BRASS

Bedrock **R**egional **A**quifer **S**ystematics **S**tudy

Objective: Understand geologic controls on ground water behavior and chemical evolution in fractured bedrock

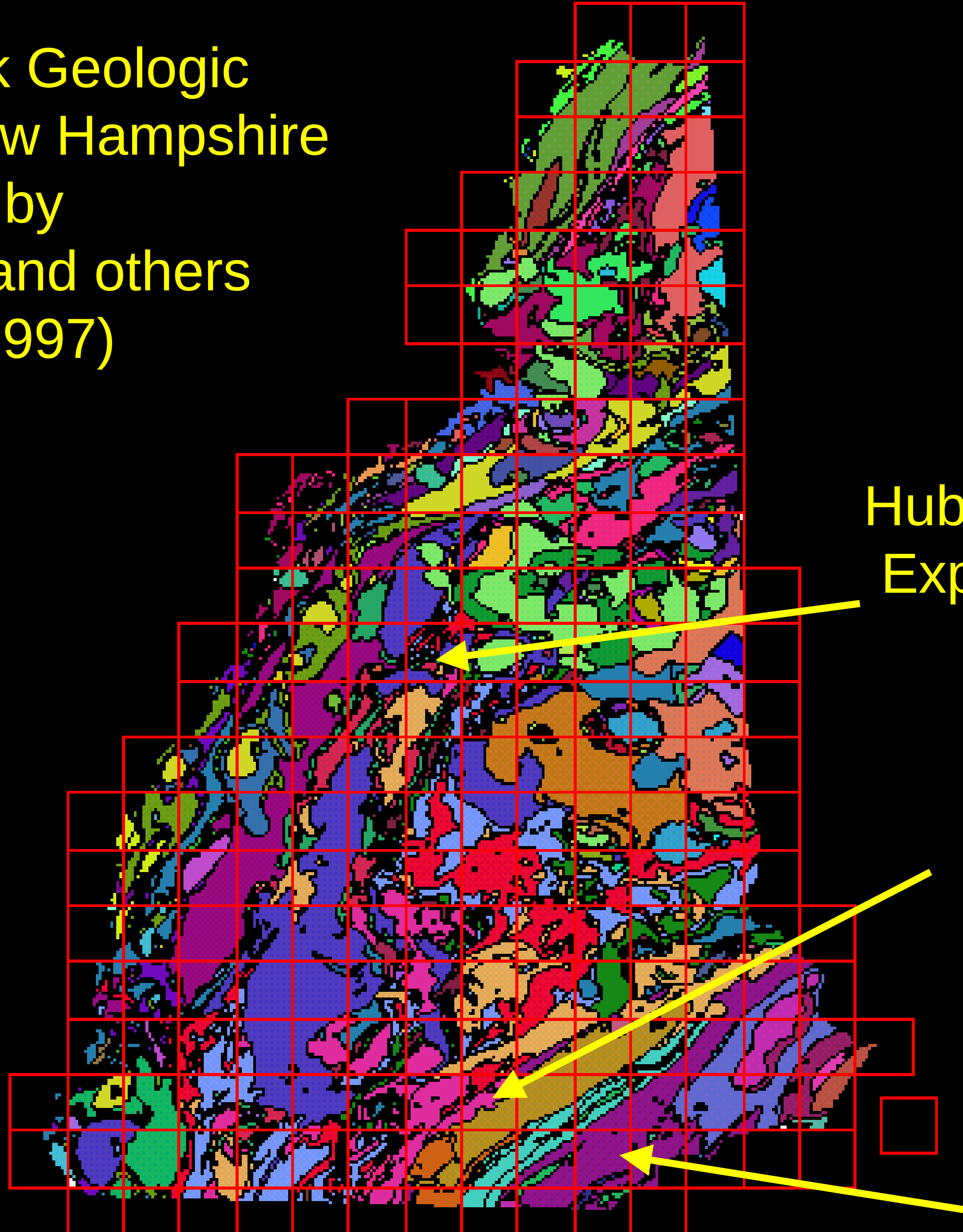
USGS

BRASS mapping and hydrogeologic studies in crystalline terranes

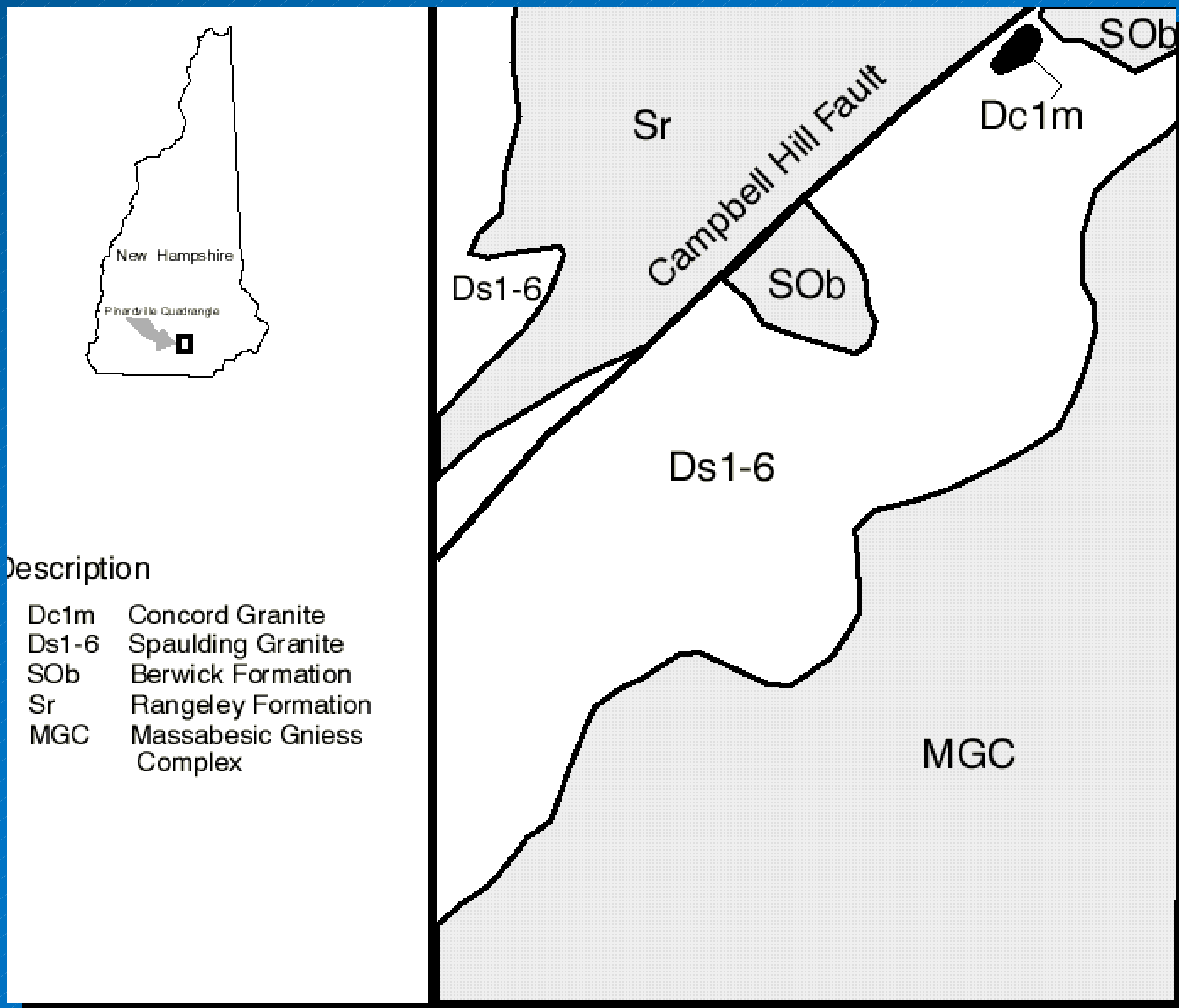
USGS

26 June, 2001

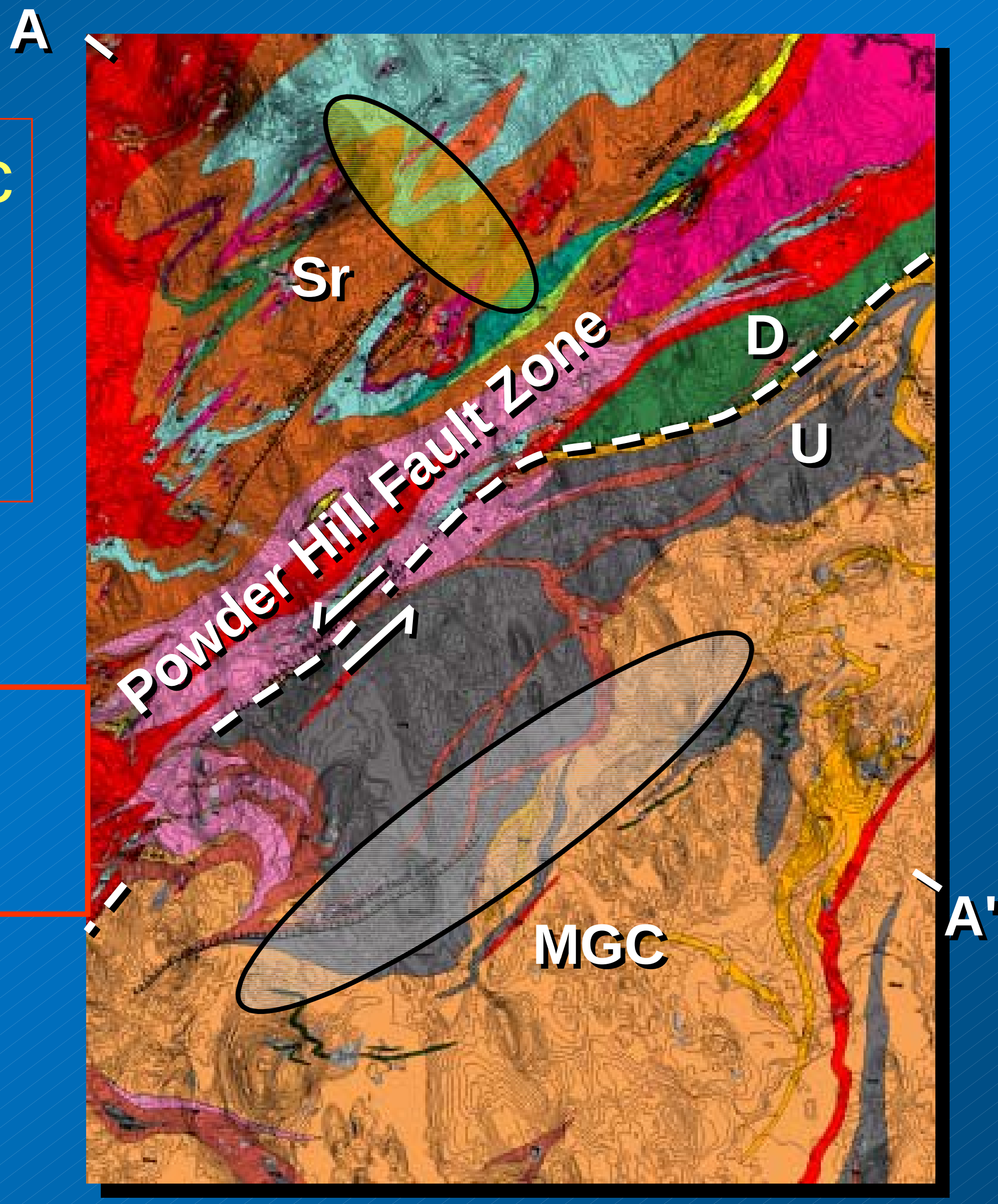
Bedrock Geologic Map of New Hampshire by Lyons and others (1997)



Pinardville Study Area



Bedrock geologic Map of the Pinardville 7.5' Quad, NH

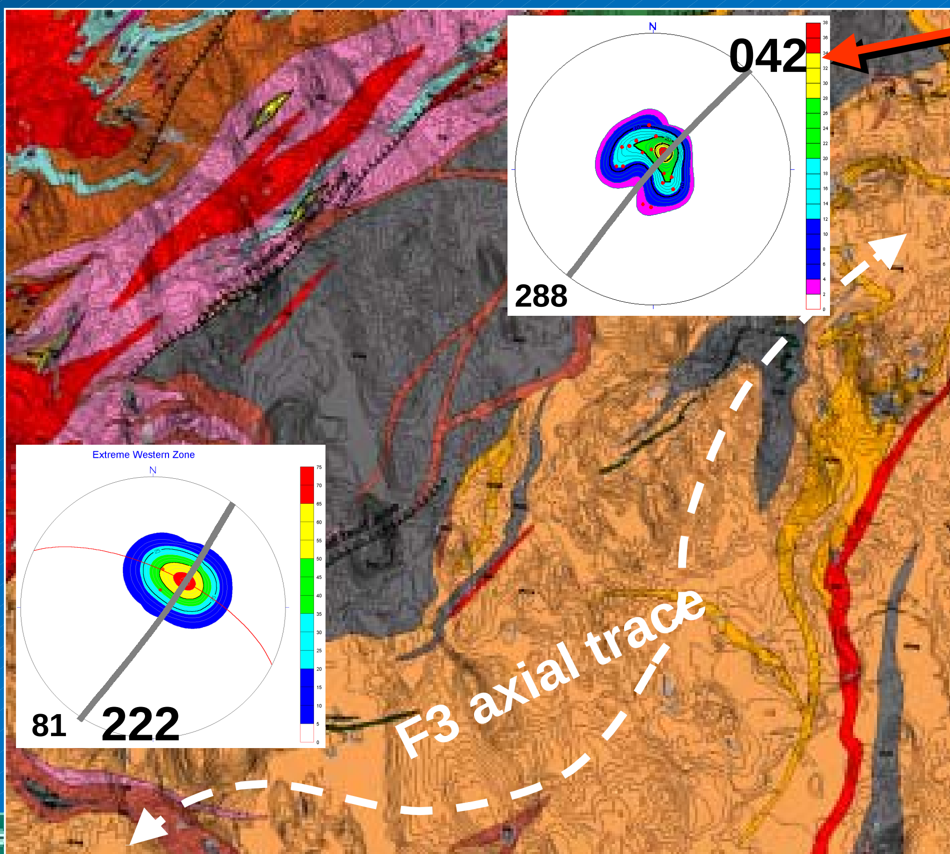


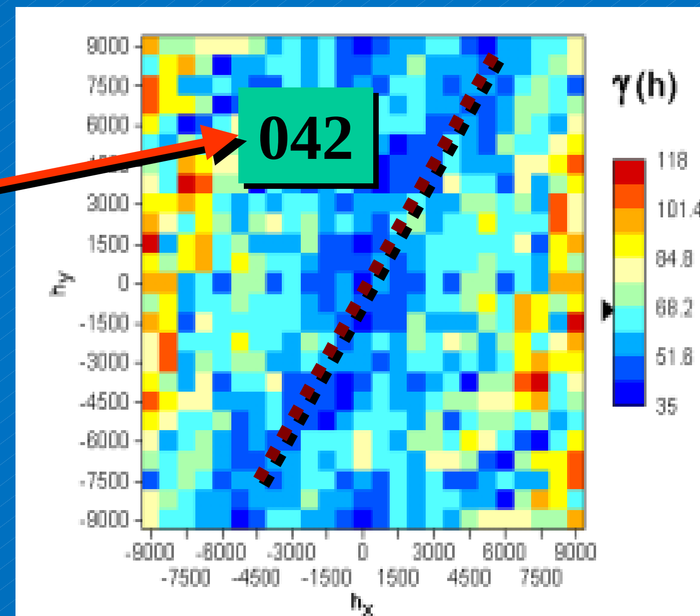
Source-water and Wellhead Protection Zones

USGS

Correlation between Fractures and Well Data

042 Trending Fractures….





*And **same** trend to well yields*

Pinardville Quadrangle: Comparison of model results with detailed mapping variables (left) versus just the statewide variables (right).

