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CAES Modeling Parameters

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Stephen Bauer, Scott Broome,
Mark Grubelich, Steve Webb

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We would like to thank Dr. Imre Gyuk for his interest and support of this work and CAES

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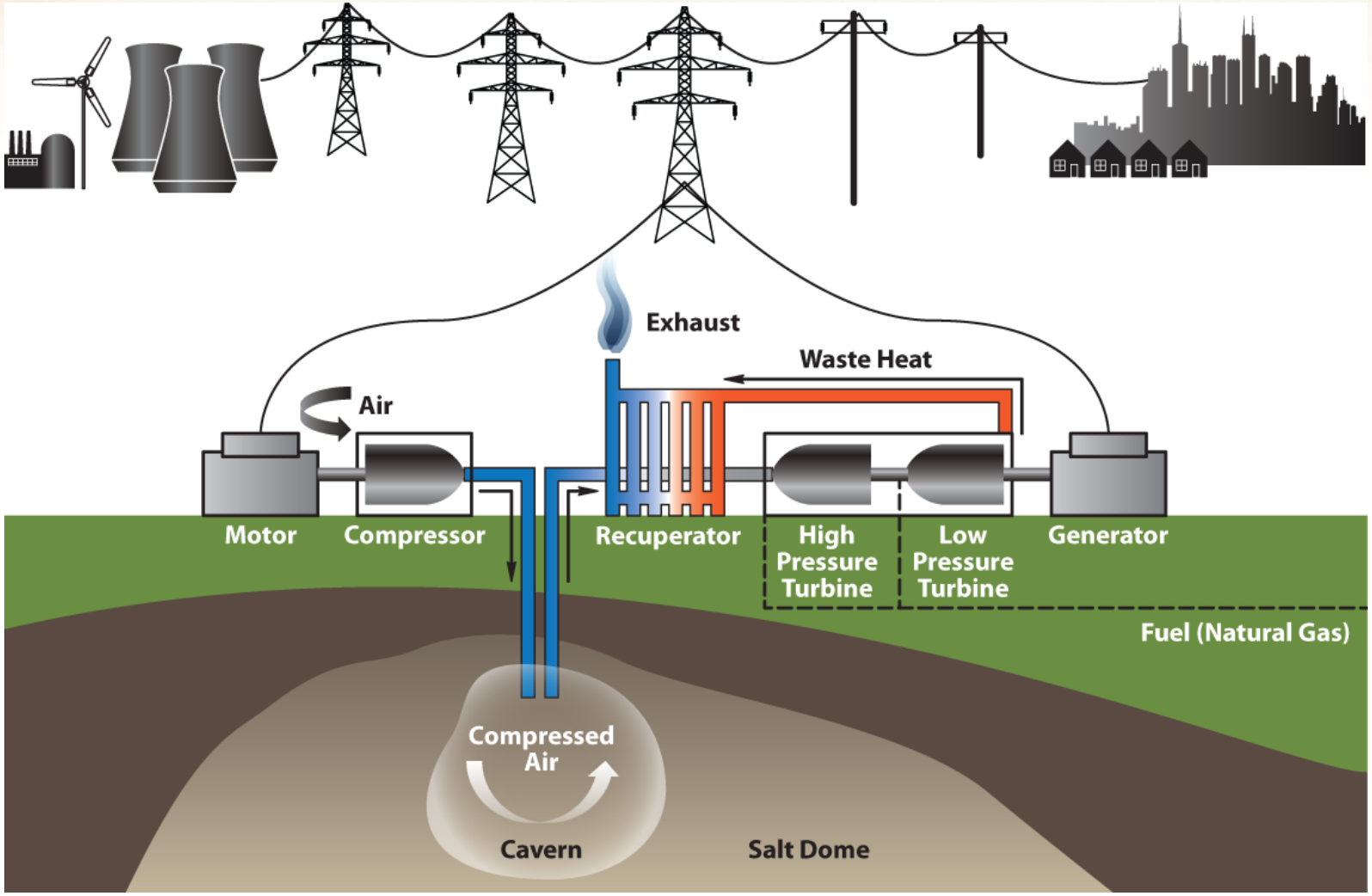
CAES in Salt Dome



