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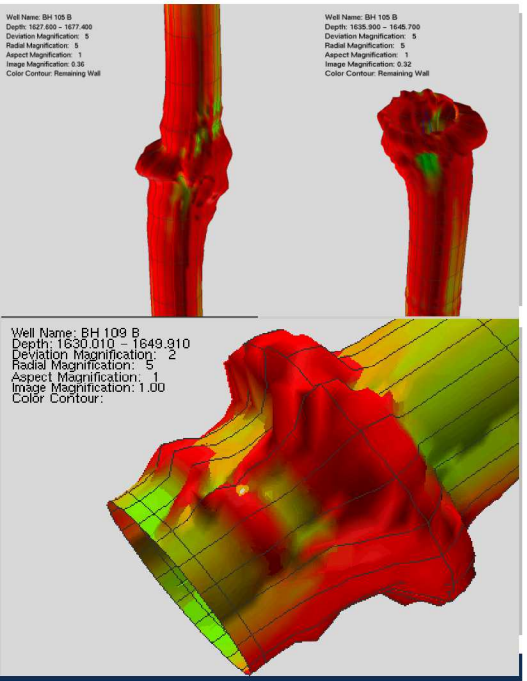

Interbed Modeling to Predict Wellbore Damage for Big Hill Strategic Petroleum Reserve

Petrochemistry-2014

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Sandia National Laboratories

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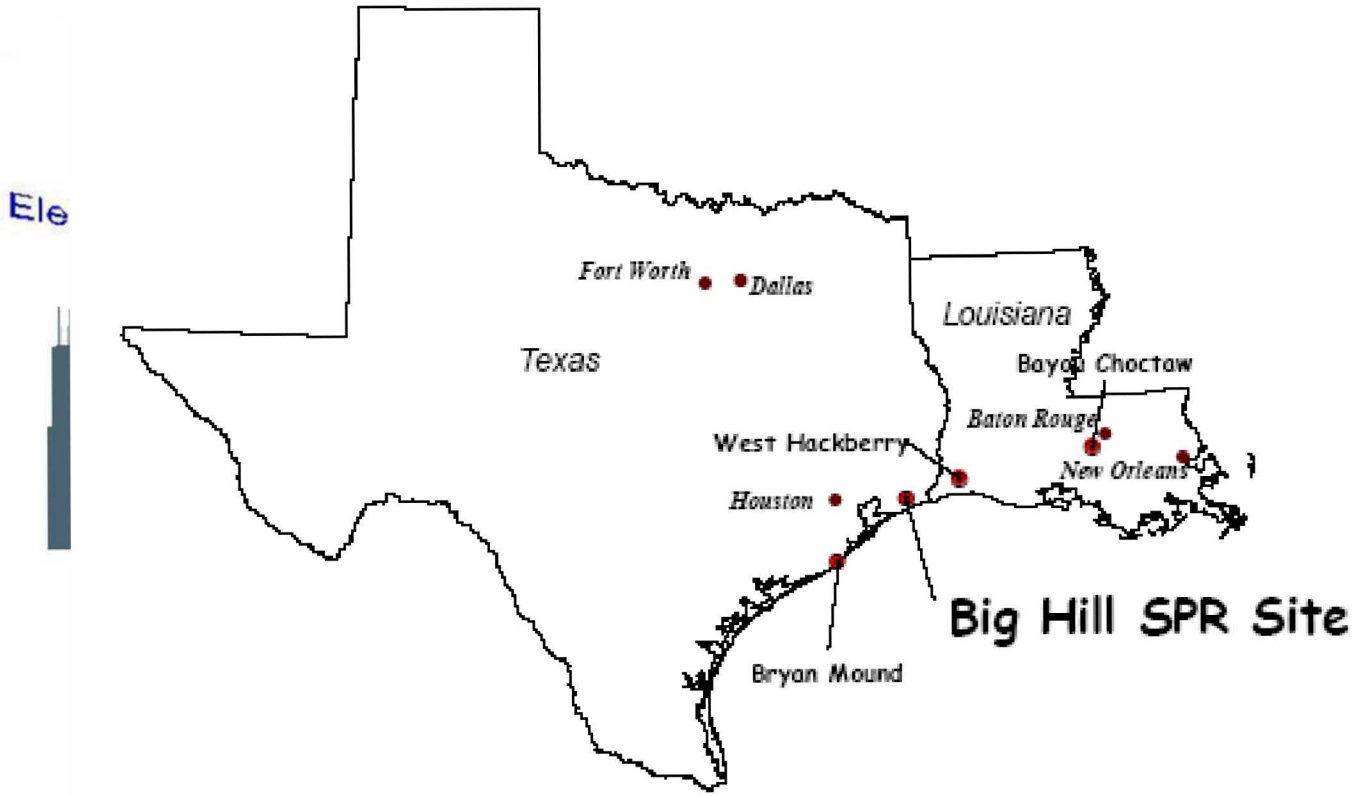
Big Hill SPR Site

- Located near Winnie, TX.
- 14 SPR caverns currently contains 170 million barrels of oil .