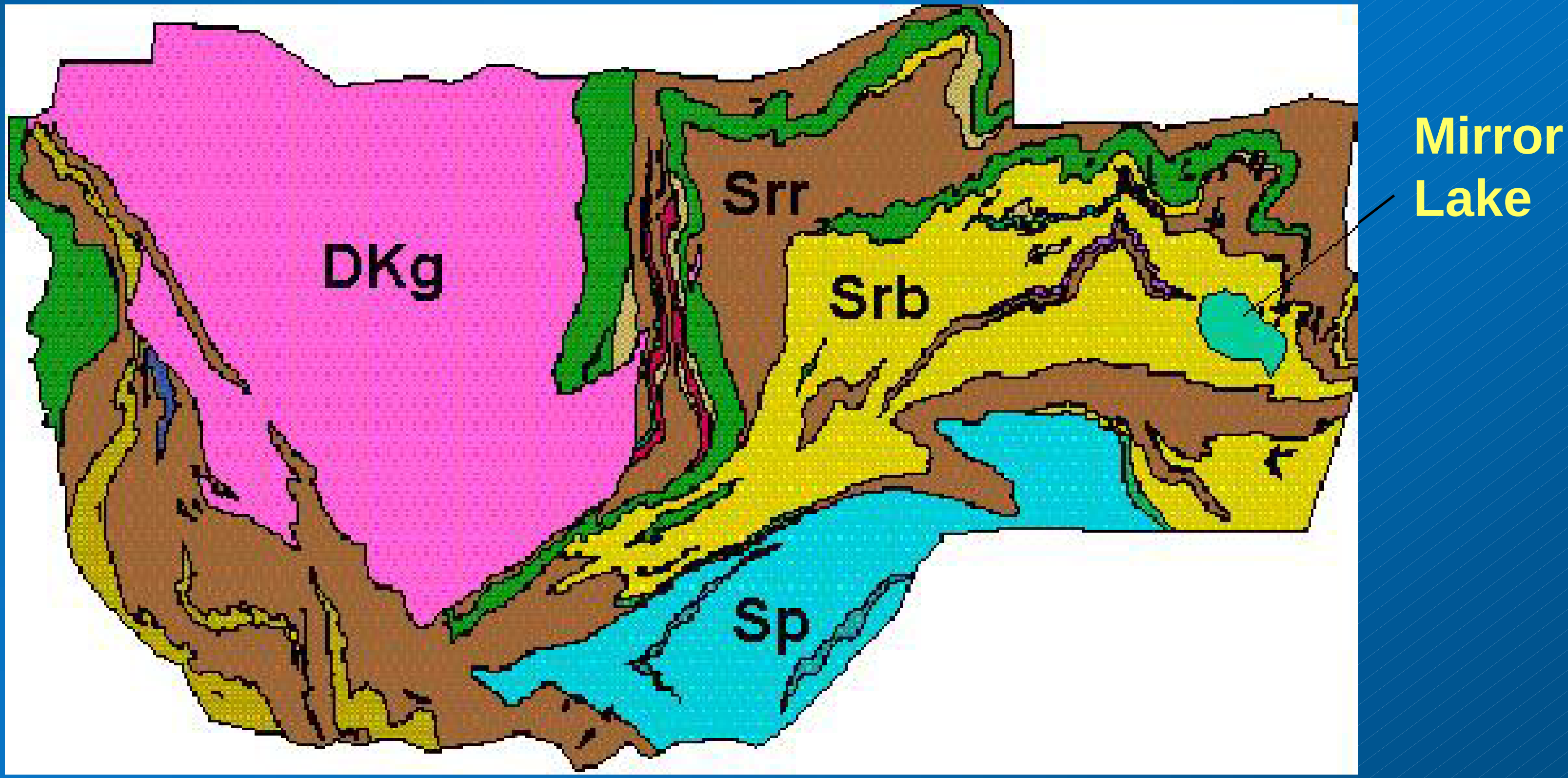
USGS

Added value of field-based methods for well-yield-probability forecasting

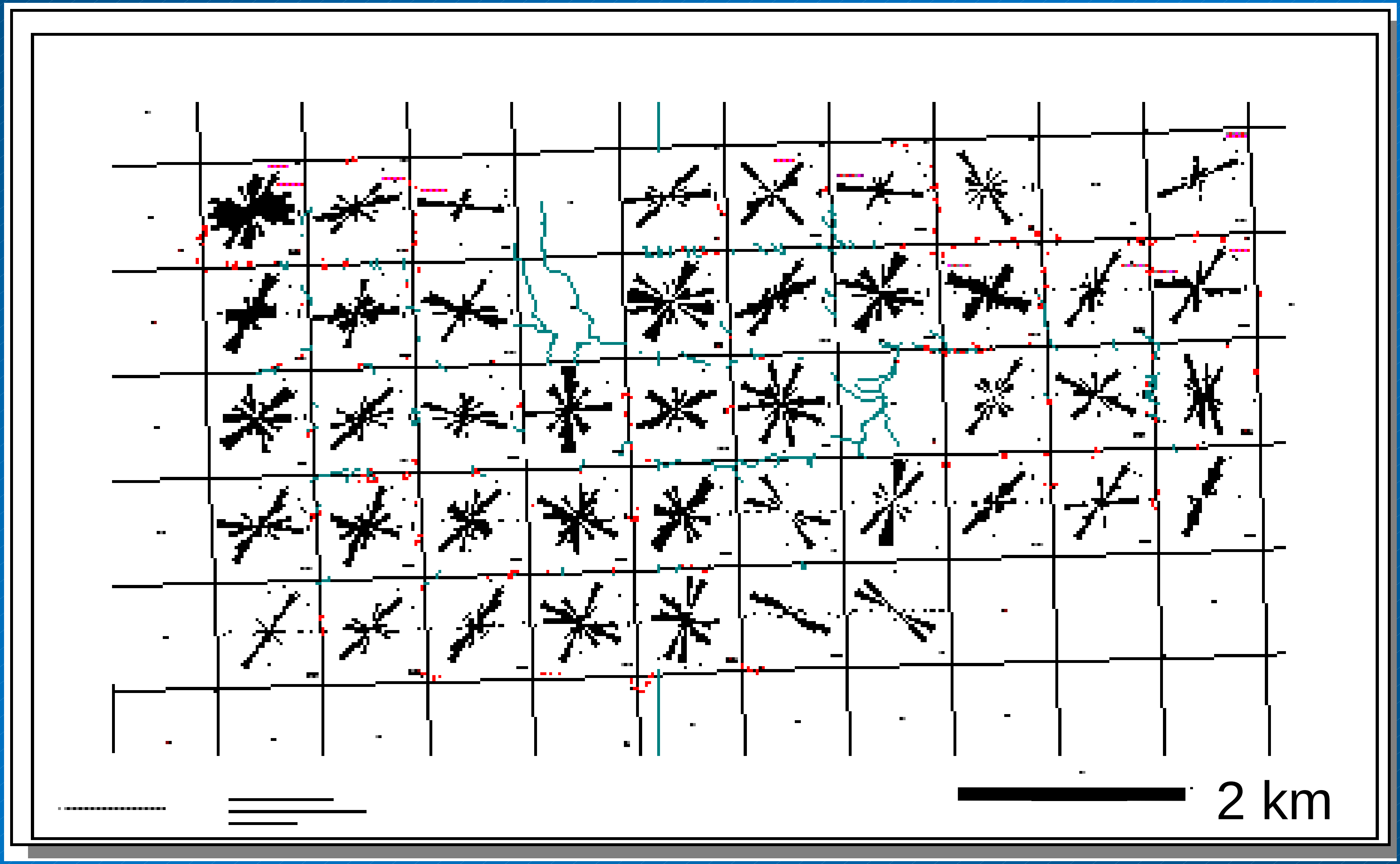
Probability of obtaining 40 gallons per minute (gpm) or more by 400 feet well depth	Percentage of quadrangle meeting probability criteria with detailed geologic mapping variables **included**	Percentage of quadrangle meeting probability criteria with detailed geologic mapping variables **excluded**
Pinardville Quadrangle:		
20	8.10	3.47
25	4.32	2.42
30	2.66	0.57
35	1.66	0.04
40	0.90	0.03
45	0.52	0.01
50	0.28	0
60	0.09	0
70	0.02	0

USGS

BRASS 1:10K-scale geologic map of USFS Hubbard Brook Experimental Forest--site of USGS Mirror Lake fractured-rock research site



Hubbard Brook fracture data



Frequency-azimuth plots (Rose diagrams)

Digital Data Acquisition

3Com Palm III PDA

- affordable
- pen-based
- portable
- widely used

Rockwell PLGR+96 GPS

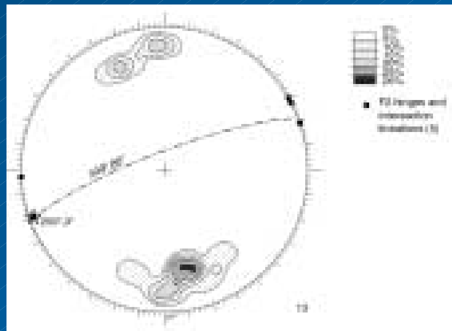
- PPS accuracy
- +/- 5 m
- 999 waypoints
- ASCII out

Laptop Computer

- Windows OS

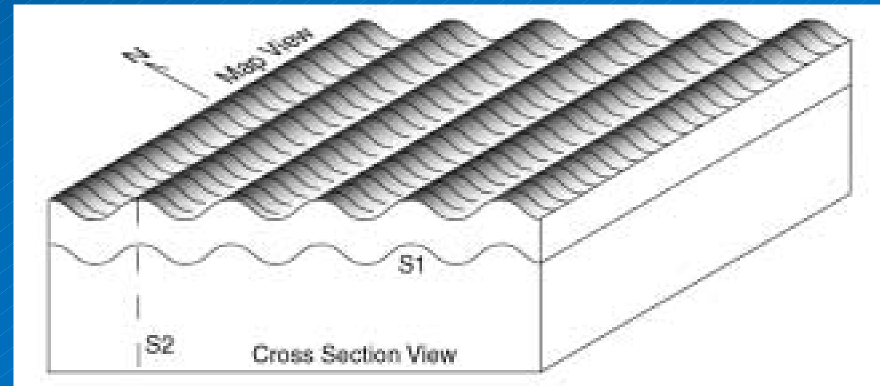
Alternatives:
DGPS
Post-processing SA

USGS



Steeply dipping

S2 cleavage & F2 folds



Combined with sub-horizontal S1

Control bedrock topography and produce

NE trending ridges and valleys

Directional anisotropy in the bedrock is a function of:

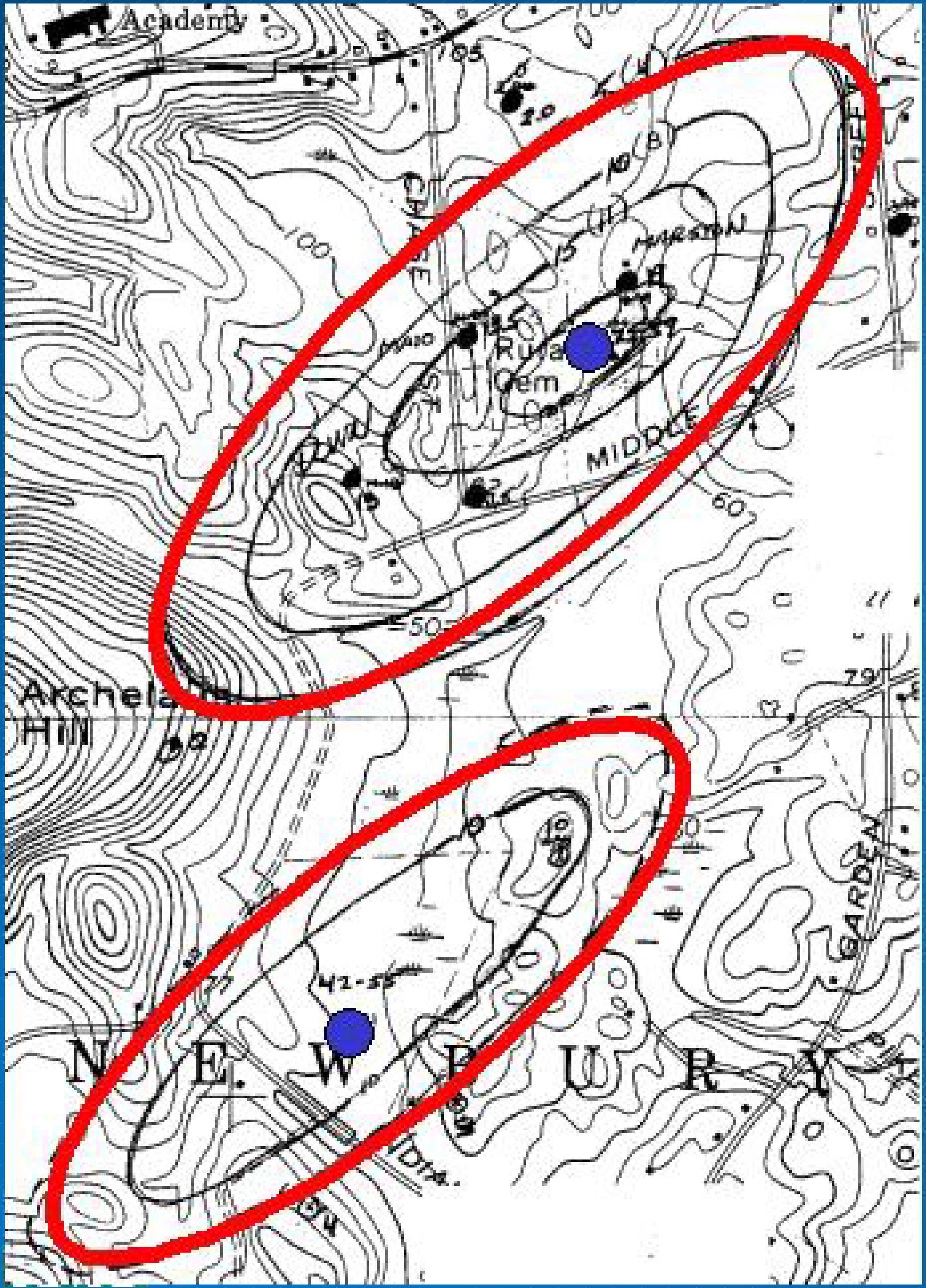
Corrugated S1

Bedrock topography

S2 cleavage with vugs

Steep fractures to NE & NW

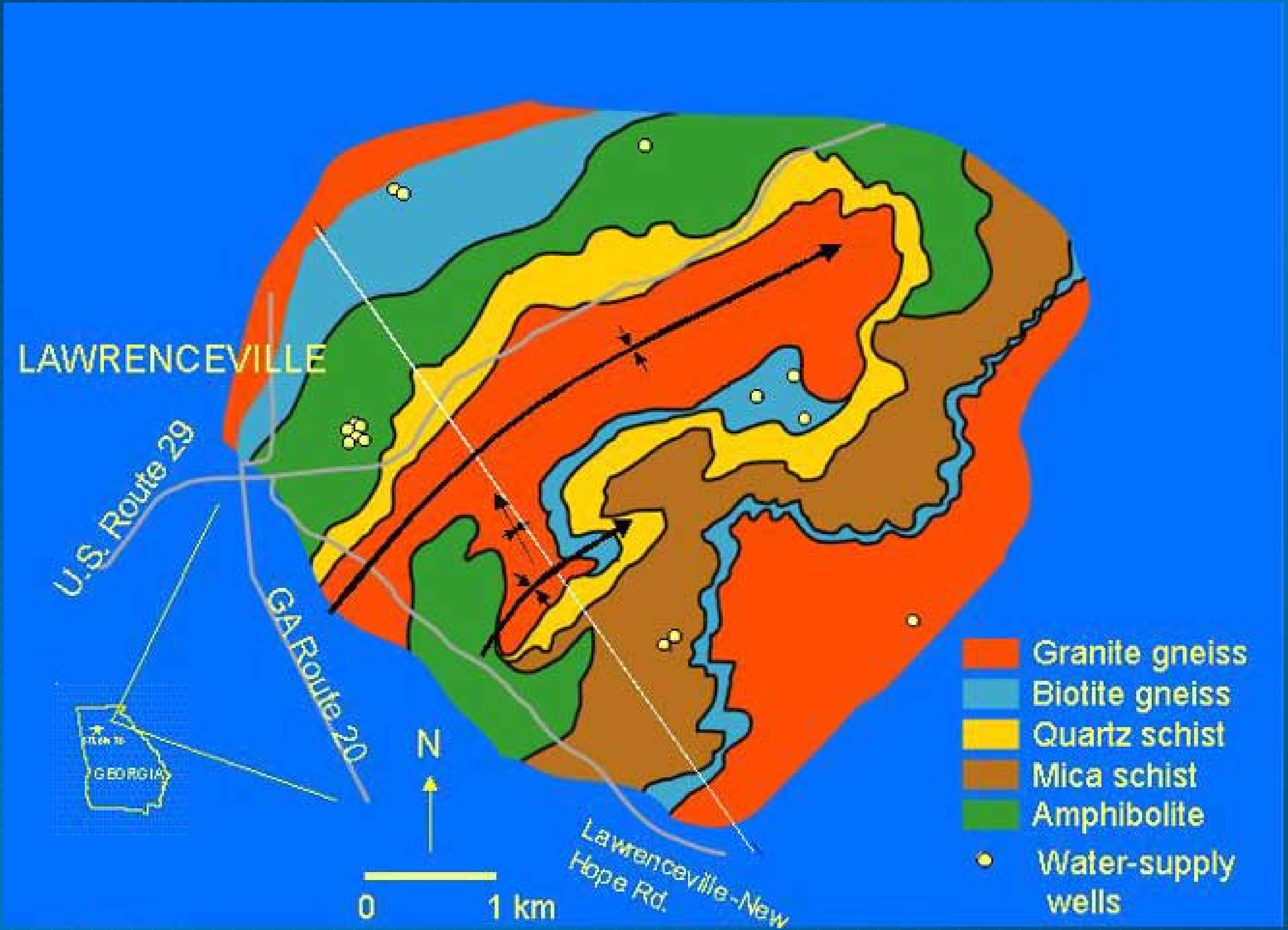
USGS



Elliptical drawdown oriented NE during 11 day pump test

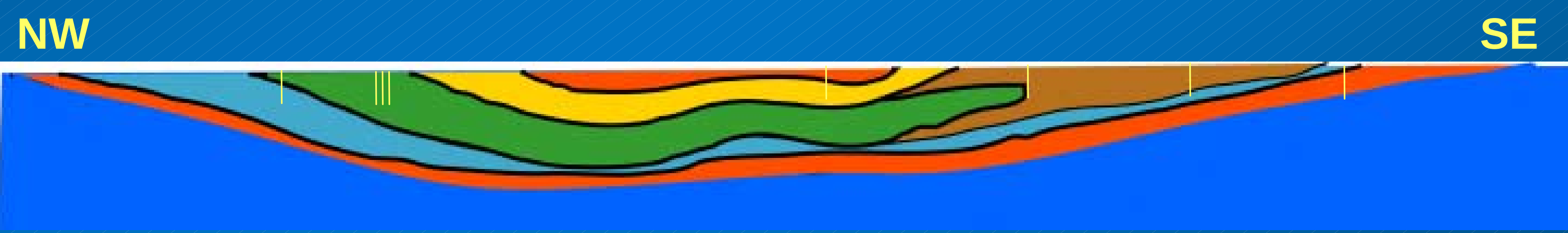
Preliminary results from Lyford and others

Drawdown agrees with directional anisotropy in bedrock


LAWRENCEVILLE
U.S. Route 29
GA Route 20
GEORGIA
N
0
1 km
Lawrenceville-New Hope Rd.
Granite gneiss
Biotite gneiss
Quartz schist
Mica schist
Amphibolite
Water-supply wells

USGS

- The Lawrenceville area consists of gently-dipping thrust sheets in a broad synform.
- The lithologies in these sheets have greatly differing ground-water yields
- Ground water yields in these rocksare controlled primarily by weathered-out voids parallel to foliation, not steeply-dipping brittle fractures--hence the strong lithologic control

