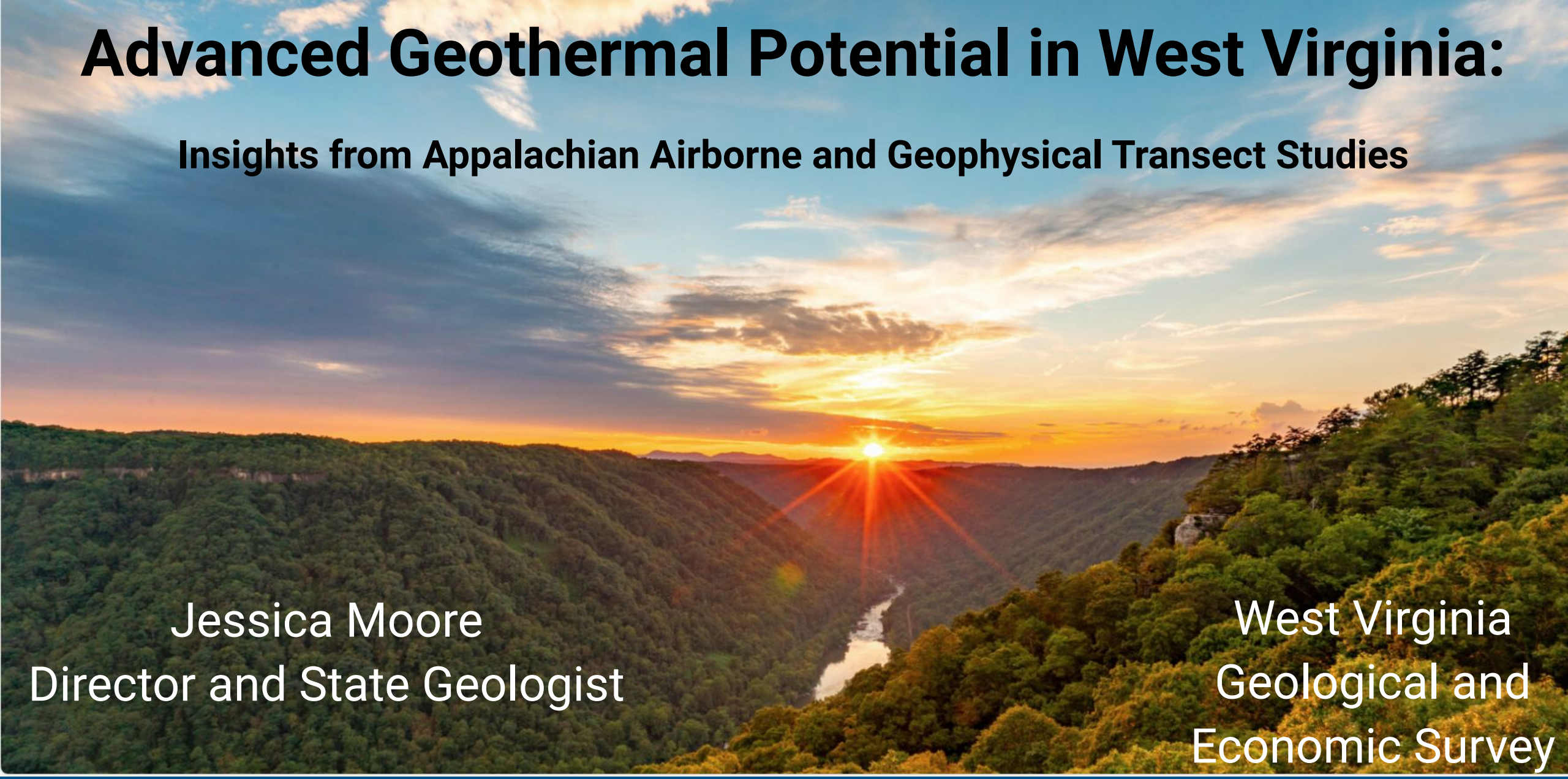
Advanced Geothermal Potential in West Virginia:

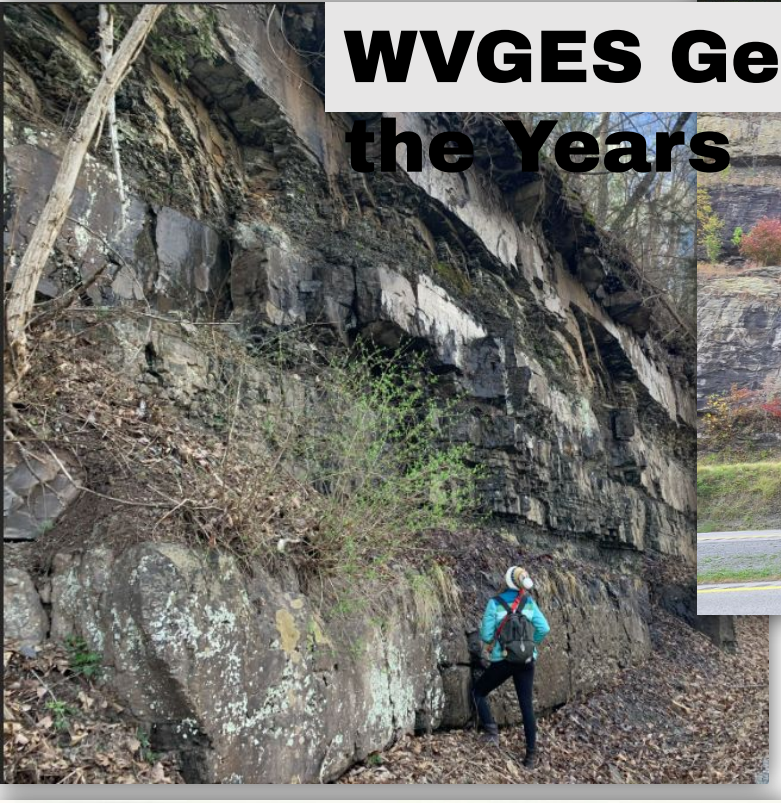
Insights from Appalachian Airborne and Geophysical Transect Studies

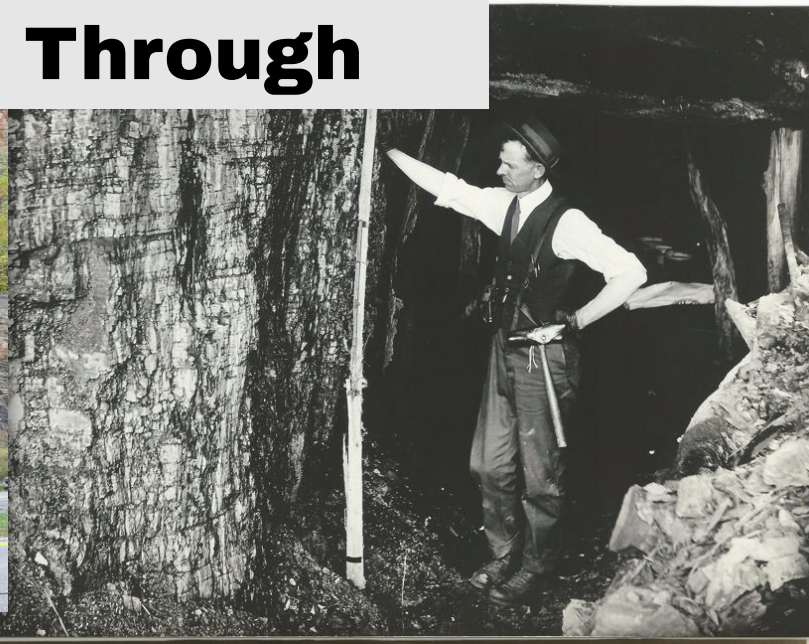


Jessica Moore
Director and State Geologist

West Virginia
Geological and
Economic Survey

WVGES Geoscience Investigations Through the Years



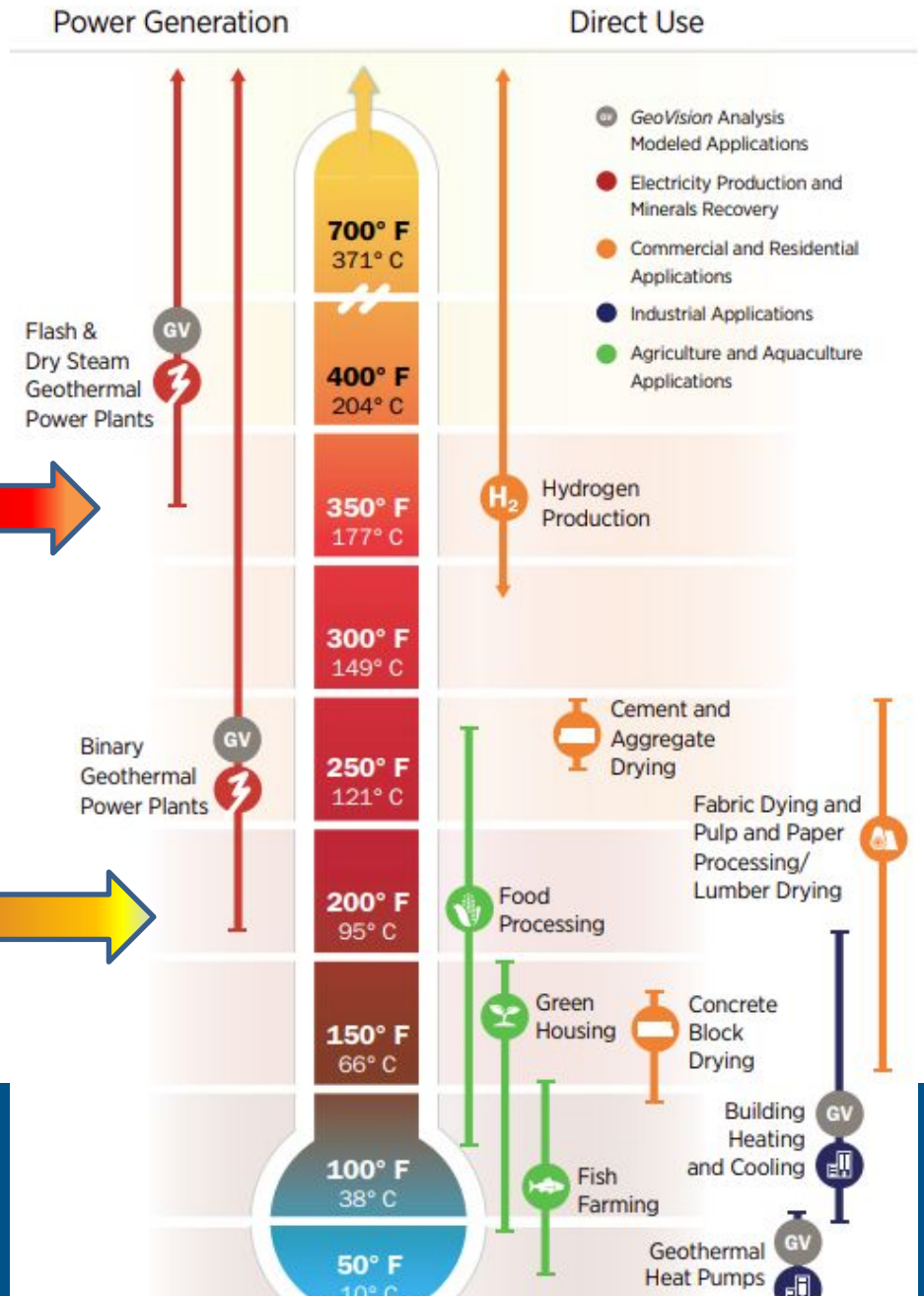


The Challenge: Geothermal Energy for Baseload Power Generation

DOE Geothermal Technologies Office *GeoVision* Report

Flash Steam Plants Above ~375° F

Binary Plants Above ~225° F

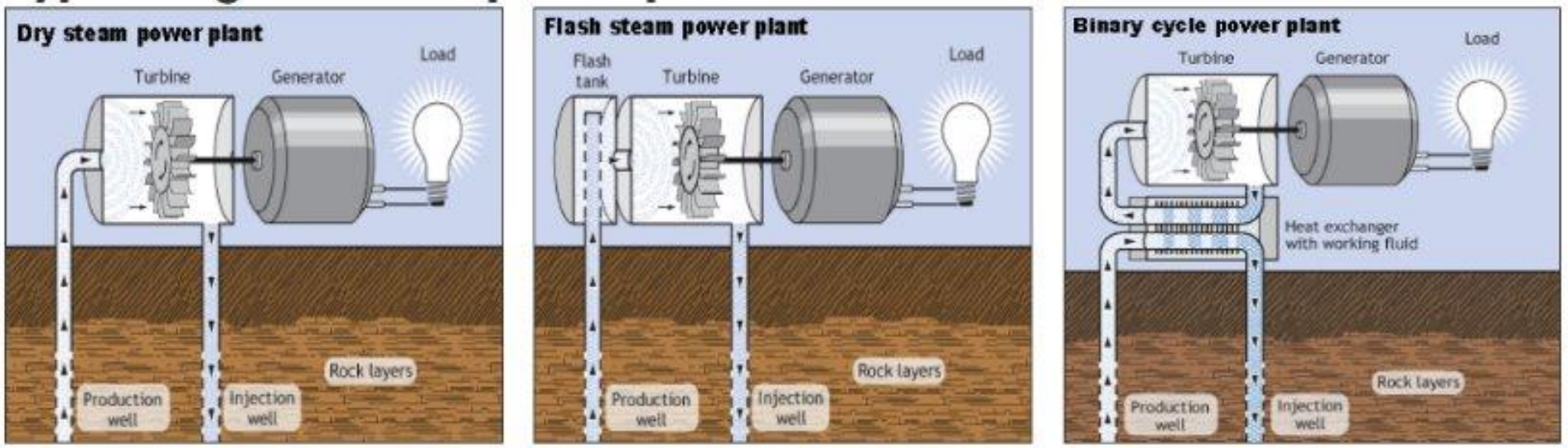


GeoVision: Harnessing the Heat Beneath Our Feet (energy.gov)

WVGES
West Virginia Geological and Economic Survey

- **Dry steam plants** use steam directly from a geothermal reservoir to turn generator turbines. The first geothermal power plant was built in 1904 in Tuscany, Italy, where natural steam erupted from the earth.
- **Flash steam plants** take high-pressure hot water from deep inside the earth and convert it to steam that drives generator turbines. When the steam cools, it condenses to water and is injected back into the ground to be used again. Most geothermal power plants are flash steam plants.
- **Binary-cycle power plants** transfer the heat from geothermal hot water to another liquid. The heat causes the second liquid to turn to steam, and the steam drives a generator turbine.

