

Kimballton: An ideal site for DUSEL

A national resource for research in physics, life sciences, chemistry, geosciences and engineering.

Robert J. Bodnar
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for the 150+ members of the Kimballton Team



<http://www.kimballton.org>

USGS
U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF GEOLOGICAL SURVEY

Geological Provinces of the United States
Millions of Years Ago (Ma)

Legend:

- Cenozoic:** 0 to 66 Ma
- Mesozoic:** 66 to 252 Ma
- Paleozoic:** 252 to 541 Ma
- Precambrian:** 541 to 2500 Ma

Geological Provinces:

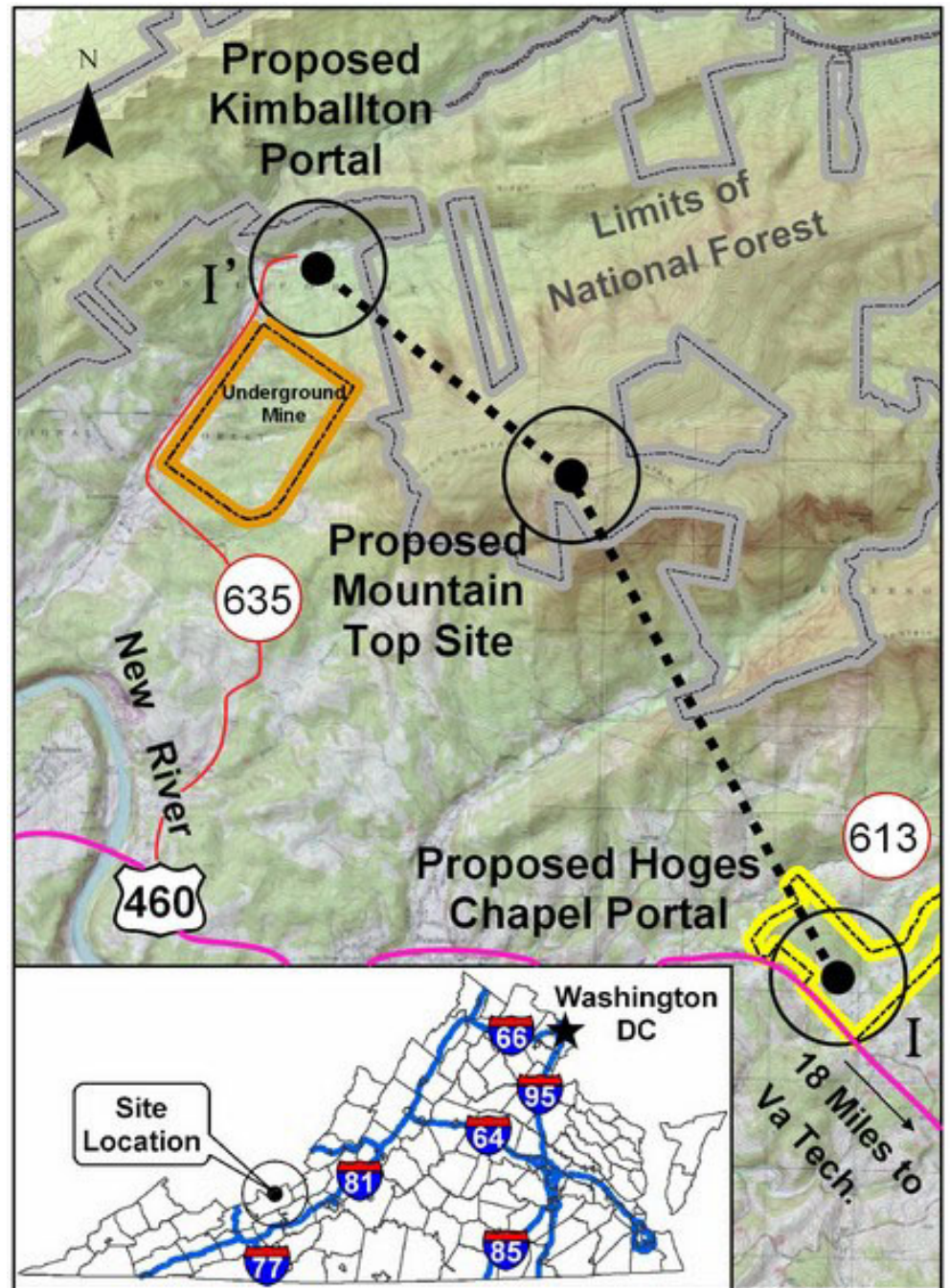
- San Jacinto:** Paleozoic, 252 to 541 Ma
- WIPP:** Paleozoic, 252 to 541 Ma
- Henderson:** Paleozoic, 252 to 541 Ma
- Homestake:** Paleozoic, 252 to 541 Ma
- Soudan:** Paleozoic, 252 to 541 Ma
- Sudbury:** Paleozoic, 252 to 541 Ma
- Kimballton:** Paleozoic, 252 to 541 Ma
- Icicle Creek:** Paleozoic, 252 to 541 Ma

Scale: 1 inch = 100 miles

Map Data: Compiled from various sources, including the USGS National Geologic Map Database.

The Kimballton site is located less than 30 minutes from Virginia Tech

- largest research university in Virginia
- 28,000 students
- technical infrastructure and academic environment in the *immediate* vicinity of laboratory is unique
- Blacksburg named one of *“Ten Dream Towns-The Perfect Places to Live Big, Play Hard and Work (if you Must)”*



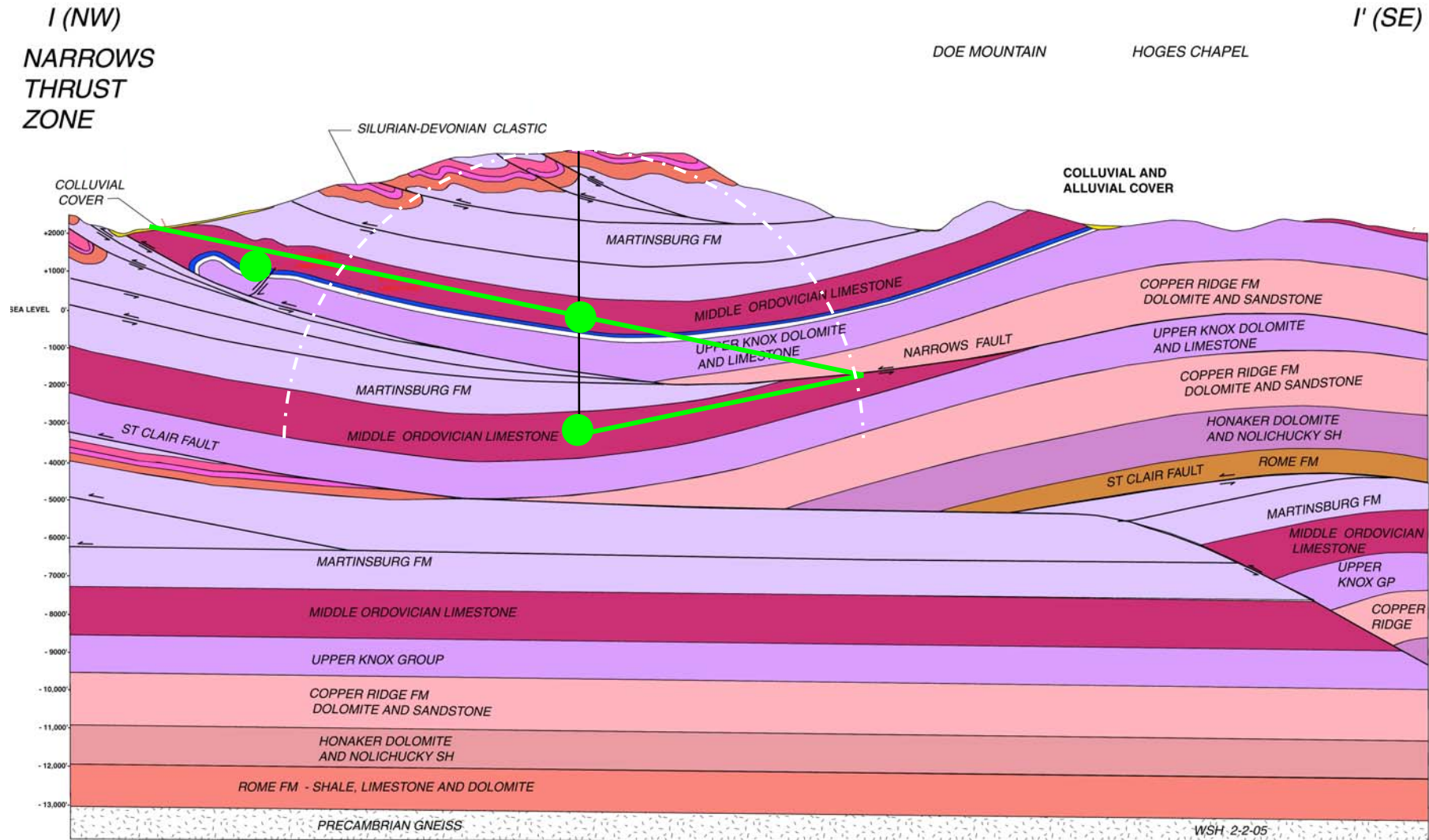


Butt Mountain

*Massive Middle
Ordovician Limestone
(host rock for DUSEL)
at Pembroke on the
New River (a few miles
from portal)*



Butt Mountain Synclinorium



NSF Vision: “Before you tell me what you want to build, tell me the questions you want to answer” (Mike Turner)

- What is ‘Dark Matter’?
- Why Does the Universe Have More ‘Matter’ than ‘Anti-Matter’?
- Are Neutrinos Their Own Anti-Particles?
- Is the Sun Getting Hotter? is There a Nuclear Reactor Within the Earth?
- What is the Survivability of Life in Extreme Environments
- Can We Realize a ‘Transparent’ Earth?
- How do Mineral and Hydrocarbon Deposits Form?
- What are the Scaling Laws for Rock Masses?
- Can We Accurately Predict Rock Failure?
- How Can We Better Manage Our Water Resources?
- What is the Role of Mineral-Microbe Interactions in Geochemistry?
- Can We Enhance the Sustainability of Earth’s Resources for Future Generations?
- etc...



