GEOMECHANICS OF CAVERN STORAGE

SMRI FALL 2021 TECHNICAL CLASS
GALVESTON, TX

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AGENDA

- INTRODUCTION
- WHAT IS A GEOMECHANICAL MODEL
- DEVELOPMENT AND SIMULATION
- RESULTS AND INTERPRETATION
- SUMMARY

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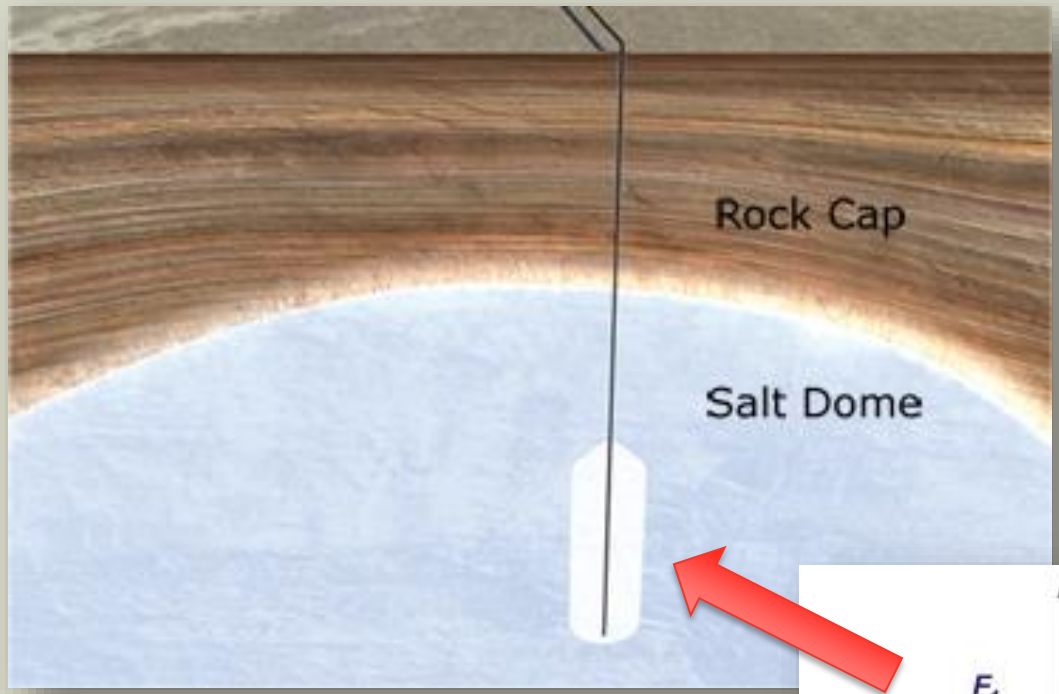
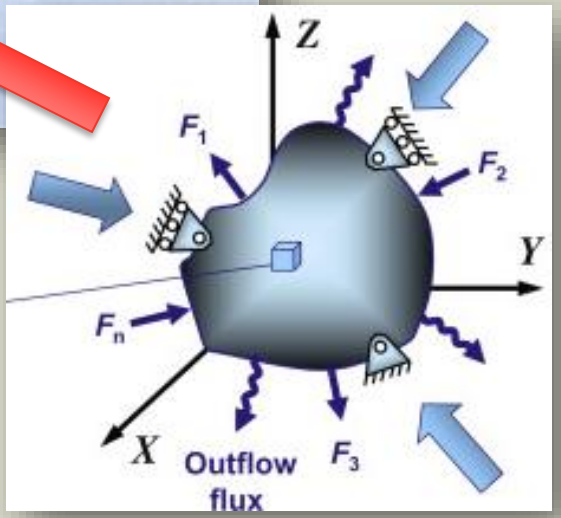
INTRODUCTION

- What are "geomechanics?"
  - The study of rock mechanical behavior
  - How does rock deform or fail in response to loads, pressures, and temperatures

- Why?
  - Develop appropriate cavern designs
  - Optimize cavern operations
  - Monitoring
  - Avoid failures / issues
  - Root cause analysis
  - Abandonment

