SPE GCS Geomechanics Congress
"Recent Advancement in Petroleum Geomechanics"

SPE International
Gulf Coast Section

Well Productivity Enhancement: From Reservoir Geomechanics to Near-Wellbore Geomechanics

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18th April 2018
Houston, Texas

SPE International
Society of Petroleum Engineers

Agenda

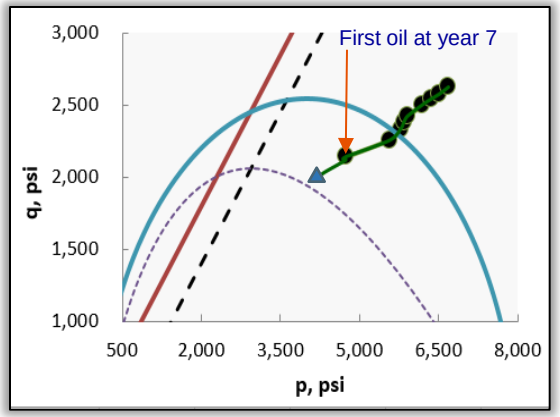
- Motivation
- General observation
- Field Examples A, B, C
- Key points

Motivation

- Well Performance cannot be detached from its field response.
- Poor understanding of Skin Evolution (related to mechanical formation damage) hindering well productivity enhancement.
- Near-wellbore scale behavior does not always follow Field scale predictions.
- Illustrate the necessity of more integrated near-wellbore geomechanics with Pressure Transient Analysis (PTA) Reservoir Surveillance and interpretations.

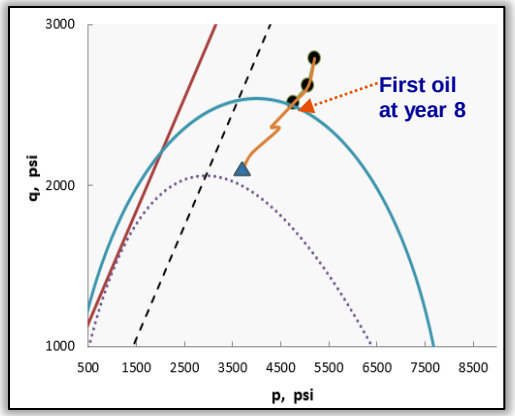
Practical implications for Reservoir/Wellbore performance

Example A

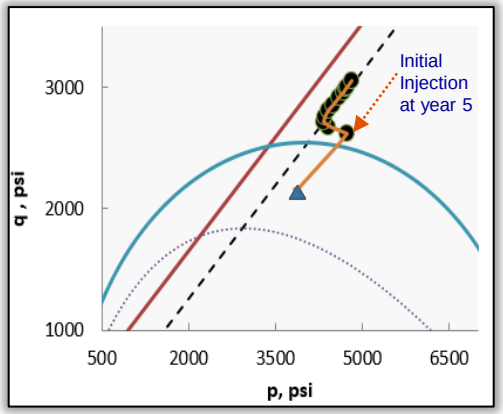


▲ *Initial Field Stress State*

Example B



Example C



What would be the expected Well performance from these Reservoir stress paths ?

General Observation

"Field A" and "Field B":

Similarities

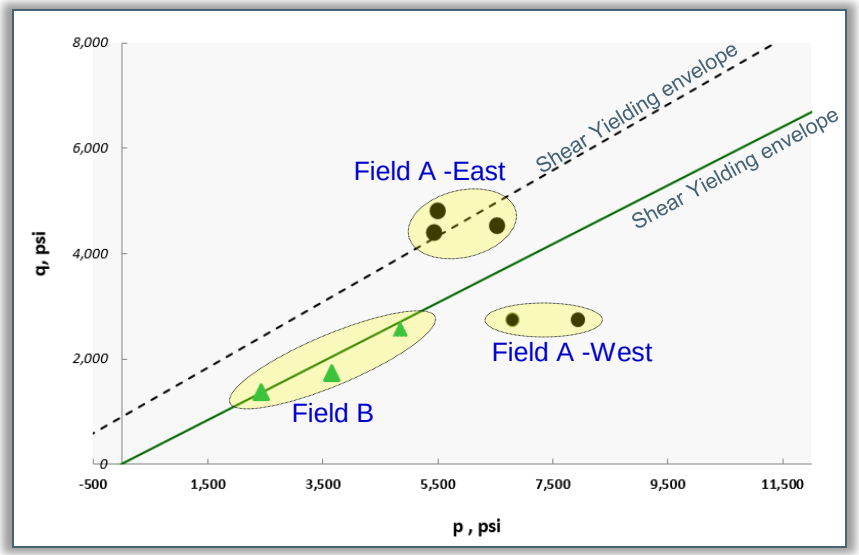
- Produce from same reservoir sands.
- Similar ϕ and k.