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CAES Modeling Parameters

Three study areas this year:

- **Related engineering/operational aspects of CAES to rock characteristics**
- **Identified issues concerning depleted natural gas reservoirs used for CAES**
- **Determined pressure cycling effects on rock mechanical response**

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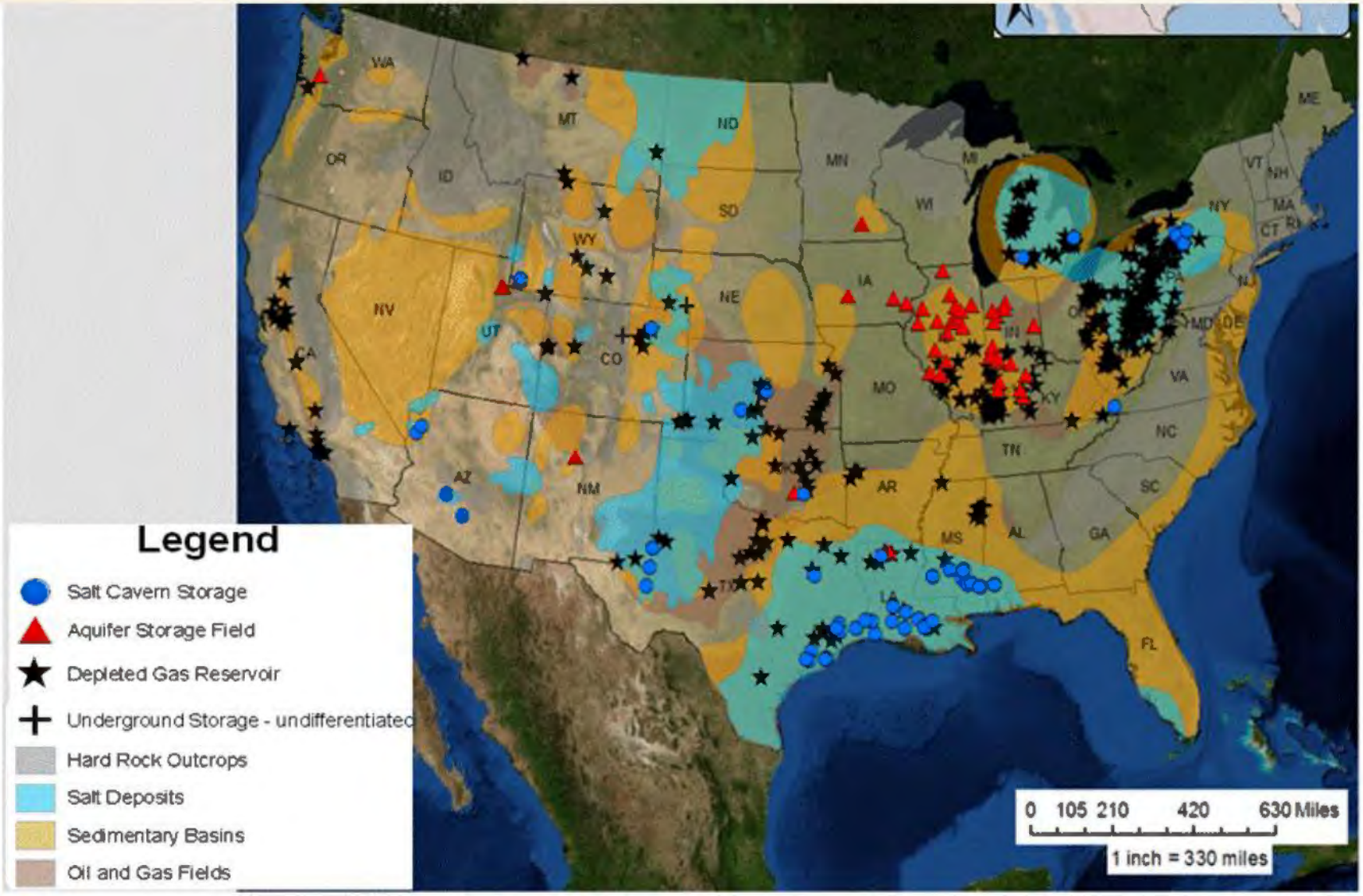
CAES geologic potential in the US?



