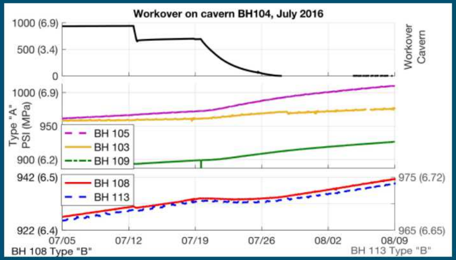
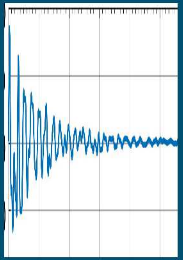
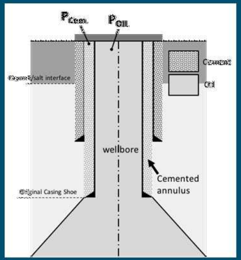
SAND2018-6375C

Depressurization Effects in Salt Dome Caverns







WORLD SALT SYMPOSIUM

June 19-21, 2018

Park City UT, USA

PRESENTED BY

David Hart, Giorgia Bettin, Steve Sobolick

Sandia National Laboratories, Albuquerque NM

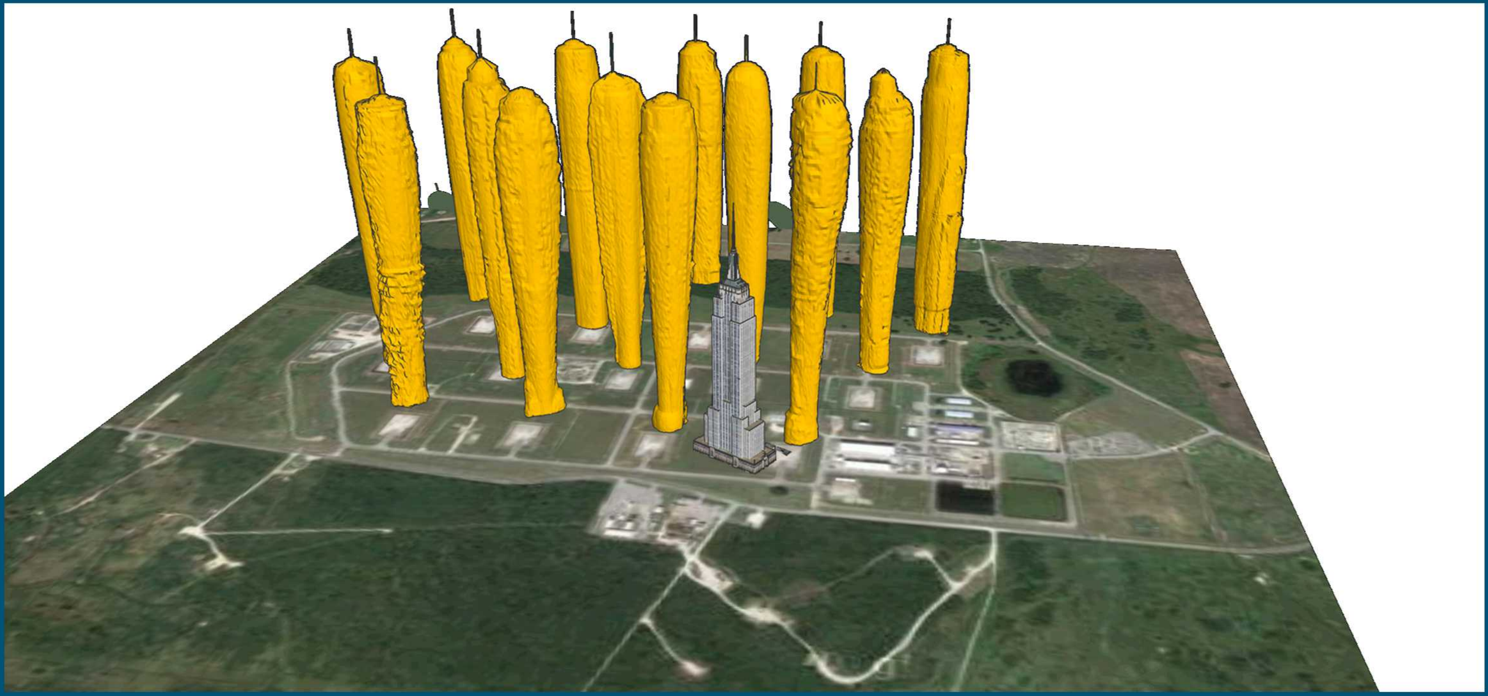
Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Introduction

WORLD SALT SYMPOSIUM
June 19-21, 2018 Park City UT, USA

The U.S. Strategic Petroleum Reserve (SPR) stores emergency supplies of crude oil owned by the U.S. Government.

- SPR contains ~693 MMbbls (million barrels) of crude oil (110×10^6 m^3)
- Stored in 60 solution mined caverns located in four different salt domes on the Louisiana and Texas coasts
- Filled to maximum capacity of 727 MMbbls (115×10^6 m^3) in 2009



Why depressurization matters

WORLD SALT SYMPOSIUM
June 19-21, 2018 Park City UT, USA

Work presented here focuses on cavern depressurization

Caverns at the SPR are depressurized many times during their operational lifespan

- SPR rules require depressurization for well workovers
- Well maintenance and repair most frequent causes
  - E.g., liner installation, lengthening hanging casing, certain logs

Depressurization leads to:

- Increased cavern closure rate during workover (**loss of storage capacity**) that occurs almost immediately
- Increased geomechanical stresses in the cavern walls (**potential for salt falls, cavern integrity concerns**)
- Enhanced strain in wellbore casings (**well integrity concerns**)
- Changes in vertical and radial stress propagates through dome and caprock (**neighboring cavern effects, potential subsidence**)

Outline

Look at depressurization effects on:

1. Neighboring cavern pressure
2. Wellbore integrity
    1. MITs
    2. Enhanced strain
3. Surface subsidence

Depressurization Effects on Neighboring Caverns

WORLD SALT SYMPOSIUM
June 19-21, 2018 Park City UT, USA

Effects on Neighboring Caverns

Study performed analyzing workovers at Big Hill site (TX)
- Site was constructed from scratch for the SPR
- Regularly spaced caverns of consistent shape and size
- Brine and oil pressure at the wellhead are recorded for all caverns

Study looked at pressure signals in caverns neighboring a cavern where a workover was taking place

Previous experience has shown a frequent **increase in pressurization rates** in neighbor caverns when a cavern is depressurized

