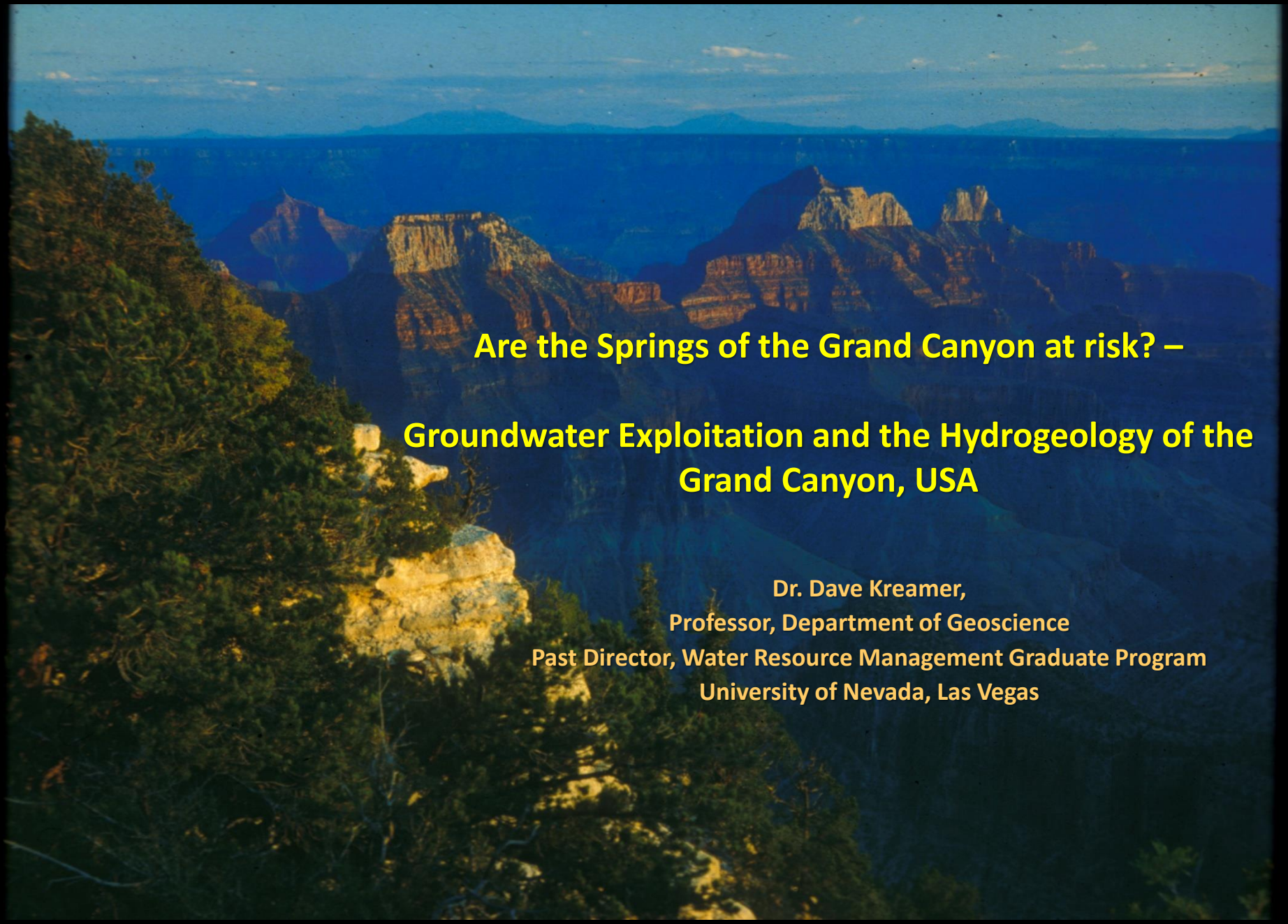

Are the Springs of the Grand Canyon at risk? –

Groundwater Exploitation and the Hydrogeology of the Grand Canyon, USA

Dr. Dave Kreamer,
Professor, Department of Geoscience
Past Director, Water Resource Management Graduate Program
University of Nevada, Las Vegas

Acknowledgements

Jim Fitzgerald
Kim Zukosky

\nd
earted graduate
men and women,
e personnel, Don
e Springer

Talk Outline

- Introduction and Grand Canyon Groundwater Issues
- Grand Canyon Spring Hydrology Basics
- Methods and Results
- Uranium Mining
- Potential for Contamination and Aquifer Disruption

INTRODUCTION

- Grand Canyon National Park: 485 thousand hectares
- Visitation: 4.5 million annually
- Elevation range: 365 meters to 2,745 meters
- Not known as “Cave Park”
- World Heritage Site

"Leave it as it is. You cannot improve on it. The ages have been at work on it, and man can only mar it."

President Theodore Roosevelt

Groundwater Issues at the Grand Canyon

- Spring environments and wildlife habitats
- Native American religious traditions
- Waste Disposal on the Rim
- Monitoring Municipal Landfills
-

Kaibab National Forest

Kaibab National Forest

North Rim

Grand Canyon National Park

Havasu Canyon

Site Description

- Location of Recharge?
  Weather in the Canyon
- North Rim vs. South Rim
- Stratigraphy
- Structural Controls


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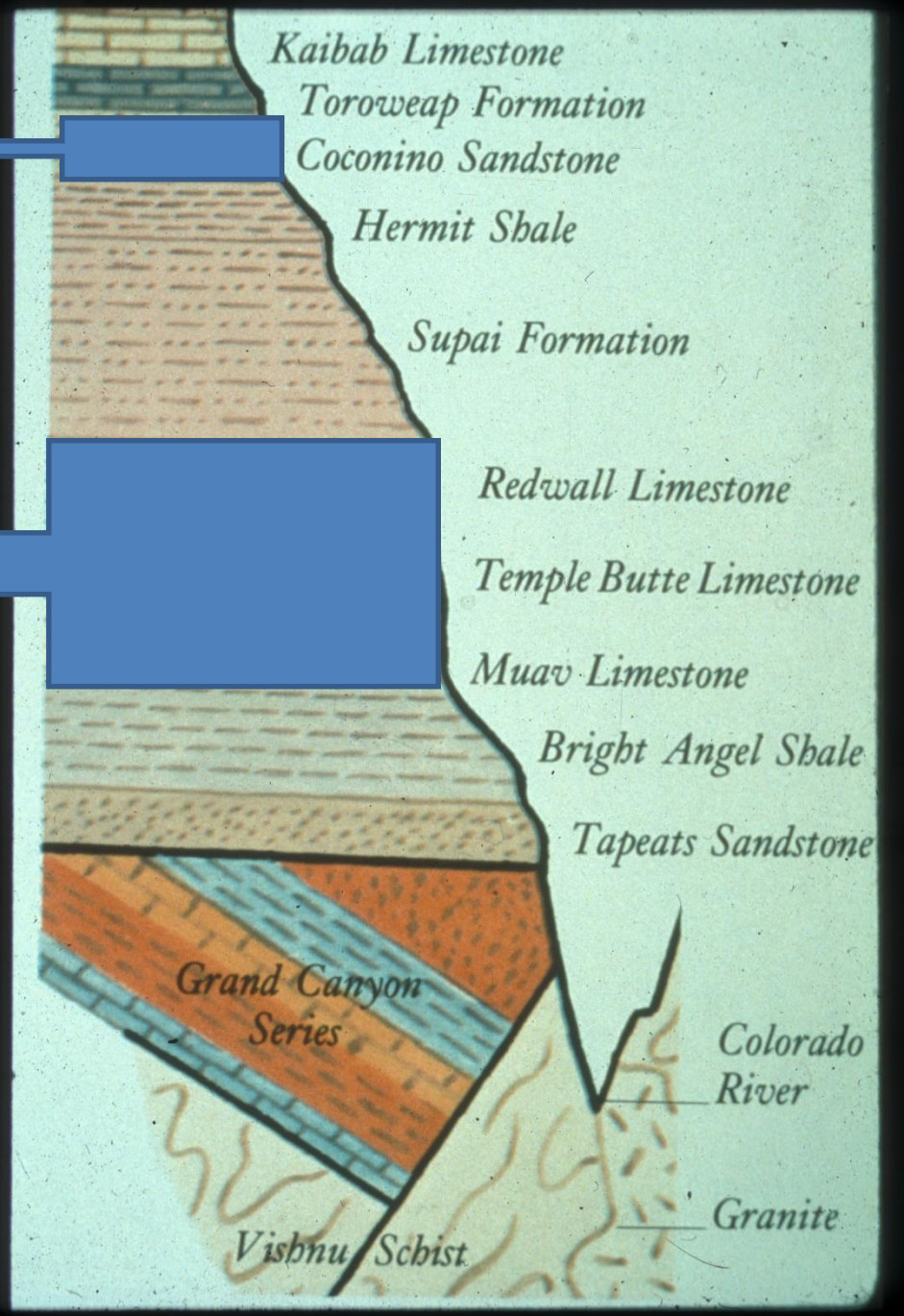
SUPERB

