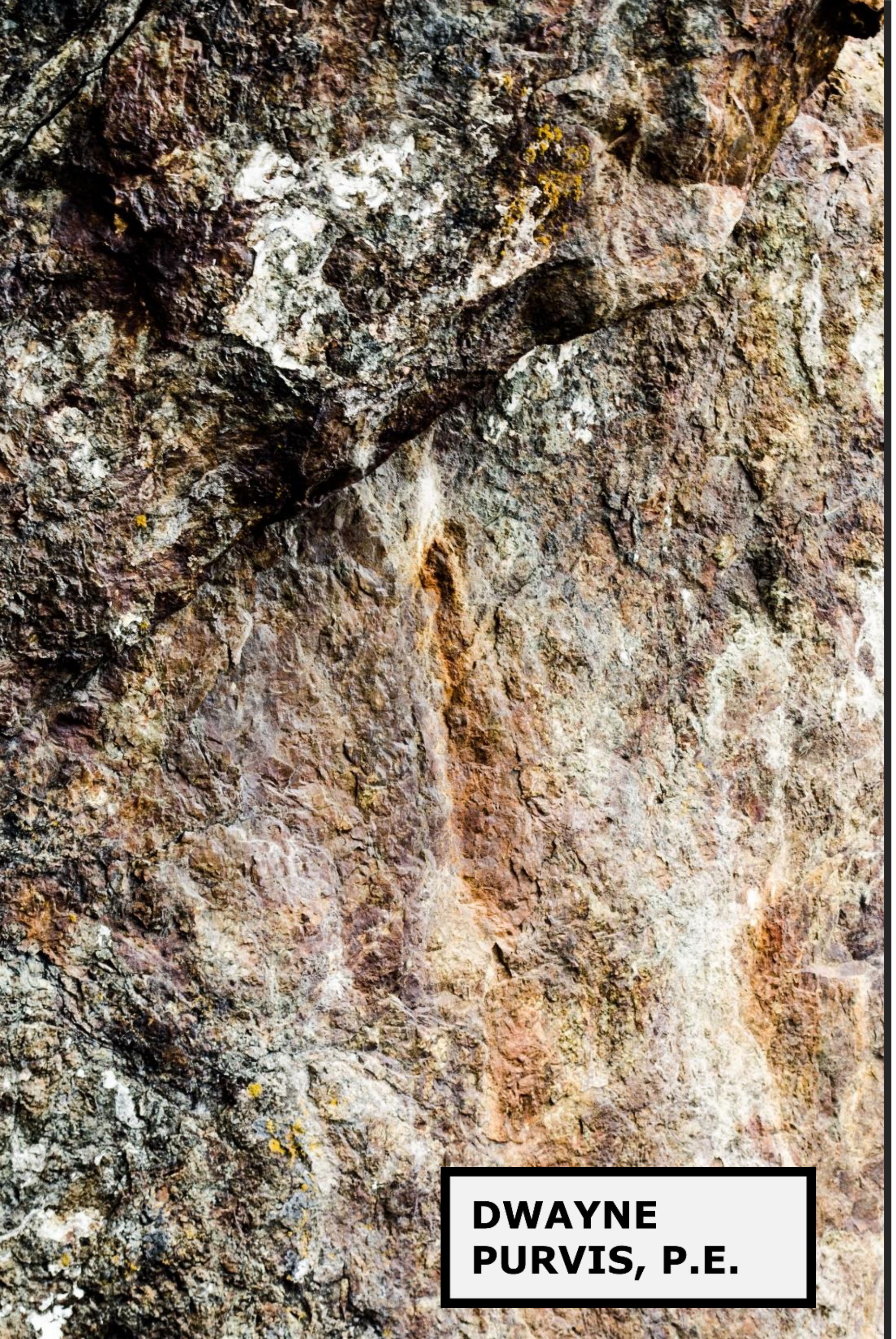


Risk and Opportunities
Created by Shutting in

DWAYNE PURVIS, P.E.

May 20, 2020

To turn the valve or not to turn the valve. . .

Economics

cash flow
cost of mothballing

Contracts

landowners
midstream
rentals
other

Operations

corrosion
scale
paraffin
asphaltenes
bacteria
emulsions

Reserves

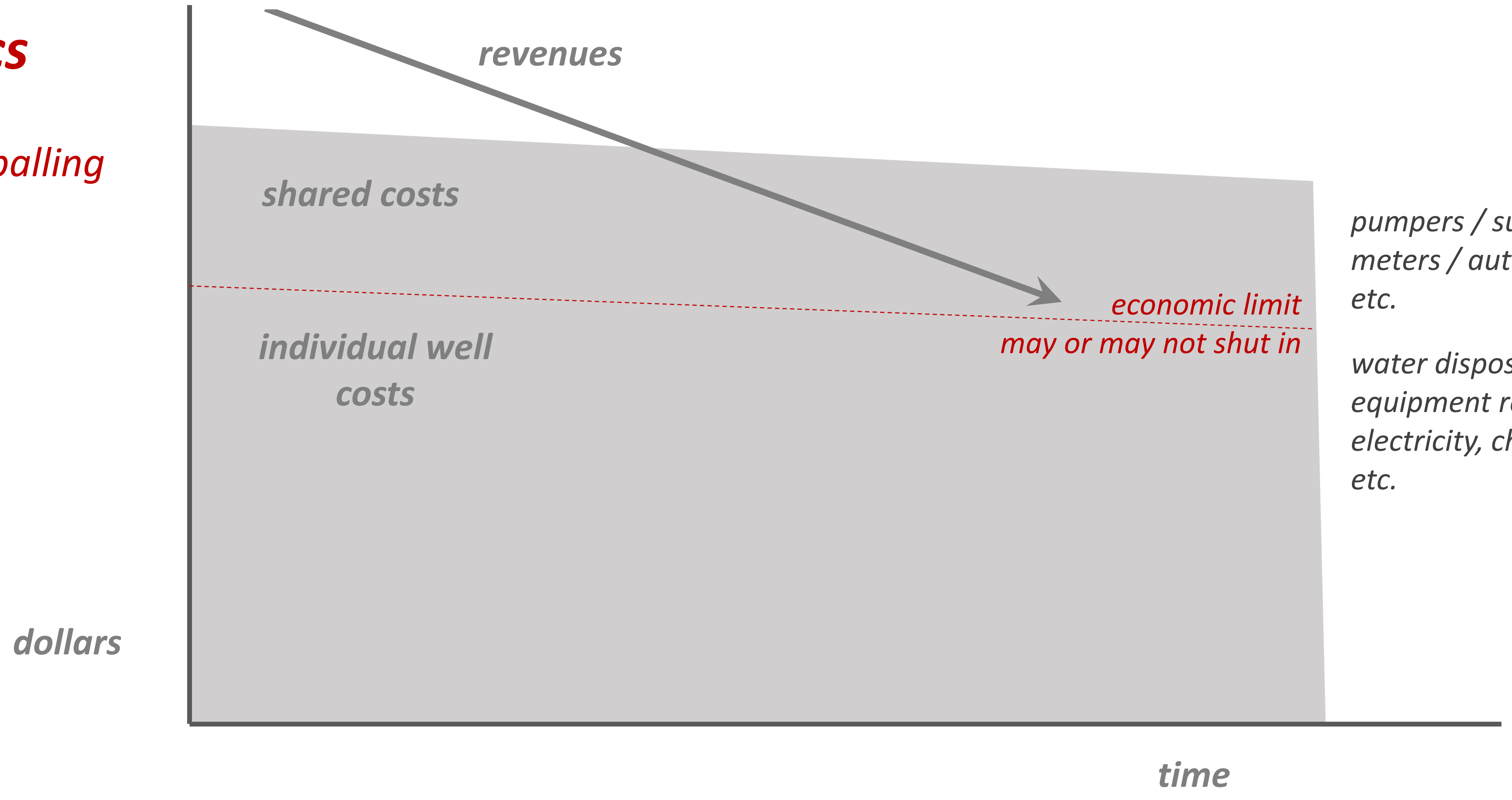
loss of productivity
flow away from wellbore

Uneconomic when revenue does not cover variable costs

Economics

cash flow

cost of mothballing



pumpers / supervision
meters / automation
etc.

water disposal
equipment rentals
electricity, chemicals
etc.

Four options for uneconomic wells. . .

Change artificial lift	lower rates at lower costs	meaningful cost
Keep producing (perhaps lower rate)	hope for price improvement maintain contractual obligations mitigate mechanical risk	monthly negative cash flow maintain revenue
Shut in (SI)	stop producing but leave well ready to produce	trivial cost no revenue
Temporarily Abandon (TA)	prepare well for longer inactivity (remove equipment, load with fluids, maybe set a plug)	meaningful cost both to shut down and to start up
Plug and Abandon (P&A)	permanent usually deferred in order to maintain option value	meaningful cost

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Shutting in production affects the whole business

Contracts

landowners
midstream
rentals
other

Land	Midstream	Rental/Other
valid while *"producing in paying quantities"*	Minimum Volume Commitments	Artificial Lift Corporate Overhead
Shut-in royalties Producers 88 form: SI for gas market, no SI for oil market most modern leases allow shut-in royalties for both	Minimum volume per delivery point Firm transport Hedge positions	Compressors ESPs Pumps SCADA Field staff G&A
Misc, *e.g.* maximum shut-in time	Misc	Misc.

