



# Unusual Reservoir Connectivity Revealed by Data Integration at the Sunrise Field

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# The Problem

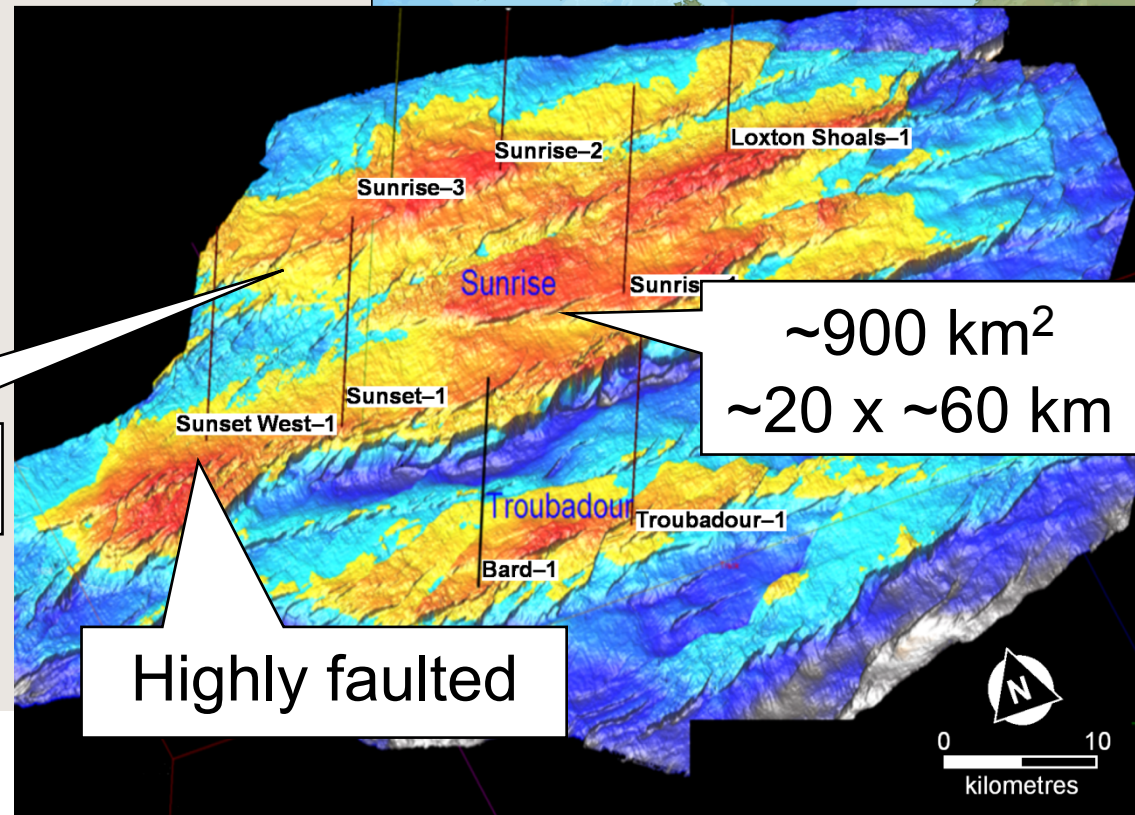
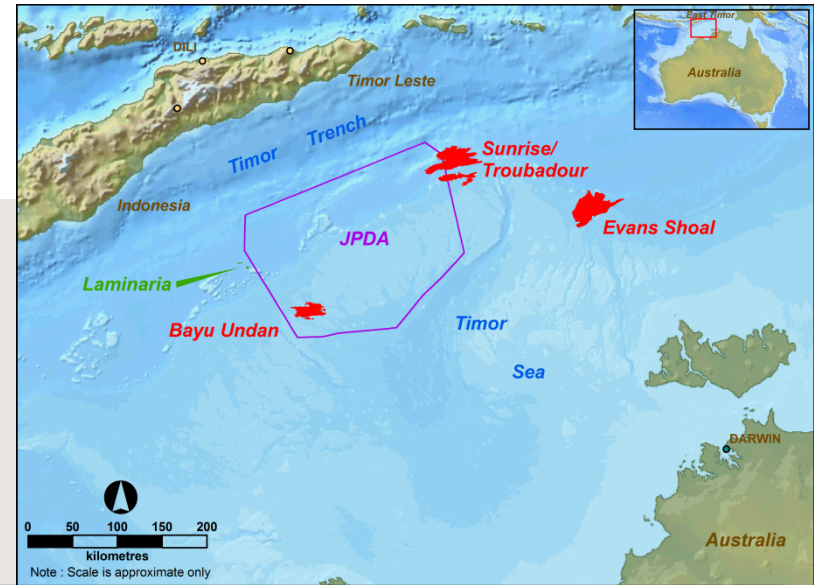
Considered potential high risk of compartmentalization in past

But uncertainty, other evidence suggests good reservoir connectivity

Challenge: relatively wide appraisal well spacing

6 Appraisal wells

Highly faulted





# Outline

## Background

Initial Insights from Static Data

Convective Mixing Over Geological Time

Re-Evaluation of Connectivity

Sunrise-3 Appraisal Well - Confirmation

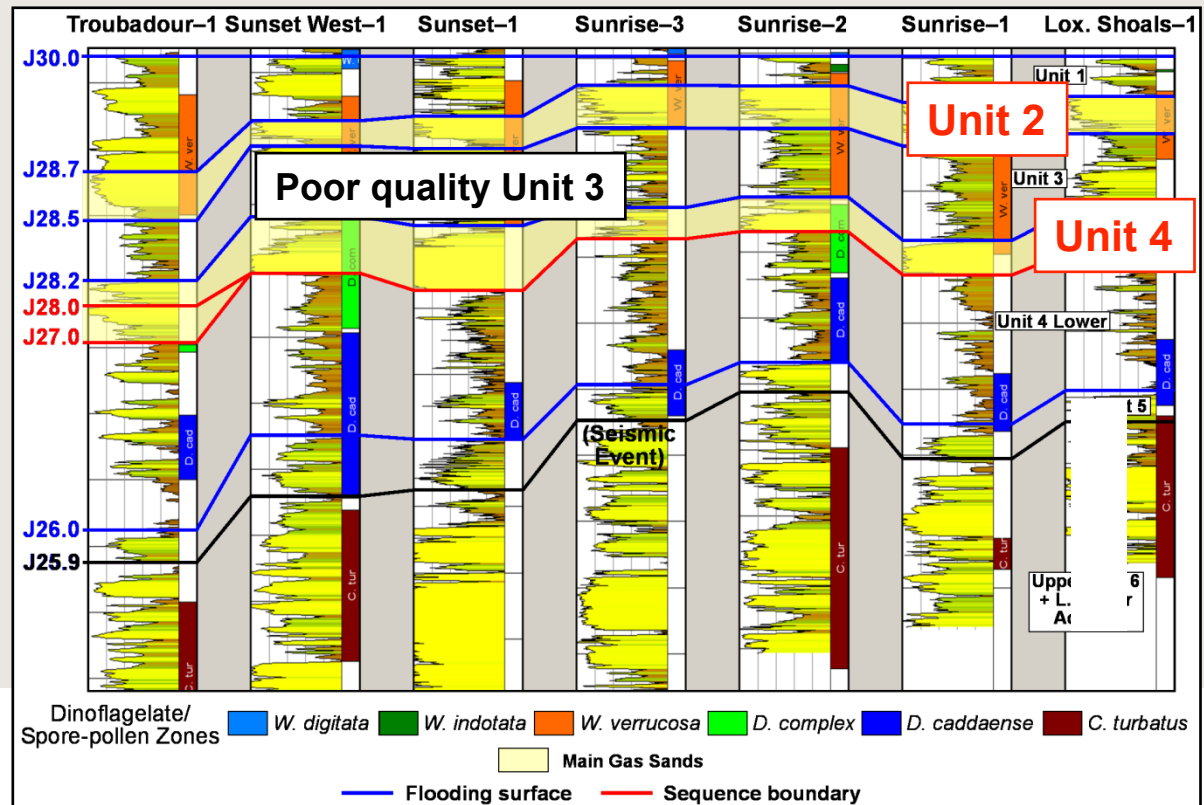
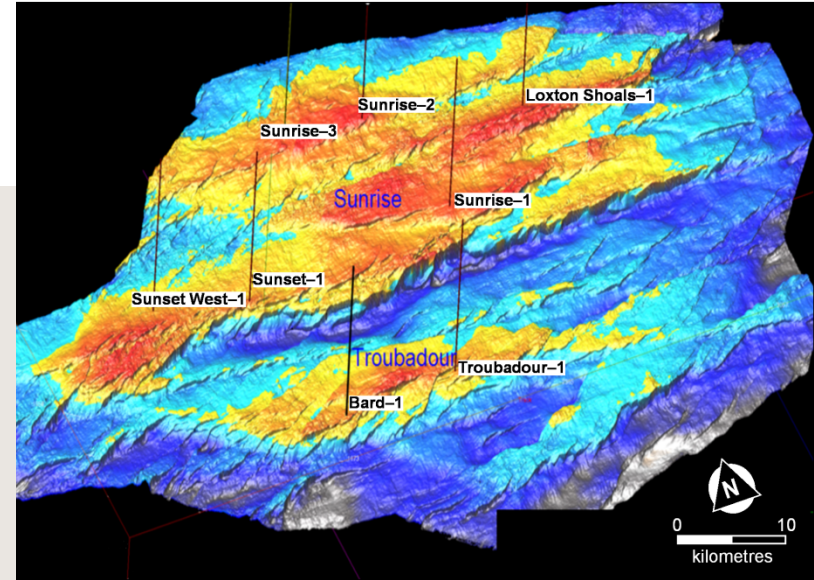
# Background

Discovered 1975

2 laterally extensive reservoirs, Units 2 & 4, ~ 15 m thick

Separated by laterally-extensive, poor-quality, Unit 3

Gas charge geologically young (0.6 – 12 Ma)