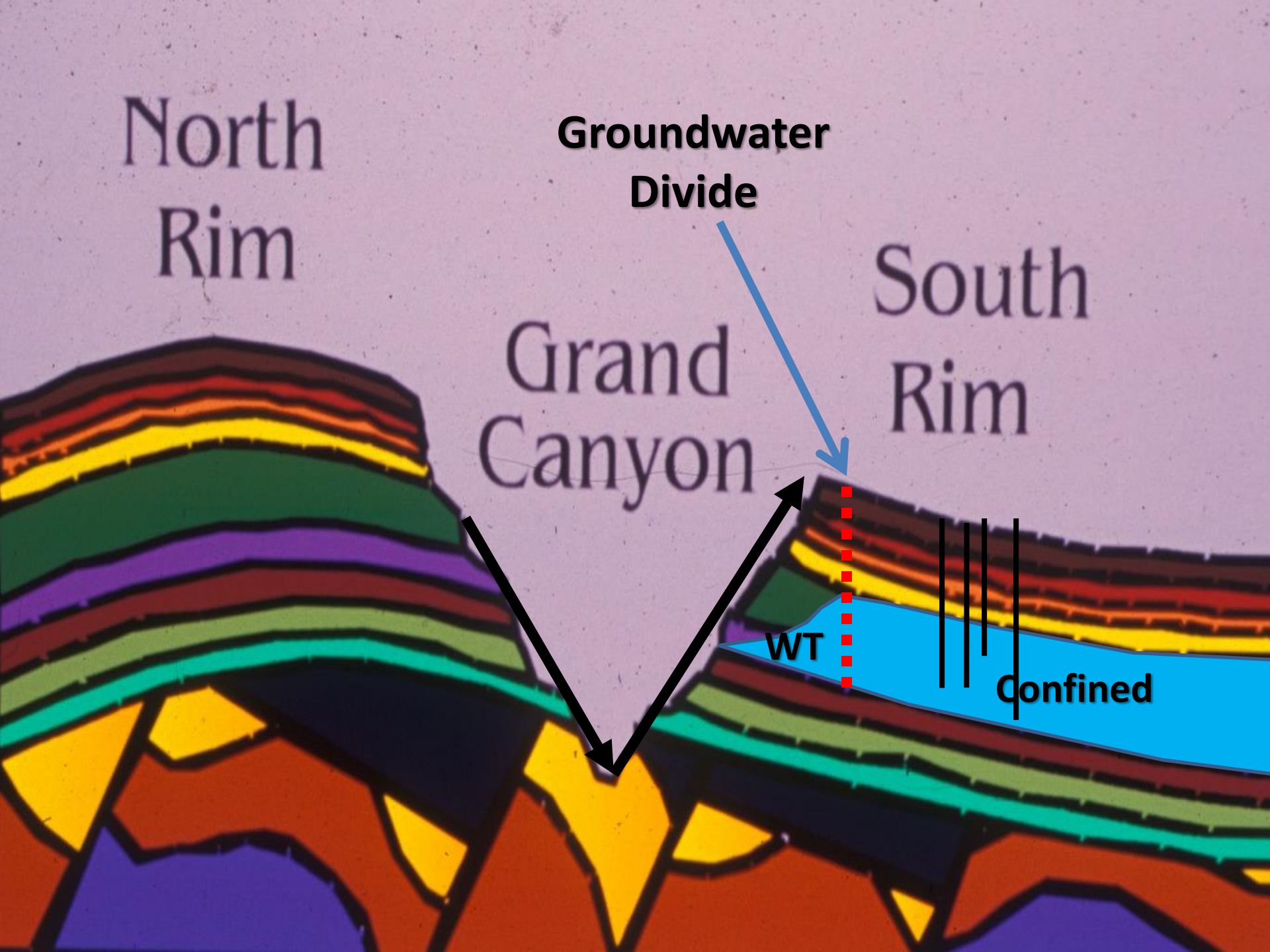

North Coyote Buttes
David Loope

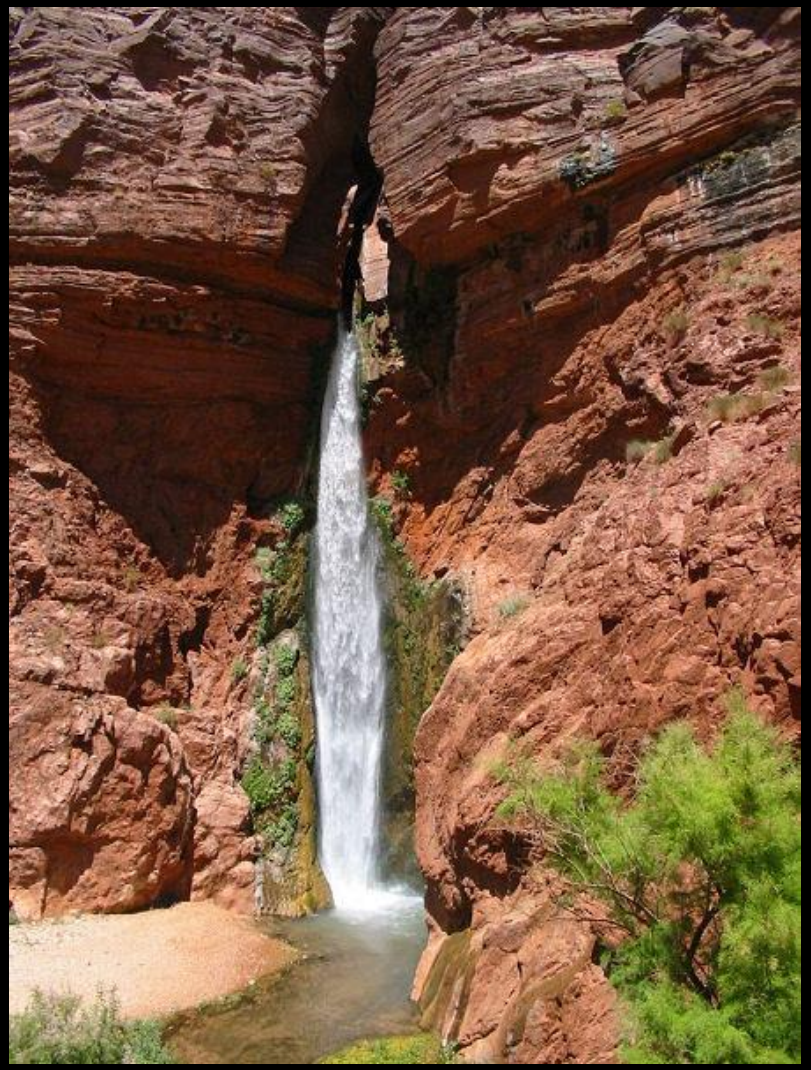
"C" Aquifer

"R" Aquifer

Stratigraphy

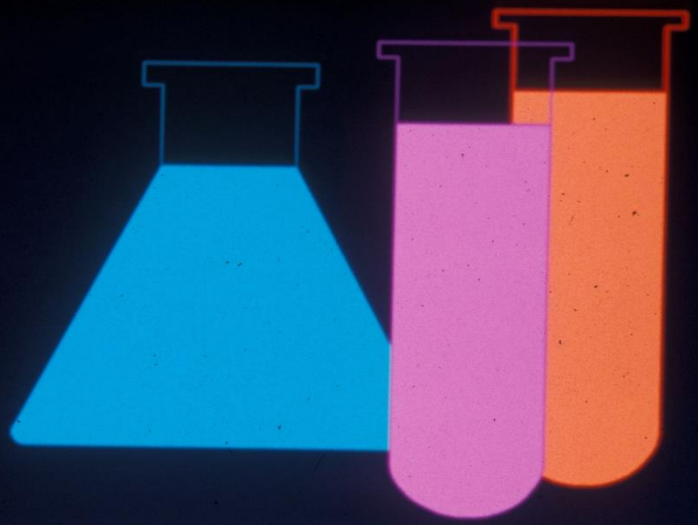



North
Rim
Groundwater
Divide
South
Rim
Grand
Canyon
WT
Confined



Methods

- Parameters
- Sampling
- Field Analysis
- Laboratory Analysis



Parameters Measured

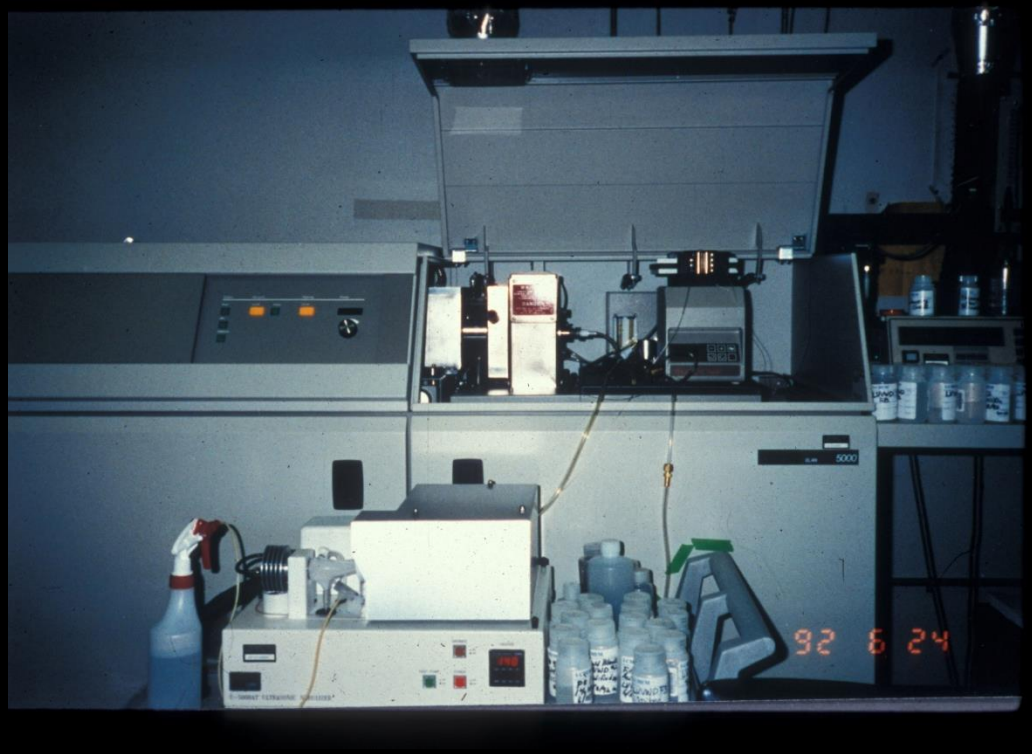
Field

- Discharge
- pH
- Alkalinity
- Temperature
- Total Dissolved Solids
- Conductivity
- Bacteriology
- Dissolved Oxygen

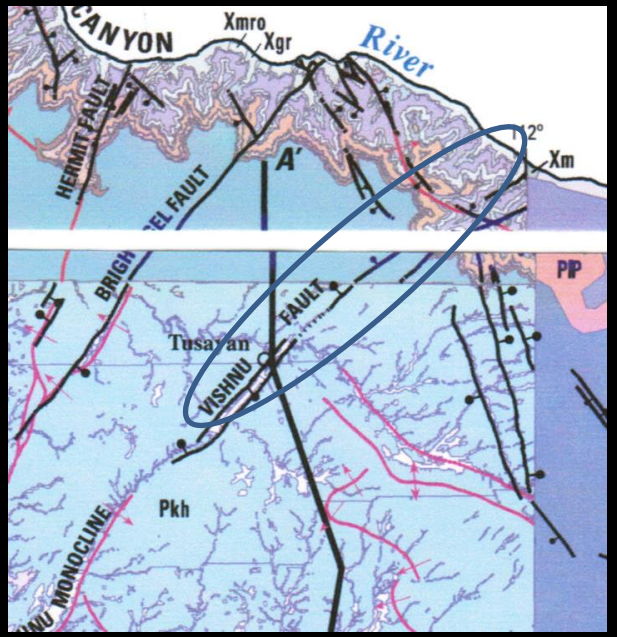
Parameters Measured

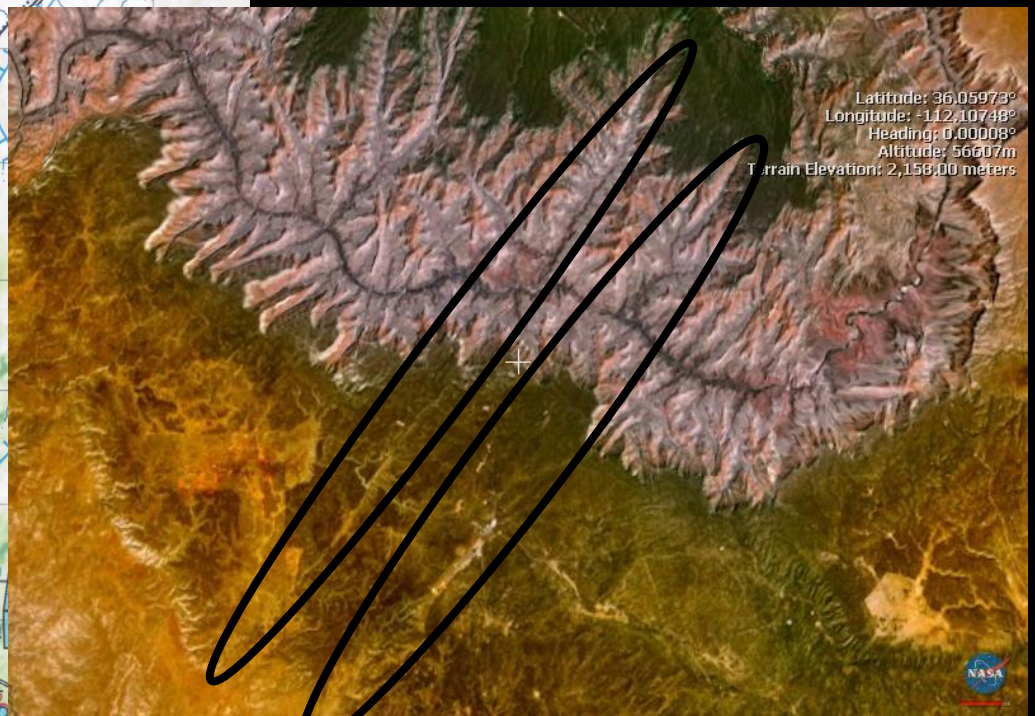
Laboratory

- Major Anions and Cations
- Stable isotopes H and O
- Chloroflourocarbons
- 50 trace Elements including the Rare Earths
- Tritium Dating
- Uranium Isotope disequilibrium




Salt Creek Spring
May 23, 2000
Lonetree Spring
May 1, 2001
Cottonwood Creek No. 2
November 29, 2000
Hermit Spring
December 4, 2000
Grapevine Main Spring
Miners Spring
June 6, 2002
Sapphire Spring
October 23, 2002
Less than 0.31
4,500
Less than 0.31
1,900
Less than 0.31
11,300
Less than 0.31
09402300
Tusayan
Canyon Spring
June 3, 2002
Less than 0.31
10,600
Canyon Mine Well
May 20, 2003
GRANDVIEW MONOCLINE
Patch Kart Well
April 13, 2004
Less than 0.31
13,700
Valle
MESA BUTTE FAULT
Rodeo Grounds Well
December 12, 2002
Less than 0.31
22,600
Williams
Parks
Ash Fork
Less than 0.31
7,500
Less than 0.3
11,100
Dogtown Well No. 1
March 30, 2001
NAD-1
June 21, 1996
Henden
June 18, 1996
Less than 0.31
5,900
WM-1
July 1
3,100
3,000
3,200
3,400
4,000
4,100
3,600
3,800
3,900
4,000