ArcReader map displaying U.S. geologic info (Lord et al, in prep)

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Possible CAES containers

Caverns in Salt (Engineered)
(optimal depths of cavern ~2000 ft)

Former Mines
(optimal depths ~2000- 4000 ft)

Mined cavities (lined or unlined)
(Depth depends on liner (or not), water curtain)

Reservoirs (NG, aquifers)
(optimal depths of reservoir ~3000 ft, K>400mD, Φ>.15)

Manmade vessels
(better conditioned if buried)

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Tasks/Deliverables
(all work begun in 2010)

- **Report on Borehole and Formation Analyses to Support CAES Development in Reservoirs.**
- **Report on Potential Hazards of Compressed Air Energy Storage in Depleted Natural Gas Reservoirs**
- **Progress Report on Experimental Deformation of Salt in Cyclic Loading, Insights from Acoustic Emission Measurements**

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Report 1

SANDIA REPORT
SAND2011-5930
Unlimited Release
Printed May 2011

Borehole and Formation Analyses to Support CAES Development in Reservoirs

Stephen W. Webb

Borehole diameter and spacing and their dependence on formation parameters are used to help **assess part of the **cost** of the subsurface development of a CAES facility in a reservoir

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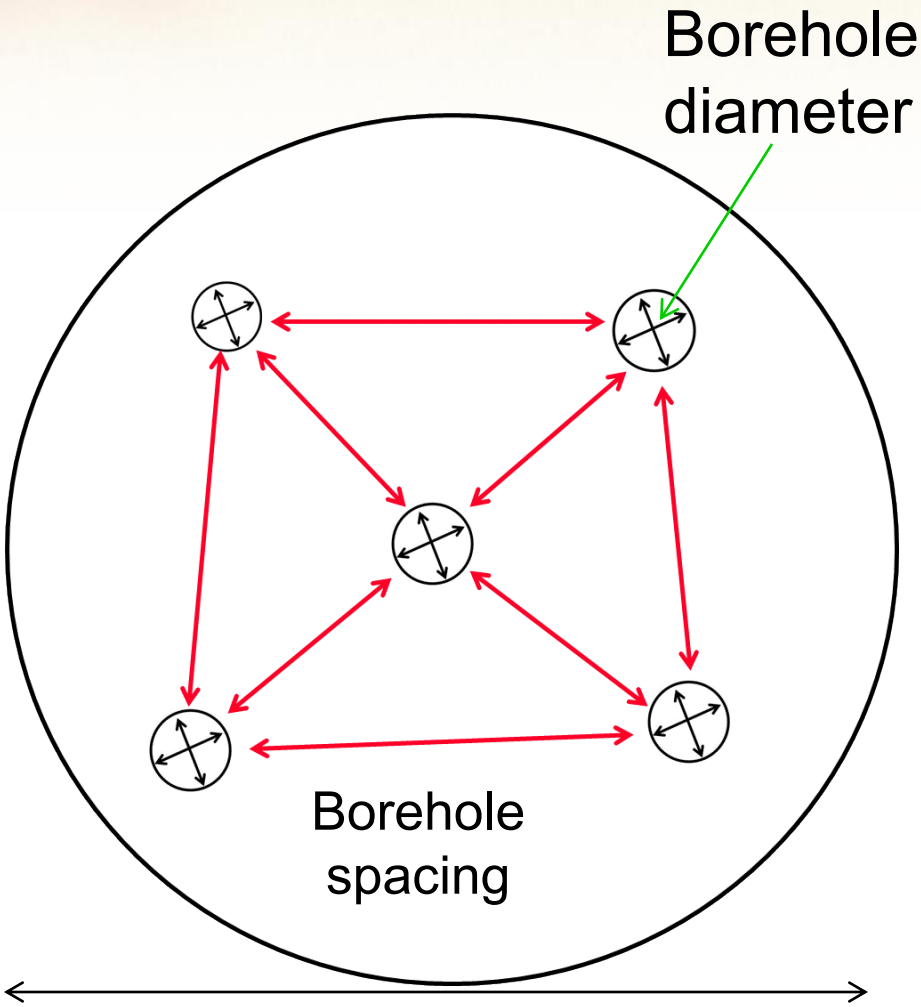
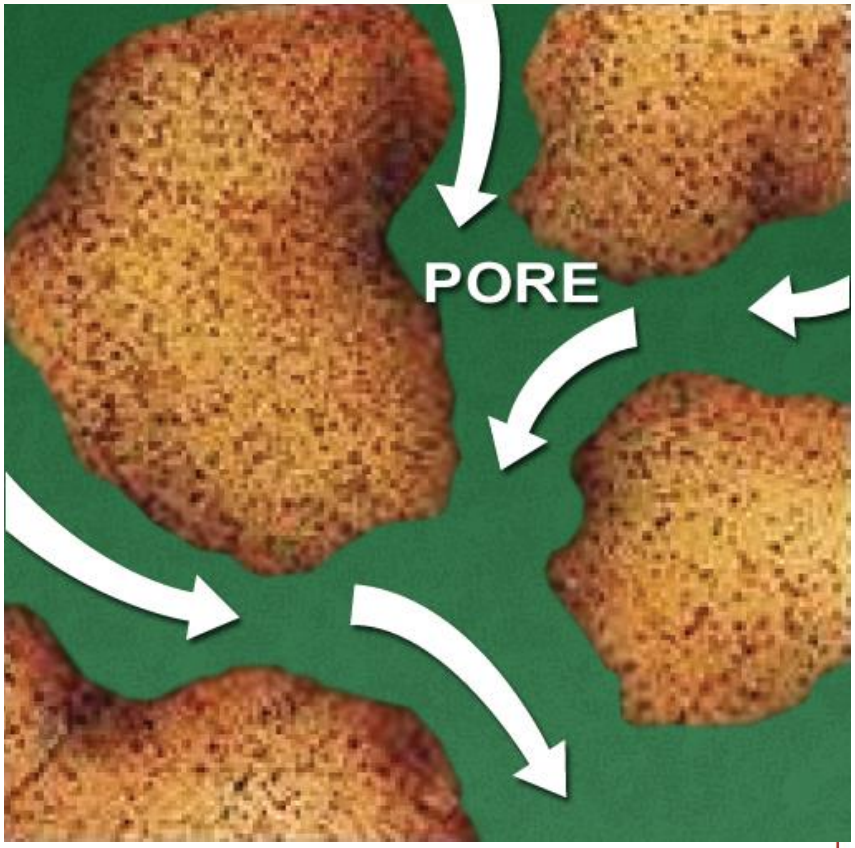
Operational & Formation Parameters





Porosity, Permeability

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Summary/Conclusion 1

- **A 2-D borehole/formation model was developed for CAES.**

  "System" performance evaluated.

  Optimal formation radius determined = f(borehole diameter, spacing)
- **Borehole diameter had only a minor influence on all the parameters including the borehole spacing and the power per borehole.**

  These differences are insignificant due to the uncertainties in the model.
- **The effect of permeability and porosity, on operational parameters was assessed.**

  Formation permeability changes had a much more dramatic effect than changes in the porosity.