Types of geothermal power plants

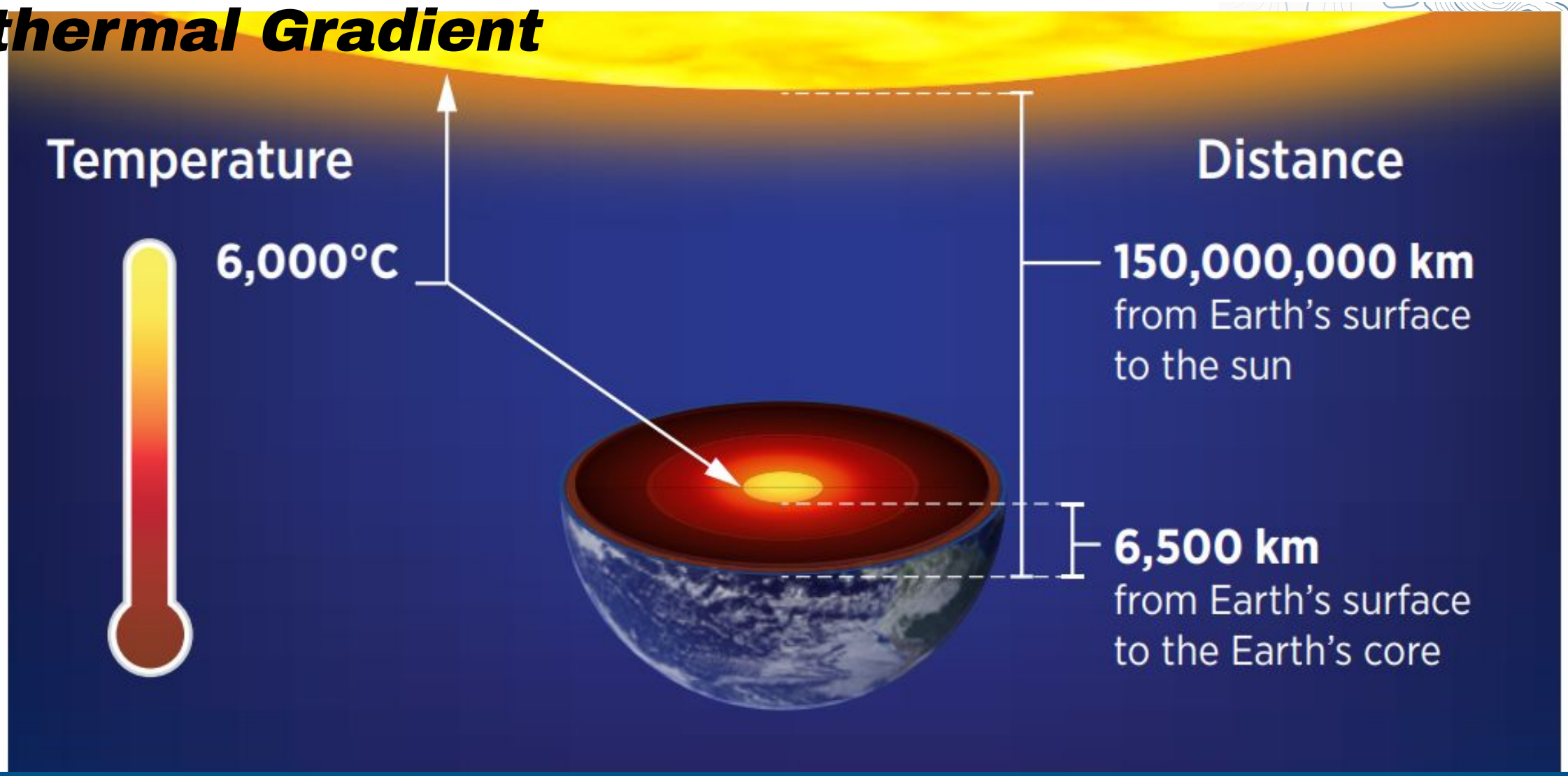


Source: U.S. Department of Energy, Geothermal Technologies Office (public domain)