Differences

- Initial rock behavior:
  ***Field A-West**: Brittle*

  ***Field A-East**: Brittle to Ductile*

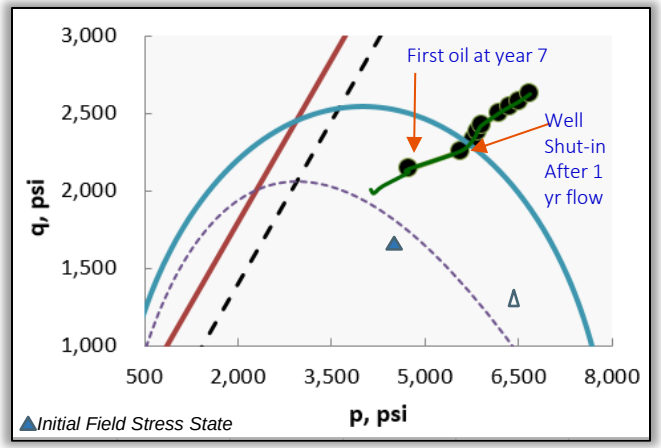
- Initial rock behavior:
  ***Field B:** Ductile*

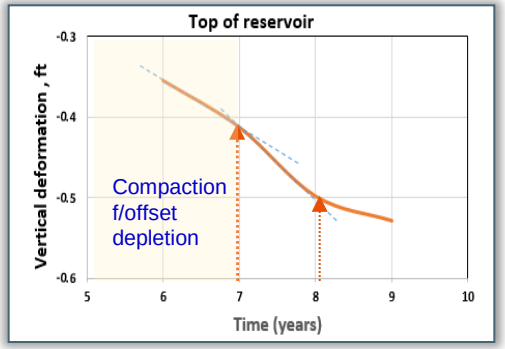


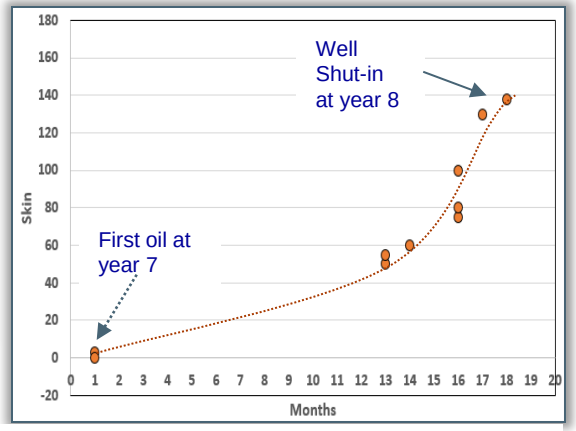
❋ "p-q" plots should be integrated as an extra tool for "Field Analogs" as they can be compared under dynamic conditions.

Example A

Example A



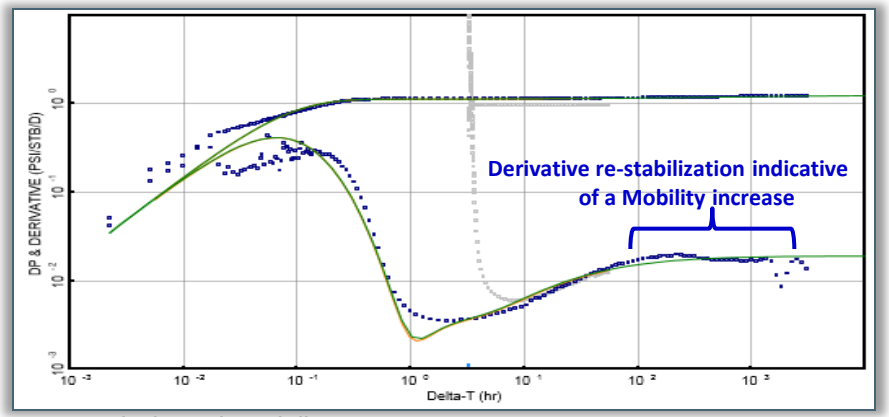




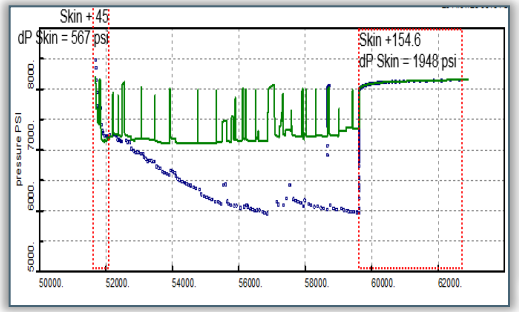
Skin from PTA Reservoir Surveillance (1 year)

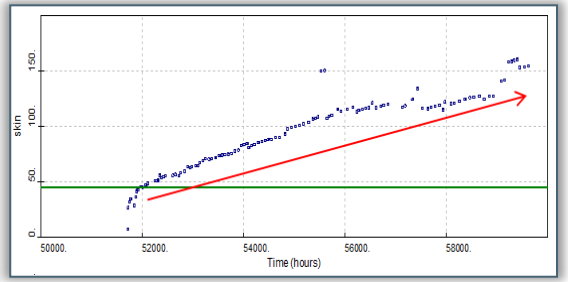
* One year of depletion moved this region to the limit of pore collapse.
* Vertical displacement at top of formation is ~ 0.52 ft within 1 yr. (only 0.1 ft is from current well).