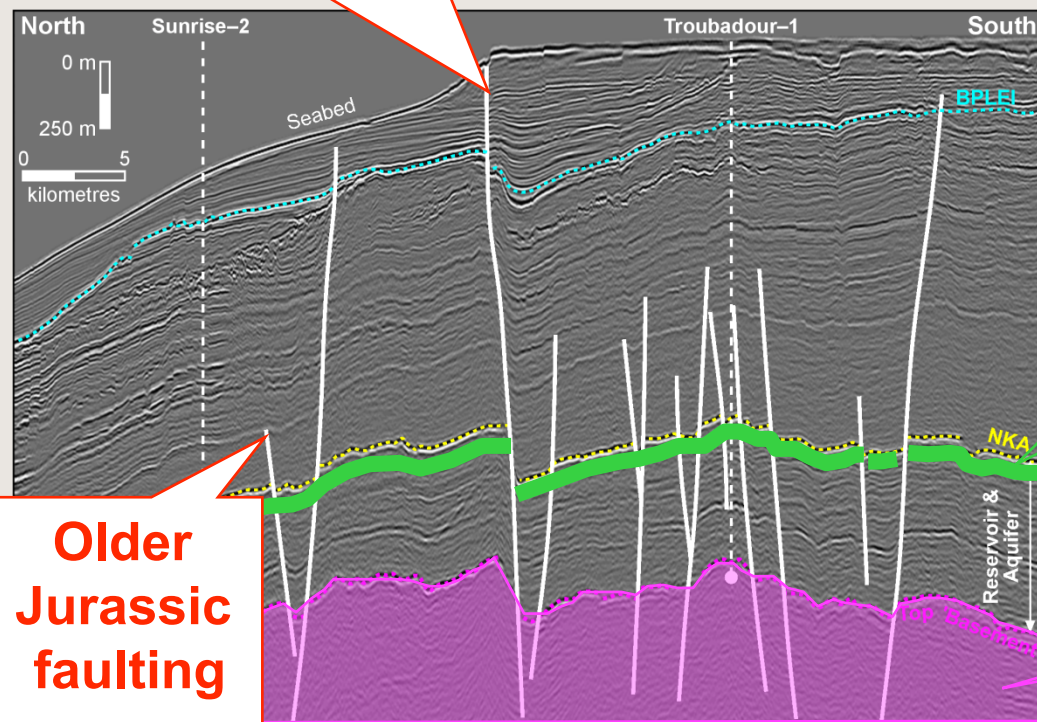
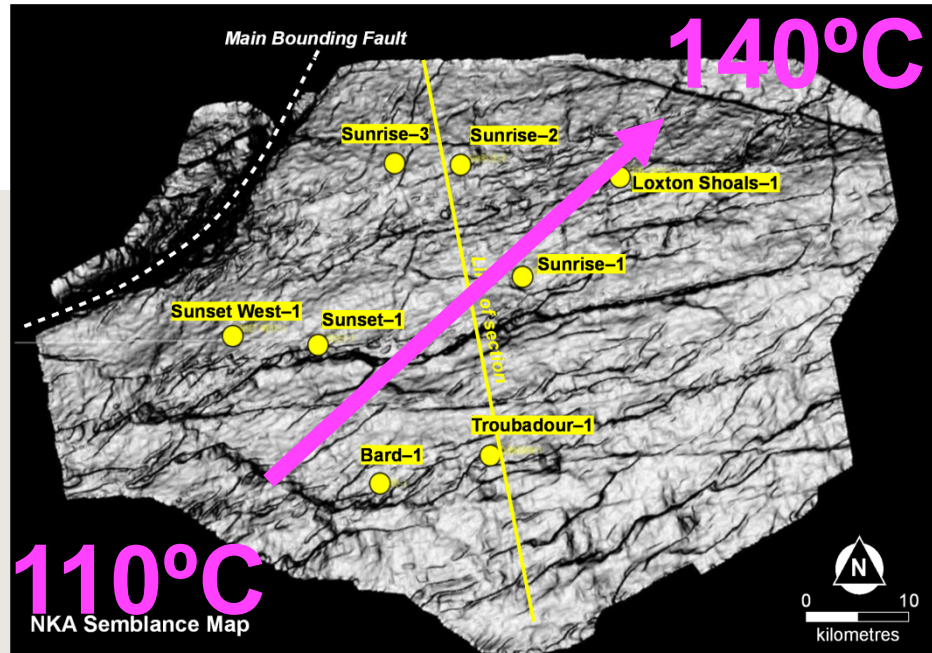