WVGES
West Virginia Geological and Economic Survey

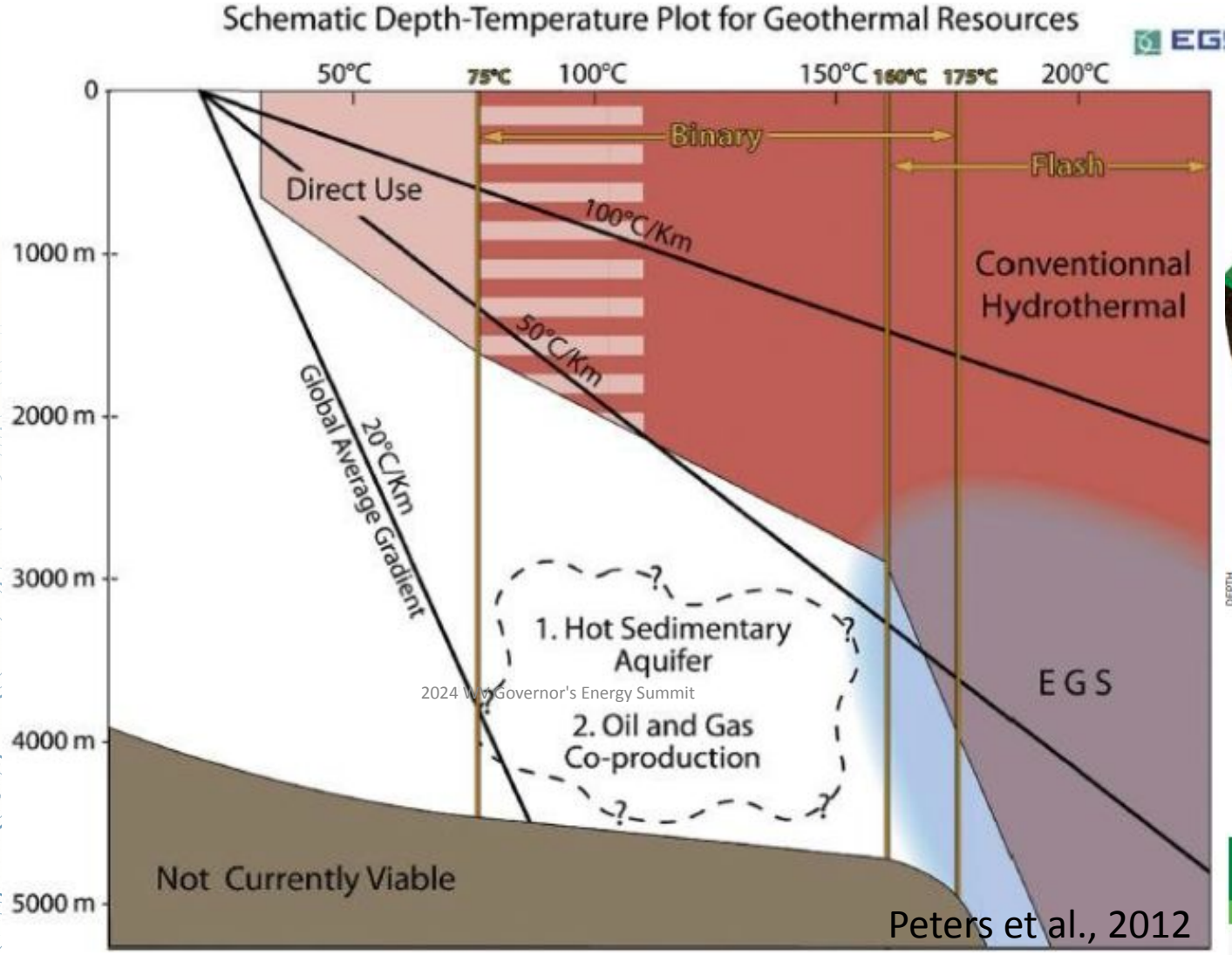
Strategy One: Look Deep

Earth's Temperature Increases with Depth = *Geothermal Gradient*

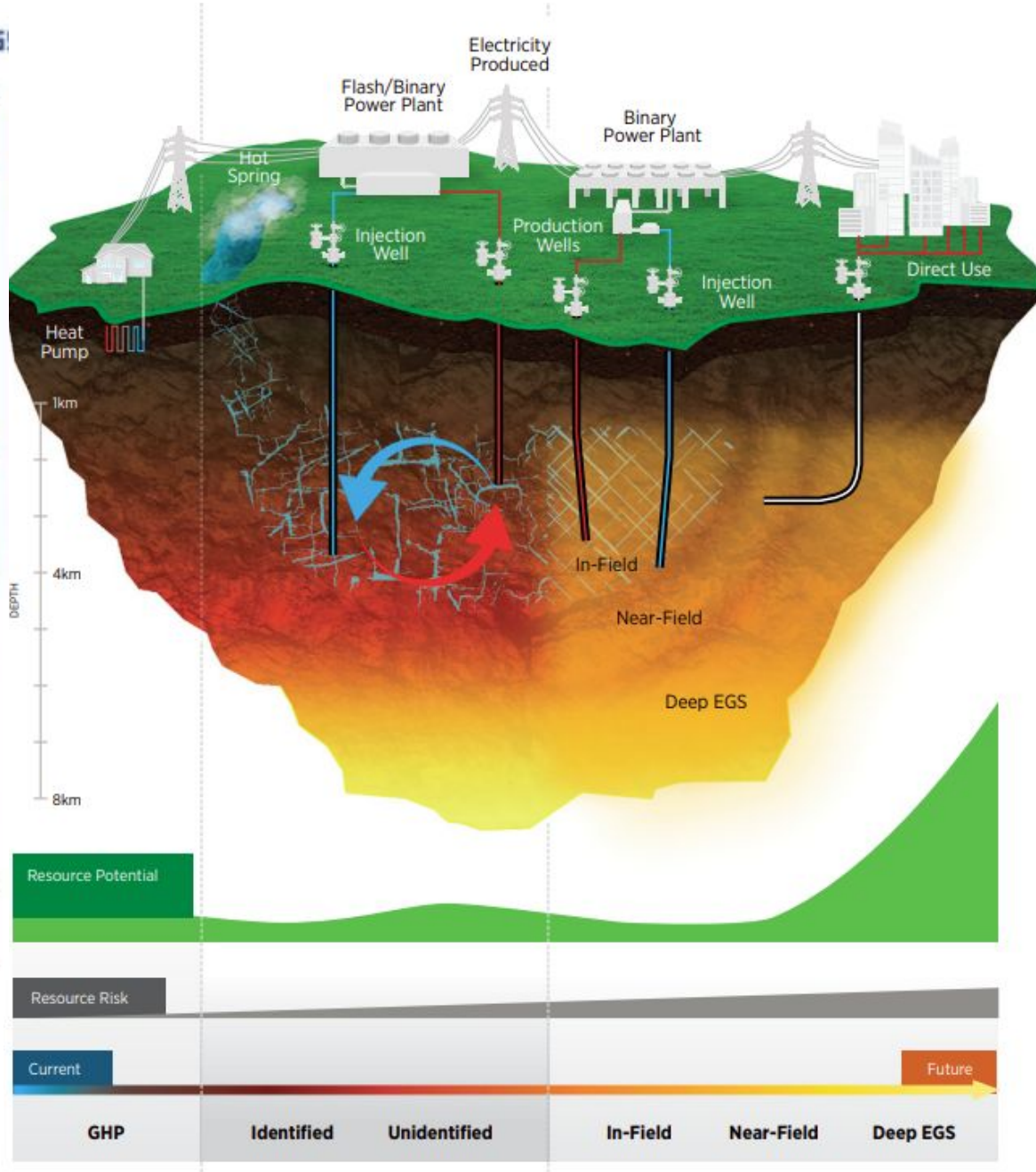


WVGES
West Virginia Geological and Economic Survey

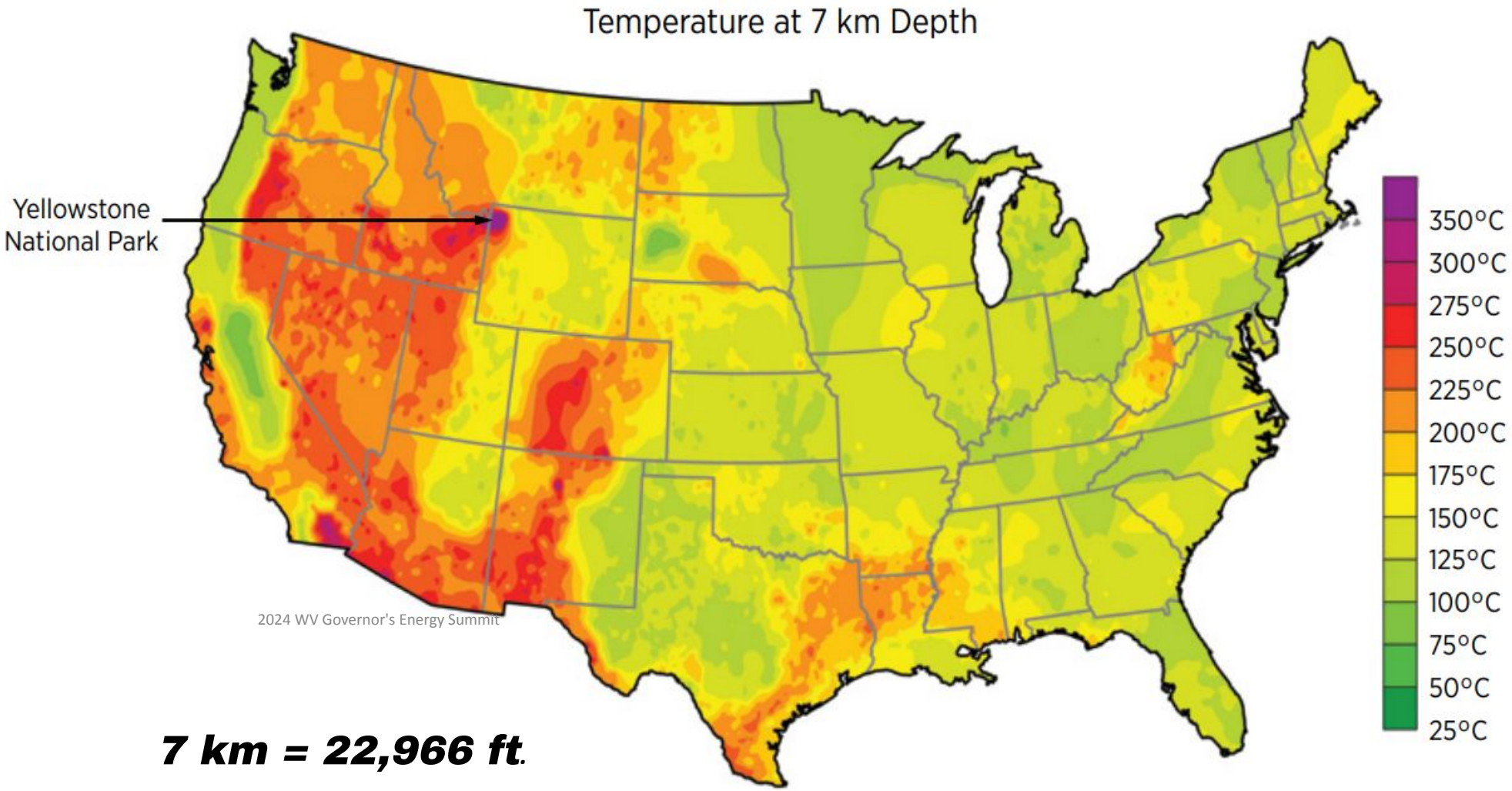
Average Gradient Range = 1.3 – 2.2°F per 100 ft.



Peters et al., 2012



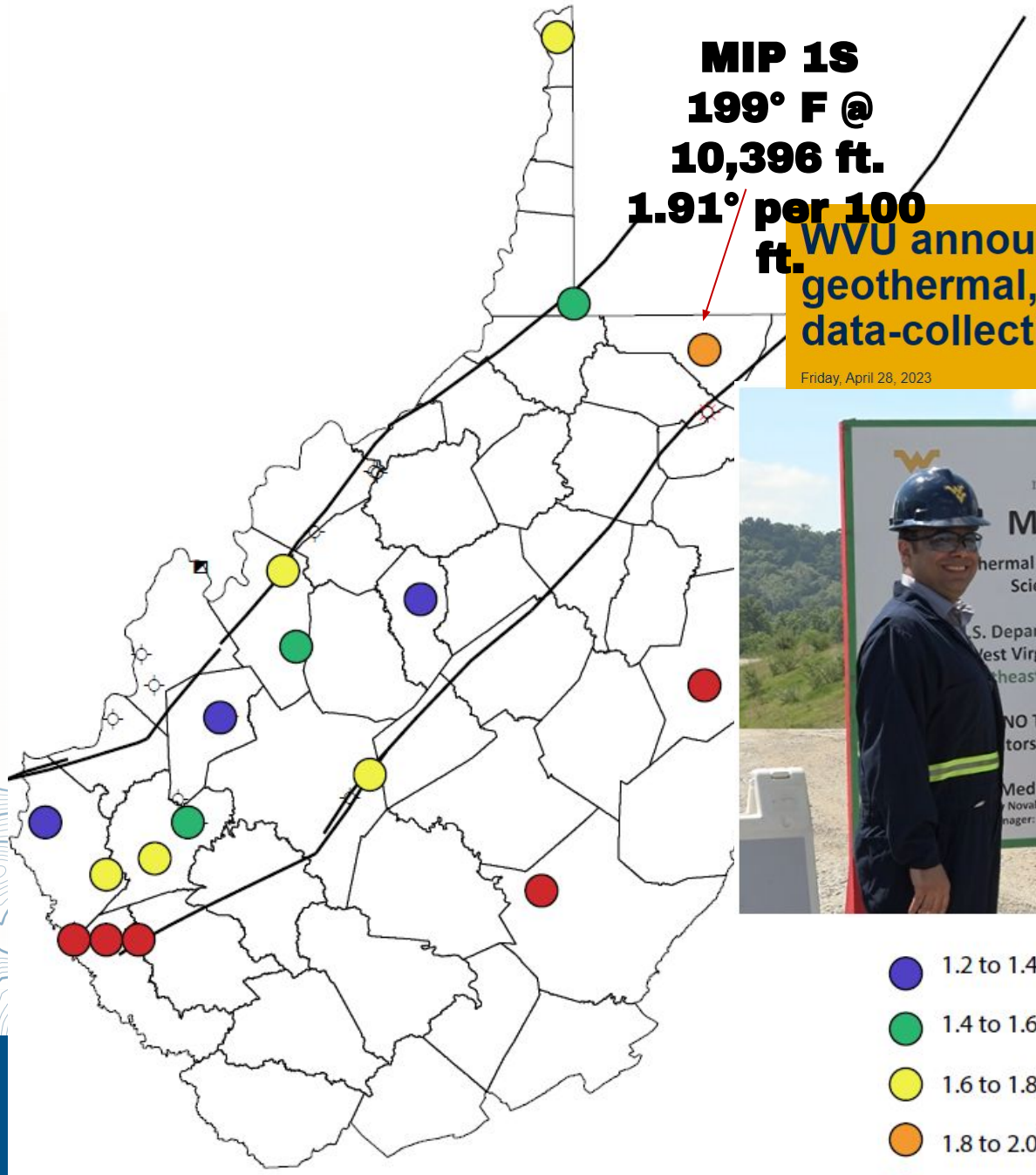
Worldwide average geothermal gradients are from 24 to 41°C/km (1.3-2.2°F/100 ft), with extremes outside this range



7 km = 22,966 ft.

Blackwell et al., 2011

WVGES
West Virginia Geological and Economic Survey

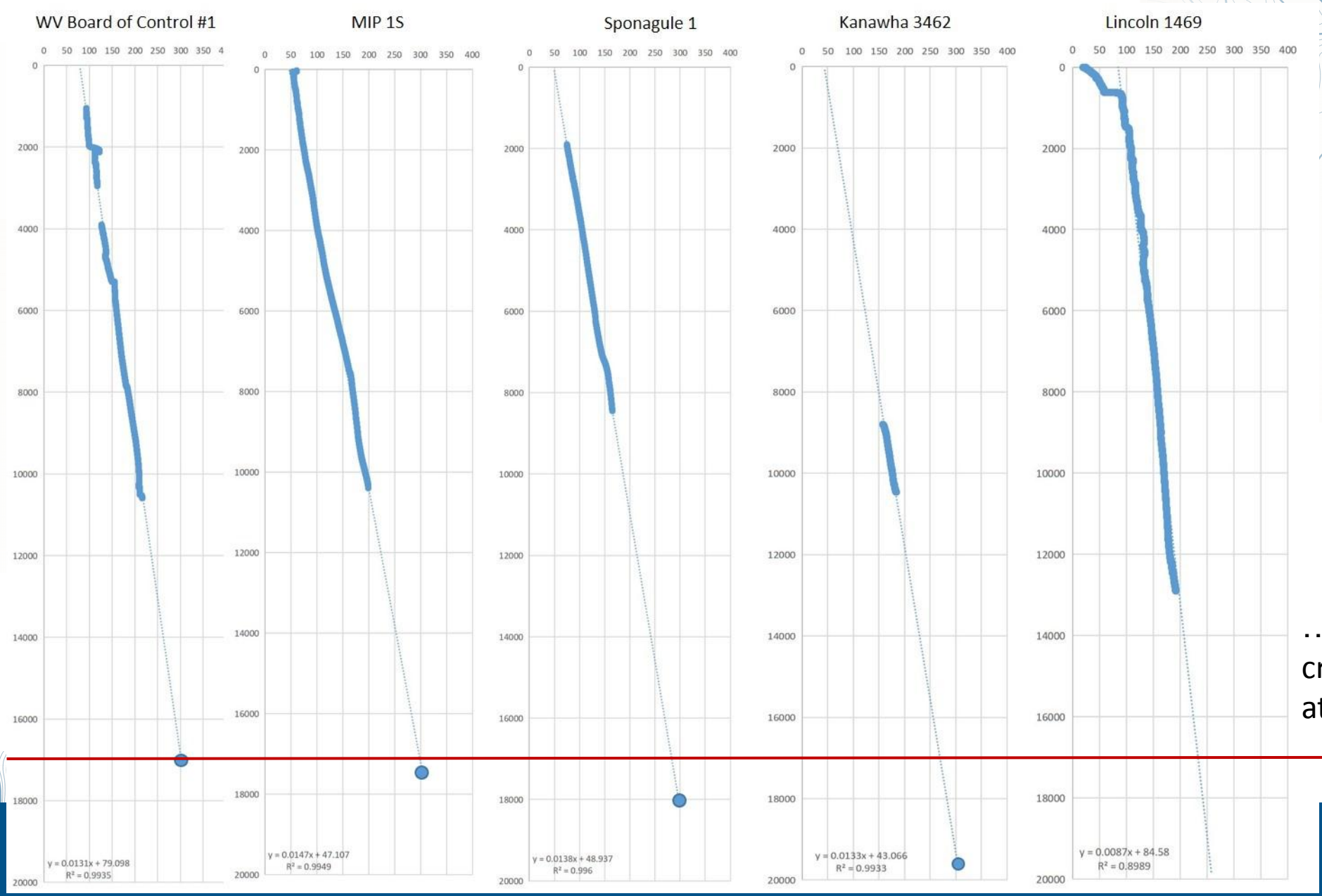


WVU announces drill date for first geothermal, carbon capture and storage data-collection well in West Virginia

Friday, April 28, 2023

- 1.2 to 1.4° F/100 ft.
- 1.4 to 1.6° F/100 ft.
- 1.6 to 1.8° F/100 ft.
- 1.8 to 2.0° F/100 ft.
- Greater than 2.0° F/100 ft.

WVGES
West Virginia Geological and Economic Survey



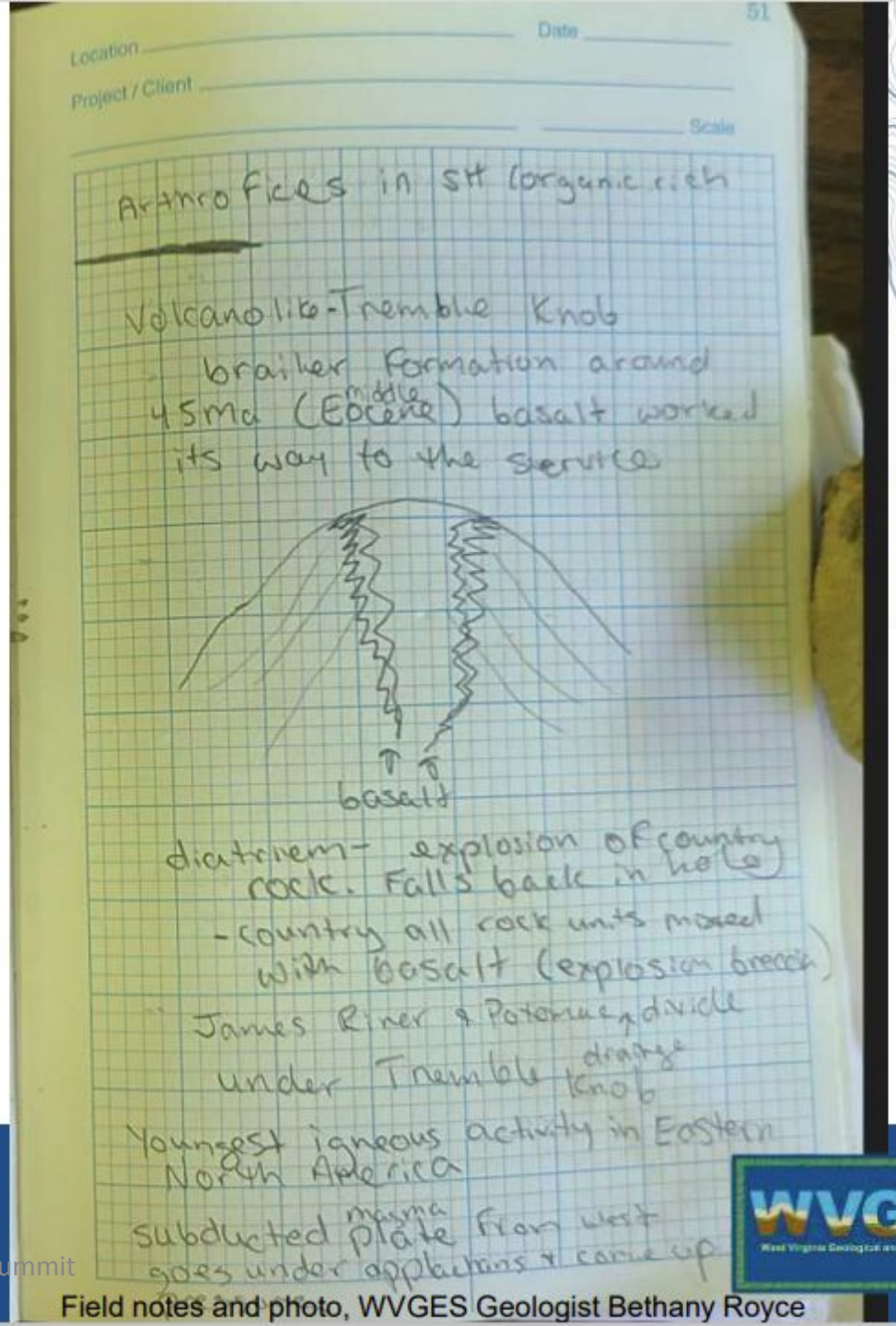
Must drill to at least ~17,000 ft. to reach 300° F temps

…and find (or create) pore space at depth!

