Underground aspects of underground compressed air energy storage (CAES)

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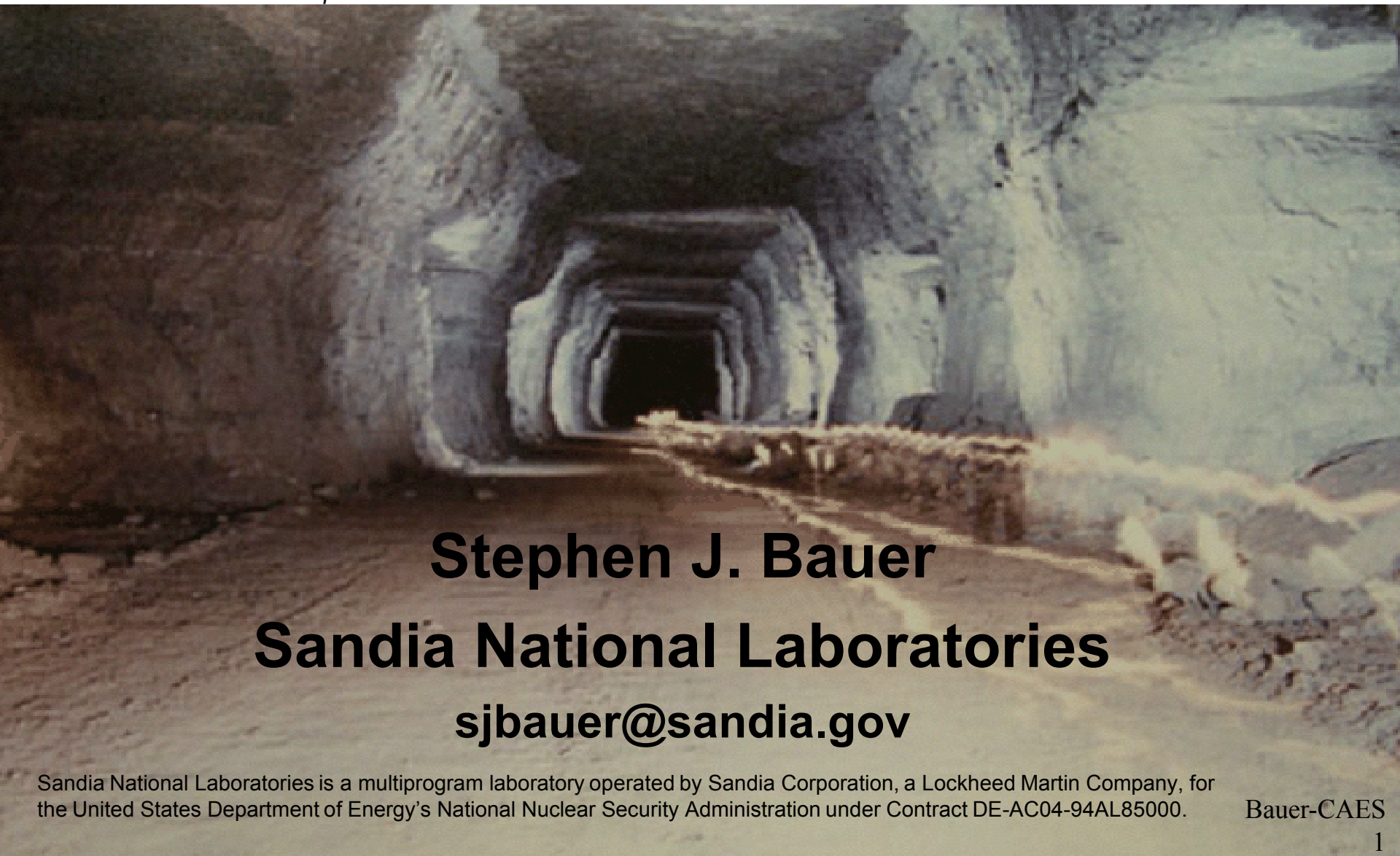
Geomechanics Research Department



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Outline CAES

- **System Considerations**
- **CAES Process**
- **CAES Feasibility**
- **Site Selection**
- **Summary, R&D,?**

CAES System Considerations

- Generation needs/desires
- Public
- Regulatory requirements/constraints
- Surface requirements/constraints
- Subsurface requirements/constraints
- Environmental Considerations