# Sunrise is in a Zone of Recent Tectonic Activity

Older Jurassic faults from rifting

Reactivated in the Neogene to Recent times

**Recent reactivated faults**



**Sunrise Reservoir Section**

**Hot radioactive granite basement**



# Outline

Background

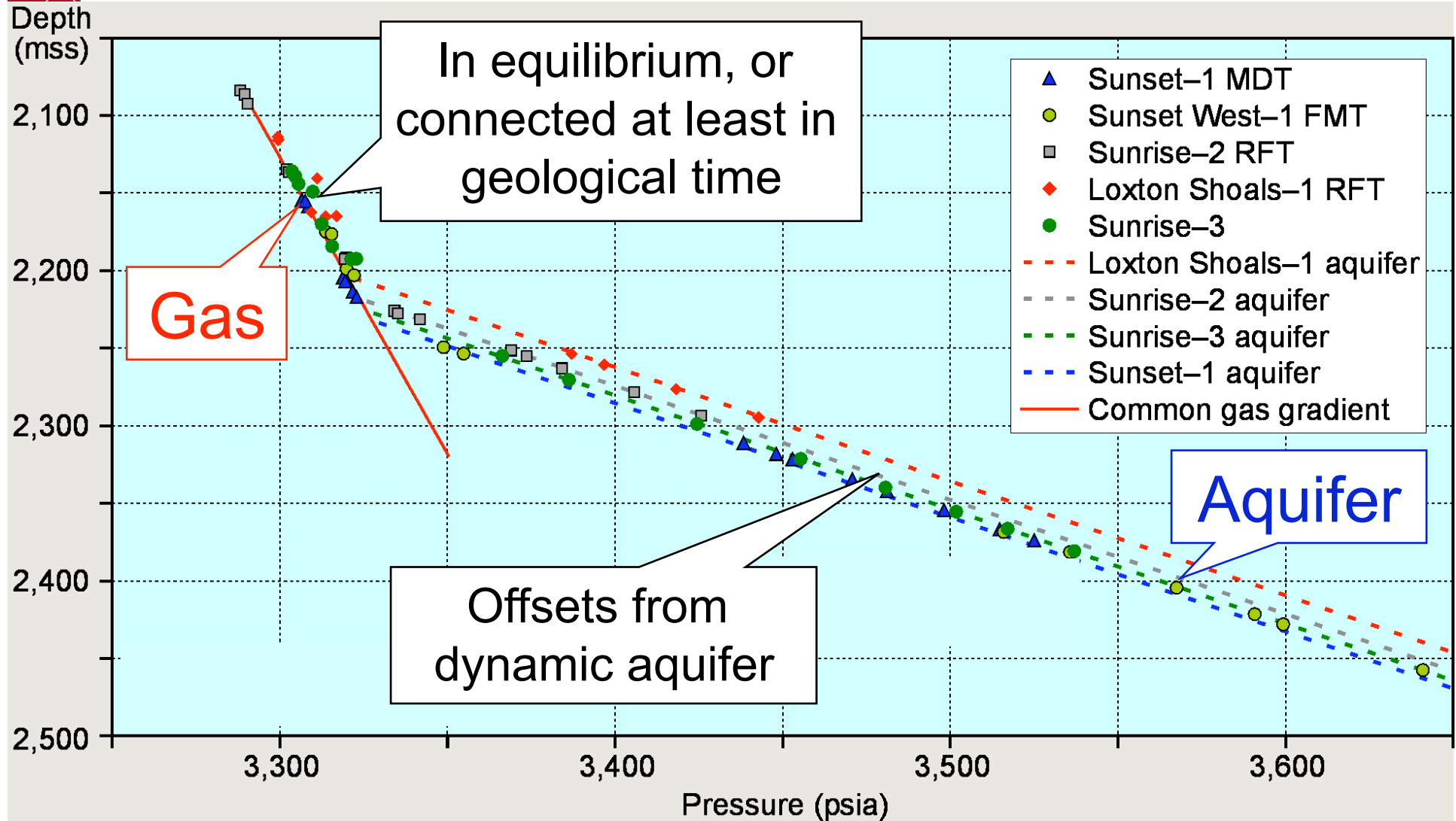
**Initial Insights from Static Data**

Convective Mixing Over Geological Time

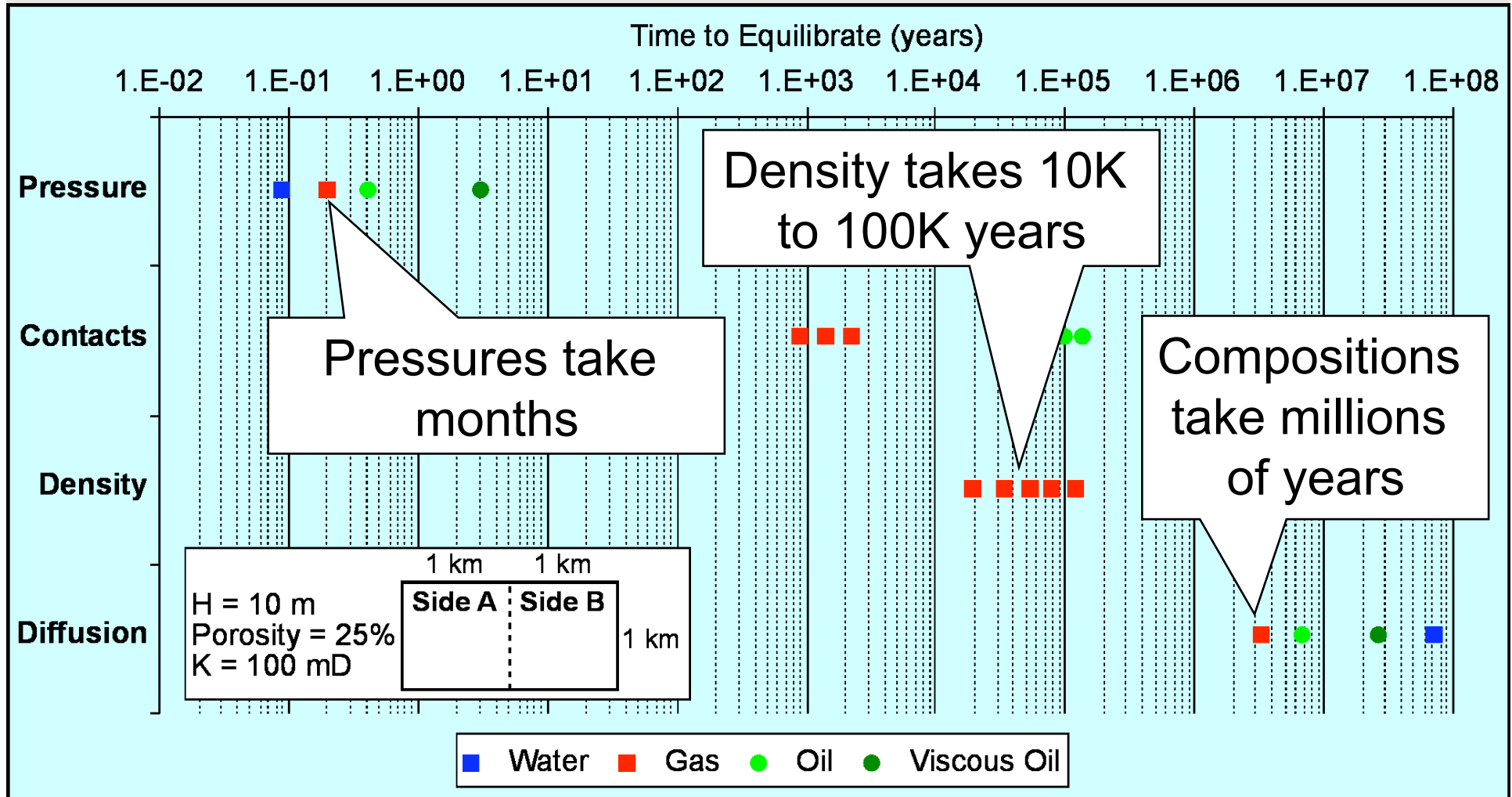
Re-Evaluation

Sunrise-3 Appraisal Well - Confirmation

# Formation Pressures



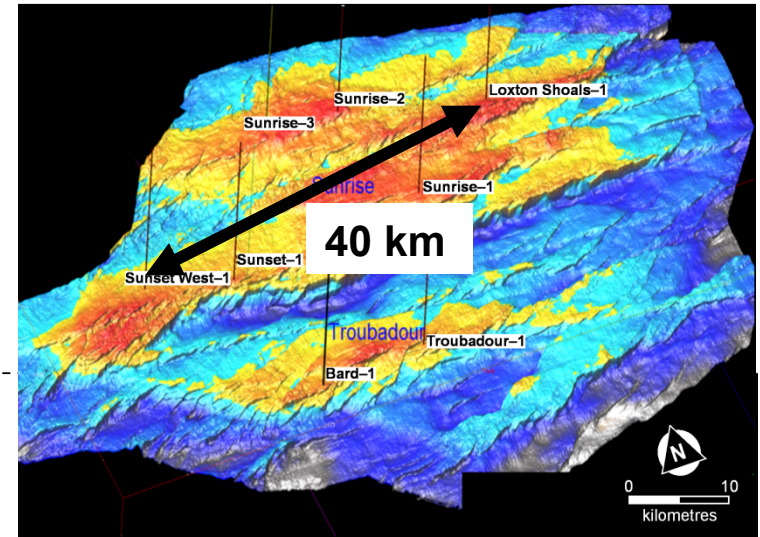
# How Much Time is Required for Equilibration?



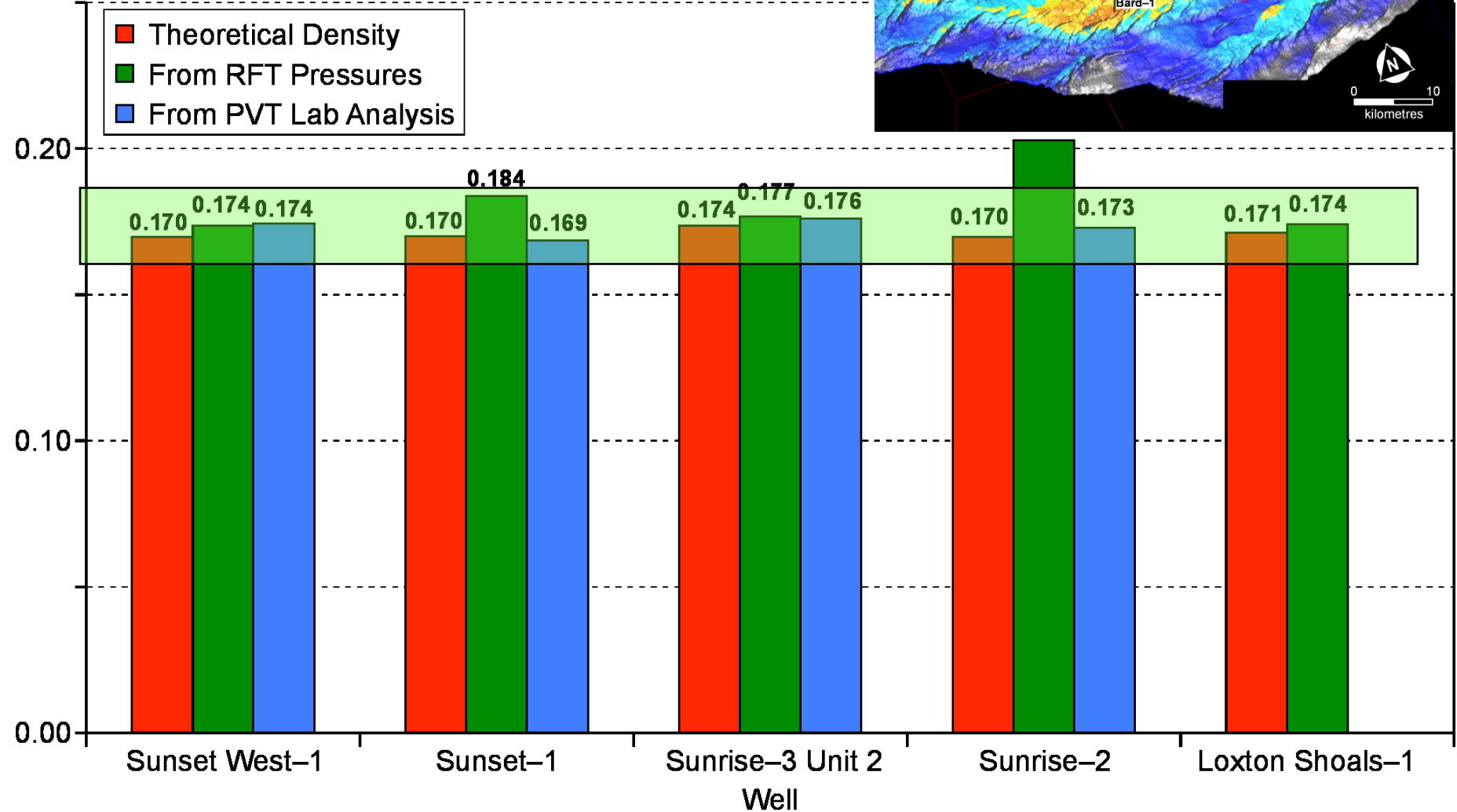
(Modified from Smalley et al., 2004)



# Equilibrium in Gas Density Across Over ~ 40 Km



In Situ Density  
(g/cc)