CANYON
Xmro
Xgr
River
HERMIT FAULT
A'
Xm
BRIGHT
FAULT
PP
Tusayan
VISHNU
MONOCLINE
Pkh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Longitude: -112.10748°
Heading: 0.00008°
Altitude: 56607m
Terrain Elevation: 2,158.00 meters

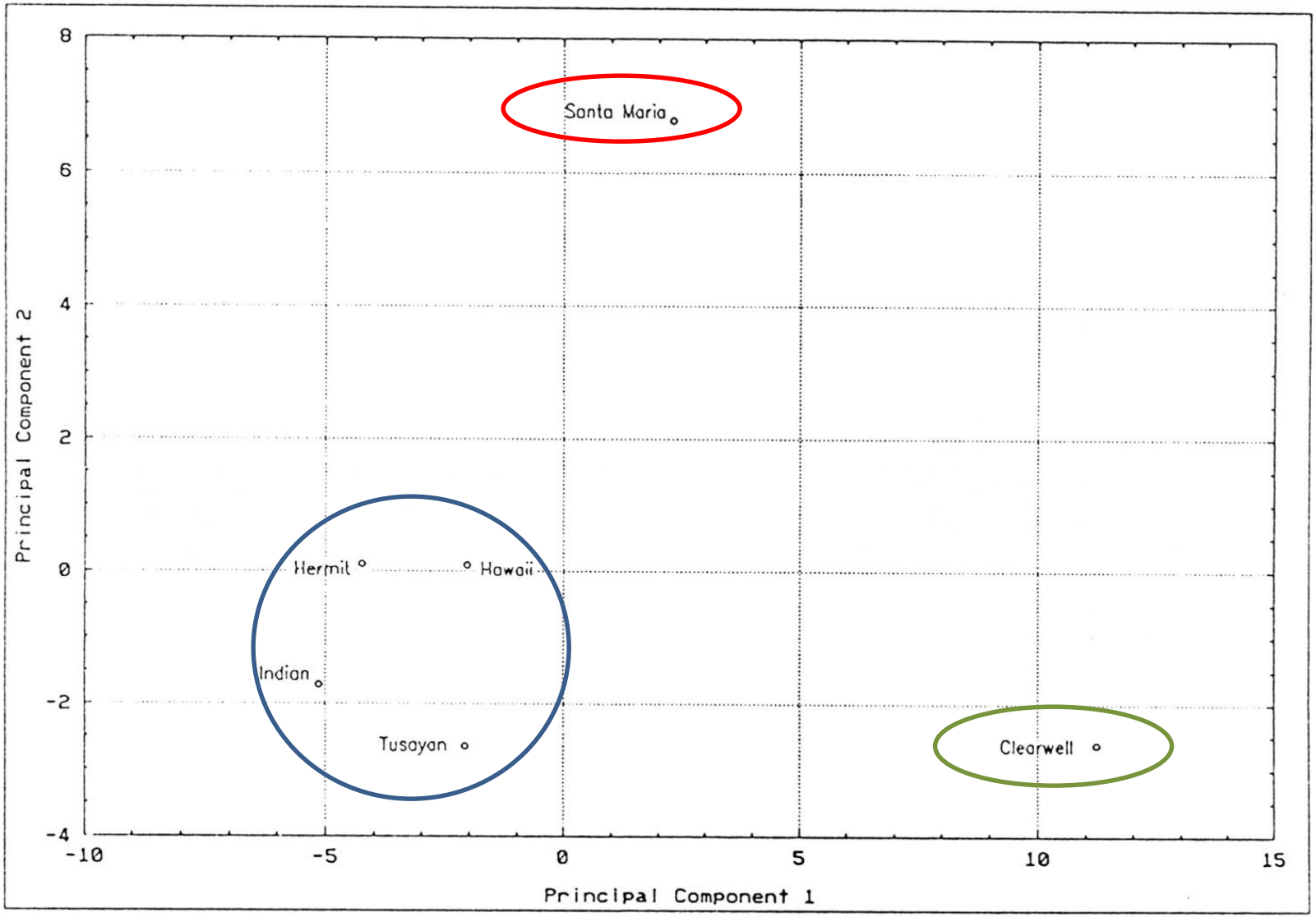
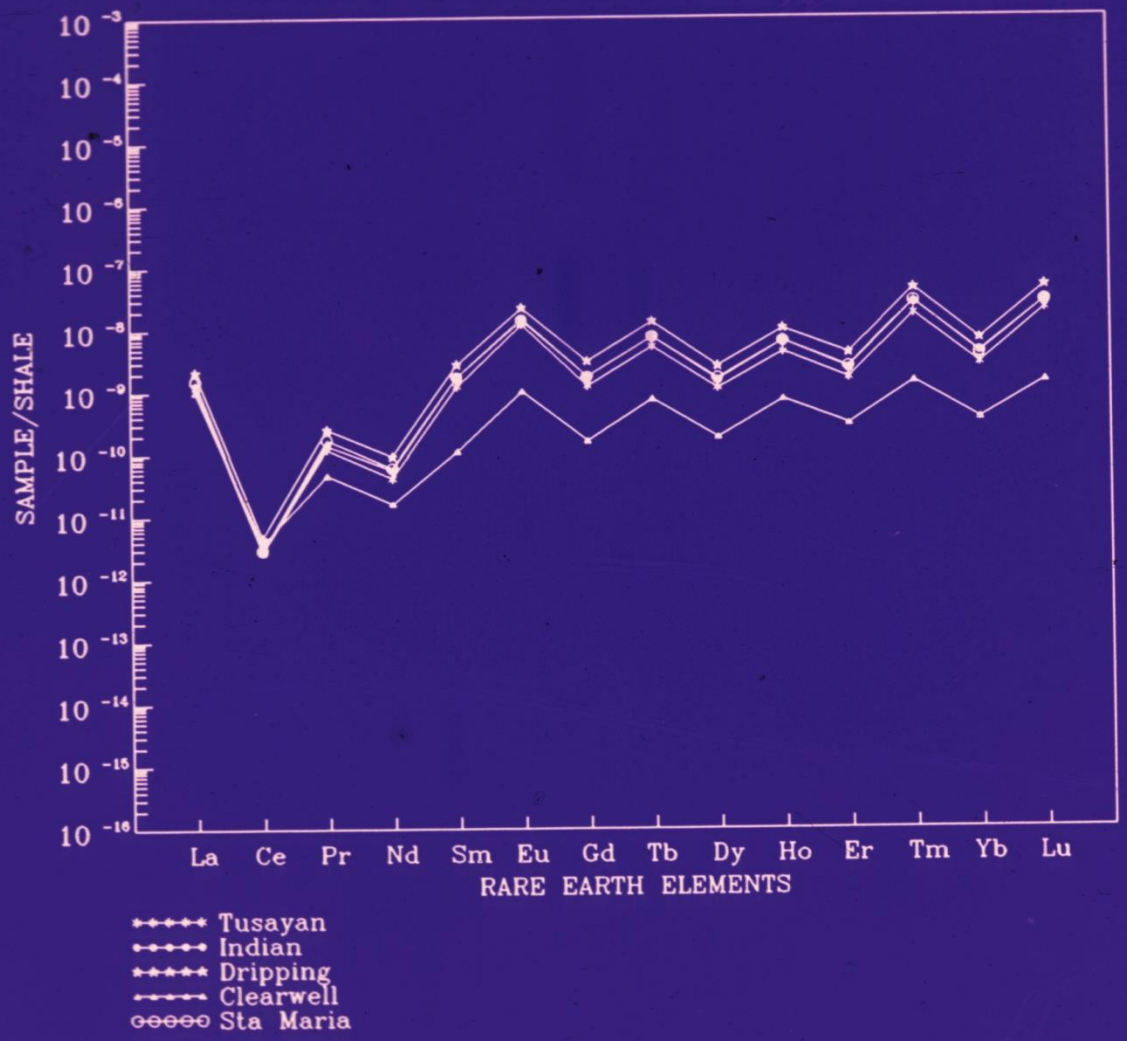
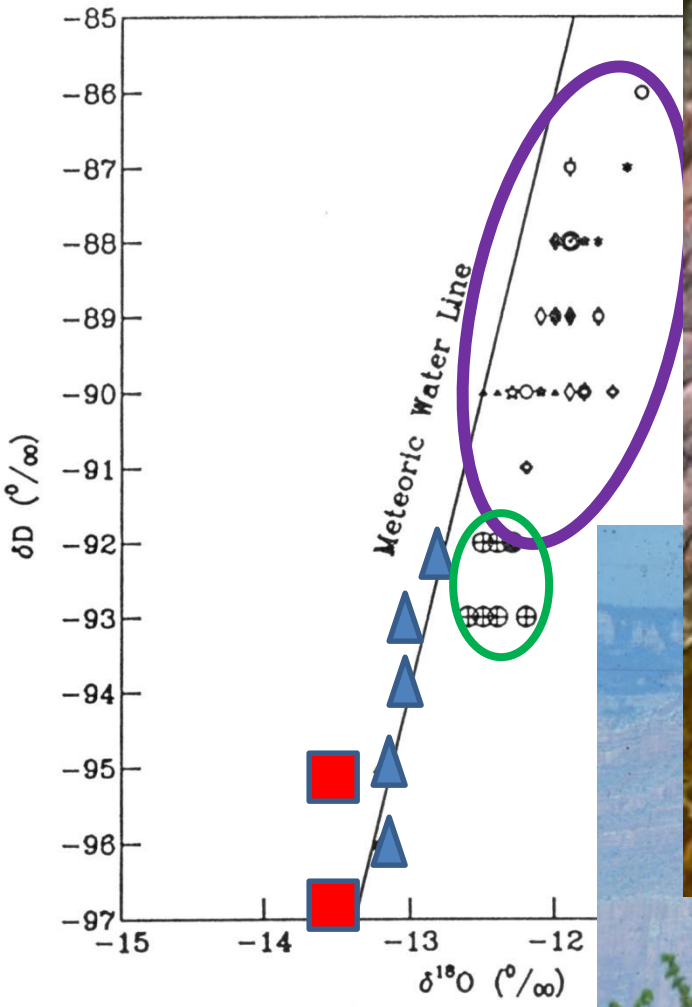
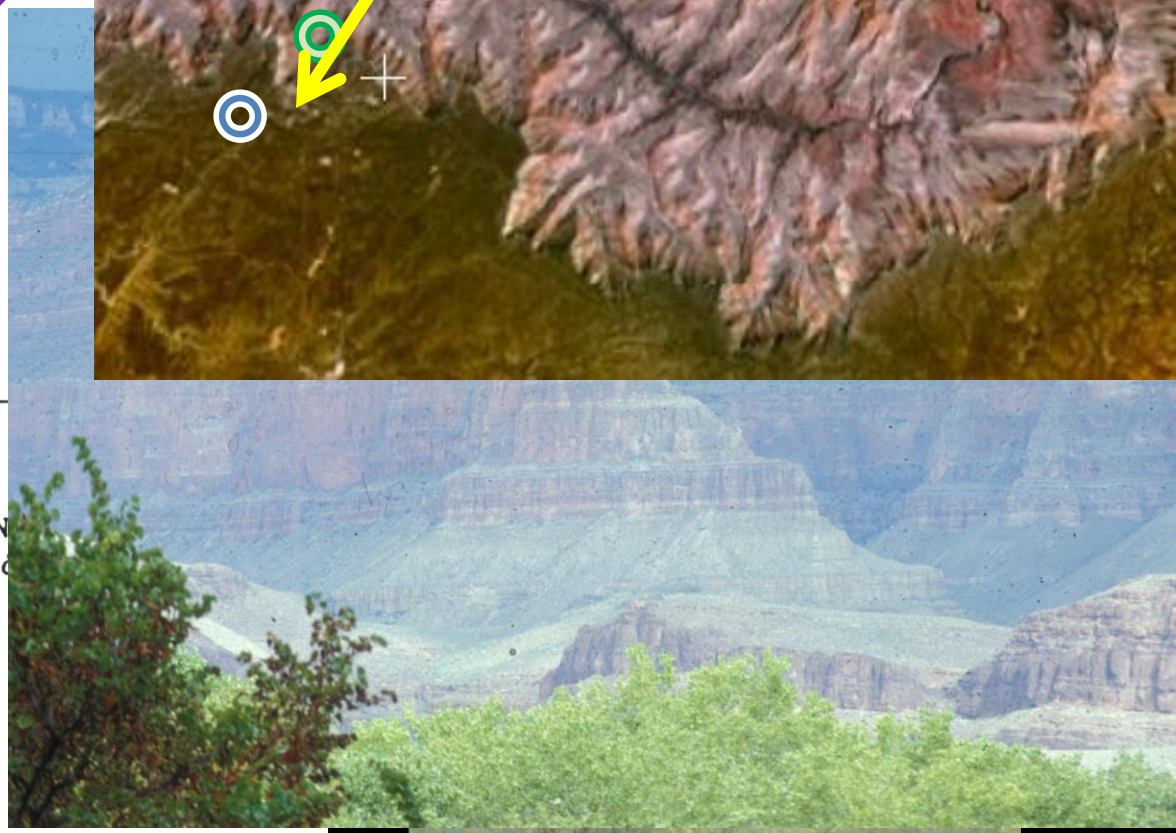