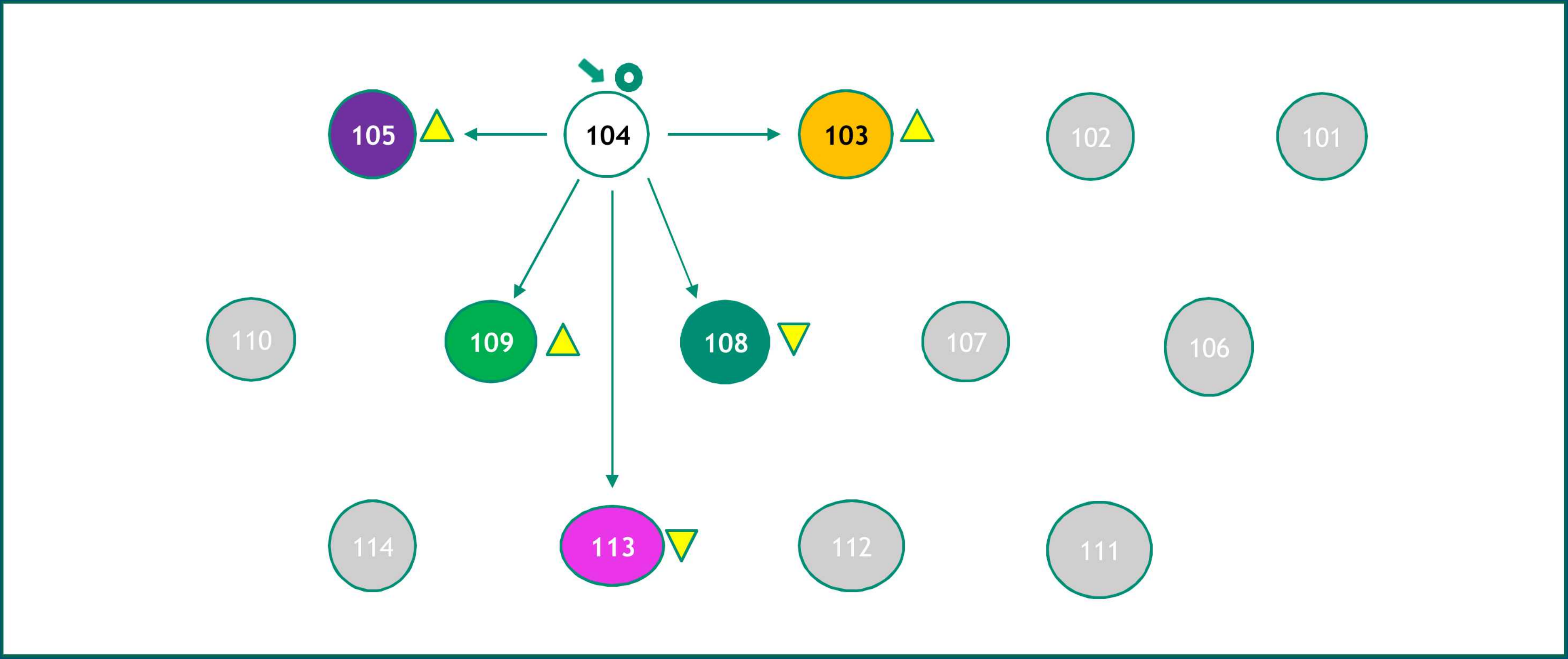
However, during a particular well integrity test, a different behavior was noted, and an investigation was conducted

Differing Behavior

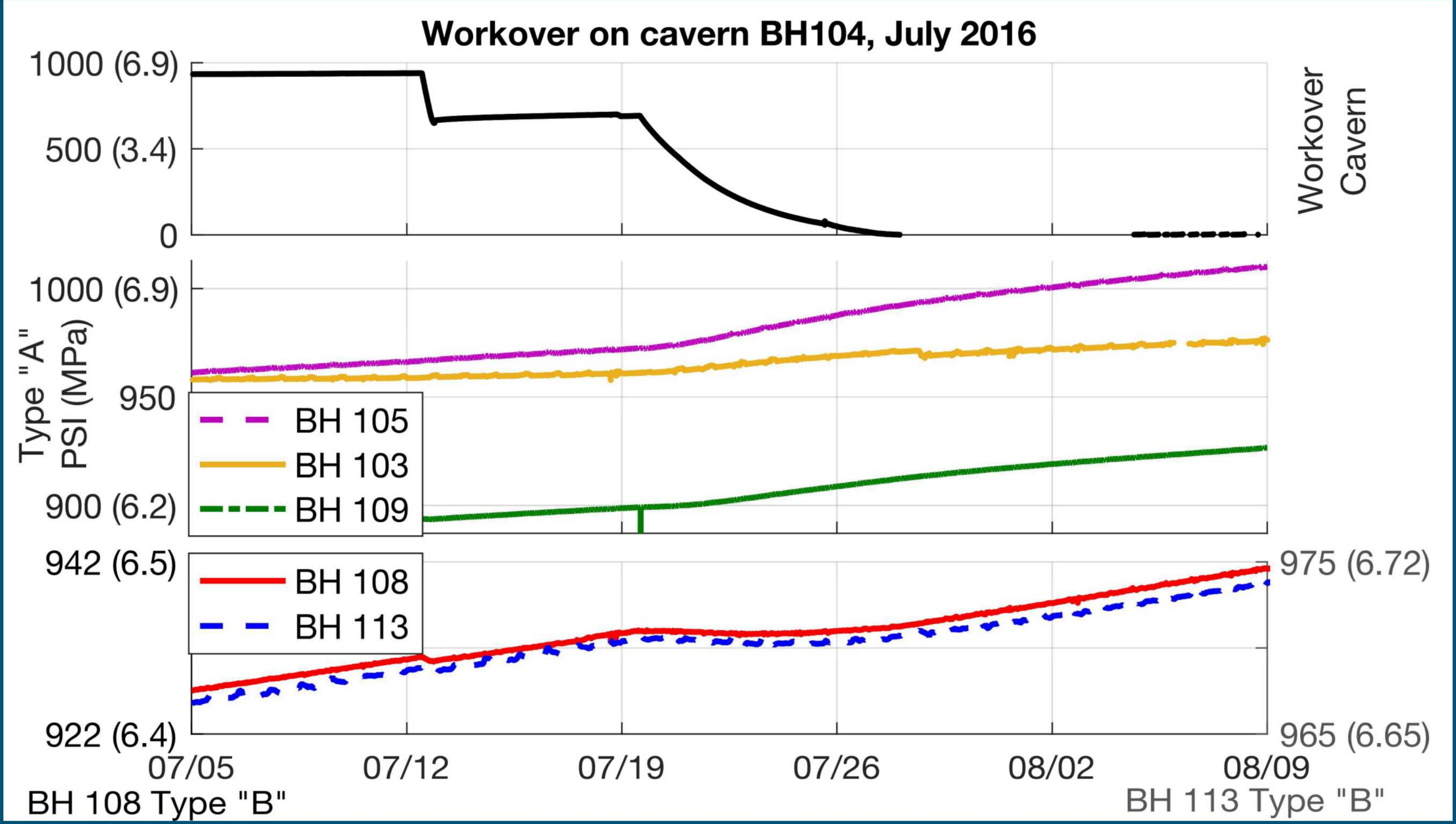
WORLD SALT SYMPOSIUM
June 19-21, 2018 Park City UT, USA

Depressurization at Cavern 104 resulted in 3 wells showing typical behavior, and two wells showing a different behavior

New behavior shows pressure **decreasing in sync** with the pressure drops in the cavern undergoing workover



Differing Behavior



Implications

WORLD SALT SYMPOSIUM June 19-21, 2018 Park City UT, USA

Two identified behaviors:

A. Pressurization rate (dP/dt) increase during neighbor depressurization
B. Pressure changes that track (at a fractional amount) the pressures in the neighboring, depressurizing cavern

- If behavior B had not been identified as normal, it would have caused significant concerns regarding the integrity of the neighboring well (the one under testing)

Behavior B was only identified as a normal response because long-term pressure trends (over 10 years) were available for analysis