  Permeability values greater than 400mD favorable

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Report 2

SANDIA REPORT
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Printed September 2011

Potential Hazards of Compressed Air Energy Storage in Depleted Natural Gas Reservoirs

Mark C. Grubelich, Stephen J. Bauer, & Paul W. Cooper

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Summary/Conclusions 2

Suggested Mitigation and Safety Strategies:
1-Empty and Purge the reservoir

2-An in-situ gas monitor should be installed down hole to provide a near source measure of natural gas presence.

3- Gas content entering the surface equipment should be monitored.
Air-fuel ratio in gas turbine can be adjusted to include the natural gas content of the compressed air from the underground .

4-Ensure that no surface breach is possible
Need sufficient overburden coupled with a down-hole shutoff valve

5-Ensure that the composition of natural gas and air remains outside the ignition envelope.
Recommend monitoring

6-Additional efforts to study and determine the effect of more complex phenomena regarding safety. An example studied assumes air is well mixed. Reality: geometry and geologic conditions will be complex and mixing may not take place. Density differences could act to stratify the air and natural gas mixture. More sophisticated modeling warranted

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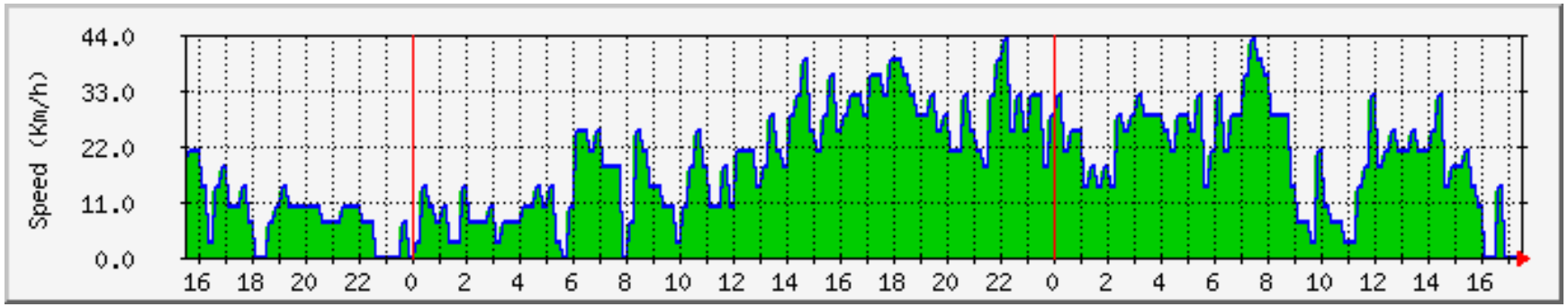
Report 3

SAND2011-2074C
May 2011
Experimental Deformation of Salt in Cyclic Creep Loading; Insights from Acoustic Emissions Measurements

S. Bauer, S. Broome, D. Bronowski,
A. Rinehart (NM Tech), M. Ingraham (Clarkson Univ.)



Hourly fluctuations in wind speed could translate to frequent pressurization/depressurizations of underground CAES containers