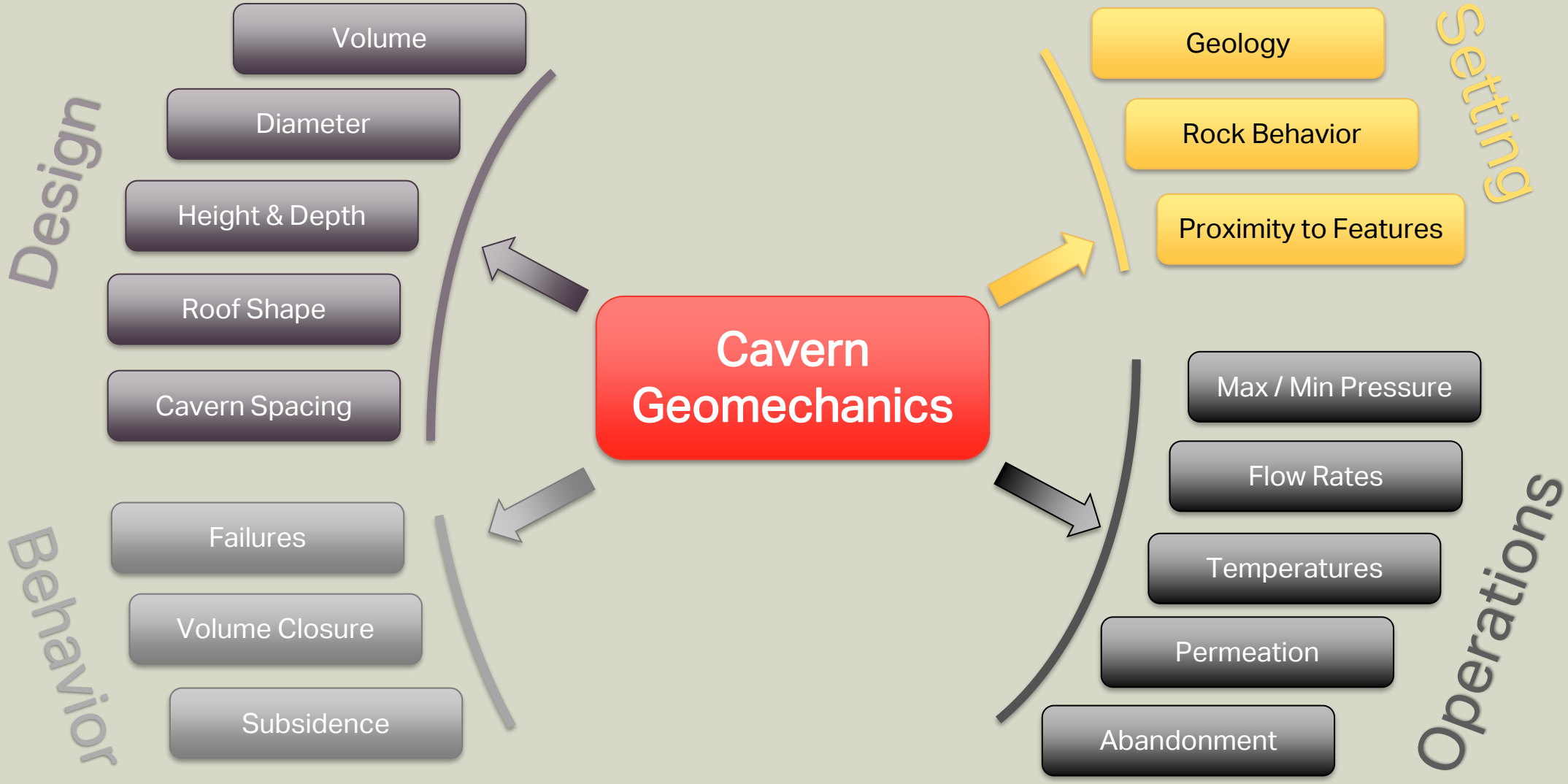
Source: TLTP





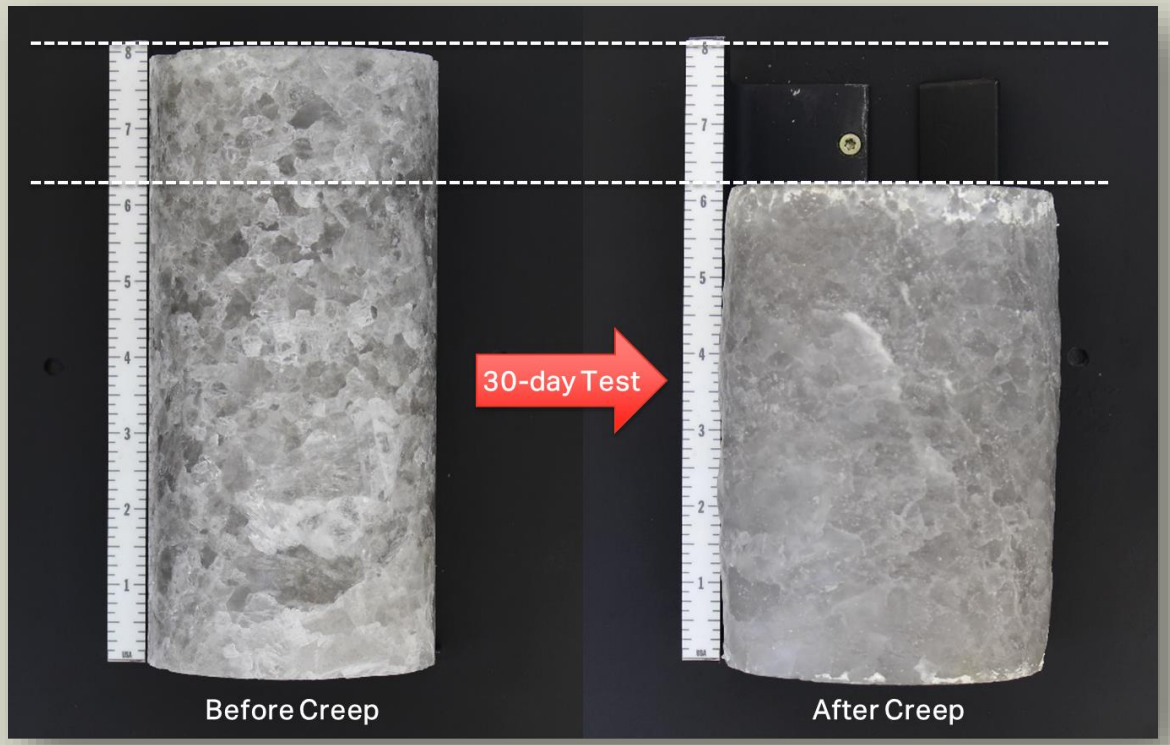
Source: B. Aadnoy, 2011

INTRODUCTION

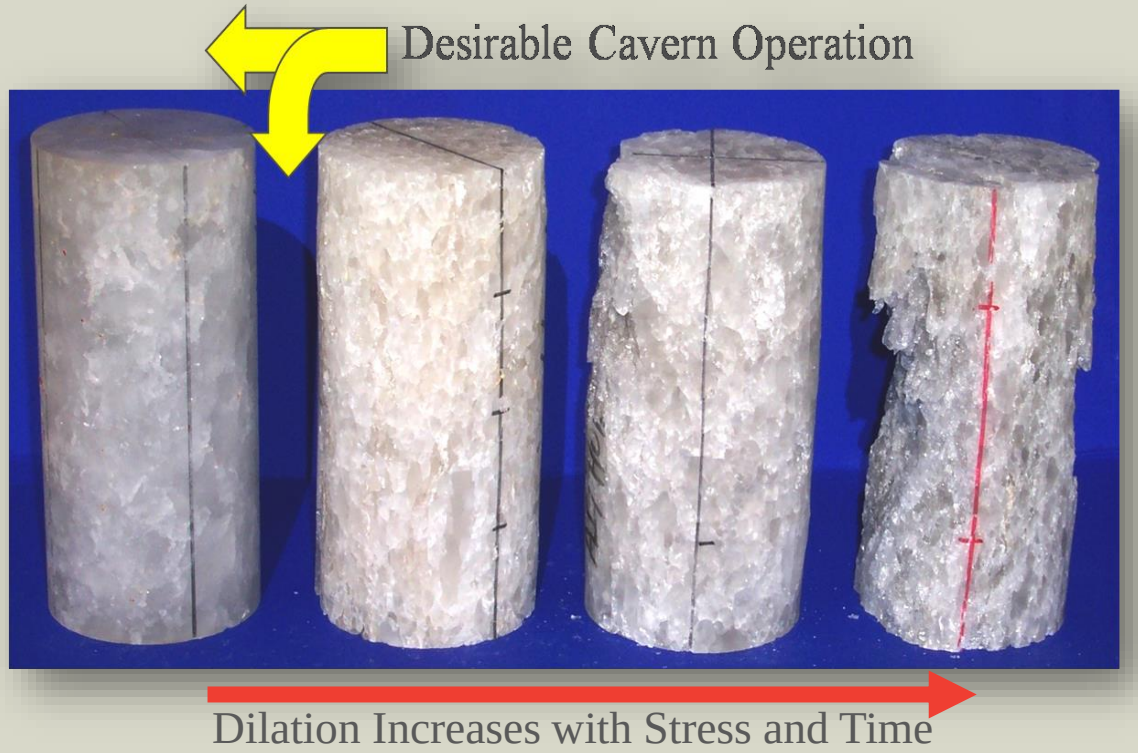


INTRODUCTION

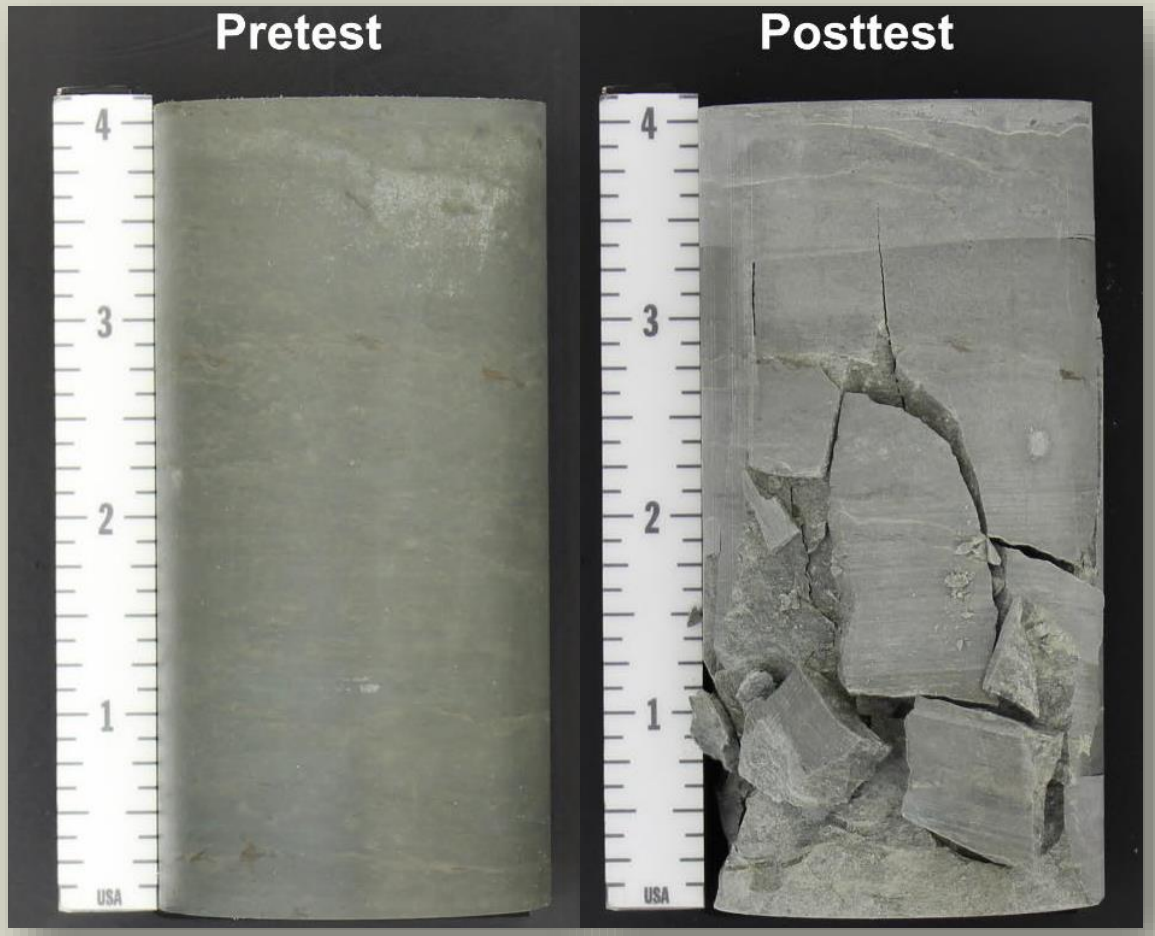