Depressurization Effects on Wellbore Integrity

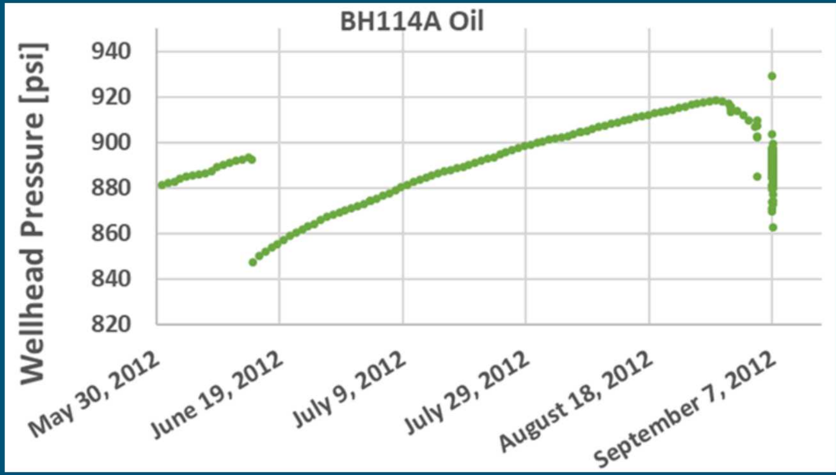
MIT Failures; Increased Casing Strains

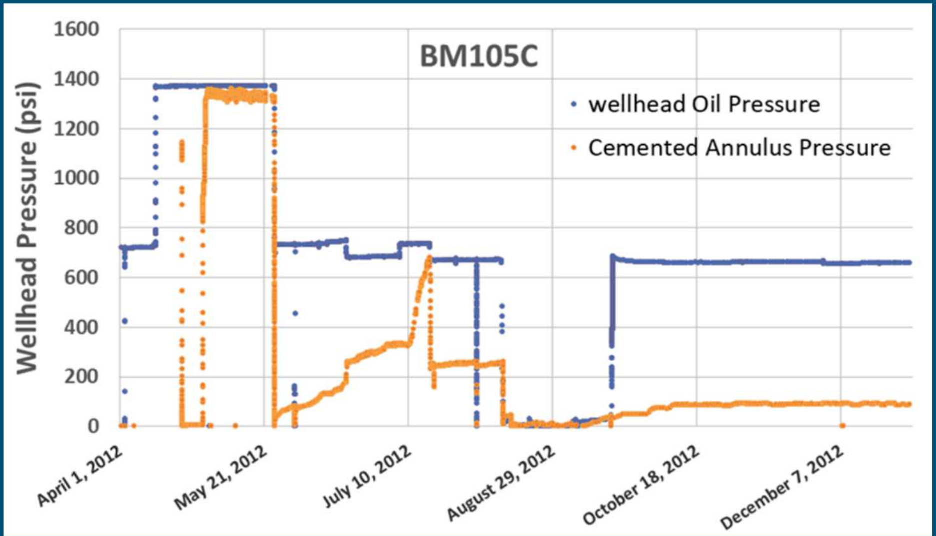
WORLD SALT SYMPOSIUM
June 19-21, 2018
Park City UT, USA

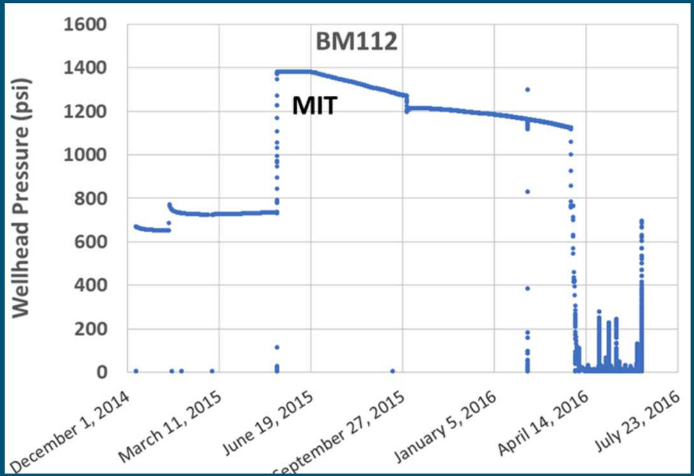
Wellbore Integrity

Integrity assessments are conducted through:

- Cavern pressure monitoring
- MITs
- Sustained casing pressure monitoring
- Casing deformation monitoring







Field Data Analysis

WORLD SALT SYMPOSIUM
June 19-21, 2018 Park City UT, USA

Study was conducted on the relationship between number of workovers and depressurization on a well and Integrity.

- Data back to 2010.
- All 4 sites
- 90 workovers, 109 MITs were evaluated

No correlation between the number of workovers and failing an MIT.

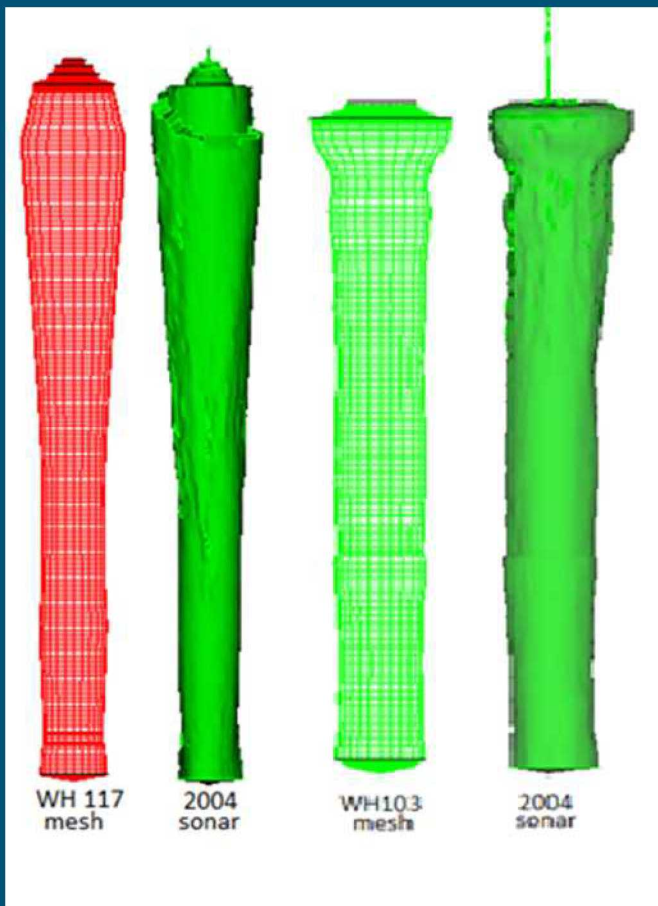
Weak relationship between workovers and high sustained casing pressure.