... the science defines DUSEL!

S1 Physics Goals

fundamental nature of neutrinos

neutrino luminosity of the sun

dark matter

neutrino mass/mixing matrix

CP violation in the neutrino sector

proton decay

stellar explosions

relic supernova neutrinos

interior structure of the Earth using geoneutrinos

nucleosynthesis

low-background counting

Require the Following ...

- Low Background Counting
 - using HPGe, scintillation, proportional counter detectors
 - relatively small
 - requires depths of 1000 or more mwe
- Solar neutrino detectors
 - using a variety of conventional and cryogenic technologies
 - are of medium size (100-1000 tons)
 - require depths of 2000-4500 mwe
- Double beta decay and dark matter detectors
 - use a variety of detection technologies (particularly those based on cryogenics)
 - relatively small (<1 ton)
 - needs a deep site (>6000 mwe)
- Other topics above
 - based on water Cerenkov, liquid scintillation or liquid argon technologies
 - very large (100 kilotons -1 megaton)
 - can operate at moderate depths (~4000 mwe)
 - high cost → designs that permit multi-science functions: detection of high energy neutrinos from terrestrial accelerators, proton decay searches, geophysics, supernova astrophysics and cosmology, etc.

➔ Requires shallow, intermediate and deep halls;

Kimballton (and others) can provide these...



.... and a *large* multi-purpose detector?

Currently being considered:

- UNO – Water Cerenkov Detector (MT)
(Competition from Hyper-K in Japan)
- LANNDD – Liquid Argon Detector (100 kT)
- Hyper Scintillation Detector (HSD)
 - Liquid Scintillation Detector (100 kT)

The science portfolio of HSD includes:

- Geophysical structure and evolution of the Earth studied via global observation of anti-neutrinos from the earth's interior
- Supernova astrophysics and cosmology (observation of live supernovae; detection of the supernova relic background)
- Elementary particles: (search for the decay of the proton; long baseline experiments using high energy neutrinos from BNL or Fermilab)

The basic advantages are:

- sensitivity to events of *both low and high energy*, ranging 4 orders of magnitude from ~ 100 keV to ~ 1 GeV;
- sensitivity to heavy particles that are invisible in Cerenkov detectors (giving 10x the sensitivity to Cerenkov detectors for certain proton decay modes)
- sensitivity to antineutrinos that can be specifically tagged by capture on protons (of importance to all the above topics, i.e. by reducing background).

Baseline issues:

- at 770 km from Brookhaven or Fermilab, Kimballton subtends a larger solid-angle than other sites
- first appearance peak is at 1.9 GeV- good match with upgraded AGS accelerator at BNL
- reduced uncertainty due to matter effects if less than 1000 km, since beam stays in Earth's crust.



Kimballton can accommodate a large detector

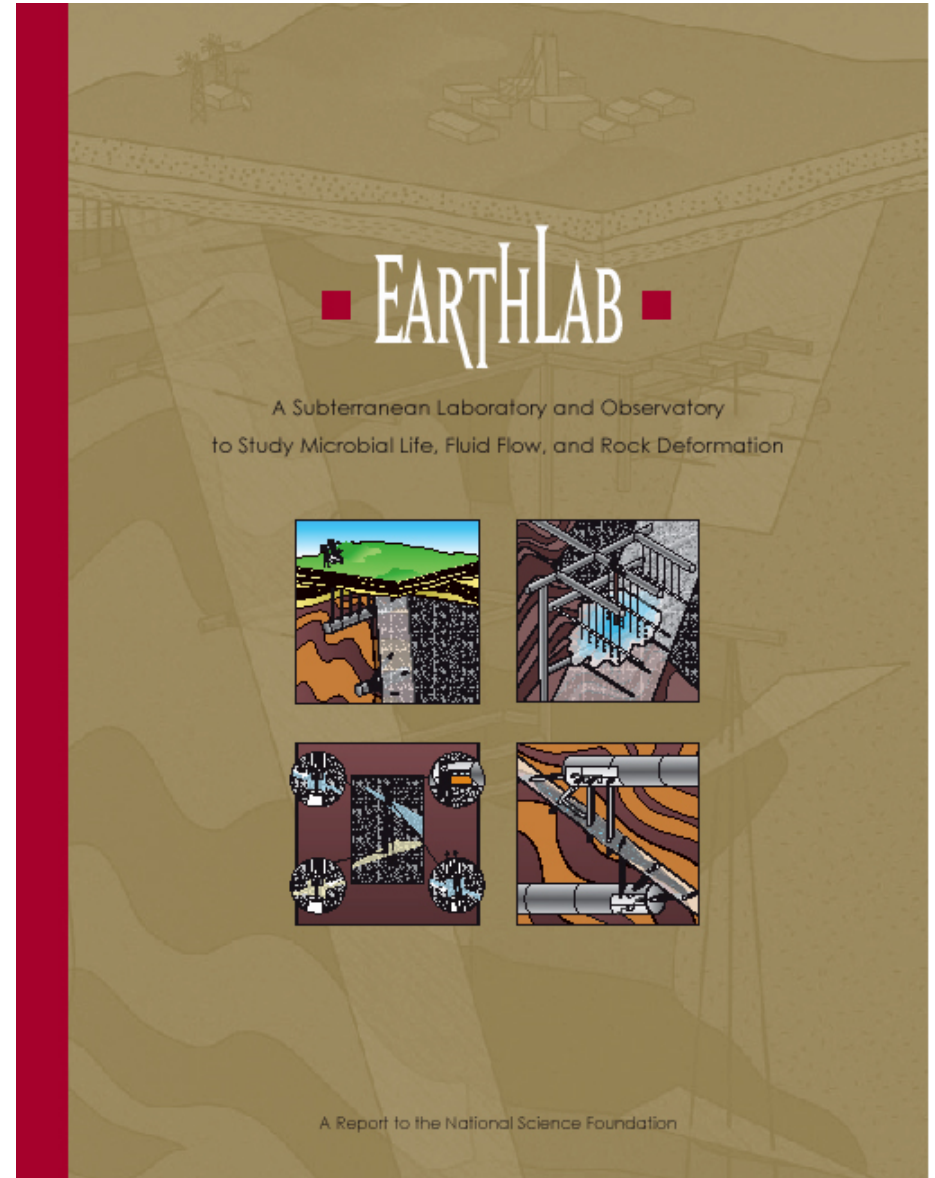
Geo-, Bio- and Engineering Connections

The EarthLab report summarized science that could benefit from an underground lab.

focused on crystalline rocks (Homestake)

identified important multi-disciplinary research

Kimballton can accommodate all science in EarthLab



S1 requirements...

- varied geology
- access at variable depths
- large, pristine blocks (proximal and distal)
- large, perturbed blocks (distal)
- remote very large block access
- run of mine access
- deep and ultradeep observatory



Kimballton (and others) can provide all of these...

But, being in sedimentary rock, Kimballton has a much broader reach. Here's why ...

- Sedimentary rocks, such as those at Kimballton, cover about 3/4 of the Earth's land surface.
- About 90% of the earth's groundwater is currently being produced from sedimentary rocks.
- Nearly all (99+%) of the world's hydrocarbon resources are hosted in sedimentary rocks (with about half in carbonate rocks similar to Kimballton).
- About 85% of underground mines are in sedimentary rocks (MSHA, 2002).
- Sedimentary rocks and deep aquifers in sedimentary basins constitute important reservoirs for carbon storage to address global warming issues.

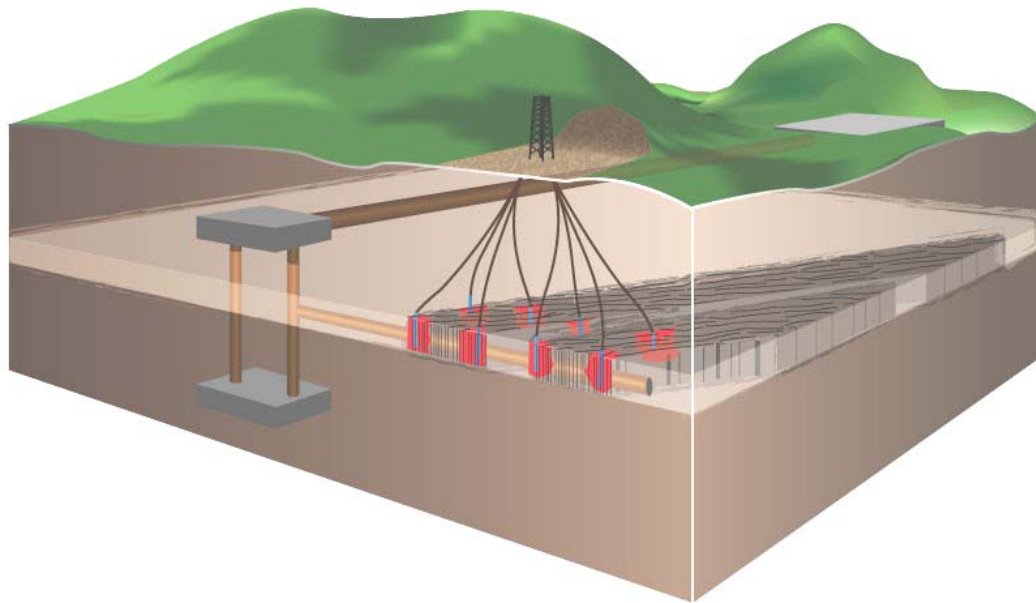
Importance of research facilities in sedimentary rock was recognized by the National Research Council

“In situ facilities should be developed in a variety of rock types with different styles of fracturing. A number of excellent facilities already exist in crystalline rocks, but there is a dearth of in situ research facilities in bedded rocks, especially where more than one fluid phase is present. Consequently, less is known about how to effectively characterize flow and transport in bedded rocks. Research at facilities in bedded rocks would have a significant impact on understanding enhanced oil and gas recovery processes in fractured reservoirs.”