Salt Creep

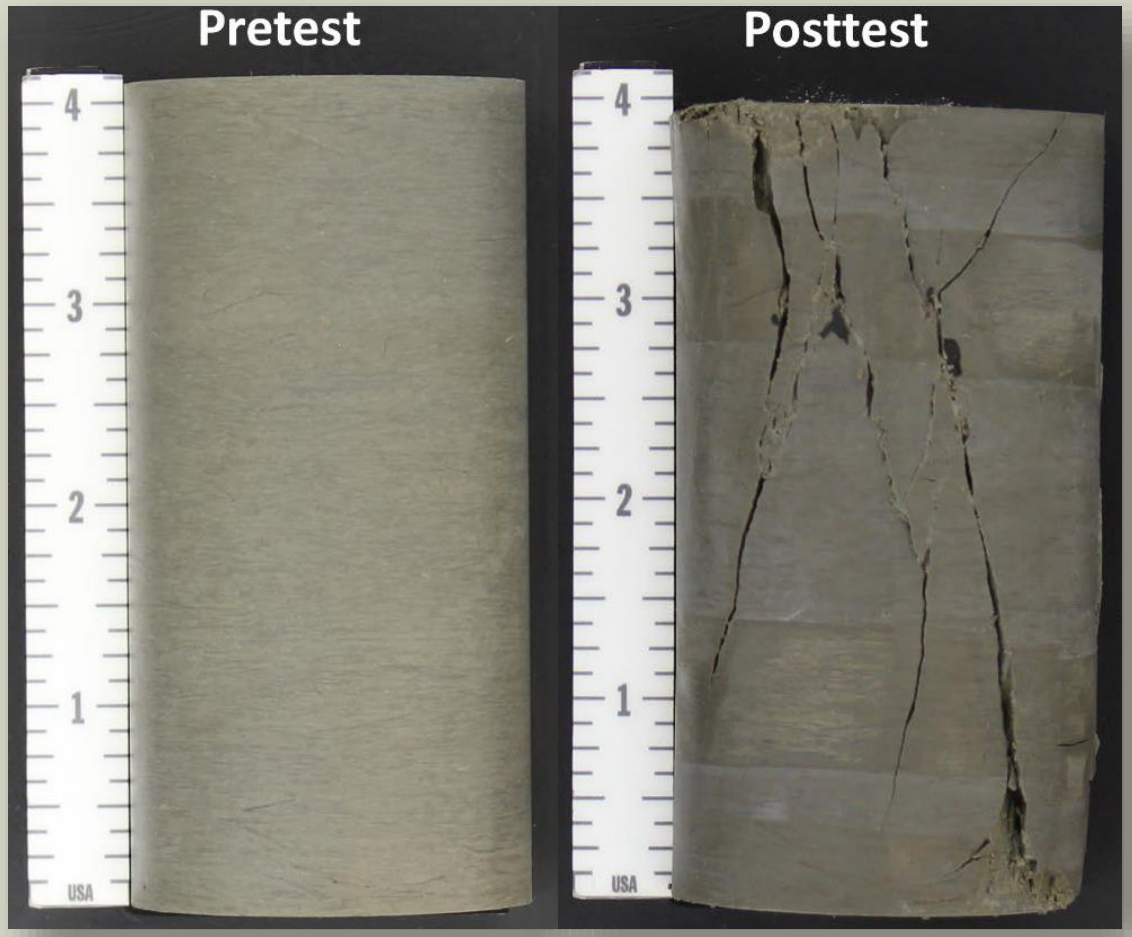


Salt Dilation / Damage



Non-Salt Geomechanics





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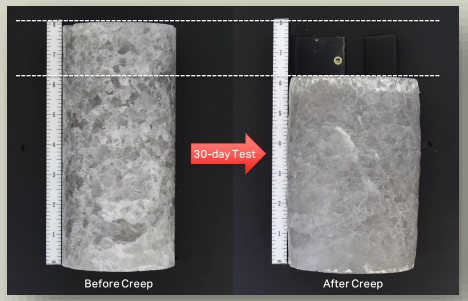