Example A (cont'd)



PTA Analysis and Modeling

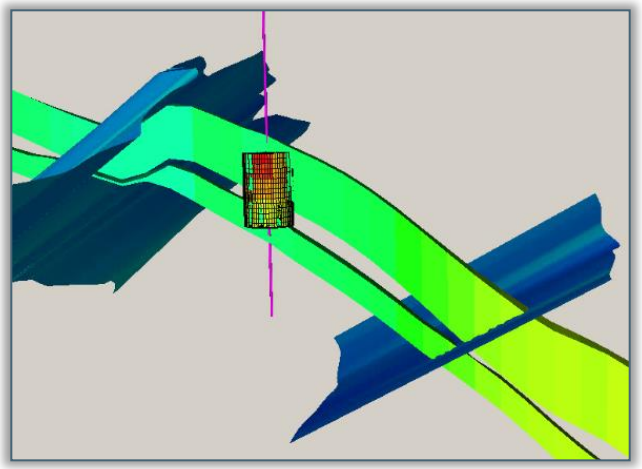


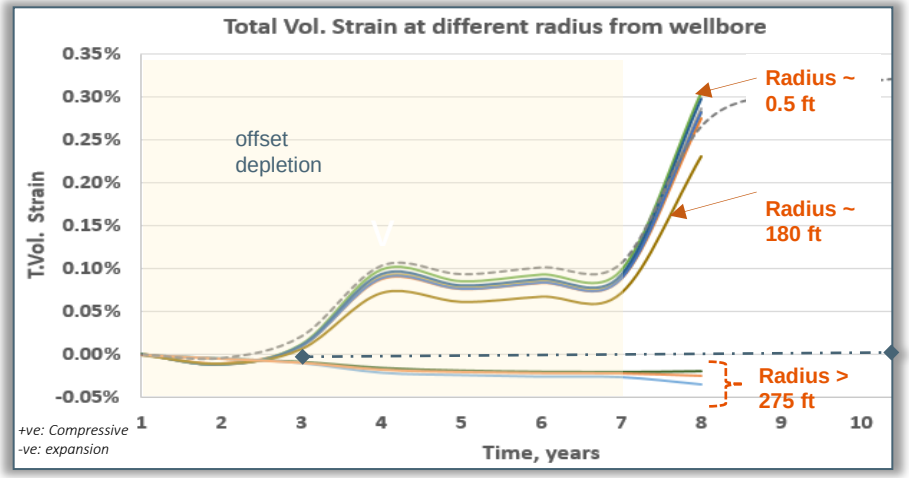


Skin from PTA modeling

- At Delta-T ~200 hrs the derivative re-stabilizes indicative of a Mobility M (kh/μ) increase reflecting an improvement in the reservoir.
- Geometry modeled with the well between intersecting barriers located +x = 250 and -y = 250 ft with a 25% decrease in Mobility and Storativity.
- Analysis suggests initial Skin total = +45, dP Skin = 567 psi.
- Skin increasing to reach its present value = + 154.6

Example A (cont'd)