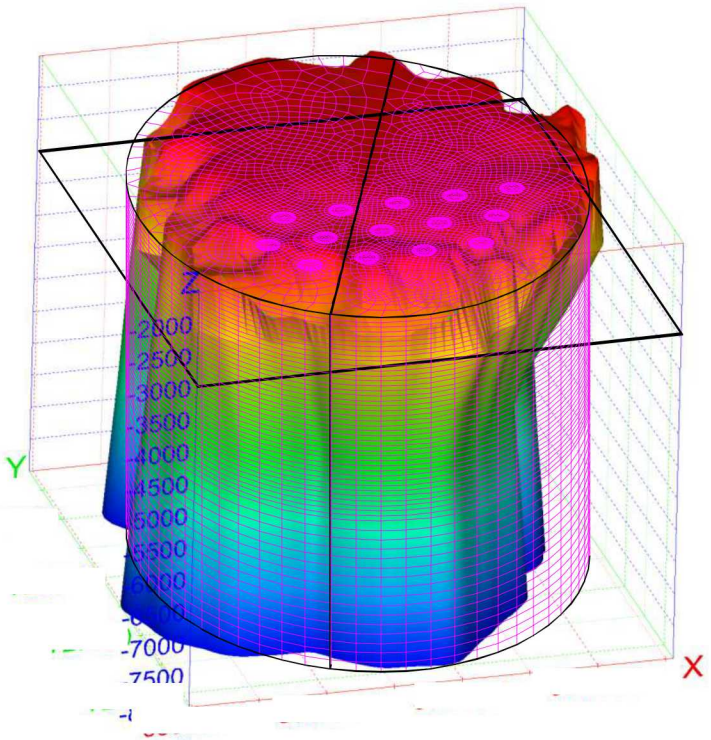
Background

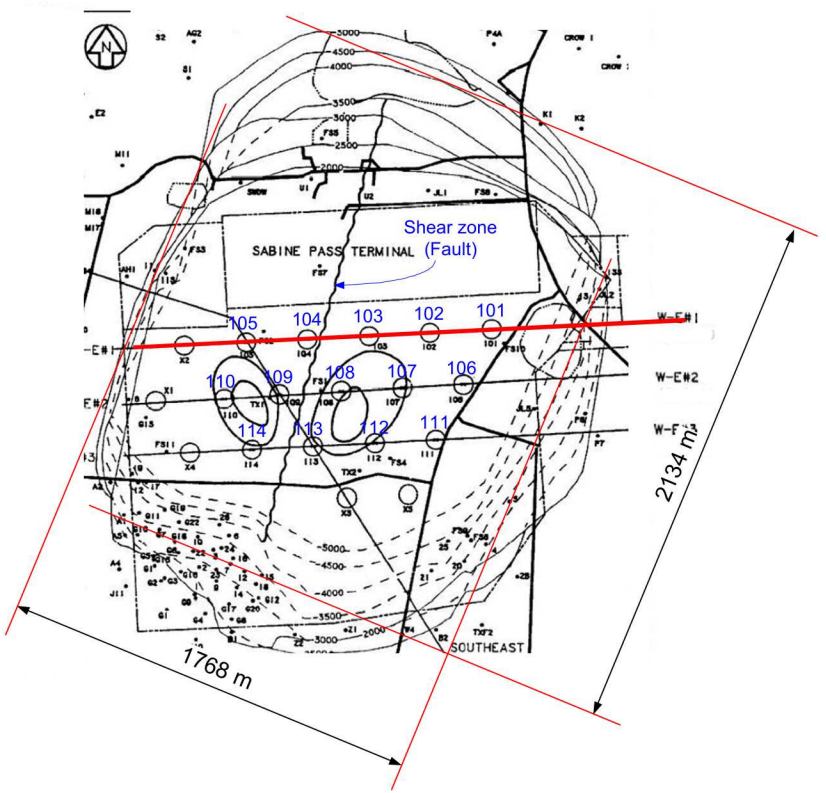
- BH105B leak started after December, 2009, and had progressed to 8600 bbl. in May, 2010.
- BH109B leak started in October, 2010. The total amount of oil leaked is estimated to be 2700 bbl.
- According to the field observations, two instances of casing damage occurred at the depth of the interbed between the caprock bottom and salt top.

