The Habban Field and the Fractured Basement Play in Yemen*

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General Comments

Yemen in 2014

Fractured basement is one of the most important targets in the recent exploration strategy. A large proportion of Yemen's proven oil reserves are in fractured basement reservoirs in many fields in two major sedimentary basins (Masilah and Sab'atayn).

Key Features and Findings

- The majority of basement rocks are metamorphic; they can acquire porosity through fracturing and alteration (cataclasites, breccias).
- Basement - fault/fracture system is more complex than two major fracture sets (NW-SE, NNE-SSW).
- 3D seismic is mandatory in developing a reasonable understanding of the fractured basement.
- For structural interpretation and fault characterization, CBM (all-azimuths) volume is used, as this gives the best seismic image.
- Predicted orientation of failure planes is strongly dependent on the interpreted fault pattern and not sensitive to the material properties.

- Faults and fractures in the in situ strike-slip faulting regime give a good explanation for the distinction between “open” and “closed” fractures.

Conclusions

- Basement plays have often been overlooked or considered to be marginally economic.
- Basement reservoirs are challenging
    - Drilling challenges
    - Development challenges
    - Production challenges
- Keys to understanding the dynamic mechanisms
    - 3D seismic
    - Fault and fracture network characterization

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The Habban Field and the fractured basement play in Yemen

AAPG-ICE, Istanbul, September 2014

Moving more. Moving the future. OMV

Outline

- Basement play around the world
- Some facts about the Basement play in Yemen
- Block S2 – Habban field

Outline

- Basement play around the world

Some facts about the Basement play in Yemen

Block S2 – Habban field

Basement Reservoirs around the World

- Basement rocks – definition

  "Any metamorphic or igneous rock (regardless of age) which is overlain by a sedimentary sequence"

After J. Gutmanis, T. Batchelor, L. Cotton, J. Baker and colleagues at GeoScience Limited