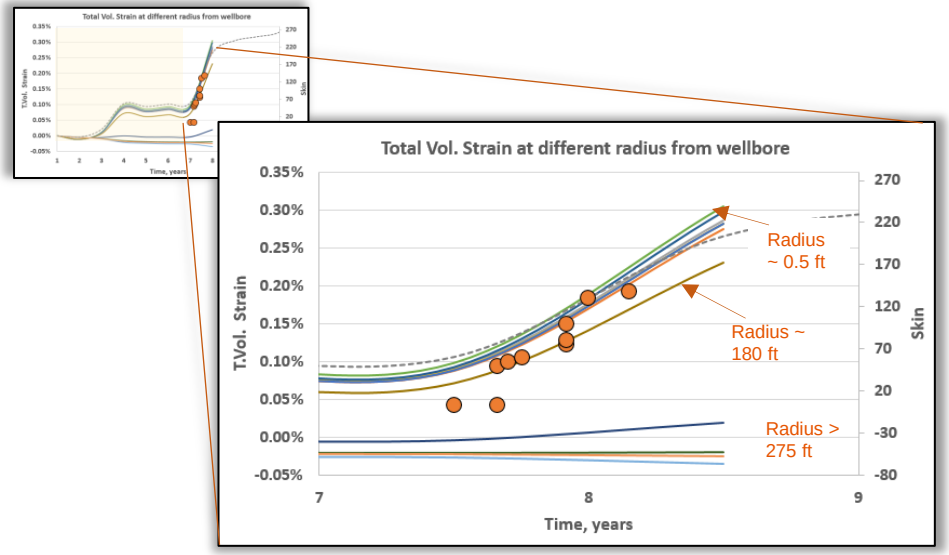


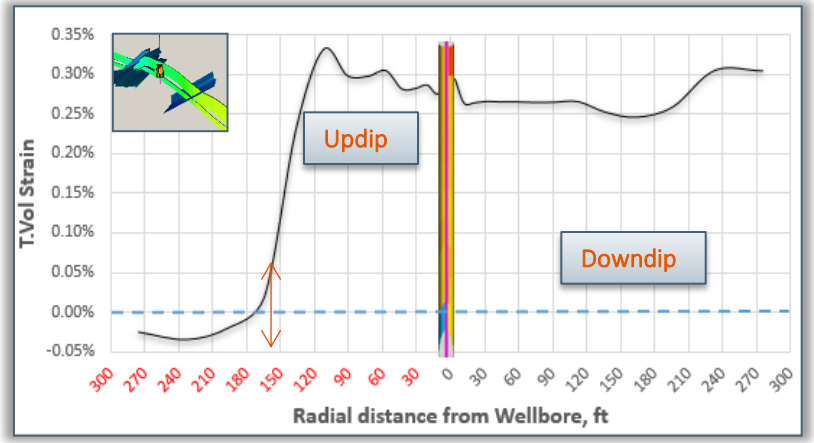


- Radial strains are expanding updip/downdip and compressive laterally (E-W).
- Hoop Strains are compressive updip/downdip and dilatant laterally.
- Vol. Strain is dilatant updip and compressive downdip.

- For a radial distance < 180 ft the zone is compacting. Dilation starts above 180 ft from wellbore.
- Thus, at some distance from the wellbore **a barrier is created separating a "dilation zone" from a "compaction zone"**
- Mechanical **Formation damage can be considered for a length < 180 ft**.

Example A (cont'd)

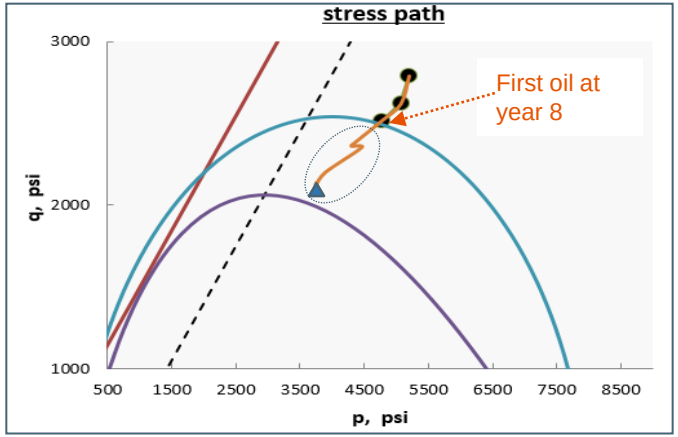




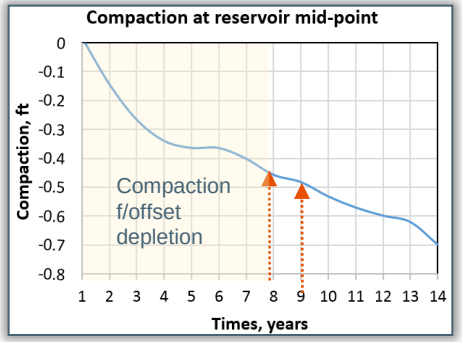
- A Vol. Strain differential ~ 0.20% between field and near-wellbore regions allows for a skin interpretation.
- In this case, 180 ft is the point at which a mobility increase is expected from PTA. Near fault can be one possible explanation for such increase.
- ***It is possible to determine a prefer orientation and distance that dominates the Skin evolution.***
- Length related to skin evolution is ~ 180 ft updip.