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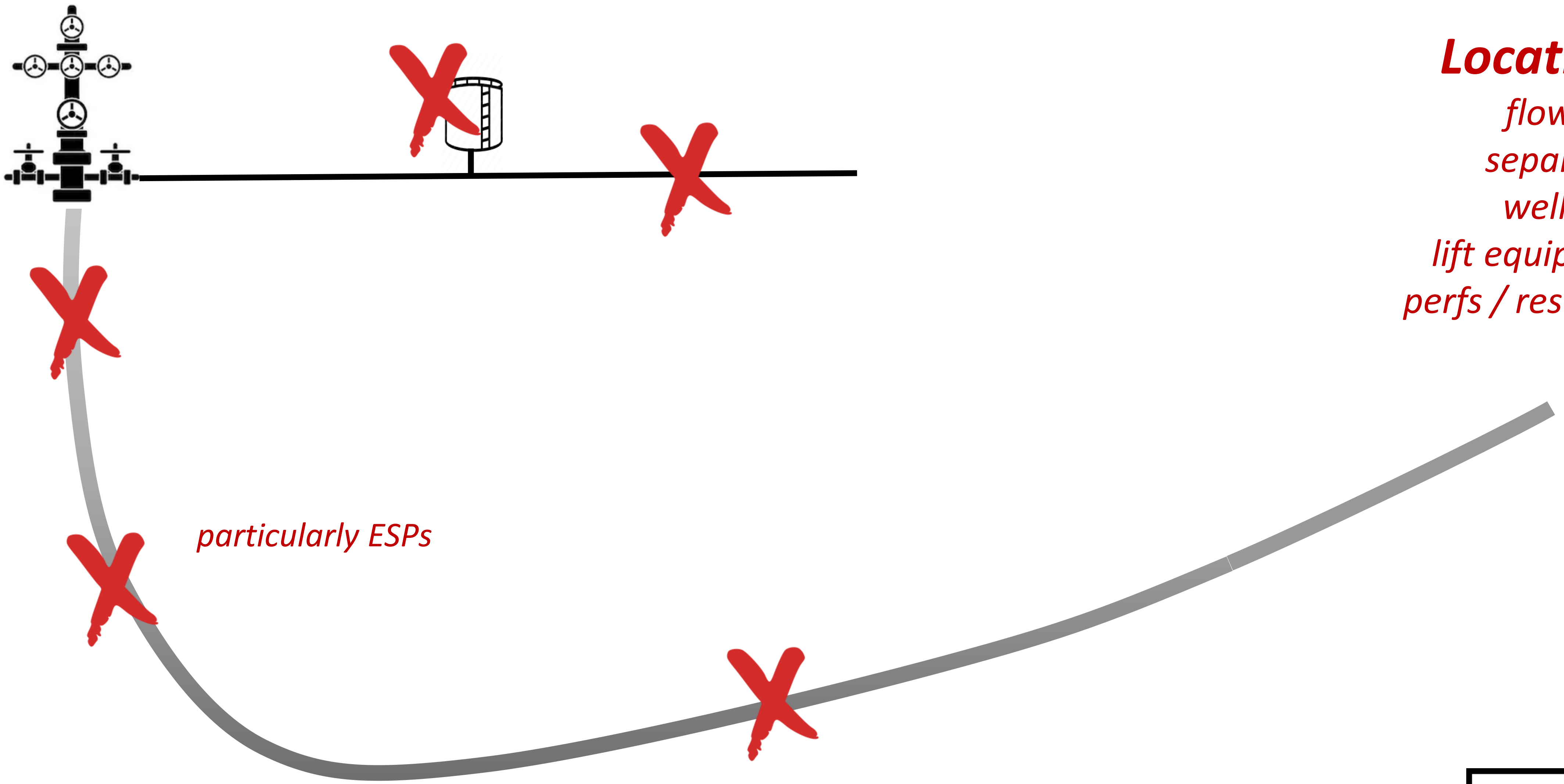
Wide range of possible operational issues

Operations

corrosion
scale
paraffin
asphaltenes
bacteria
emulsions

Corrosion	*CO_2, H_2S* *Formation water*	*Inhibitors* *Oxygen-scavenger*
Bacteria		*Bactericide*
Scale	Calcium Carbonate Calcium Sulfate Barium Sulfate	Choice of chemicals, Inhibitors
Paraffin, Asphaltenes	Oil properties	Inhibitors
Emulsions	Oil + Water + Surfactant or Fines (natural or artificial)	Demulsifier, solvents

Wide range of possible locations



Locations

flow lines
separators
wellbores
lift equipment
perfs / reservoir

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Shallow but broad menu of damage mechanisms

	Closing	Downtime	Opening
No hydraulic fracture (millidarcy rock)		fluid movement within and between reservoirs	fines migration
both	sand production	chemical between fluids (emulsion, asphaltene, scale) chemical with rock (emulsion, swelling, fines) capillary blocking	sand production stress-dependence
Large hydraulic fracture (micro- to nanodarcy rock)	water hammer stress-cycling	water weakening	

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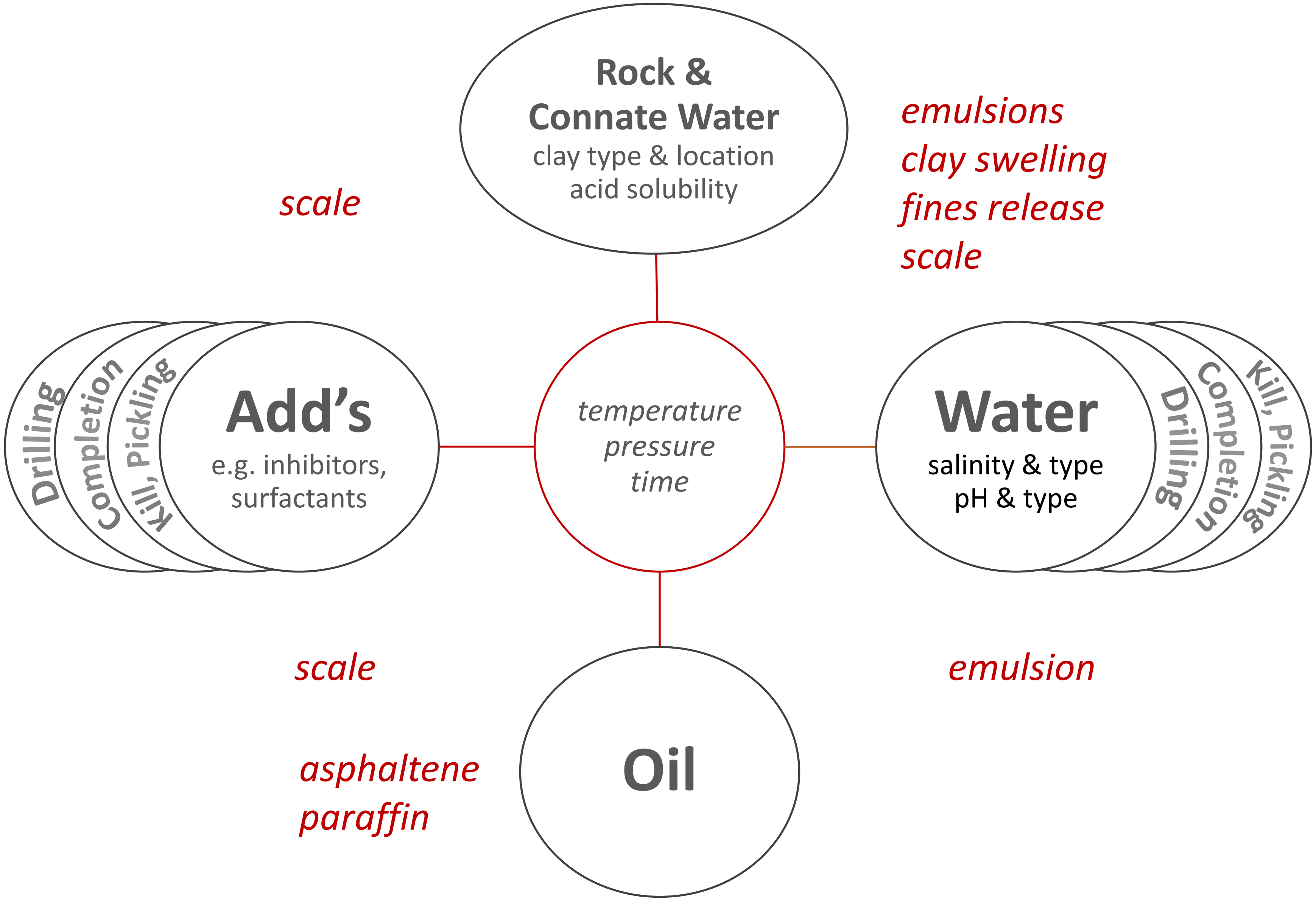
Complex interactions make chemical issues