(NRC, 1996)

Example 1: Multidisciplinary Research Opportunities

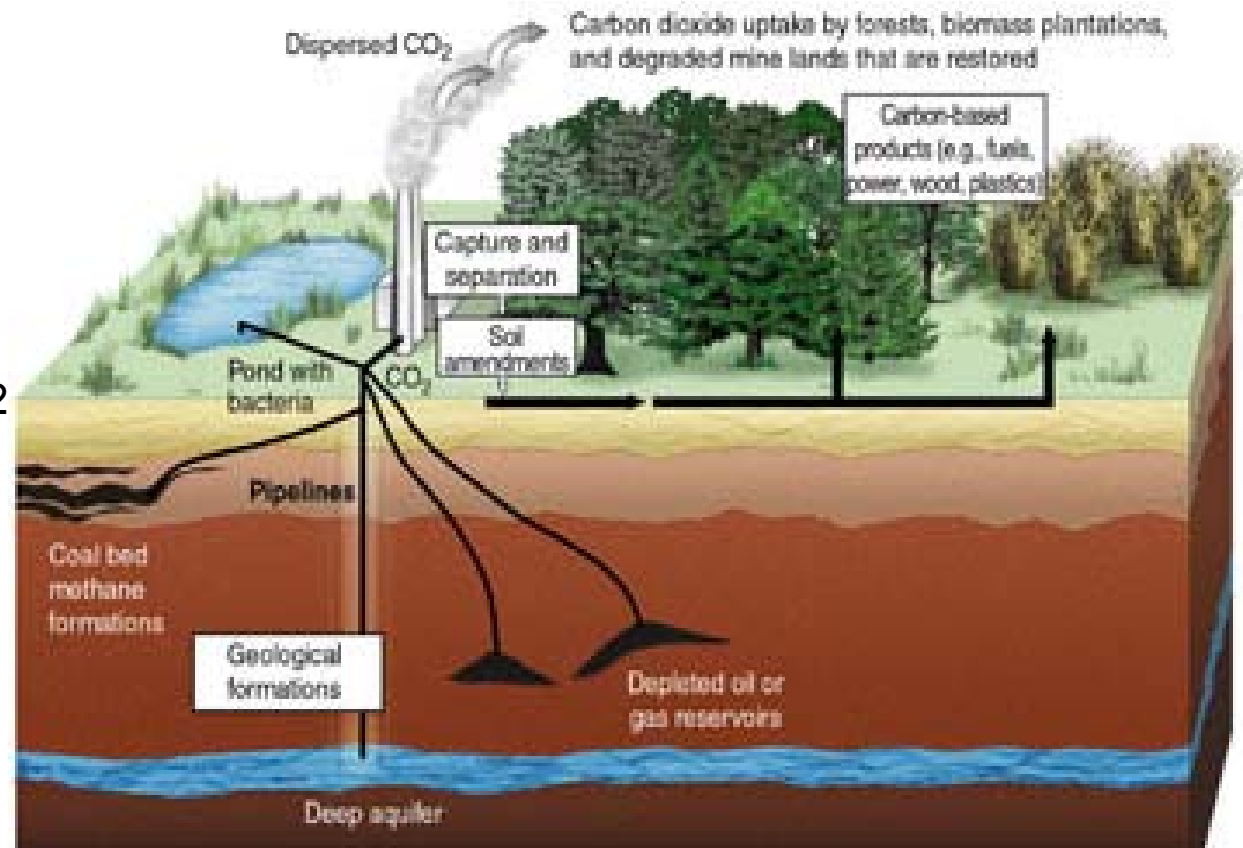
Coupled Processes Related to Petroleum Reservoir Formation and Characterization



- Geology
- Geophysics
- Rock Mechanics
- Drilling Technology
- Geochemistry
- Hydrology
- Microbiology
- Etc.

Example 2: Carbon Management and Climate Change

The Kimballton plant fires 0.75MT of limestone, providing a major point source of CO₂ for carbon management research.



Sinks at Kimballton include:

- Deep aquifers
- Deep gas deposits
- Uneconomic coal beds
- Deciduous forests

Example 3: Water Resources

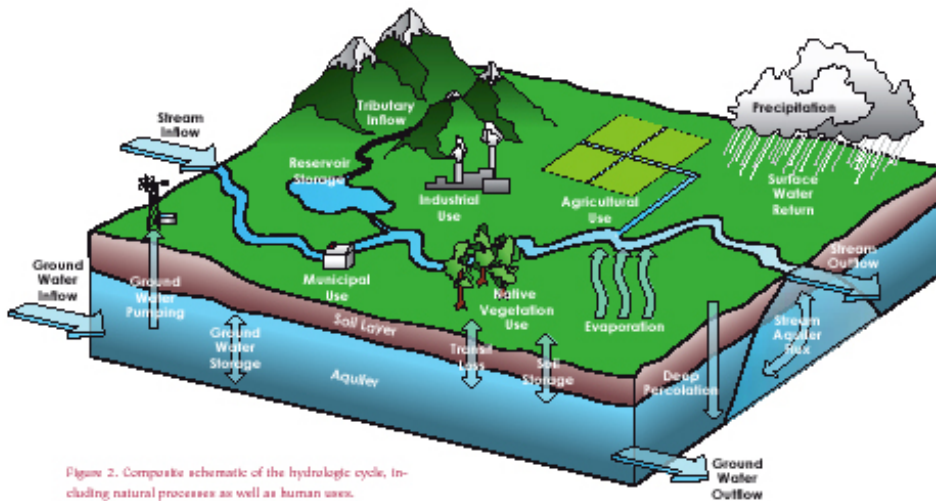
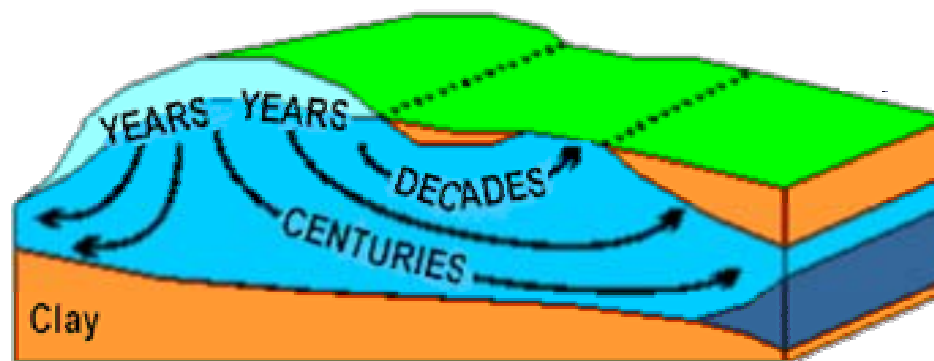


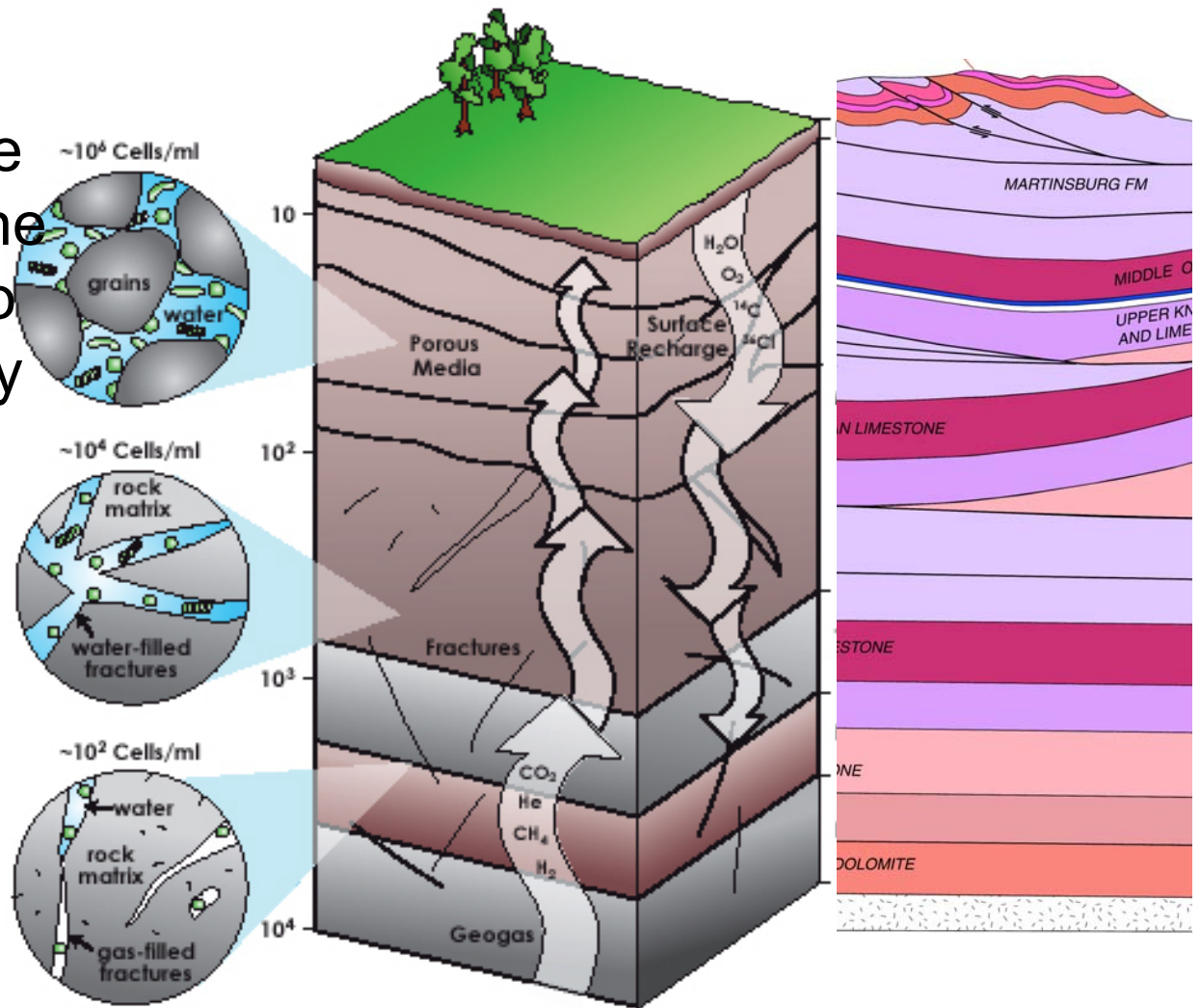
Figure 2. Composite schematic of the hydrologic cycle, including natural processes as well as human uses.