Approach

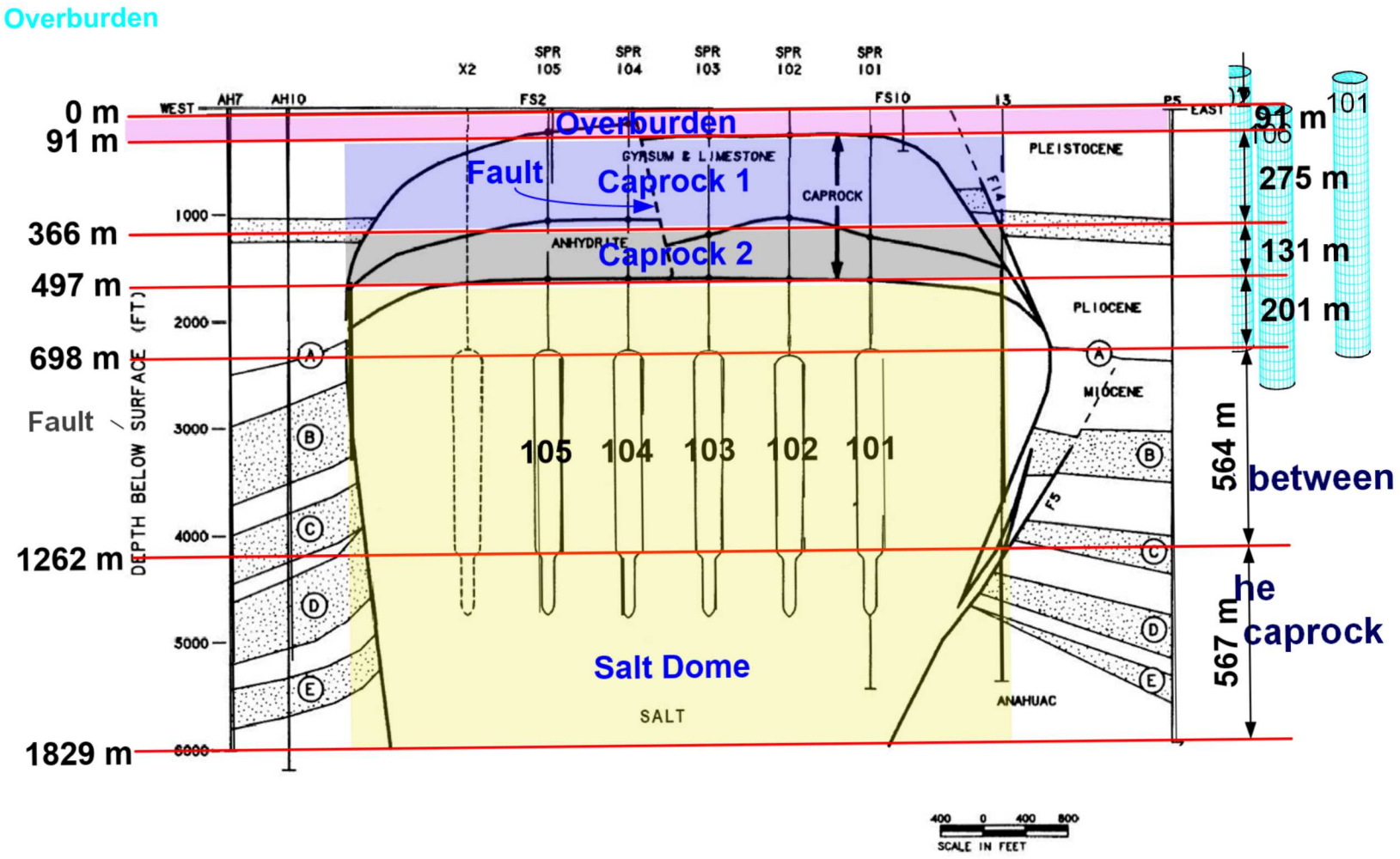
- This study attempts to find causes of the leaks through numerical analyses.
- The FEM 3-D model, which considers actual geometries and locations of fourteen caverns, salt dome, a fault, and interfaces between lithologies, was developed.
- The horizontal and vertical strains above the center of each cavern in the interface between caprock and salt dome were calculated and compared to the field data.
- The evolution of the horizontal and vertical strains was investigated.

