

Springs, Travertines, Xenowhiffs and Continental Smokers



Linking **Earth's mantle** to **water quality** and **unique microbial ecosystems**



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Sciences**

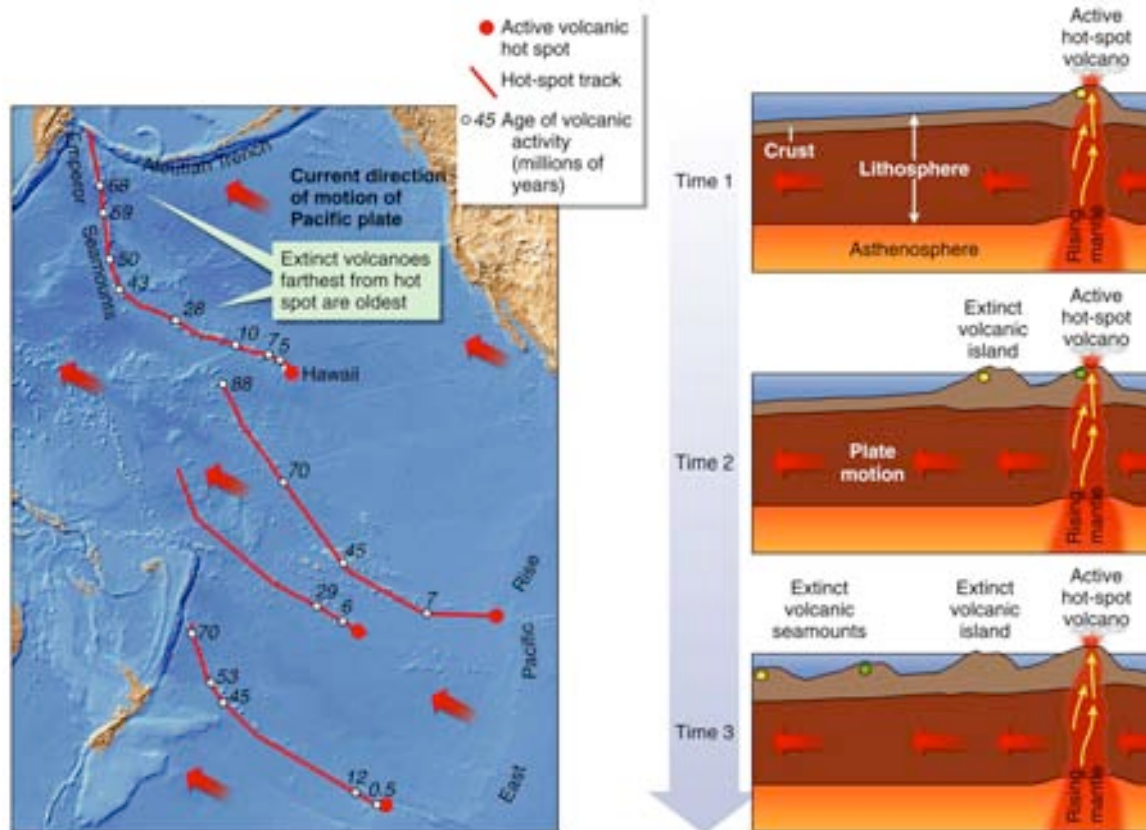
with

Cristina Takacs-Vesbach, Diana
Northup, Cliff Dahm, Dave
Hilton, Tobias Fischer, and
Students: Dennis Newell, Matt
Kirk, Eileen Embid, Brandi
Cron, Ara Kooser

**Science funding by NSF Hydrologic Sciences
and Continental Dynamics**



We recognize that plate tectonic theory provides explanations for observations about volcanism



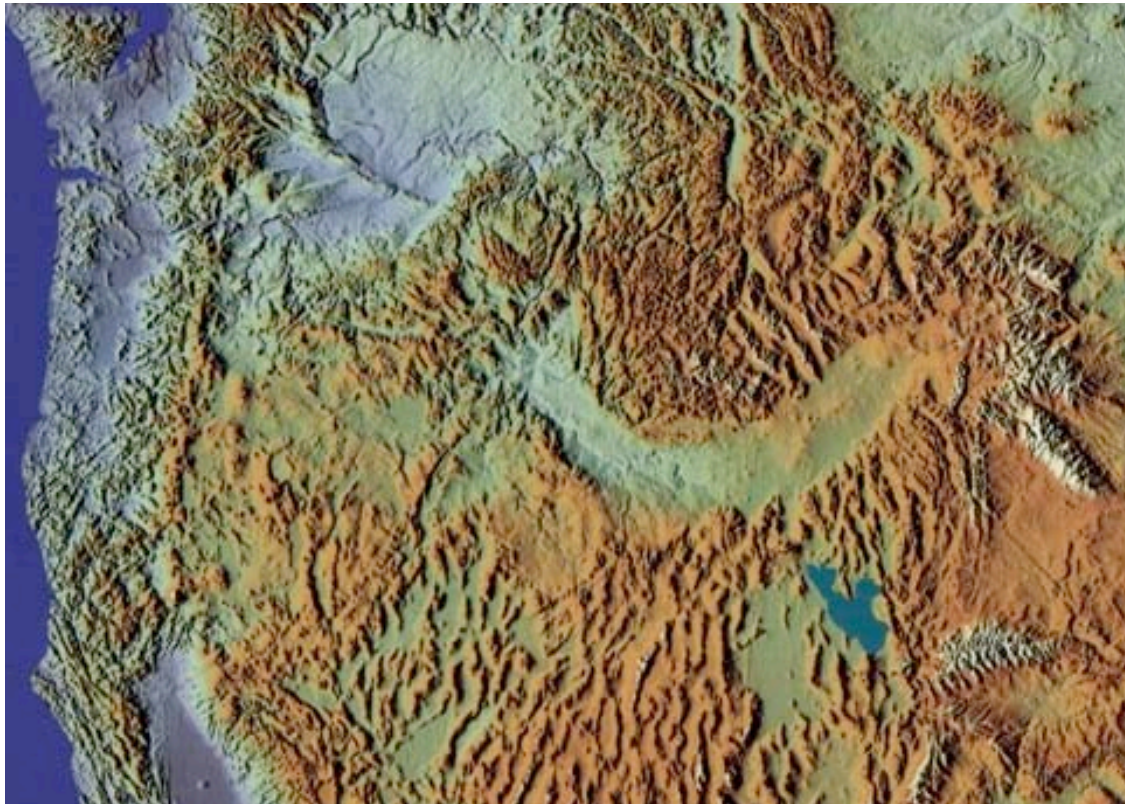
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Example:

Topographic expression and age progression of Hawaii and Emperor Seamount chain in the Pacific.