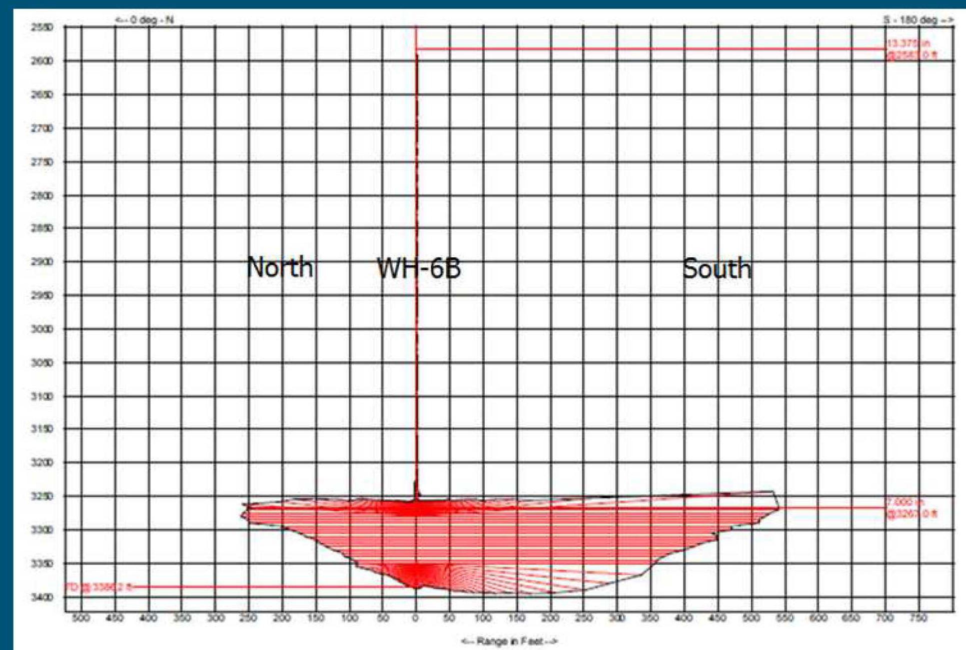
Geomechanical Analysis of Stress States

WORLD SALT SYMPOSIUM
June 19-21, 2018
Park City UT, USA

3 caverns were chosen for their different shapes

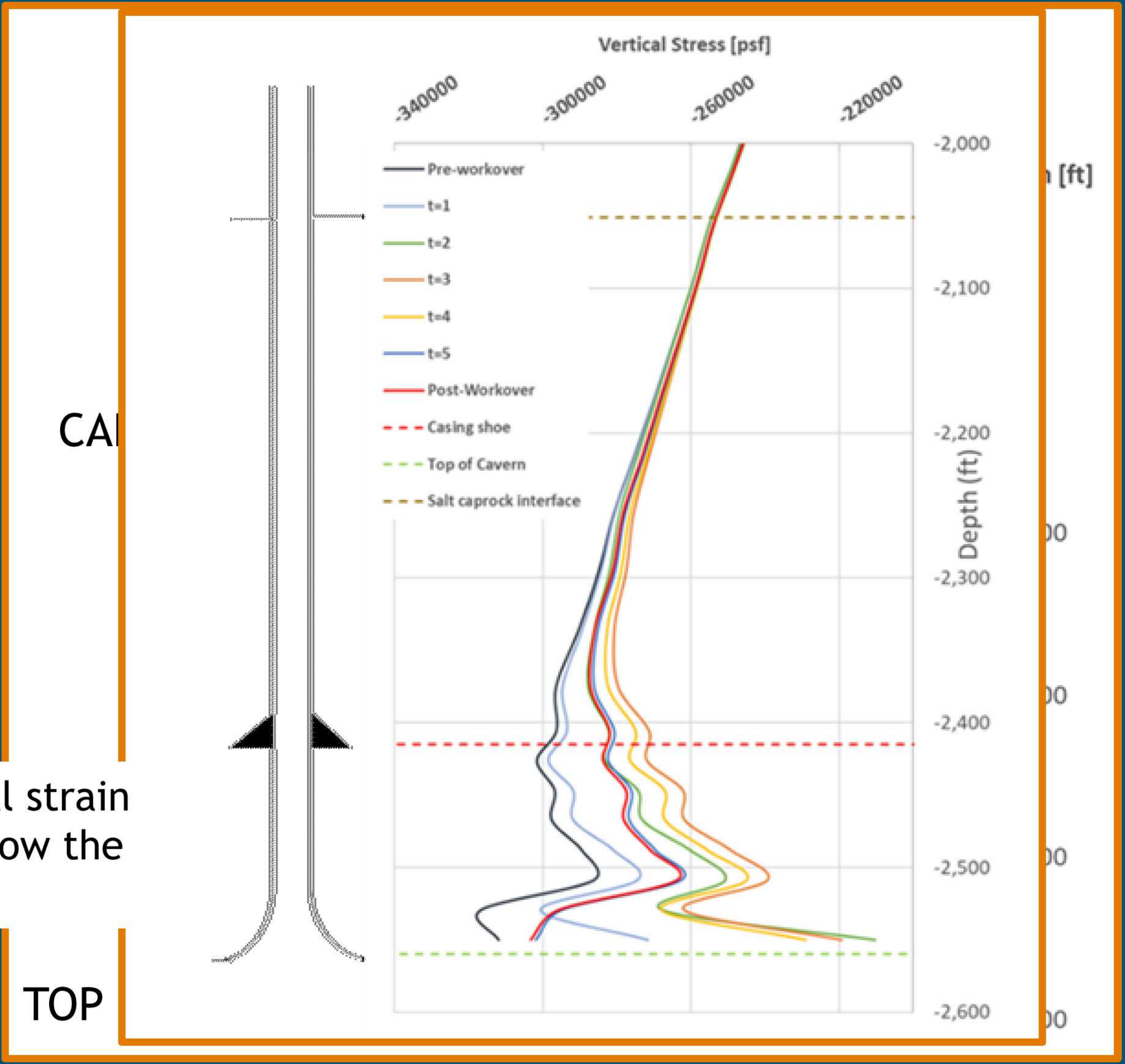
3D finite element geomechanical models were used to evaluate the stresses and displacement along the wellbore during a workover.