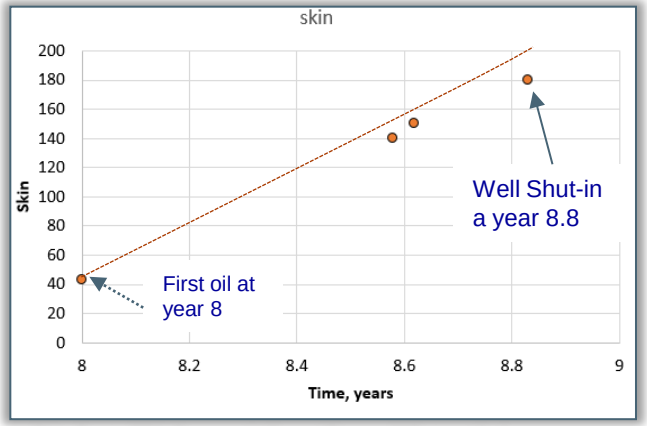
Example B

Example B



Initial Field Stress State

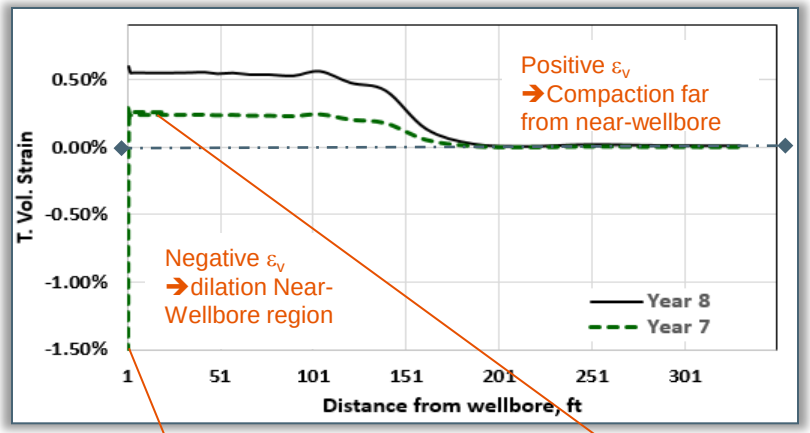


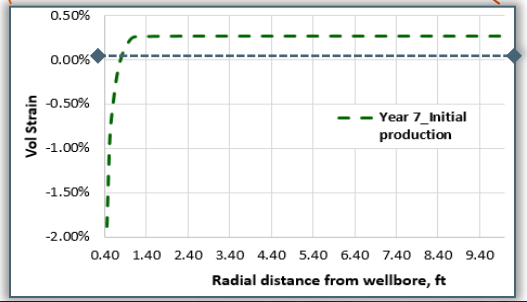


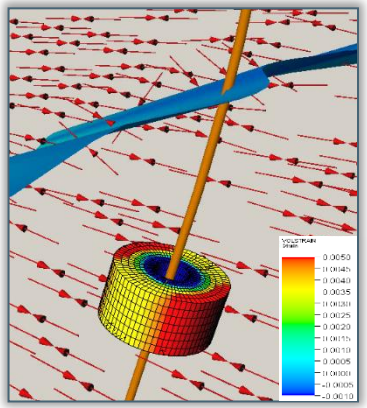
Skin from PTA Reservoir Surveillance (10 months)

- High initial P_{conf} induces ductile rock at the moment of drilling & Production.
- When open to production, the region is right in a critical state near to the shear compaction.
- From p-q plot an initial high skin is expected for this well.
- After 10 month of production well is shut-in.

Example B (cont'd)





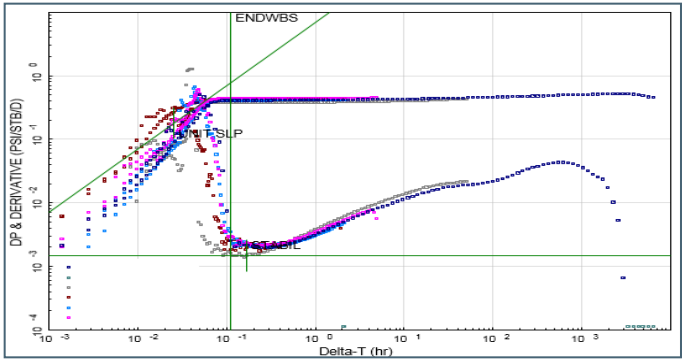


S_{hmin} orientation

* Upon production, large plastic shear strains (dilatancy) are induced in the near-wellbore region. Initial dilatant behavior has the tendency to decrease (not improved mobility).

* Thus, ***at some distance from the wellbore a barrier is created separating a "dilation zone" from a "compaction zone"***

Example B (cont'd)

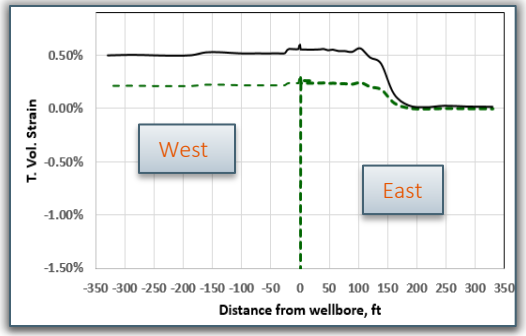


PTA Reservoir Surveillance

- High initial skin ~ 43 units.
- Skin increasing until reaching its present value = +180

- Geometry modeled as parallel barrier opening up on one end: +y = 150 and -y = 150 ft

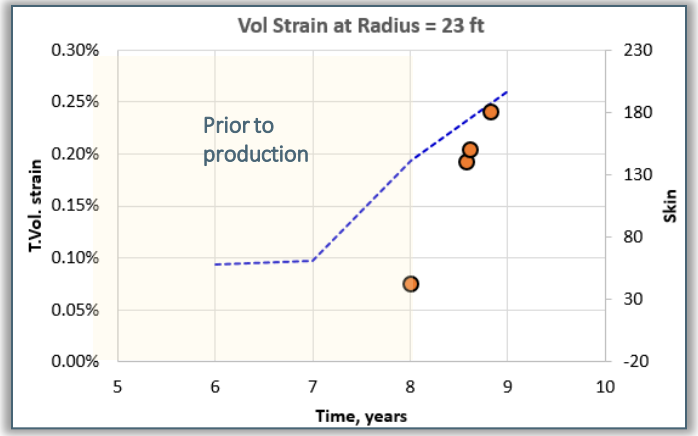
Having 2x and then 20x Mobility and storability increases 1500 ft and 9000 ft, respectively, in the two unbound directions.