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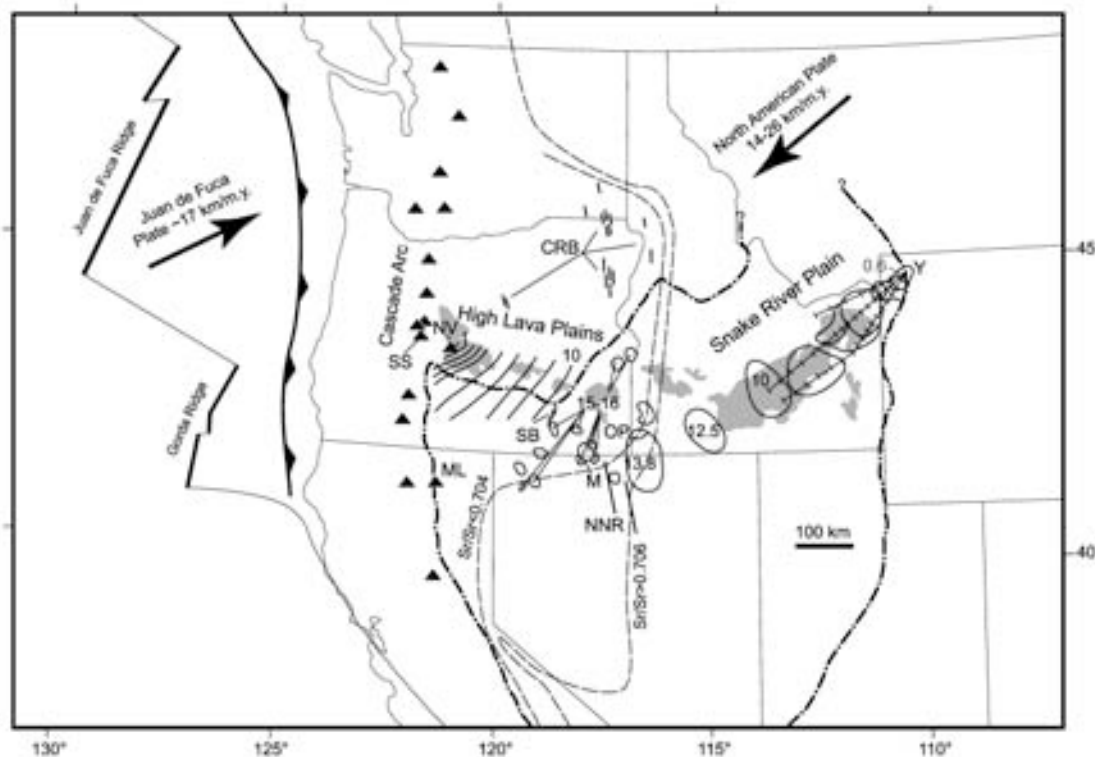


Example:

Topographic expression and age progression of Columbia River basalts, Snake River Plain and Yellowstone in the western U.S.



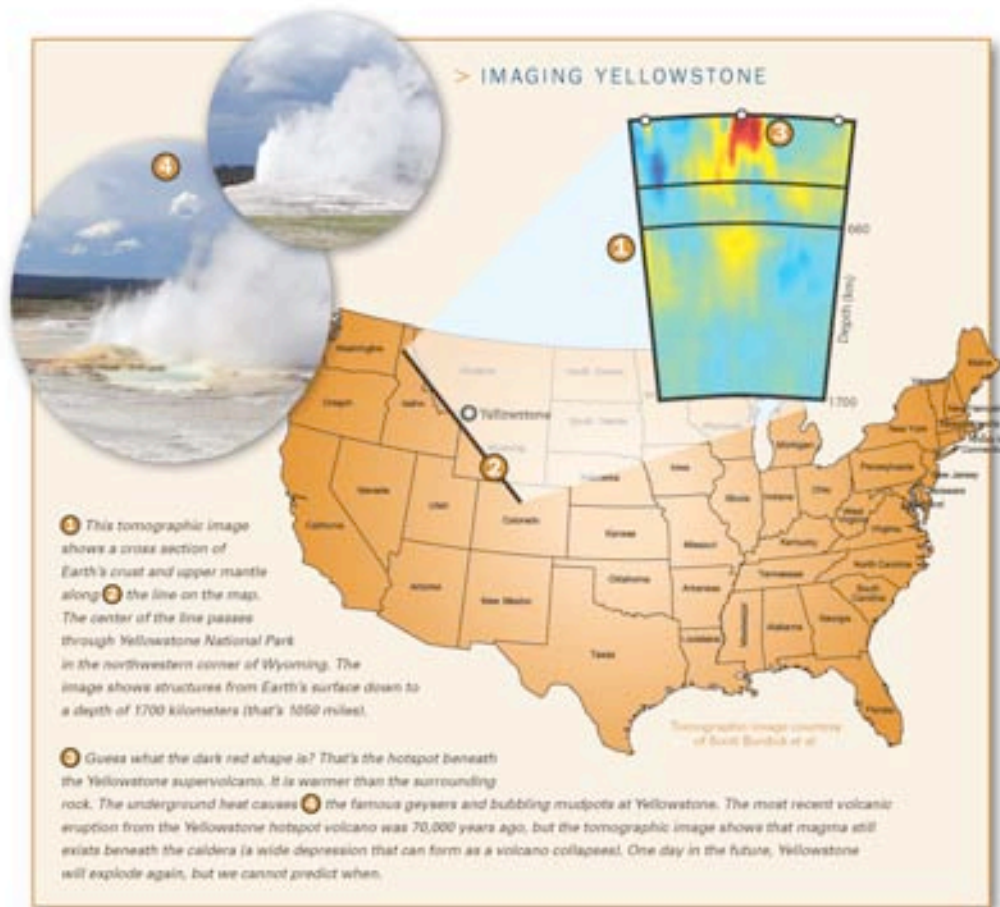
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Example:

Topographic expression and age progression of Columbia River basalts, Snake River Plain and Yellowstone in the western U.S.

Earthscope helps us understand major **material transfers** from deep-earth to surface.