Kimballton provides access to varied lithologies at varying depths to study fluid flow at various spatial and temporal scales



Example 4: microbial activity at depth

Kimballton provides access from the base of the rhizosphere to the hydrothermal zone to study the survivability and variability of life in extreme environments, and provides access to the same geologic units at several depths



DUSEL at Kimballton provides opportunities to collaborate with the SECUREarth initiative

- **Drastic increase in oil and gas recovery**
- **Safe and economic CO₂ sequestration**
- **Safe and defensible disposal of nuclear waste disposal**
- **Sound basis for management and protection of water resources**
- **Efficient and reliable environmental cleanup**
- **Reliable and defensible predictions of Climate Change**
- **Drastically improved use of renewable energy**
- **Sound fundamental basis for transition to hydrogen economy**

from: <http://esd.lbl.gov/SECUREarth/>

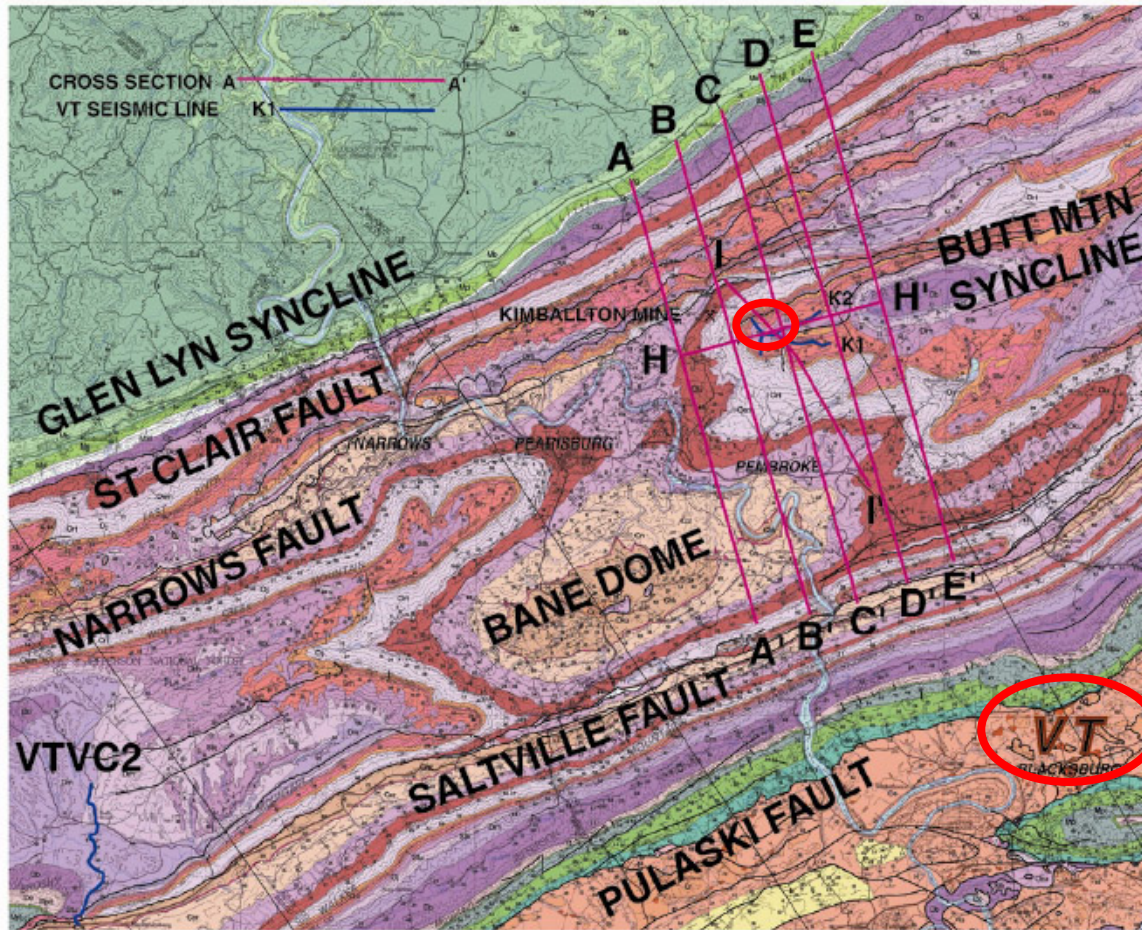
Kimballton provides unparalleled synergy between many NSF divisions, DOE programs, and Industry



Constructability

Any DUSEL site is only viable if one has permission to build and use it, can build it for a reasonable cost, and in a timely fashion and with manageable risk, and also provide a safe work environment.

Local Geology



The folded nature of the geology provides surface outcrops of formations that occur at depth, providing confidence that we can predict which rocks units will be encountered at depth

Gunung Mulu National Park, a Karst cave (limestone)
Dimensions: L=600m, W=400m, H=100m, Ar=162,700m²

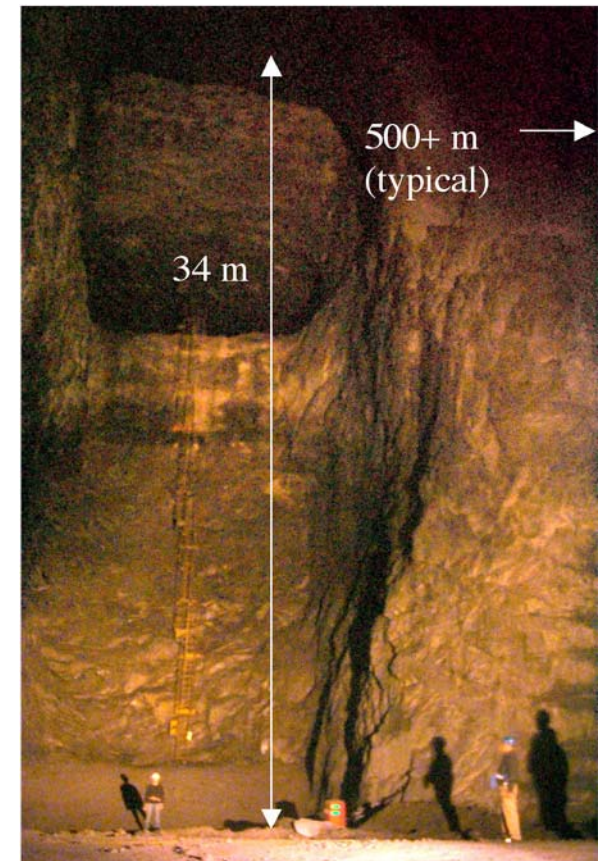
The Largest Cavern in the World!



Large caverns already exist
in limestone, and at the
Kimballton site at 2300 ft.