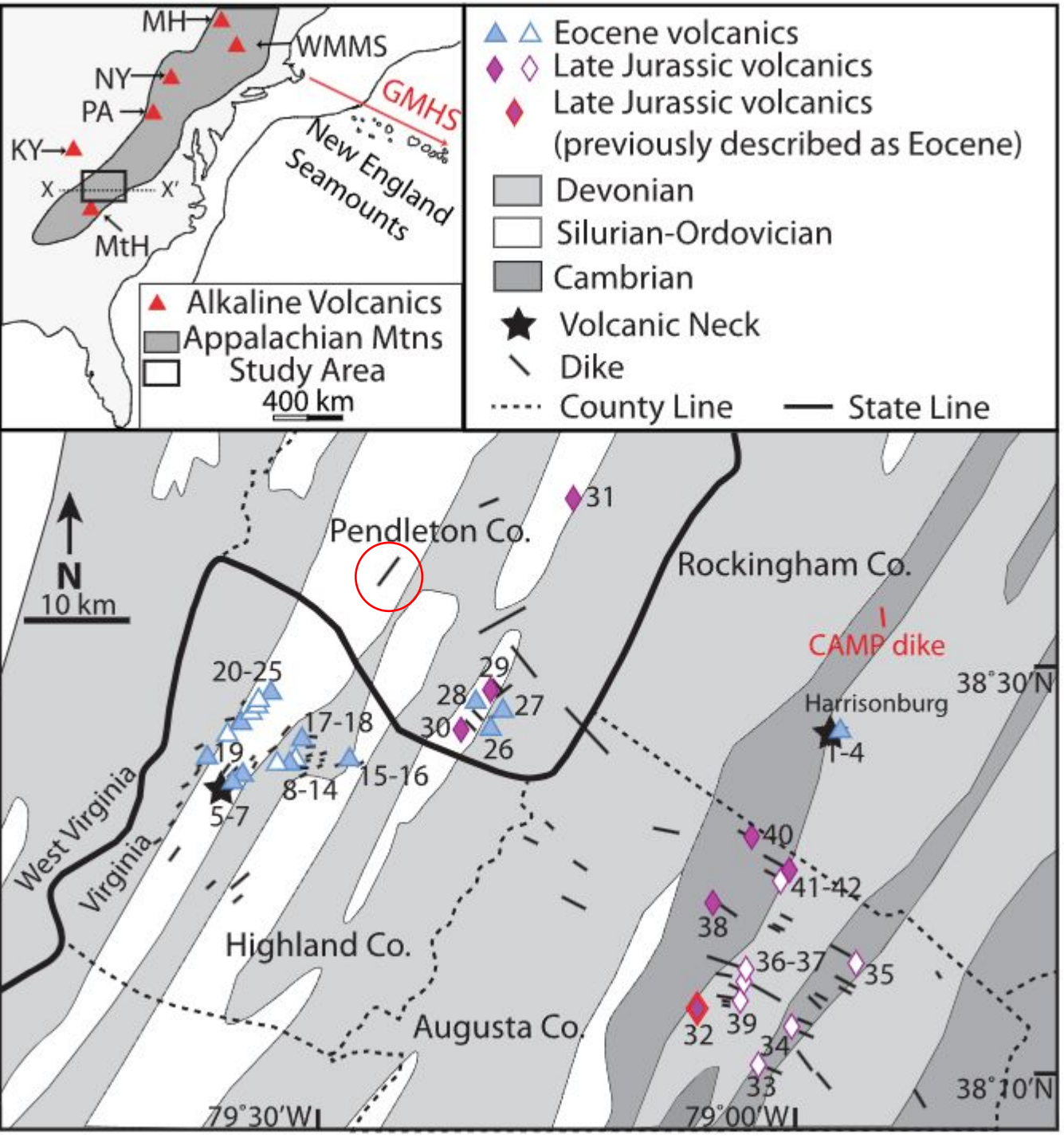
WVGES
West Virginia Geological and Economic Survey

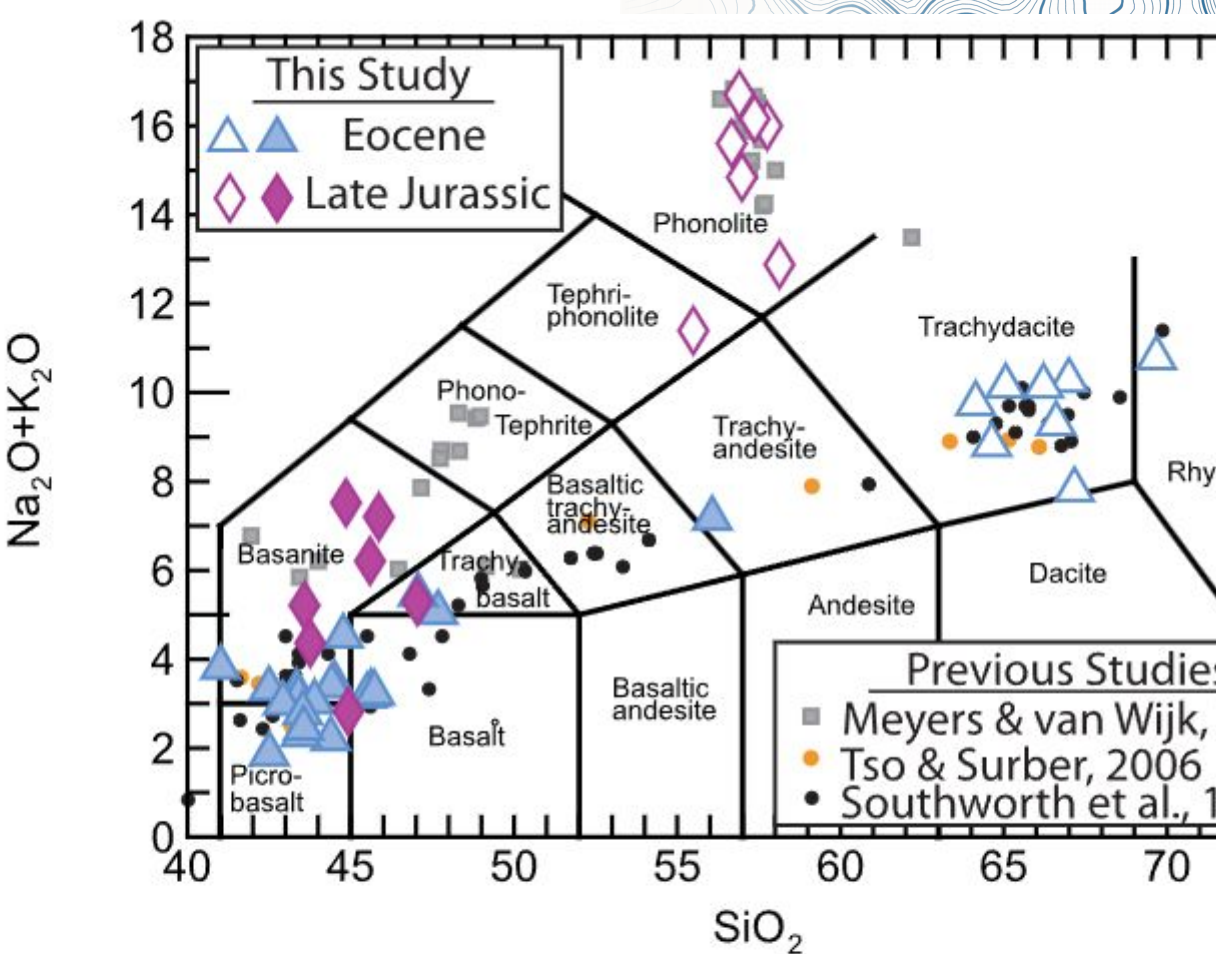
Strategy Two: Investigate the Volcano

Trimble Knob, Monterey, VA. Volcano-like explosive feature



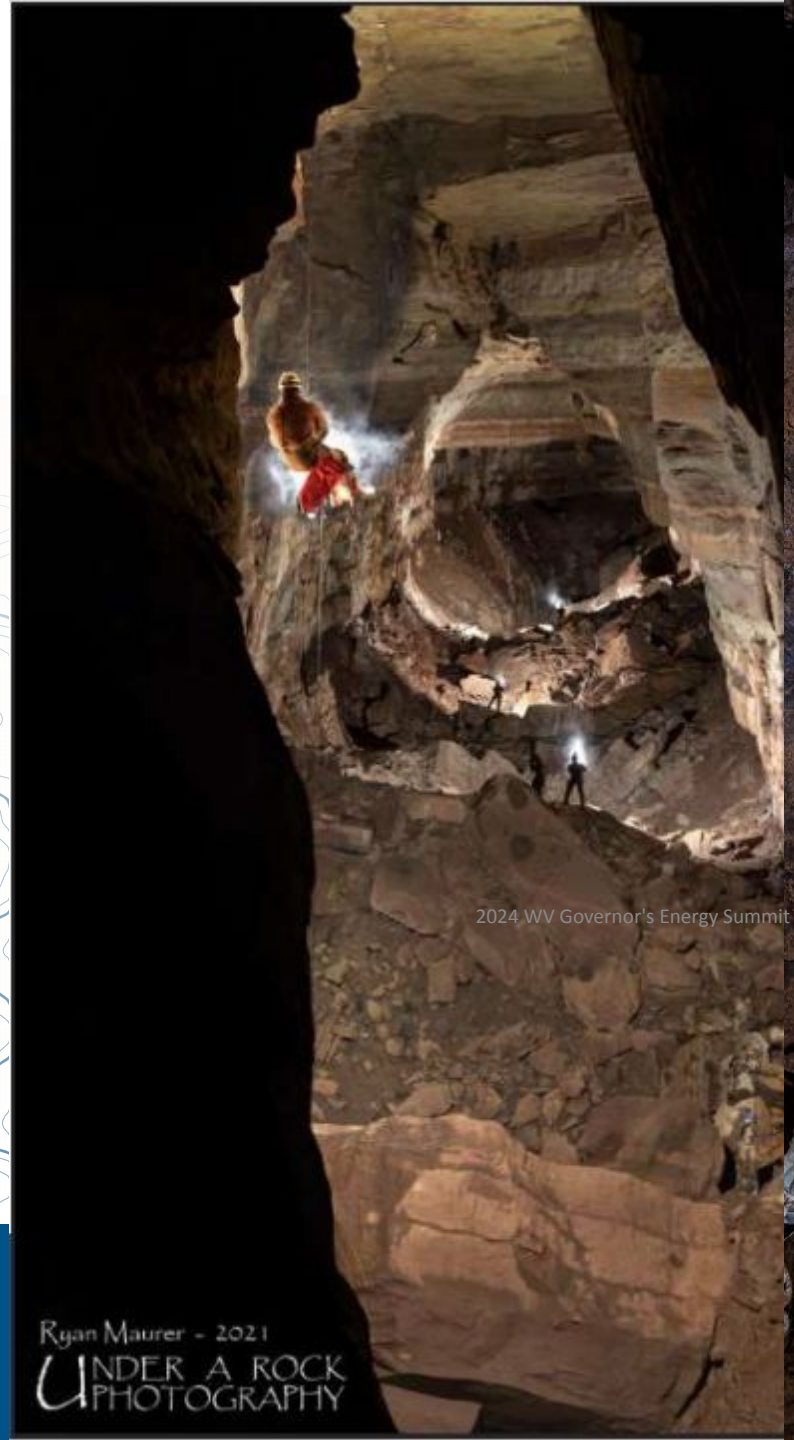
Field notes and photo, WVGES Geologist Bethany Royce





Sponagule #1 well drilled into an igneous intrusion (red circle); temps are still not as high as Huttonsville well

Post-rift magmatic evolution of the eastern North American "passive-aggressive" margin (wiley.com)



nes the vesicular basalt intrusion into limestone and
is thought to be the youngest documented intrusion on
nger than previously documented bodies.