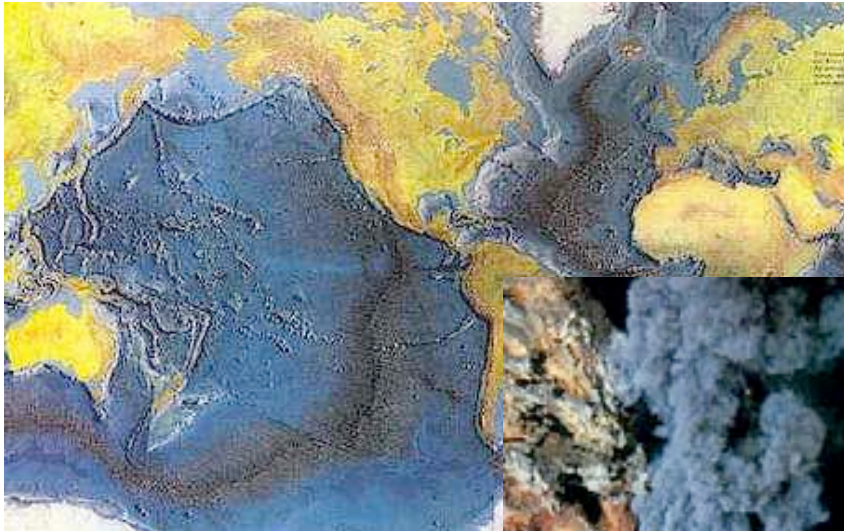
But what about **OTHER** fluids?



Photo: Gary Ladd



A tectonic/fluid/biological connection



Connecting mantle processes to groundwater-research approach



- Tale of a **Dissected Aquifer**: Grand Canyon travertines (aka tufas!)
- **Xenowhiffs** (foreign gases entrained in the hydrologic system): what they tell us about neotectonism
- Active **mantle degassing** of the western US- implications for water quality and groundwater management
- **Continental Smokers**- Spring mounds and geomicrobiology





CO₂ – rich springs and travertines (including ‘mound springs’) are connected...’freshwater’ limestone

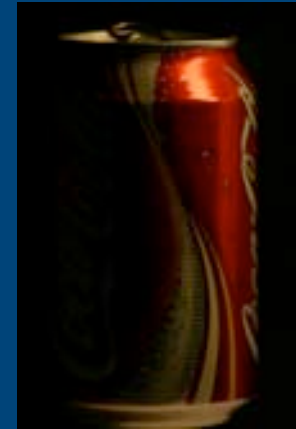


What is the origin of CO₂ necessary for such massive travertines?

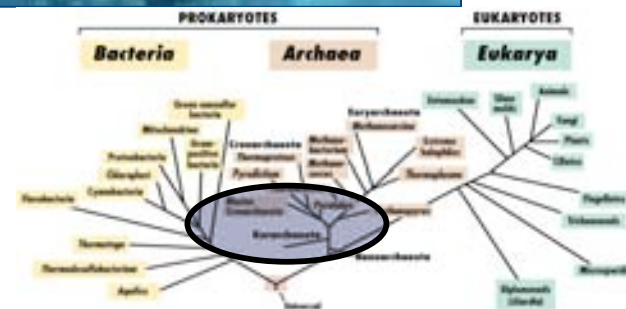


Possible CO₂ sources

atmosphere	}	<i>'Upper World' sources</i>
soil respiration		
mantle degassing	}	<i>'Lower World' sources</i>
crustal sources		



Hot and Not so hot Marine 'Black' Smokers and Continental 'Smokers': Key Comparisons



Proximal magmatic settings:

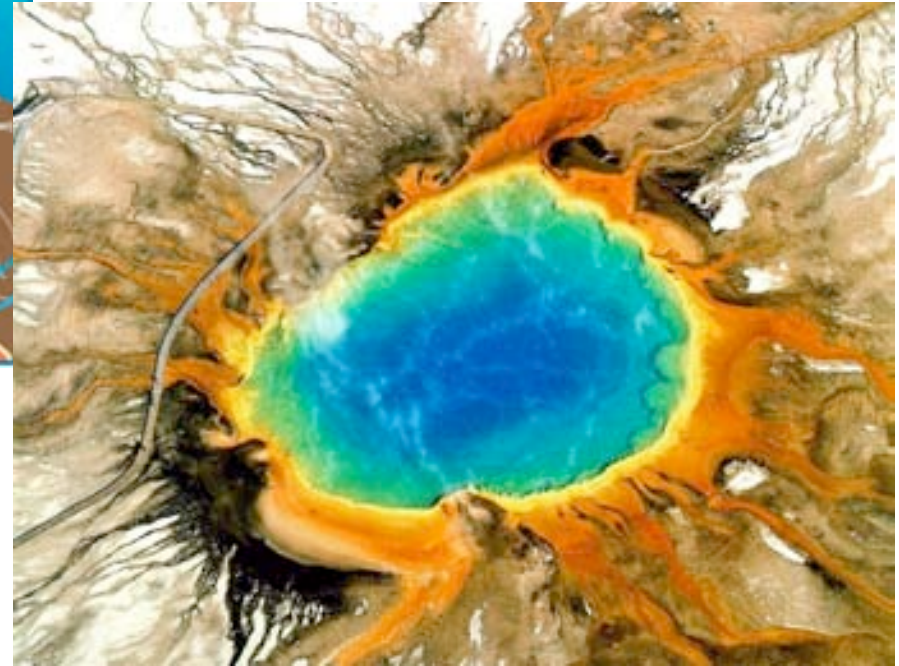
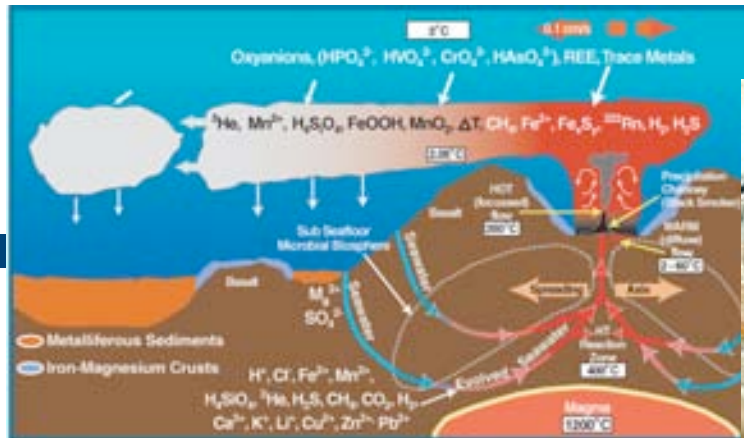
High geothermal gradients (thermal- to hyperthermophiles: 'life zone' greatly compressed)

Pressures range from high hydrostatic (marine) to extremely variable (fumarolic systems)

Extreme chemical gradients

Presence of high CO_2 and H_2 , H_2S , CH_4 anaerobic to microaerophilic conditions

Hot and Not so hot Marine ‘Black’ Smokers and Continental ‘Smokers’: Key Comparisons



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Hot and Not so hot Marine ‘Black’ Smokers and Continental ‘Smokers’: Key Comparisons