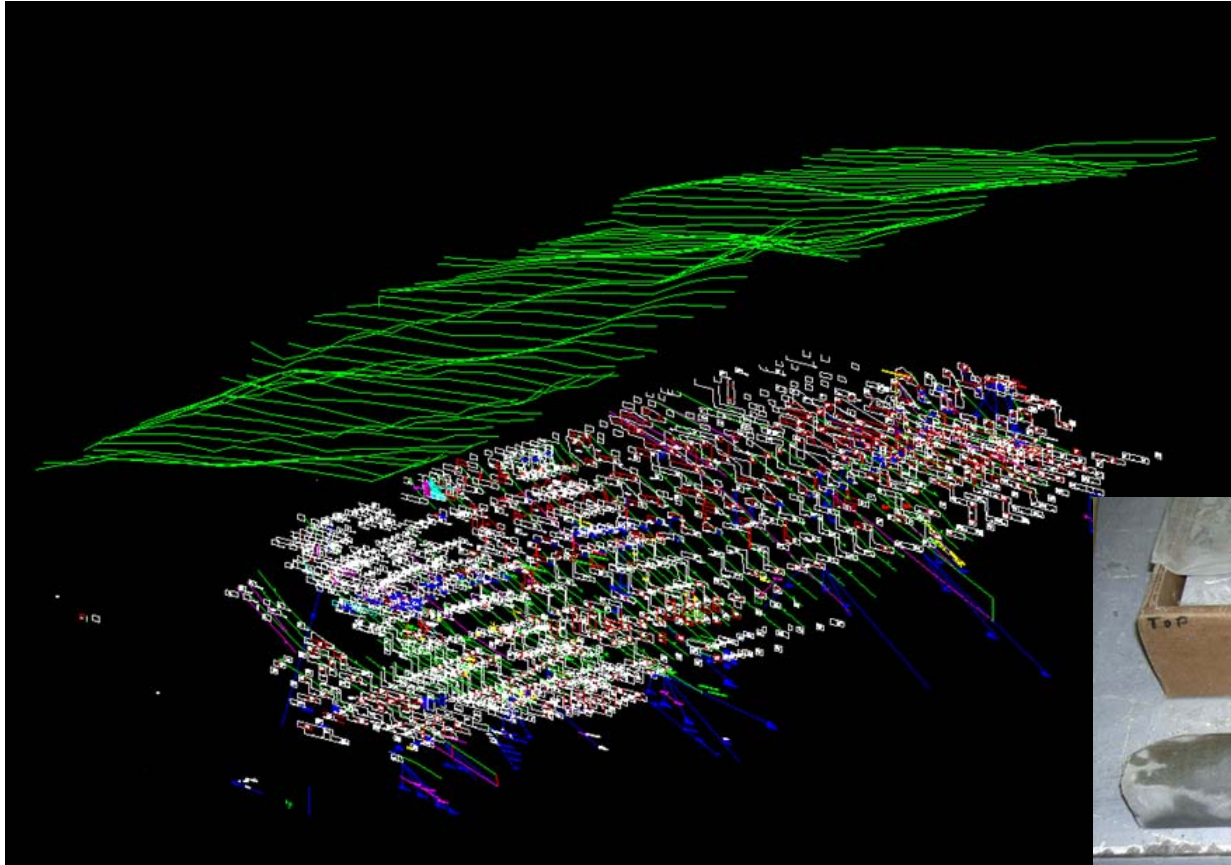


Gran Sasso (4700 ft depth)



Kimballton

Kimballton Limestone Mine



Over 50 miles of drive-in drifts down to 2300 ft and access to extensive coring provides in-situ information.

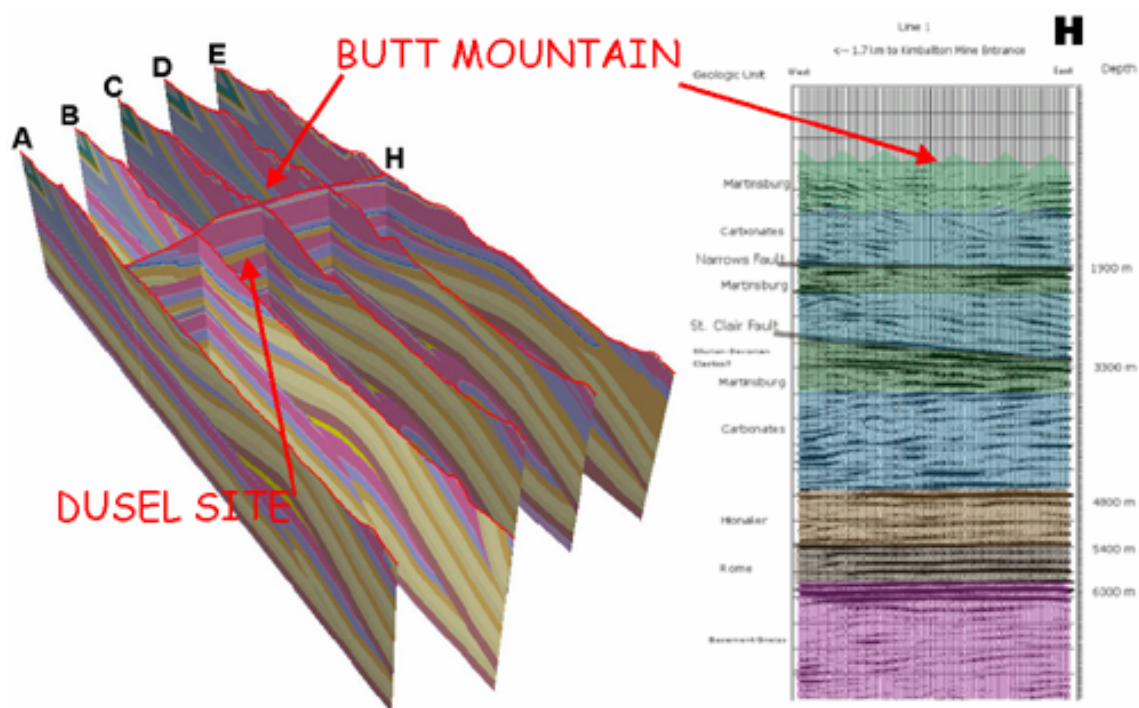
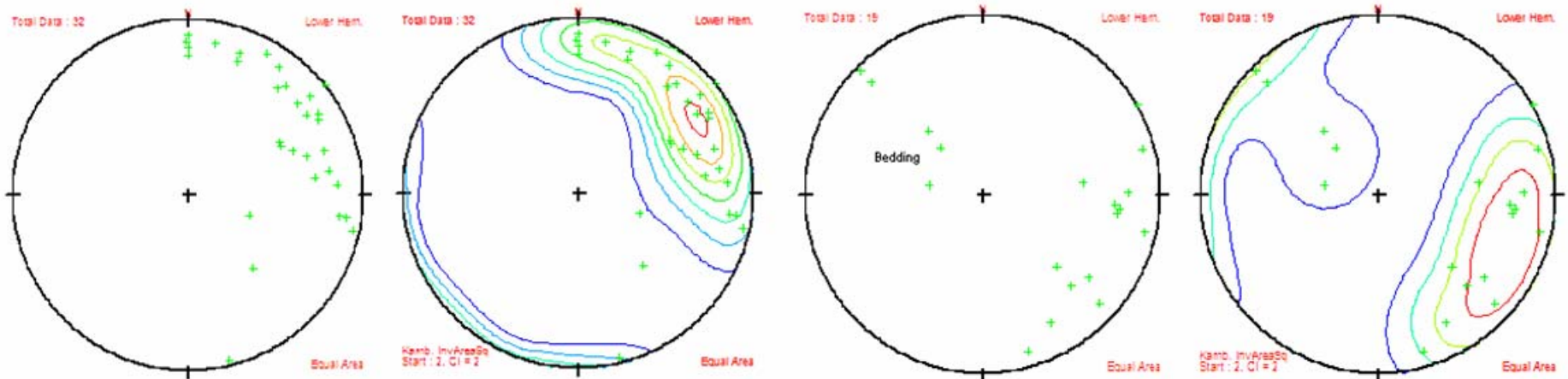


Figure 12: Lineament study of Kimballton area. Widely spaced fractures separated by unfractured blocks.

Seismic imaging and lineament studies support the geologic model.

Fracture data collection – Kimballton mine

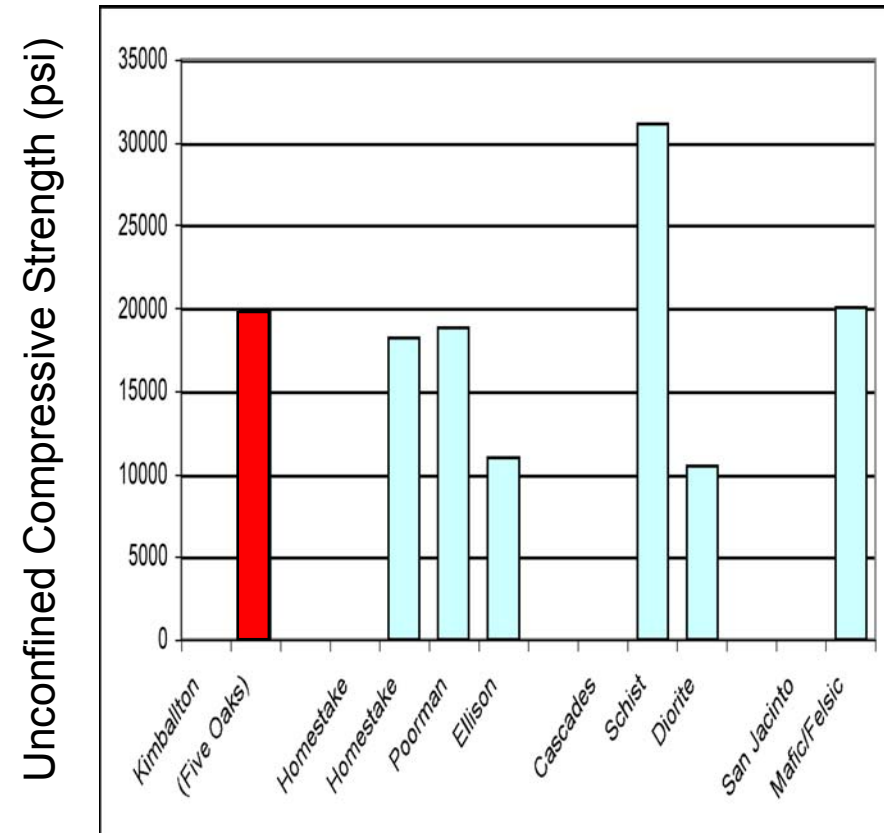
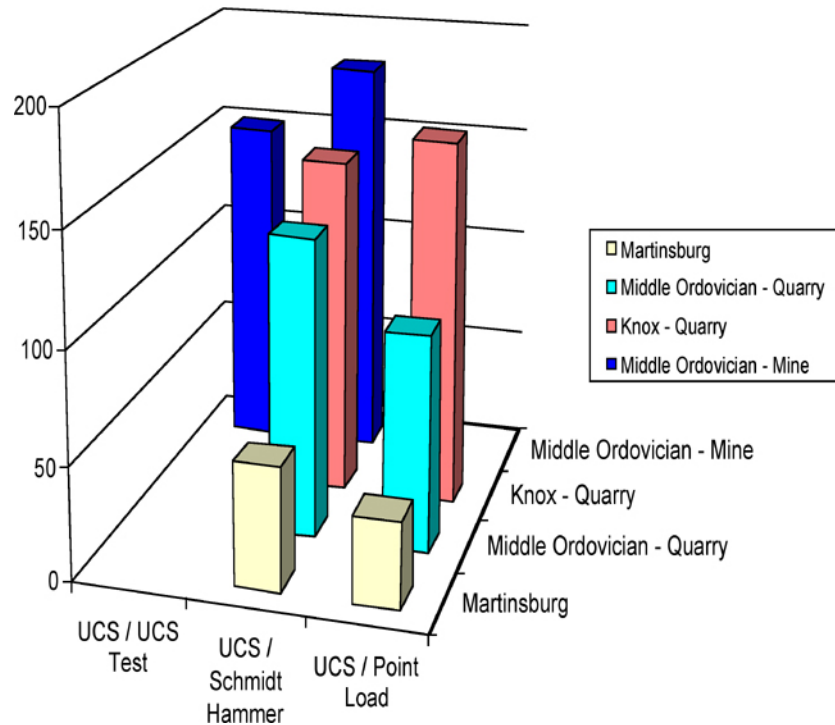


