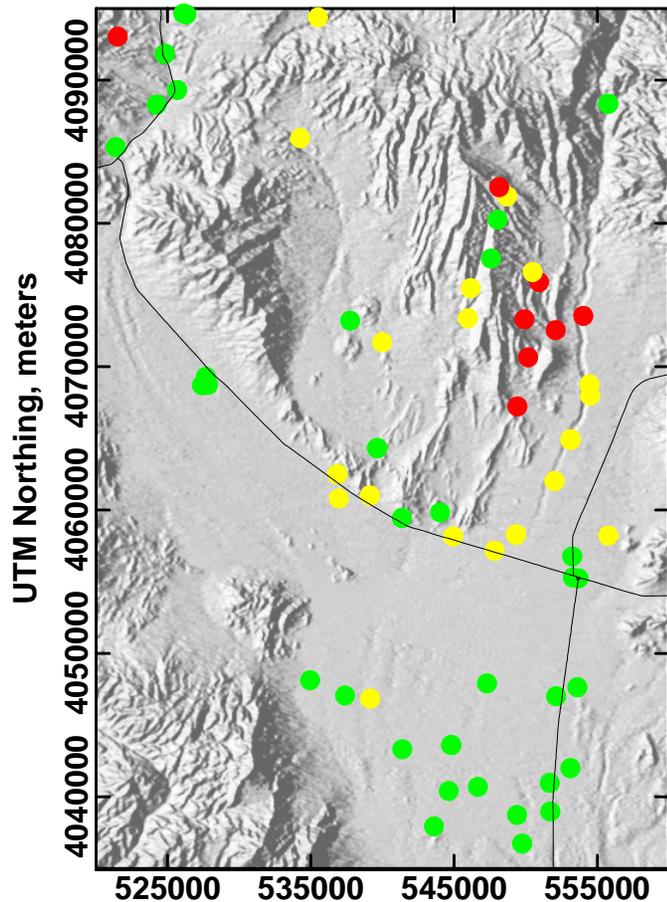
- Western Yucca Mountain Facies  
Na, HCO<sub>3</sub>, F, Ca
- Eastern Yucca Mountain Facies  
Na, HCO<sub>3</sub>, Ca, <sup>234</sup>U/<sup>238</sup>U
- Fortymile Wash Facies  
Na, HCO<sub>3</sub>
- Bare Mountain Facies  
HCO<sub>3</sub>, SO<sub>4</sub>, Cl, Ca
- Amargosa River Facies  
Na, Ca, SO<sub>4</sub>, HCO<sub>3</sub>, Ca
- Eastern Amargosa Facies  
SO<sub>4</sub>, Na, Cl