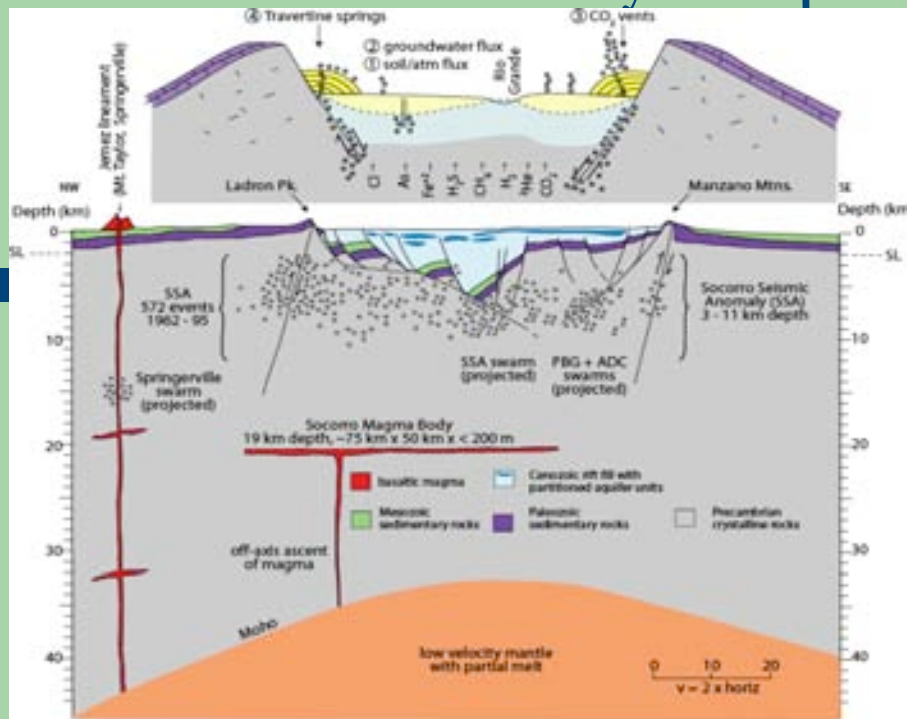


Photo: Dennis Newell

Proximal magmatic settings:

High geothermal gradients (thermal- to hyperthermophiles: ‘life zone’ greatly compressed)
 Pressures range from high hydrostatic (marine) to extremely variable (fumarolic systems)
 Extreme chemical gradients
 Presence of high CO_2 and H_2 , H_2S , CH_4 anaerobic to microaerophilic conditions

Extensional tectonic settings in general:

Ambient to moderate geothermal gradients (mesothermophiles: ‘life zone’ greatly expanded)
 Pressures range from atmospheric to moderate hydrostatic
 Extreme chemical gradients
 Presence of high CO_2 and H_2 , H_2S , CH_4 anaerobic to microaerophilic conditions



CO_2 – rich springs and travertines (including ‘mound springs’) are a manifestation of significant and persistent Earth outgassing along faults





The Pagosa, CO



Glenwood Springs, CO



Montezuma Well, AZ



Travertines as chemical volcanoes



**Mound springs and
carbonates of
Springerville, AZ**

Photo: L. Crumpler



Geology: Not just rocks...It's a gas!



Cool CO₂-rich spring mounds of the Rio Grande rift, NM



Mantle-derived helium present in CO₂-spring waters

LCR, AZ

Region	Location	³ He/ ⁴ He (Rc)
Rio Grande Rift	Central New Mexico	0.11 – 6.0
Colorado Plateau	Grand Canyon	0.07 – 1.2
Arizona Transition Zone	Verde Valley	0.3 – 1.16
Rocky Mtns	Colorado	0.1 – 2.1



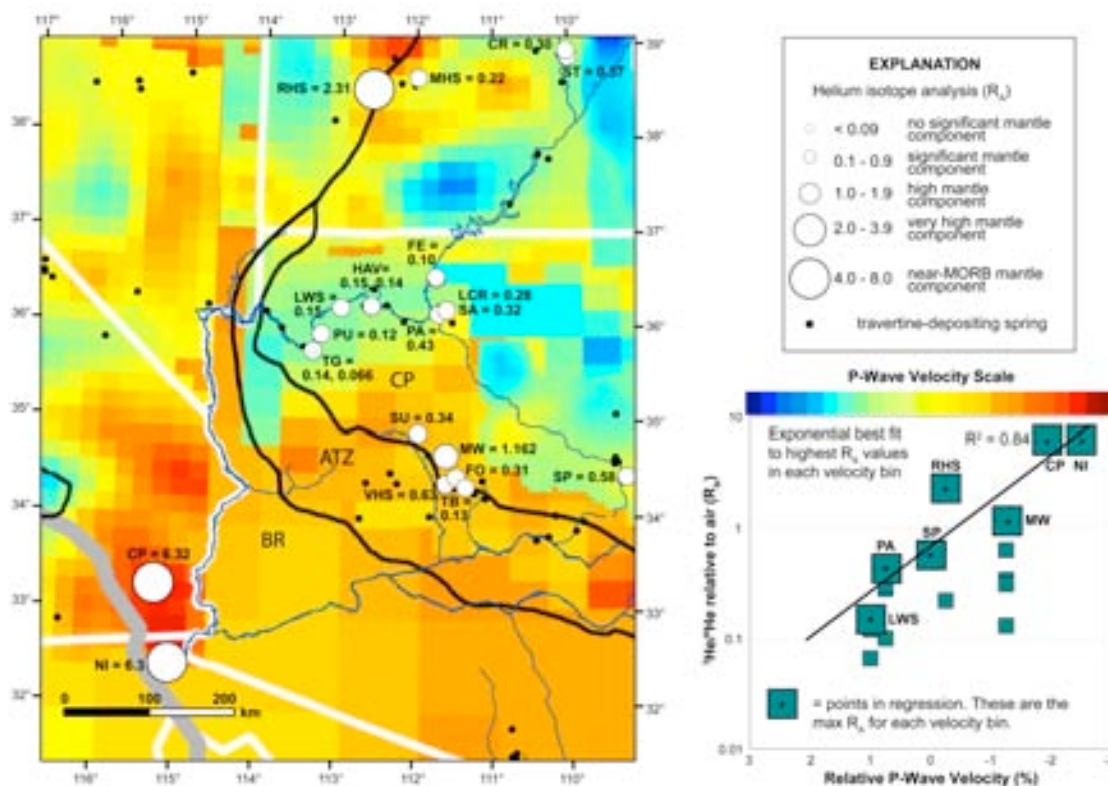
Montezuma Well, AZ



Steamboat Springs, CO



CO₂ Springs and Mantle Degassing



Crossey et al., Fig. 13

Crossey et al., 2009, GSA Bull.