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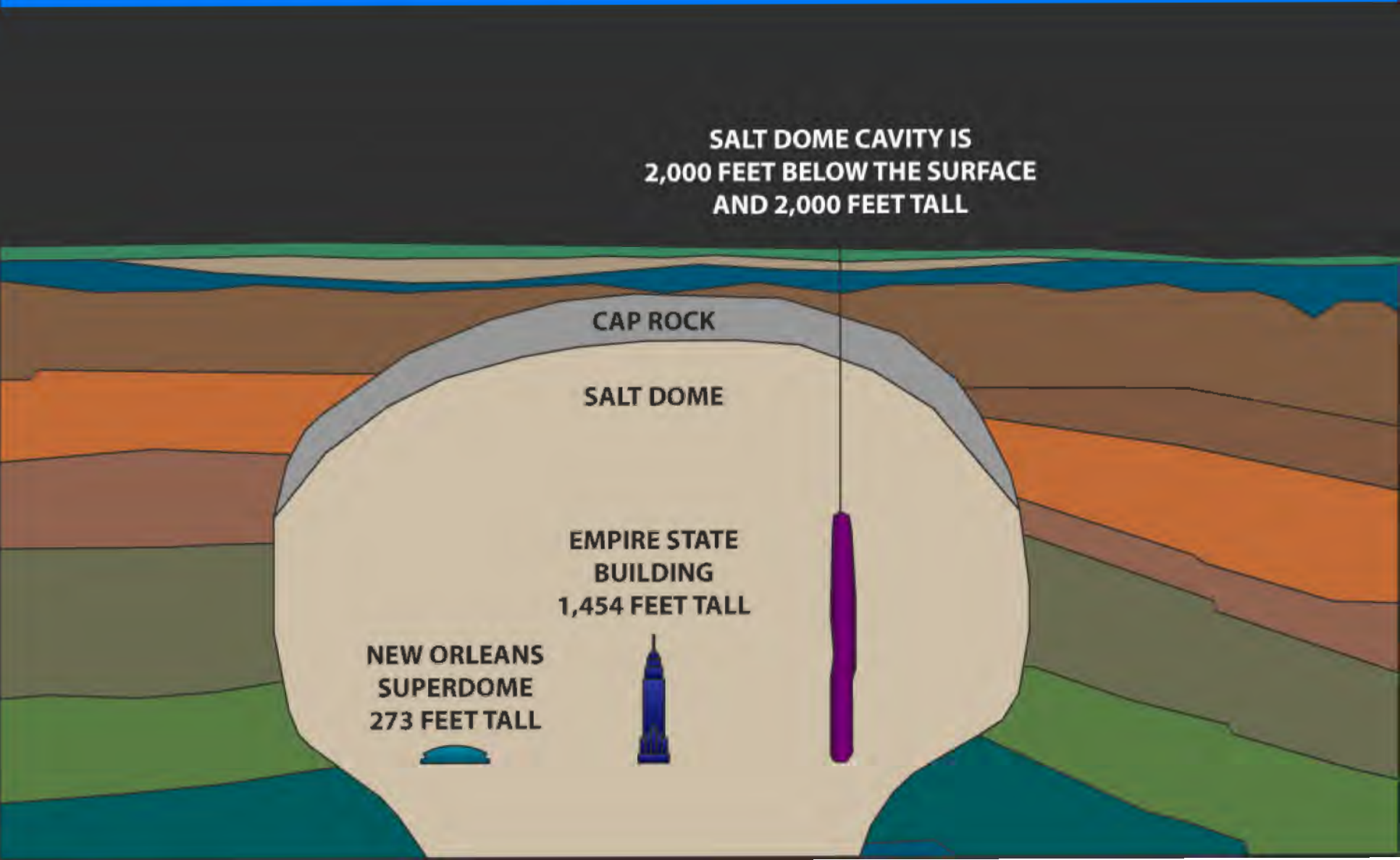