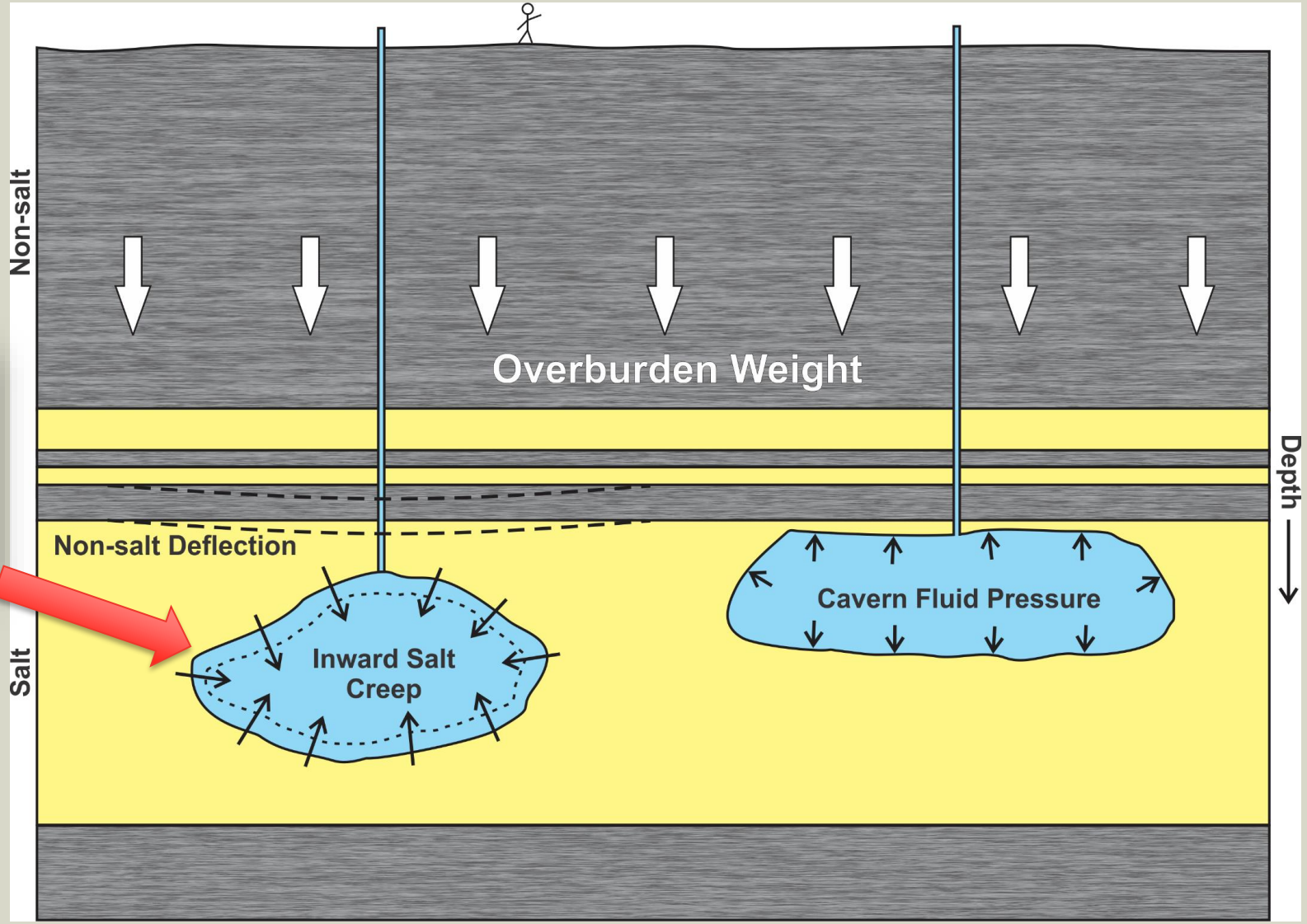

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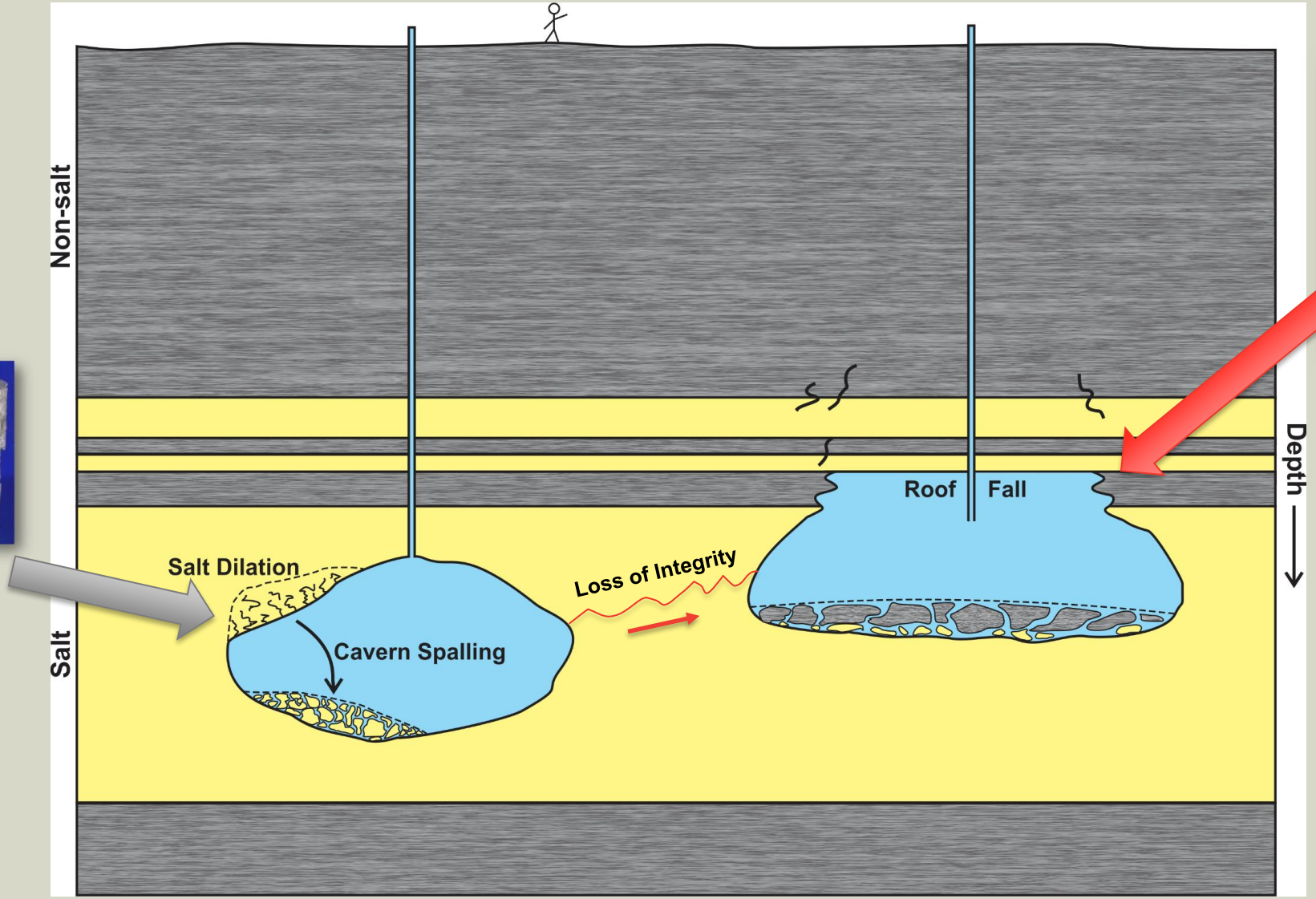

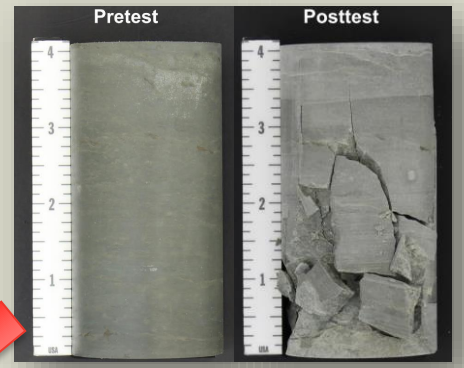

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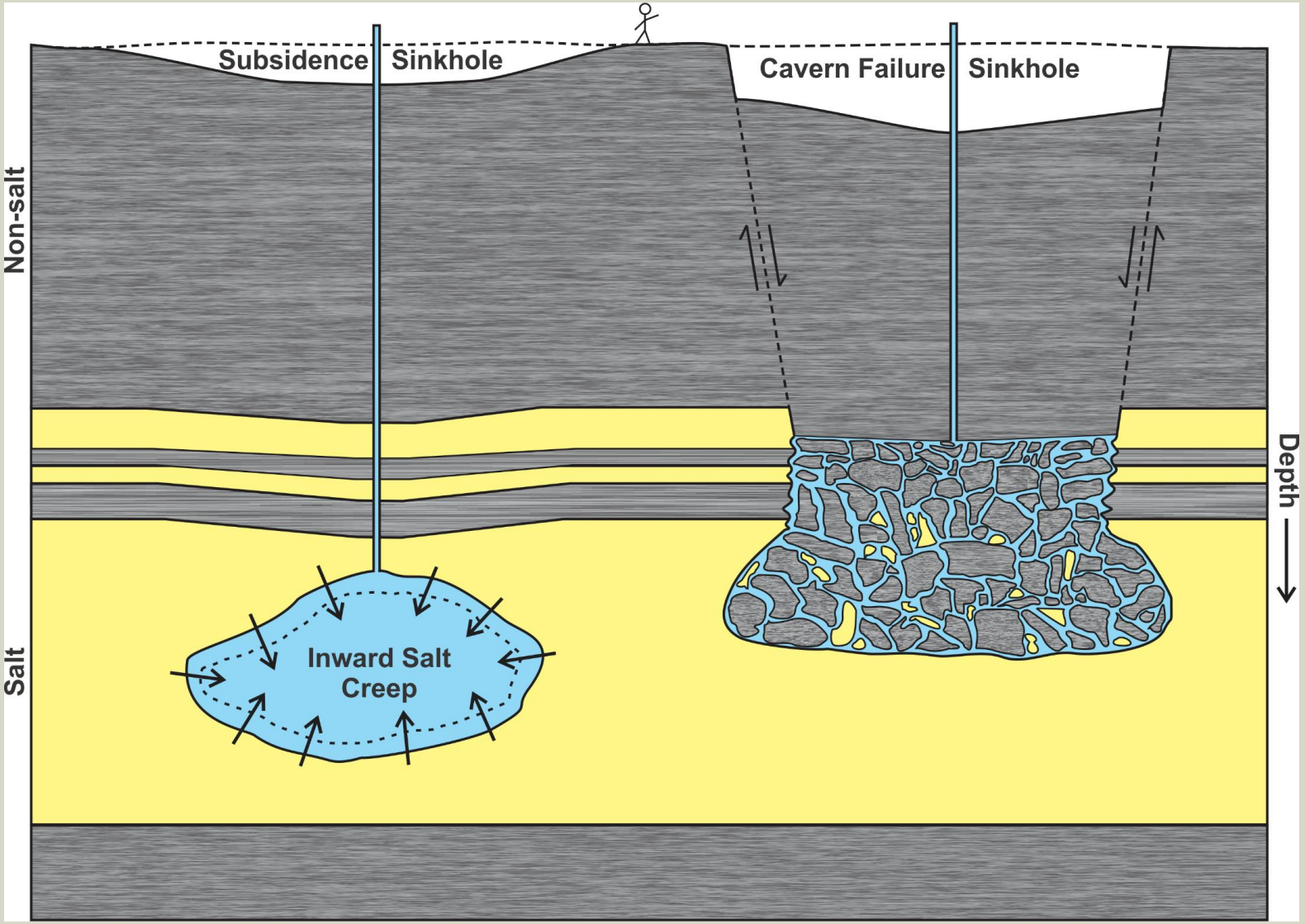

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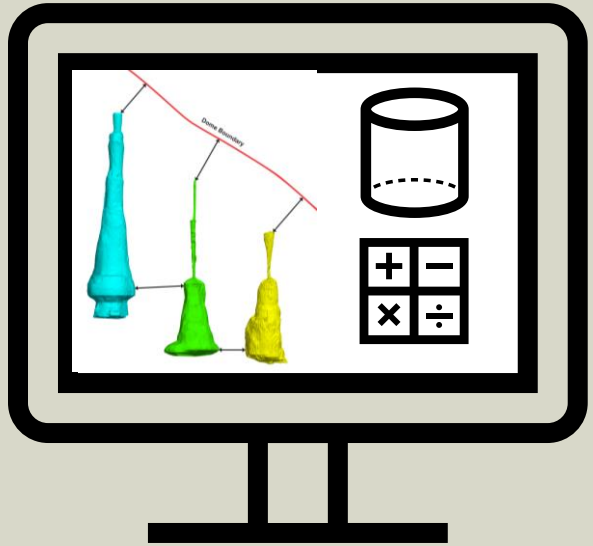
WHAT IS A GEOMECHANICAL MODEL?