Open circles represent areas where facies become less distinct due to mixing









UTM Easting, meters

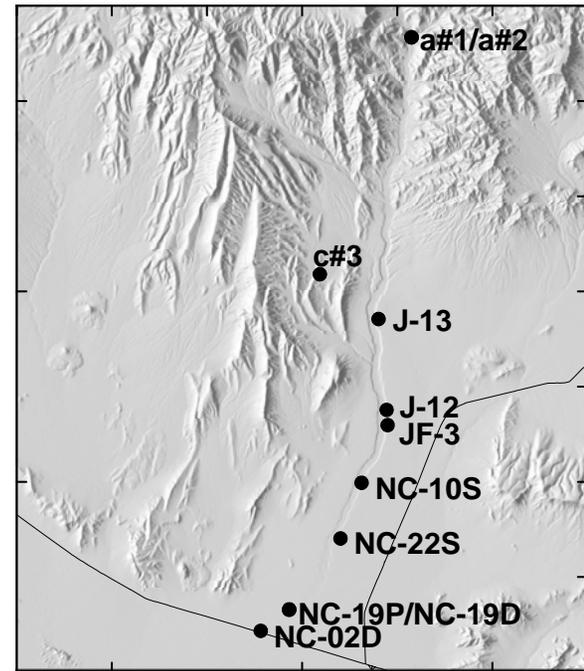
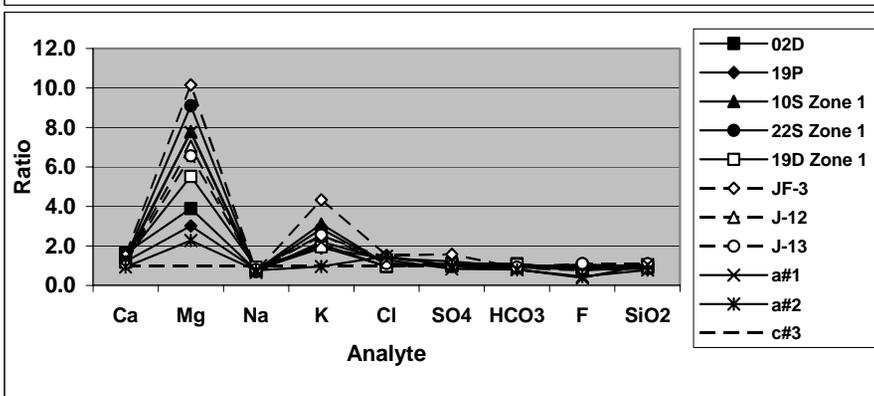
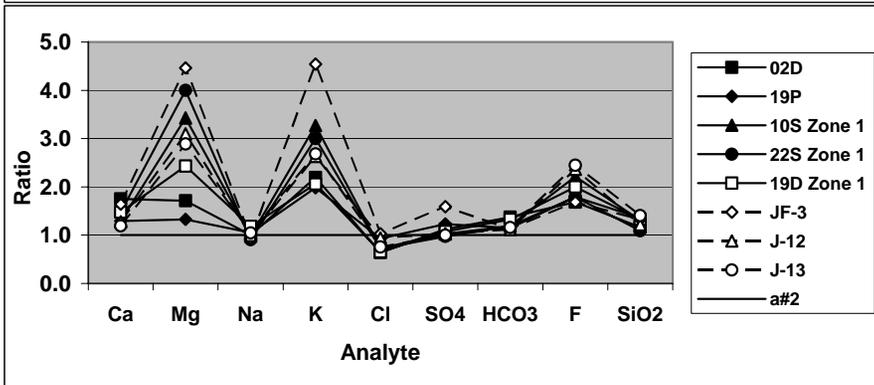
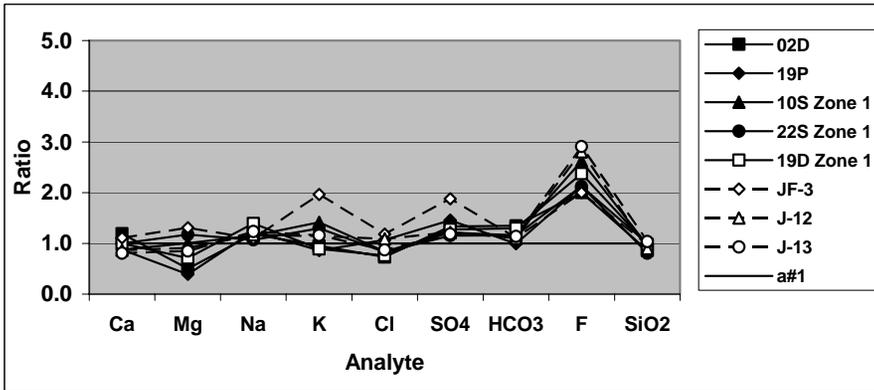
$^{234}\text{U} / ^{238}\text{U}$

- 0.0 to 2.0
- 2.0 to 4.0
- 4.0 to 6.0
- 6.0 to 8.0

One distinguishing feature of the eastern Yucca Mountain facies is elevated  $^{234}\text{U}/^{238}\text{U}$ . These elevated ratios have been interpreted by Paces, et al. 2002 as indicating limited local recharge through the thick sequence of unsaturated rocks underlying Yucca Mountain.

The elevated uranium isotope ratios decrease to the south and within the Fortymile Wash facies.