Figure 9 2-D plot of Principal Component 1 vs. Principal Component 2 for December 1992.


SAMPLE/SHALE
10 -3
10 -4
10 -5
10 -6
10 -7
10 -8
10 -9
10 -10
10 -11
10 -12
10 -13
10 -14
10 -15
10 -16
La Ce Pr Nd Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
RARE EARTH ELEMENTS
Tusayan
Indian
Dripping
Clearwell
Sta Maria


−85
−86
−87
−88
−89
−90
−91
−92
−93
−94
−95
−96
−97
δD (°/∞)
Meteoric Water Line
−15
−14
−13
−12
δ18O (°/∞)
Monument
Page
Hawaii
Dripping
Sta Maria
Tusayan
Canyon
North Rim
Horn
Salt
Hermit
Indian
Clearwell

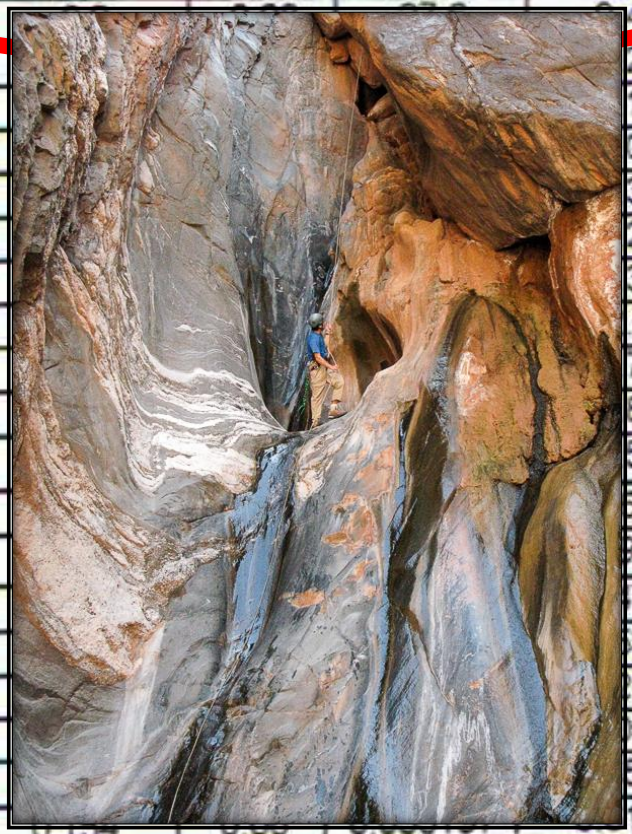

Latitude: 36
Longitude: -112
Heading: 0
Altitude:
Terrain Elevation: 2,158.00

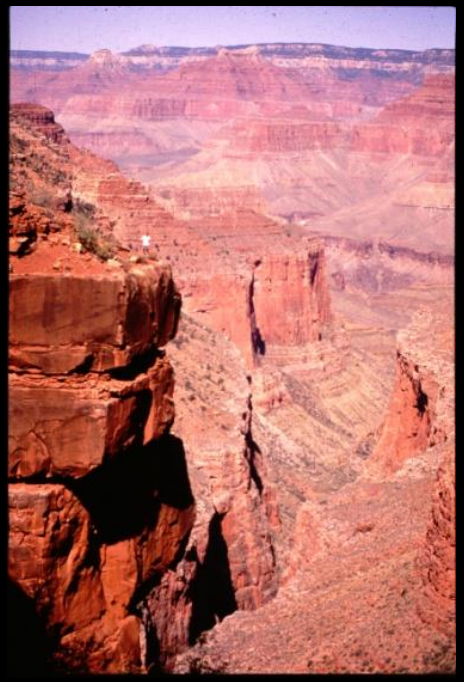



HIGH PRESSURE
WATER LINE
KEEP OFF

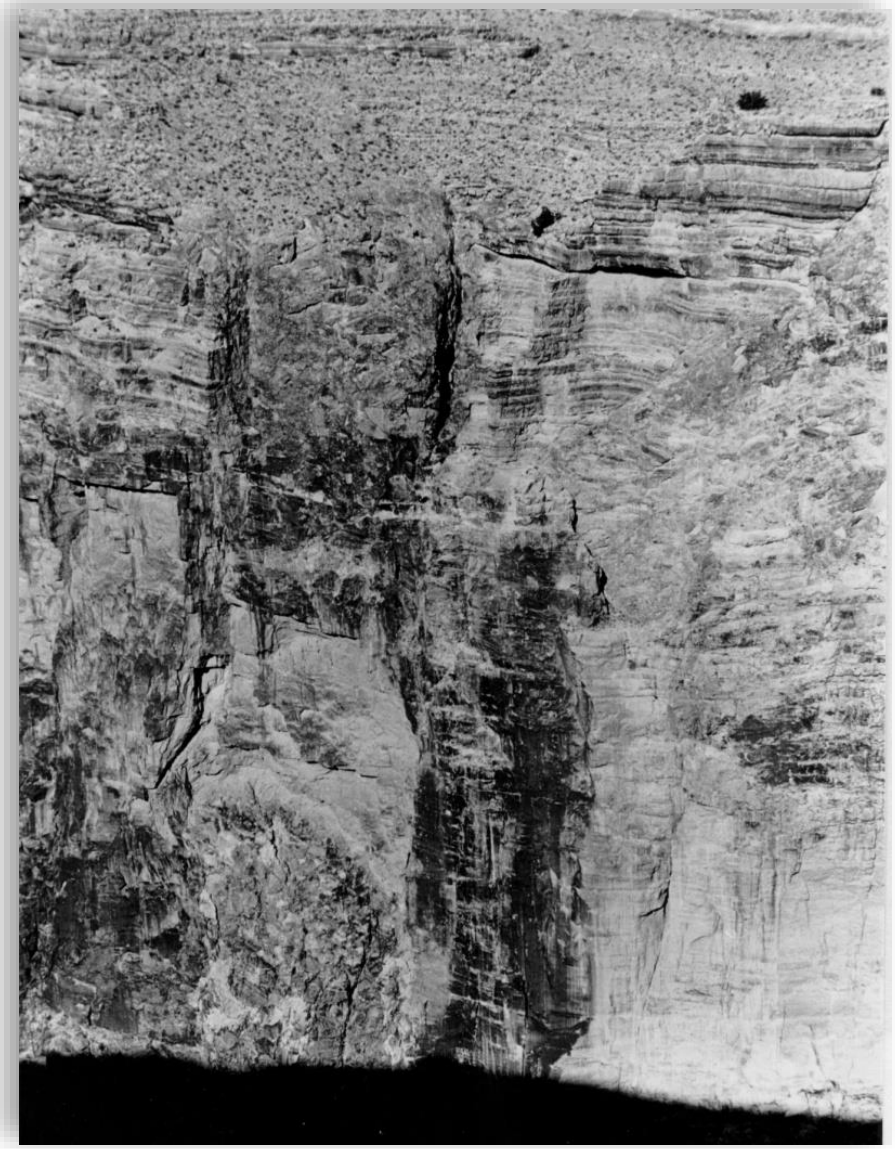
Results from spring water uranium analyses.

Sample Station	Date	238 (pCi/l)	1-σ	238 (ug/l)	234 (pCi/l)	AR	1-σ
Dripping Spring	3/17/95	0.47	0.05	1.3	1.65	3.5	0.946
Santa Maria Spring	3/17/95	2.21	0.03	6.2	4.3	1.9	0.083
Hawaii Spring	3/18/95	0.94	0.02	2.6	2.68	2.8	0.21
Hermit Source Spring	3/18/95	1.01	0.02	2.8	2.89	2.9	0.18
Monument Creek	3/18/95	3.24	0.04	9	6.71	2.1	0.066
Cedar Spring	3/18/95	5.57	0.05	15.6	10.59	1.9	0.052
Salt Creek	3/19/95	5.23	0.05	14.6	8.03	1.5	0.041
Horn Creek	4/30/94	8.76	0.09	24.7		0.94	0.032
	3/19/95	33.21	0.12	92.7	27.82	0.8	0.011
	6/5/95				48	1	0.023
Two Trees Spring	4/30/94				26	3.5	0.654
	6/5/95				16	3.7	0.31
Pipe Creek	4/29/94				04	2.8	0.52
	6/4/95				33	2.7	0.157
Burro Spring	4/29/94				23	2.6	0.59
Cremation Creek	6/4/95				35	2	0.108
Sam Magee Spring	6/3/95				.2	1.6	0.083
Lonetree Spring	6/3/95				71	1.6	0.071
Boulder Creek	6/3/95				84	2	0.084
Grapevine Spring	5/13/95				54	3.6	0.286
Grapevine East Spring	5/13/95				68	1.7	0.198
Grapevine-Hell Spring	5/13/95				94	2	0.117
Cottonwood Spring	5/12/95				7	3.6	0.42
Cottonwood West Spring	5/13/95				3	2.2	0.095
Page Spring	5/12/95				24	1.6	0.139
	9/9/95				19	1.6	0.111
Indian Garden Pump Station	4/30/94				56	4.8	9.25
Bright Angel Creek (N. Rim)	4/30/94				19	3.8	5.32