Hydrocarbon Production from Fractured Basement Formations v10 -2012

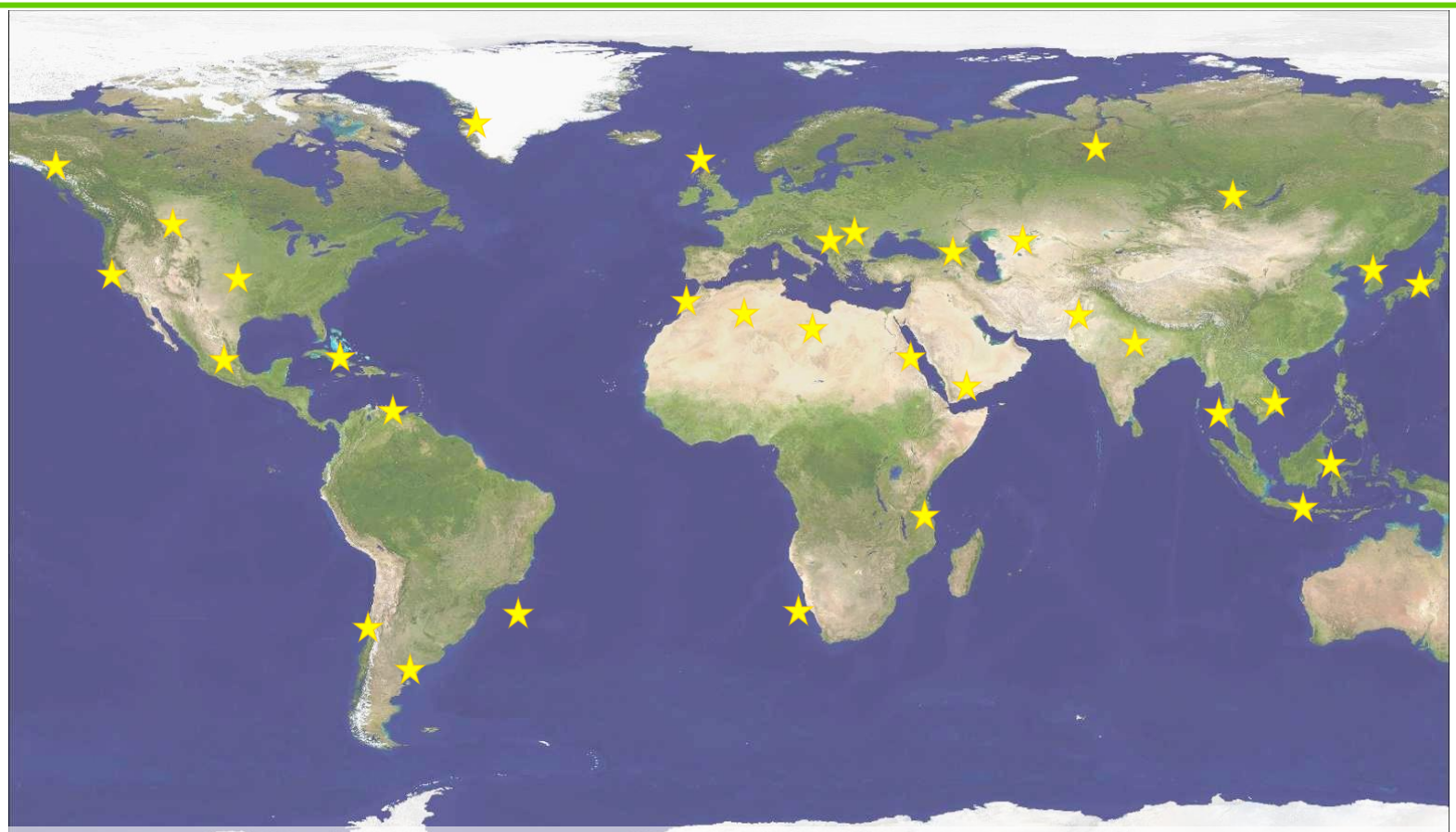
Basement Reservoirs around the World

Fractured Basement Characteristics - Key points

- **Naturally fractured reservoirs**
- Little to no matrix porosity and permeability
- Lithology often plays a major role in controlling reservoir quality
- **Basement charging** – different possibilities
  - Updip/lateral migration from an adjacent kitchen area into structural highs, or
  - Downward migration due to differential stresses, or
  - Long-distance lateral migration

After J. Gutmanis, T. Batchelor, L. Cotton, J. Baker and colleagues at GeoScience Limited
Hydrocarbon Production from Fractured Basement Formations v10 -2012

Basement Reservoirs around the World



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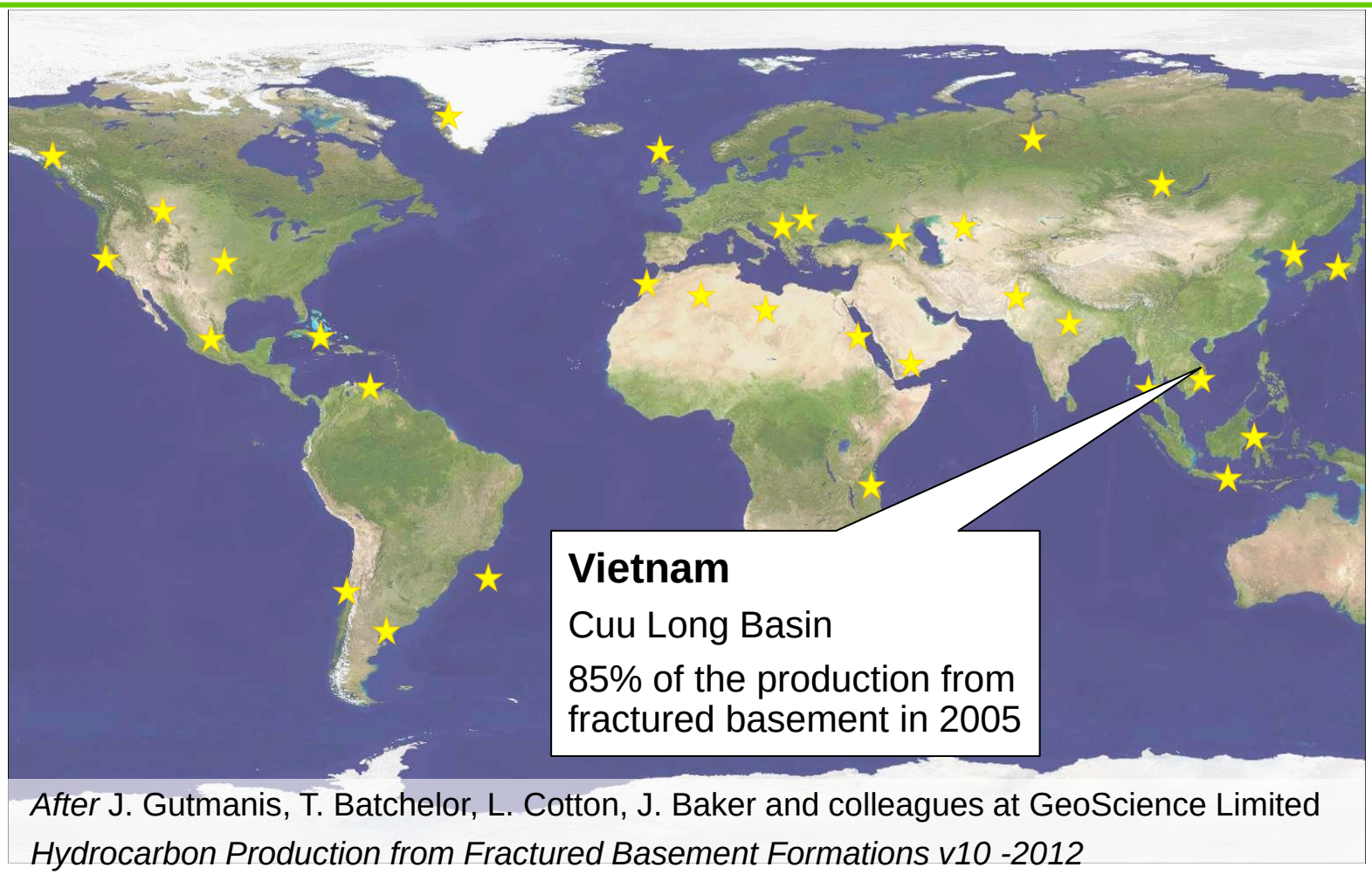