Enhanced Stain effects: Vertical Strain

Cavern WH117

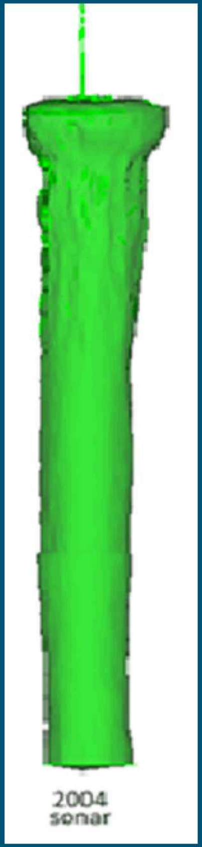


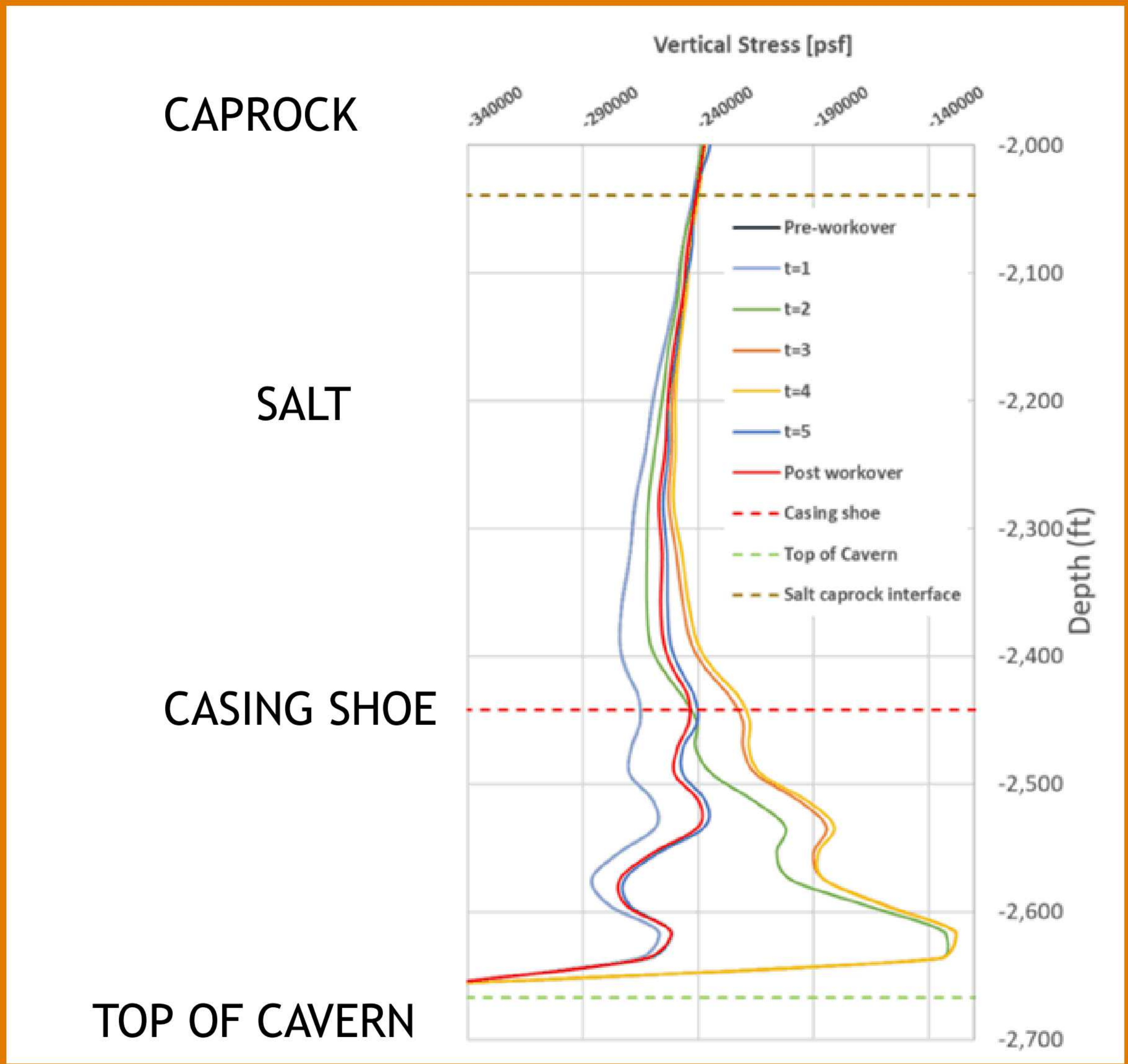
Most vertical strain happens below the casing shoe

Enhanced Stain effects: Vertical Strain

Cavern WH103

Flat roof affects the stresses along the wellbore. Depth of maximum vertical strain is pushed into the wellbore

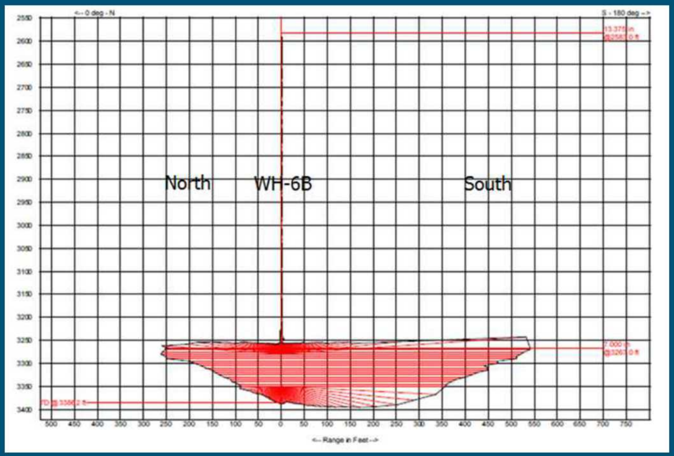


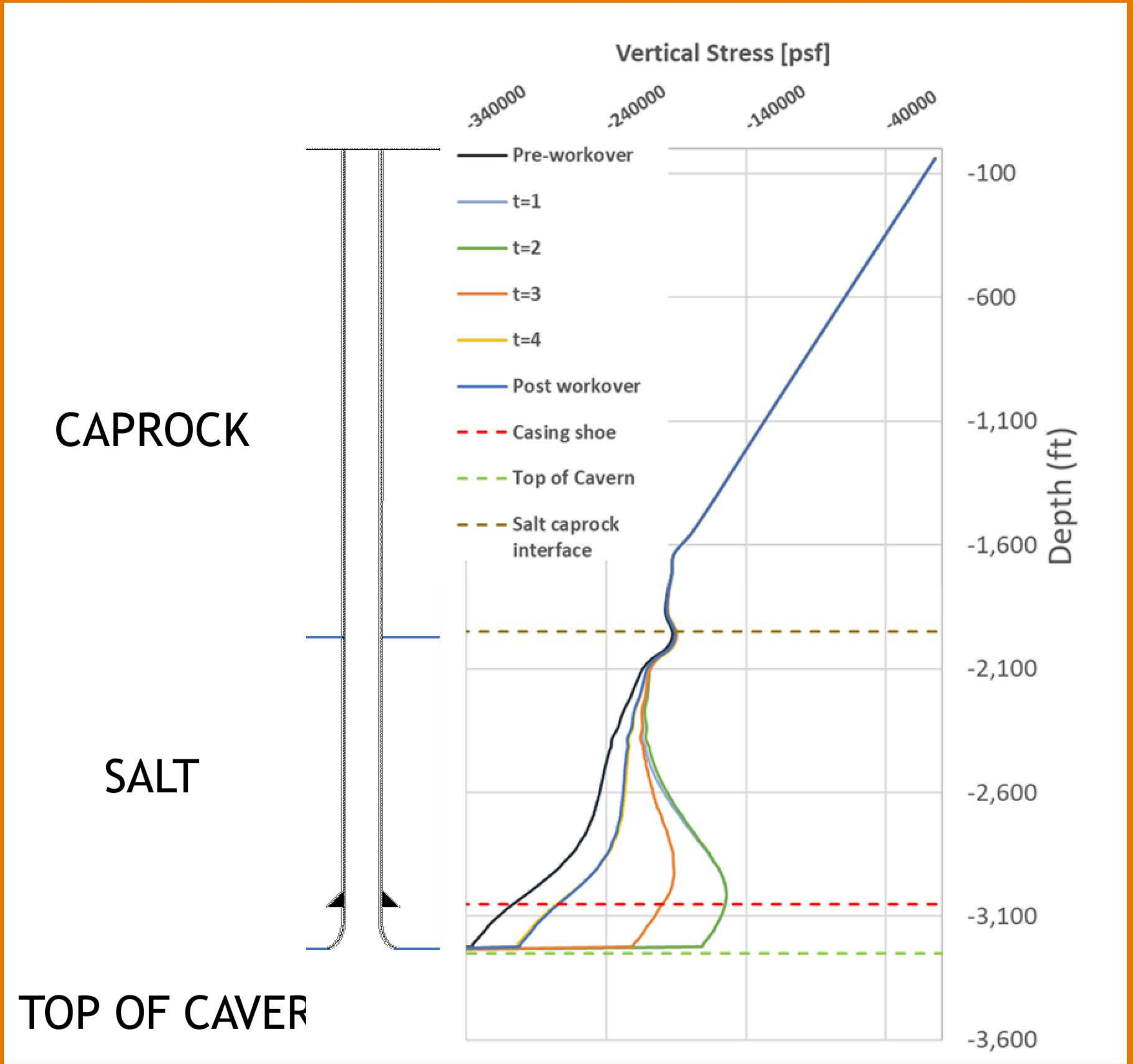


Enhanced Stain effects: Vertical Strain

Cavern WH6

For this cavern with a very large flat roof, enhanced strain effects affect the wellbore thought out the whole salt back.