- What is a model?
  - A simplified representation of reality
  - Something we create to approximate a real thing
  - Helps us analyze how the real thing behaves

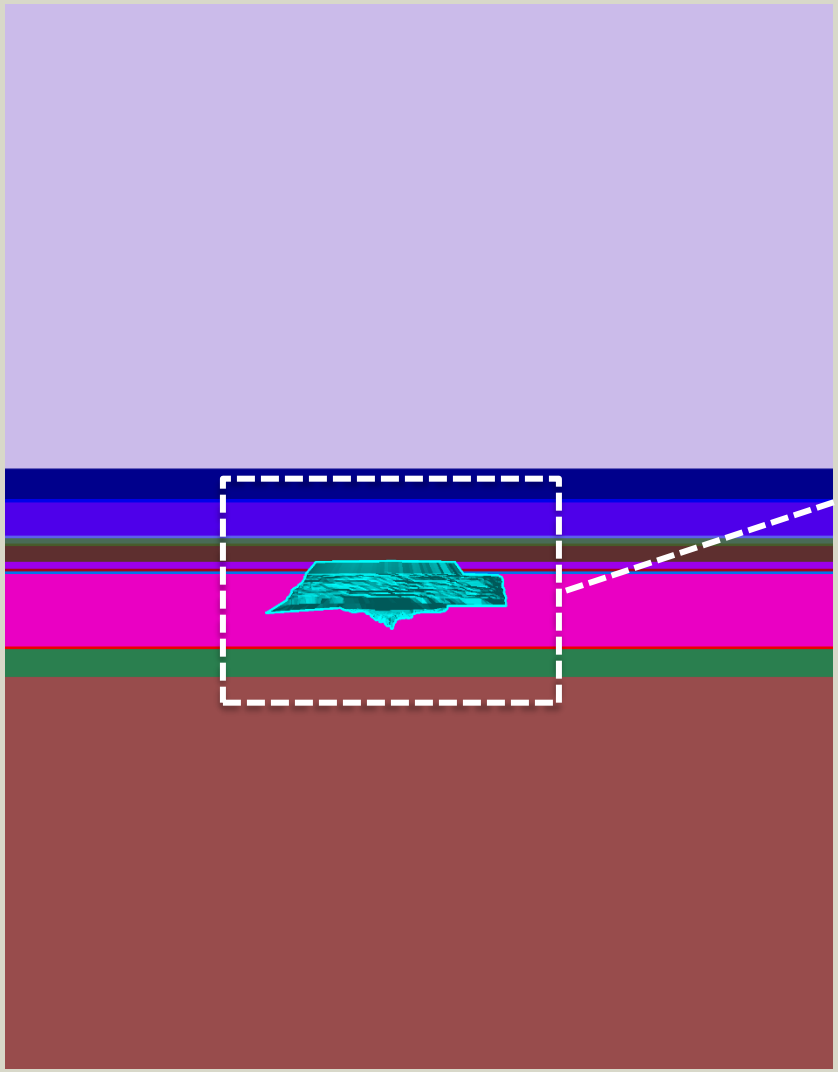
Source: Core77

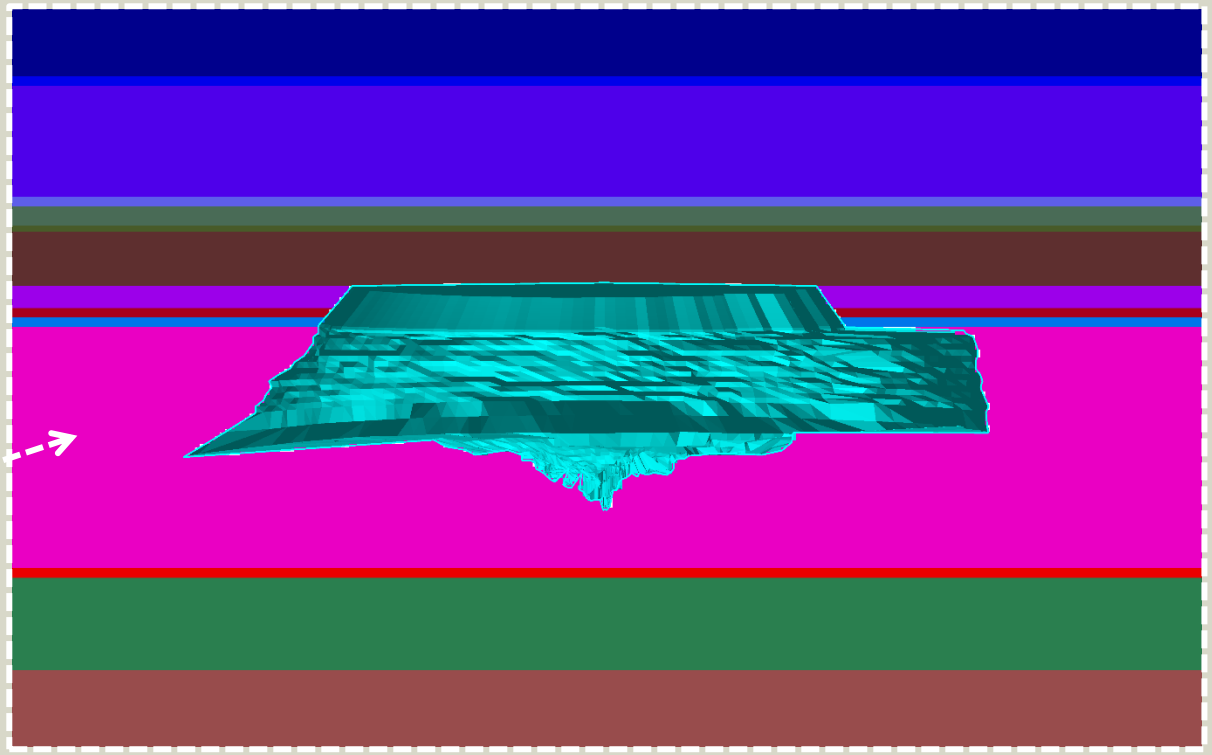
- A geomechanical model is similar
  - A mathematical representation of an actual geologic system (e.g., a salt cavern)
  - Simplify the complex actual system into something we can analyze

Source: LADWP



WHAT IS A GEOMECHANICAL MODEL?

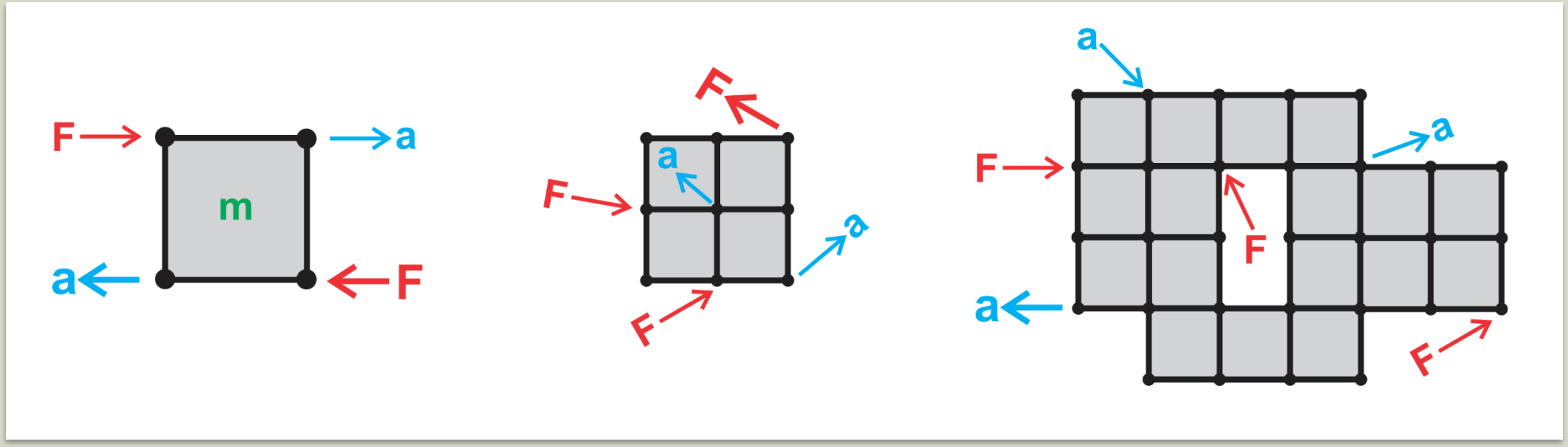




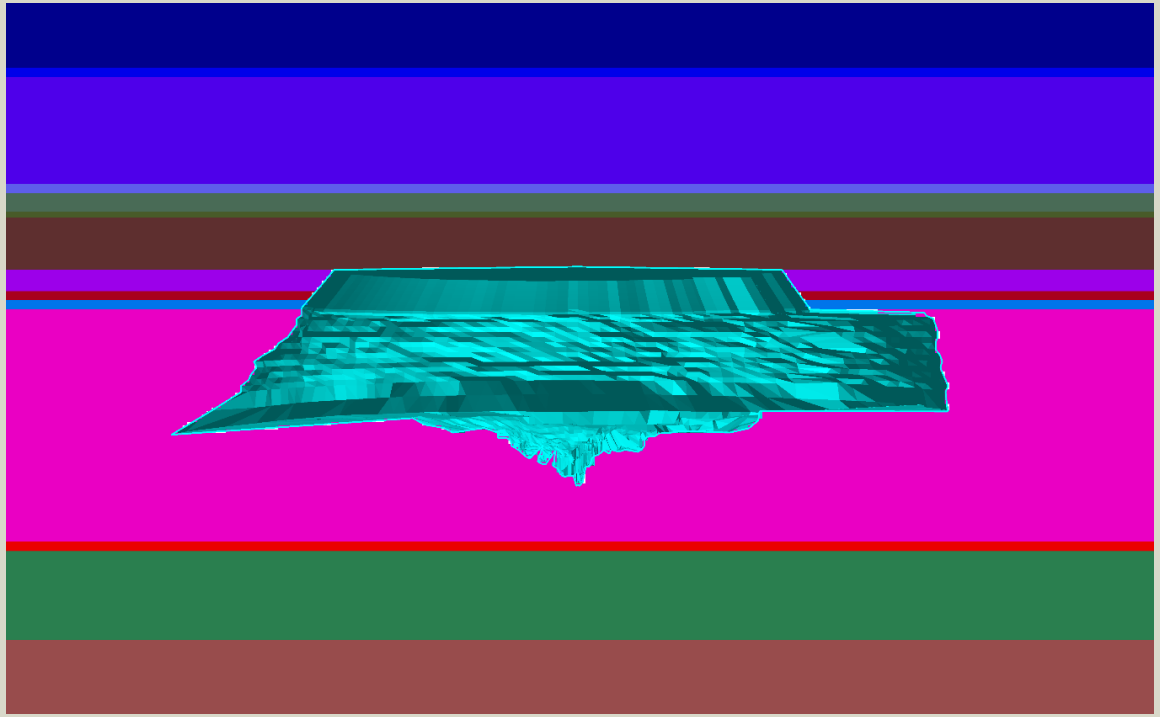
- How do we assess the stability? Minimum pressure? Complex!
- Is there an equation? No!
- Where to begin?