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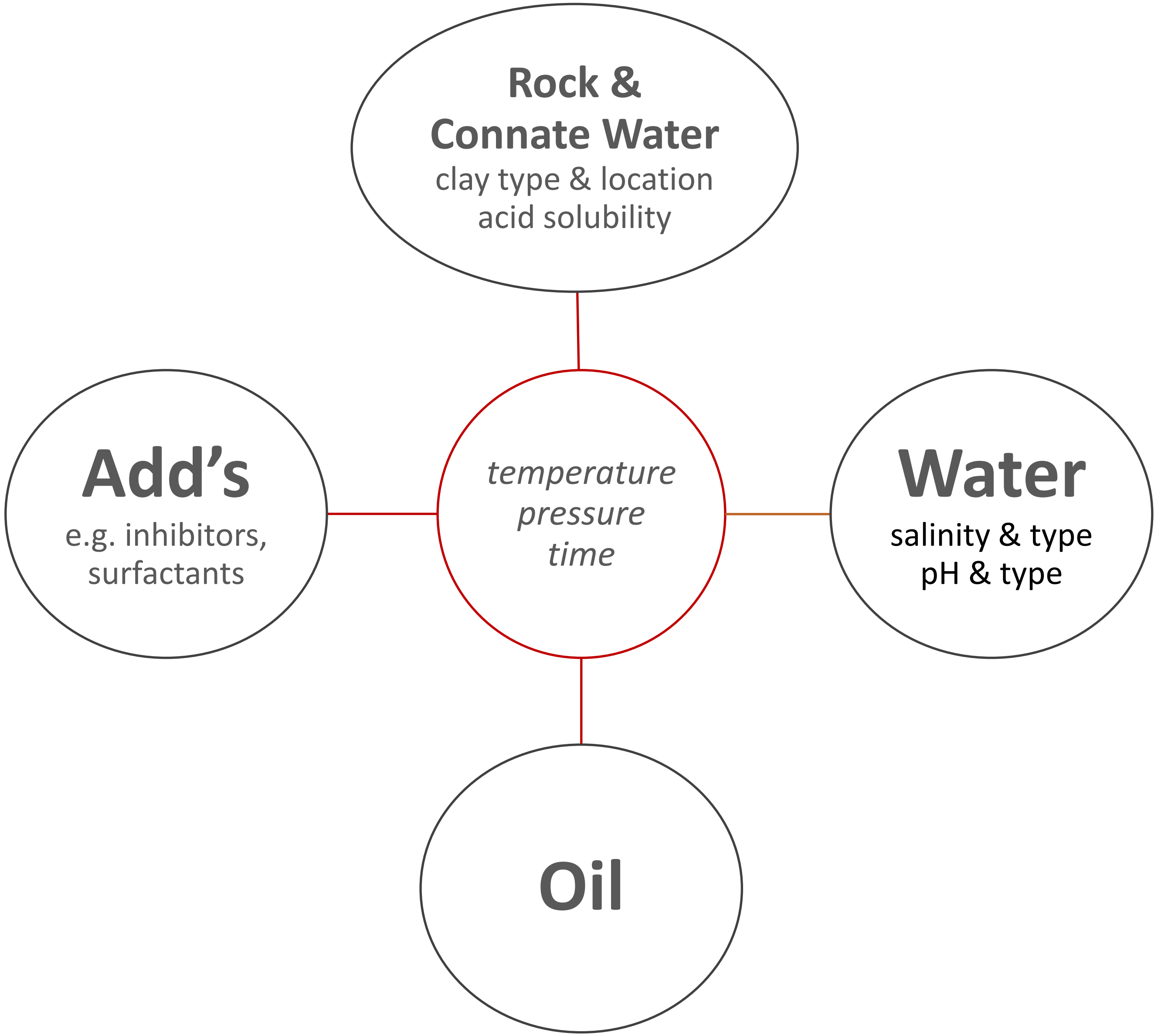
Complex interactions make chemical issues



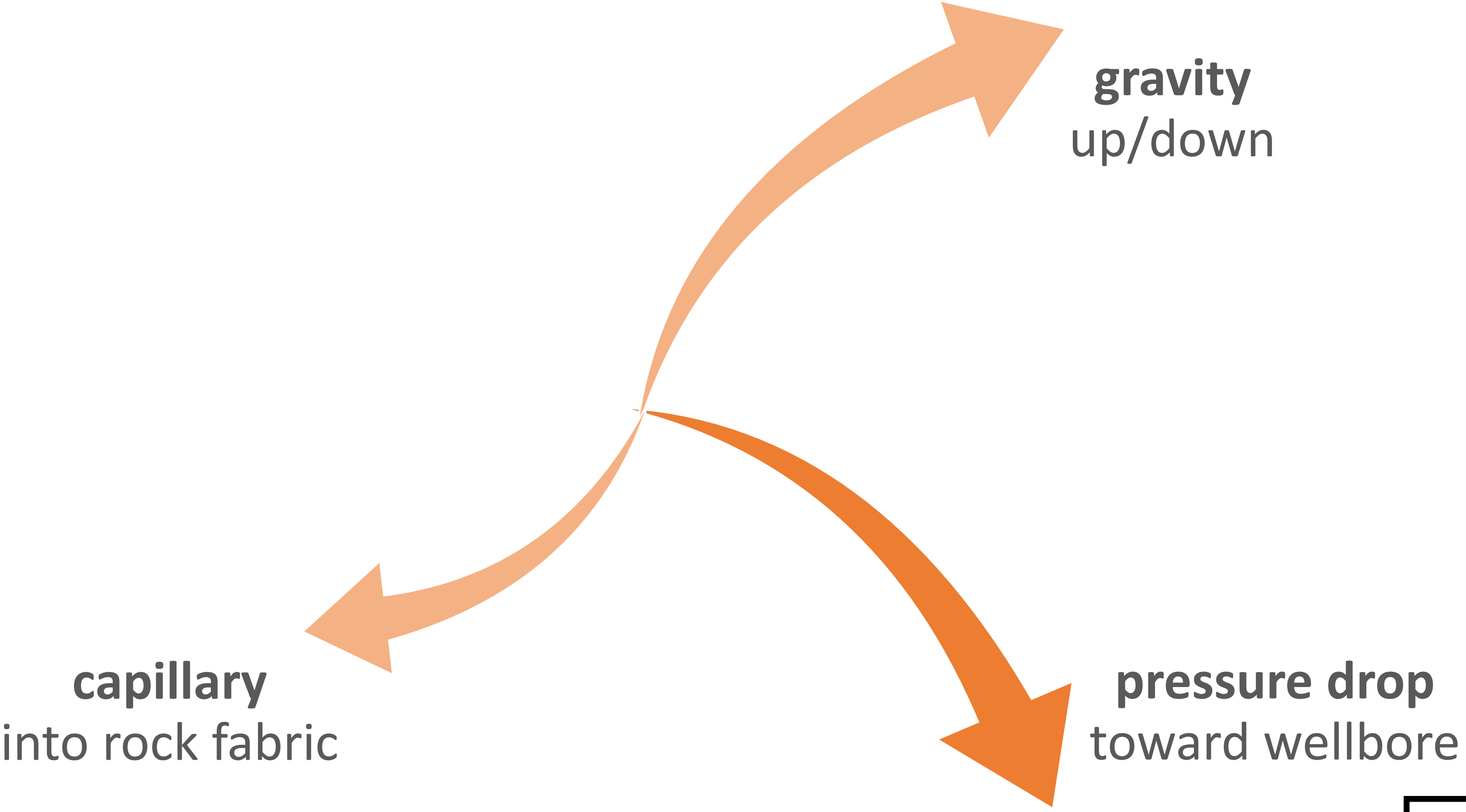
Red flags:

- *operational issues*
- *authigenic clays (or precursors such as feldspars)*
- *history of unexplained loss of productivity*

To do:

- *native fluids on perfs*
- *good chemicals partner*
- *lab research*

Two forces remain after shut-in



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Two forces remain after shut-in

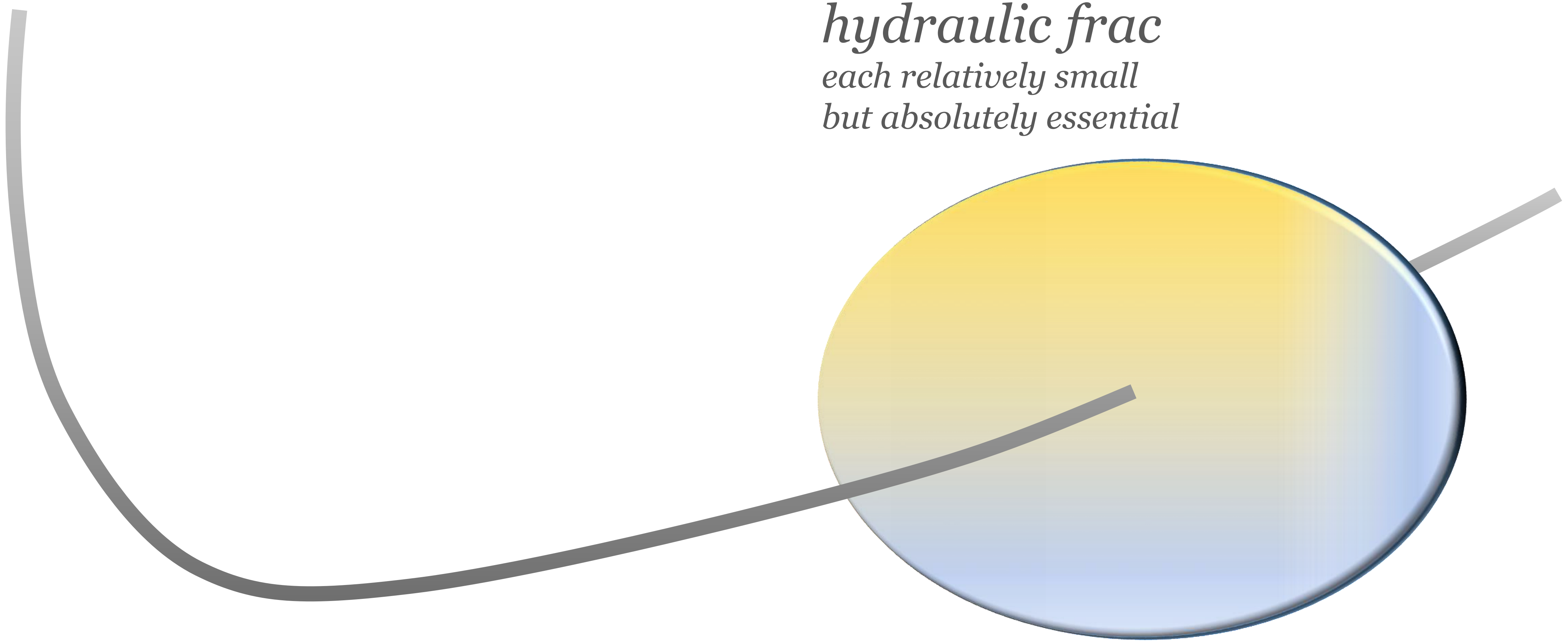
- *backflow into reservoir*
- *crossflow between perfs*
- *reservoir fluid moves away from wellbore (or towards it!)*
- *water pulled into reservoir*