Strategy Three: Add Earth MRI + MAGIC Surveys

EARTH MRI: The Earth Mapping Resources Initiative

Mapping the Nation

What is Earth MRI?

Through Earth MRI, the USGS Mineral Resources Program and partners are updating the Nation's maps of geology and mineral resources. Earth MRI collects the data needed to identify mineral resources, as well as to evaluate energy and groundwater resources and natural hazards.

Who is Earth MRI?

The USGS partners with State geological surveys, Federal agencies, Tribes, academia and private industry.

Why do we need Earth MRI?

The U.S. is undermapped. Earth MRI provides a fuller picture of the Nation's geologic resources to address pressing issues:

Critical minerals for consumer, defense and energy technologies. Earth MRI data are needed to evaluate domestic mineral resources and inform strategic decisions about where and how minerals may be sourced.

Rebuilding from natural disasters. Earth MRI data are used to find domestic sources of construction materials to rebuild from hurricanes and floods.

Danger of geologic hazards. Earth MRI data help identify potential hazards like landslides and earthquakes.

Demand for water. Earth MRI data can help characterize groundwater resources.

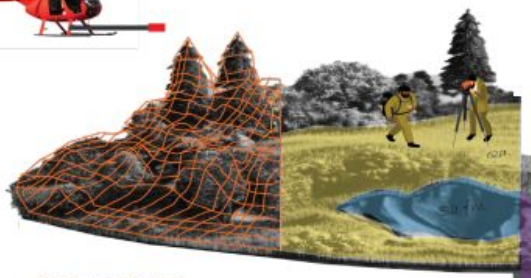
Demand for energy. Earth MRI data are used to evaluate geologic energy resources ranging from geothermal to hydrogen.

We collect multiple types of data…

Topography

High-resolution elevation data help identify **geological structures,** estimate **volumes of materials** and model **how water moves** across the Earth's surface.

Geology



Geologic maps identify **rock types on the Earth's surface.** Earth MRI's geologic mapping advances understanding of areas with mineral potential.

Geochemistry

Labs measure **concentrations of minerals in rocks** and inform remediation by showing **how minerals interact with the environment.**

Geophysics

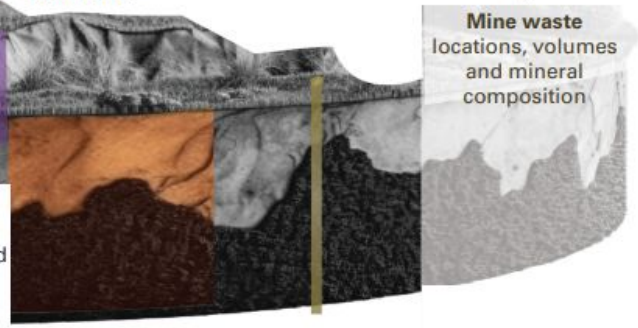
Magnetic and radioactive signatures of underground rocks can identify **buried minerals and large geological structures.**

Borehole Information

Old and new rock samples and drill cores help identify **rock types below the Earth's surface.**

…and more

- **Hyperspectral imagery** to identify minerals on the surface of the Earth and in mine wastes
- **Mine waste** locations, volumes and mineral composition



…for a fuller picture of the Earth and its resources.

Connect with Earth MRI
www.usgs.gov/special-topics/earth-mri

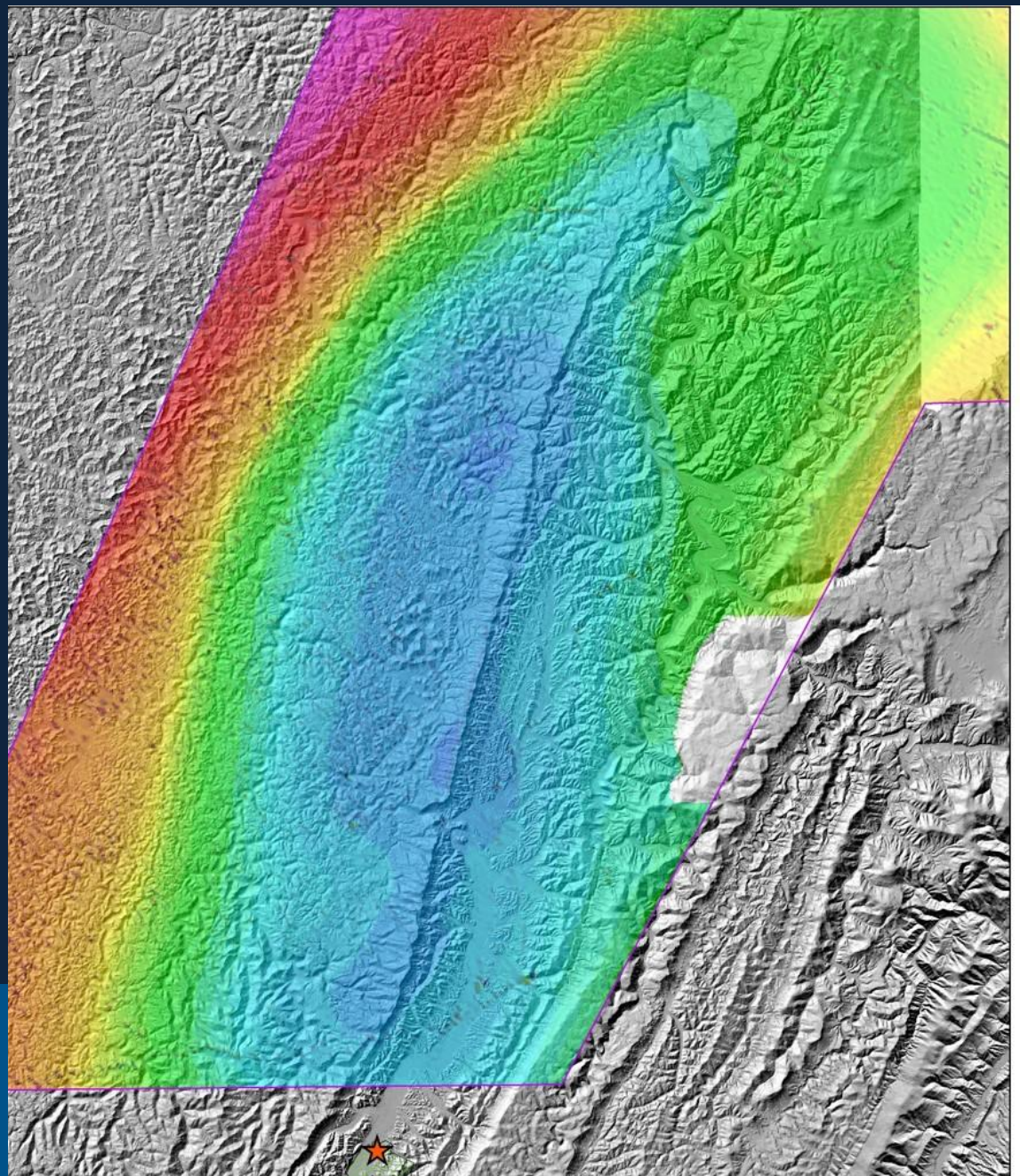
Darcy McPhee
Program Manager
dmcphee@usgs.gov

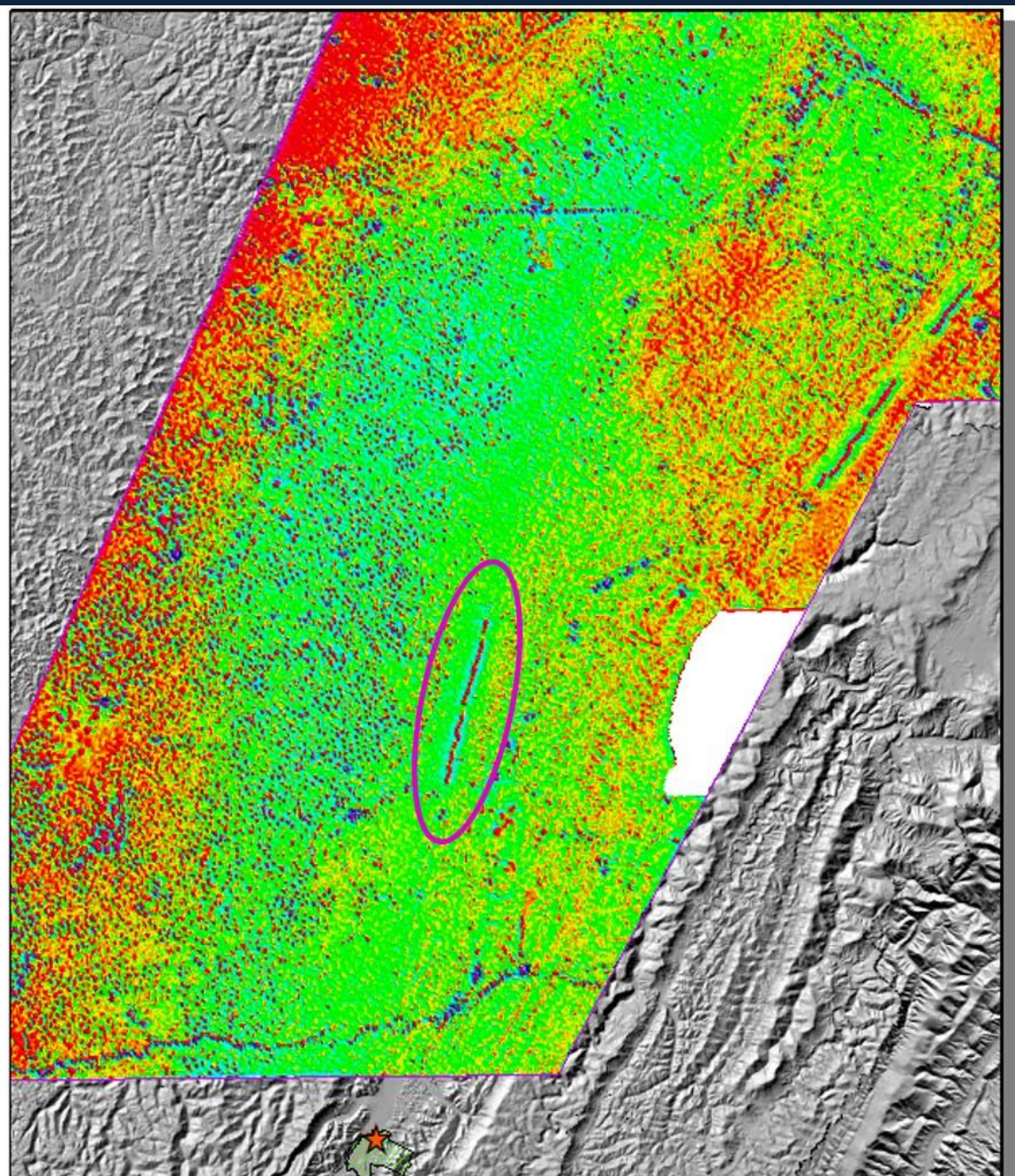
Jamey Jones
Science Coordinator
jvjones@usgs.gov

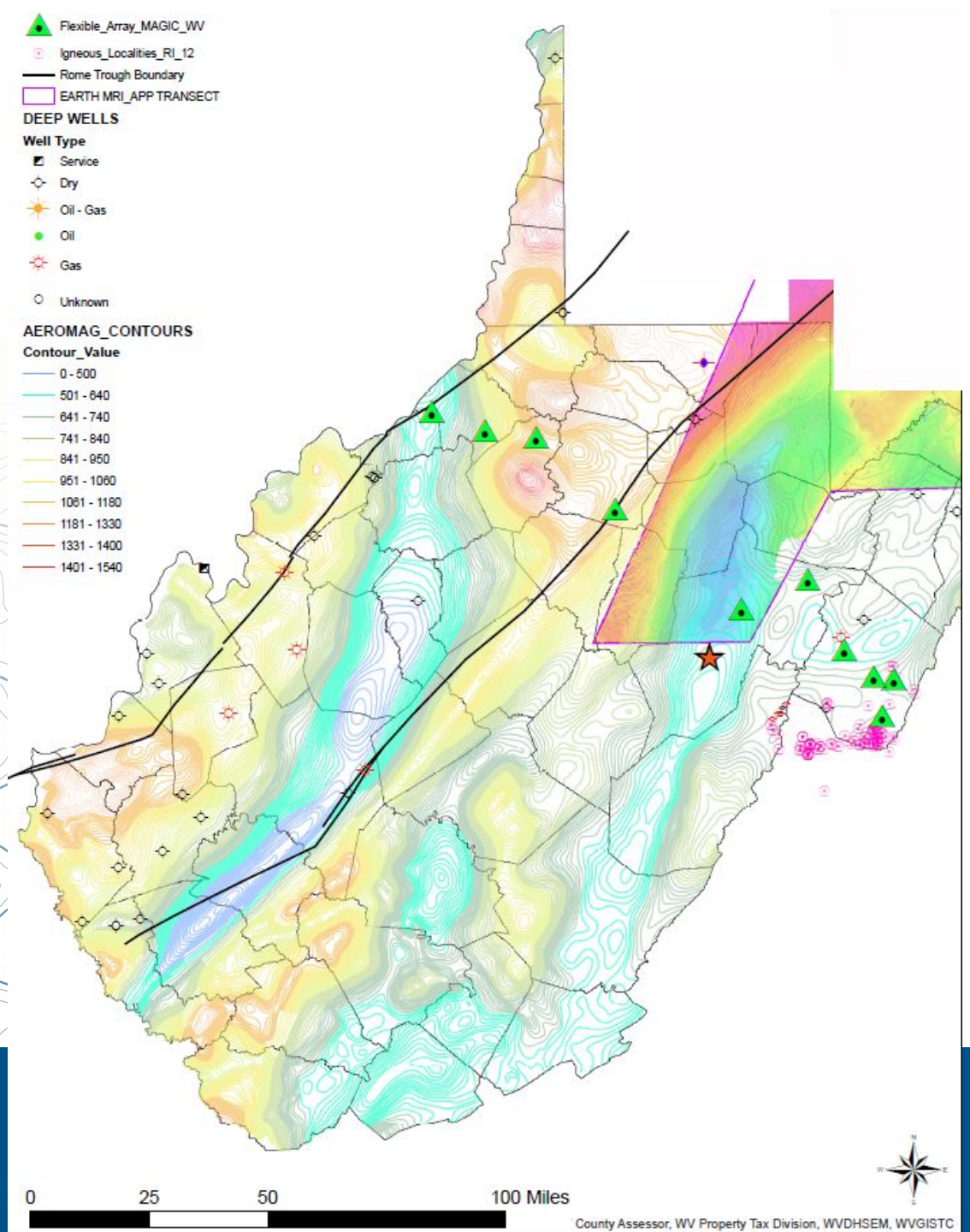
U.S. Department of the Interior
U.S. Geological Survey