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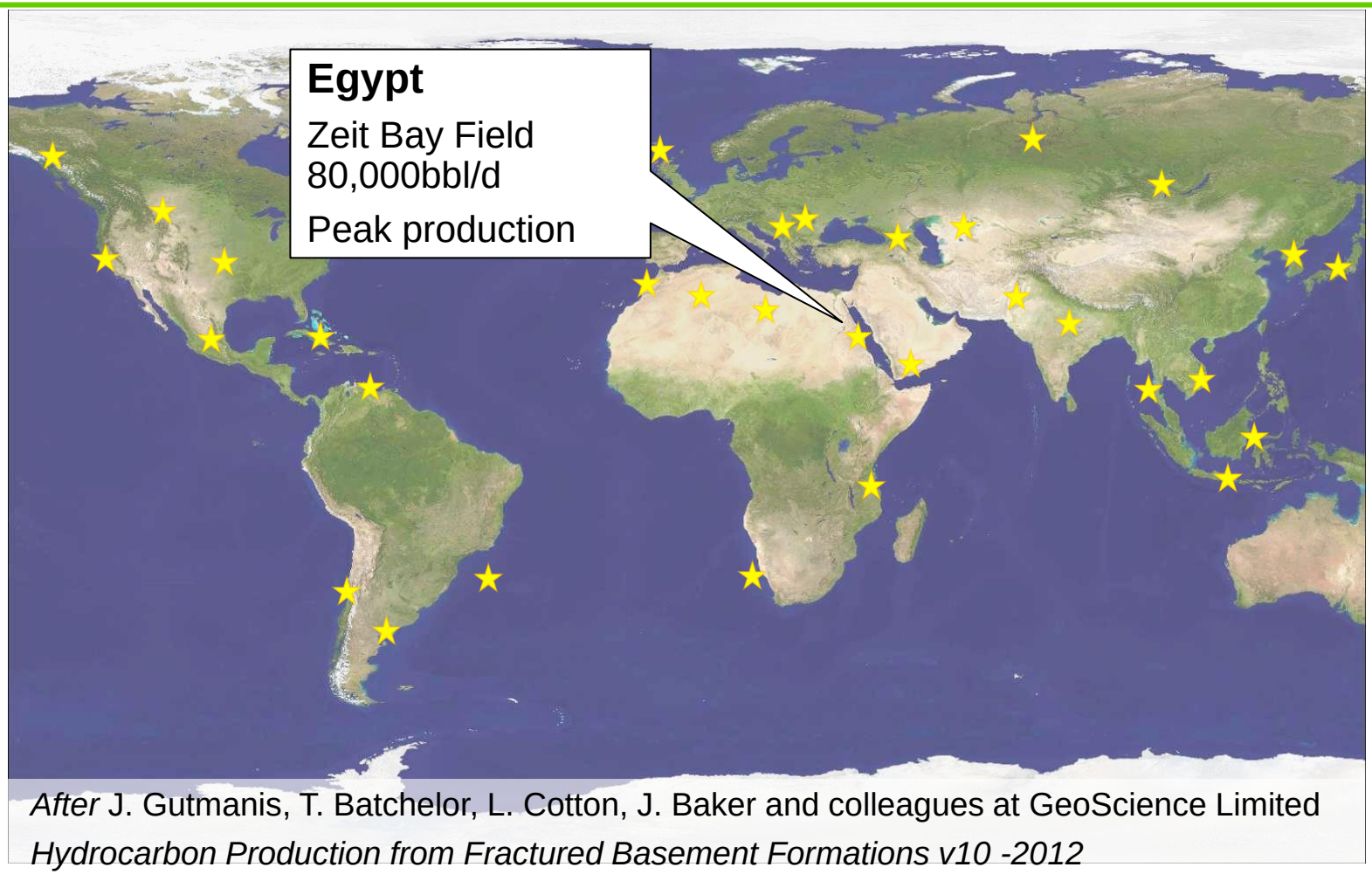