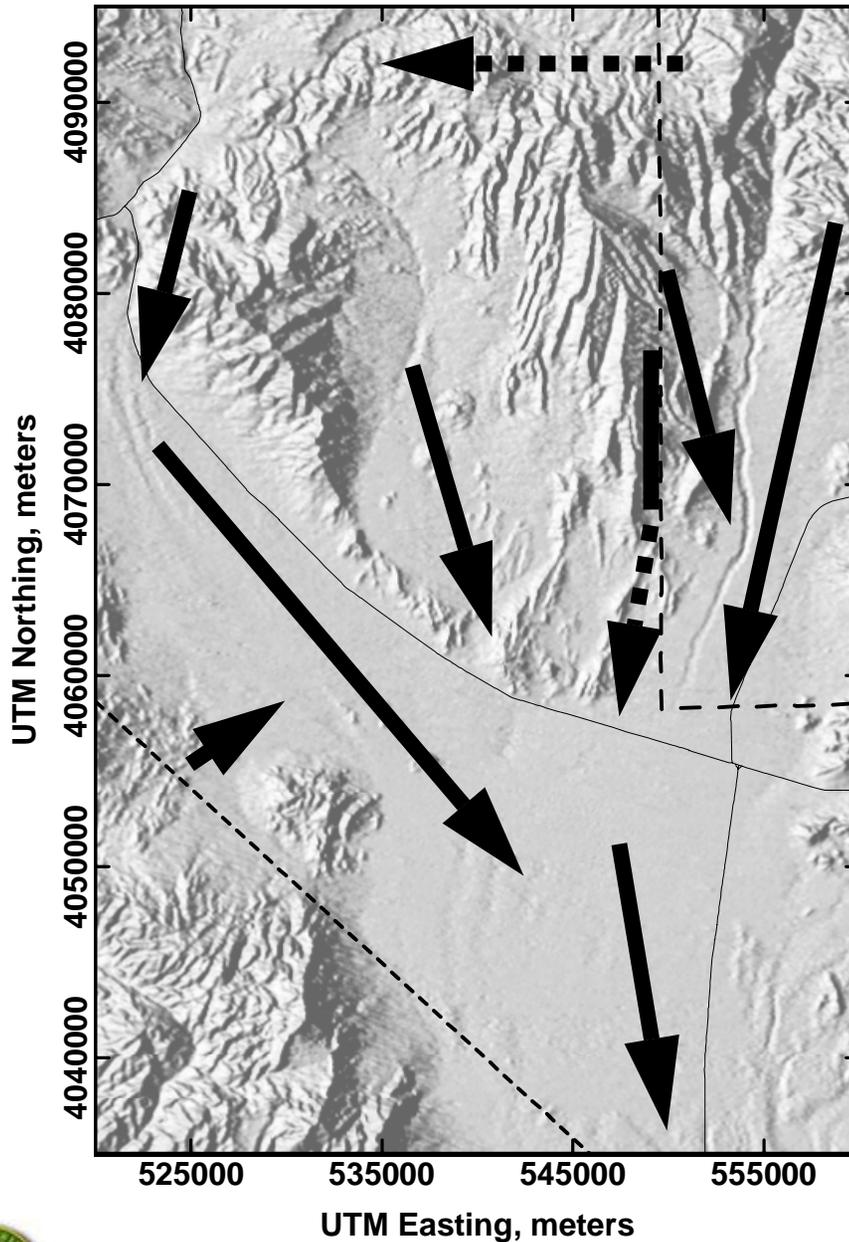


**Spider diagrams demonstrate the relation between the eastern Yucca Mountain facies and the Fortymile Wash facies.**

**Mixing between waters from the 2 facies results in elevated fluoride concentrations in the Fortymile Wash facies below their confluence.**

**Elevated magnesium and potassium result from the influence of alluvium in the Fortymile Wash facies.**





**Generalized major flow paths identified from hydrochemical and isotopic parameters**

- - - NTS Boundary
- ..... Nevada-California Boundary
- 1:100,000 Major Roads
- ➔ Flow Line