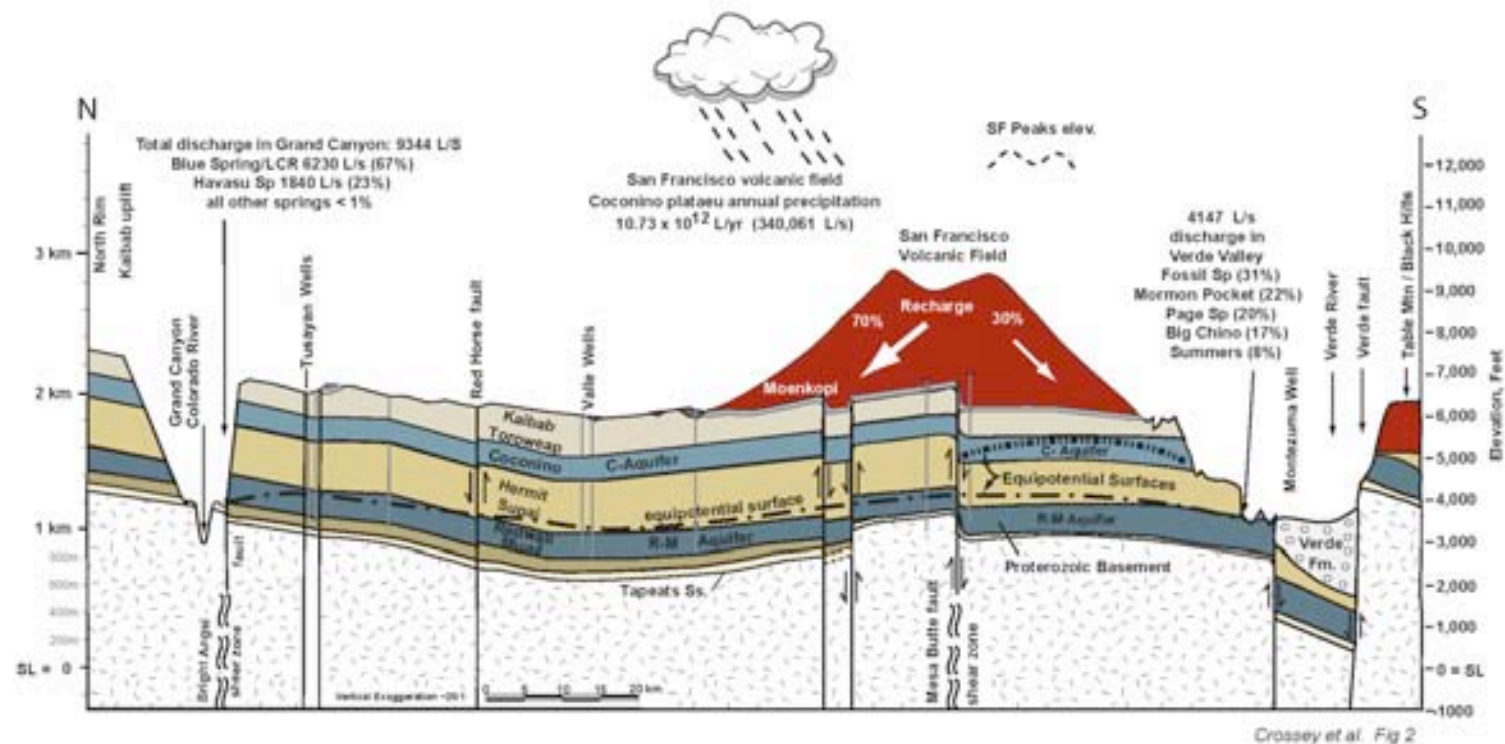
Travertines of Grand Canyon are linked to other indications of mantle tectonism in the region: Late Quaternary volcanism



See Karlstrom et al., 2007 (GSAB), Crow et al., 2008 (Geosphere), and Karlstrom et al., 2008 (Geology) for neotectonic incision story of Grand Canyon