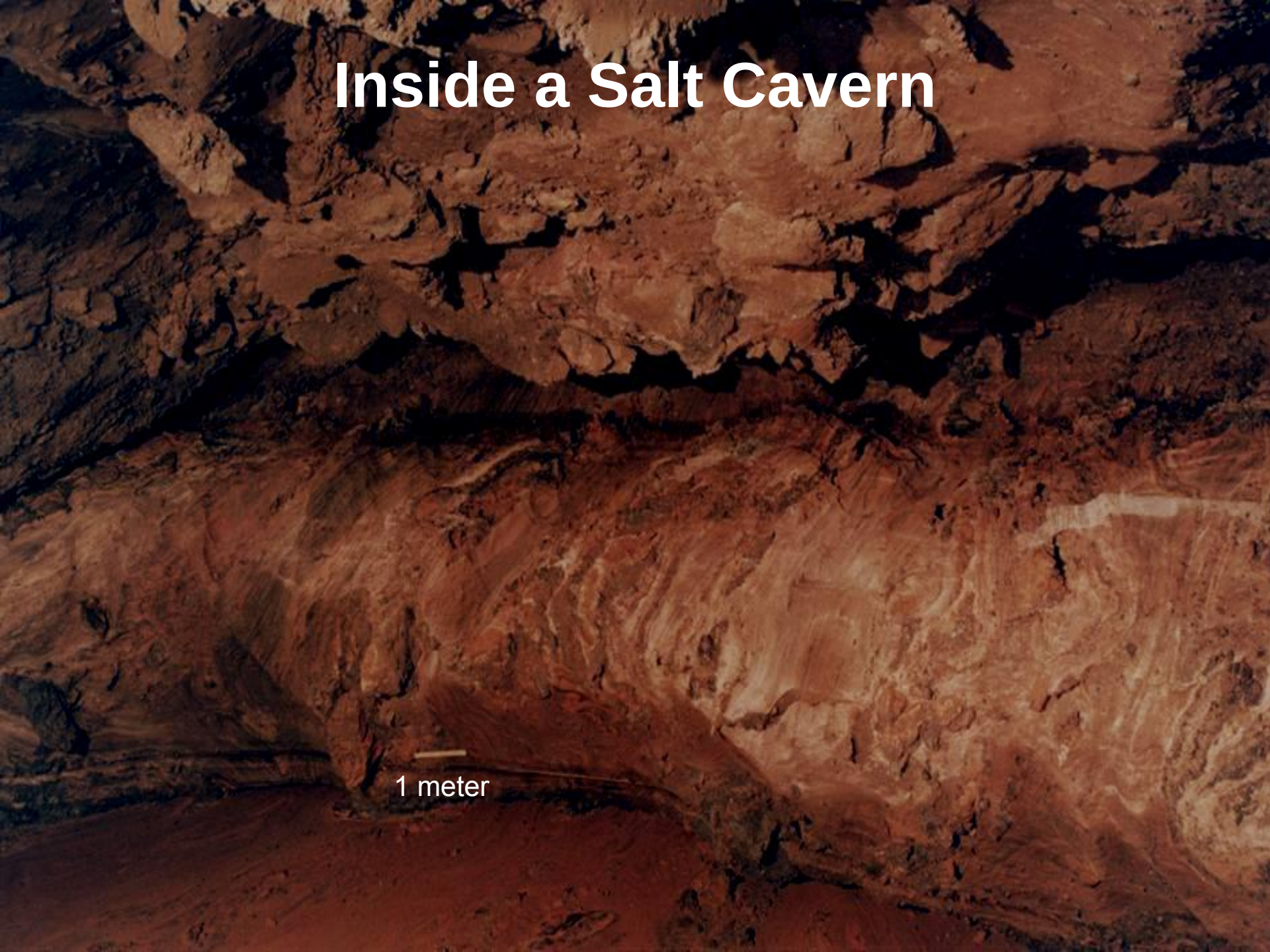
Size Comparison