July 2024

Earth MRI Central Appalachian Transect



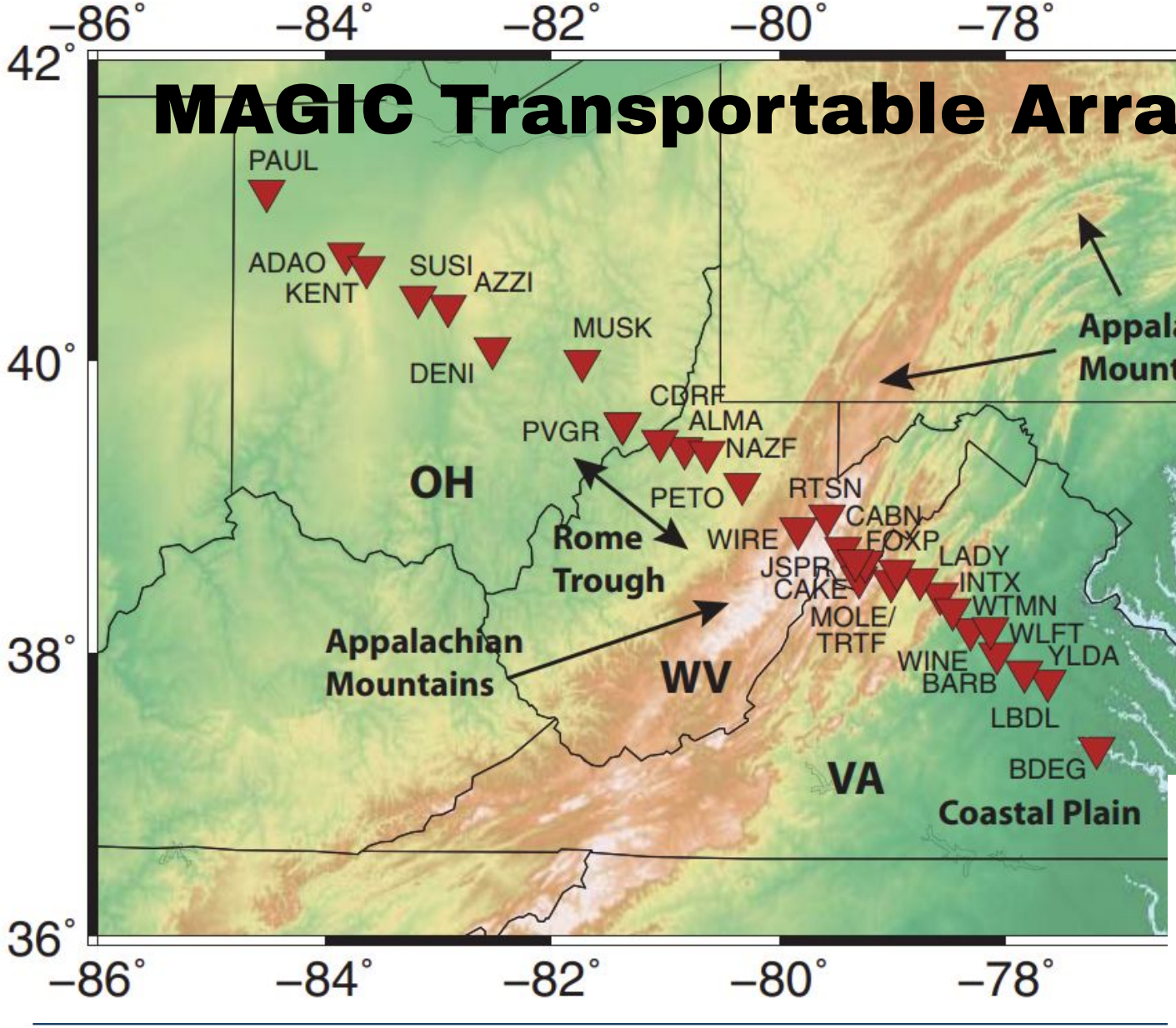




Could Magnetic Lows Help Identify Geothermal Anomalies?

- Magnetic lows are sometimes related to geothermal anomalies due to the properties of magnetic minerals at high temperatures
- Two major magnetic low trends are observed
- Western trend does not correlate to increased temperatures
- Wells w/ elevated temperatures are no on trend
- MAGIC Array cuts across the trends

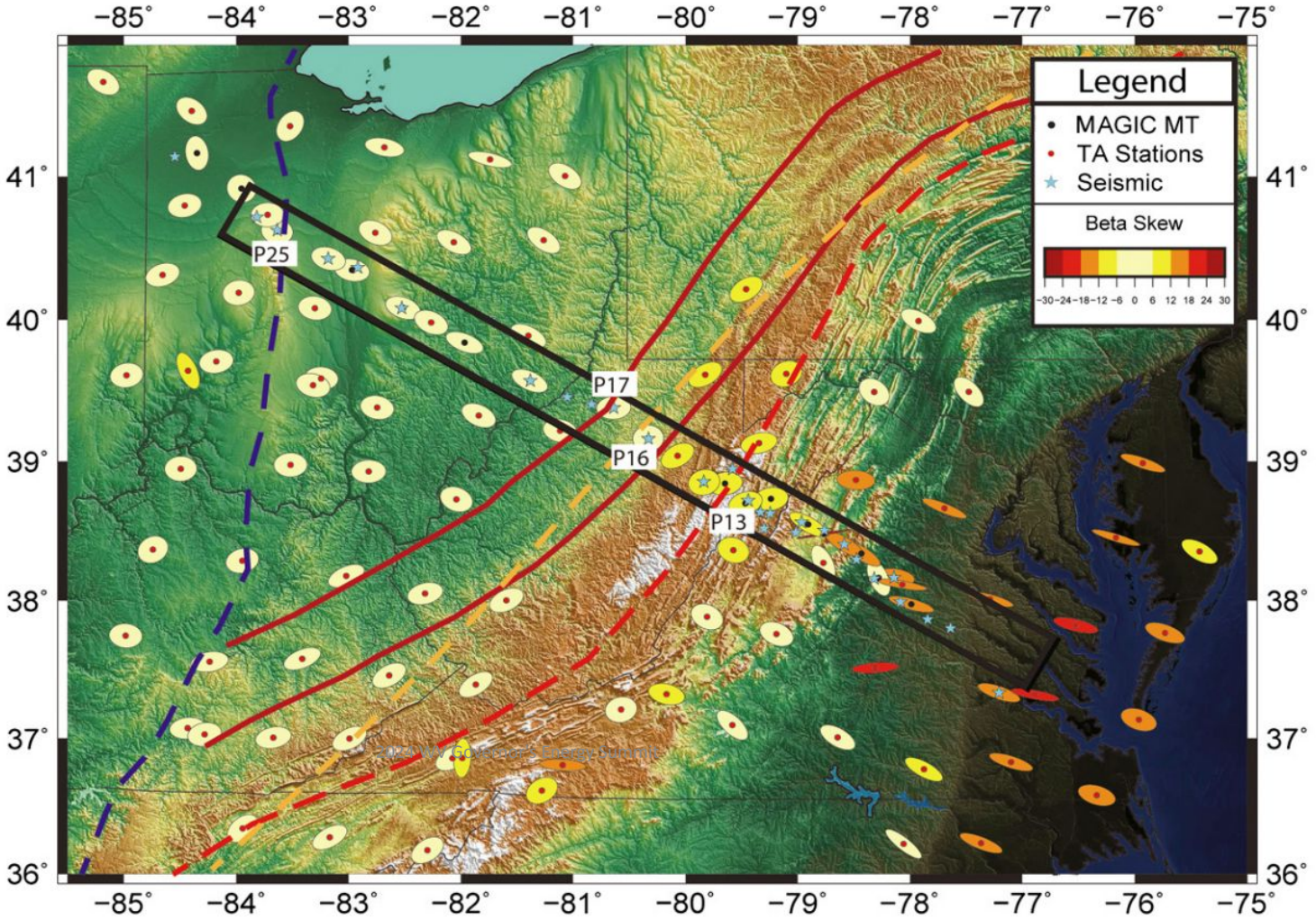
MAGIC Transportable Array

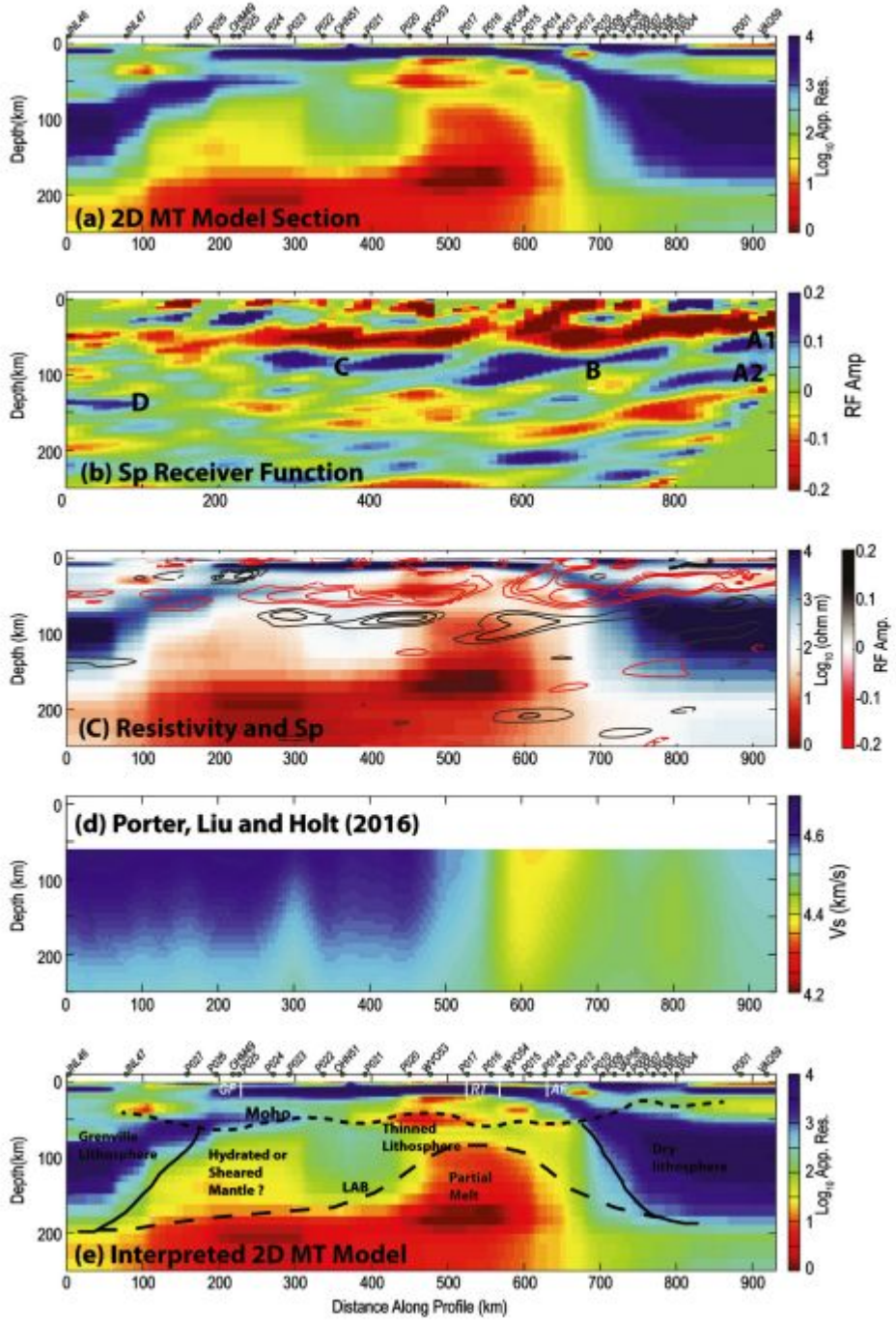


USArray - MAGIC

ARAGON ET AL. ANISOTROPY BENEATH CENTRAL APPALACHIANS

Thin lithosphere beneath the central Appalachian Mountains: A combined seismic and magnetotelluric study (yale.edu)