- Due to well orientation, estimations of strains do not decrease or increase updip/downdip but in the lateral direction.

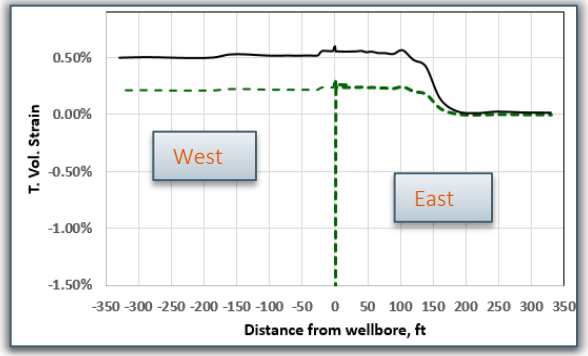
- Faults seem not to be interfering.

Example B (cont'd)



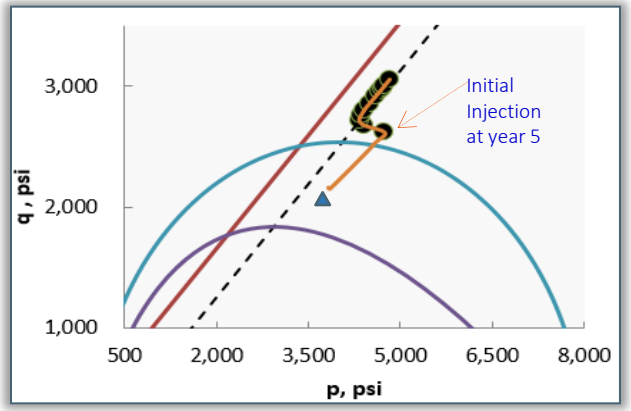
* ***Strains analysis indicates a preferential orientation of formation damage laterally away from faults*** direction.
* A ***Vol. Strain differential > 0.20% between field and near-wellbore regions allows for a skin interpretation***.
* Length related to skin evolution is ~150 ft downdip

* Good match of εv with observed skin evolution.
* Parallel boundaries from PTA are in agreement with the contractant strain at a Radial distance of ~ 150 ft.
* Initial plastic shear strains (dilatancy) near-wellbore (<1.5 ft) decreases with not improvement in reservoir mobility (as expected from high ductility)

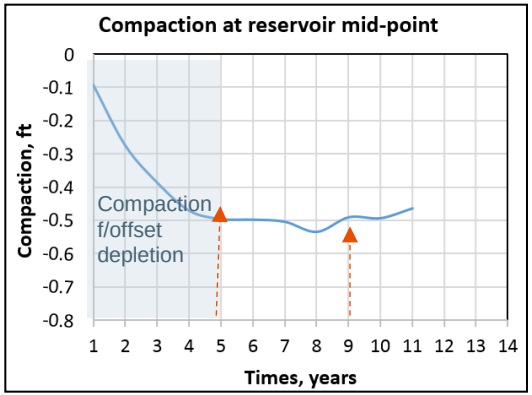


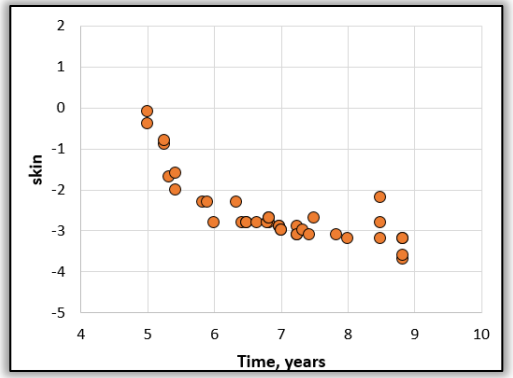
Example C

Example C



▲ *Initial Field Stress State*

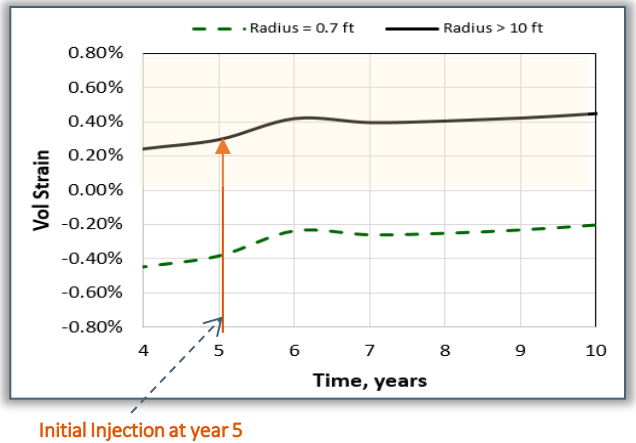




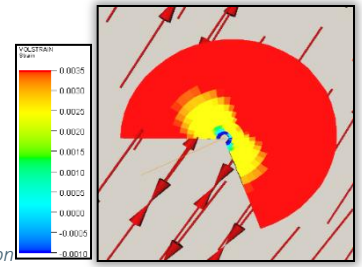
Skin from PTA Reservoir Surveillance (4 years)