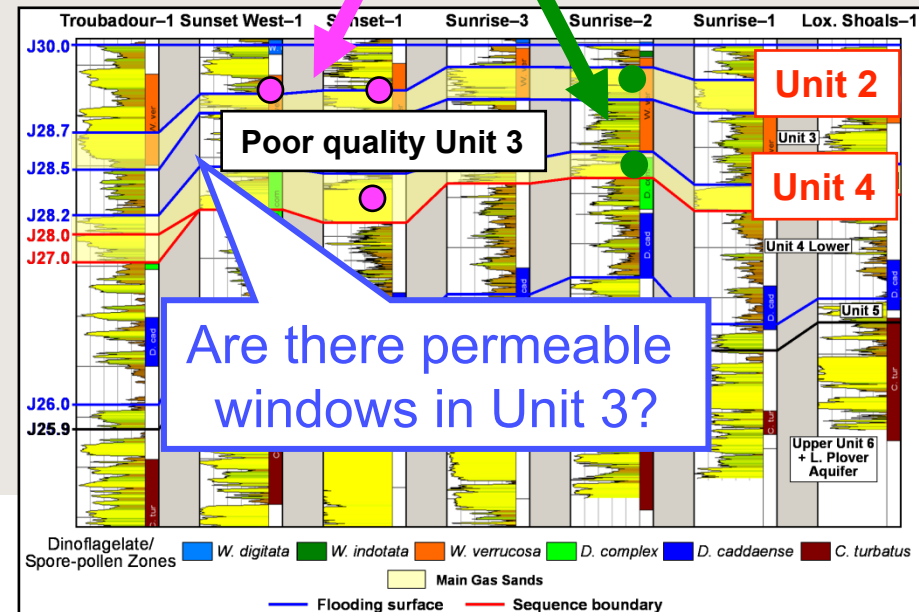
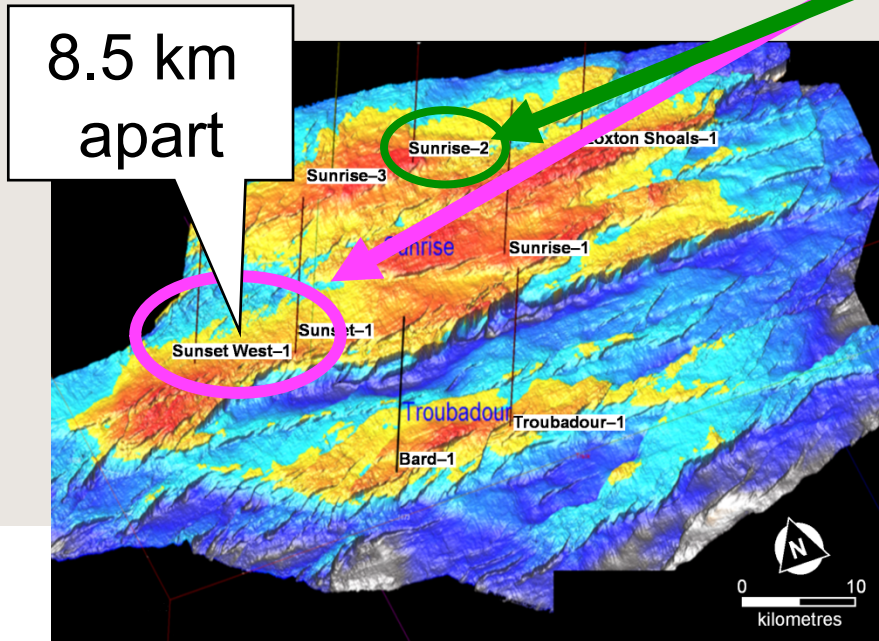
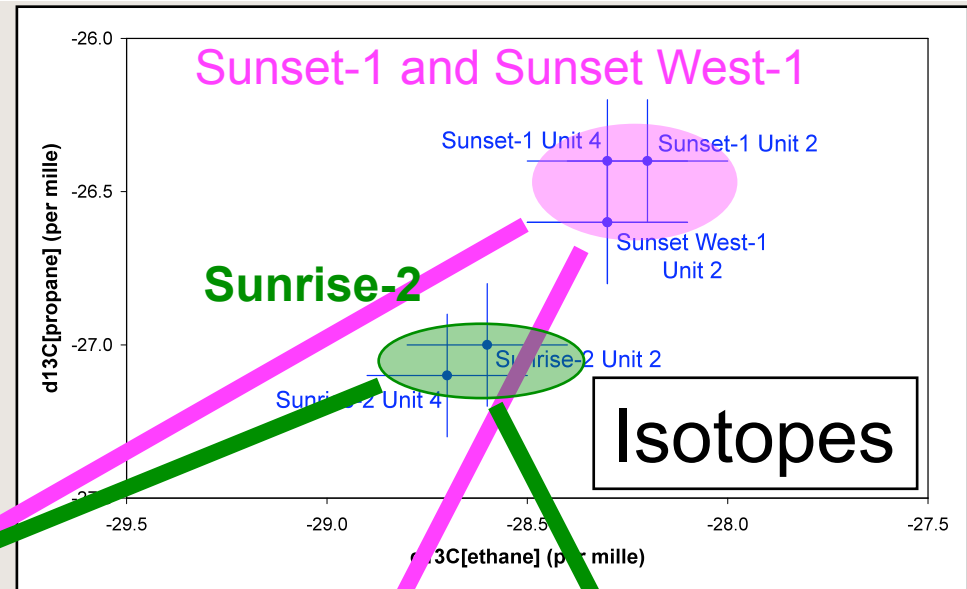


# There is Unusual Geochemical Equilibrium in This Geologically Young Field

How did gas mix so well across “impermeable” Unit 3?

How did gas mix so well laterally over distances of 8.5 km to 20 km?

Similar patterns in compositions, nitrogen, CO<sub>2</sub> and helium





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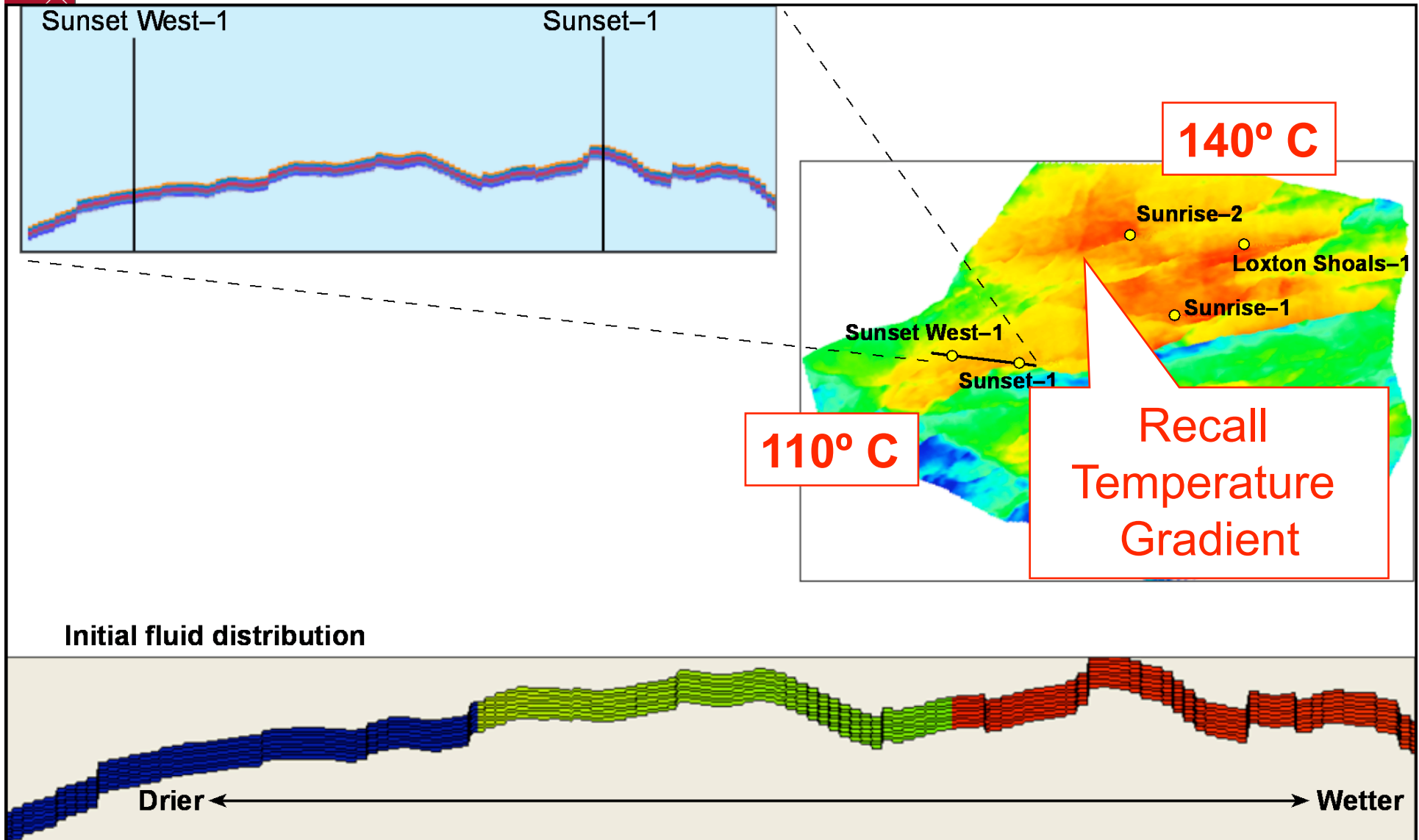
Initial Insights from Static Data