Salt Dome

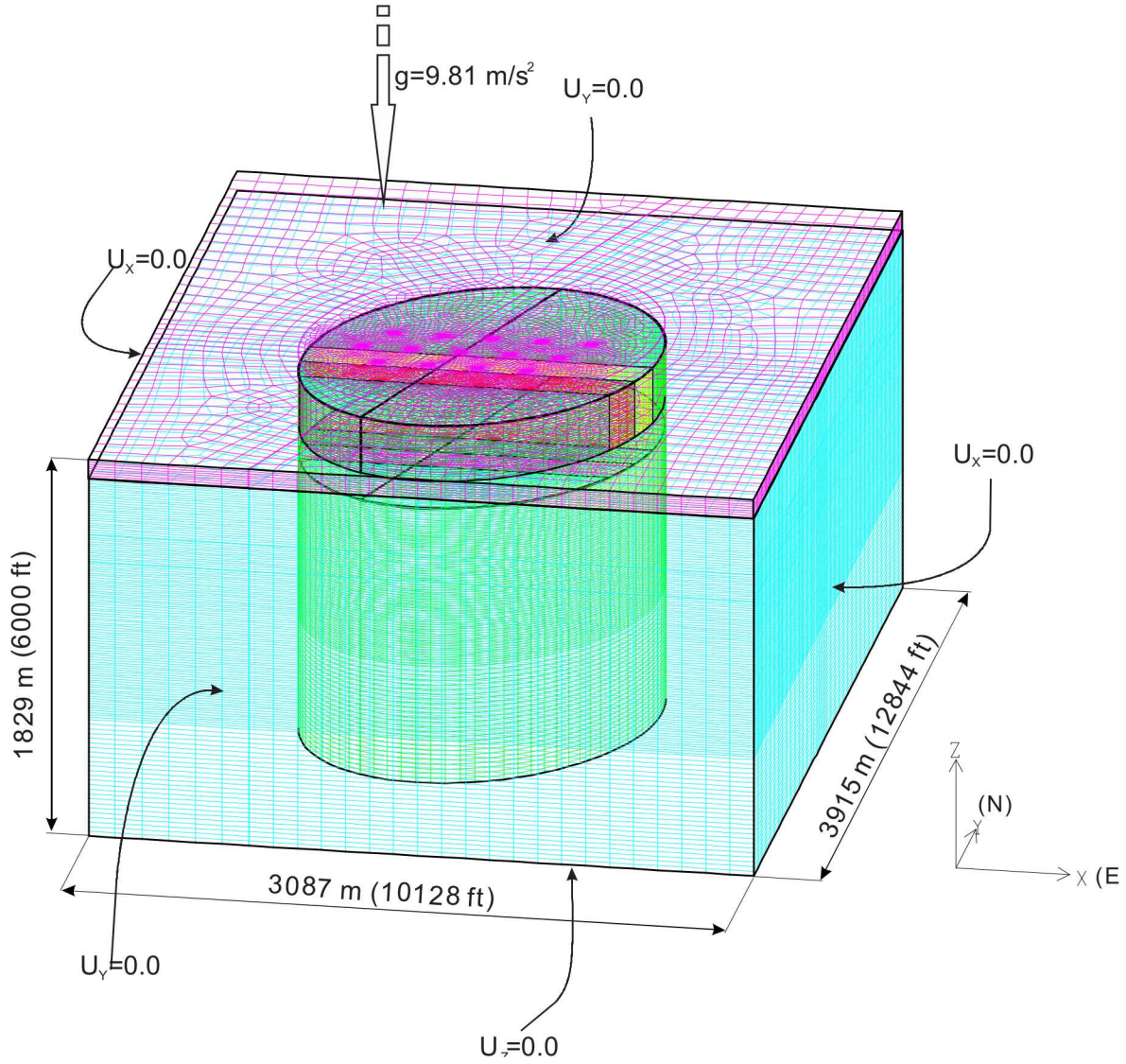

Z
Y
X
-2000
-2500
-3000
-3500
-4000
-4500
-5000
-5500
-6000
-6500
-7000
-7500


Shear zone
(Fault)
SABINE PASS TERMINAL
105
104
103
102
101
110
109
108
107
106
114
113
112
111
W-E#1
W-E#2
W-F
2134 m
1768 m
SOUTHEAST

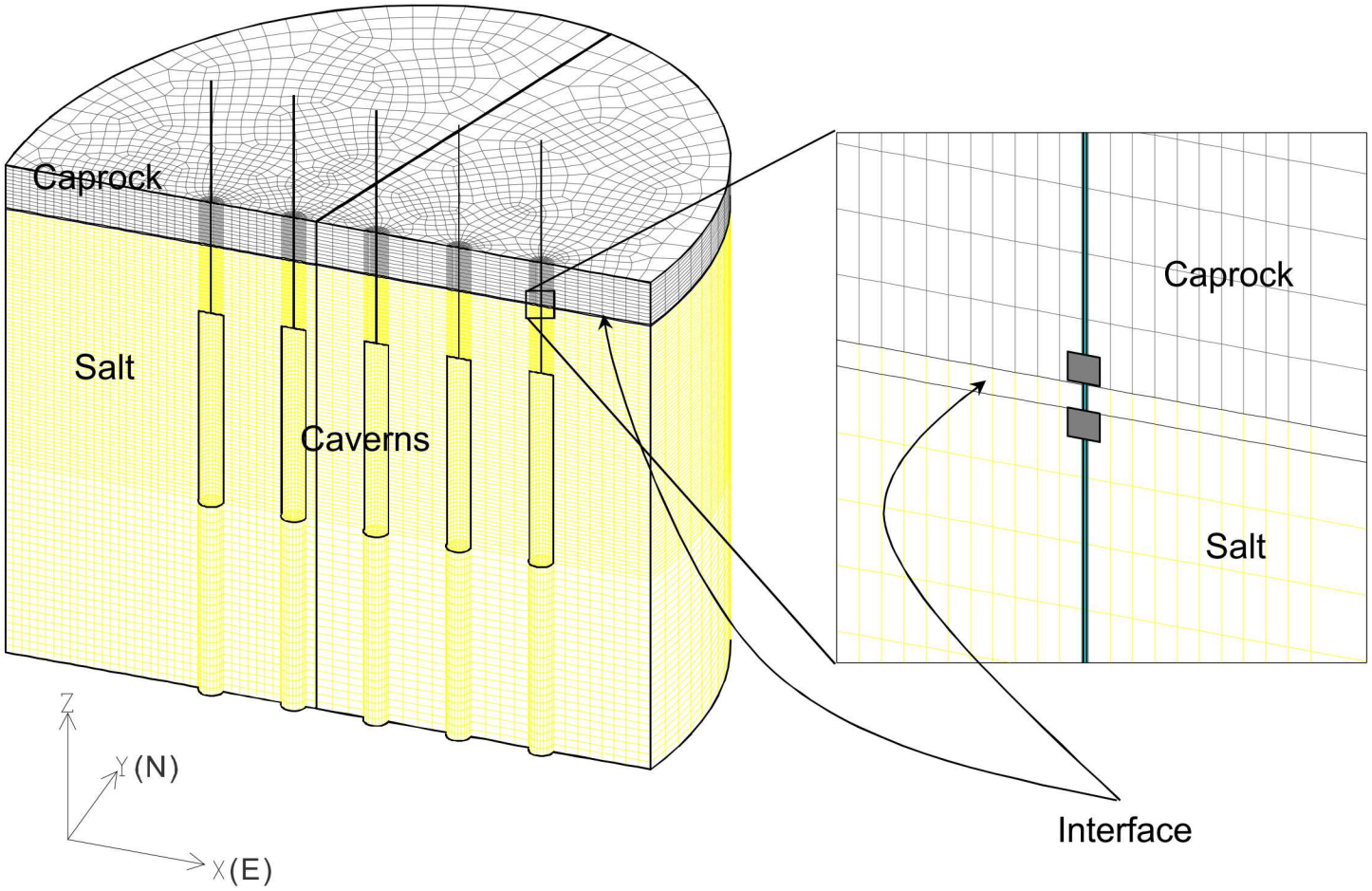
FEM Mesh


Overburden
0 m
91 m
366 m
497 m
698 m
1262 m
1829 m
Fault
Overburden
Fault
Caprock 1
Caprock 2
CAPROCK
GYPSUM & LIMESTONE
ANHYDRITE
PLEISTOCENE
PLIOCENE
MIOCENE
ANAHUAC
SALT
Salt Dome
105 104 103 102 101
X2
SPR 105
SPR 104
SPR 103
SPR 102
SPR 101
FS2
FS10
I3
P5
WEST
EAST
AH7
AH10
DEPTH BELOW SURFACE (FT)
1000
2000
3000
4000
5000
6000
A
B
C
D
E
F14
F5
91 m
275 m
131 m
201 m
564 m
between
567 m
he
caprock
101
106
400 0 400 800
SCALE IN FEET