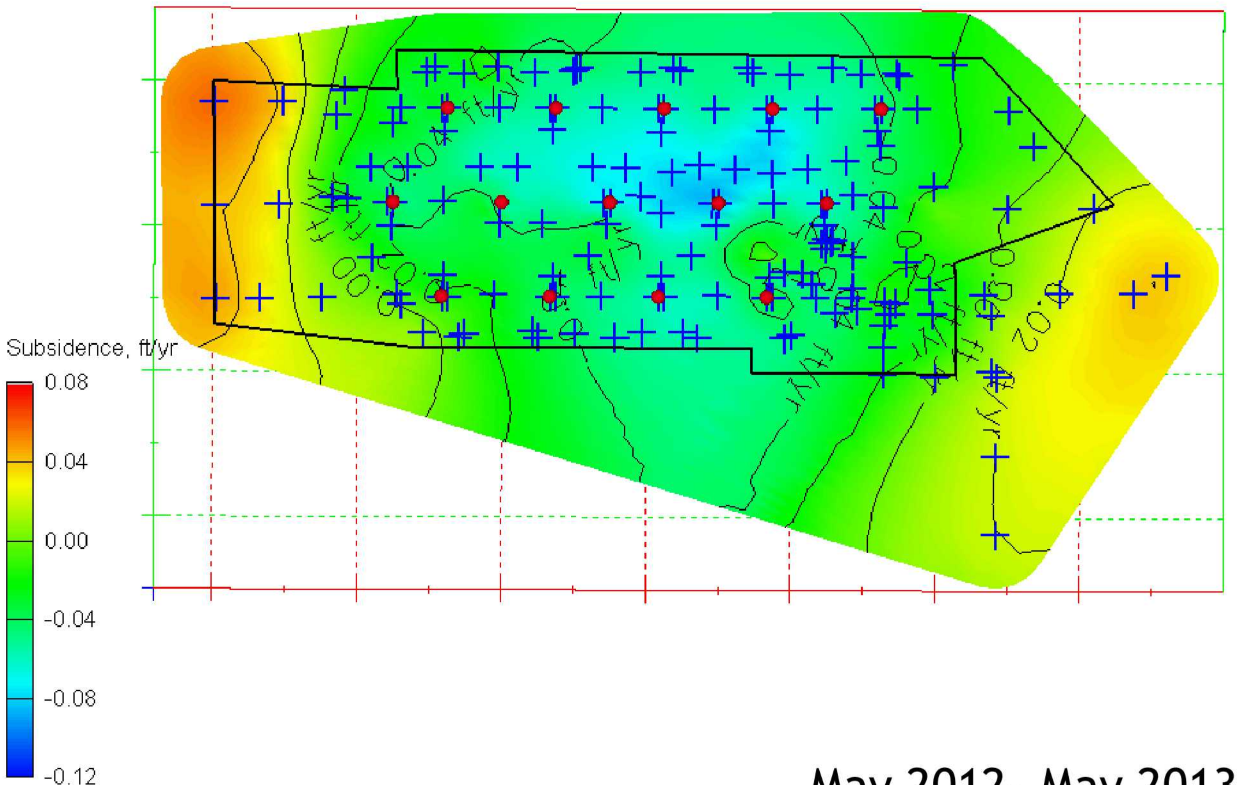


Depressurization Effects on Surface Subsidence

WORLD SALT SYMPOSIUM
June 19-21, 2018 Park City UT, USA

Subsidence

Subsidence rate for the site was found to increase during a period where large number of workovers were carried out in a small amount of time.



May 2012- May 2013

Acknowledgements

WORLD SALT SYMPOSIUM
June 19-21, 2018 Park City UT, USA

Special thanks to the SPR Cavern and Well Integrity team, particularly:

- Rob Ariatti and Paul Malphurs from US DOE
- Bryan Bellevue, Dean Checkai, Jeff Knippa, Bob Murray, Joe Nealy, and Adam Snarski from Fluor Federal Petroleum Operations
- Anna Lord, Barry Roberts and Steve Sobolik from Sandia National Laboratories

Questions?

Introduction

Why is depressurization such a big deal?

Cavern depressurization occurs many times during an SPR cavern's lifetime for:

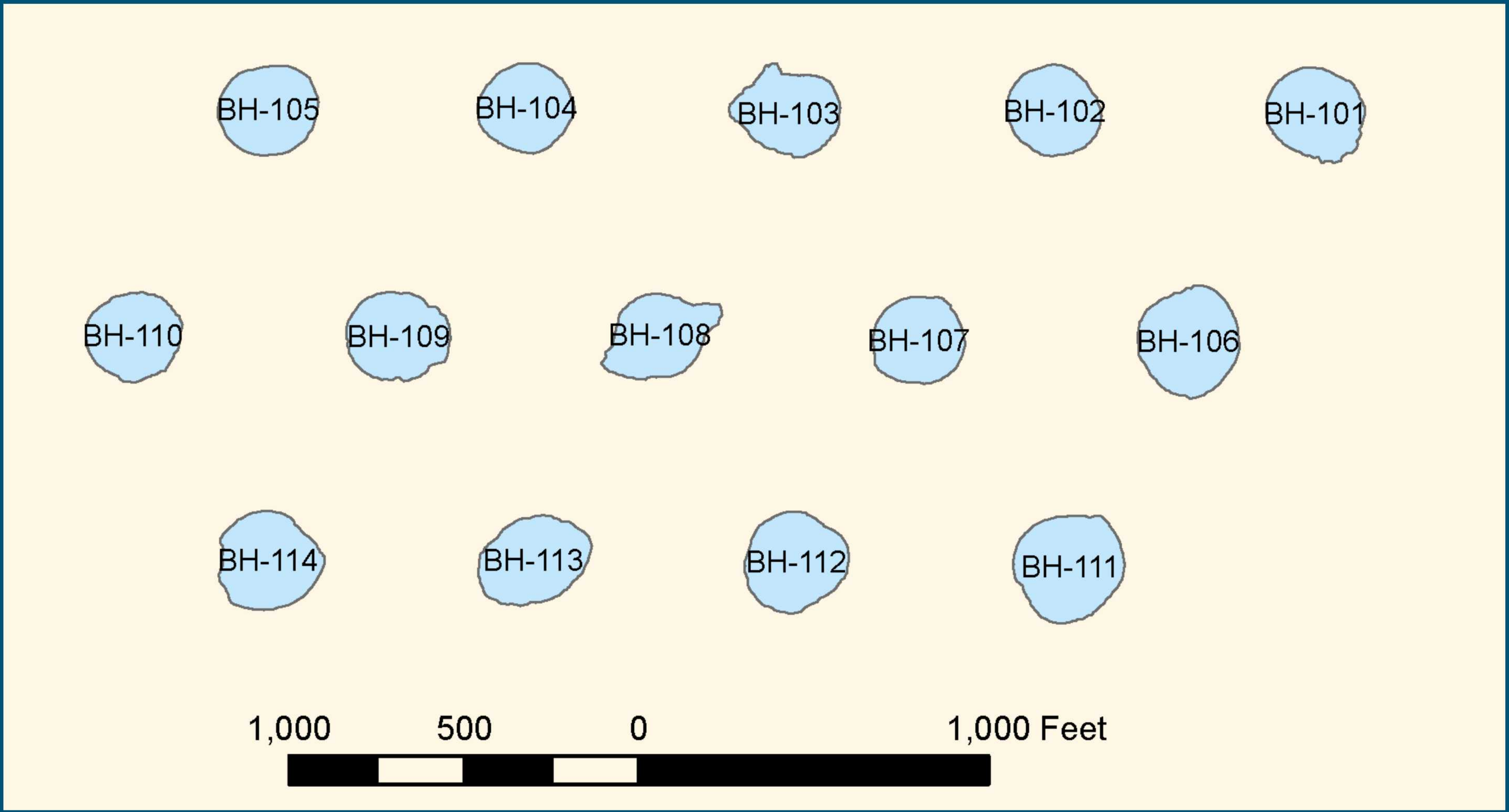
- Maintenance, such as lengthening hanging casing
- Repair, such as addition of a liner
- Logging when hanging casing must be removed (MAC, SONAR)