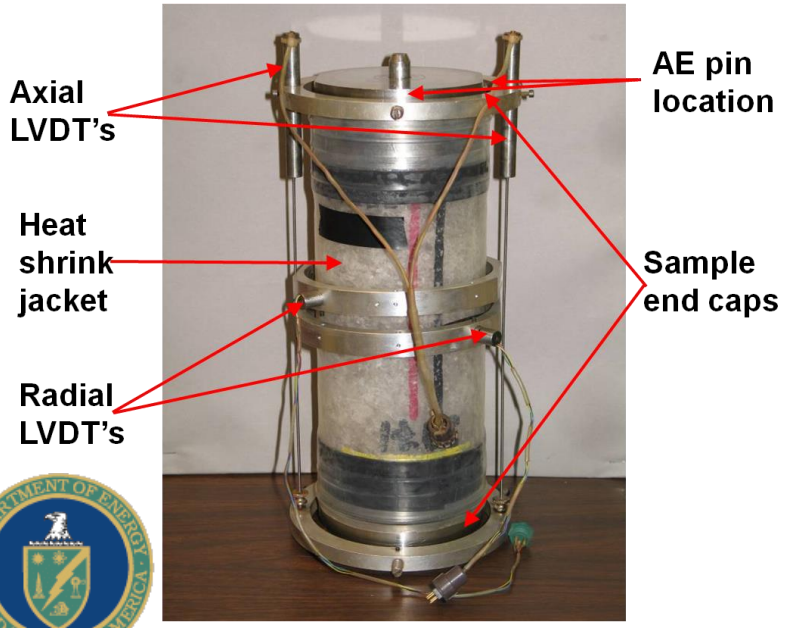


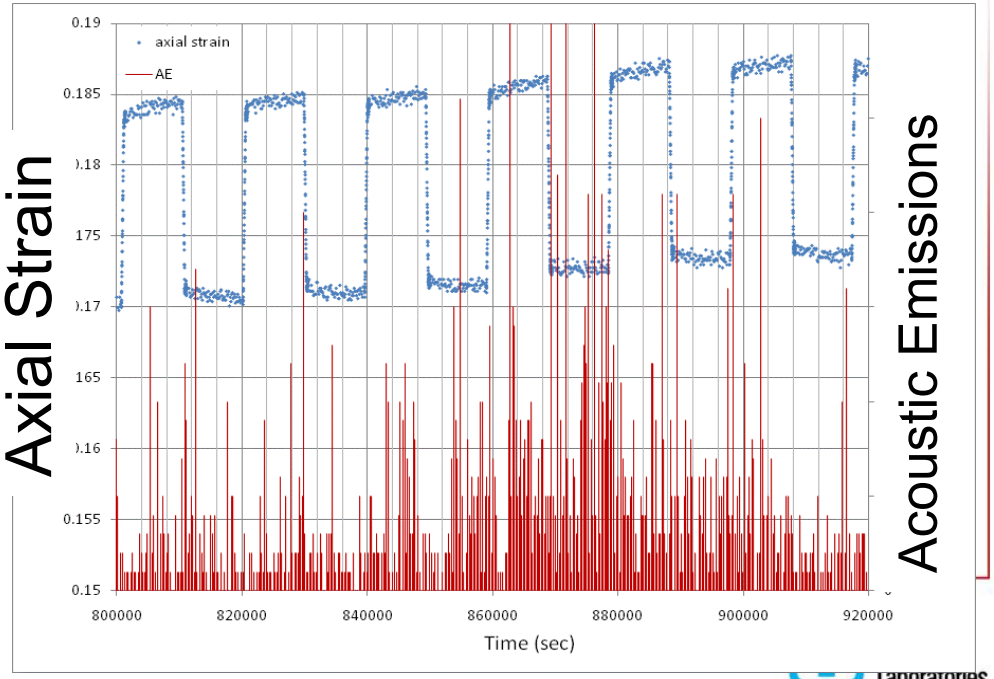
Inside a Salt Cavern



Summary/Conclusions 3

- Cyclic loading caused cracking at low differential stresses in rock salt
- Acoustic emissions used as diagnostic for rock salt deformation in the laboratory AND technology can be applied to cavern scale monitoring
- *AE system being installed at some storage caverns to assess progressive subsurface damage.
- *Damage/dilatancy criteria used to determine operational limits of salt caverns should be revisited





Leveraging Other CAES R&D

- **Poster on CAES Analyses (this meeting)**
- **Evaluated buried reinforced concrete containers for CAES (Akin & Bauer, 2011)**
- **Evaluated mined rock caverns for CAES (Bauer et al, in prep)**
- **Research program by Solution Mining Research Institute on rapid gas cycling effects on rock salt**

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Future Tasks to be considered

- Borehole evaluation study for horizontal boreholes
- Continue work on cyclic behavior of salt
- Fully develop work on pore pressure cycling effects on reservoir rocks (sandstone)
- Field evaluation of depleted reservoirs for CAES
- Develop US map for underground storage potential

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thanks
Questions?