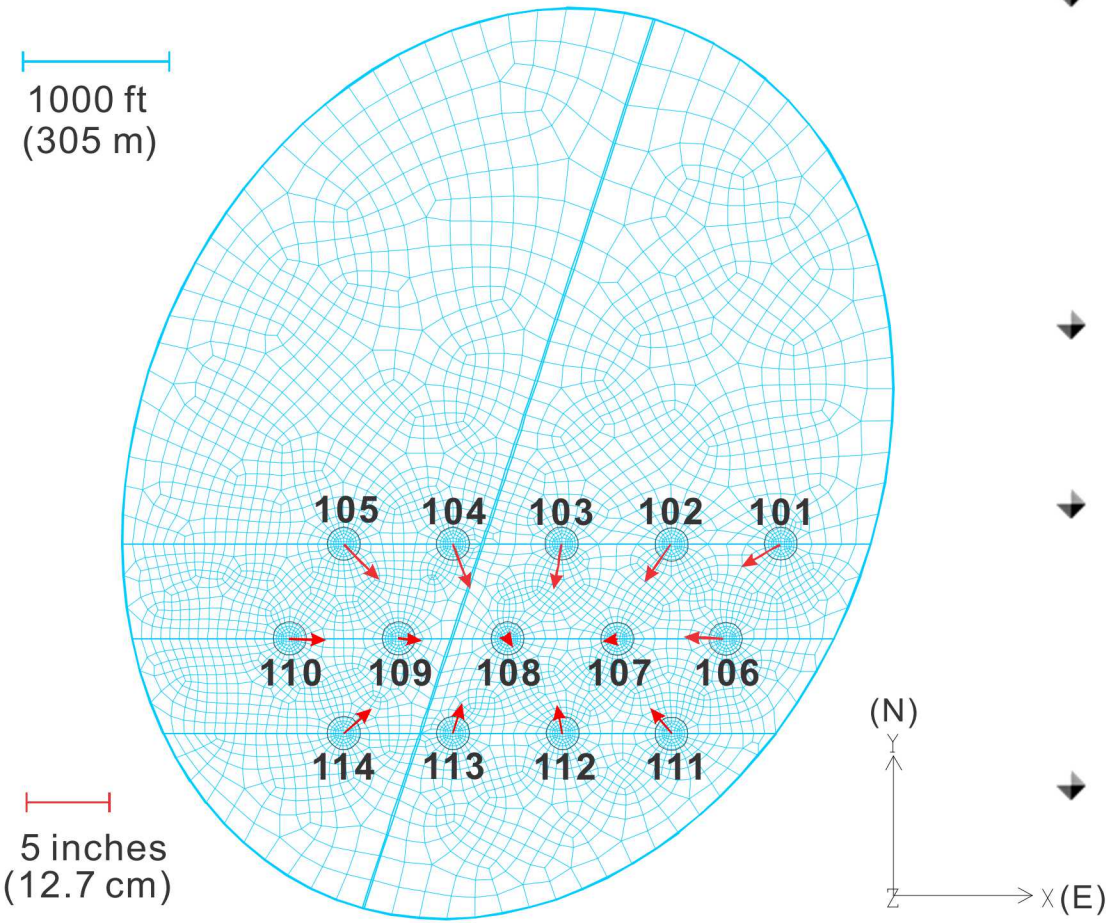
Boundary Conditions



Interface between Caprock and Salt

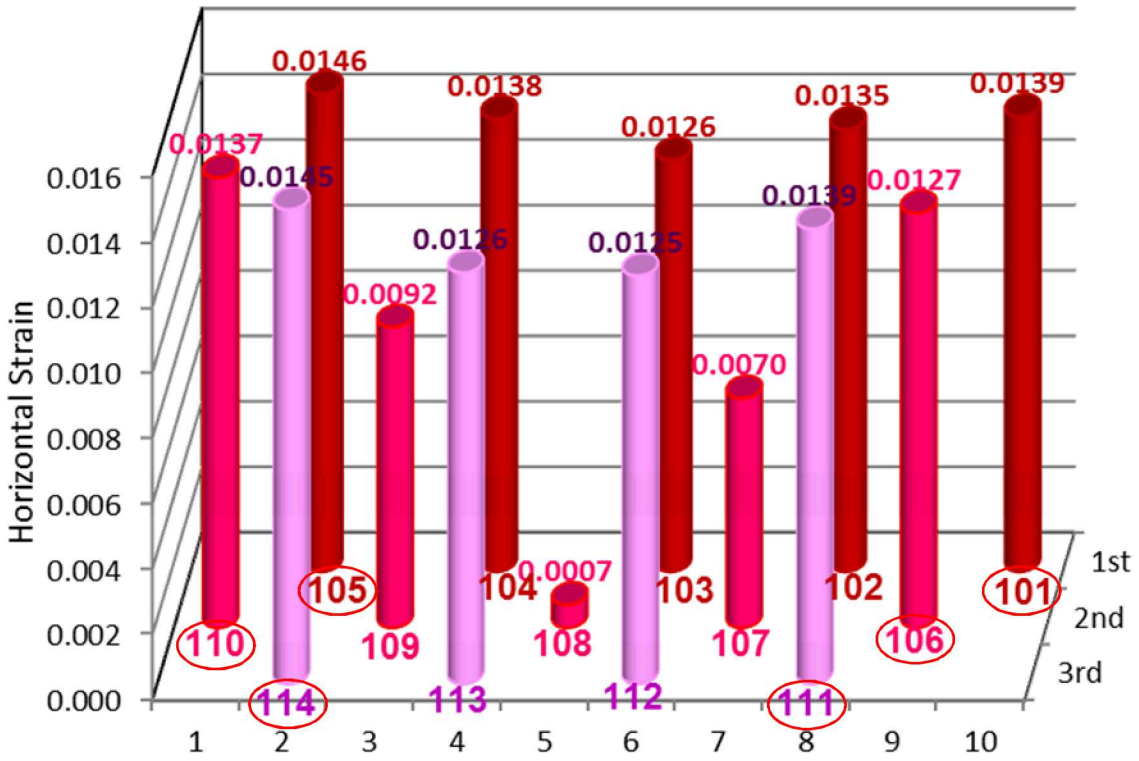


Predicted Direction and Magnitude of Horizontal Movement at 2010



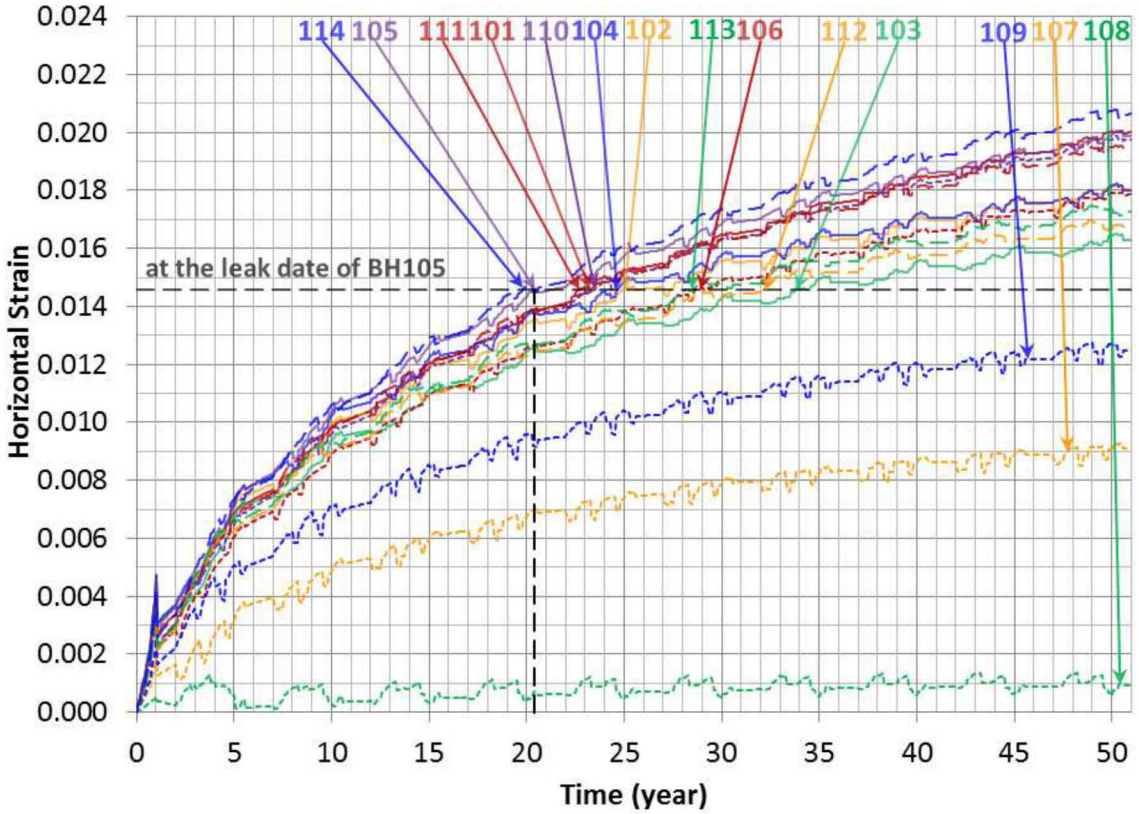
- **The salt top subsides because the volume of caverns below the salt top decrease with time due to salt creep closure, while the caprock doesn't because the caprock is thick and stiffer.**
- **Every center node on the salt top above the fourteen caverns moves toward Cavern 108 over time.**
- **The horizontal node movement above Cavern 108 is predicted to be least because Cavern 108 is located in the middle of fourteen caverns.**
- **The horizontal node movement above Cavern 105 is predicted to be largest.**