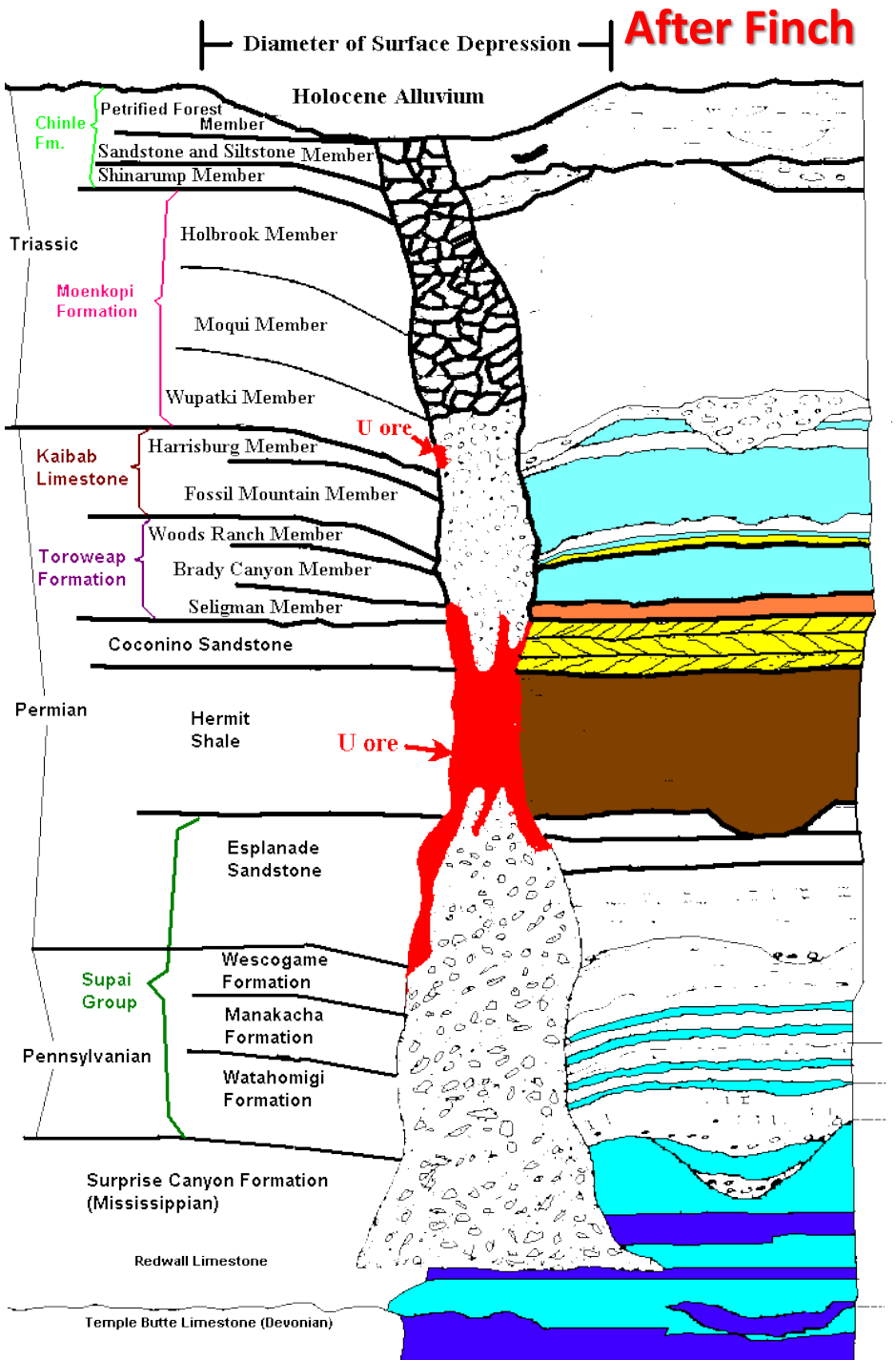




Uranium Breccia Pipe Deposits



Laughlin, 1983

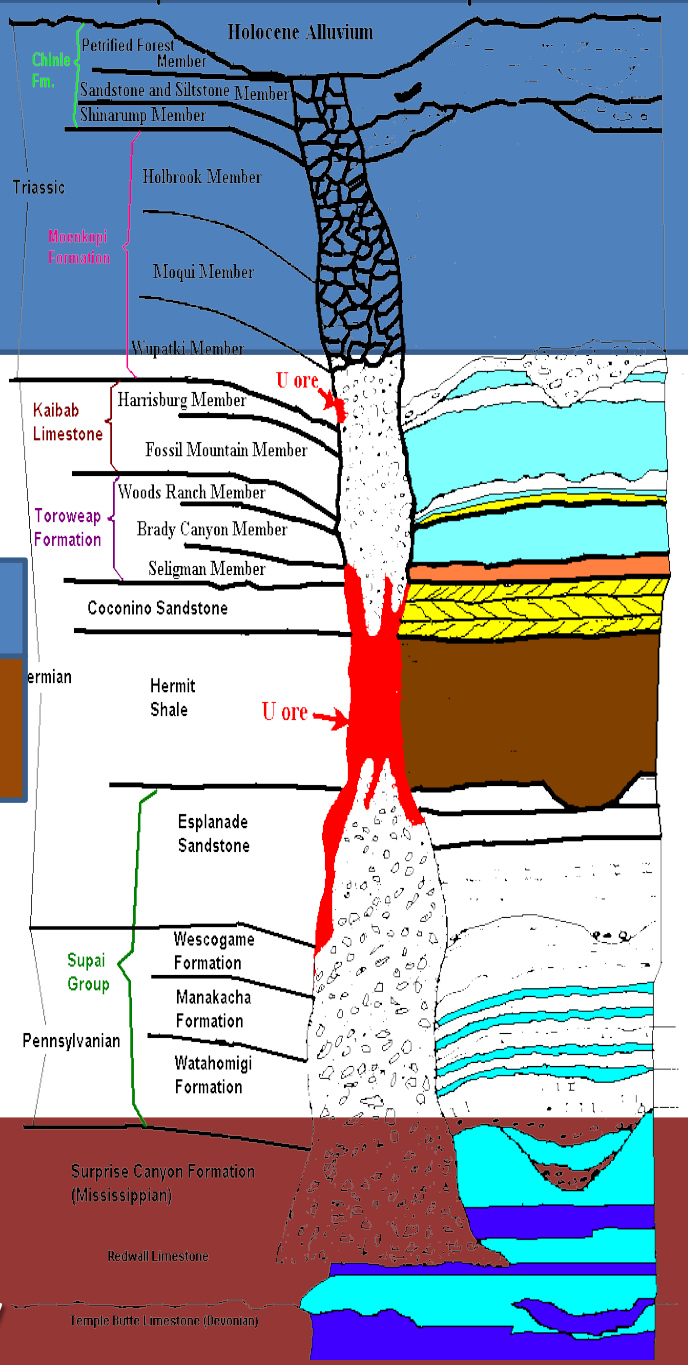


Piercing the Perched Aquifer?

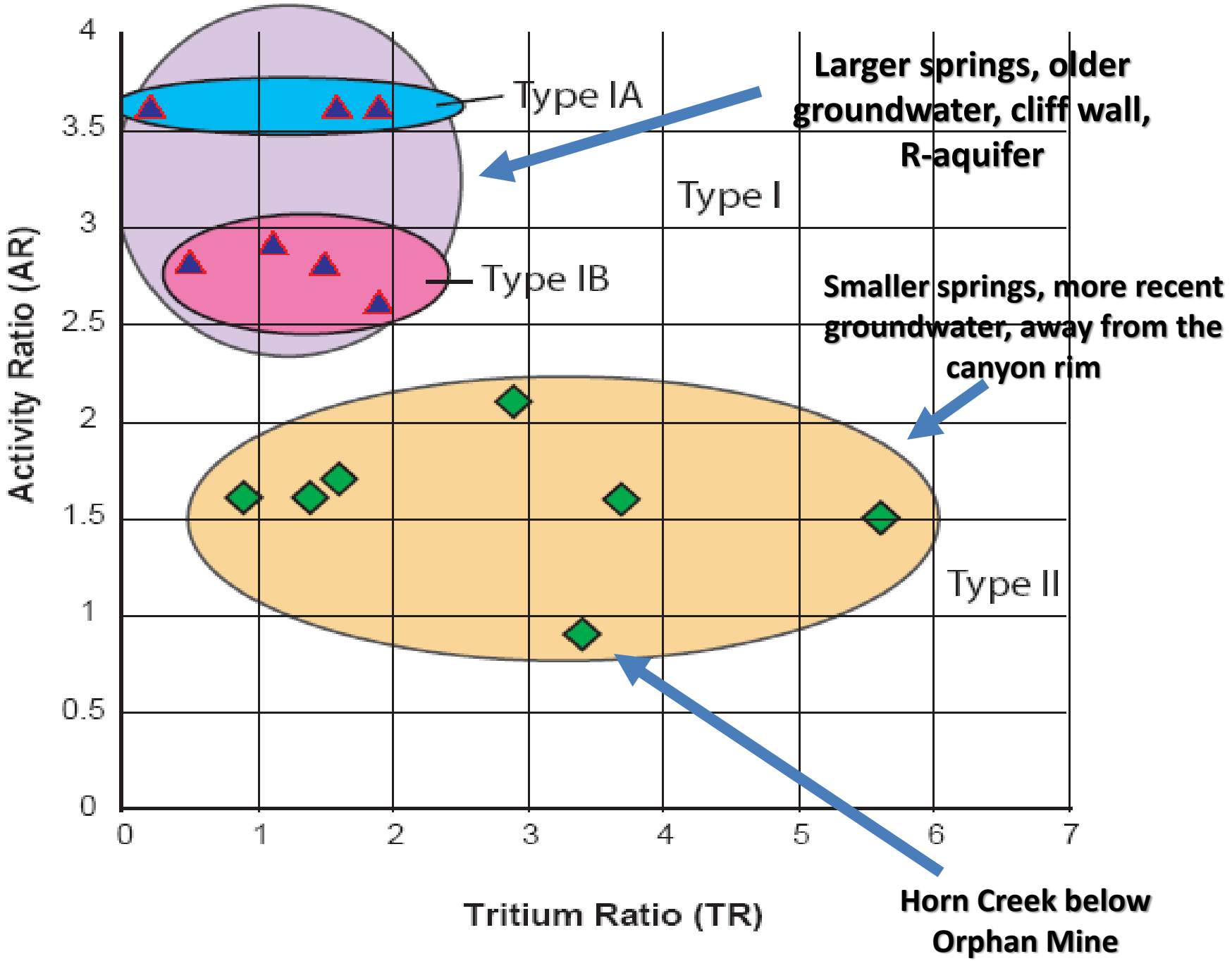
Vertical Shaft

Perched Water

Hermit Shale – Low permeability



Redwall - Muav


Activity Ratio (AR)
Tritium Ratio (TR)
0
0.5
1
1.5
2
2.5
3
3.5
4
0
1
2
3
4
5
6
7
Type IA
Type IB
Type I
Type II
Larger springs, older groundwater, cliff wall, R-aquifer
Smaller springs, more recent groundwater, away from the canyon rim
Horn Creek below Orphan Mine