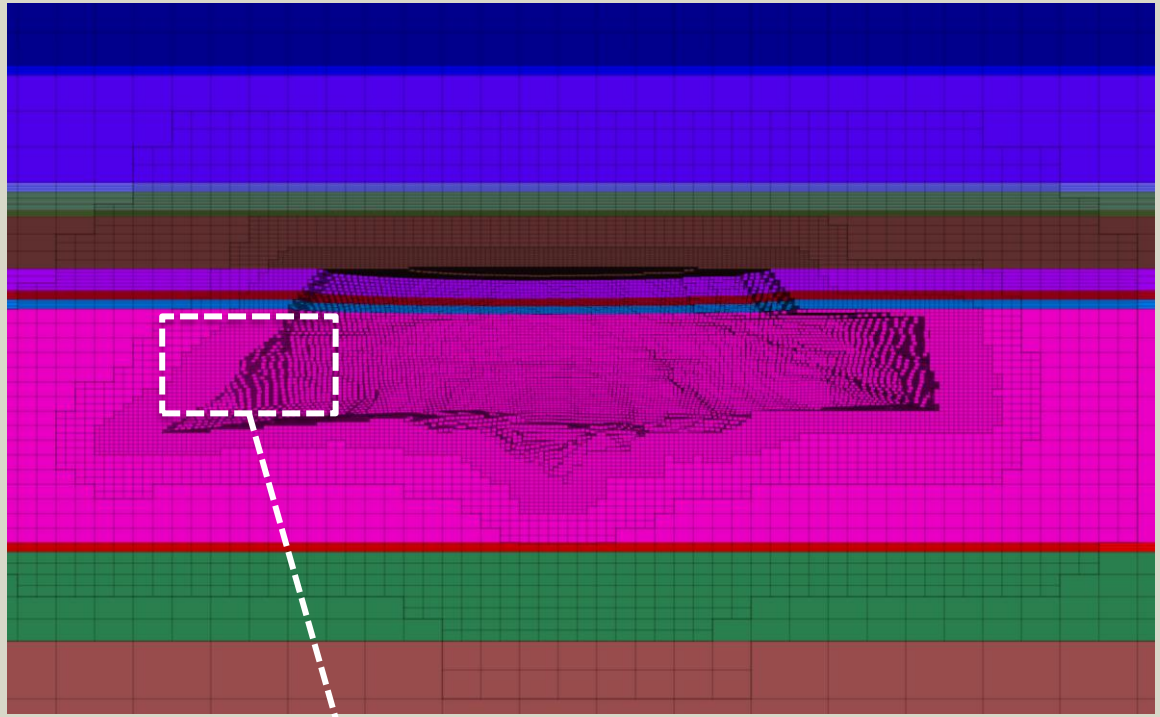
WHAT IS A GEOMECHANICAL MODEL?

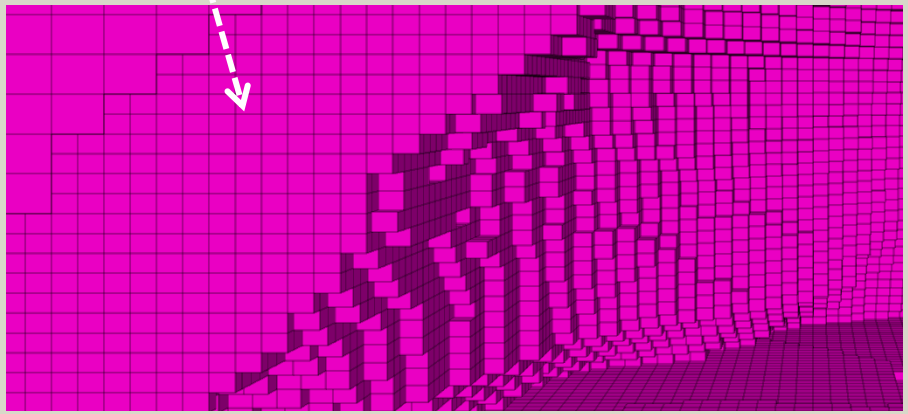
- We have to simplify the cavern into something we can analyze with basic math
  - Force = Mass x Acceleration
  - Stress = Stiffness x Strain
  - etc...



WHAT IS A GEOMECHANICAL MODEL?







- Millions of “Lego blocks” and millions of equations to solve… we need a computer!

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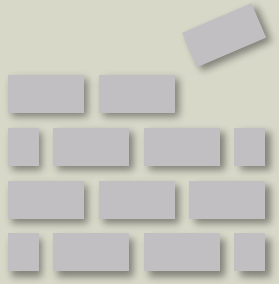
DEVELOPMENT AND SIMULATION



Model Development

- Build the model
- Define inputs

Set Up Modeling Scenario

- Timeline
- History + Future

Run Simulation

- Track convergence
- Scrutinize output

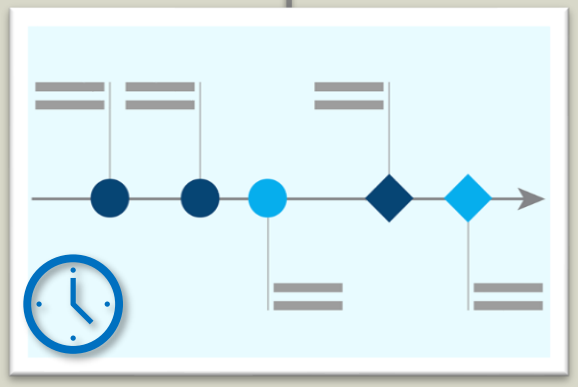
Interpret Results

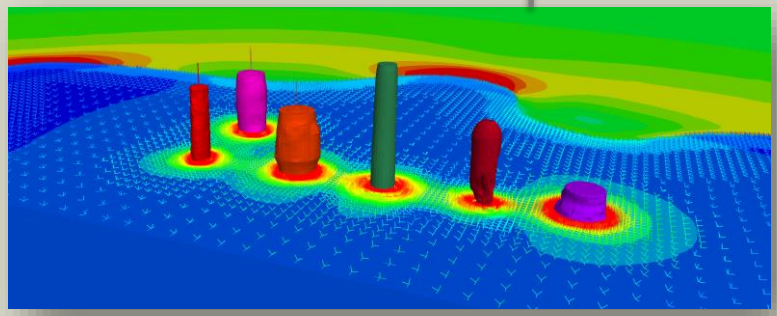
- What does it mean
- How do we apply the observations

DEVELOPMENT AND SIMULATION

- Cavern Shape / Size
- Neighboring Caverns
- Geologic Structure
- Rock Properties
- In Situ Conditions
- Loads / Pressures
- Mesh / Grid / Numerics

Model Development → **Modeling Scenario** → **Simulation** → **Results**





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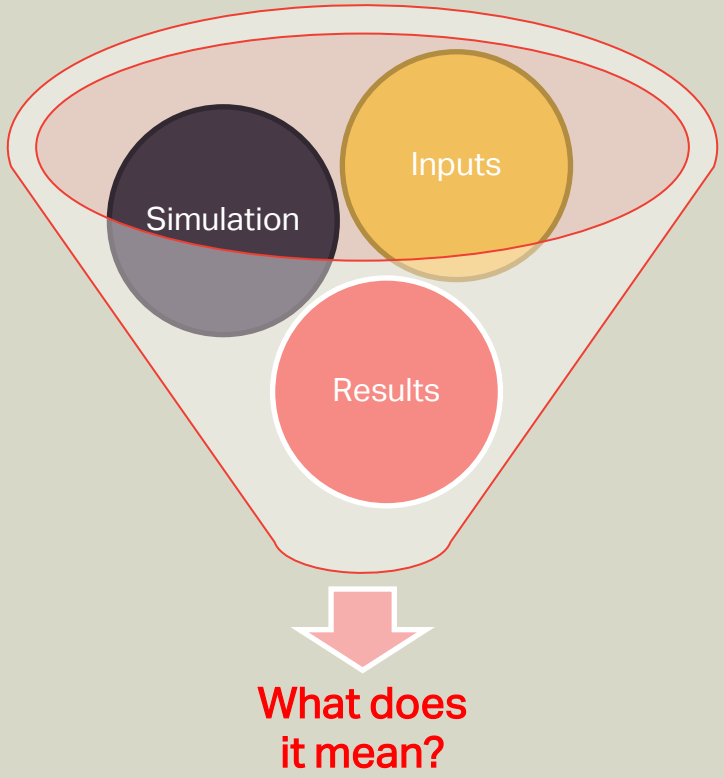
RESULTS AND INTERPRETATION