Horizontal Strains at the Interface



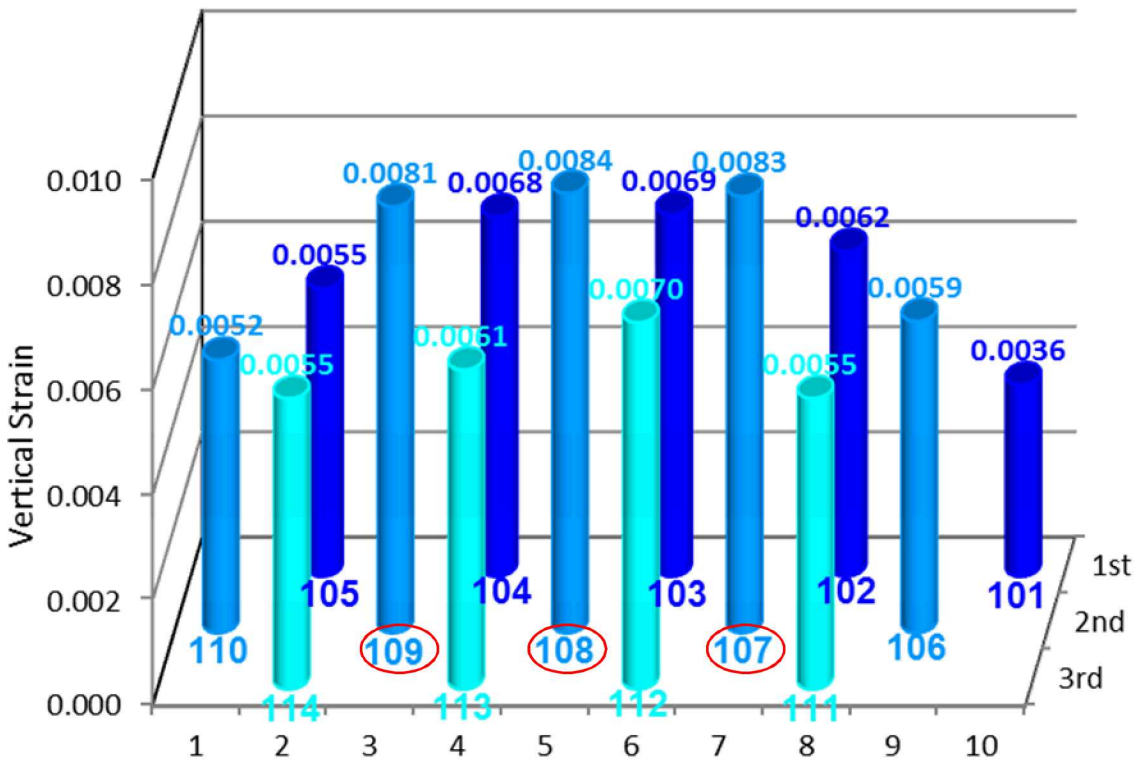
- **The horizontal strains above 101, 105, 110, 111, 106 and 114 are larger than others.**
- **The well casings above them could be failed by shear strain.**
- **Casing of wellbore 105B separated at the interbed and oil leaked. The cause of failure could be shear strain created by the differential horizontal movement of the top of salt relative to the caprock.**

Predicted Horizontal Strain Histories



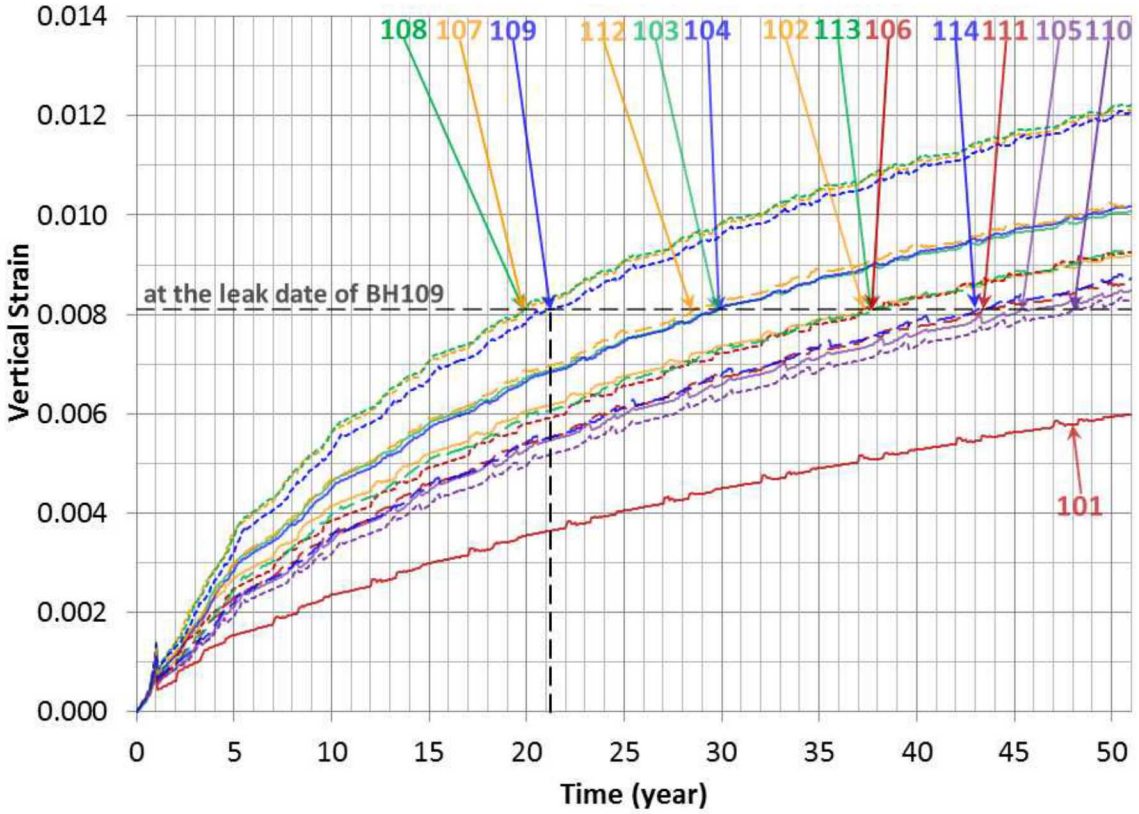
- **The strain was predicted to be 1.46% when the well casing of Cavern 105 was failed at 20.4 years (Dec. 2009). Therefore, the strain of 1.46% could be shear displacement failure limit (dashed line).**
- **From this limit, the well casings of Cavern 114, 105, and 111 are predicted to fail already/near future due to shear strain.**