gravity
up/down

capillary
into rock fabric

pressure drop
toward wellbore

Additional critical "equipment" in shale wells



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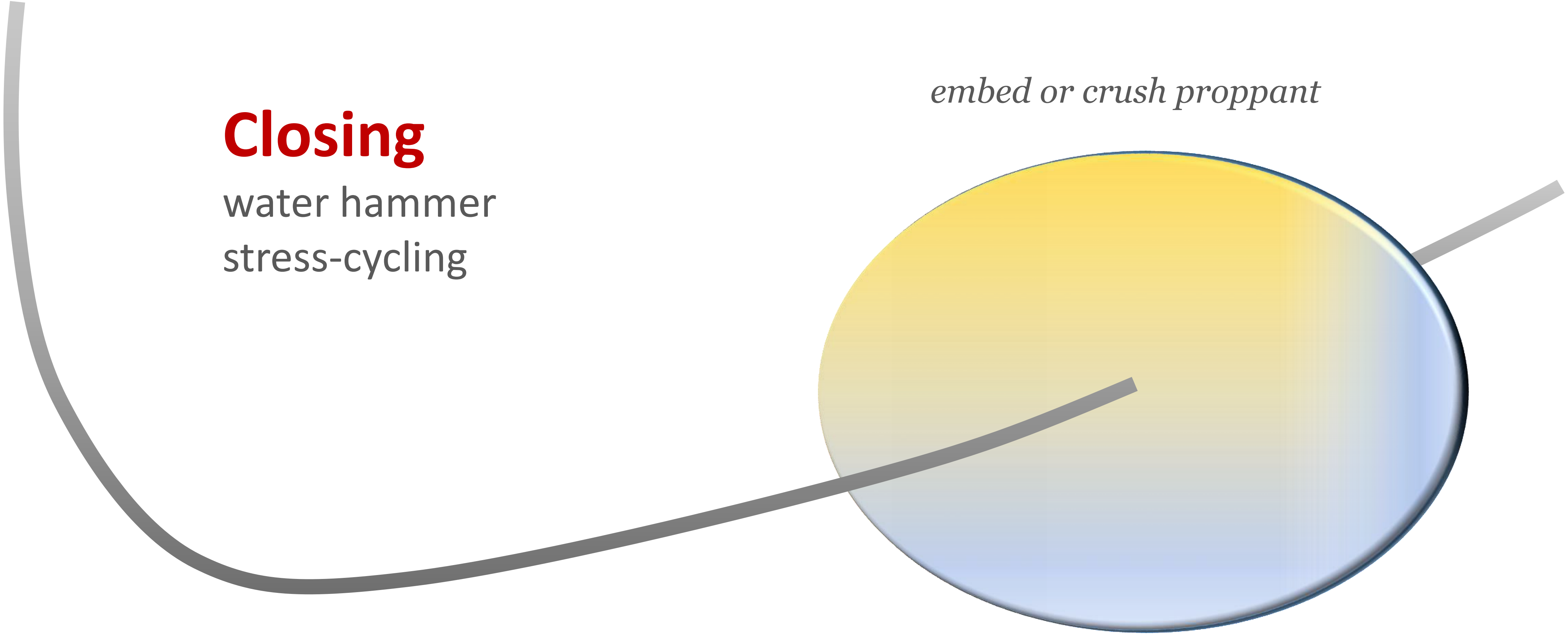
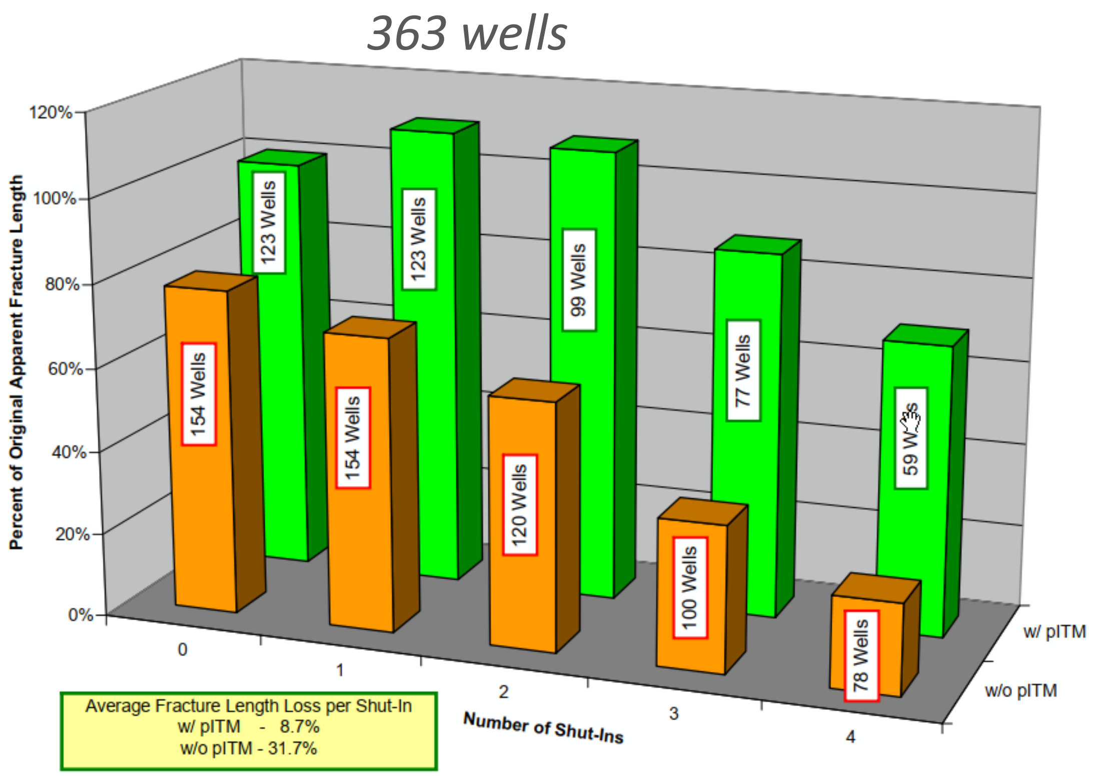
Potential damage to hydraulic fracture (1/3)

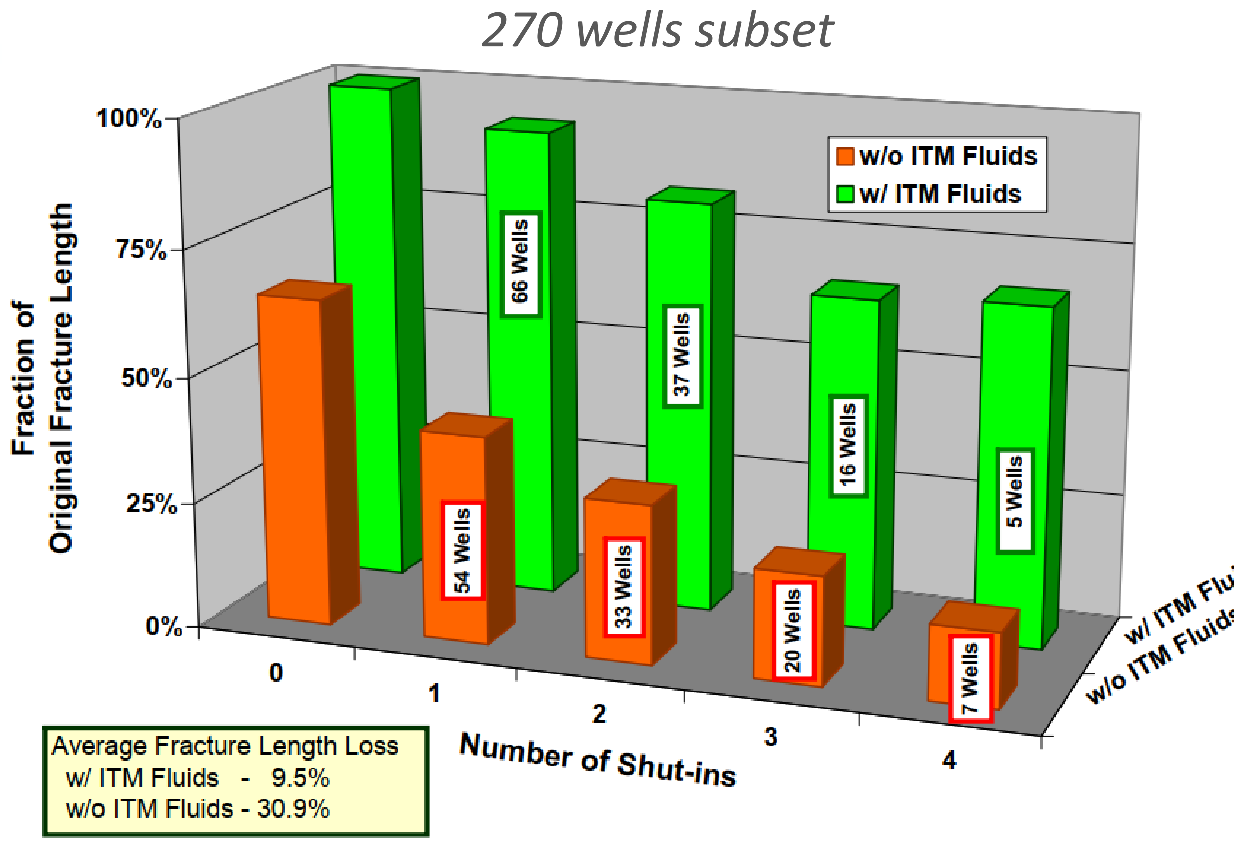
Closing

water hammer
stress-cycling



Gain or loss of productivity with early shut-ins





"The event of a shut-in is generally, but not always, harmful."
"Shut-in related damage continues to accrue during subsequent shut-in events."
"The duration of the shut-in has no obvious correlation to the severity of the damage. . ."
"[T]he longer that production period can be sustained, the less severe the harm. . ."