- Building and running a geomechanical model is (mostly) straightforward

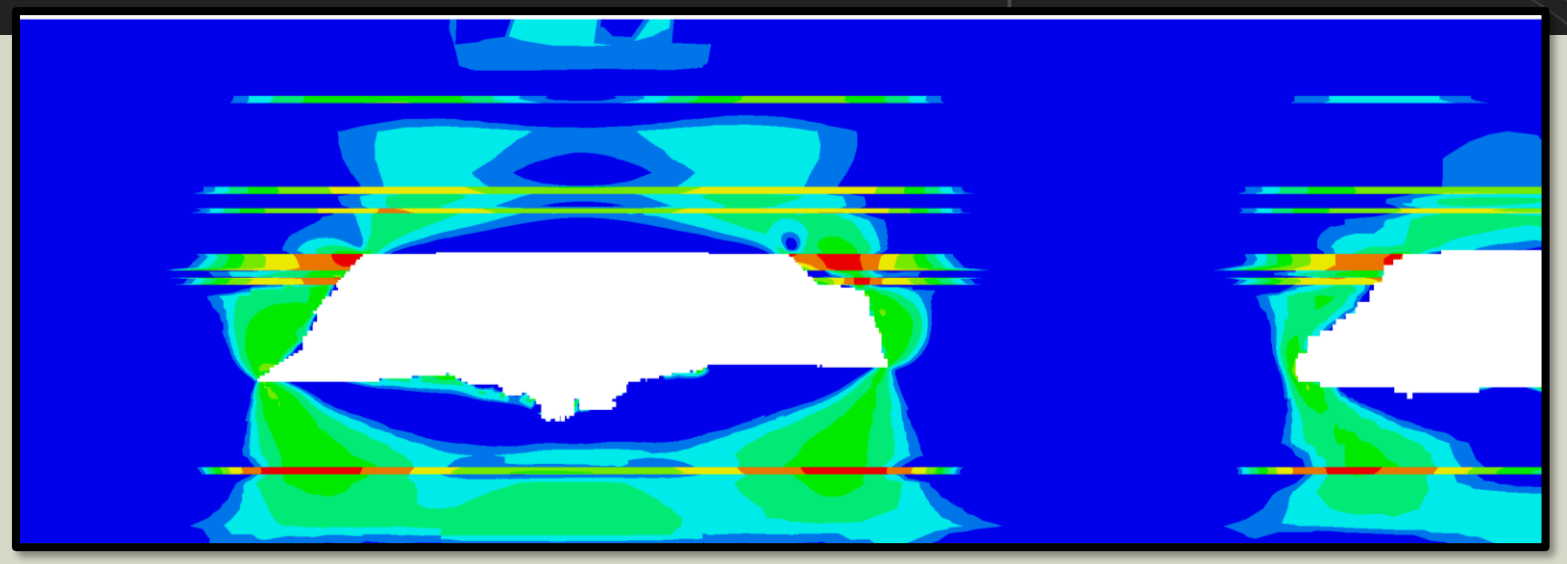
- The real challenge comes when you need to analyze the results and interpret the outcome
  - What do the results mean?
  - Is the cavern okay?
  - Do we need to operate the cavern differently?
  - What if one of the model inputs is uncertain?

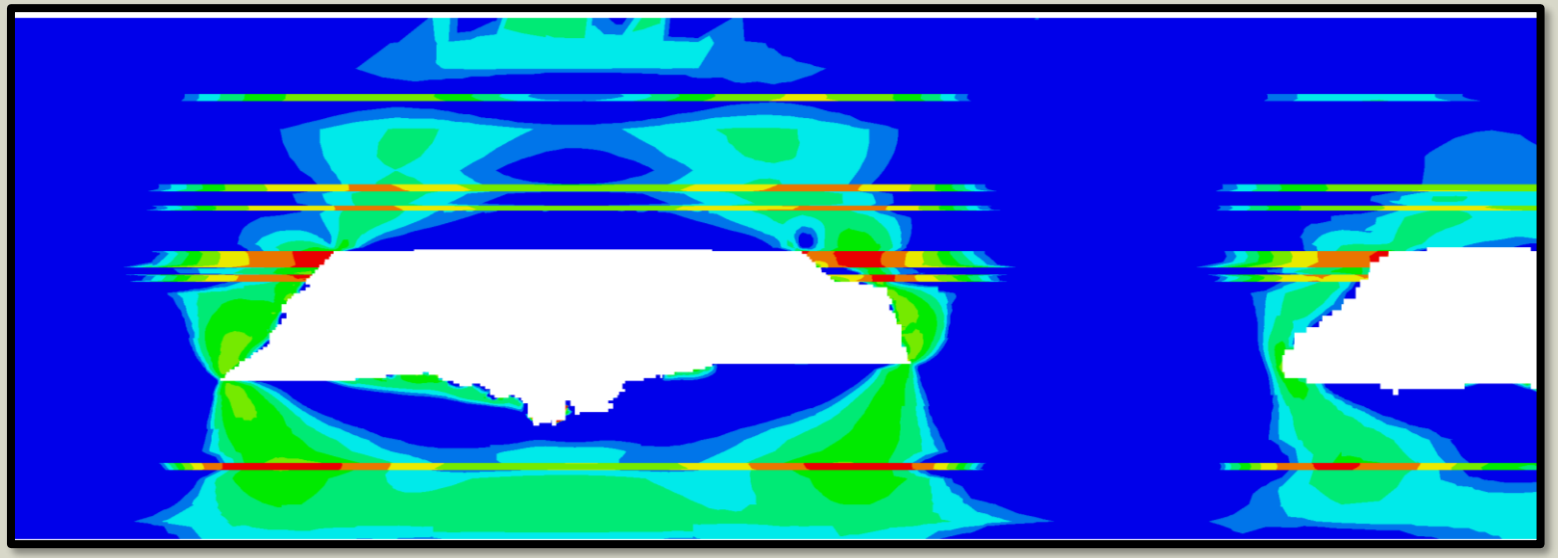
- The simulation will only produce basic results (stress, displacement)
  - The model will not simply show a pass/fail regarding stability
  - We need to look at several different results and often have to calculate additional outputs