Evans et al., 2019; Long et al., 2020

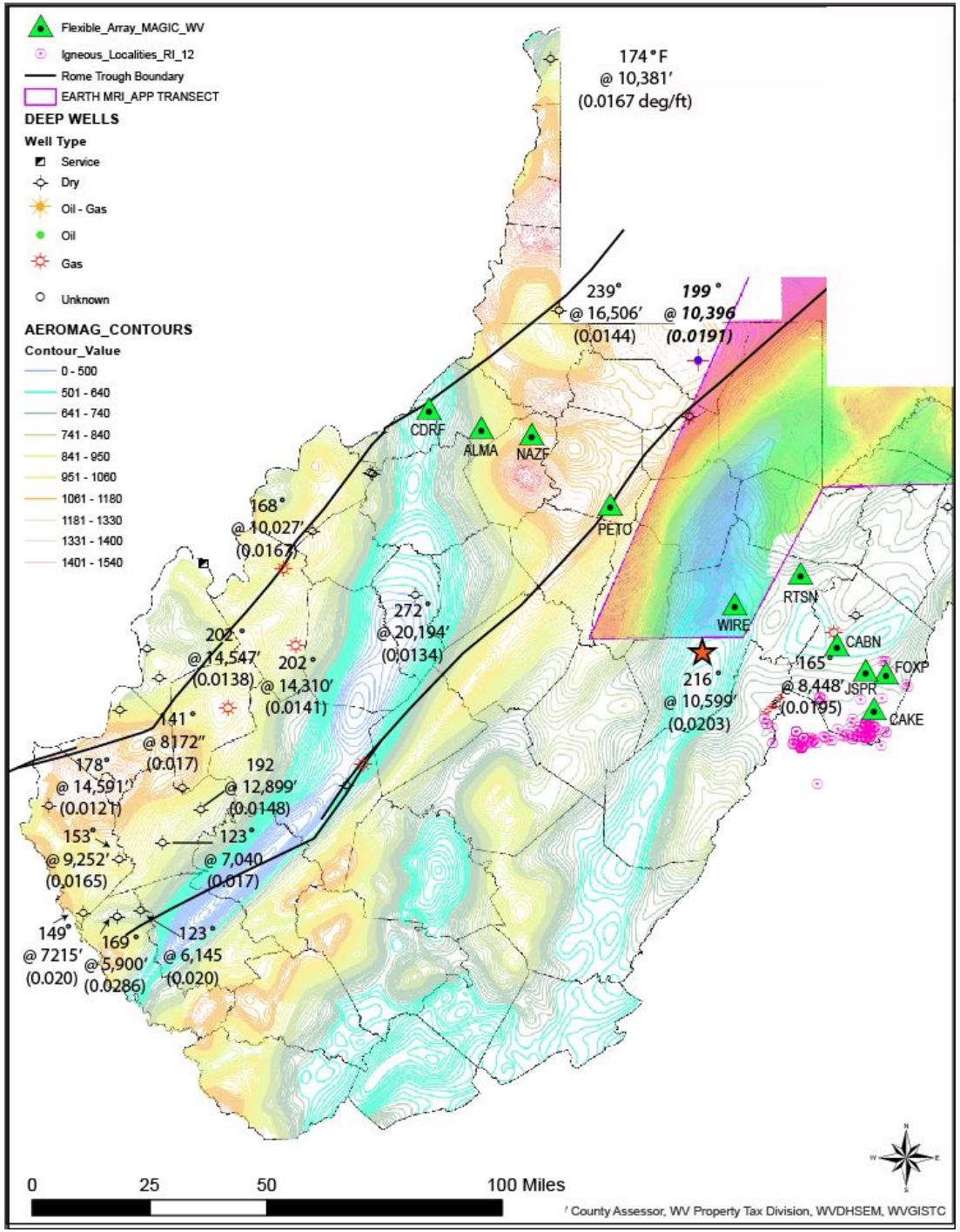
Key Findings of the MAGIC Experiment

"Perhaps one of the most surprising and perplexing observations made over the past 15 years of EarthScope and related science is the presence of an apparent "hole" in the lithosphere beneath the Central Appalachians in Virginia and West Virginia that correlates very closely with the presence of comparatively recent (Late Jurassic and Eocene) volcanism. While th undergone a series of major tectonic events over th these events significantly pre-date the volcanic episodes."

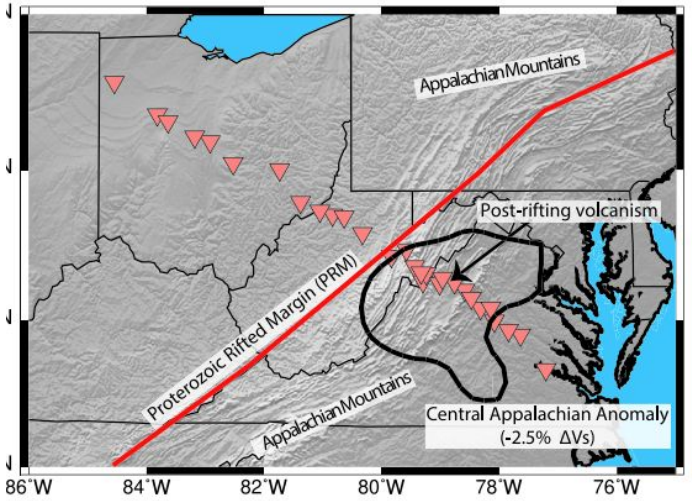
Evaluating Models for Lithospheric Loss and Intraplate Volcanism Beneath the Central Appalachian Mountains

Maureen D. Long[1], Lara S. Wagner[2], Scott D. King[3], Rob L. Evans[4], Sarah E. Mazza[5], Joseph S. Byrnes[6,7], Elizabeth A. Johnson[8], Eric Kirby[9], Maximiliano J. Bezada[6], Esteban Gazel[10], Scott R. Miller[11], John C. Aragon[1,12], and Shangxin Liu[3]

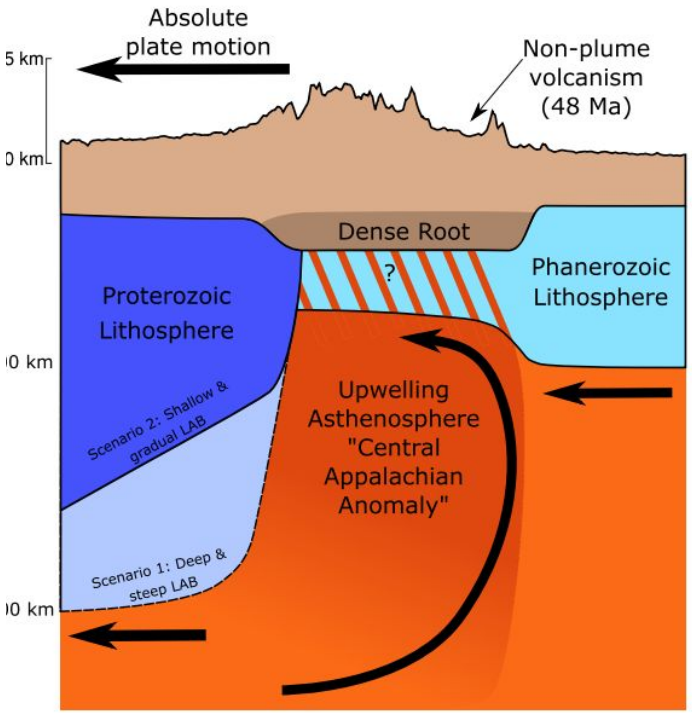
WVGES West Virginia Geological and Economic Survey



- **Comparison of bottom hole temperatures (BHTs) from wireline logs across the MAGIC survey area suggests elevated thermal gradients in the Valley & Ridge across the Central Appalachian Anomaly**



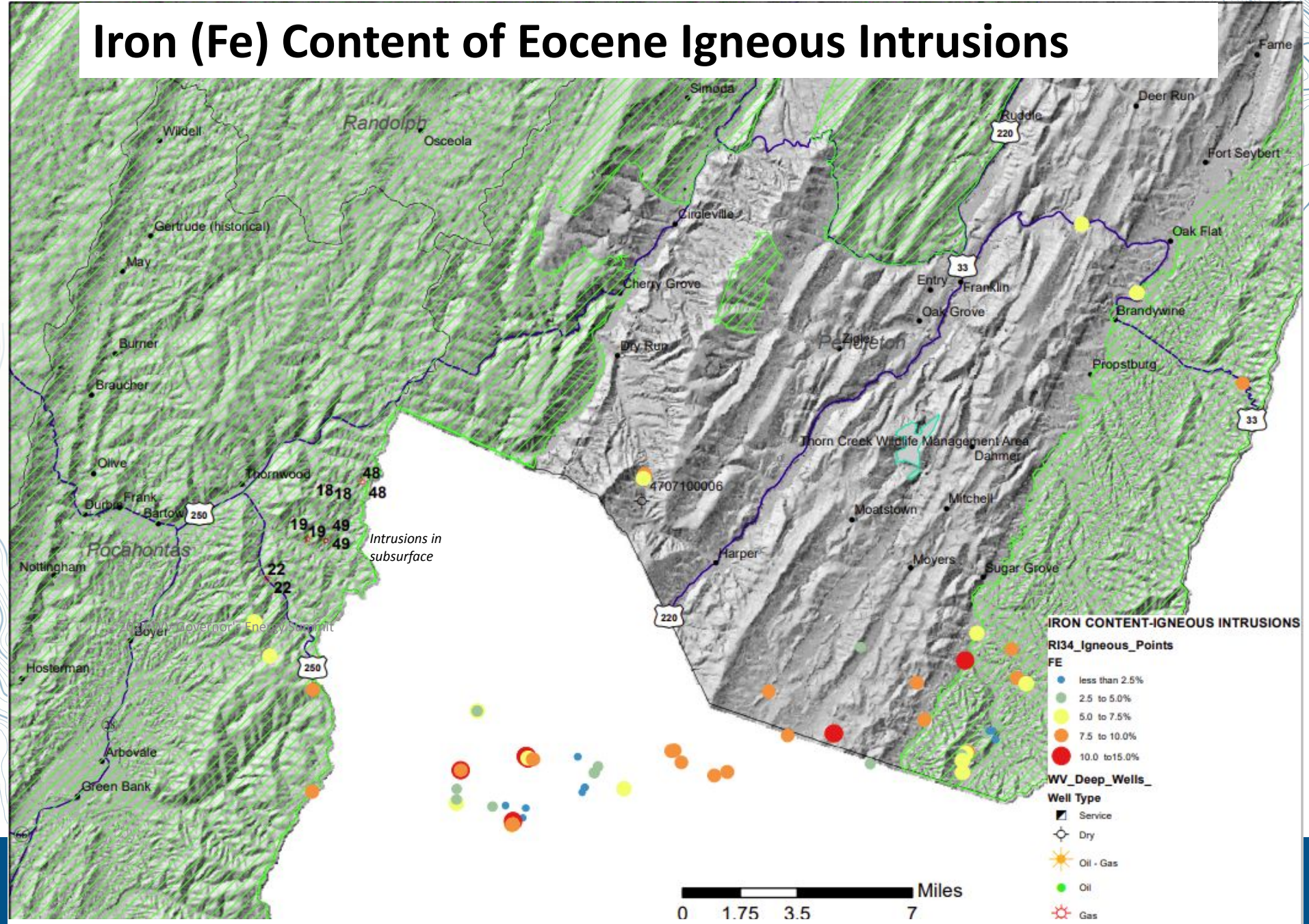
- **Thermal anomaly not observed as part of magnetic anomaly in the deepest part of Rome Trough**



- **Igneous intrusions associated with non-plume volcanism have potentially significant geochemistry**