Rock Strength

Kimballton rocks are as strong as those at other sites!

(Contrary to the assumption that all sedimentary rocks are weak)

Unconfined Compressive Strength - Summary

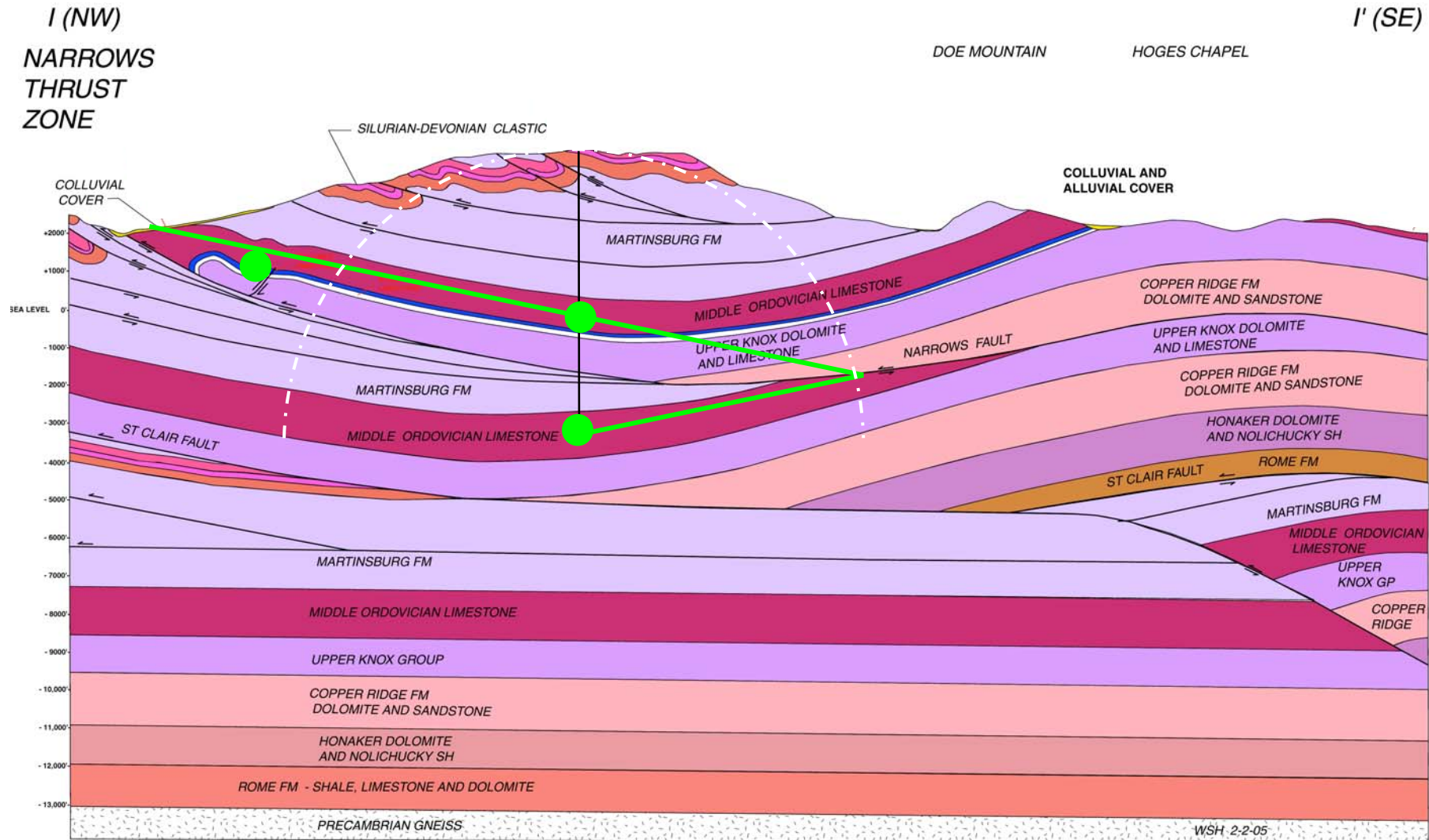


Estimated Q-values and depth to squeezing for rock units at Kimballton

Rock Unit	Most likely Q-value	SRF	Q	Critical depth for squeezing (km)
Middle Ordovician Limestone	32	0.5 to 1.0	32 to 64	3.7 to 7.5
Copper Ridge Knox	21	0.6 to 0.8	21 to 26	2.4 to 3.0
Martinsburg Formation	18	0.8 to 1.4	12 to 23	1.4 to 2.7

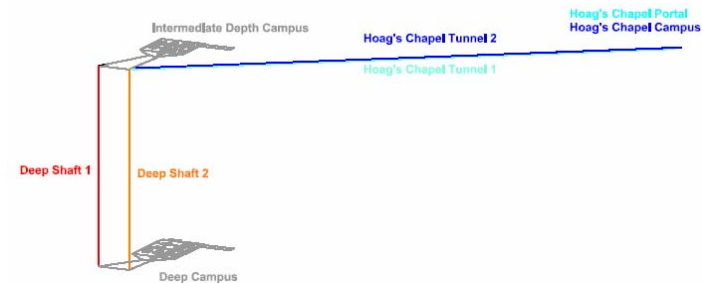
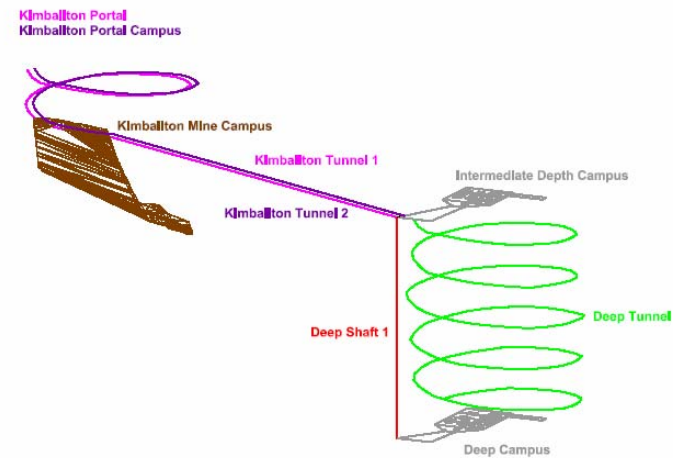
The rock falls into the 'good' range for tunneling.