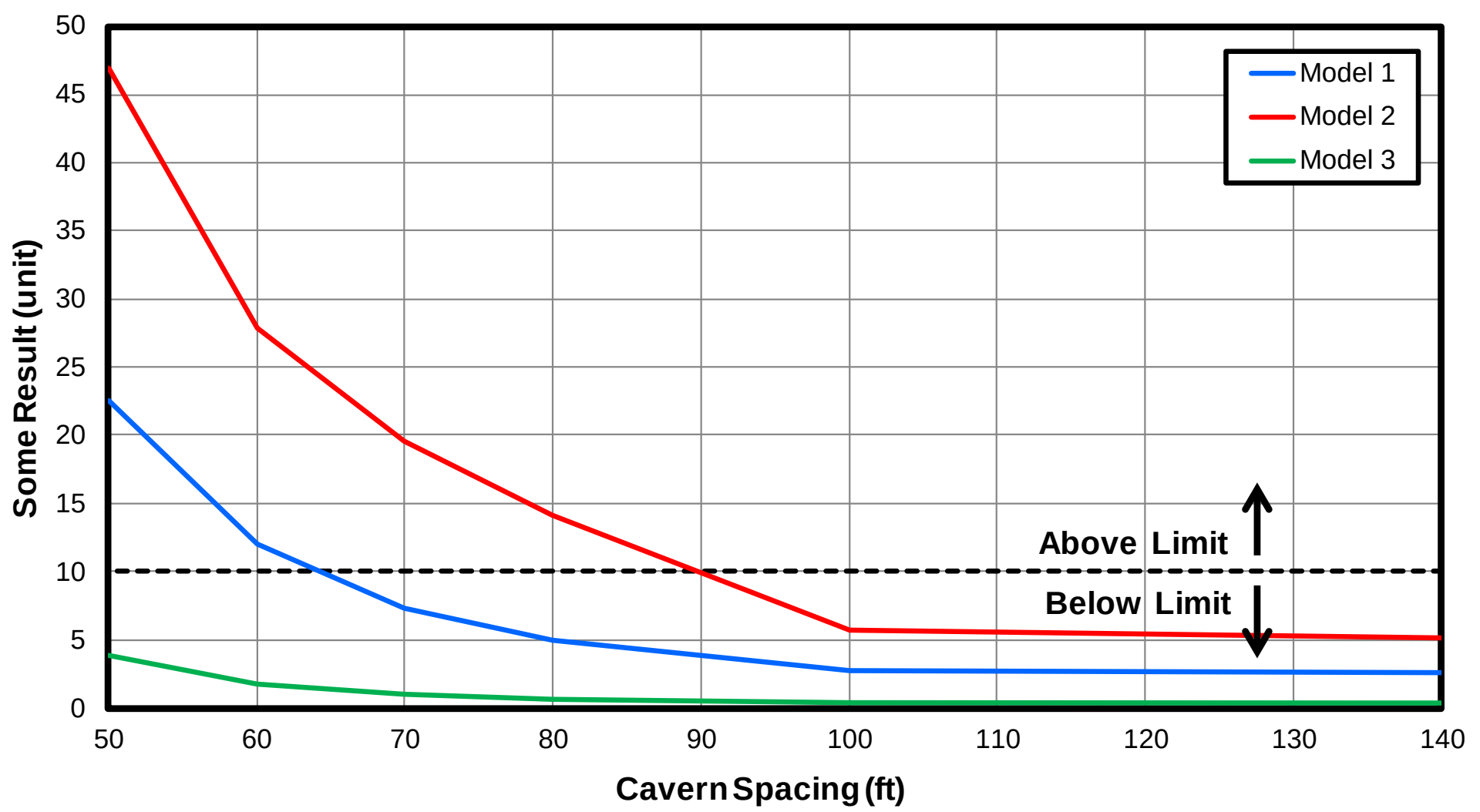
RESULTS AND INTERPRETATION

- What do these results actually mean? How do we apply them?
- What could be affecting the results… making them too unrealistic?
  - Assumptions
  - Simplifications
  - Unknowns
  - ???
- How do these results compare to actual observations?

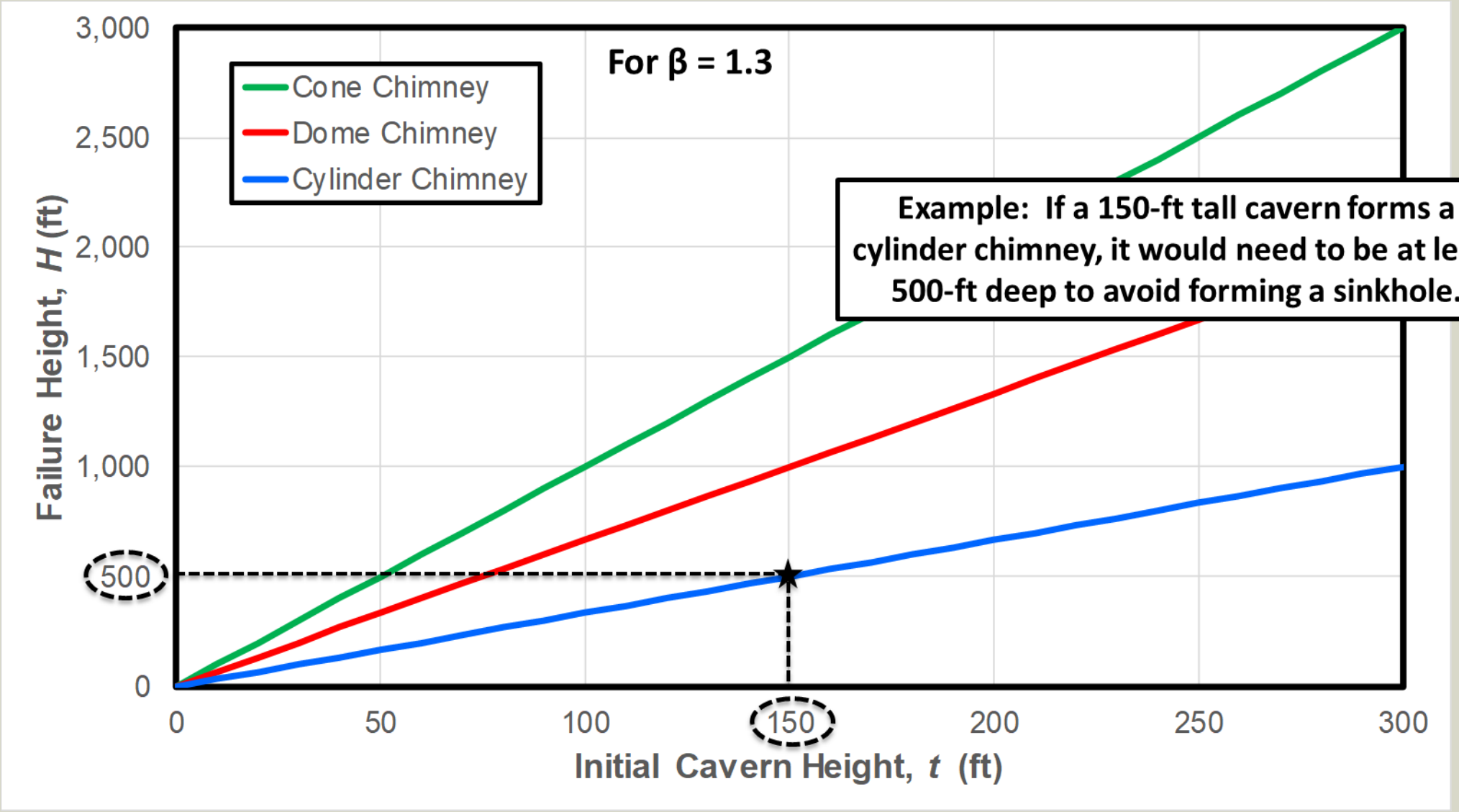




RESULTS AND INTERPRETATION



RESULTS AND INTERPRETATION



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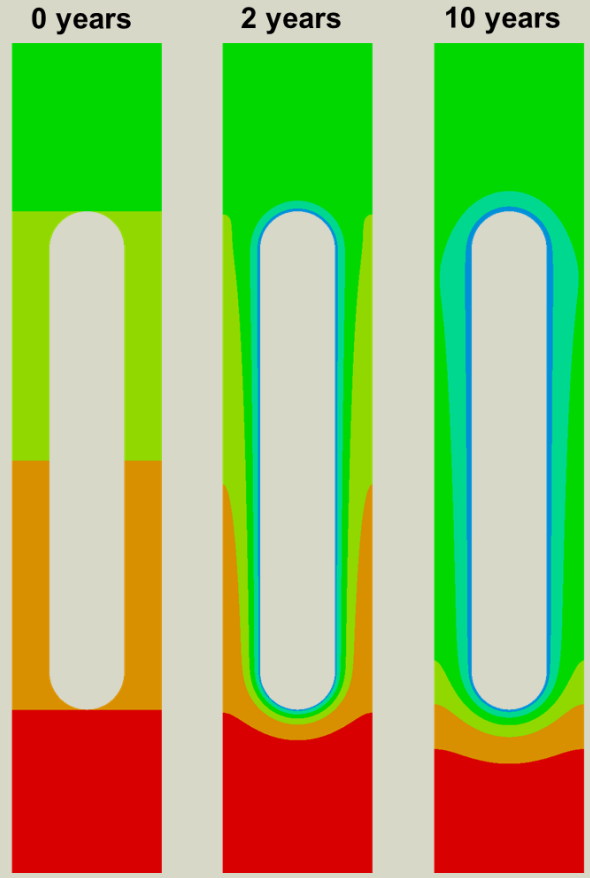
SUMMARY

- Geomechanics are critical for designing and evaluating salt caverns
  - Optimize performance
  - Avoid problems / failures
- A geomechanical model is a simplified representation of a real geologic system
  - We have to simplify the real system because it is too complex to analyze
  - We start with simple "blocks" that are easy to analyze with fundamental math
  - Assemble those blocks into a geomechanical model that is similar to the actual cavern
- Several inputs need to be defined or estimated for the geomechanical models
  - Geology, material properties, in situ conditions, historic and future operations, etc…
  - A geomechanical model is only as good as its inputs (garbage in, garbage out)



SUMMARY

- A computer is used to quickly solve the millions of equations necessary for the simulation
- The geomechanical model does not simply provide a pass/fail
  - Results are not black and white… they are often on a spectrum from good to bad
  - We need to look at several different results (what's the big picture?)
  - The results need to be interpreted based on our experience, judgment, and physical observations
- A geomechanical model has limitations
  - Remember, a model is not reality… it is only a simplified representation of reality
  - How do our simplifications, assumptions, and unknowns affect the results?
  - How do the results compare to actual observations?

QUESTIONS?

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