**Convective Mixing Over Geological Time**

Re-Evaluation of Connectivity

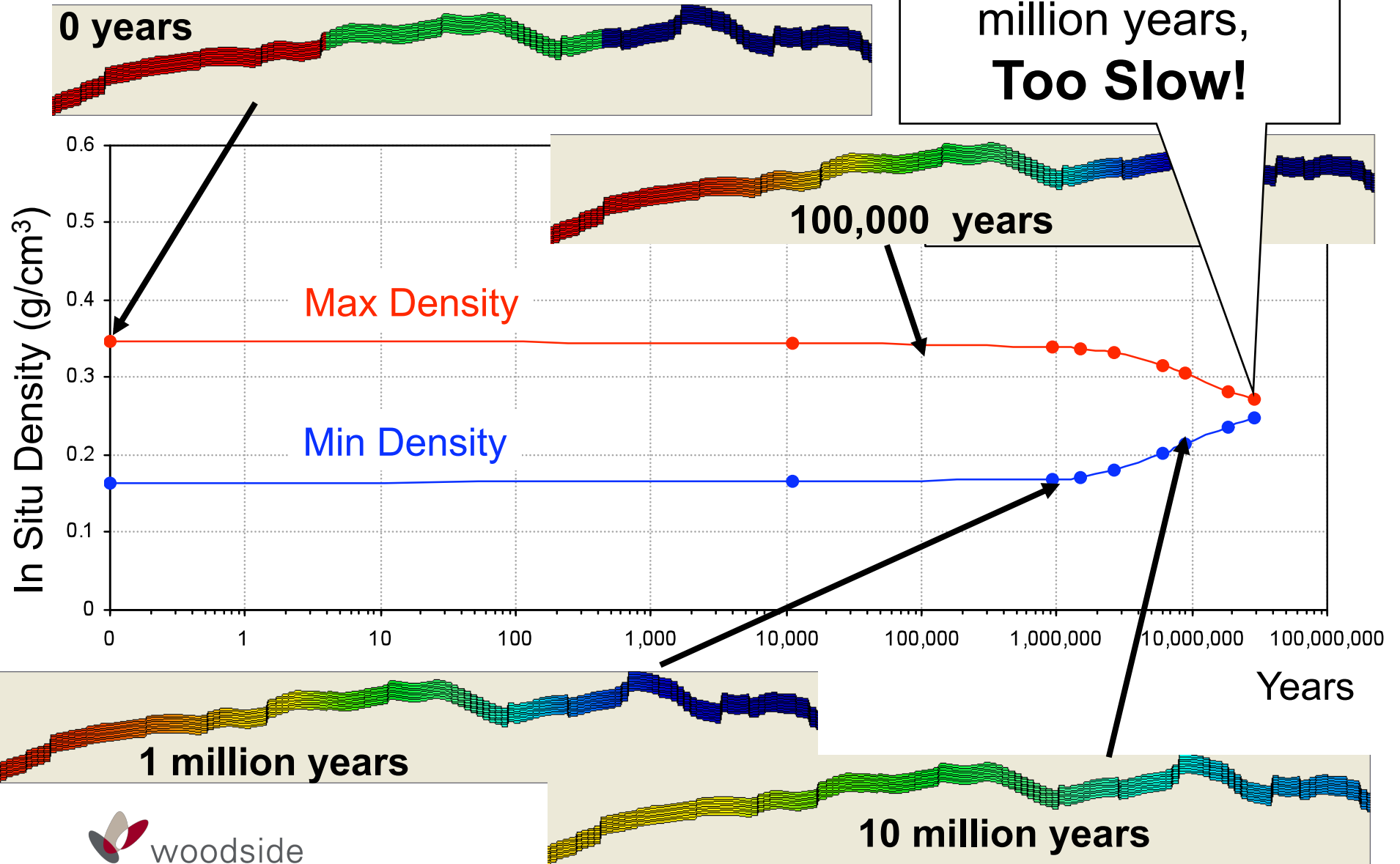
Sunrise-3 Appraisal Well - Confirmation

# Examine Convective Mixing of Gas Over Geological Time Using Numerical Simulation (in Permedia “Mpath”)



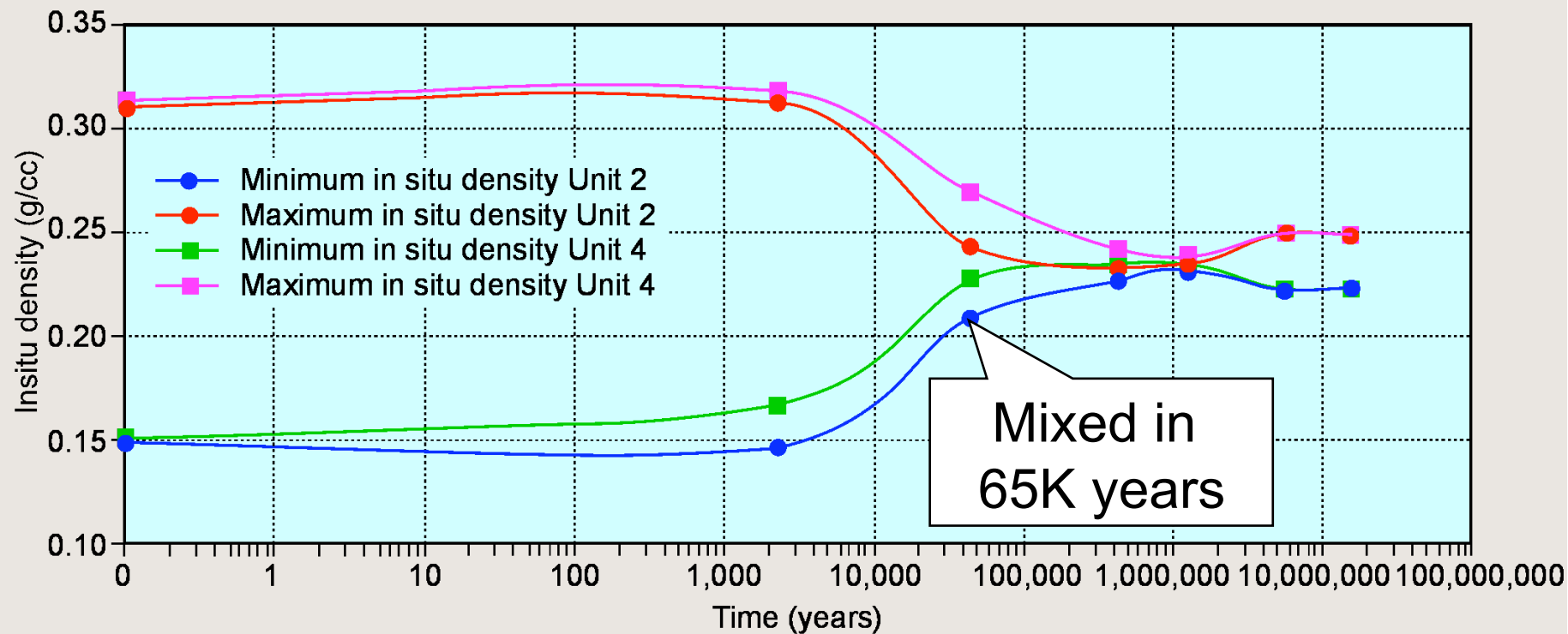
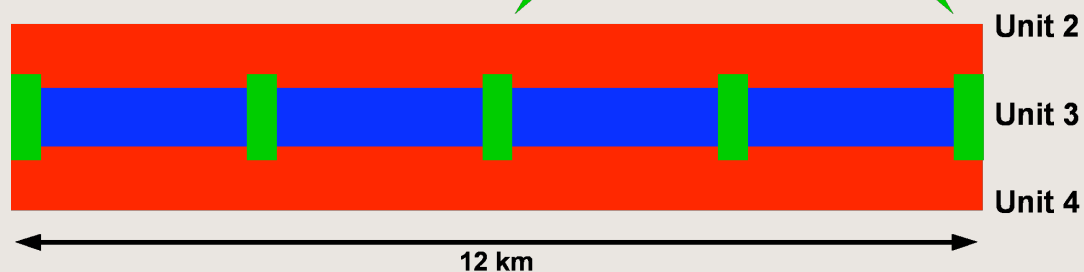
# Mixing in a Single Layer

Equilibrium in 25 million years,  
**Too Slow!**

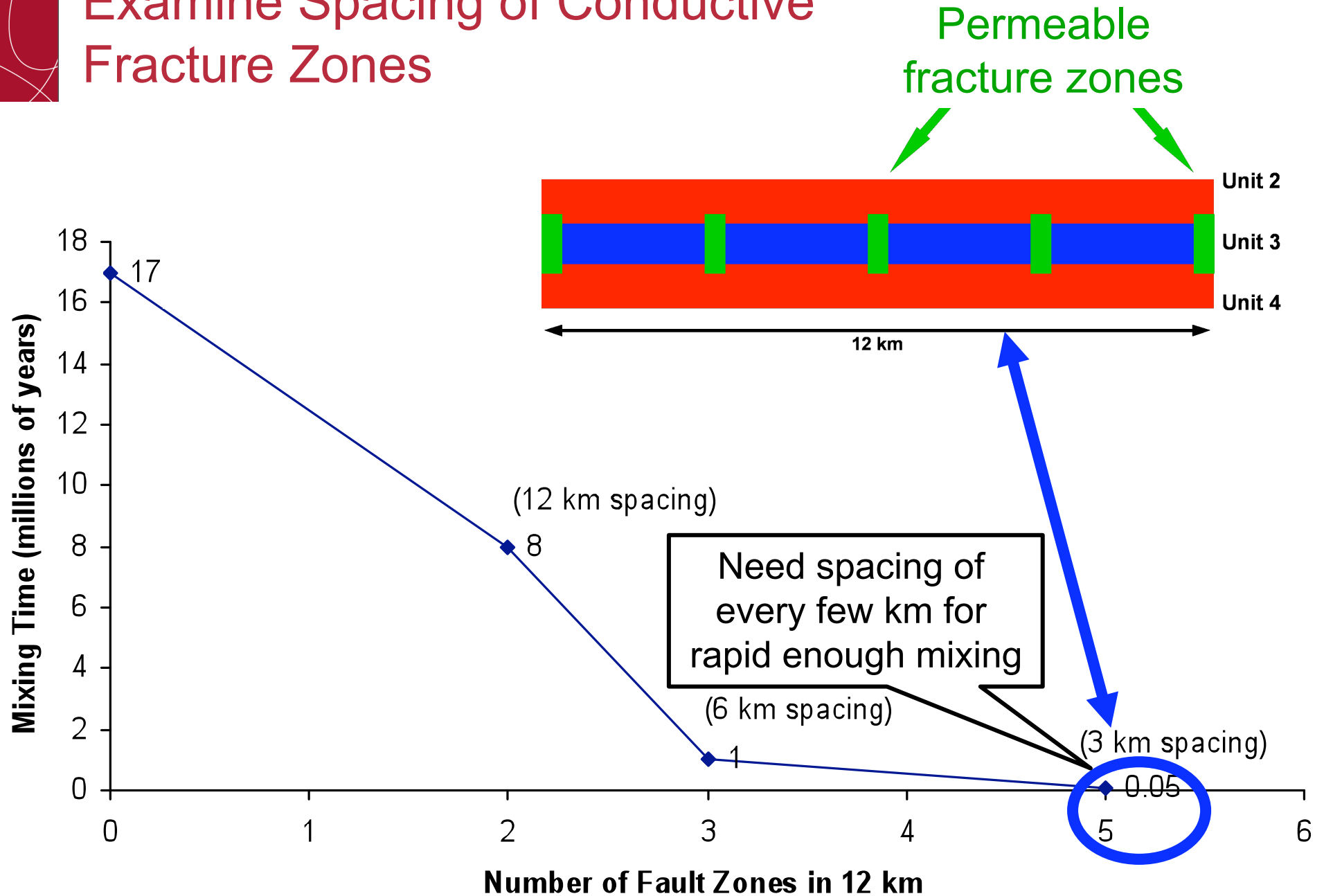


# Sandwich Model with Permeable Fracture Zones

Permeable fracture zones



# Examine Spacing of Conductive Fracture Zones





# Outline

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Initial Insights from Static Data