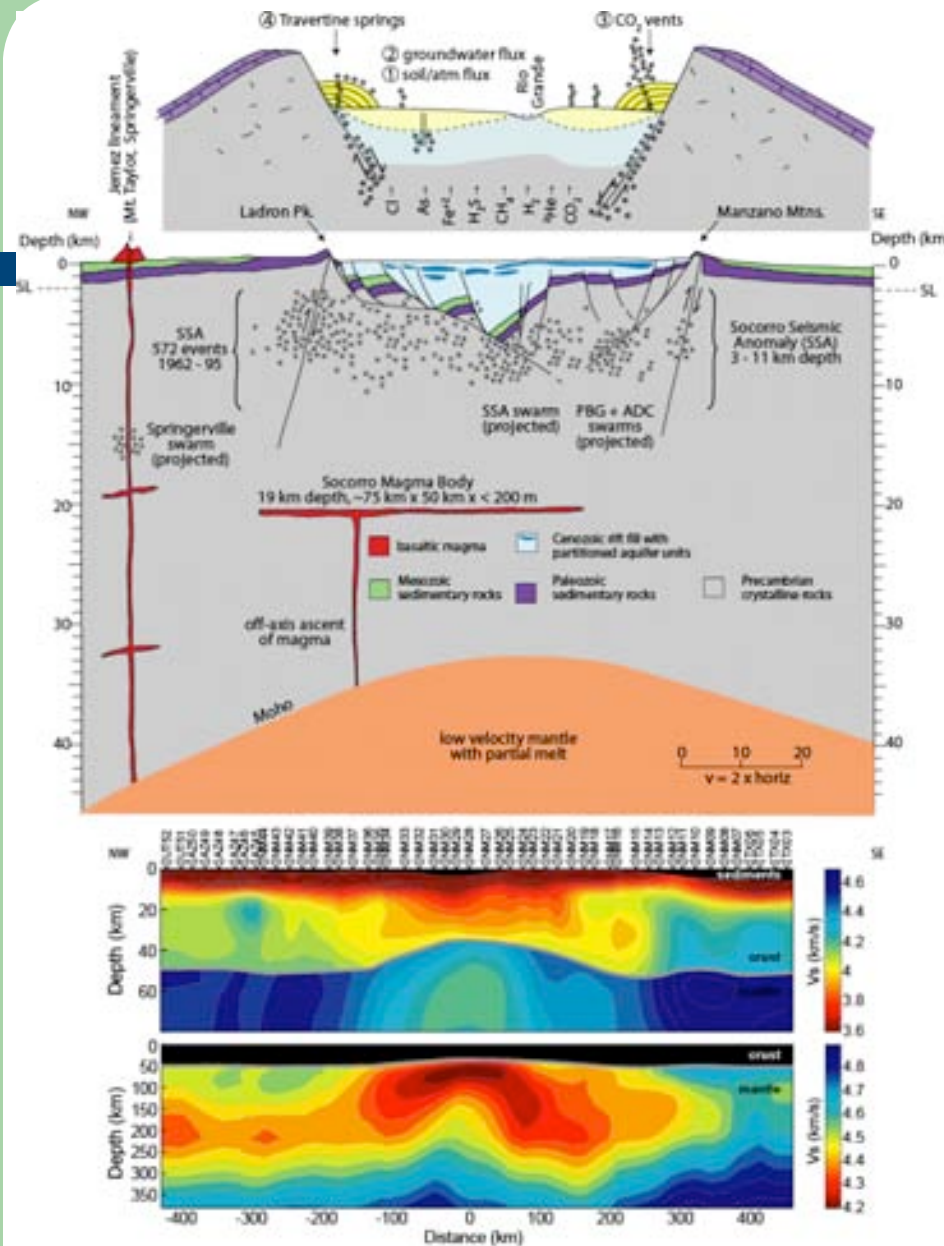


Hydrologic model for the Colorado Plateau



from Crossey et al., GSAB, 2009

Elements of a Continental Smoker: Example--Rio Grande rift



Unique microbial communities

*Travertine & CO₂-rich springs
(and GW inputs)*

*seismicity and
normal faulting*

*Heat+fluid conveyed with asthenospheric-derived
basaltic magma through lithospheric mantle*

Thinned crust

Upwelling asthenosphere

Crossey et al., in prep

ES CP-RGR Interp. Wksp – L. Crossey

The Trail of Time at Grand Canyon: Using Teachable Moments

Laura J. Crossey & Karl Karlstrom
University of New Mexico
with Steve Semken, ASU
Mike Williams, UMass



What IS the Trail of Time? The BIG idea....

- The Trail of Time is an interpretive walking timeline trail that focuses on Grand Canyon vistas and rocks to guide visitors to ponder, explore, and understand the magnitude of geologic time and the stories encoded by Grand Canyon rock layers and landscapes.

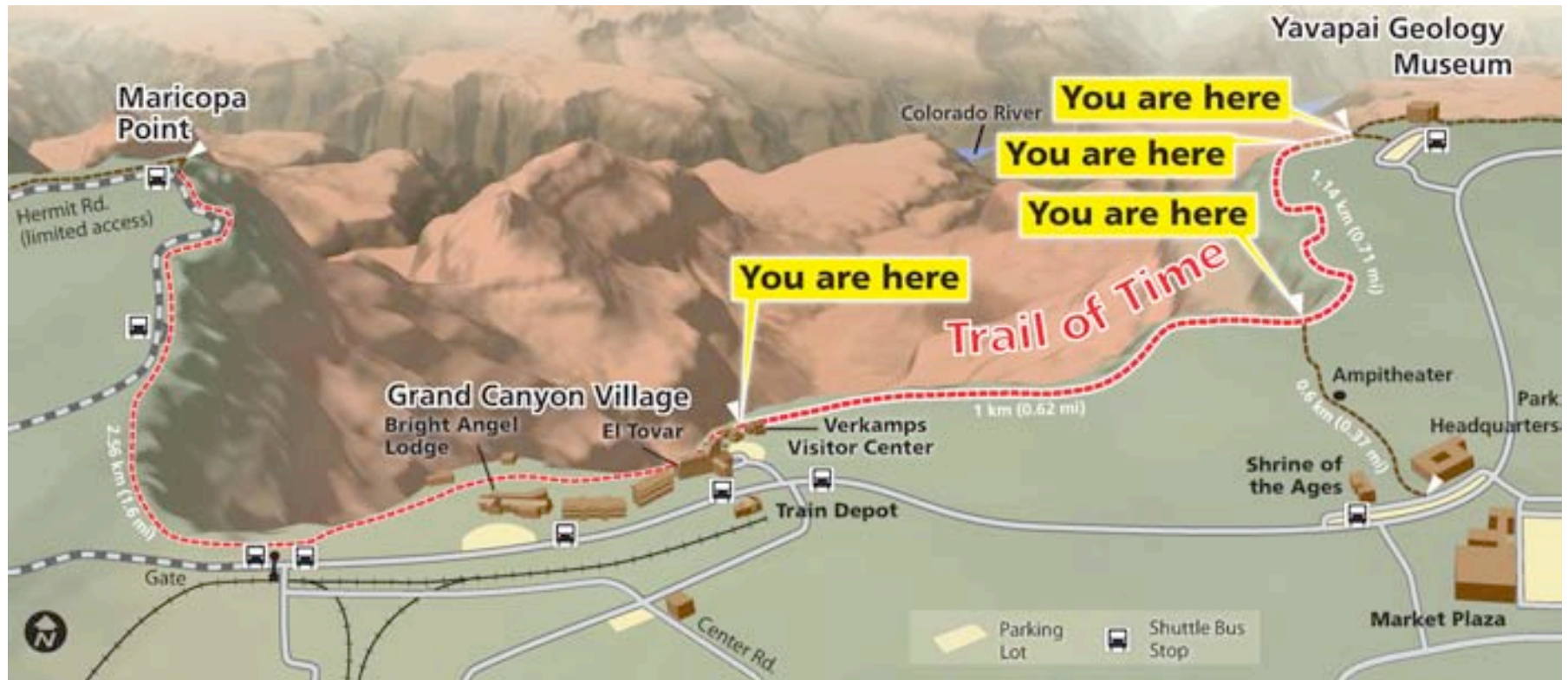


The World's Largest Geoscience Exhibition at the World's Grandest Geologic Landscape



Location Location Location!

Prime Real Estate- The Rim Trail-



An NSF-funded ISE (Informal Science Education) Program
(\$2.3M for 2006-2010) to K. Karlstrom & L. Crossey, UNM

Elements of the Trail of Time- Main Trail



The heart of the Trail of Time is a set of bronze time markings: small markings every meter (one for each million years) and labeled time markings every tenth meter— 2,000 markers!