Vertical Strain at the Interface



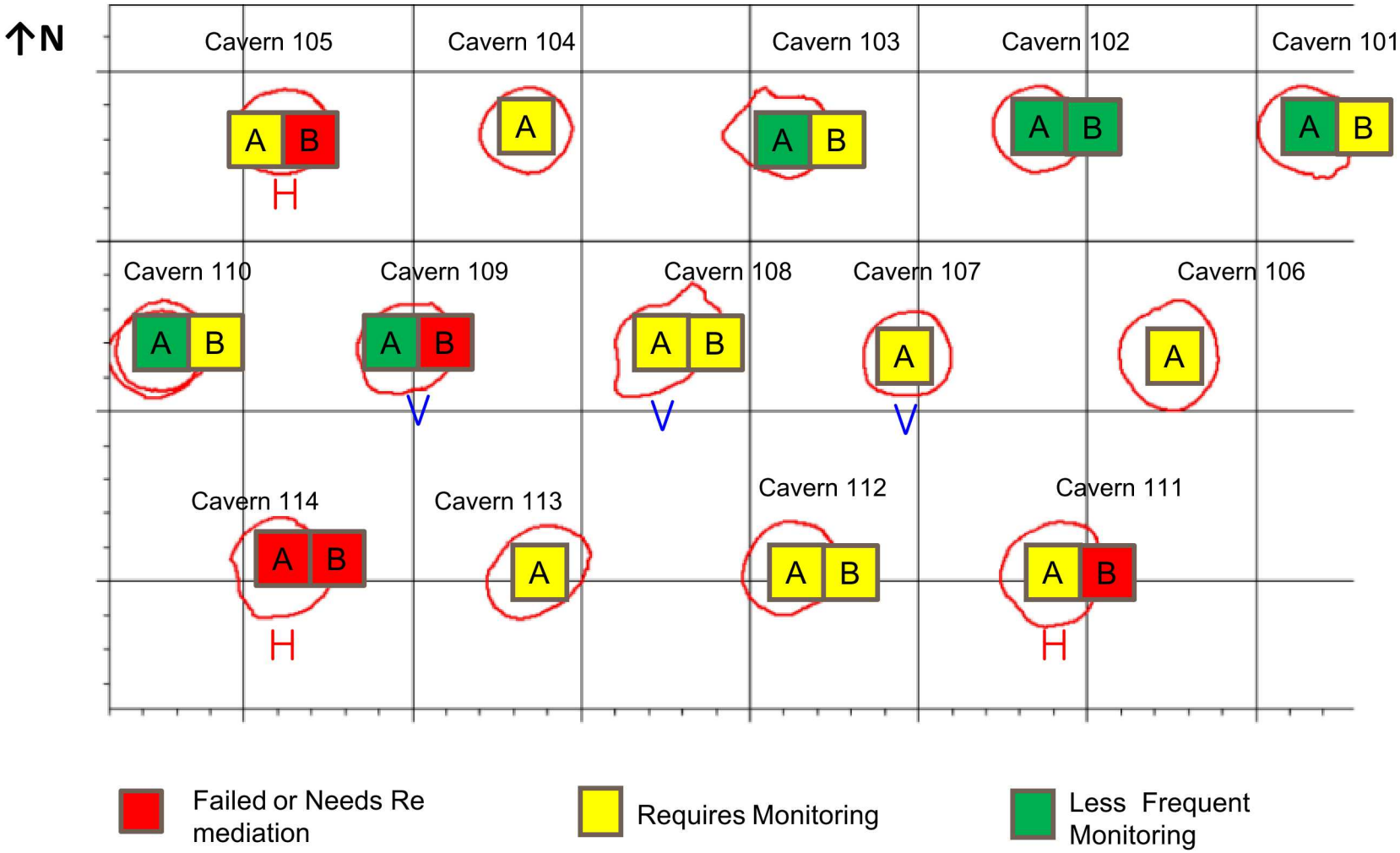
- The vertical strains above Caverns 107, 108, and 109 are larger than others.
- The well casings above them could fail by tensile strain.
- Casing of wellbore 109B was failed at the interbed and oil leaked. The cause of failure could be tensile strain created by the downward movement of salt dome top.

Predicted Vertical Strain Histories



- **The vertical strain was predicted to be 0.81% when the well casing of Cavern 109 failed at 21.2 years (Oct. 2010). Therefore, the strain of 0.81% could be the vertical strain failure limit (dash line).**
- **From this limit, the well casings of Cavern 108, 107, and 109 are predicted to fail already/near future due to tensile strain.**

Conclusions-Big Hill Caverns Aerial View Multi Arm Caliper Survey Classification



Conclusions

- The salt top subsides because the volume closure of caverns below the salt top decrease with time due to salt creep, while the caprock subsides at a slower rate because the caprock is thick and stiffer.
- This discrepancy yields a deformation of well.
- Eventually, every wellbore would fail at some time due to salt creep and stiff caprock.

Future Work

- The failure modes in this study are simplistic as each mode (horizontal and vertical strain) is considered separately.
- In reality both modes are need to be coupled to influence the strength of the casings.
- This model did not consider the stiffness of the wellbores which would impede the movement of the salt dome top.
- For a more realistic simulation, two new models will be constructed:
  - **A global model** which includes representations of the wellbore casings for all the caverns to calculate large-scale displacements
  - **A single-cavern wellbore model** to evaluate the effect of those displacements on the as-built casing designs.