CAES Process

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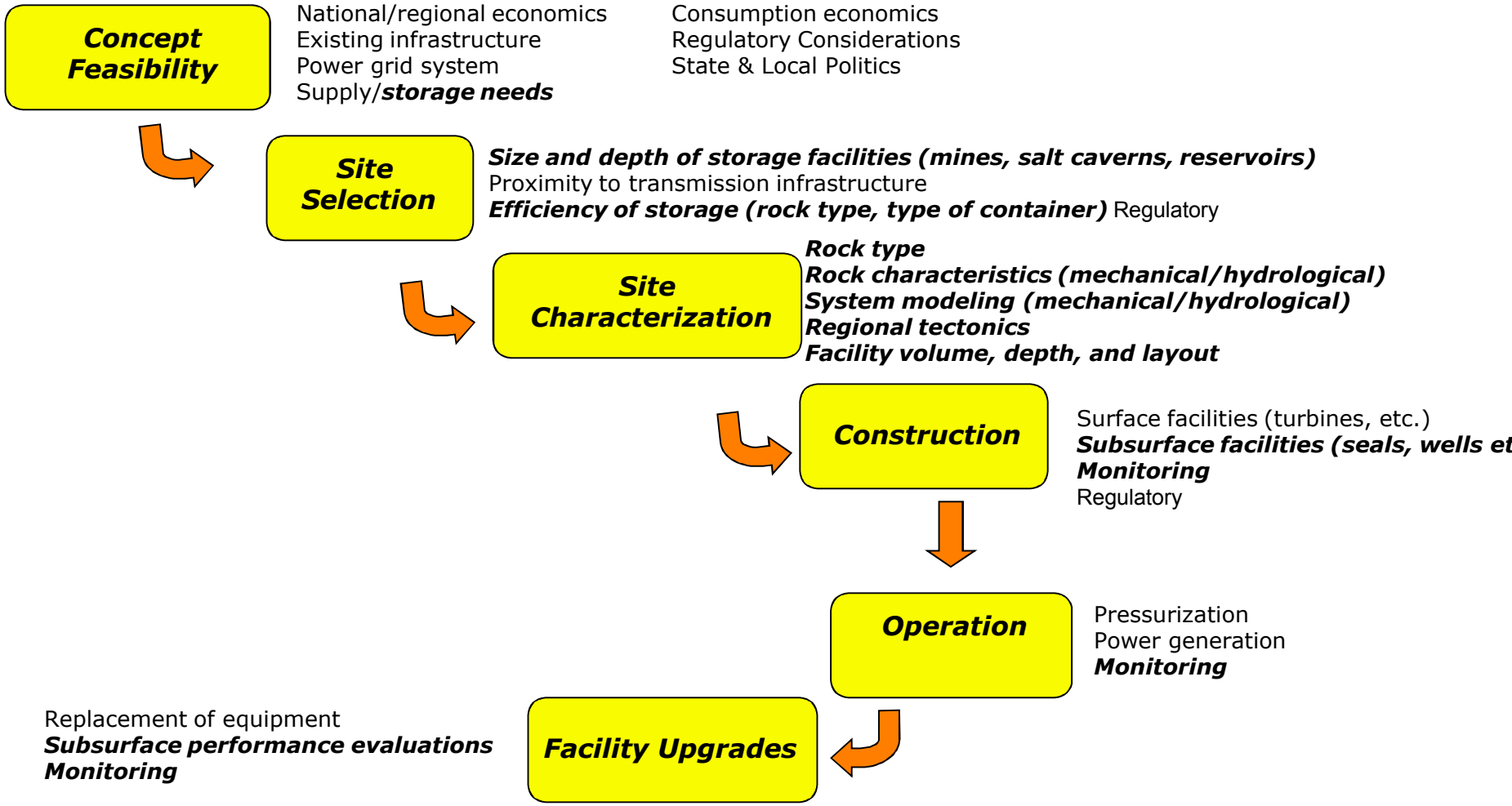

Concept Feasibility storage needs

Anywhere, US

(maybe even NY)

storage - power relationships

HOW MUCH SPACE DO YOU NEED?

WHERE DOES IT NEED TO BE?

WHAT FLOW RATES DO YOU NEED?

FOR HOW LONG?