Butt Mountain Synclinorium



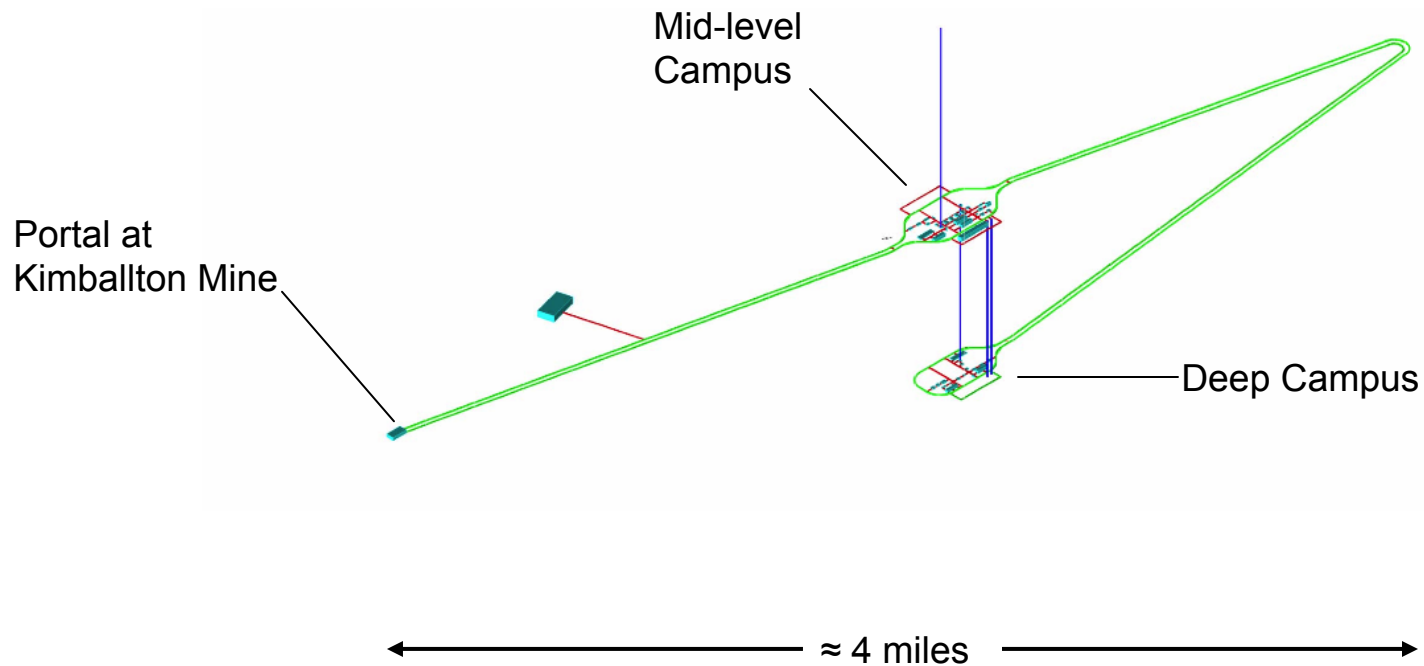
Conceptual Design

- work in progress...
- goals:
 - shallow (early)
 - central (mid-term)
 - deep (completion)
 - manifestly expandable

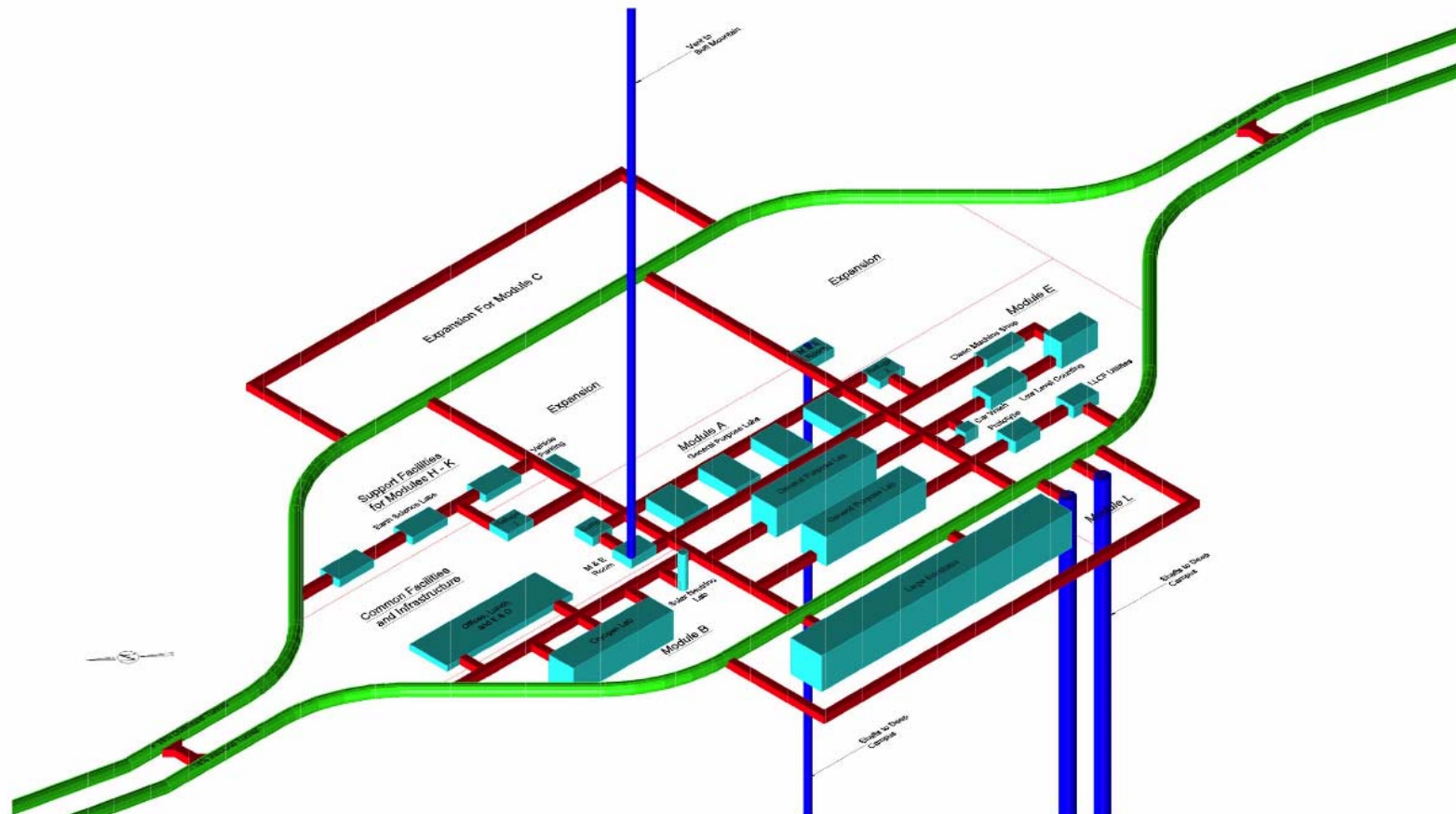


two of several options being considered

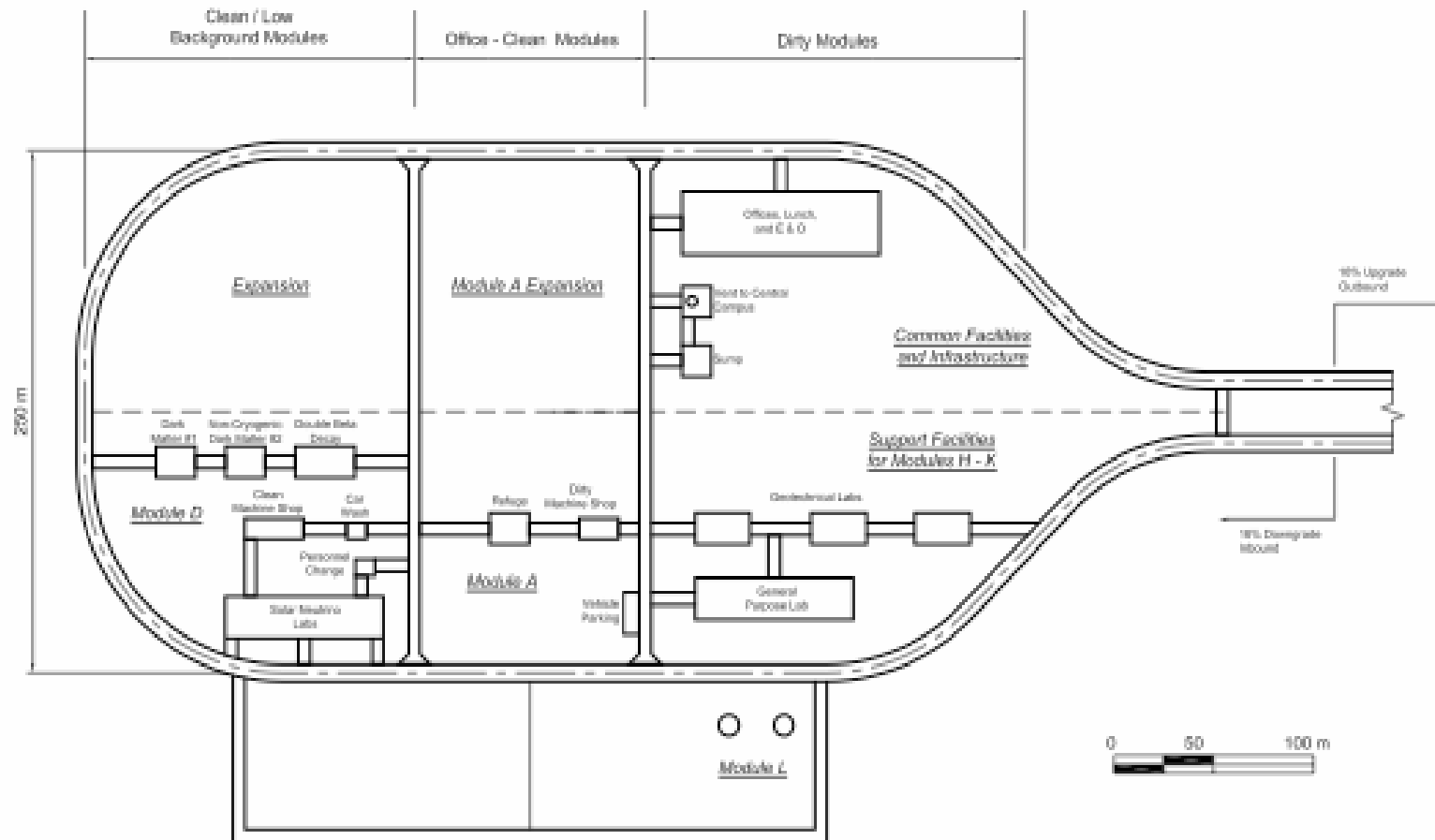
Conceptual Design of DUSEL at Kimballton



Conceptual Design of DUSEL at Kimballton: Mid-level Campus



Conceptual Design of DUSEL at Kimballton: Deep Campus



Public Support/Opposition

An important consideration in determining the “constructability” of DUSEL is related to support or opposition by local governmental and community awareness groups. [The Kimballton DUSEL initiative enjoys strong support from the local communities.](#)



Something we don't expect at Kimballton

Environmental Implications

Another important consideration is short and long-term environmental health effects. The Kimballton site involves mining environmentally benign limestone, and the rocks and water contain no known hazardous components.