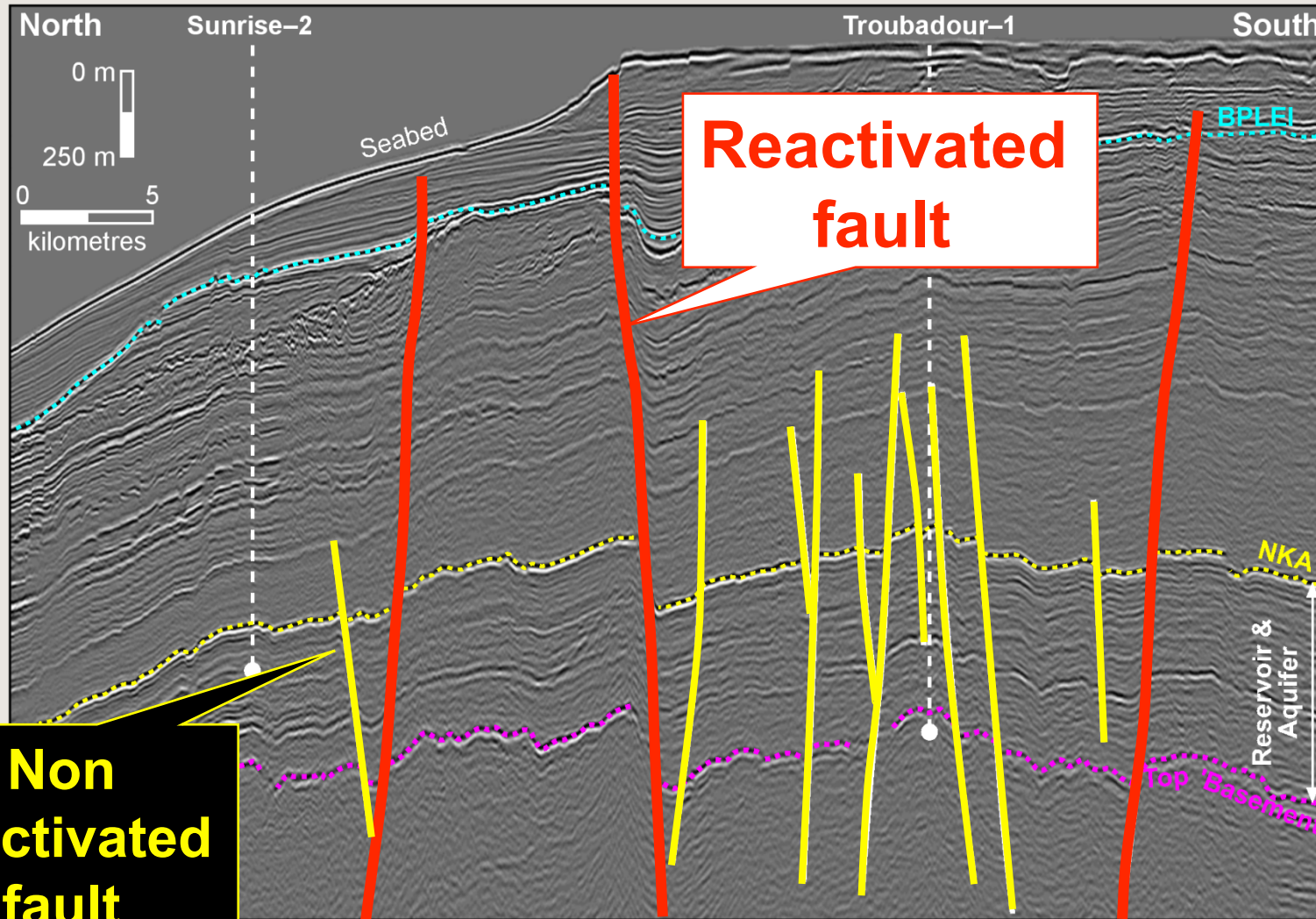
Convective Mixing Over Geological Time

**Re-Evaluation of Connectivity**

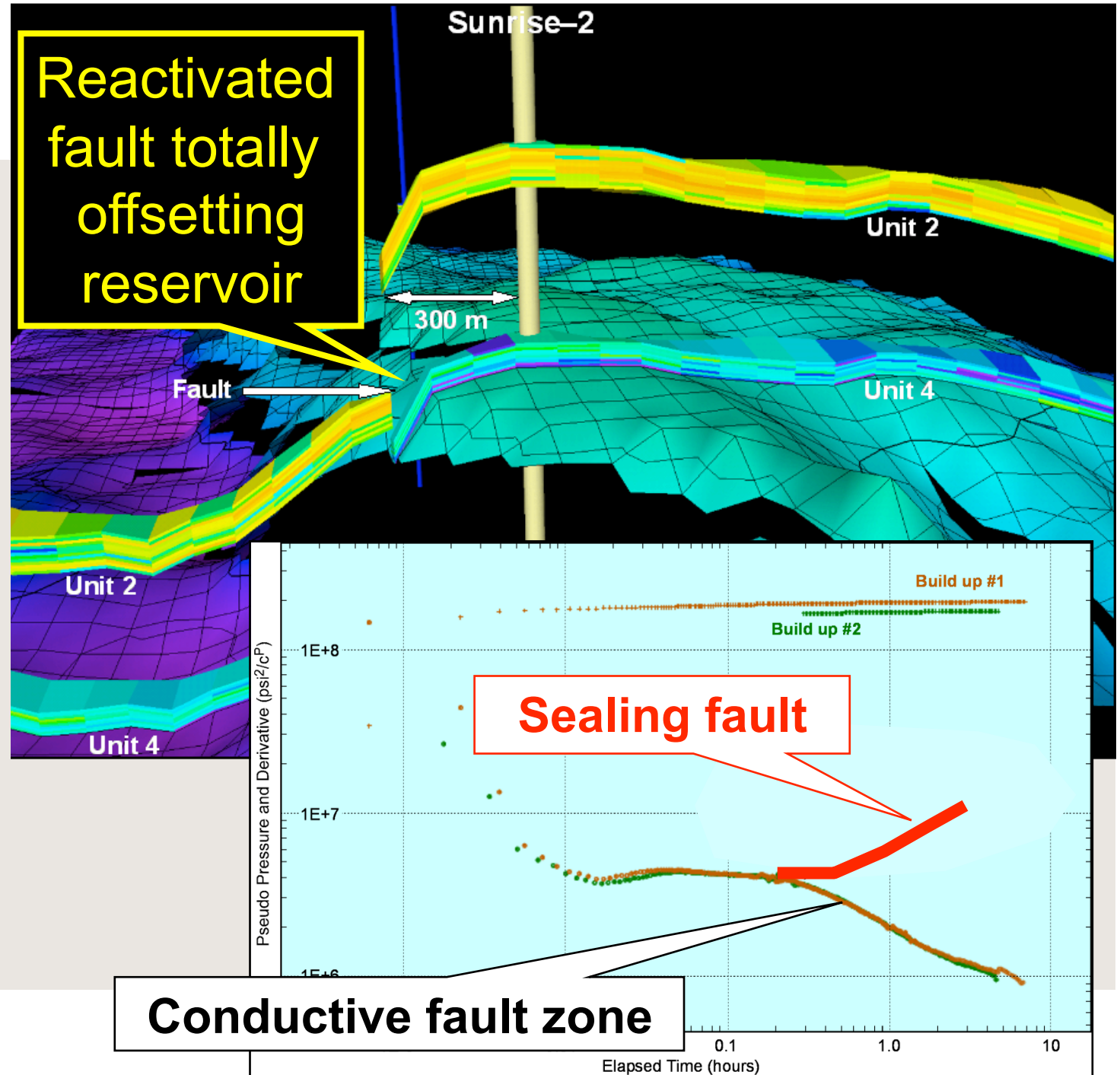
Sunrise-3 Appraisal Well - Confirmation



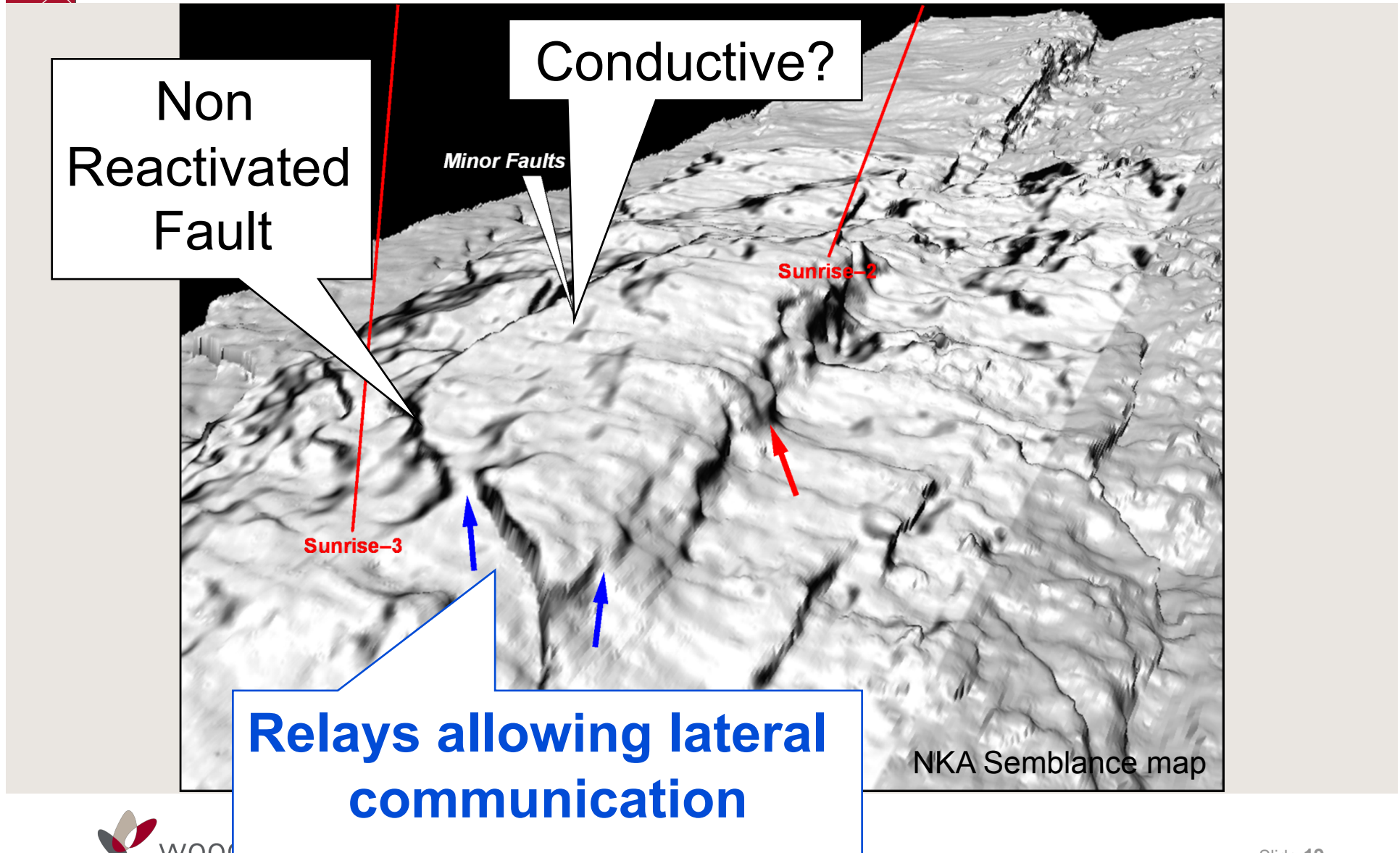
# Are Some of the Faults Actually Conductive?