Source: SPE 166101 and SPE 165705 by Dr. James Crafton (deceased) and Sandra Noe (Flotek)

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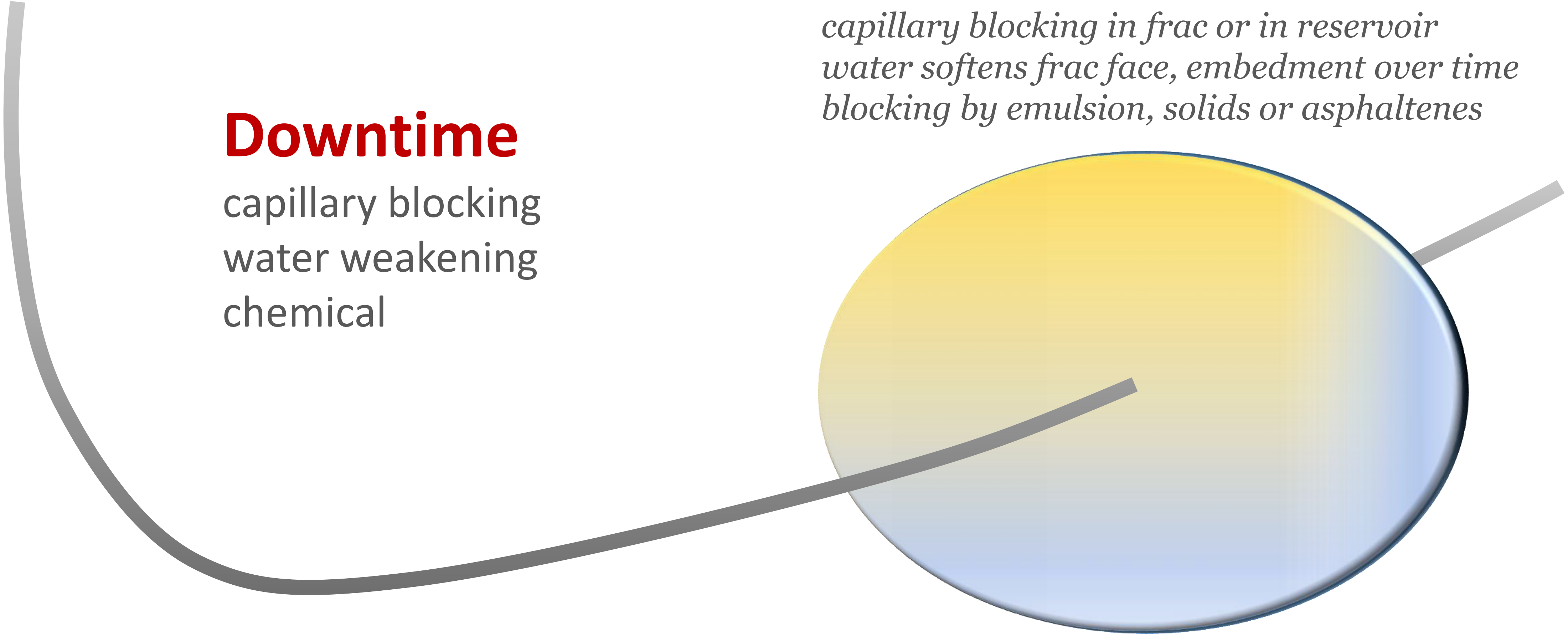
Potential damage to hydraulic fracture (2/3)

capillary blocking in frac or in reservoir
water softens frac face, embedment over time
blocking by emulsion, solids or asphaltenes

Downtime

capillary blocking
water weakening
chemical



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Initial production ≠ Productivity

Immediate flowback

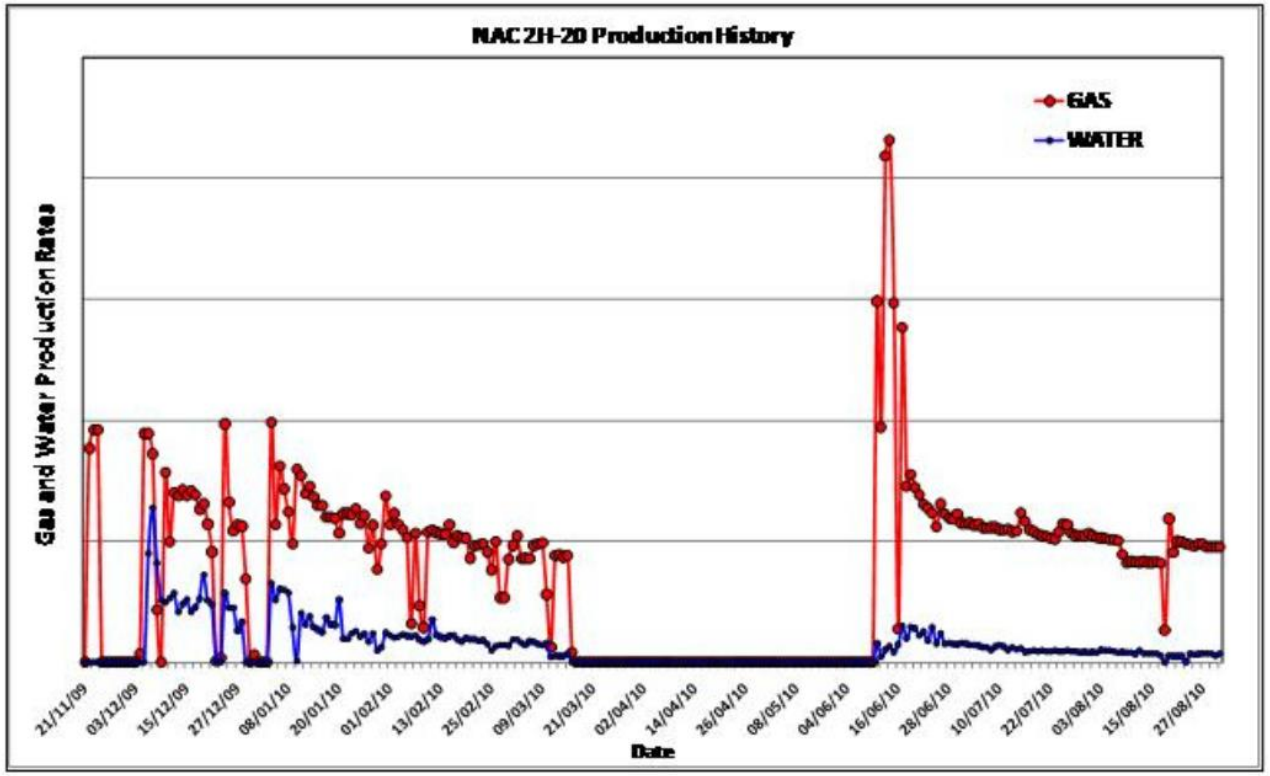
Delaying flowback after frac treatment can increase short-term production but reduce long-term recovery.

(Practice of delay called "soaking," "shake and bake," "resting" or "conditioning.")

Mechanism is water imbibition to formation, reducing near-frac permeability.

Similar practice in flowback of water used to protect against offset frac.

*No longer regarded as best practice.**



"[W]e observe that after extended shut-in the rate increases with a higher decline, the pressure is recharged but shows higher decline. . ."

Source: SPE 144321 and SPE 187506
**except some controversy in Bakken*

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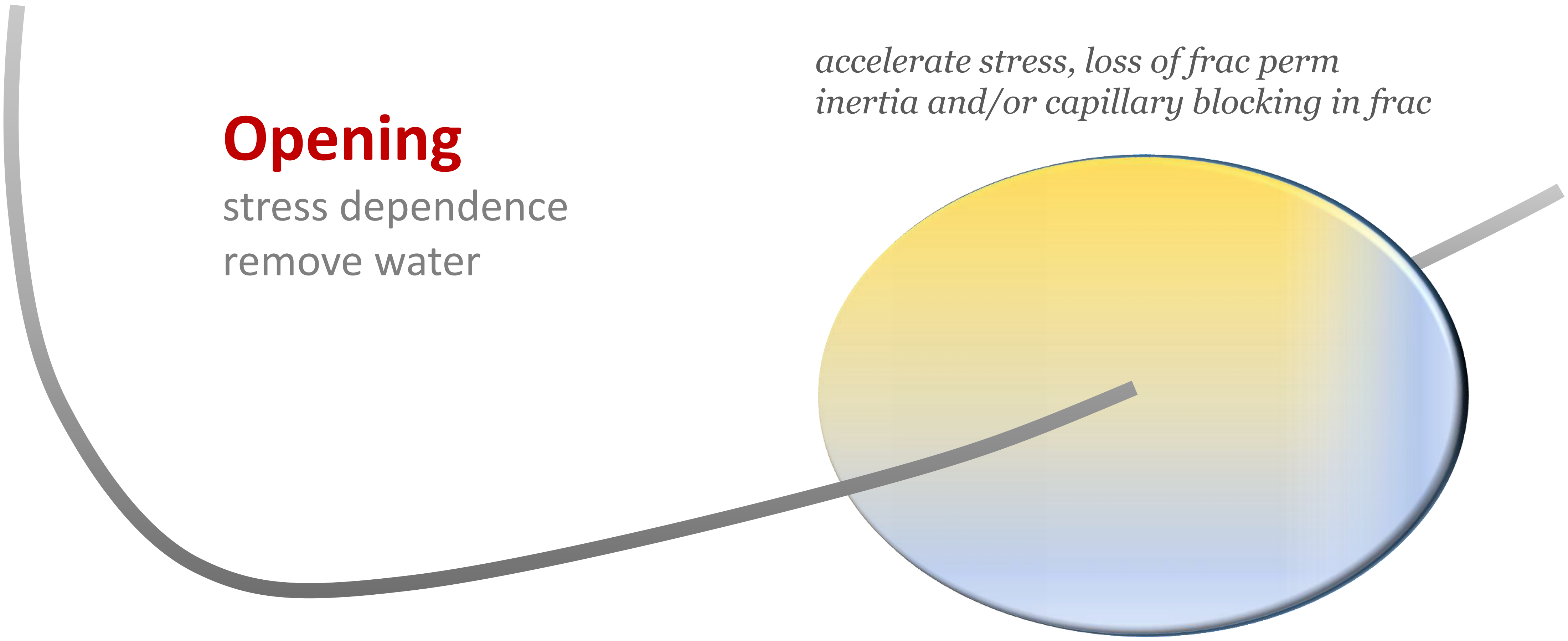
Potential damage to hydraulic fracture (3/3)