Strategy Four: Add a Wildcard

Iron (Fe) Content of Eocene Igneous Intrusions

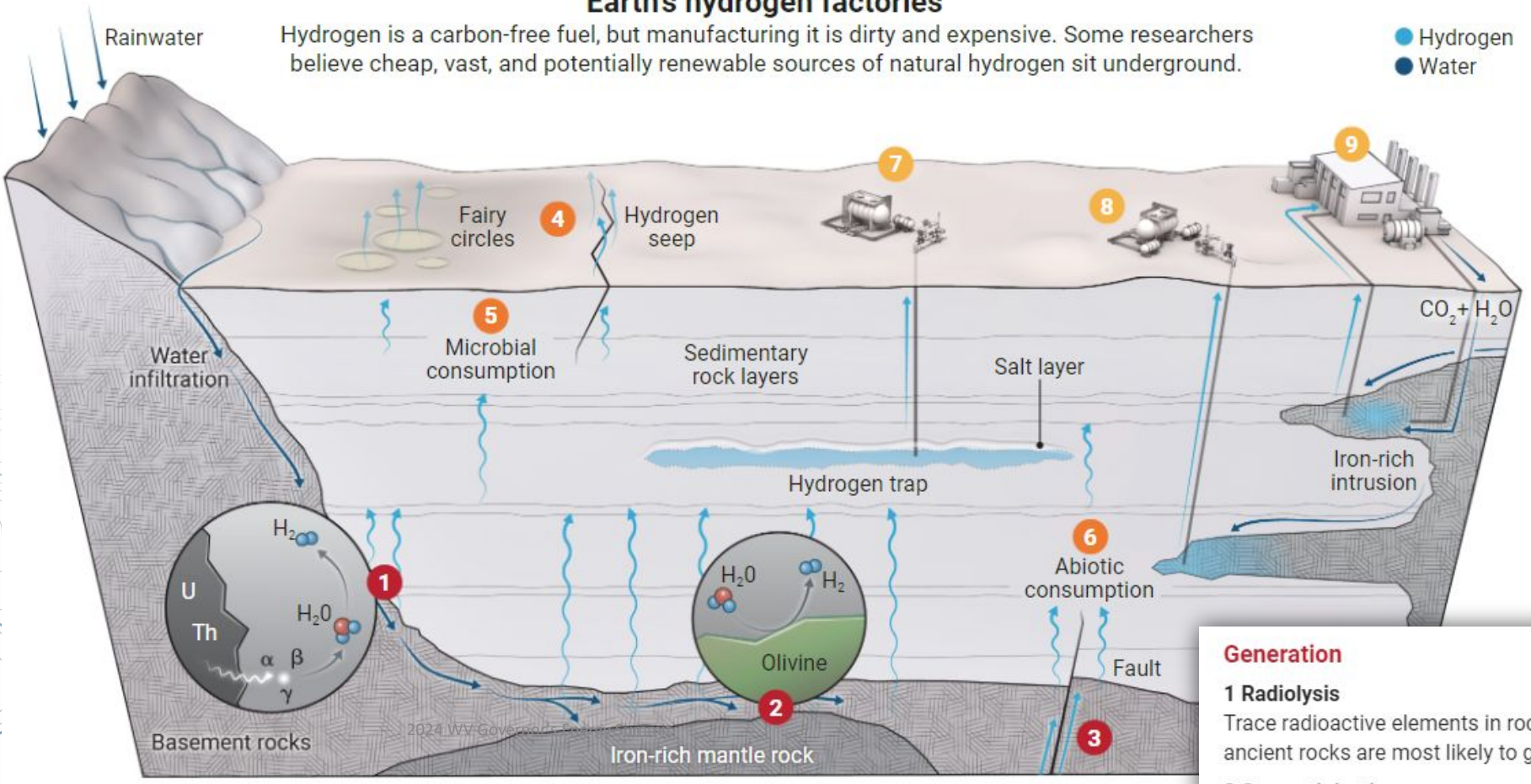


Legacy geochemical data collected during STATEMAP bedrock mapping projects

WVGES
West Virginia Geological and Economic Survey

Earth's hydrogen factories

Hydrogen is a carbon-free fuel, but manufacturing it is dirty and expensive. Some researchers believe cheap, vast, and potentially renewable sources of natural hydrogen sit underground.



Generation

1 Radiolysis
Trace radioactive elements in rocks emit radiation that can split water. The process is slow, so ancient rocks are most likely to generate hydrogen.

2 Serpentinization
At high temperatures, water reacts with iron-rich rocks to make hydrogen. The fast and renewable reactions, called serpentinization, may drive most production.

3 Deep-seated
Streams of hydrogen from Earth's core or mantle may rise along tectonic plate boundaries and faults. But the theory of these vast, deep stores is controversial.

Hidden hydrogen: Earth may hold vast stores of a renewable, carbon-free fuel | Science | AAAS

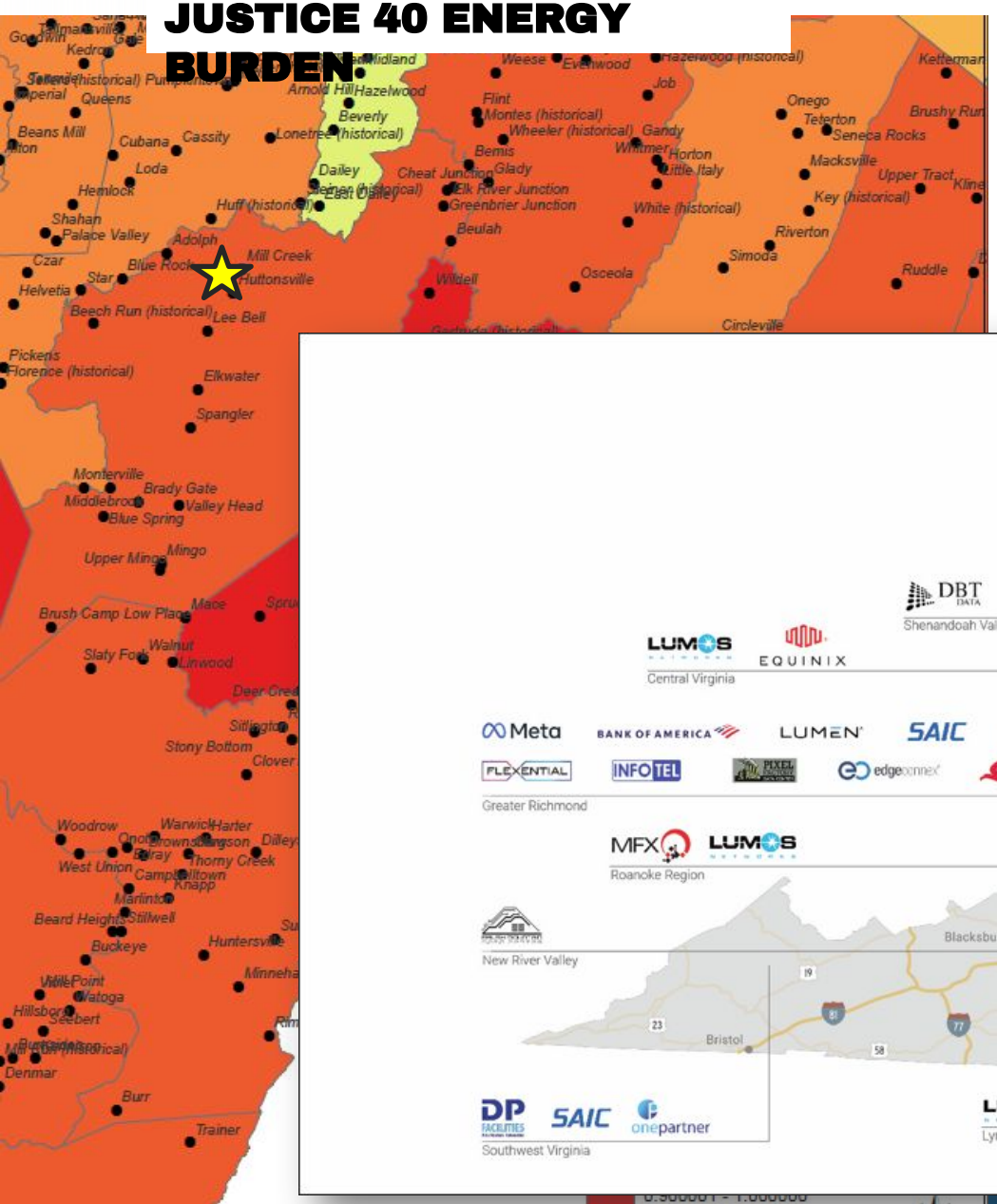
WVGES
West Virginia Geological and Economic Survey

Leveraging Subsurface Geological Datasets for Advanced Energy in Appalachia

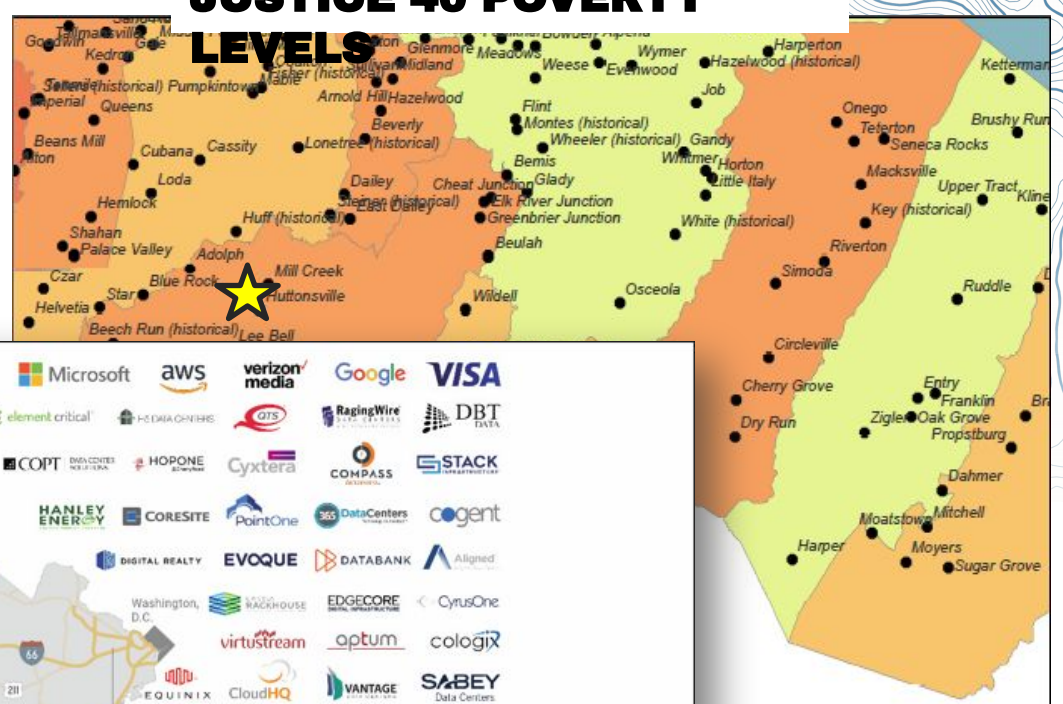
- Legacy and modern pre-competitive subsurface datasets are a powerful tool for understanding multiple emerging energy sectors
- Energy demand from AI threatens to outpace clean energy gains
- Geothermal systems in the Appalachian basin hold potential for electrical power generation but also critical minerals, natural H2, carbon storage
- Could unlock new energy sources in an area of the state with the greatest needs
- Partnerships are key to success.

Why It Matters

JUSTICE 40 ENERGY BURDEN

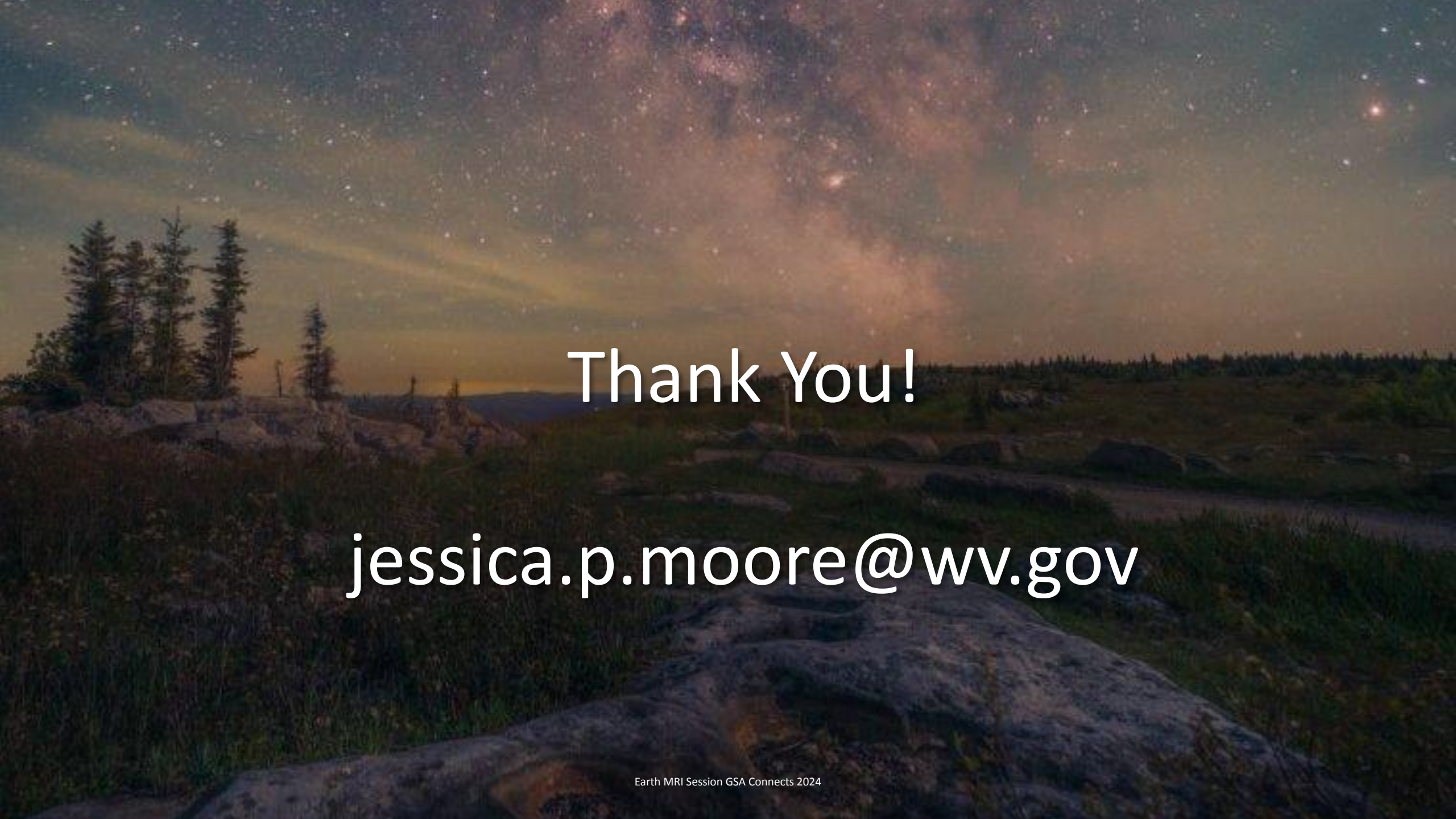


JUSTICE 40 POVERTY LEVELS



ome below Fed Poverty Level

110000
210000
350000
450000
540000
620000
710000
800000
880000


Thank You!
jessica.p.moore@wv.gov