# Carbon-14 Dating

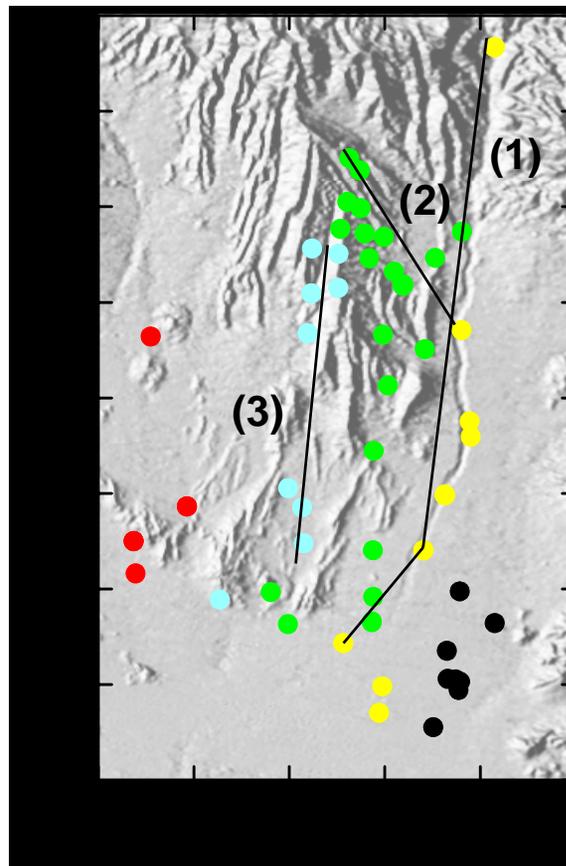
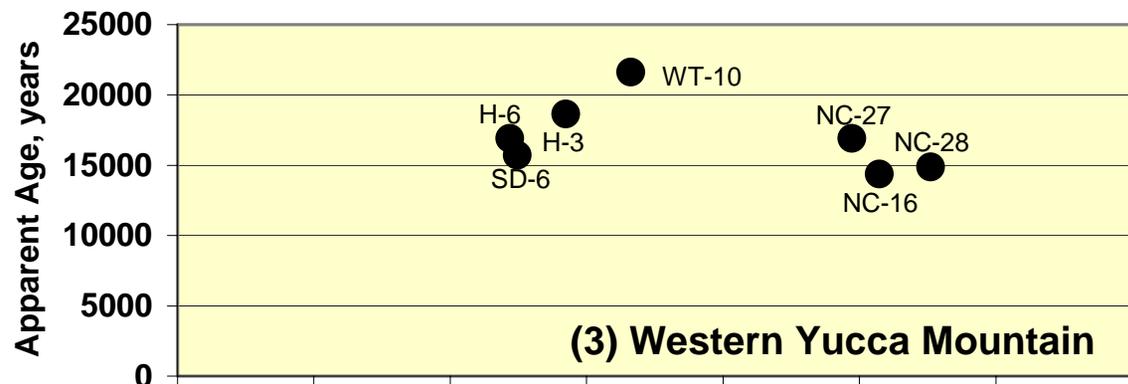
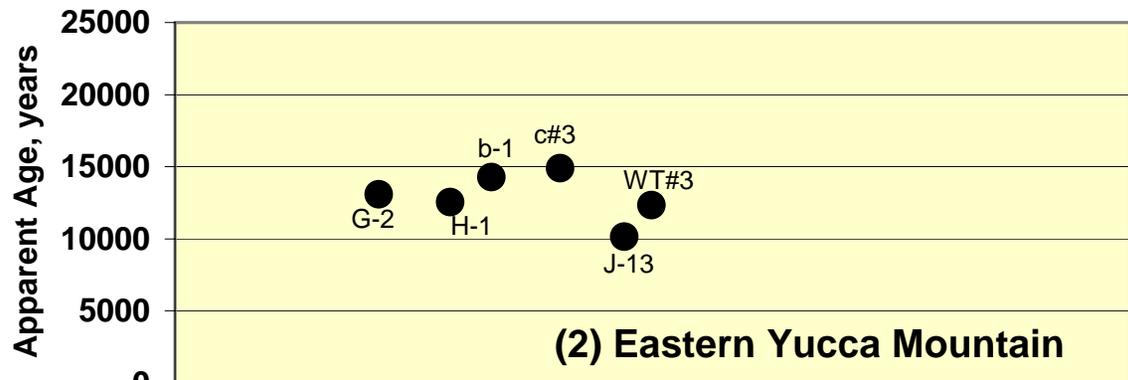
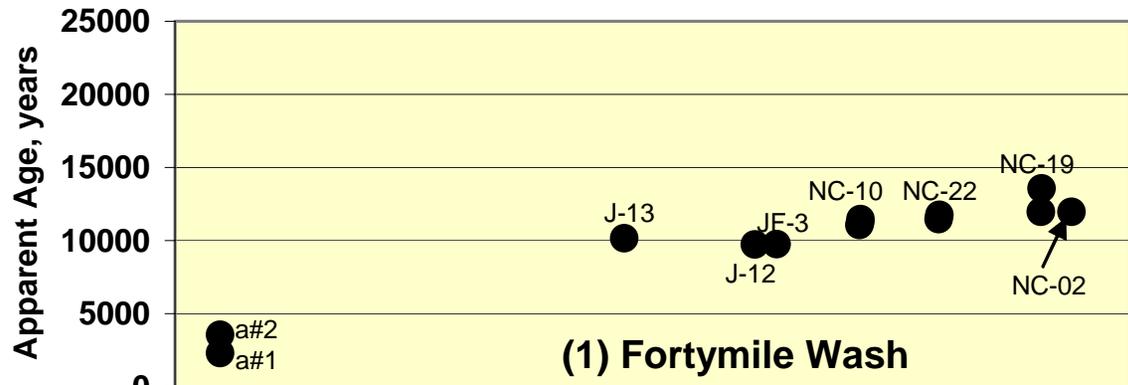
- **Carbon-14 is a radioactive isotope with a half-life of 5730 years**
- **Assumptions for groundwater dating**
  - **Water acquires its initial carbon-14 content as it percolates through the soil zone and enters the groundwater system**
  - **In the absence of water/rock interaction, the carbon-14 content would change only as a function of radioactive decay, thus allowing the direct measurement of groundwater age**
- **Theoretically, carbon-14 measurements from wells situated along known flow paths would allow calculations of travel time between each well pair**