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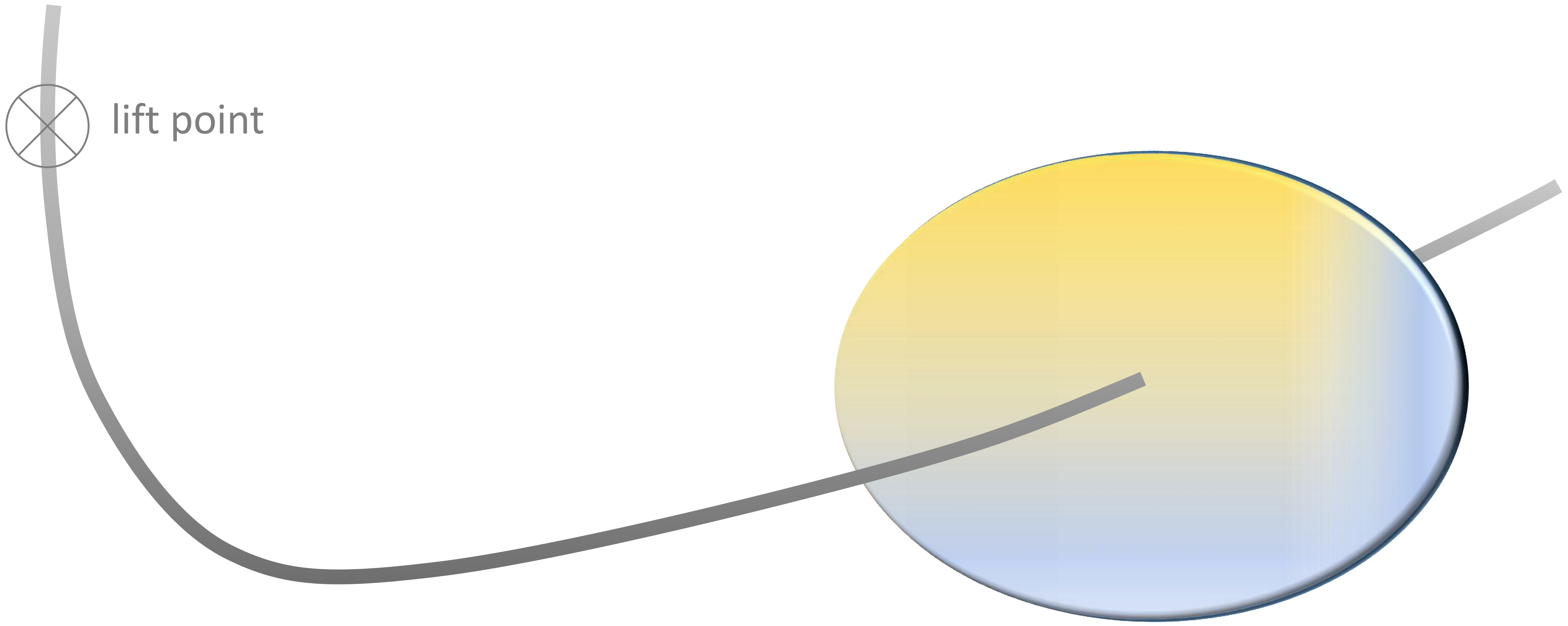
Removing water from hydraulic frac



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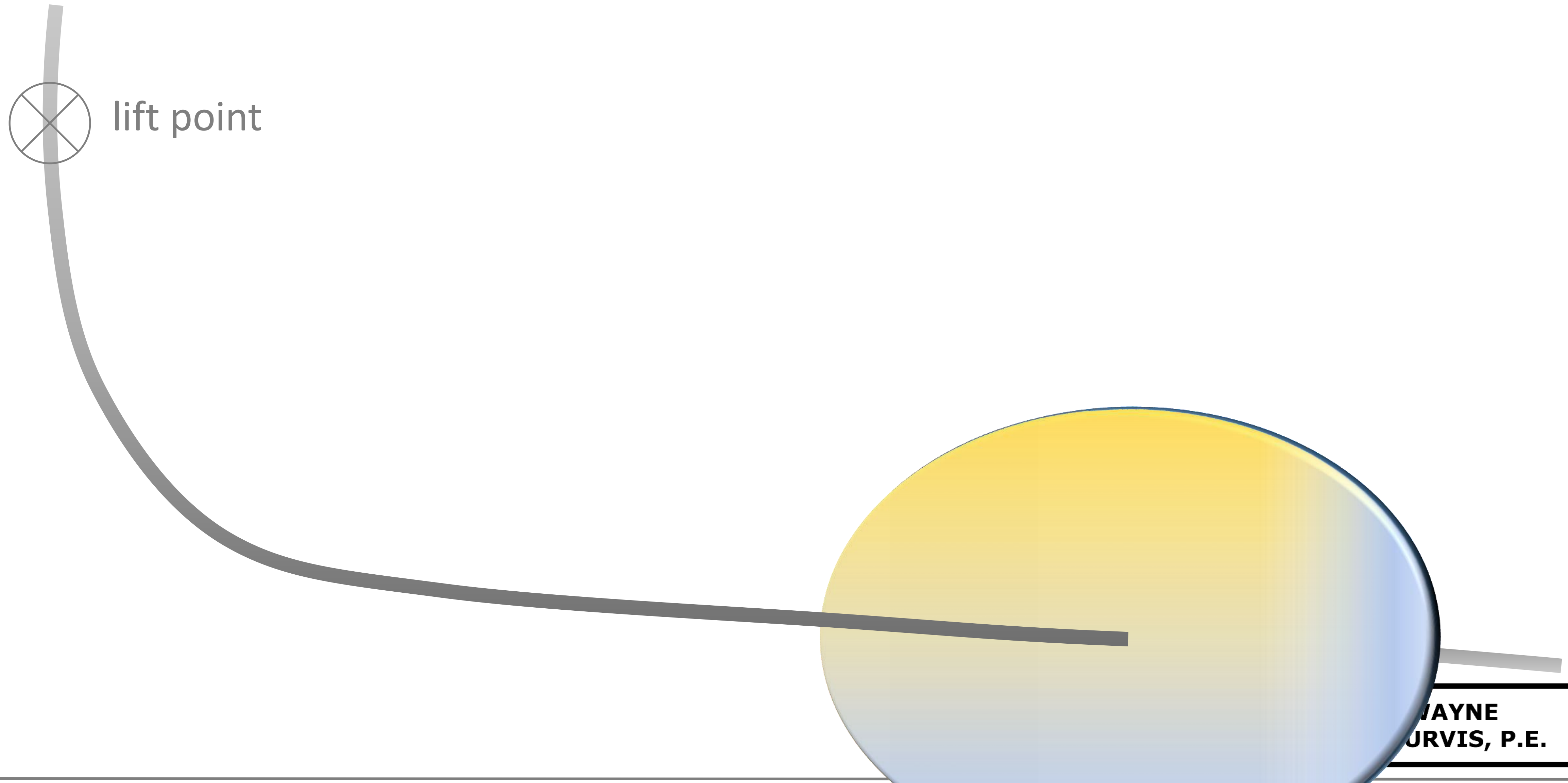
Removing water from hydraulic frac



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Choke management applies to restart as well

Choke Management

(Practice also called "slowback")

Producing a well too fast can damage conductivity of hydraulic frac and reduce recovery.

Primary mechanism is accelerated mechanical stress pinching already narrow fractures. (Also flushing proppant from the reservoir.)

"Fastback" may improve net present value.

"The flowback period of the unconventional wells is very critical as it can cause detrimental economical effects if not properly optimized. "

"Flowback production at high rates and unmanaged flowing bottomhole pressure can result in near wellbore damage and an overall decrease in productivity. . ."

Source: SPE 196203

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Different plays/parts present different risk factors

Risk factors		Higher risk	Lower risk
Capillary blocking	- lower initial water saturation - free water production	Bone Spring west side Barnett	
Loss of conductivity	- less stiff/more ductile rock (lower Young's modulus, clay content) - softer rock - higher stress (often deeper)	Haynesville Marcellus Utica Barnett combo	Barnett Fayetteville
Age/pressure of wells	- younger, less depleted/damaged wells but - older less able to unload water		

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"We are not in the business of making oil.
we are in the business of making money."

decisions

analysis

data

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“We are not in the business of making oil. we are in the business of making money.”

Near-term, high value

restart strategy
reserves on restart
completion design
well locations &
well spacing