Research Conclusions

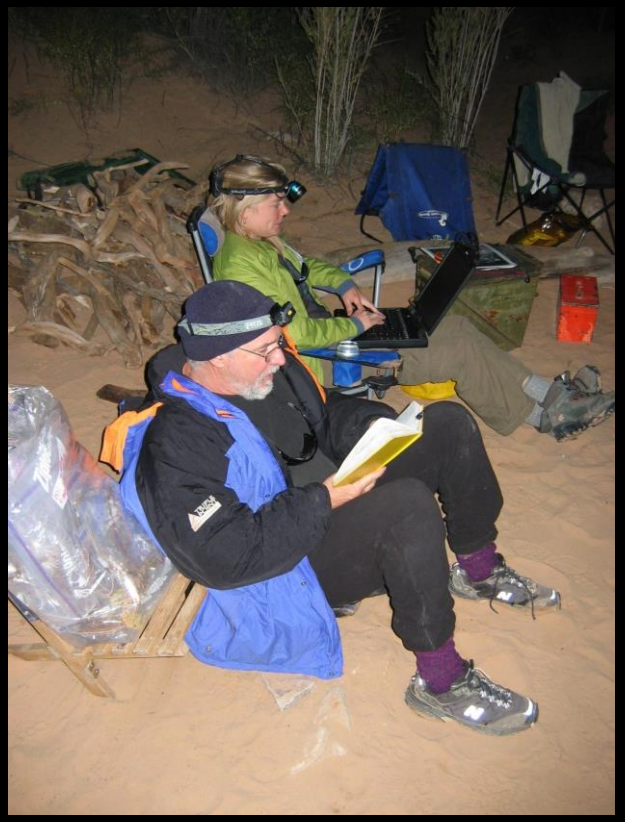
Springs issuing from similar stratigraphic units and geographic areas have similar trace element chemistry

Local groundwater chemistry is similar to springs, particularly Redwall-Muav limestone group

Research Conclusions
(continued)

South Rim Waters are depleted in the light rare earth elements as compared to the heavy rare earth elements

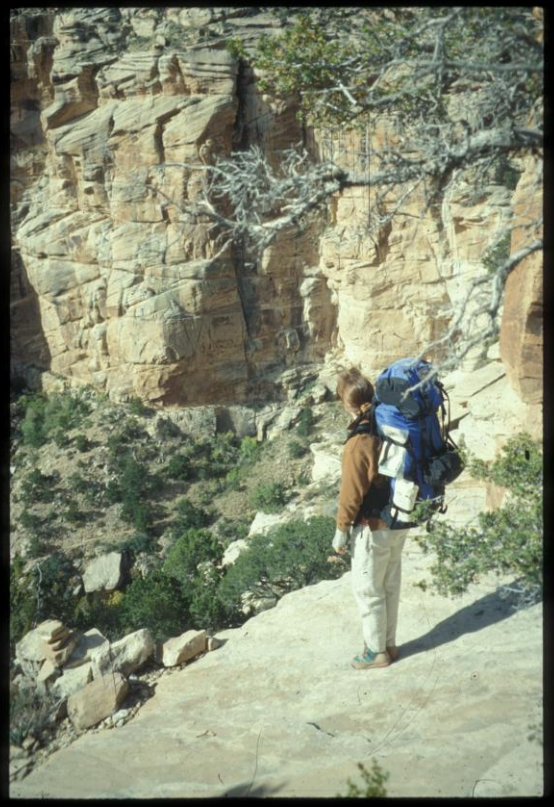
High uranium concentrations below site of Orphan Mine



Research Conclusions
(continued)

Low tritium in springs and local groundwater, likely result of pre-1950's rainwater recharge to local aquifer

No chlorofluorocarbons in springs; perhaps pre-1930's rainwater replenishment of groundwater system

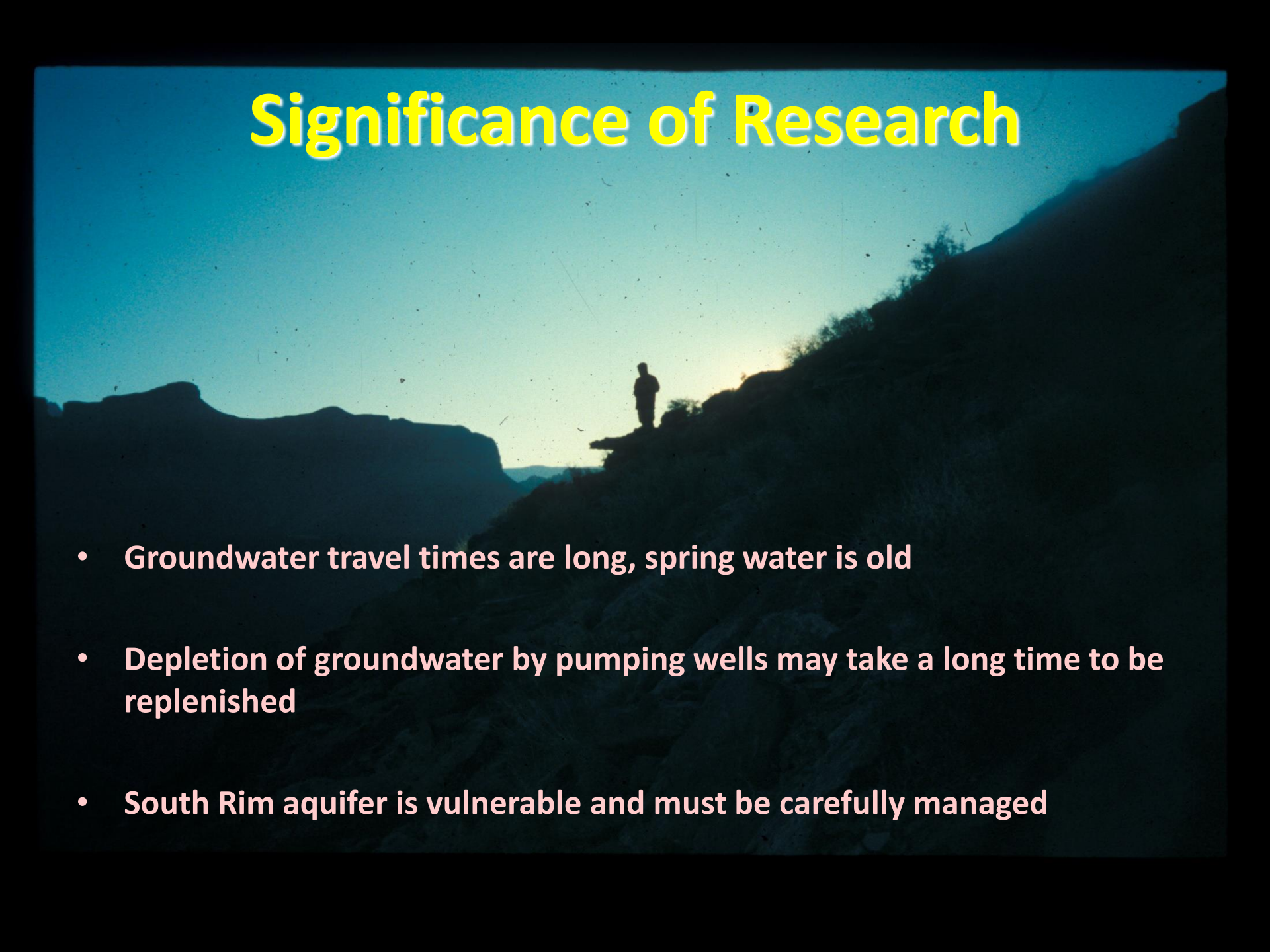


Research Conclusions
(continued)

Uranium Isotope Disequilibrium methods seem to distinguish spring waters

Stable isotopes of hydrogen and oxygen are different for North and South Rim waters

Significance of Research



- Groundwater travel times are long, spring water is old
- Depletion of groundwater by pumping wells may take a long time to be replenished
- South Rim aquifer is vulnerable and must be carefully managed

Conclusion

Water quality can be used for better understanding

Thank you!