Site Selection Host Rock Considerations- constraints

- **at depth in competent rock**
- **well sealed container**
- **large volume**
- **can deliver air at desired rates**
- **favorable stress state**
- **can withstand pressure cycles**
- **no detrimental conditions/circumstances**

Concept Feasibility storage needs

Desirable Siting Conditions

- **Depth : 500 - 1500m**
- **Volume > 0.2 x10^6 m^3**
- **Competent structure, non-oxidizing**
- ***In situ* stresses compatible with desired pressures**
- **Favorable hydrologic conditions**
- **Favorable openings**
- **Competing circumstances**

Site Selection Host Rock Considerations

- Mines- as is, lined, curtained, resealed
- Caverns (salt)
- Reservoirs - aquifers, gas, fractured systems, engineered

Site Selection Host Rock Considerations - Mines

- Potential for pre-existence of large underground volumes
- Excellent permeability
- Potential for *in situ* characterization
- Potential for recorded history
- Often a conflict between desired use and development history (maximize extraction)
- Often good electrical connections
- Beneficial use for old mines
- Limited locations
- Good chance of flooding*

*may need to be engineered

Inside a mine

Site Selection Host Rock Considerations - Reservoirs

- Potential for pre-existence of significant underground volumes
- “Natural” environment for intended purpose
- Limited *in situ* characterization
- Potential for known reservoir history
- From history - performance
- Near well bore conditions important
- Possibly many boreholes required for flow
- Relatively constant pressure operation

Site Selection Logical Path - Reservoirs

- Review of area geology
- Porous media surrounded by impermeable media
- Porosity- pore or fractured
- Impermeable barrier for containment
  - **structural**
  - **stratigraphic**
  - **engineered***
- Site Characterization/Analyses
- Flow characteristics consistent with needs

Structural trap

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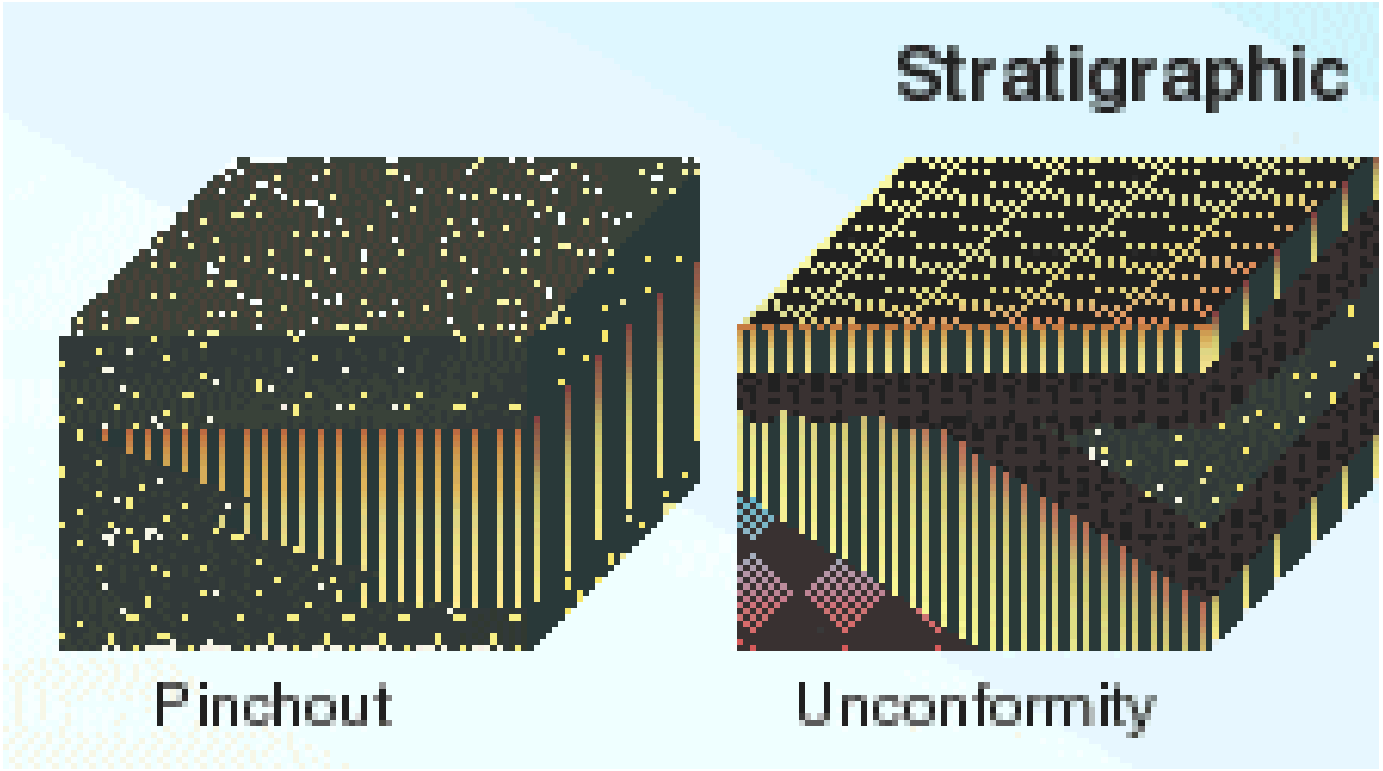
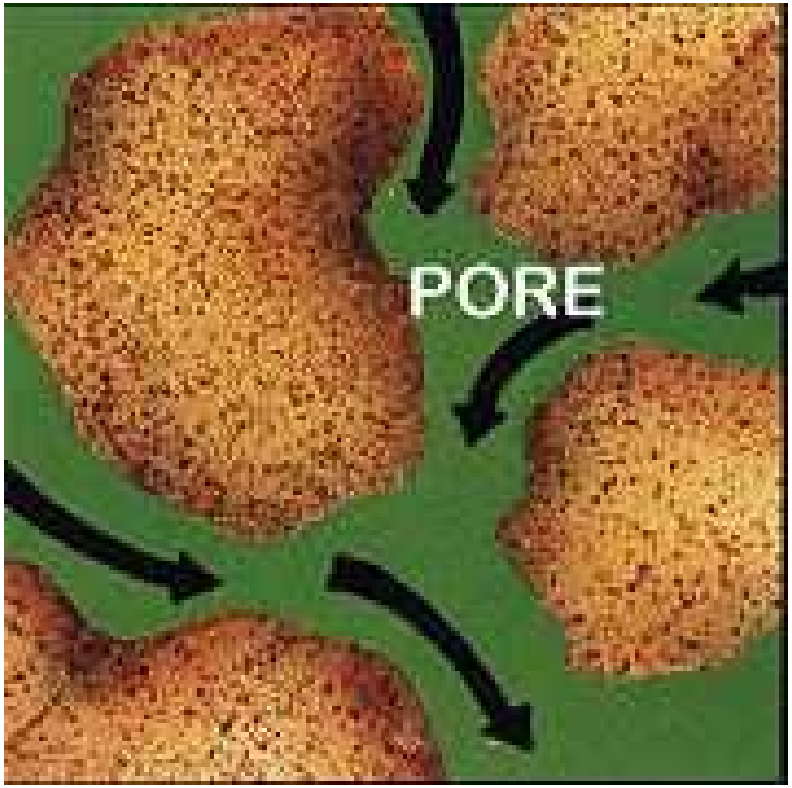
Anticlinal structural trap