* Due to its initial state and high ductility upon injection, wellbore moves along the compacting endcap until reaching the yielding envelop to remain on it. Not critical shear failure is expected.

Example C (cont'd)



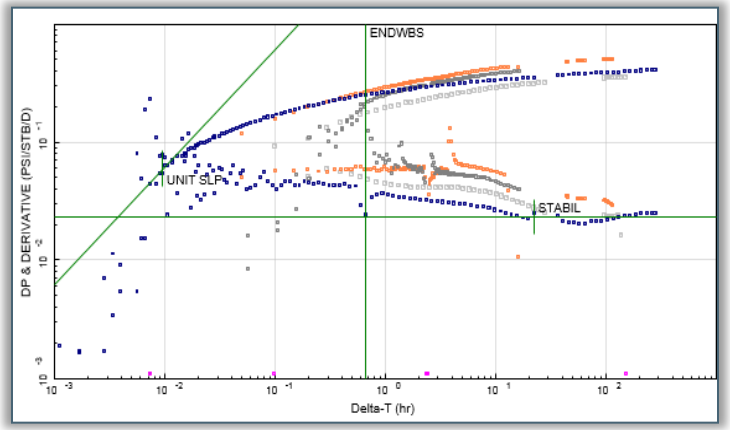
Initial Injection at year 5



S_{hmin} orientation

- Upon Injection, initial negative volumetric strains are induced and remains constant in the near-wellbore region.
- ***At radial distance > 10 ft Vol Strains become positive and without any change over time.***
- For this well, any subsequent/potential failure needs to be analyze by looking at plastic strains changes only.
- Near-wellbore contraction is observed with preferential lateral orientation (associated Producer well is Updip). Far-field deformation is lower towards the producer (however, stimulation in high inclined well can be difficult to over pass).

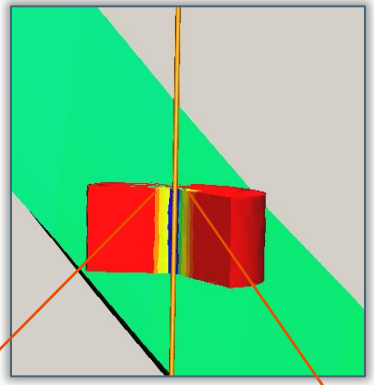
Example C (cont'd)

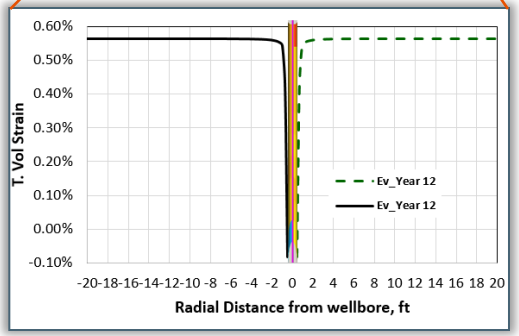


* Boundaries are not needed to obtain the History Match indicating constant "kh"

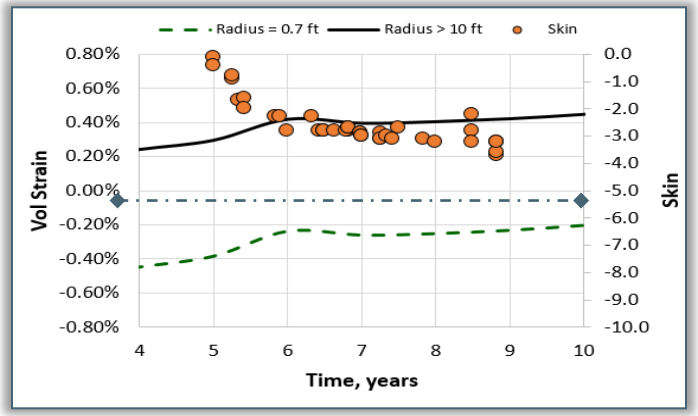
* Global Skintotal = +1 including the geometric skin as the transient moves from the inner area with lower Mobility to the outer area with higher Mobility.