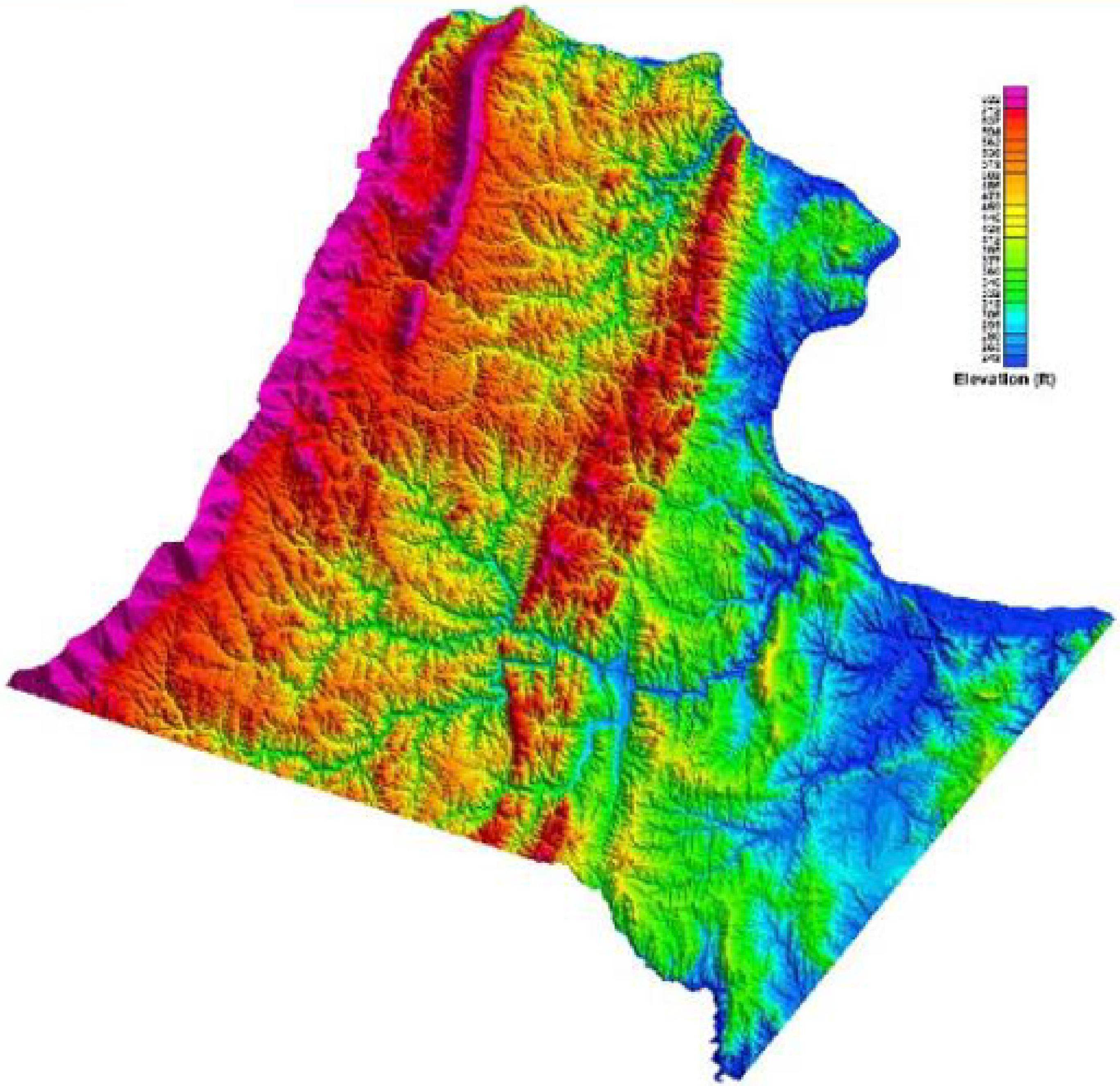


- Careful geologic mapping can determine promising new sites for ground-water exploration in this area

LOUDOUN COUNTY DATABASE

- **High-resolution DEM (15-meter grid size)**

--assembled from 700 tiles by Kerry Lagueux & Luke Blair USGS

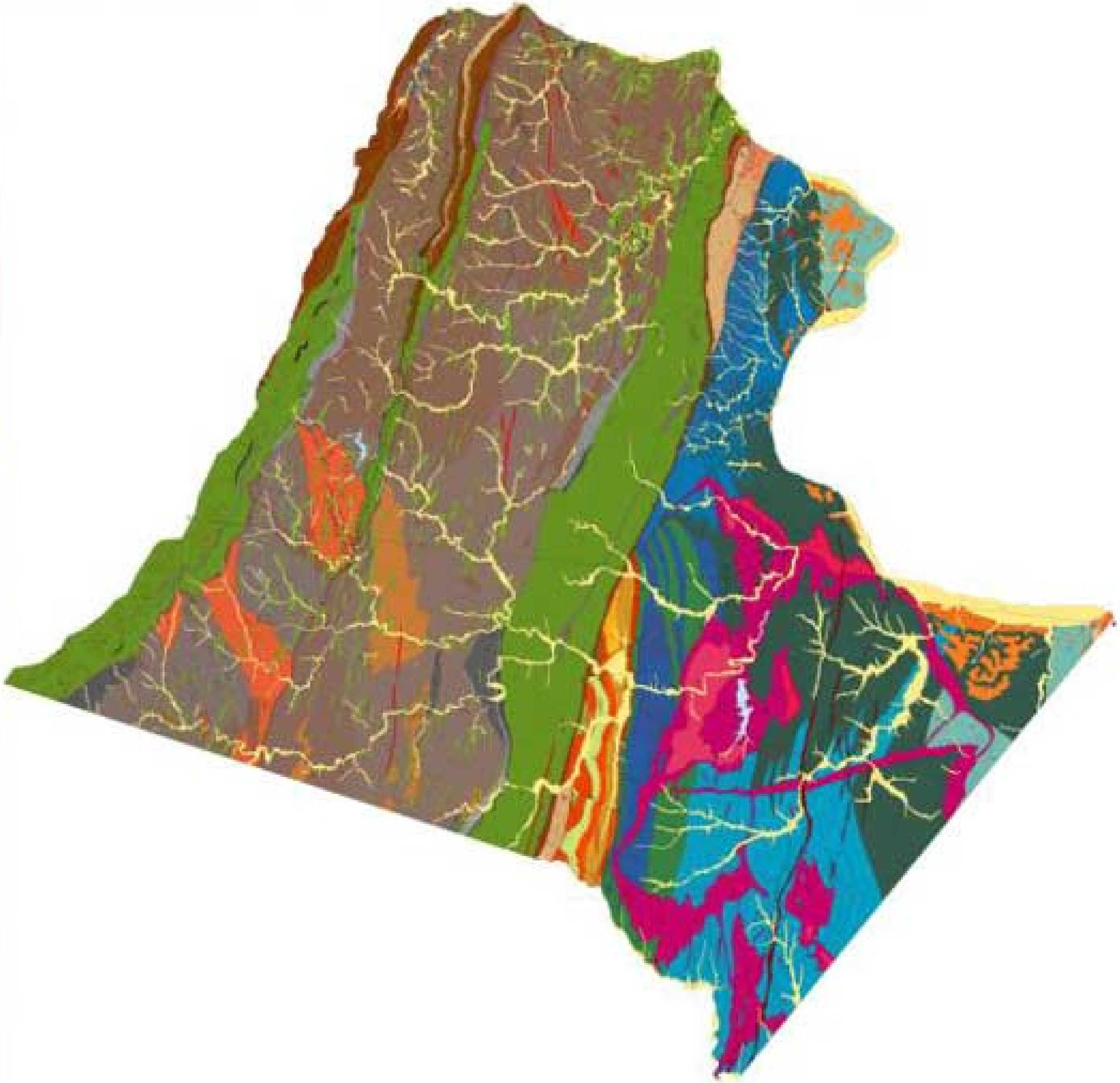


LOUDOUN COUNTY DATABASE

- **Detailed geologic map (1:50,000-scale map of 1:24,000-scale geology)**

Southworth and others, 1999 USGS Open-File Report 99-150

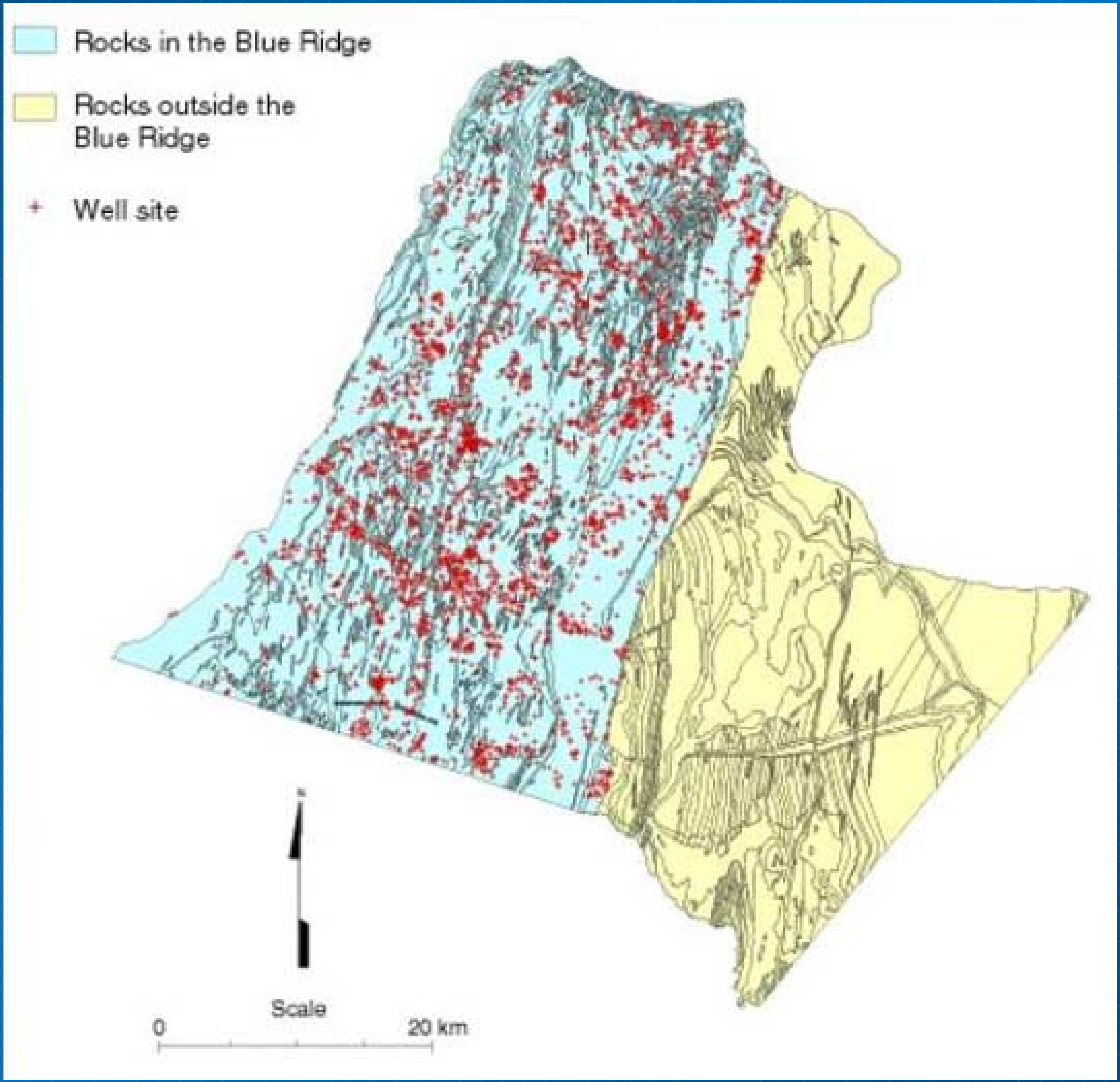
USGS



LOUDOUN COUNTY DATABASE

- **Yield data for 3,561 wells in western Loudoun Co.**

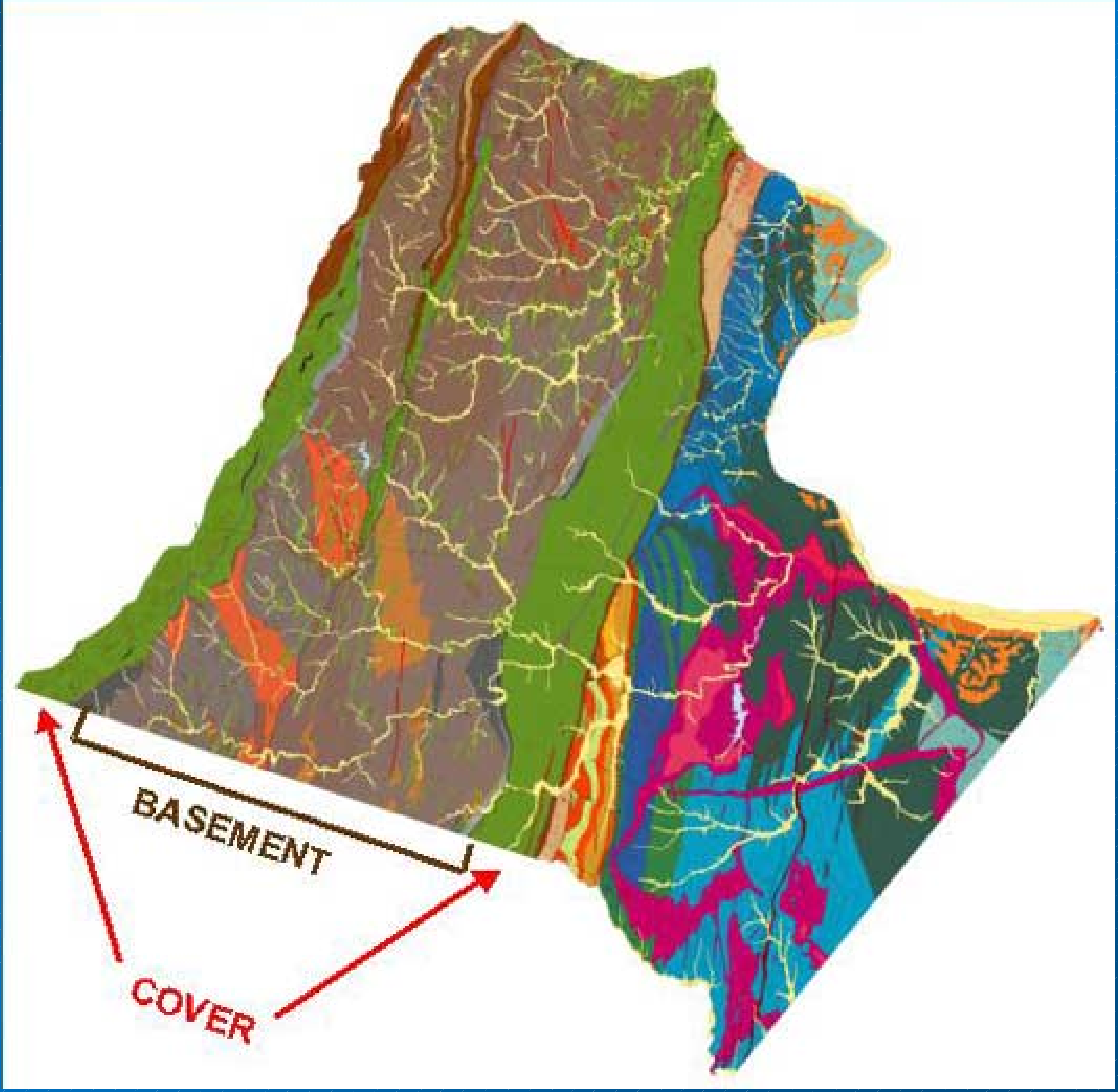
- **Usable for time-trend and lithology-yield analyses, and variography**