# Sunrise-2 Well Test (Unit 2) Revisited



# Reprocessed Seismic Shows Fault Relays Allowing Lateral Communication Through Large Faults





# Outline

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Convective Mixing Over Geological Time

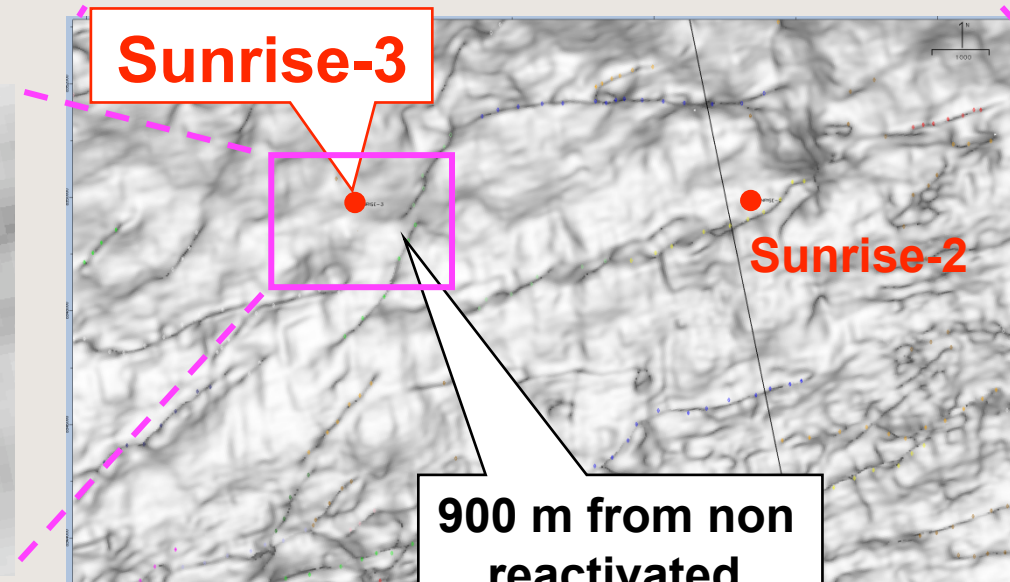
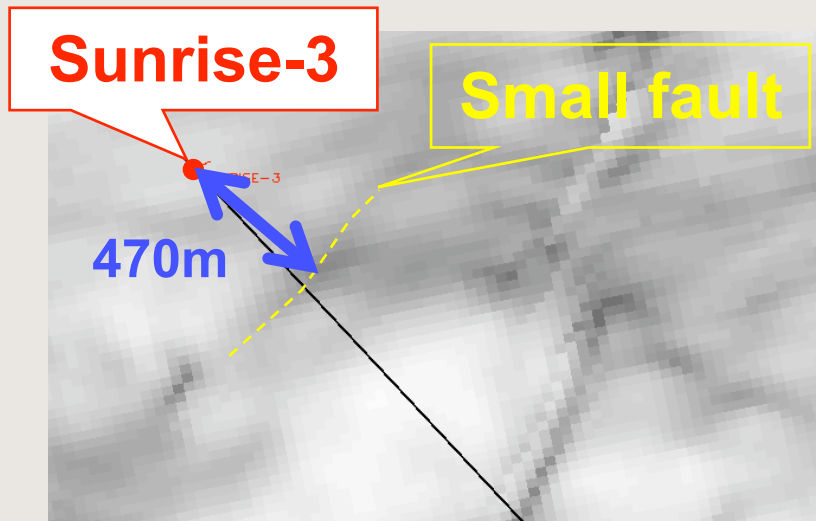
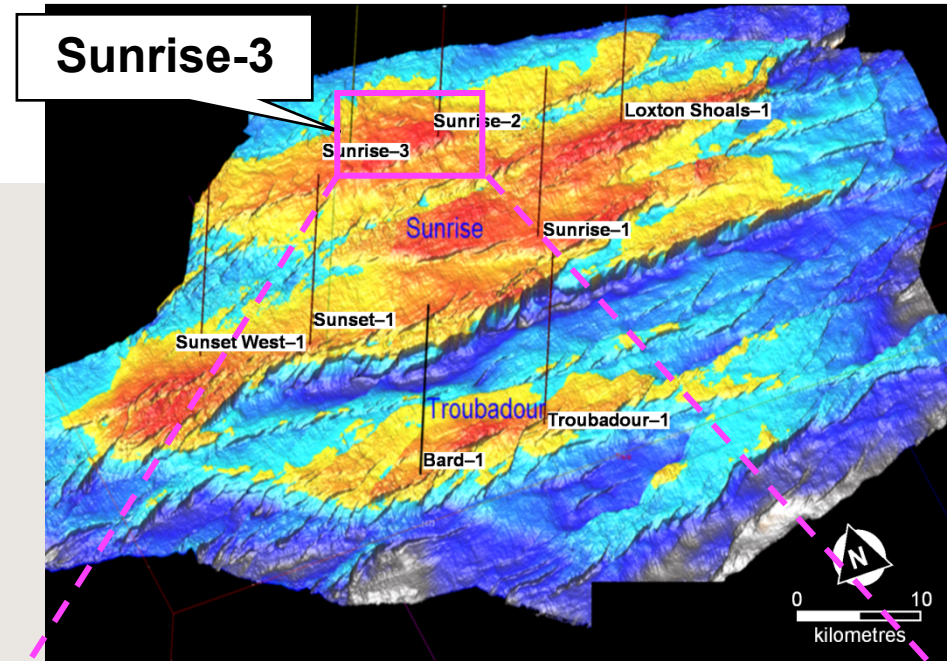
Re-Evaluation of Connectivity

**Sunrise-3 Appraisal Well - Confirmation**

# Sunrise-3 Appraisal (2008)

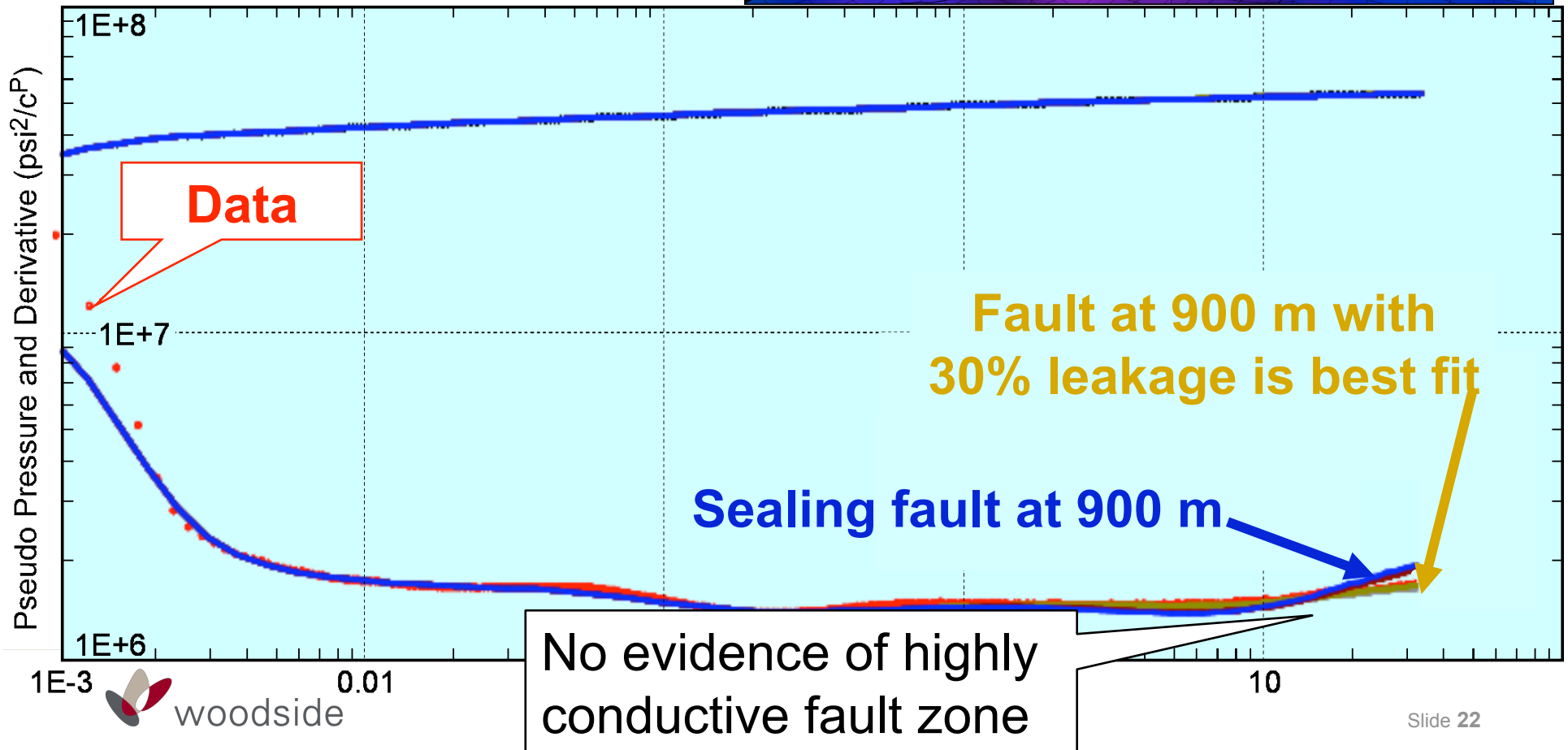
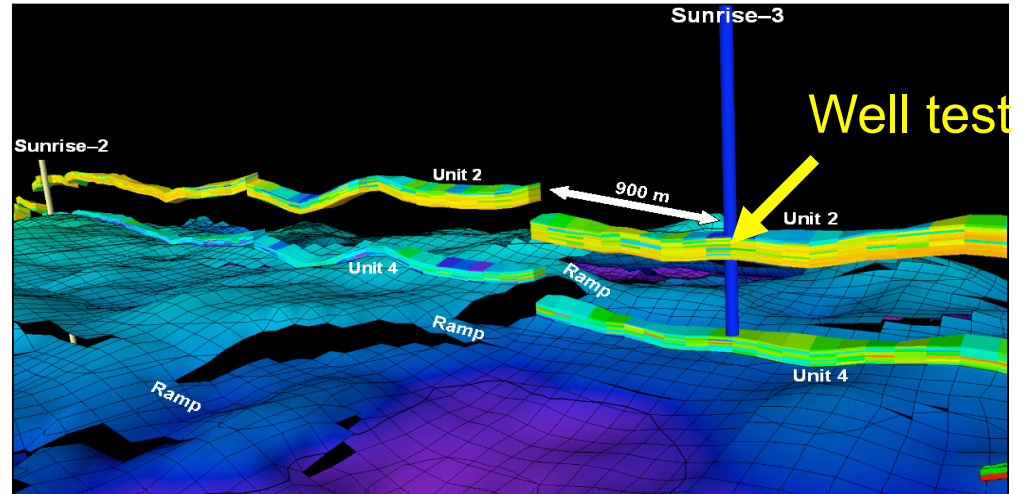
## Goals:

- Test sealing ability of large fault 900 m away
- Test vertical connectivity of small fault 470 m away





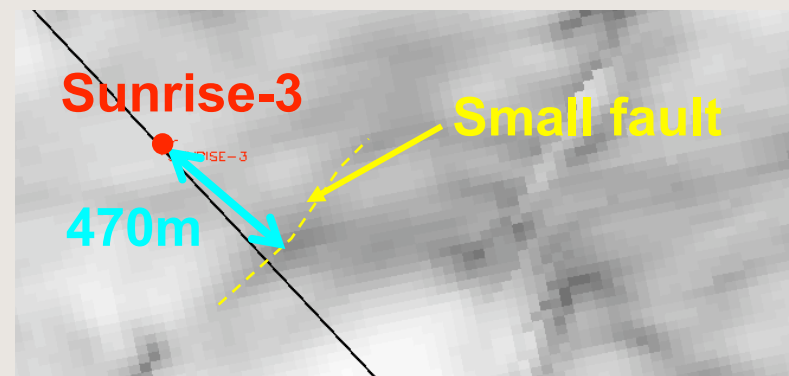
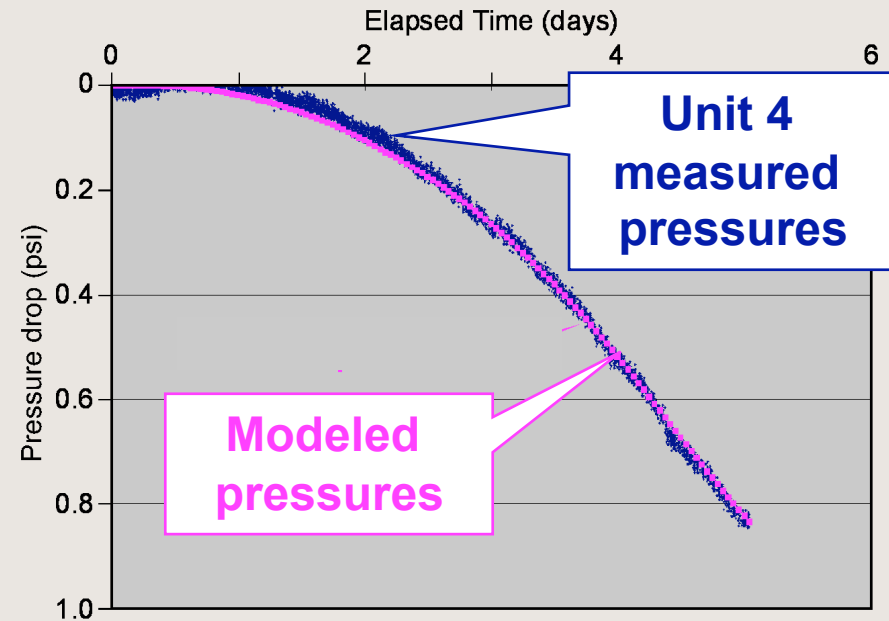
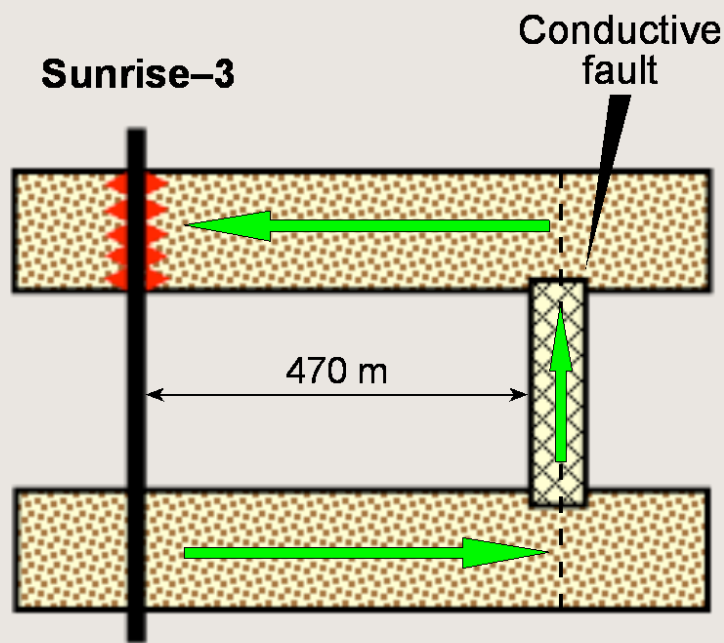
# Sunrise-3 Unit 2 Well Test



# Sunrise-3 Vertical Interference Test Between Units 2 and 4

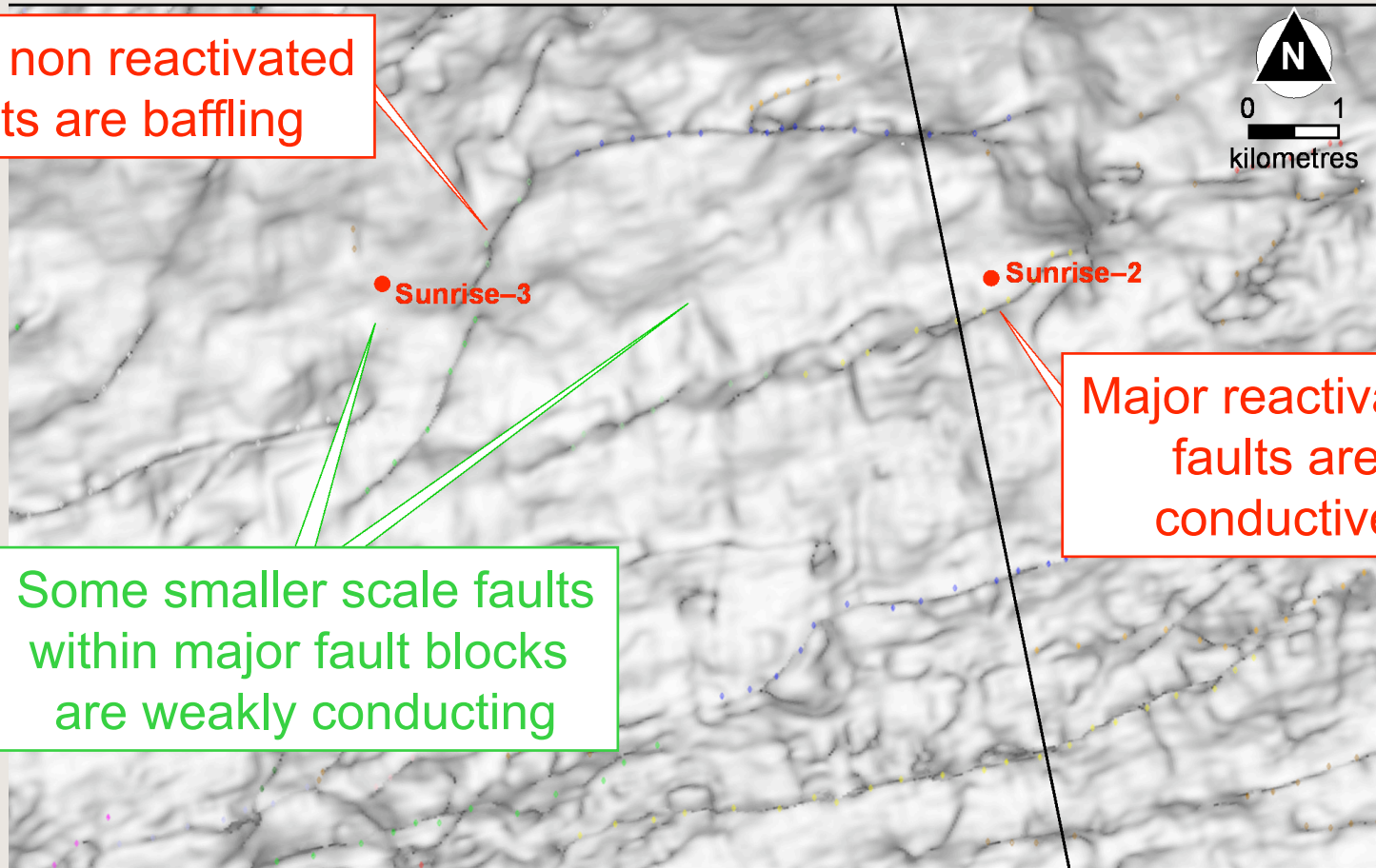
Vertical connectivity in production time confirmed

Subtle vertical connection through small fault is best match



## Conclusion: Sunrise is Well Connected Vertically & Laterally Over large Distances, Much Probably in Production Time

Major non reactivated faults are baffling



Major reactivated faults are conductive

Some smaller scale faults within major fault blocks are weakly conducting

- Confidence in conclusions from consistent message across all data sets
- Modelling of convective mixing in geological time can be a powerful tool





# Acknowledgements

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