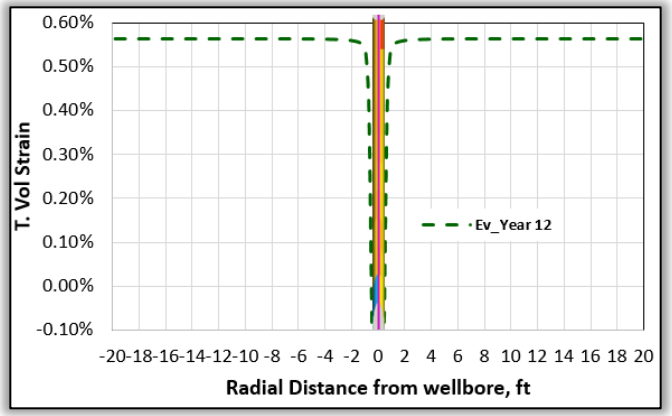
* Vol. Strains changes are limited to the very near-wellbore region (~ 1 ft).





Example C (cont'd)



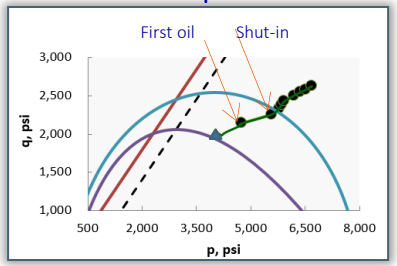


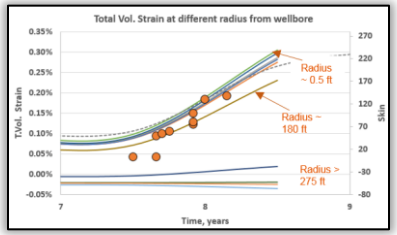
- Good match of εv with observed skin evolution.
- Initial plastic shear strains (dilatancy) near-wellbore (<1 ft). Follow by constant compressive Vol Strain.
- A Vol. Strain differential > 0.20% between field and near-wellbore regions allows for a skin interpretation

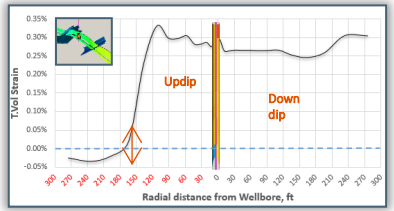
- Vol. Strains shows symmetrical deformation away from wellbore.
- No preferential orientation of formation damage with relation to the skin

In Summary

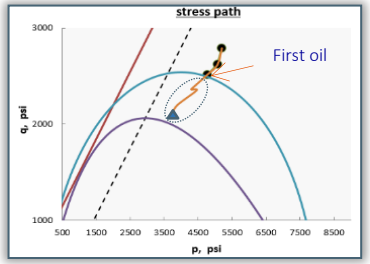
Example A

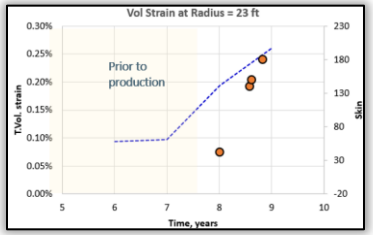


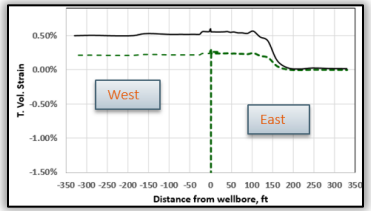




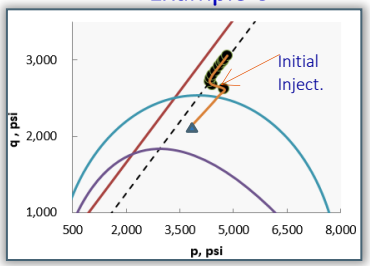
Example B

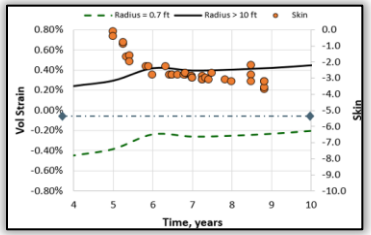


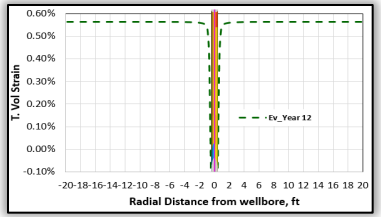




Example C







Key Points

1. PTA Reservoir Surveillance should not be excluded from Geomechanics integrated analysis.

2. Skin evolution can be monitored as a Volumetric strain evolution. Any estimated Plastic strain will track it as well, but skin related to elastic behavior would be excluded from analysis.

3. More importantly, Strain analysis can determine, not just skin evolution with time but, the distanced and orientation affected by deformation and allow Well productivity to be maintained or improved.

4. There is still uncertainty in defining the onset level of strain that will induced skin issues (~ a differential of 0.20 %).

5. Software with explicit near-wellbore modeling needs to provide gridding alignment with reservoir/geological grids.

6. Numerical simulations of PTA with coupled-geomechanics need to be implemented for more accurate dP Skin estimations.

Thank you !