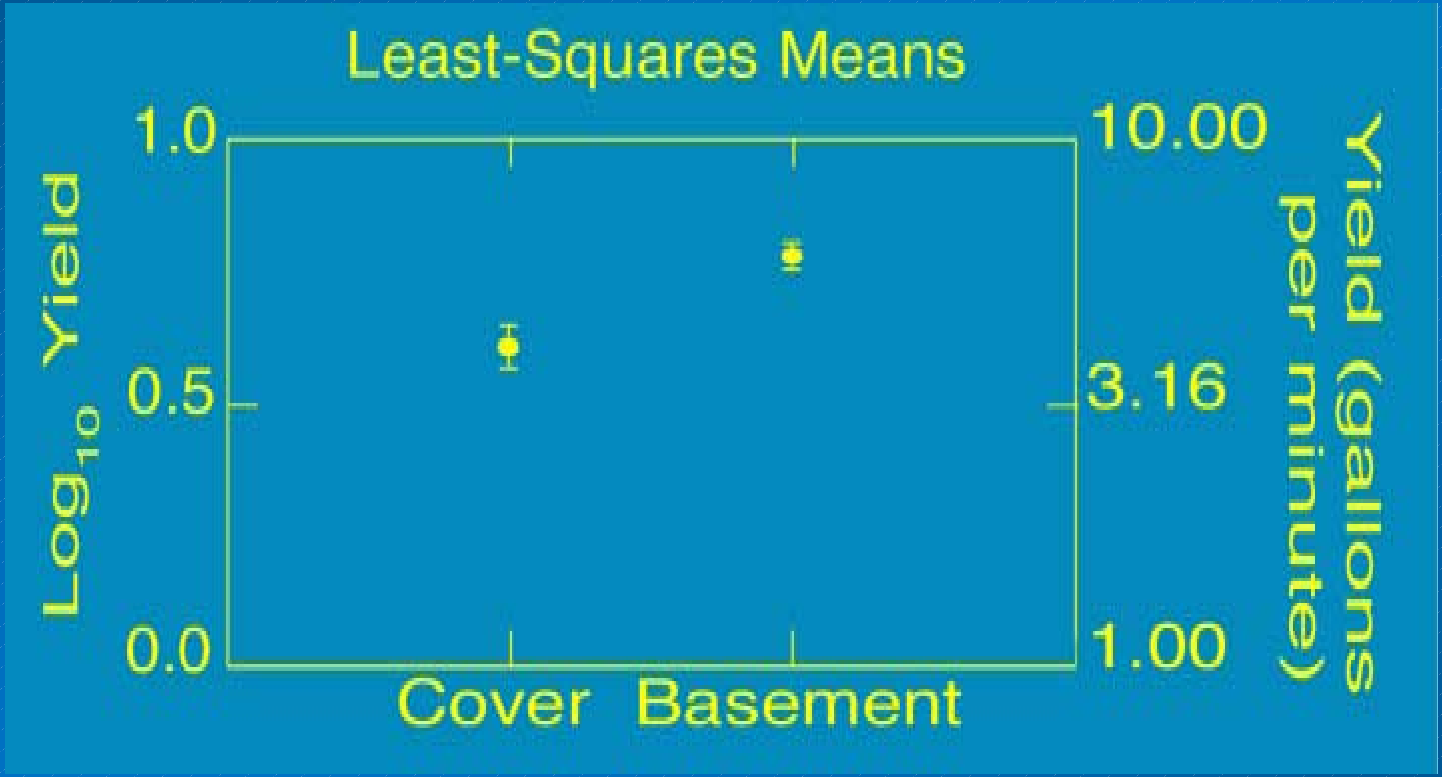
USGS

YIELD AND GEOLOGY

1. Basement vs. Cover



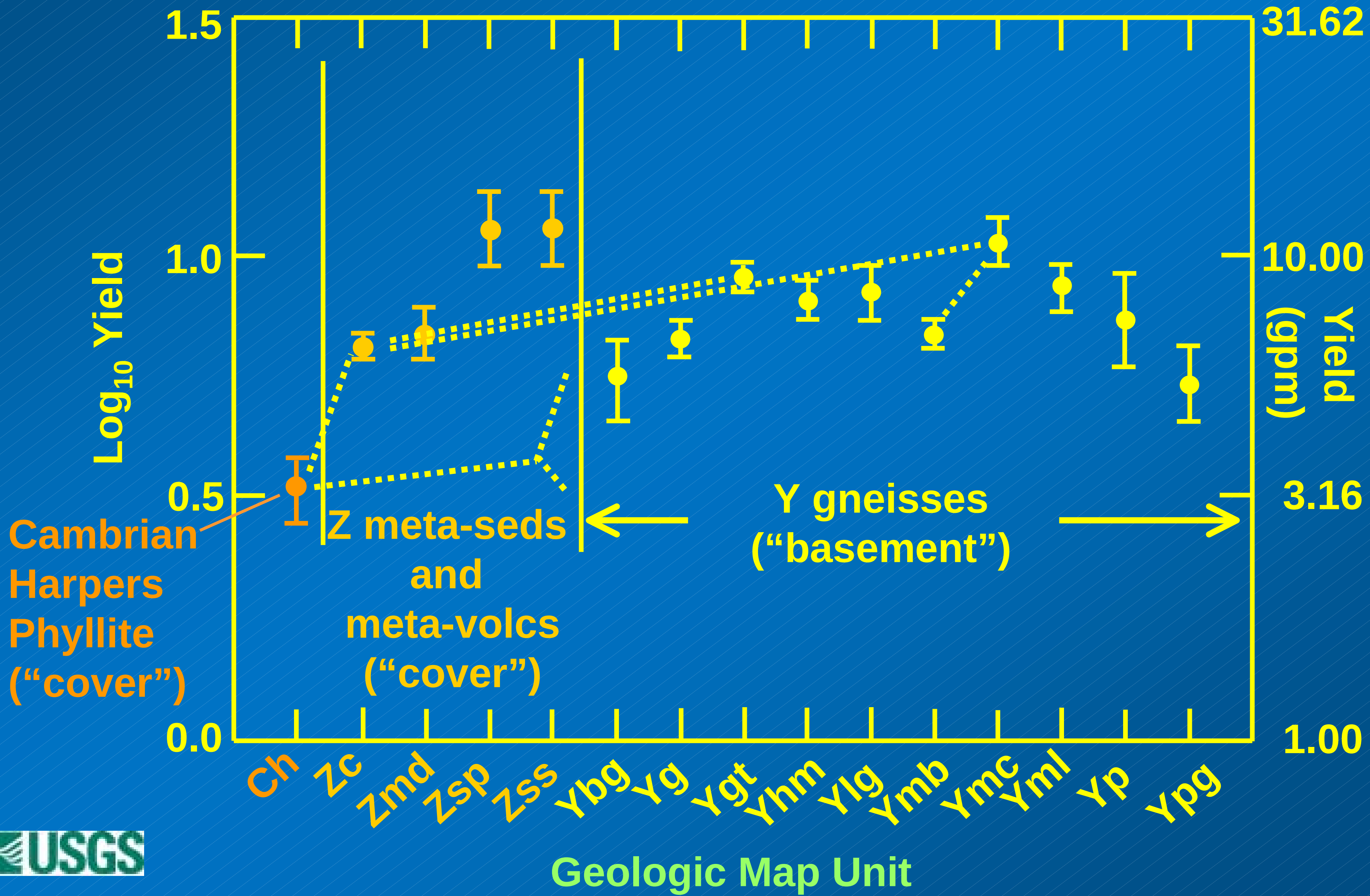
THERE IS A SIGNIFICANT DIFFERENCE IN MEAN YIELD BETWEEN WELLS IN BASEMENT AND COVER



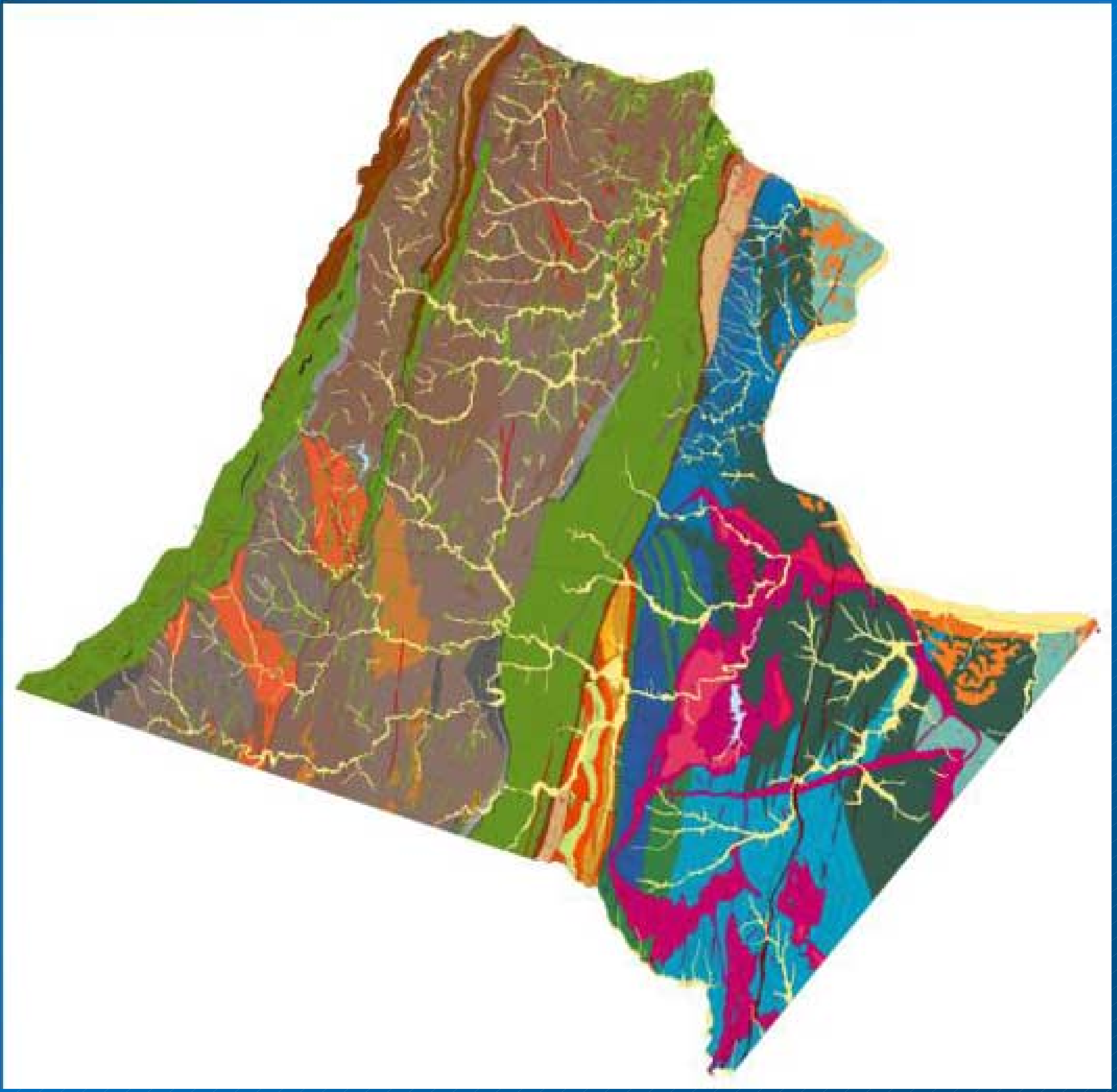
YIELD AND GEOLOGY

2. Geologic map units

THERE IS A SIGNIFICANT DIFFERENCE IN MEAN YIELD BETWEEN WELLS IN HARPERS PHYLLITE AND OTHER ROCKS, AS WELL AS DIFFERENCES BETWEEN OTHER PAIRS OF LITHOLOGIES

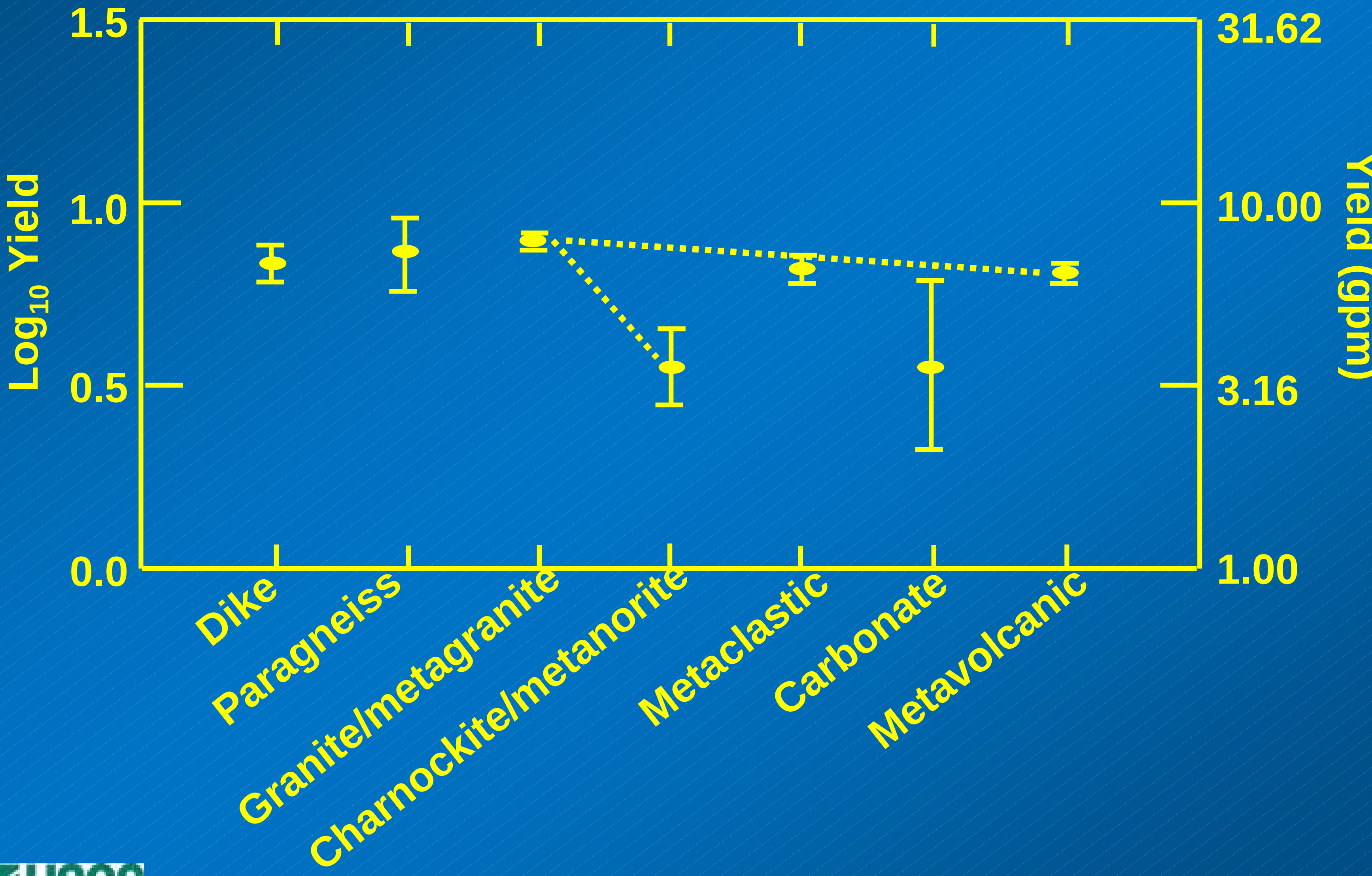


YIELD AND GEOLOGY

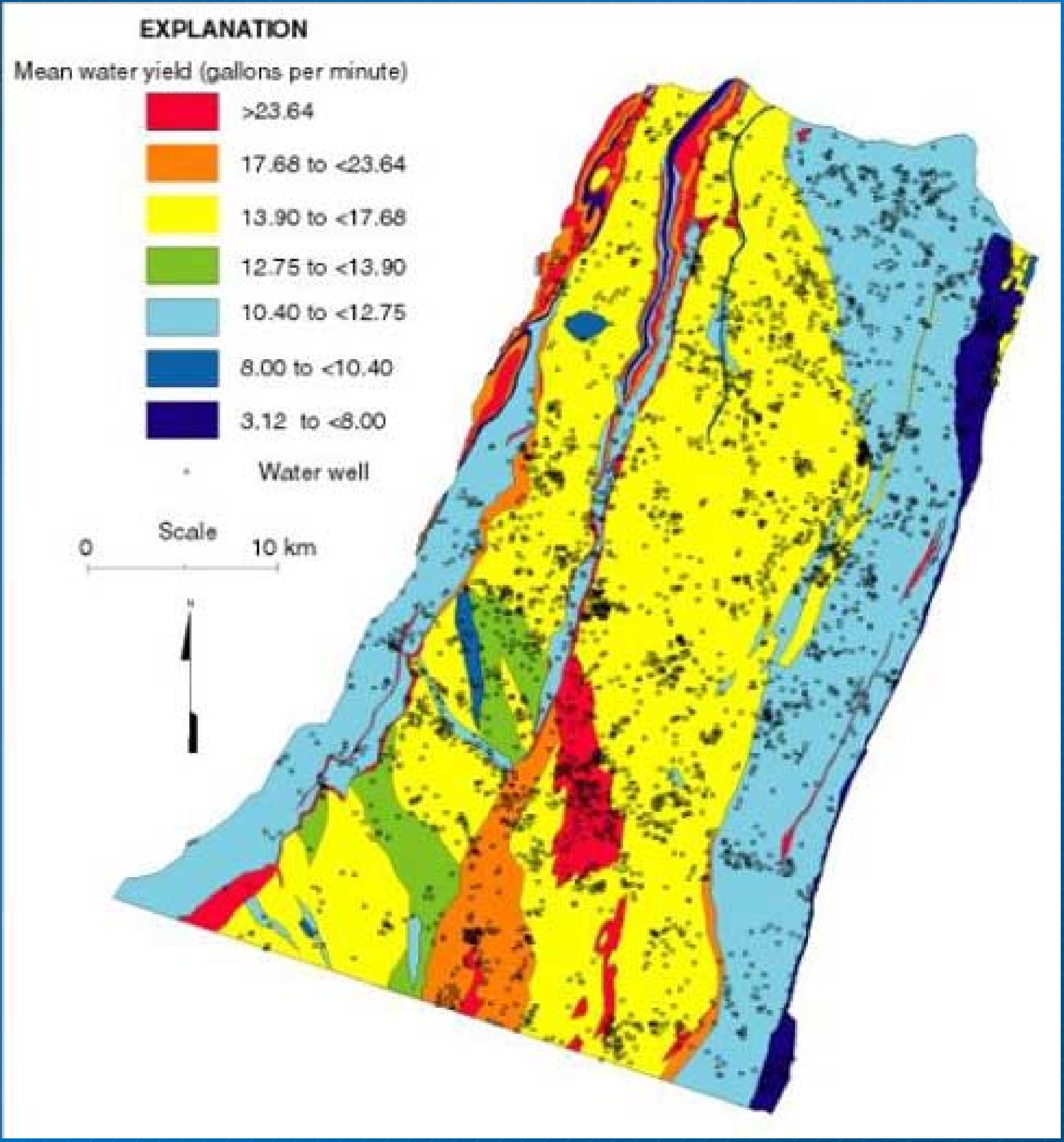


3. Generic rock types

THERE IS A SIGNIFICANT DIFFERENCE IN MEAN YIELD BETWEEN WELLS IN GRANITIC GNEISS AND TWO OTHER ROCK TYPES



Derivative map of western Loudoun County grouping geologic map unit by yield

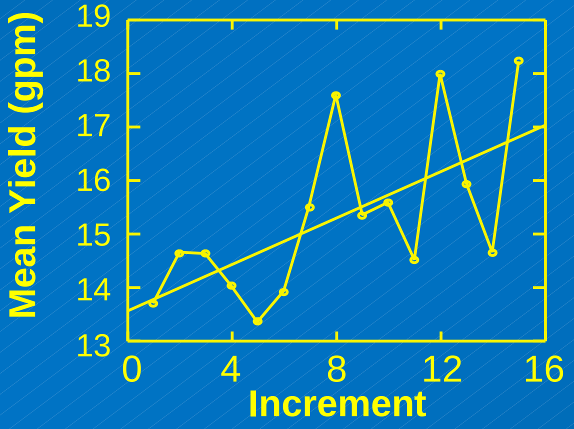


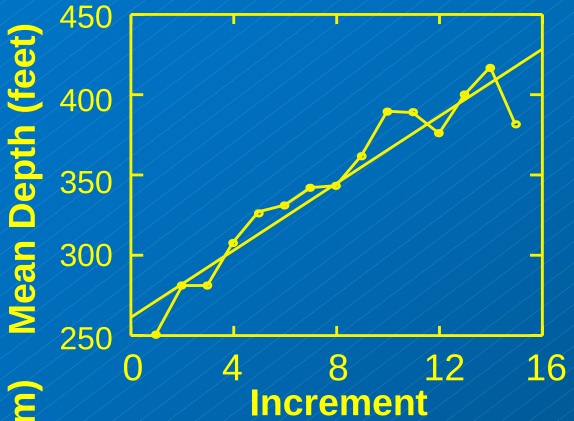
TIME-TREND ANALYSIS SHOWS THAT:

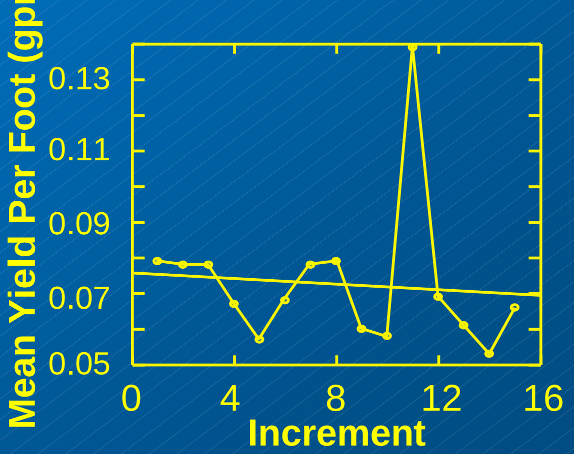
Mean yield has increased over time...