Depressurizing one cavern can impact neighboring caverns

- Pressure changes propagate through the salt radially
- Changes in vertical pressure affect the overburden and caprock pressure across the dome

A study was performed looking at neighboring cavern effects at the SPR Big Hill site (TX, USA)

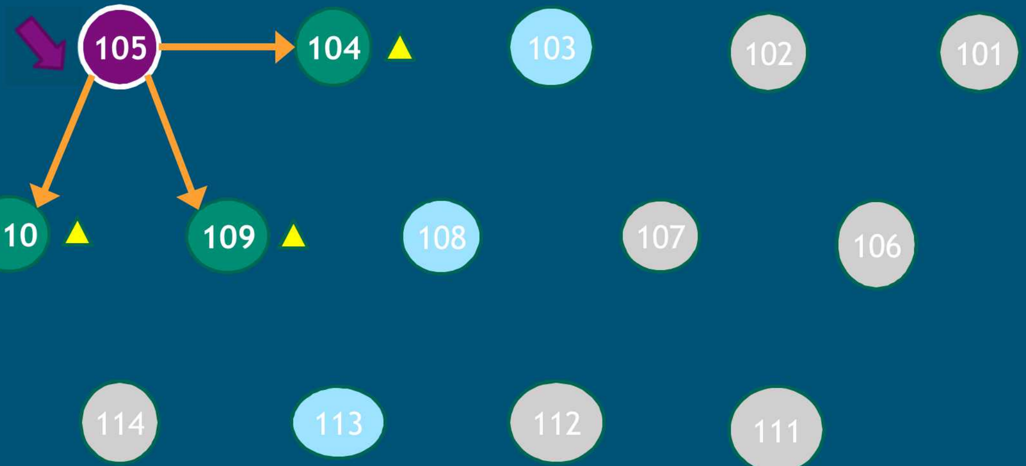
Big Hill Site: 14 caverns



304.8 152.4 0 304.8 m

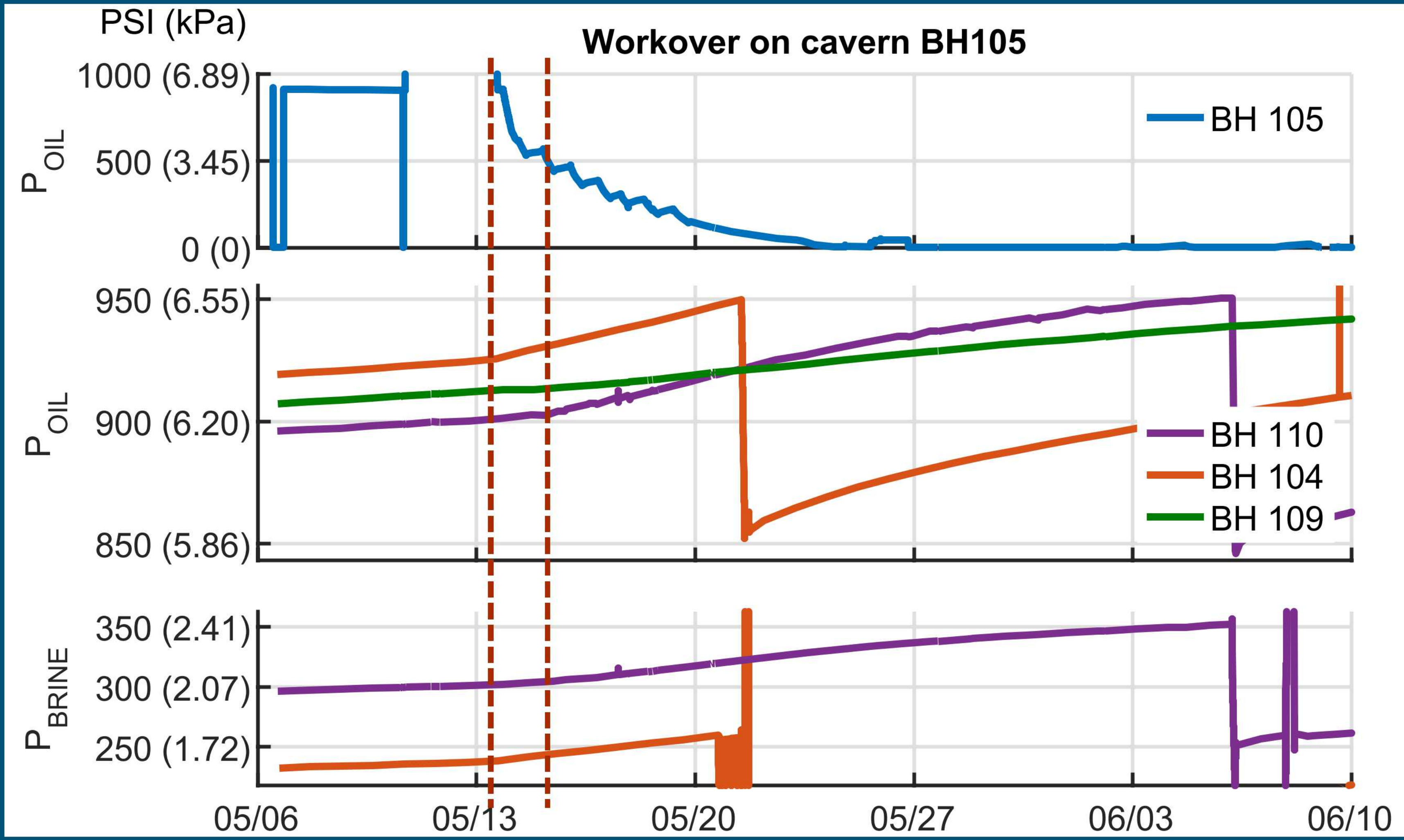
Single Cavern Depressurization

Cavern 105 depressurized for 49 days for well workover



Pressurization rate (dP/dt) **increased** in neighbor caverns as pressure decreased in 105