# Problems with Travel Time Calculations from Carbon-14 Ages

- **Carbon-14 measurements may give erroneous estimates of residence time if assumptions are not met (previous slide)**
  - **Acquisition of dead carbon from aquifer rocks will result in determined carbon-14 ages that are anomalously old**
  - **Mixing of water from different sources such as merging flow domains or recharge along flow paths results in carbon-14 ages that are not the true age of the groundwater that entered the system upgradient**





**Apparent carbon-14 age estimates**  
**Not corrected for water/rock interaction**

4090000 4085000 4080000 4075000 4070000 4065000 4060000 4055000

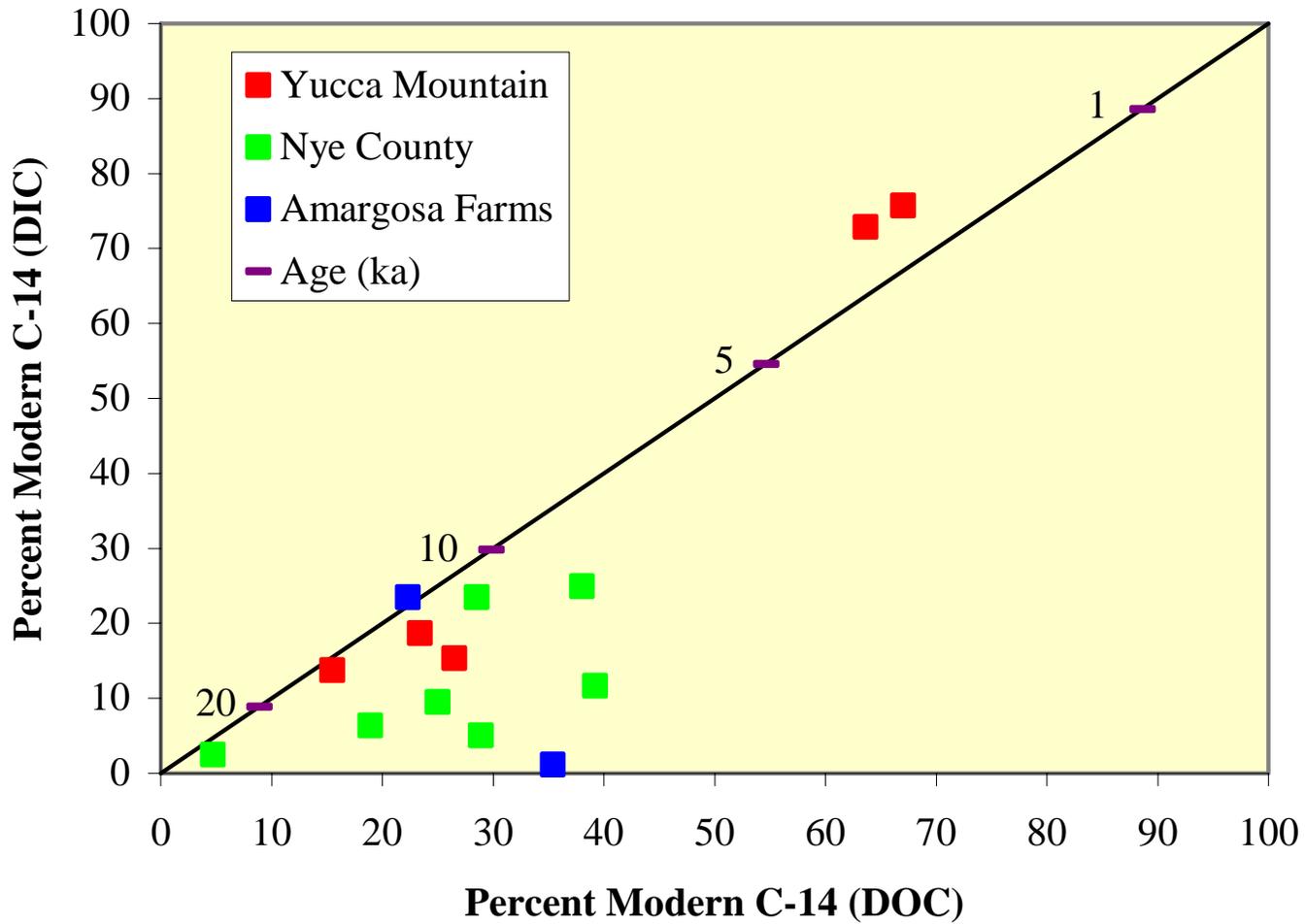
UTM Northing, meters



# Dissolved Organic Carbon-14 Ages

- **While dissolved inorganic carbon-14 activities are altered by water/rock interactions, the dissolved organic carbon-14 should remain unaffected**
- **Dissolved organic carbon-14 measurements are still affected by mixing, the introduction of recharge, and the presence of organic contaminants**
- **The following graph shows the results of initial investigation of the utility of DOC-14 measurements in conjunction with DIC-14 in estimating groundwater ages**





# Conclusions

- **SZ waters near Yucca Mountain can be divided into 6 distinct hydrochemical facies that maintain their chemical and isotopic character over long distances**
- **These hydrochemical facies can be used to identify general flow domains and identify mixing relations between facies**
- **Water from the eastern Yucca Mountain facies may obtain its unique isotopic signature due to recharge through the fault controlled washes on the northern end of Yucca Mountain. This water then flows south/southeast until it eventually merges with water of the Fortymile Wash facies**
- **Water from the western Yucca Mountain facies flows to the south at least as far as the southern tip of the mountain and perhaps as far as Highway 95**
- **Although estimates of travel time over long distances based on carbon-14 ages are difficult, travel times within part of Fortymile Wash and western Yucca Mountain appear to be on the order of thousands of years**



# Ongoing Activities that will Enhance Our Understanding of Saturated Zone Flow

- **Continued measurements of unsaturated zone pore-water chemistry in the deepest part of the unsaturated zone (UZ) will help assess the nature of the UZ-SZ interface and refine the interpretation of flow paths away from the proposed repository**
- **Continued refinement of the methods used to sample and analyze dissolved organic carbon-14, along with dissolved inorganic carbon-14 measurements and reaction path modeling will provide better estimates of transport along certain flow paths (conducted under the Science and Technology program)**
- **Continued investigation of 3-D flow and the interface between the volcanic aquifer and alluvium south of Yucca Mountain will help refine the interpretation of flow paths (conducted as part of the Nye County program)**