…but mean depth drilled has increased at a slightly greater rate...

…so that <u>mean yield per foot drilled</u> has actually <u>decreased</u> over time



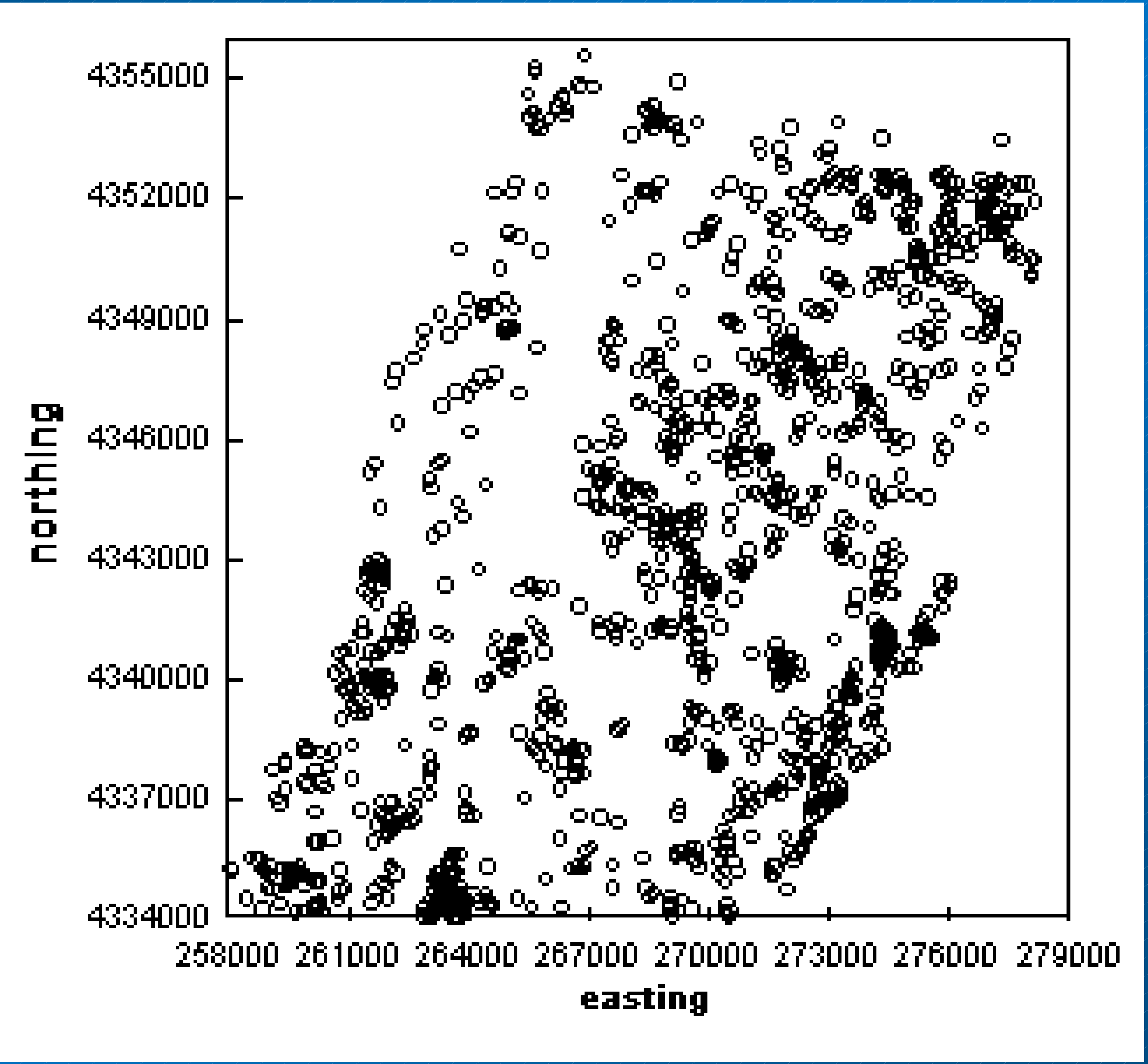




NORTHERN BLUE RIDGE BASEMENT, WESTERN LOUDOUN COUNTY

- 1313 wells

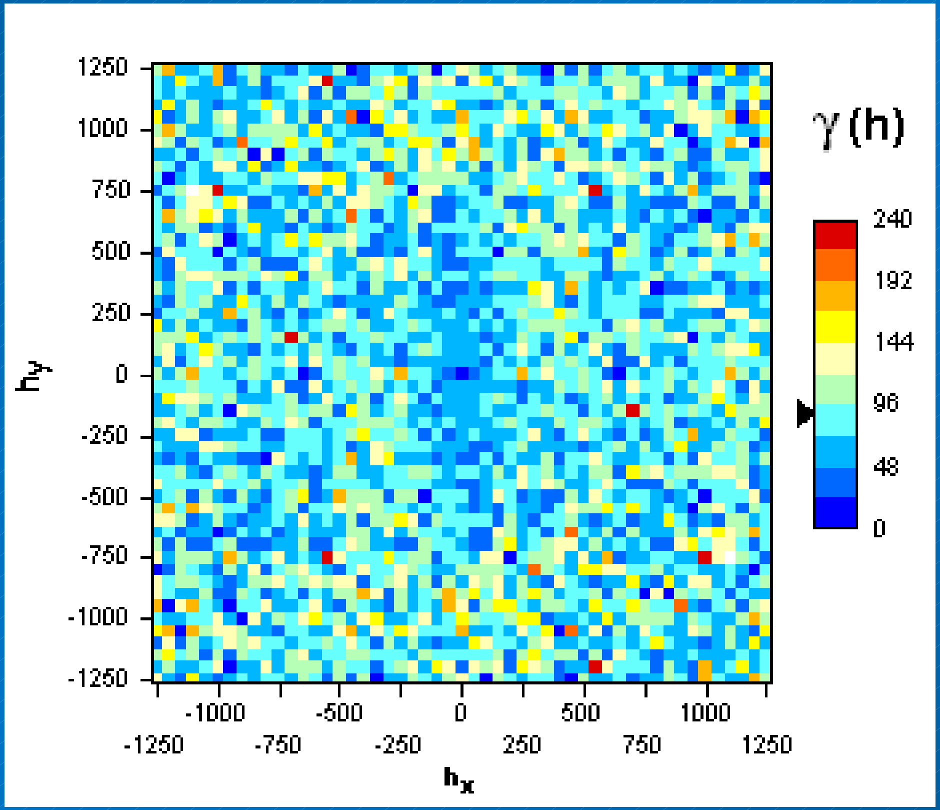
- ~800,000 pairs of wells to compare



USGS

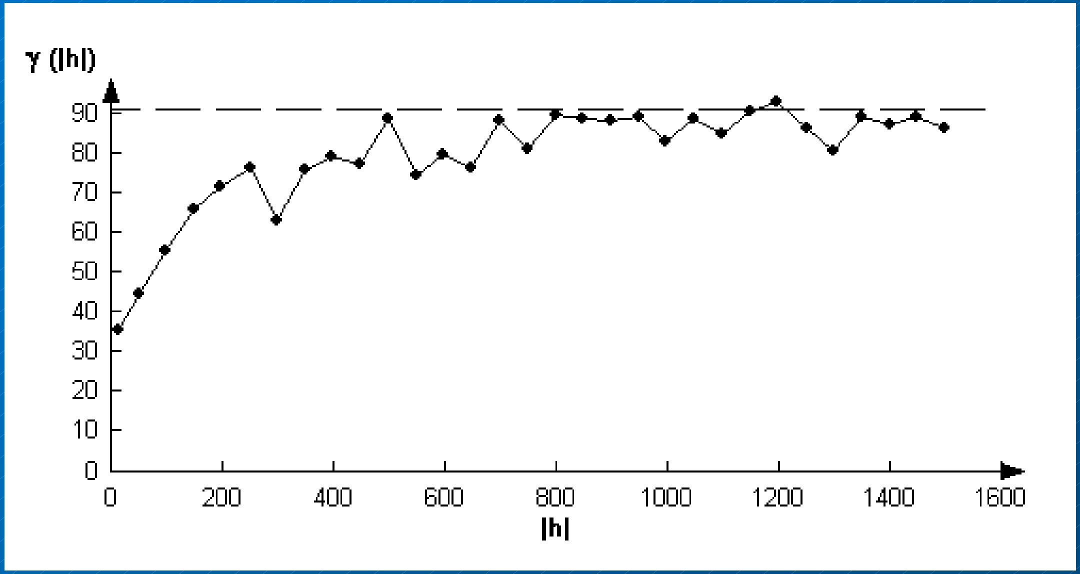
NORTHERN BLUE RIDGE BASEMENT, WESTERN LOUDOUN COUNTY
--50-METER LAG
(local scale)

Two-dimensional variogram surface:



A north-south trend visible

Omnidirectional variogram:



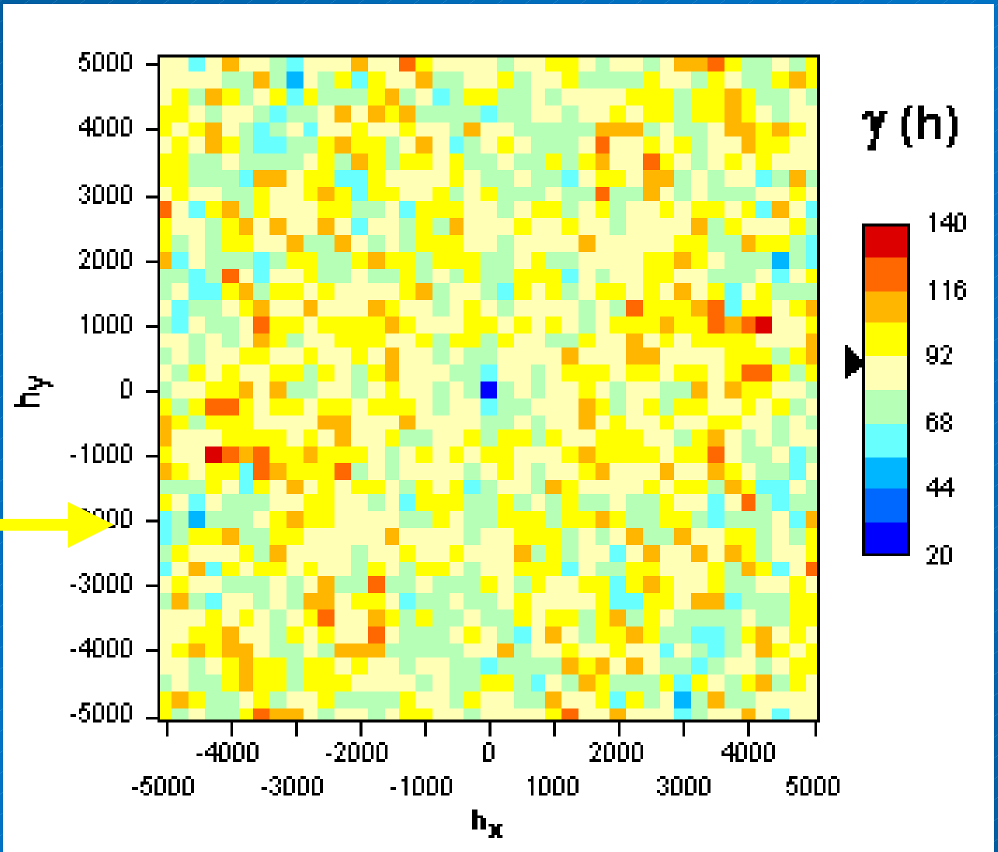
High continuity at local scale

USGS

NORTHERN BLUE RIDGE BASEMENT, WESTERN LOUDOUN COUNTY --250-METER LAG (larger scale)

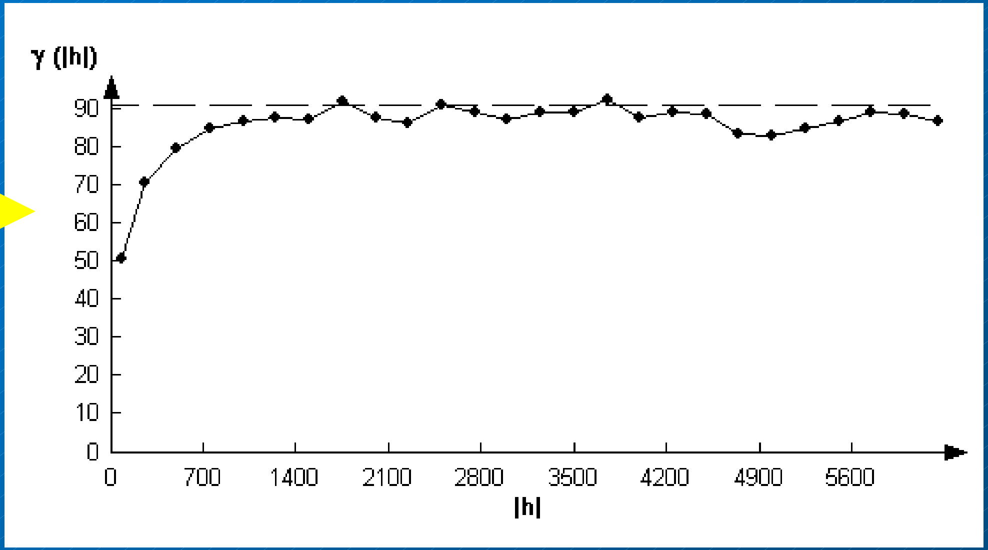
Two-dimensional variogram surface:

two NE-SW directional trends discernable



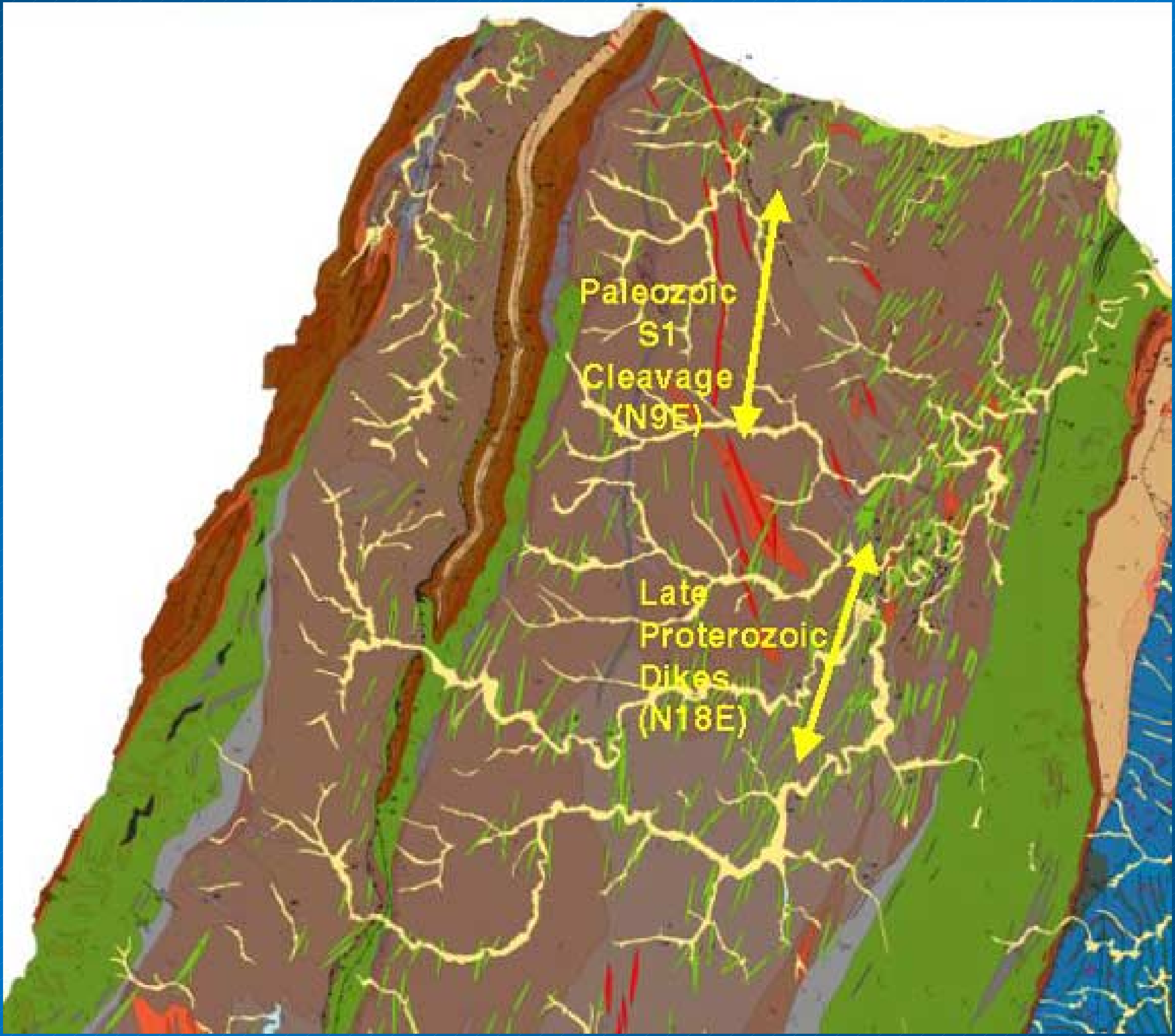
Omnidirectional variogram:

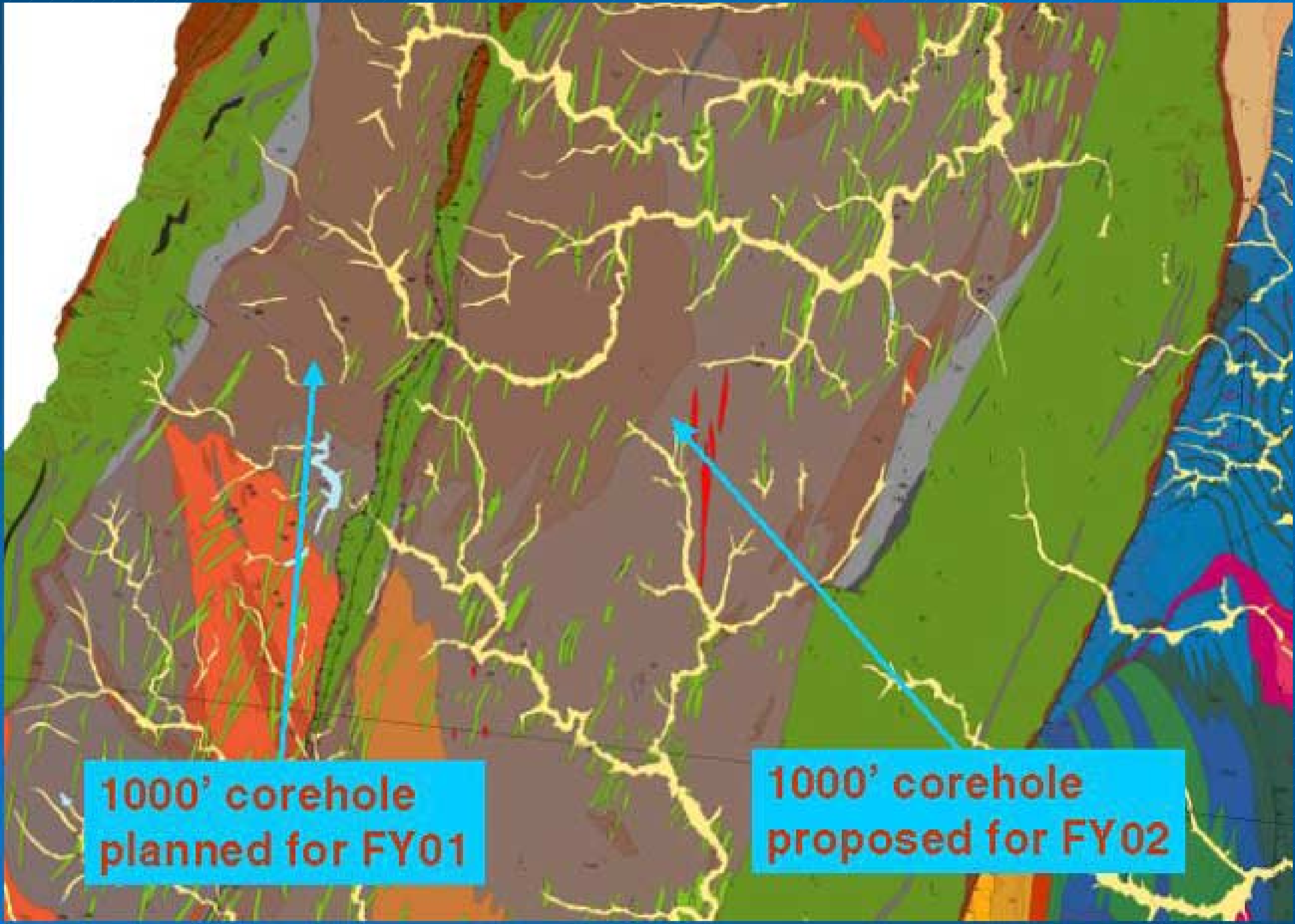
High continuity at local scale; "hole" effect at 5000m



USGS

Possible NE-trending structures correlative with variography in northern Blue Ridge



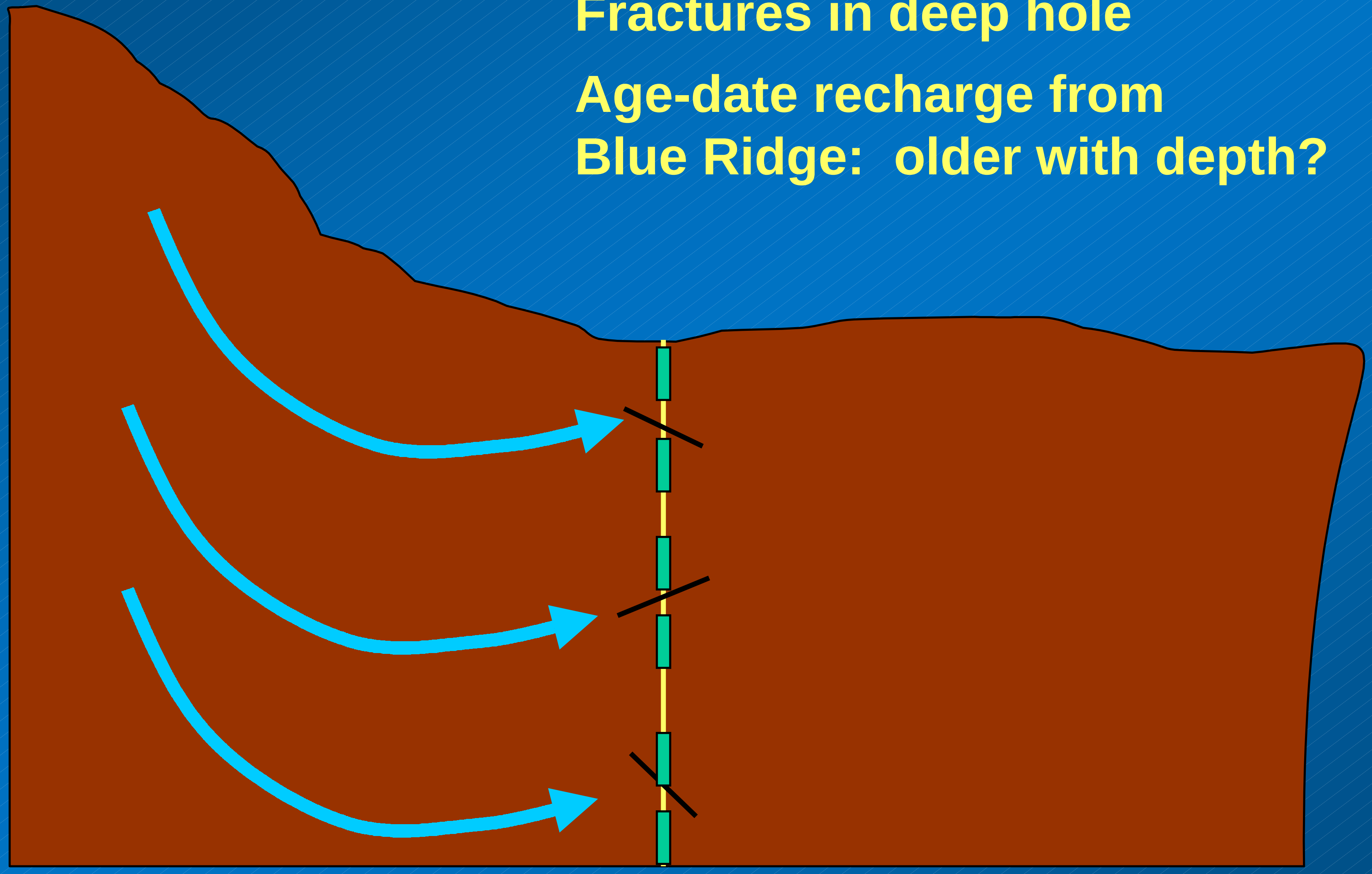

1000' corehole
planned for FY01
1000' corehole
proposed for FY02

USGS

Blue Ridge

Isolate water-transmitting Fractures in deep hole

Age-date recharge from Blue Ridge: older with depth?



NCDENR/DWQ/GW
Resource Evaluation Program

Piedmont & Mountains Project
2000 Update

USGS

USGS

USGS

NCDENR/DWQ/GW
Resource Evaluation Program

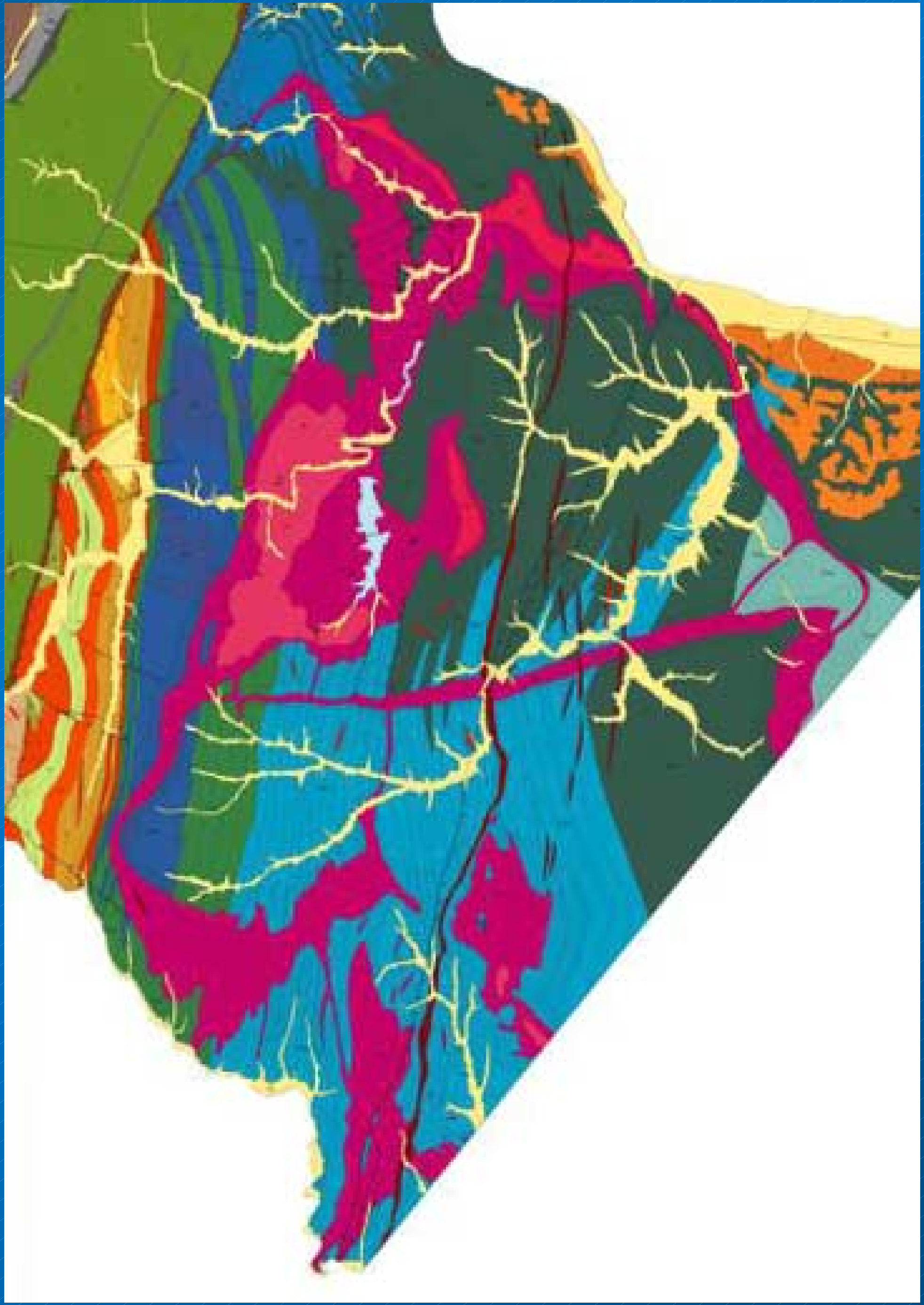
Piedmont & Mountains Project
2000 Update

BRASS mapping and hydrogeologic studies in sedimentary/igneous terranes

LOUDOUN COUNTY STUDIES

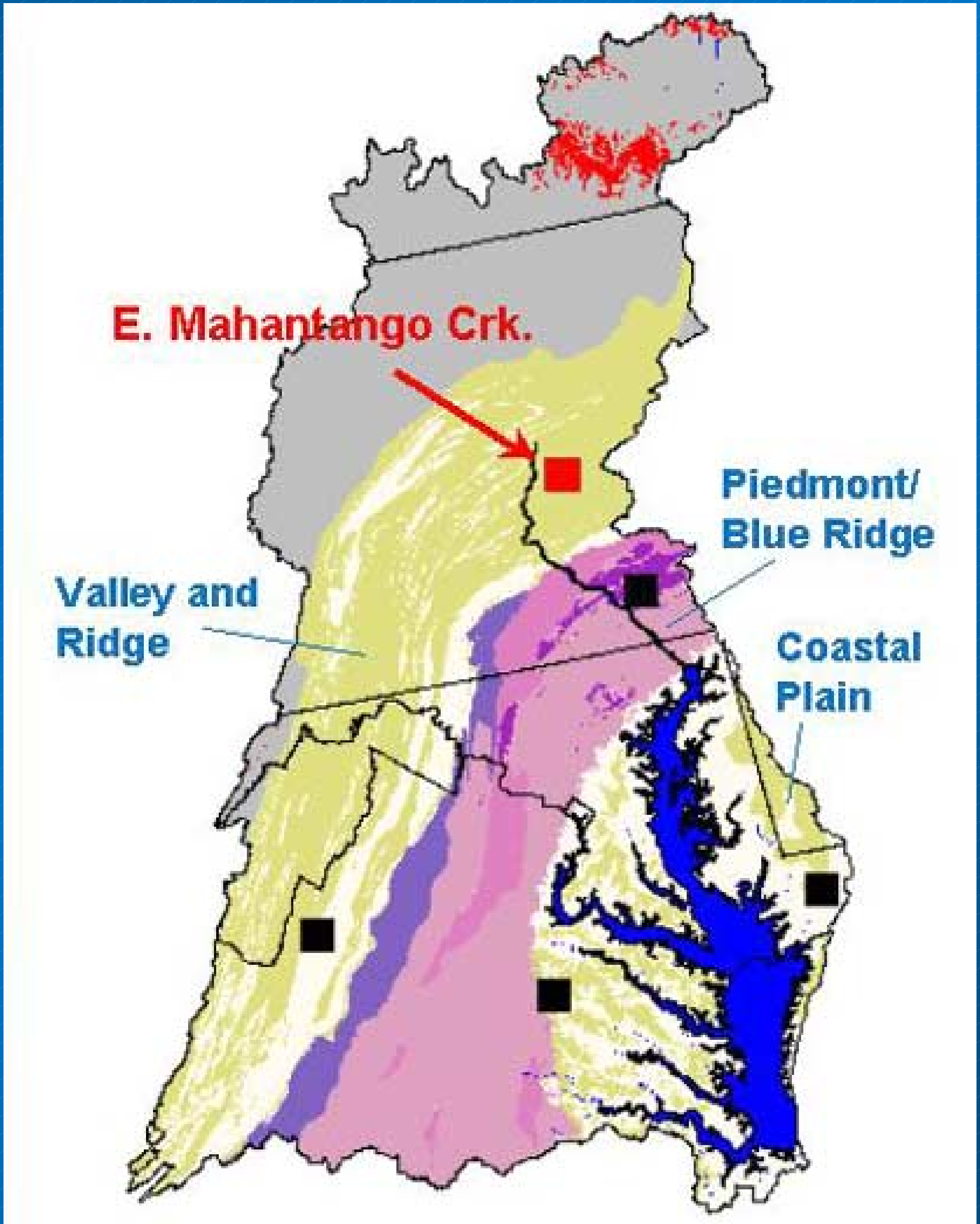
Fracture flow hydrogeology of the Culpeper basin

Mike Ryan
Herb Pierce
Joe Smoot
Dave Sutphin



USGS Chesapeake Bay watershed nutrient study

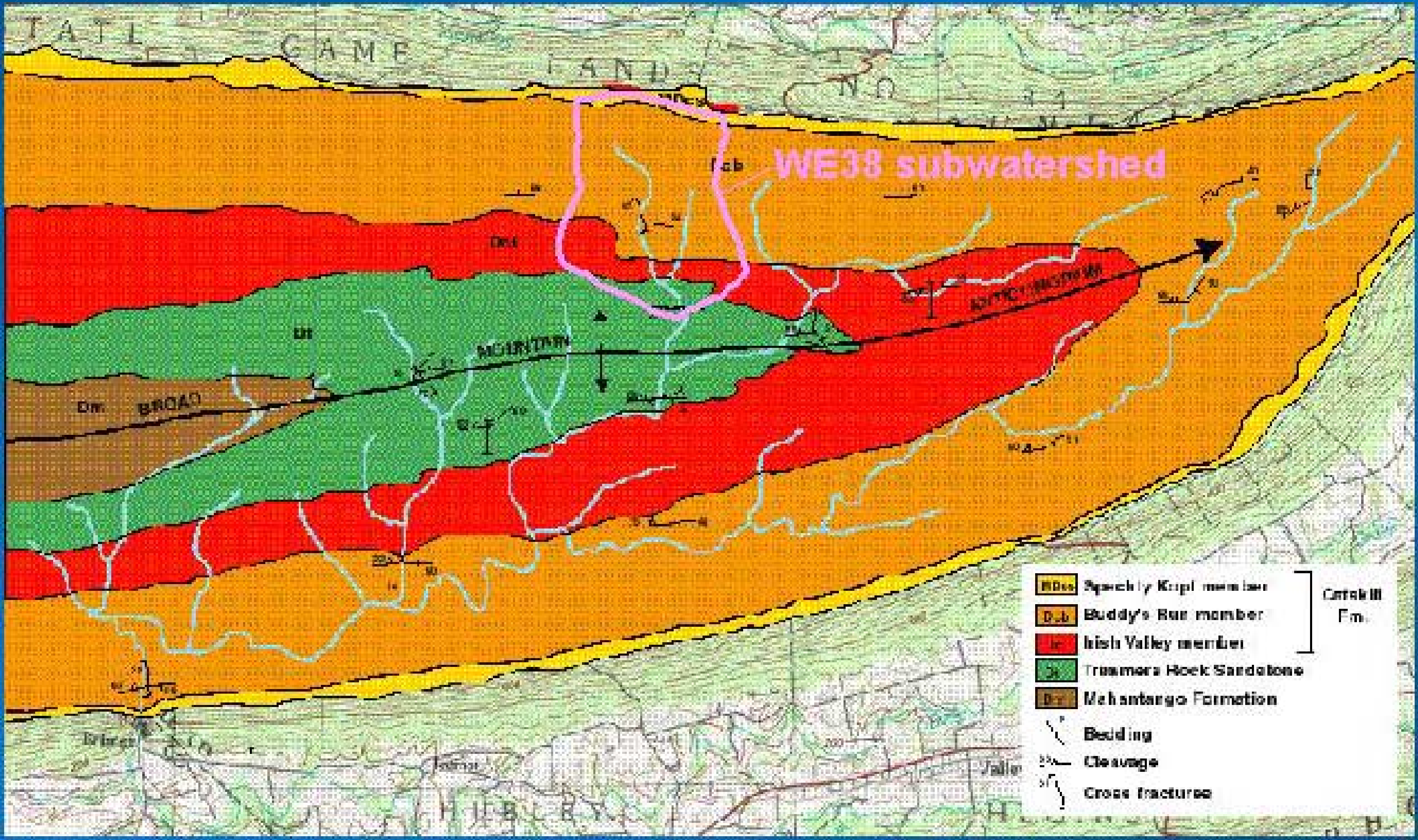
- Model influx of nitrogen into Bay
- “Targeted watersheds” in high-nitrate-source areas underlain by fractured bedrock
- What is effect of bedrock geology on base flow and ground-water travel times?