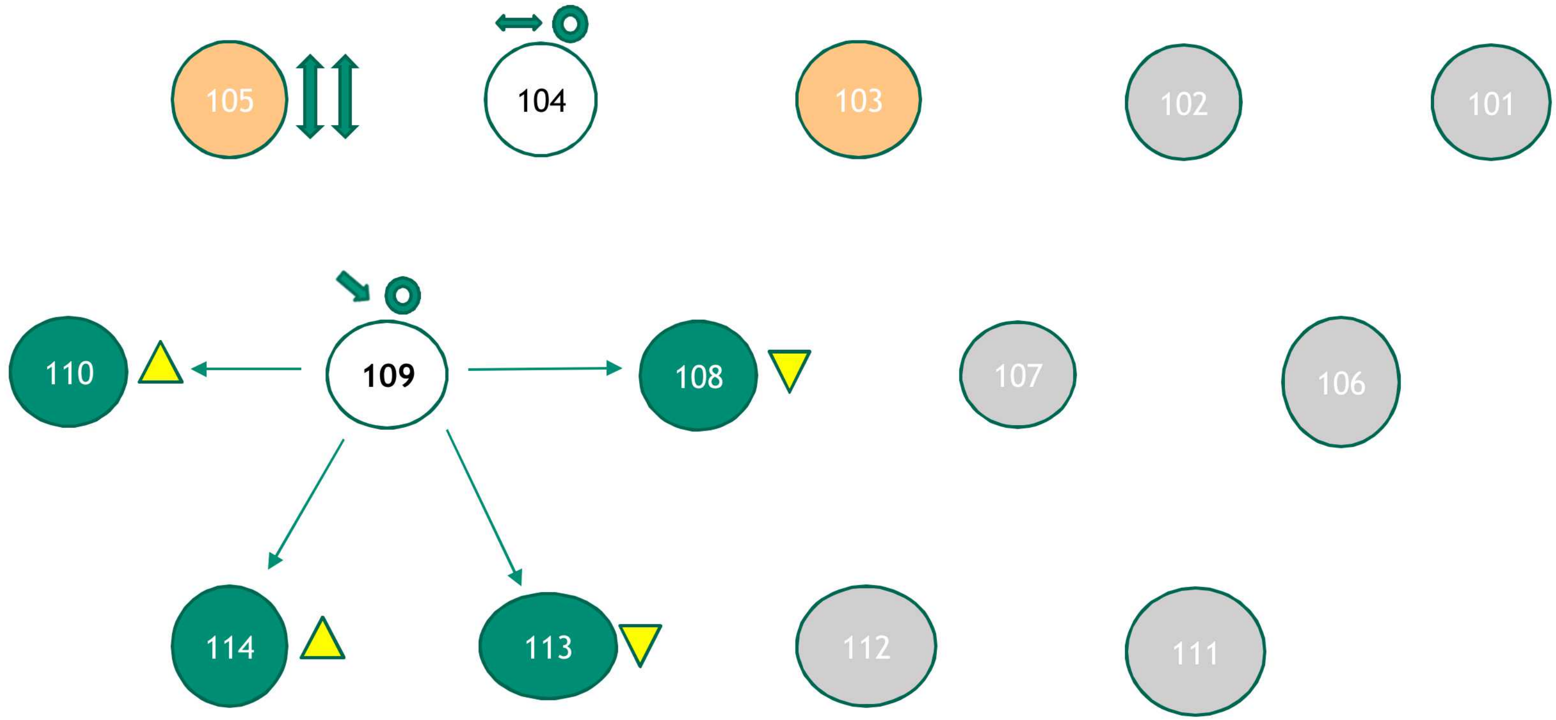
Single Cavern Depressurization



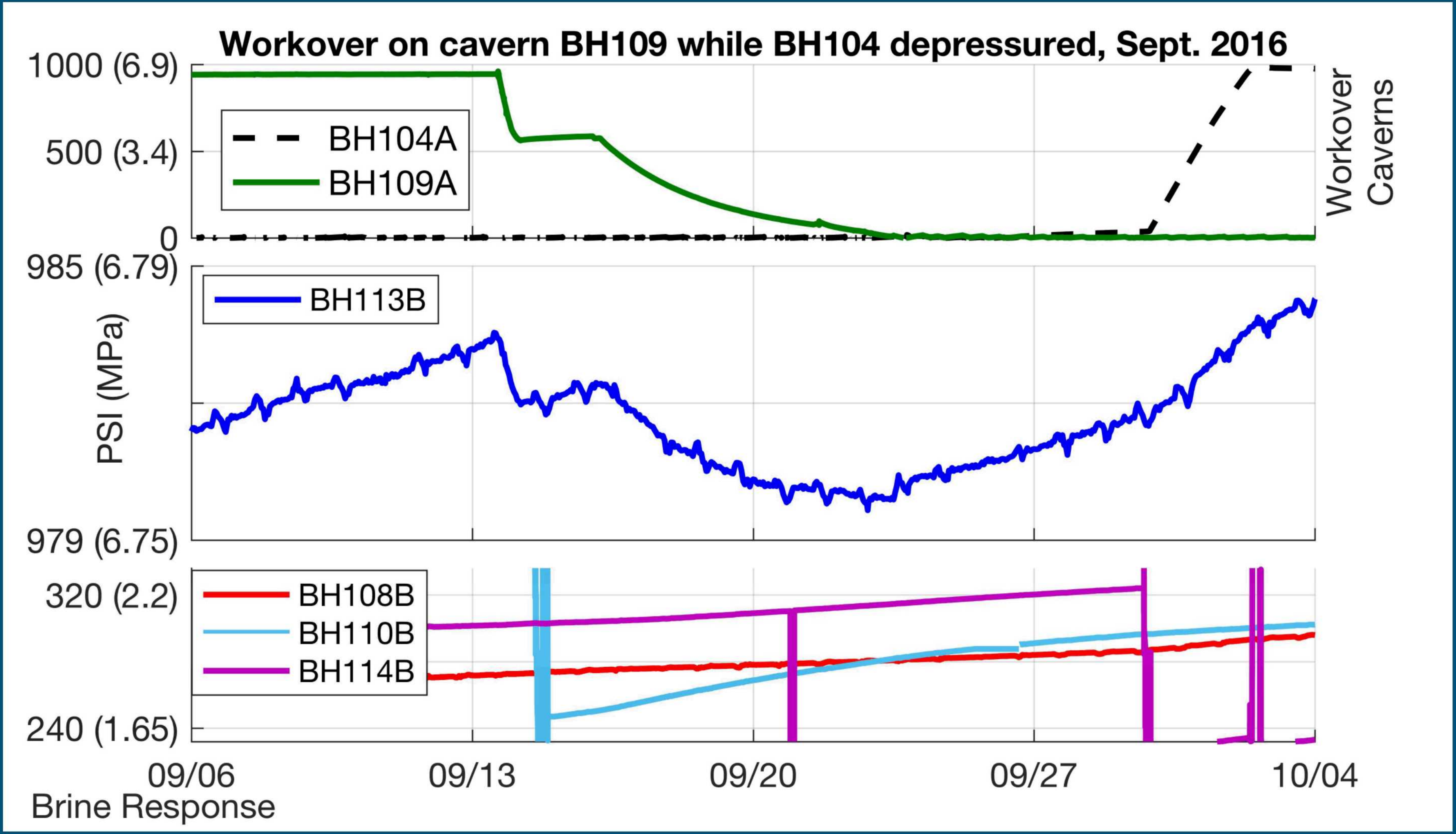
Simultaneous Depressurization

Depressurization of Cavern 104 was followed by depressurization of Cavern 109 with an overlap

Same two caverns (108 and 113) show the "new" behavior



Simultaneous Depressurization



SPR Well Configurations

WORLD SALT SYMPOSIUM June 19-21, 2018 Park City UT, USA

SPR caverns generally have two wells with one the following two configurations (