You'll always know "when" you are along the timeline

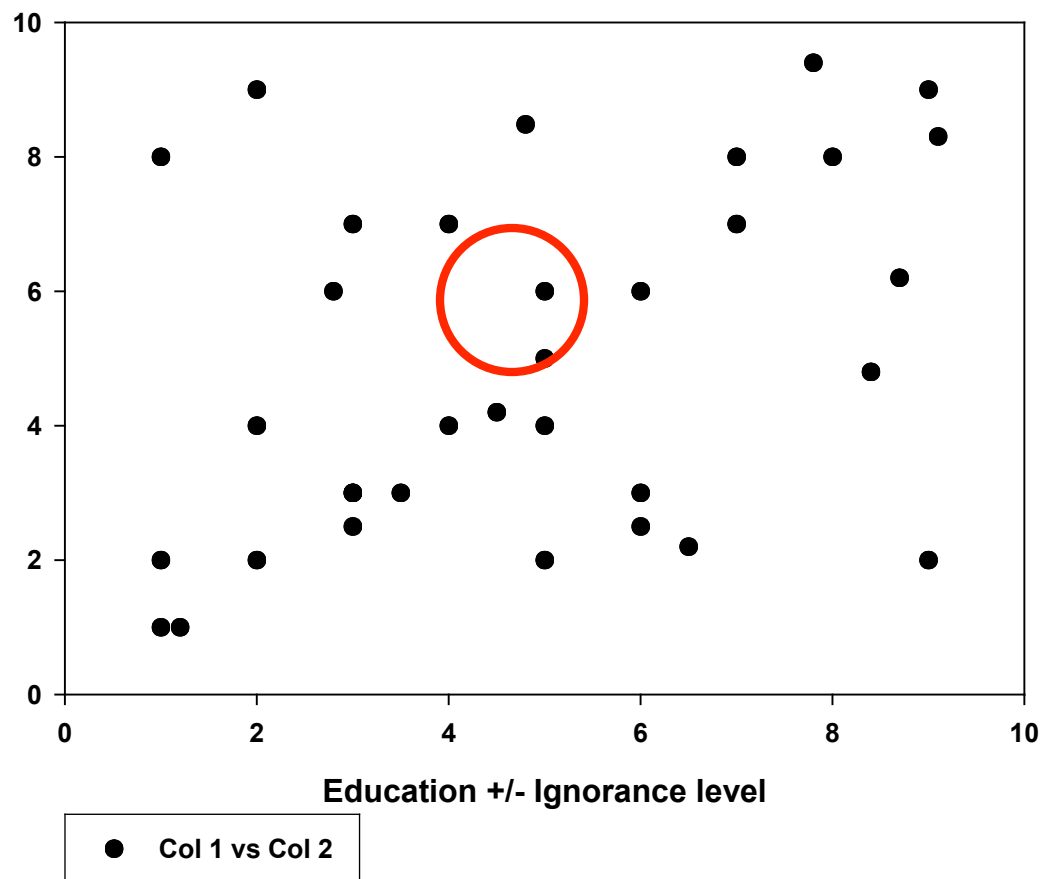
Trail of Time at Grand Canyon
expected opening Summer/Fall 2010



Targeting Geologic Audiences:

“aim at 6th grade comprehension” common approach

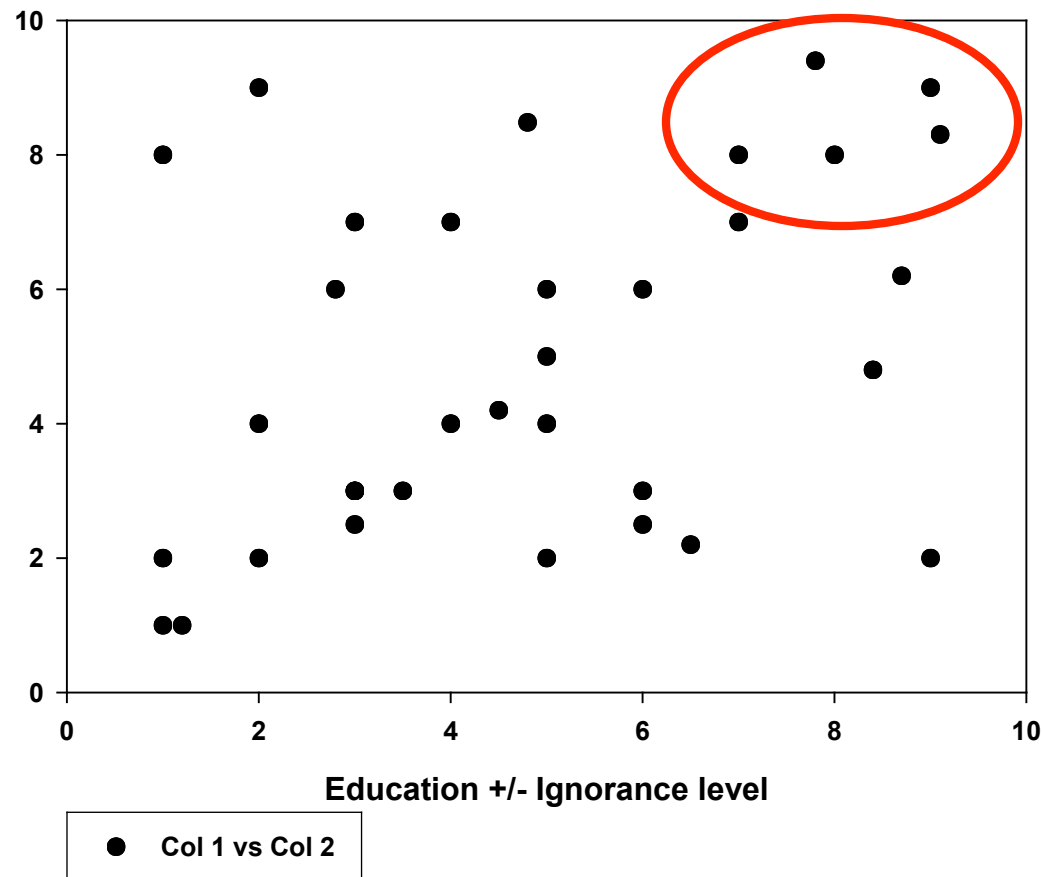
Bogus 2D graph of visitor Intelligence vs. Ignorance



Targeting Geologic Audiences:

“experts” approach favored by scientists

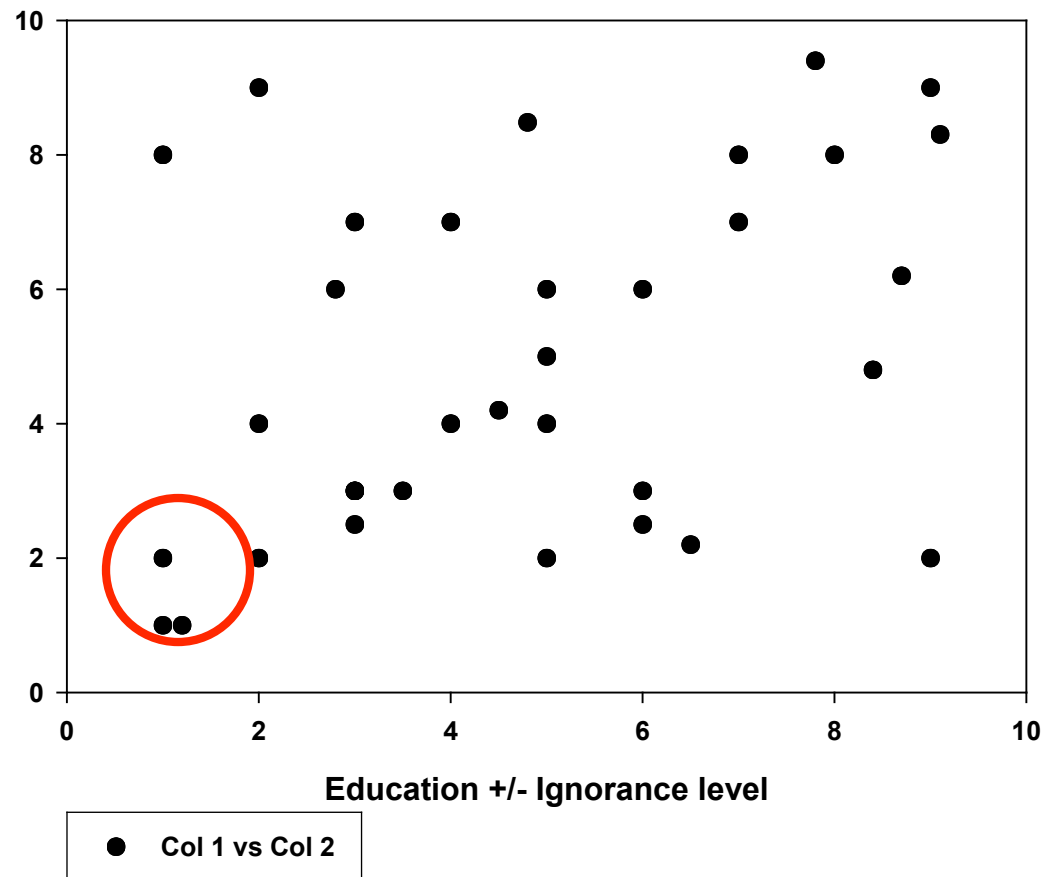
Bogus 2D graph of visitor Intelligence vs. Ignorance



Targeting Geologic Audiences:

“lowest common denominator” approach

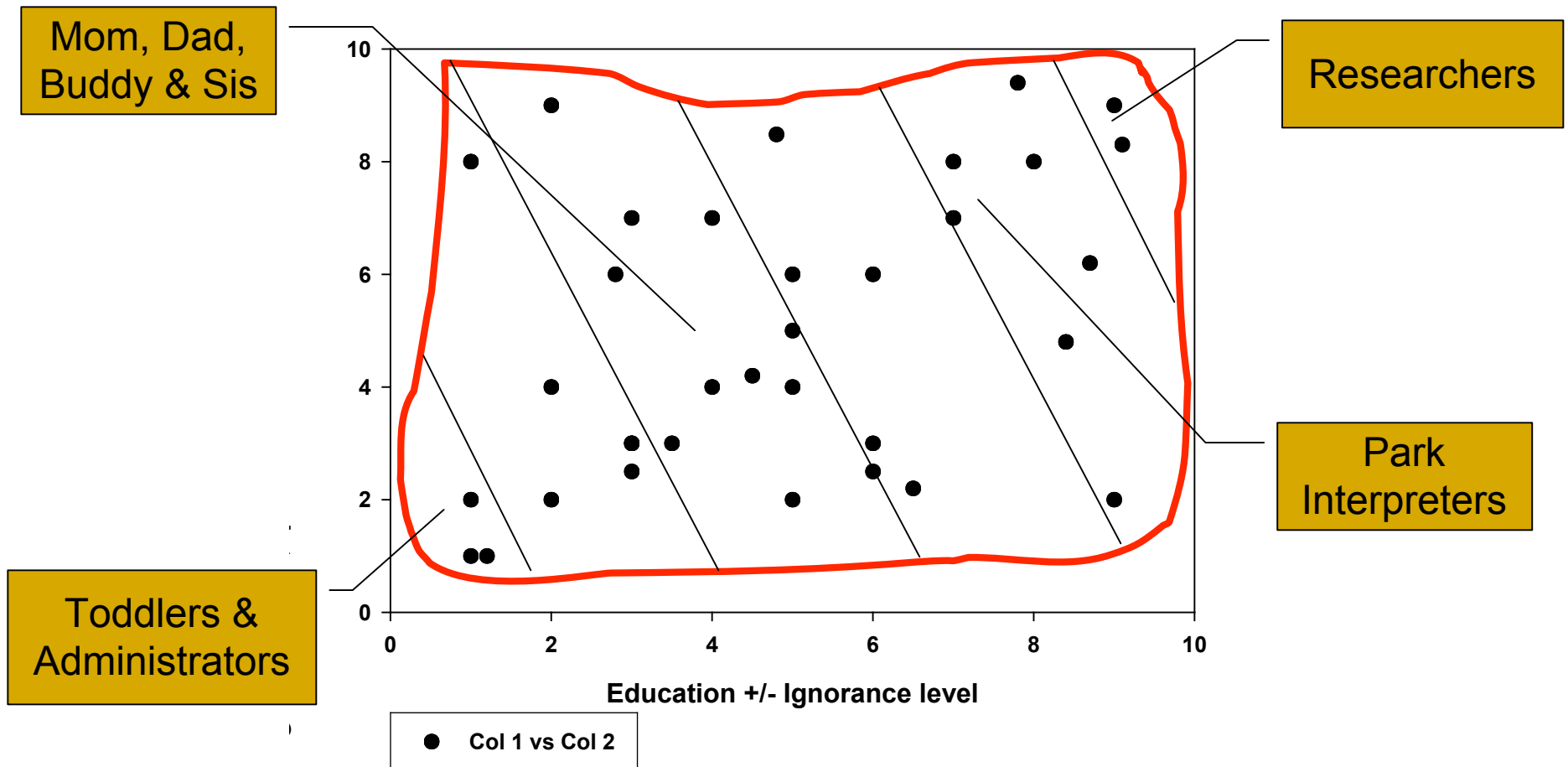
Bogus 2D graph of visitor Intelligence vs. Ignorance



Targeting Geologic Audiences:

“get everybody with multiple layers of info” approach

Bogus 2D graph of visitor Intelligence vs. Ignorance



**Link the NSF-supported
university researchers...**



**... to the
National Park
Service...**



... to the 5 million visitors!