Opportunities

study
RTA
PTA
Interference testing

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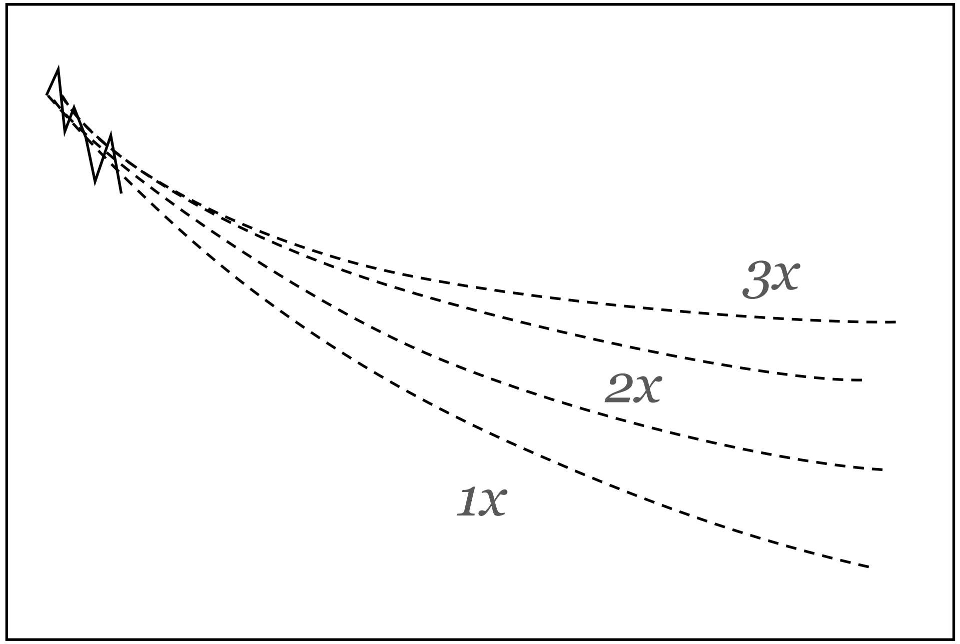
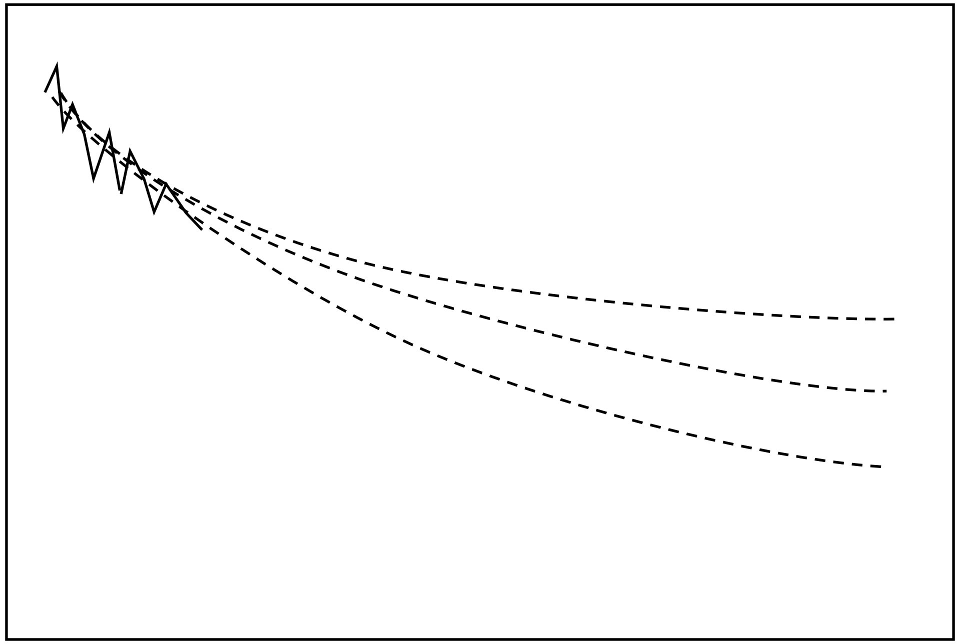
Decline curve analysis is low-resolution but. . .



. . .improves slowly with time, but. . .



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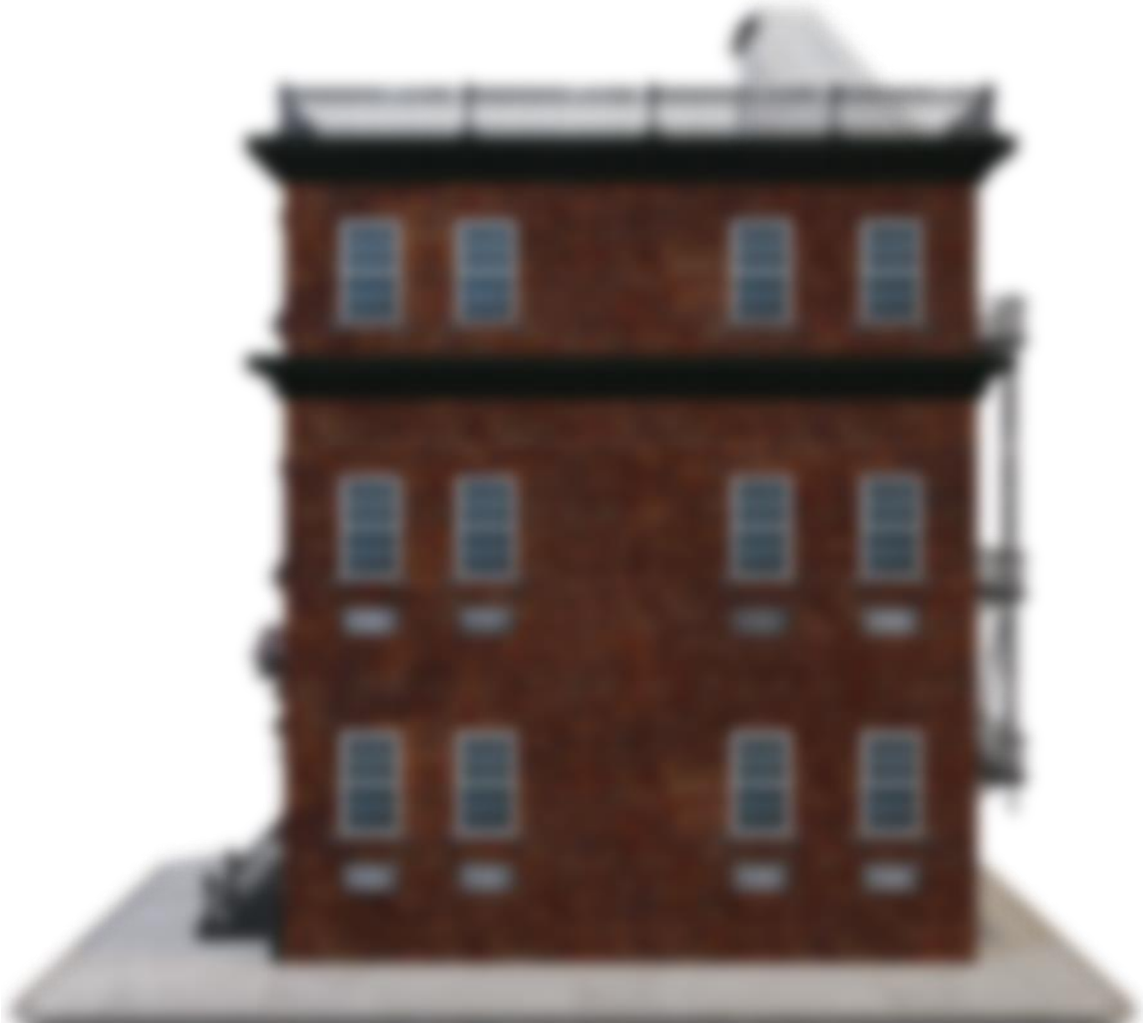