USGS

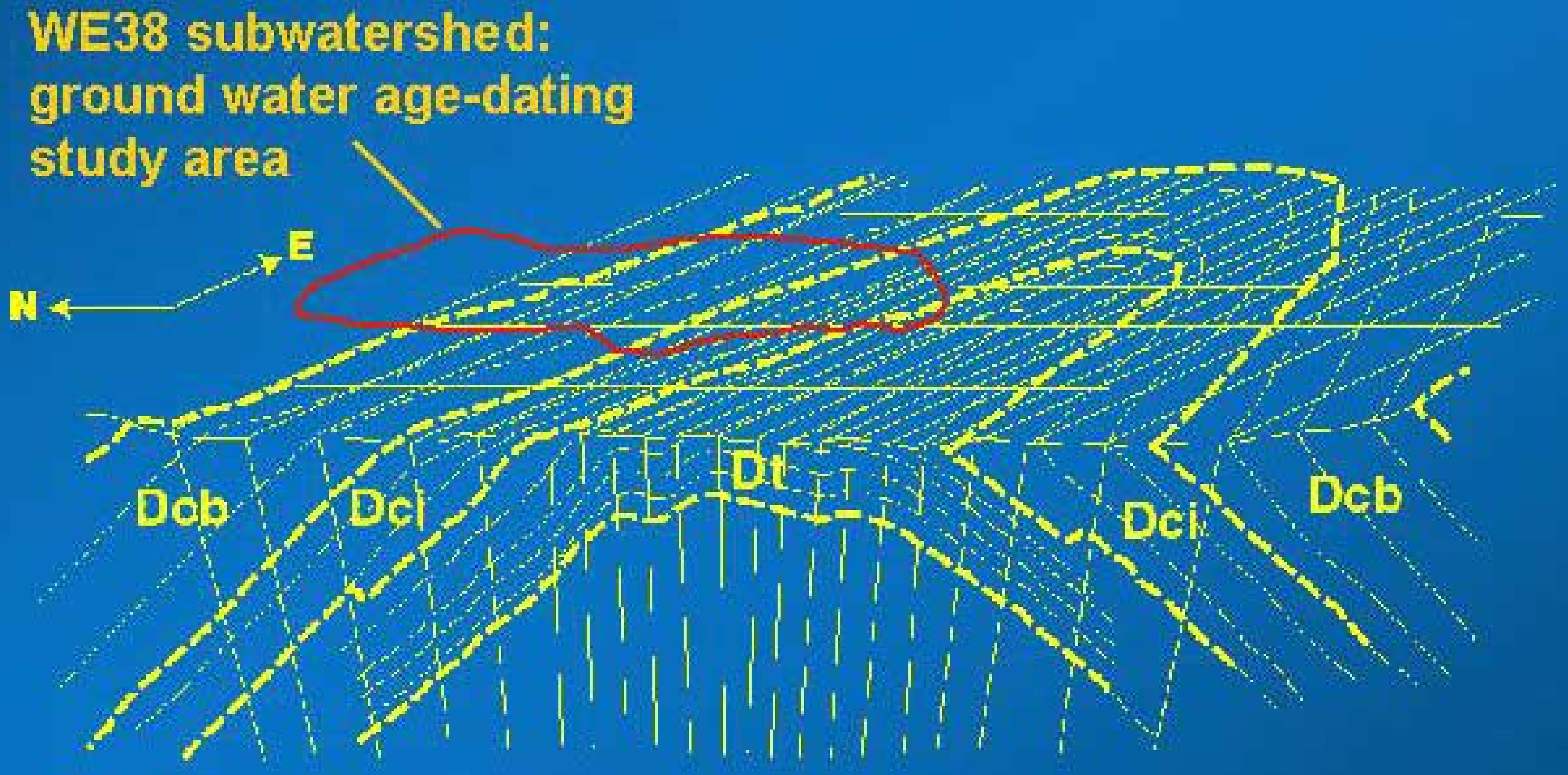

View of East Mahantango Creek watershed

Geology of East Mahantango Creek watershed
--anticline in Devonian-Mississippian sandstones and shales

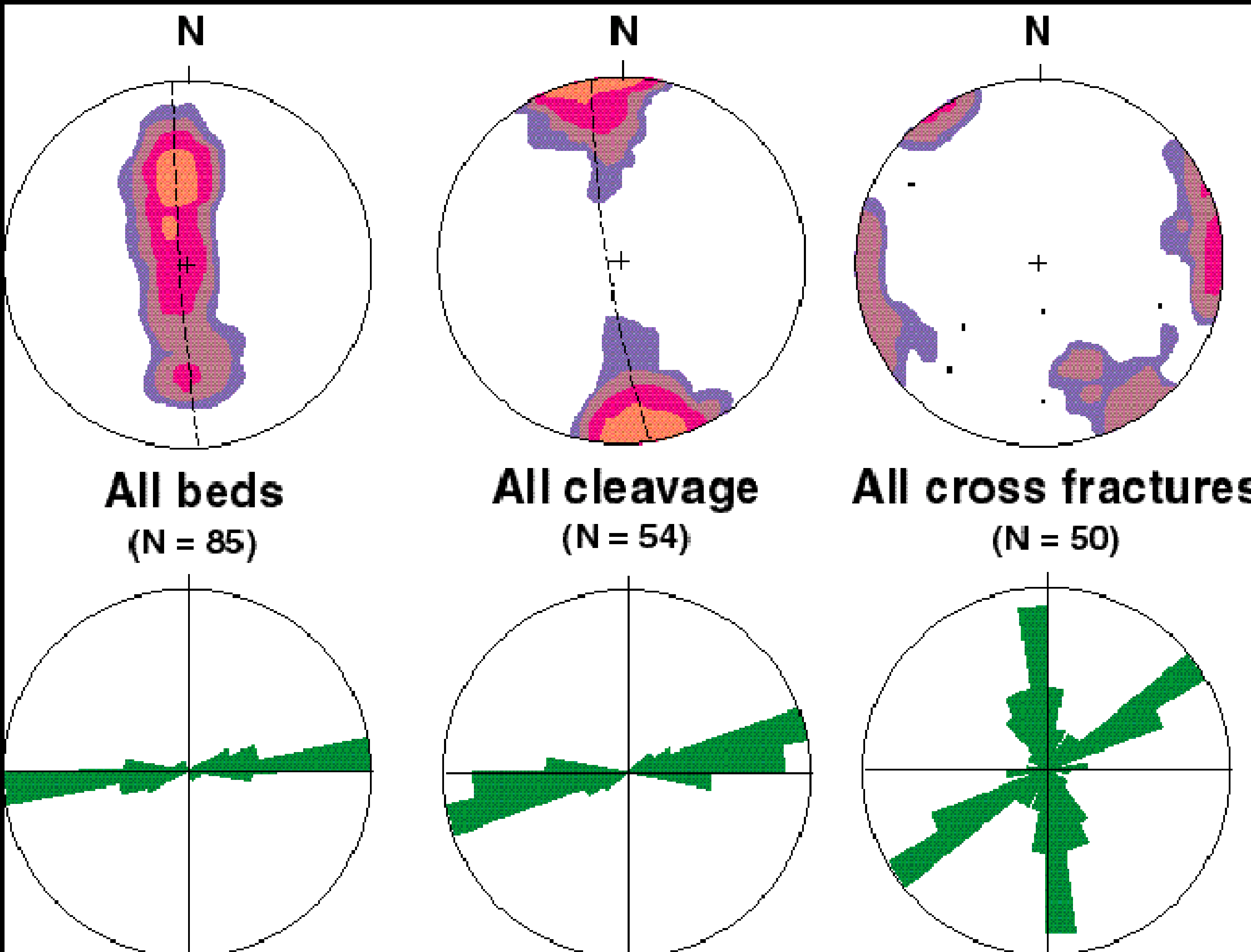


USGS

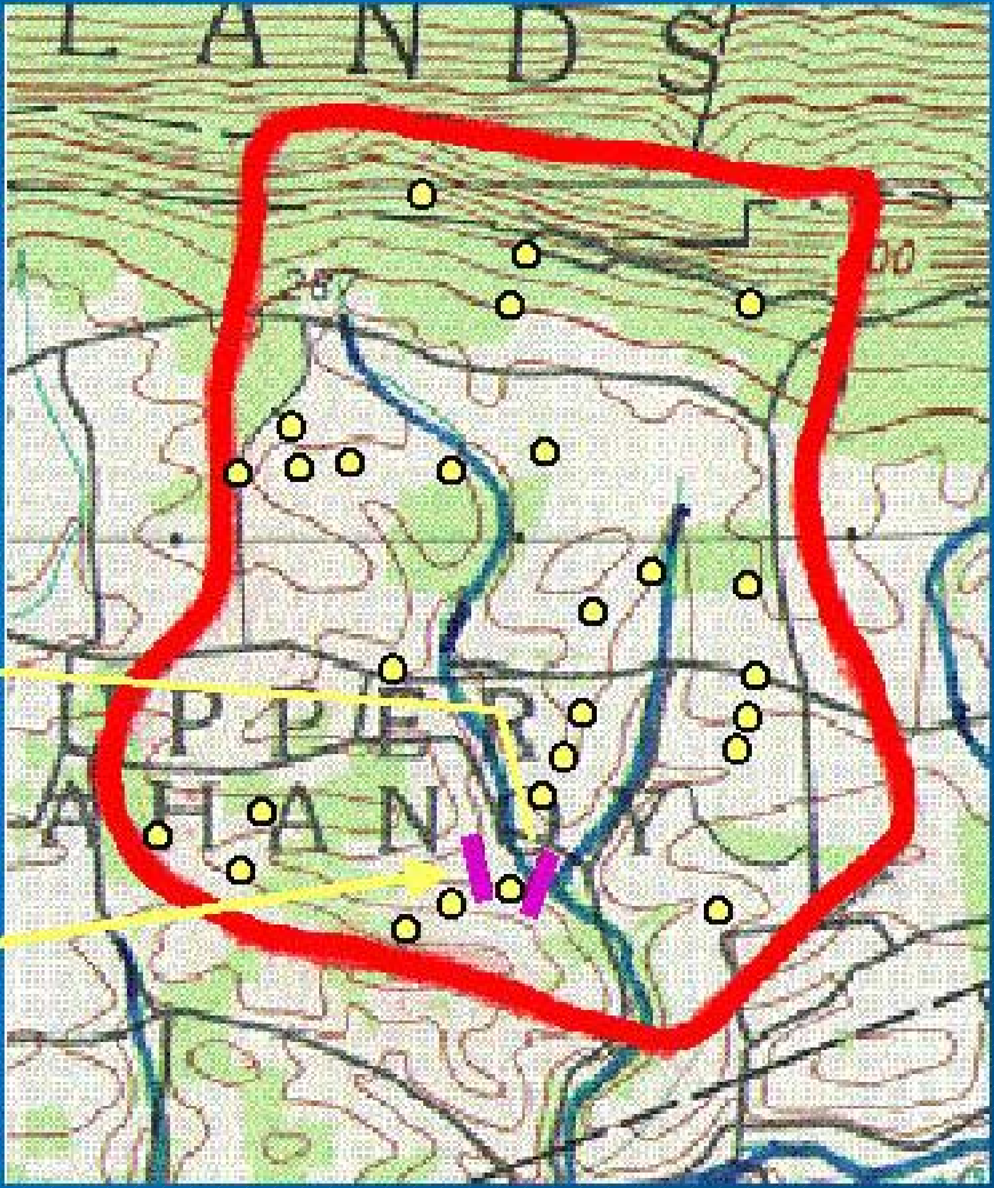
East Mahantango Creek watershed bedrock fracture framework




Parting and cleavage


N
N
N
All beds
(N = 85)
All cleavage
(N = 54)
All cross fractures
(N = 50)

WE38 SUBWATERSHED



EAST
PIEZOMETER
TRANSECT

WEST
PIEZOMETER
TRANSECT

East piezometer transect

East Piezometer Transect

--Preferred CFC-12 ages NE of stream are older...

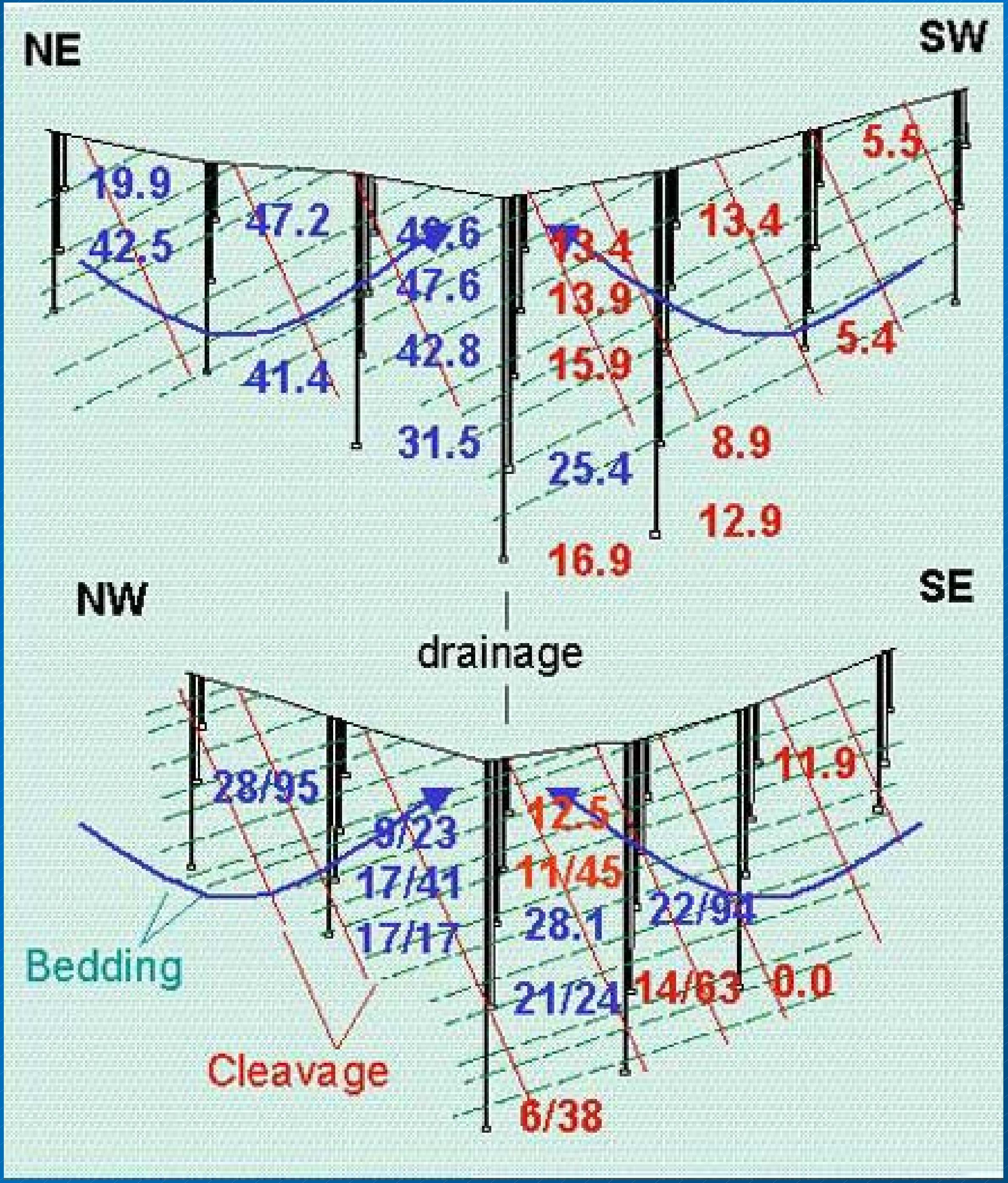
..than those underneath and SW of stream

..although these ages are really mixture ages!