DUSEL @ Kimballton will not have the problem seen here associated with a mine in Idaho.

Research Environment

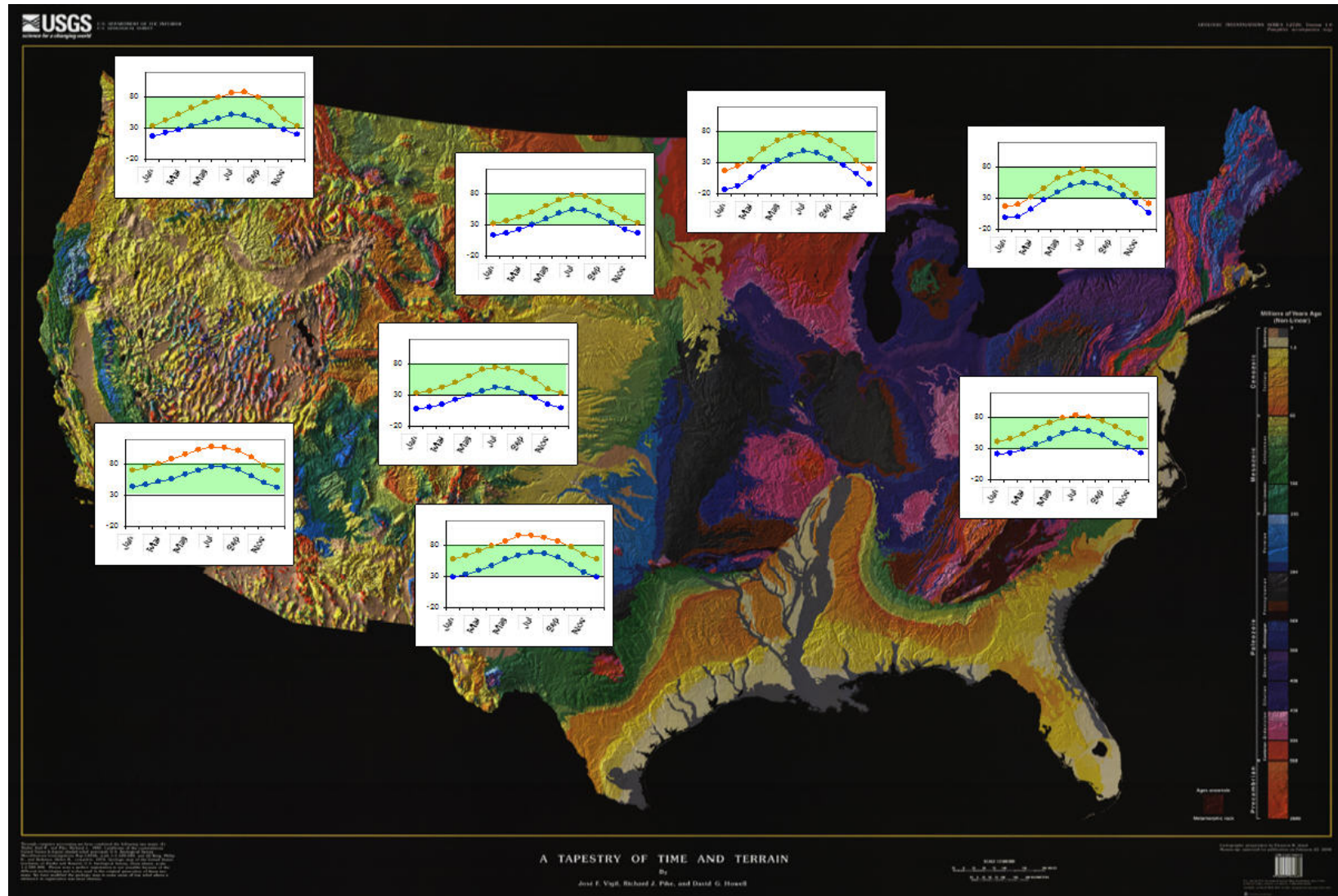
visiting DUSEL should be a pleasant and rewarding experience

- Within 1 day's drive of 50% of the U.S. population
- Less than 30 minute drive to top-50 research institution
- Within 45 minutes of airport serviced by four national carriers
- Moderate climate, without harsh winters or blistering summers
- Single-purpose DUSEL site
- Excellent E&O opportunities and existing programs



Virginia Tech Campus
(28,000 students)

Pleasant climate in winter AND summer



Average Monthly High/Low (30-80 degree in green)

Kimballton Science Team

over 150 researchers from 28 organizations, including
63 active senior researchers listed on the S2 proposal

CNA Consulting
Draper Aden & Associates
Duke University
Georgia Tech
Iowa State University
Michigan Technological University
Naval Research Laboratory
National Inst. Standards & Tech.
New Mexico Tech
MIT
North Carolina State University
Oak Ridge National Laboratory
Penn State University
Princeton University

Purdue University
Radford University
Schnabel Engineering
Technical Univ. Munich
University of Alaska
University of Alberta
University of Hawaii
University of Missouri-Rolla
University of North Carolina
University of Minnesota
University of Oklahoma
University of Tennessee
Virginia Commonwealth Univ.
Virginia Tech



new members are welcome

Support

VT administration (provided initial \$1.6M)

Governor Mark Warner included a \$150M bonding authority in his budget, contingent upon DUSEL being located at Kimballton

Virginia Senators Warner and Allen support DUSEL

Virginia Congressional Representatives support DUSEL

U.S. Forest Service supports DUSEL at Kimballton

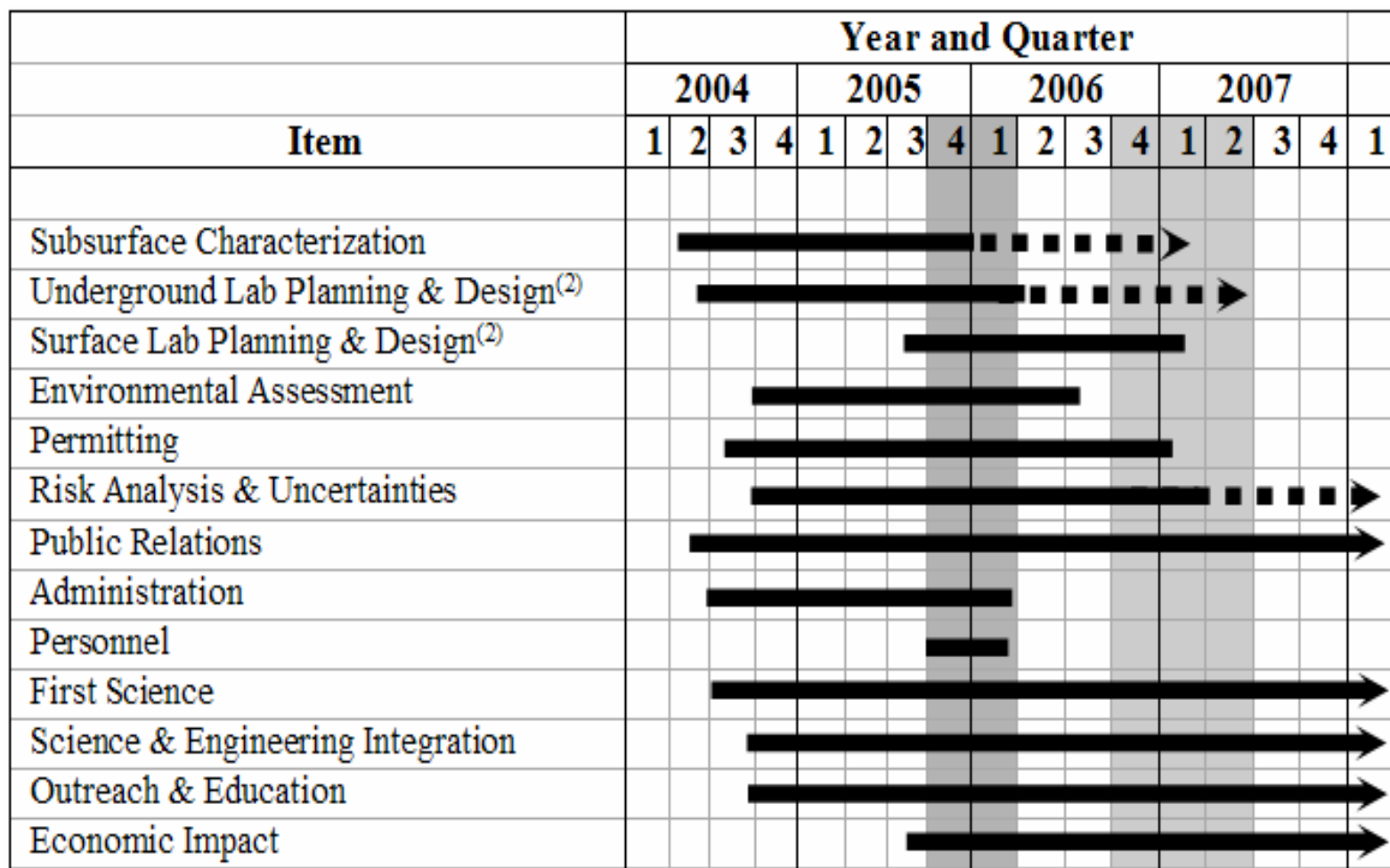
Giles County Board of Supervisors supports DUSEL

New River Valley Planning District supports DUSEL

Blacksburg Partnership supports DUSEL

Giles County Rural Development Group supports DUSEL





Kimballton S2 Process Timeline