photo courtesy of Cleet Carlton of Golden Gate Photo (fair use policy)

Stratigraphic trap



Porosity



Site Selection Critical Parameters - Reservoirs

- Adequate volume = porosity x rock volume

  (then increase rock volume by 1-2 orders of magnitude)
- Impermeable containment – how to determine?
- Adequate/attainable flow characteristics
  - single or multiphase flow
  - testing and calculations

Estimates for reservoirs

Start with mass flow rate needed

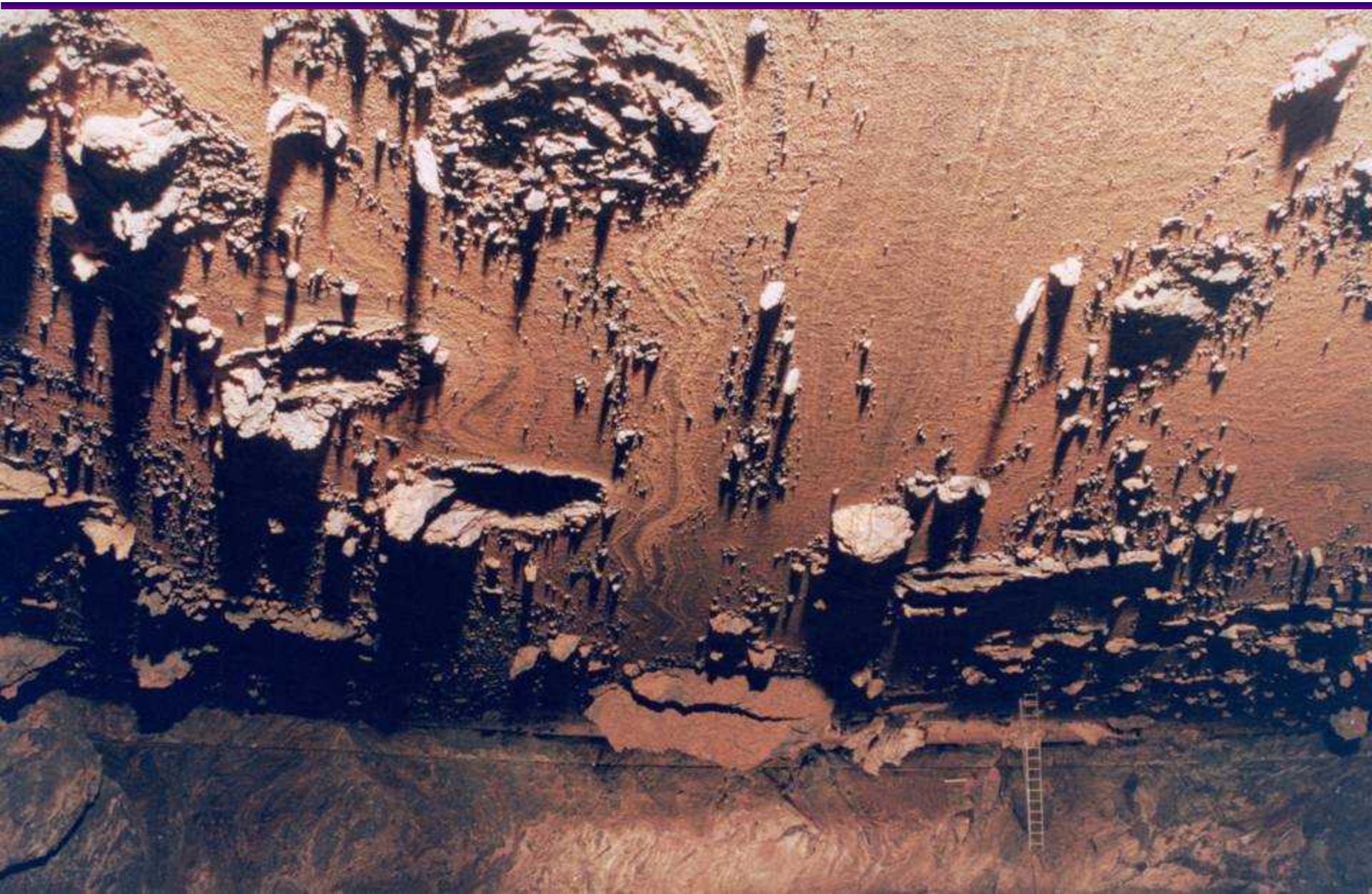
Porosity minimum 15% (PEI)
Permeability > 300 md (PEI)
Rock volume f(porosity, permeability)
Number of wells
Size of wells

Other items: closure, caprock, etc

Site Selection Host Rock Considerations – Salt Caverns

- Potential for pre-existence of significant underground volumes
- Cavern development technology well understood
- Domal versus bedded salt
- Excellent permeability
- Limited *in situ* characterization
- Development, well history important
- Conflict between desired use/development history (developed for brine vs. storage)
- Need to dispose of brine
- New development costs fairly well established
- Mechanical properties very important
- Performance analyses needed

Inside a cavern



Inside a cavern

Summary

- **Opportunities exist for containers for underground compressed air storage in geologic formations**
- **Geology, rock mechanics, flow characteristics are all important**

Research Opportunities

Systems Approach

Can surface technology needs change underground requirements?

Homework on availability (study geology)

Evaluate reservoir engineering in concert with geology (generic studies)

Engineered Reservoirs

Mine sealing technologies

Salt caverns will work well- break down regulatory barriers

Site specific conditions importatnt

Improved Efficiencies

- **Thermal energy recovery**
- **Low pressure turbines**

Site Selection Logical Path - Caverns

- Geologic Review (presence of salt)
- Contacts with state geologists
- Study of geologic conditions
- Study of cavern history
- Contact with owners
- Site Characterizations/Analyses
- Determine potential for cavern integrity

Site Selection Host Rock Considerations- Mines

- Mine data base
- Contacts with state geologists
- Calls to mining companies
- Study of geologic conditions
- Calls to owner- obtain history
- Site visits/assessments
- Site Characterizations/Analyses