West Piezometer Transect

--Ages are even more mixed, but % of young water (2nd #) shows older waters generally prevailing to NW

…and younger to SE



NE — SW

Depth (ft.)	E1	E2	E3	E4	E5	E6	E7
10	19.9/90	(47.2)	(48.2)	8.7/12.6/78	10.9/100		(5.5)
20	(42.5)		(46.4)	6.3/13.8/85			
30		(41.4)	(44.4)	12.9/16.2/78			
35						1.4(5.4)	
45			(33.7)	18.2/21.5/67	8.9/100		
60				21.4/19.2/57	12.6/82		

drainage

NW — SE

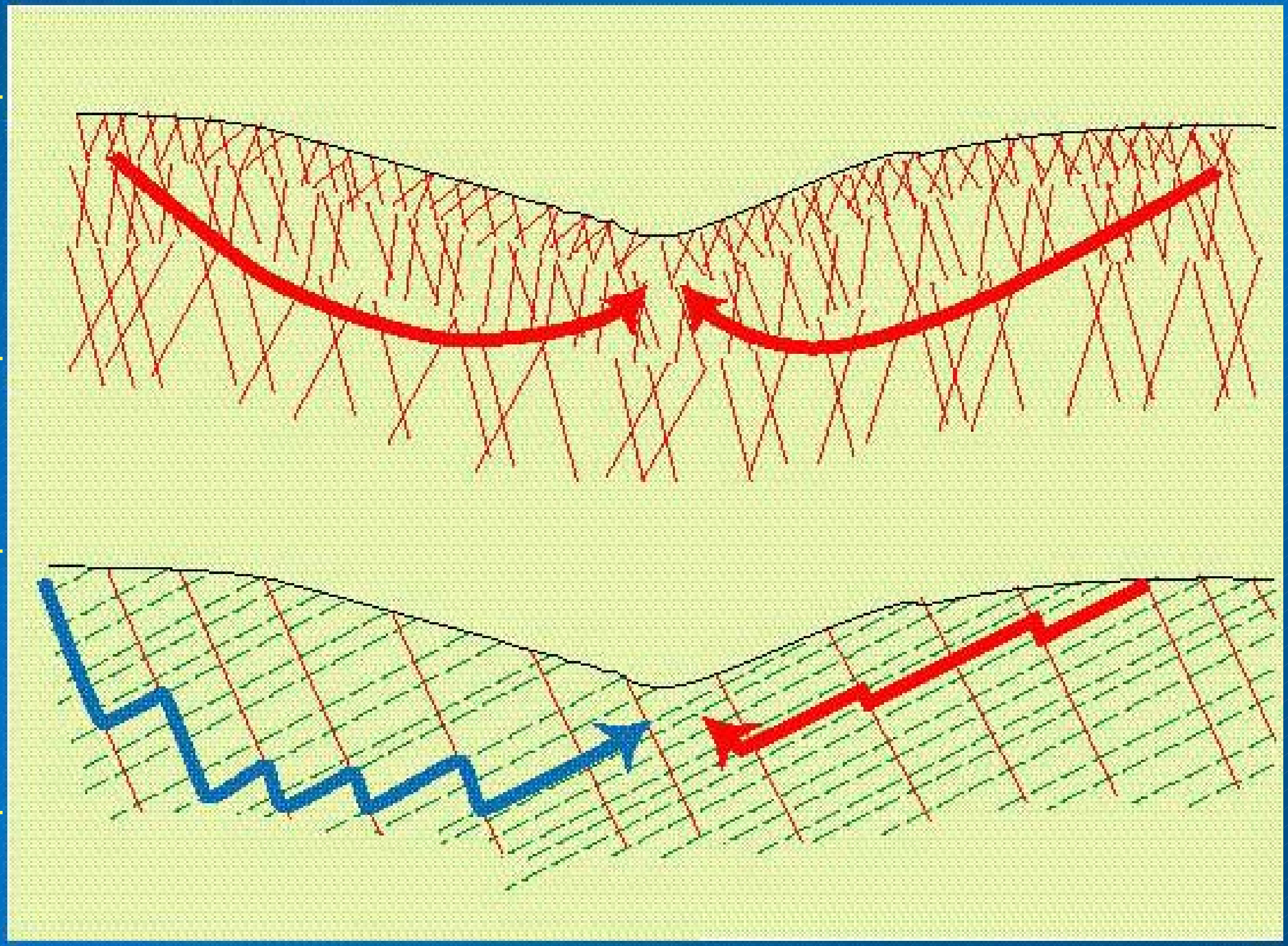
Depth (ft.)	W1	W2	W3	W4	W5
10			12.5/100		15.4/11.9/100
20	27.9/95	8.7/23	10.9/45		
30		17.4/41	28.1/100	22.4/94	
40		16.9/17		14.4/63	
45			20.6(24)		
65			6.4/38		0.2/0/100

3H/3He age/CFC-113/12 age of young fraction/% young water
(CFC-12 piston flow age)

Bedding-plane anisotropy explains disparity in ground-water ages, travel times

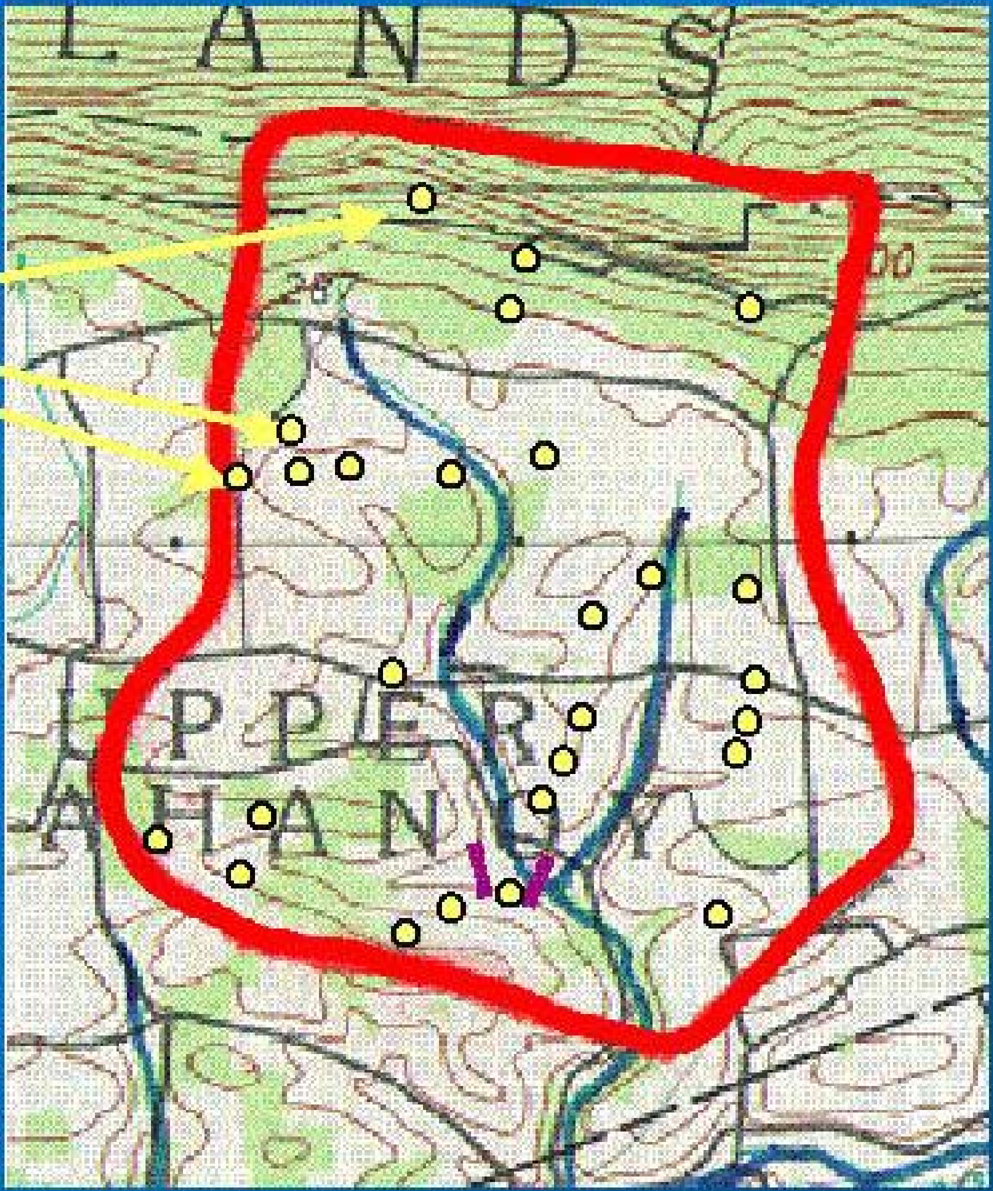
<u>Layered-density, isotropic fracture model</u>
Young, equal GW ages at discharge

<u>Bedding-plane fracture model</u>
Predominantly young water downdip to discharge; old water updip to discharge



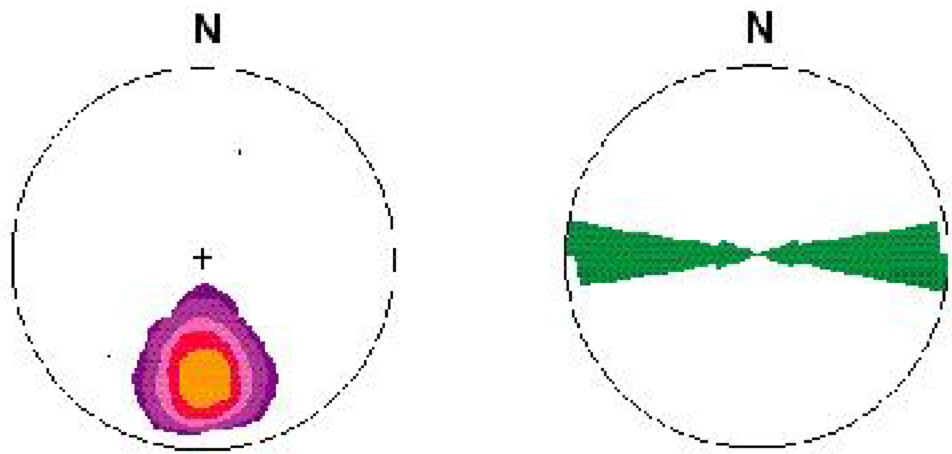
WE38 SUBWATERSHED

CORE
LOCATIONS

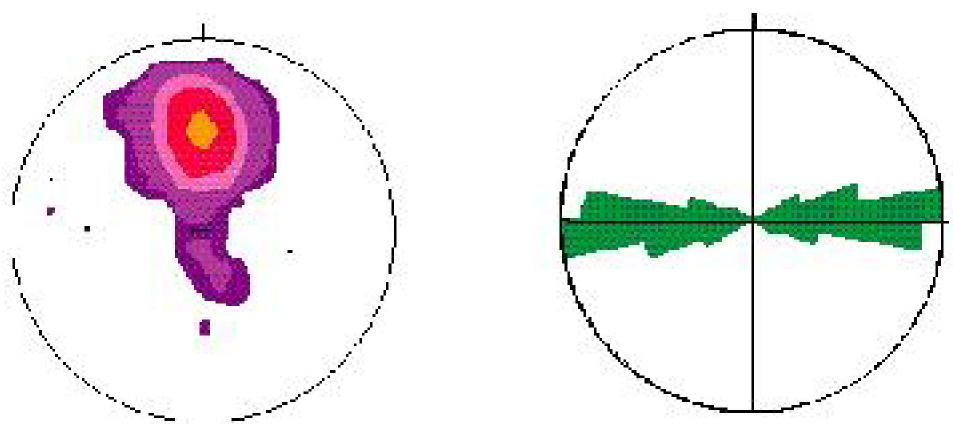


Kevin Troutman examining core

Kevin Troutman measuring core with Brunton



WE38 cores, bedding-plane parting
(N = 1125)

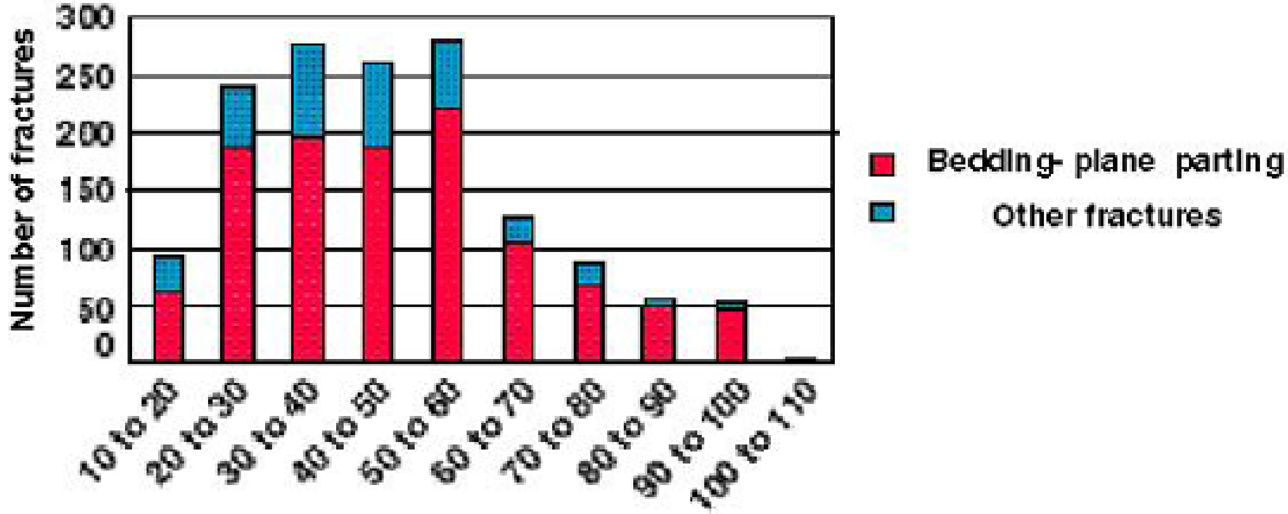


WE38 cores, cleavage and cross fractures
(N = 358)

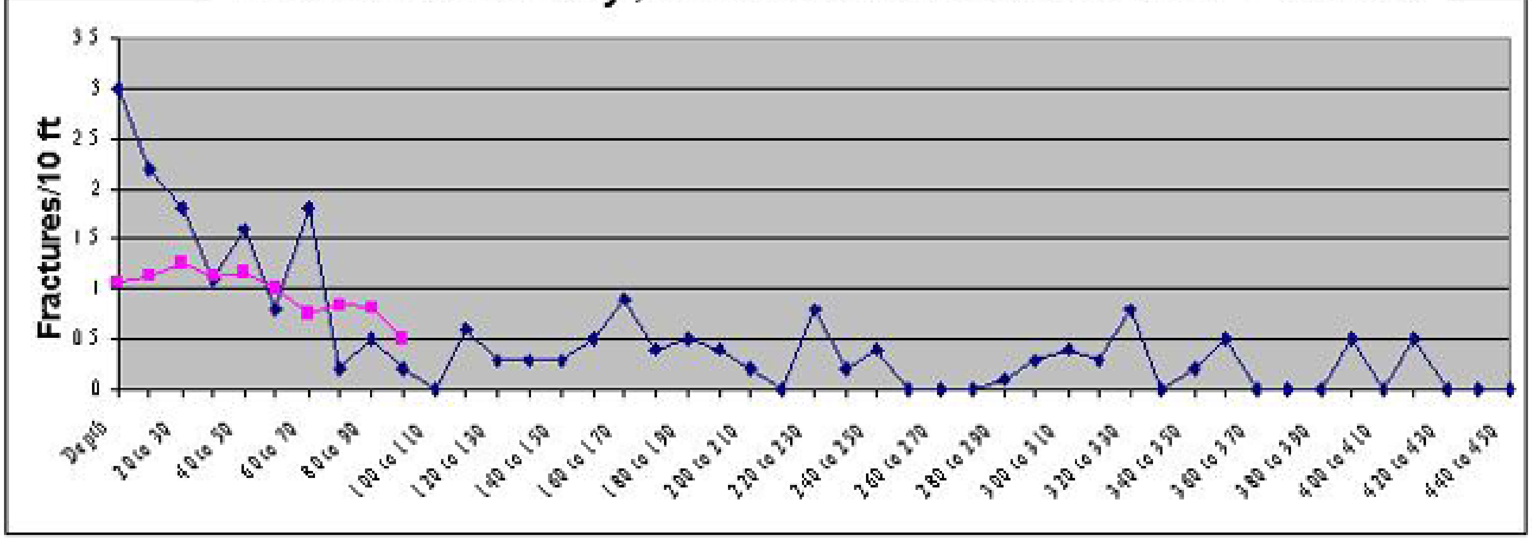
USGS

USGS

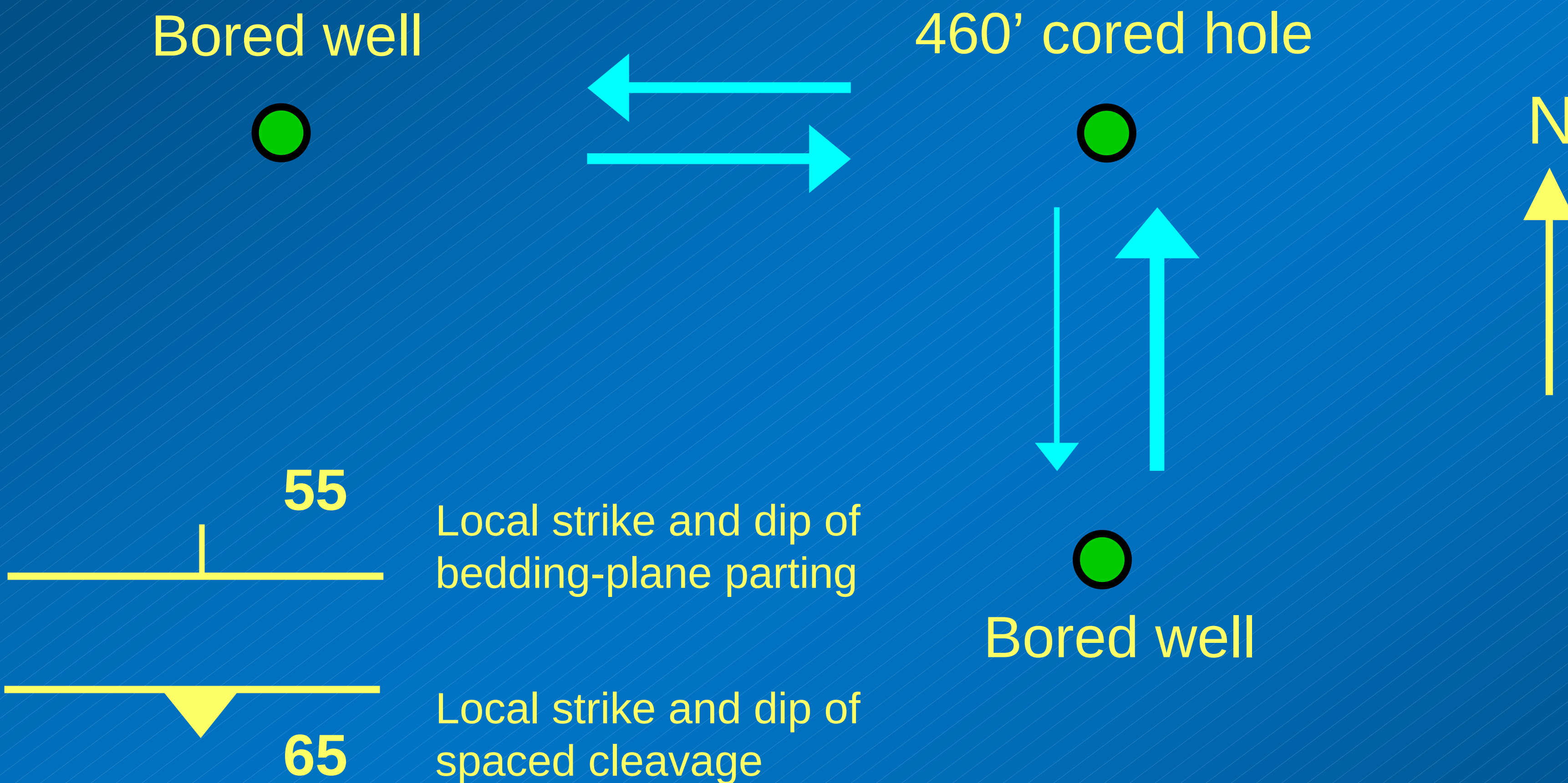
Total Fractures, WE38 cores



Fracture Density, WE38 and USGS-ARS-1 cores



USGS



Cross-hole pump tests at Mahantango will test effect of anisotropic fracture geometry on GW flow