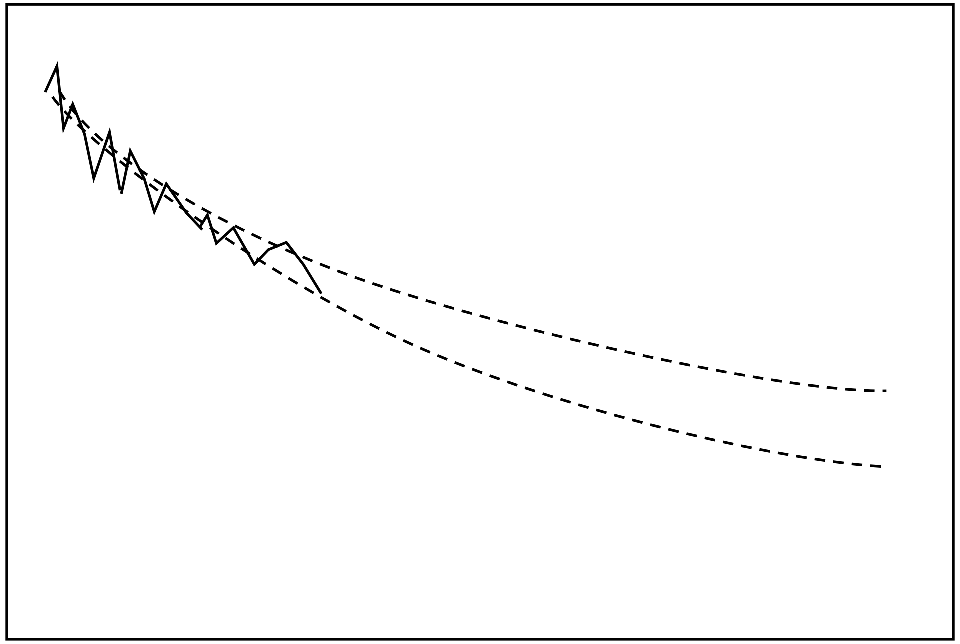

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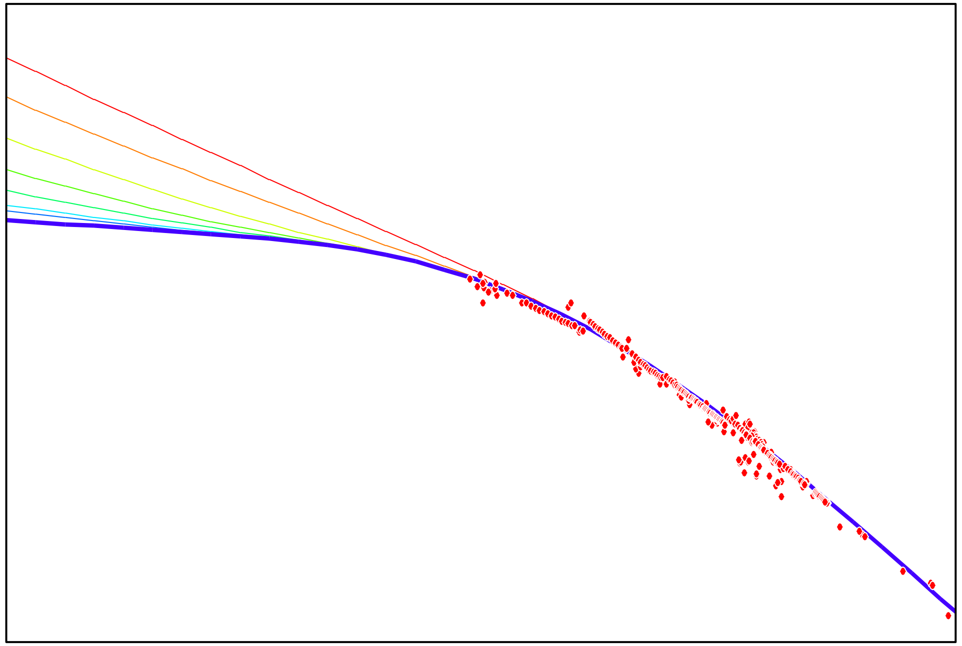
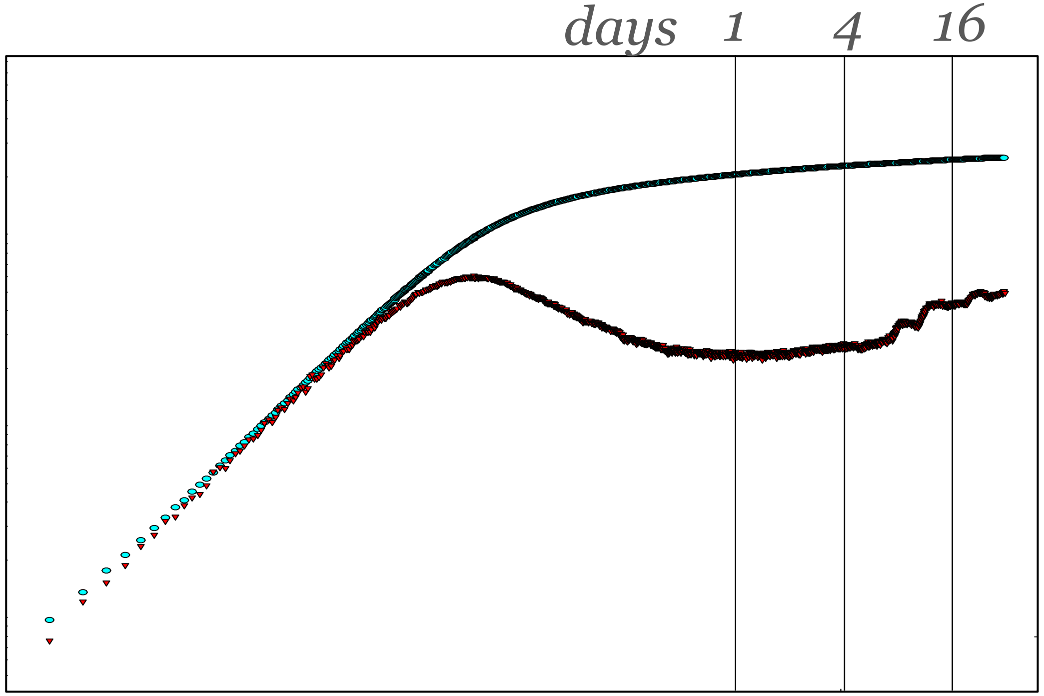
RTA clarifies the picture sooner.



RTA
adds constraints
accelerates insight

PTA offers a different view. . .



PTA
closer to wellbore (usually)
more about properties
single point in time

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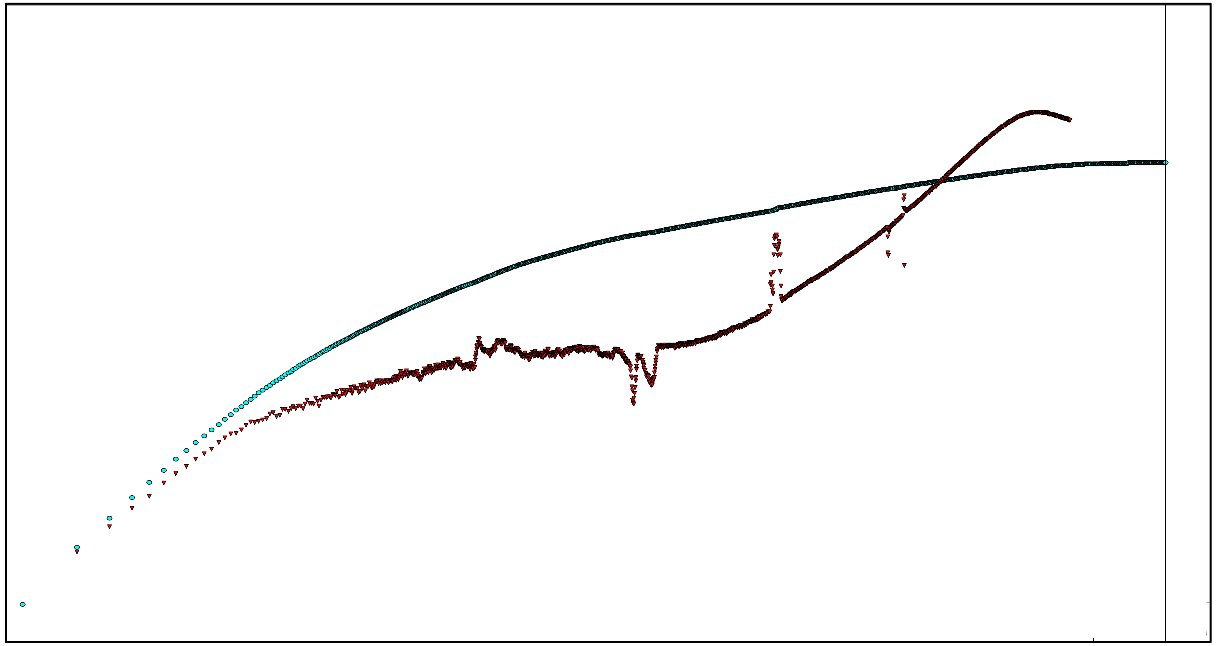
PTA offers a different view. . .

210 days



PTA
longer => farther
interference

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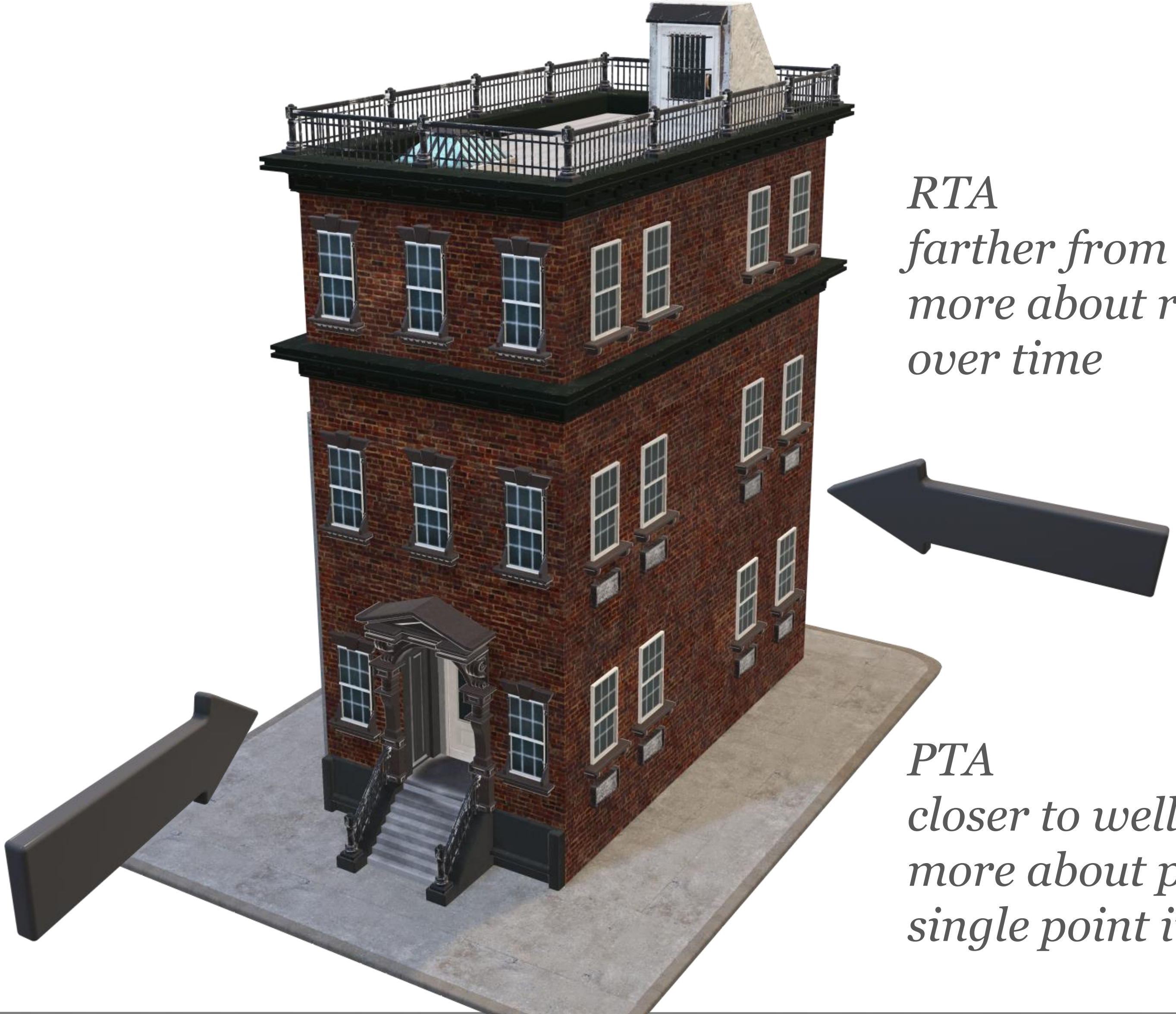
. . .to make a more complete picture



RTA
farther from wellbore
more about reserves
over time

INTERFERENCE
farther from wellbore
connection between wells

PTA
closer to wellbore (usually)
more about properties
single point in time

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. . .to make a more complete picture

Combined, the views yield
. . .more information
. . .more unique interpretation
. . .more confidence

on high-value, next-step issues
- *restart strategy*
- *reserves on restart*
- *completion design*
- *well locations &*
- *well spacing*

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The next early time data. . .

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. . .becomes more clear

Insights can be reused
decline parameters
well spacing
field extensions

Aim small, miss small

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Thank You!

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