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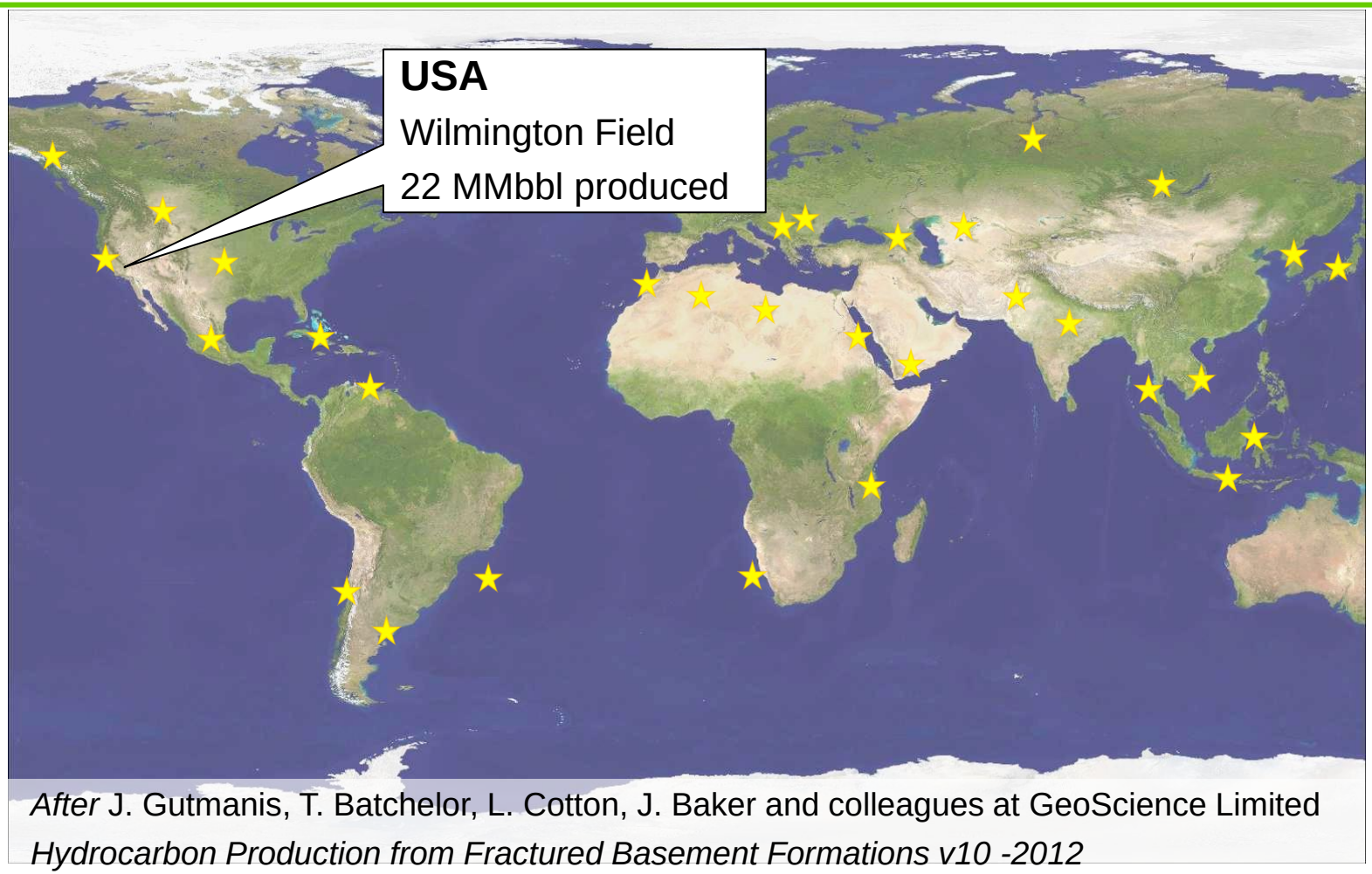

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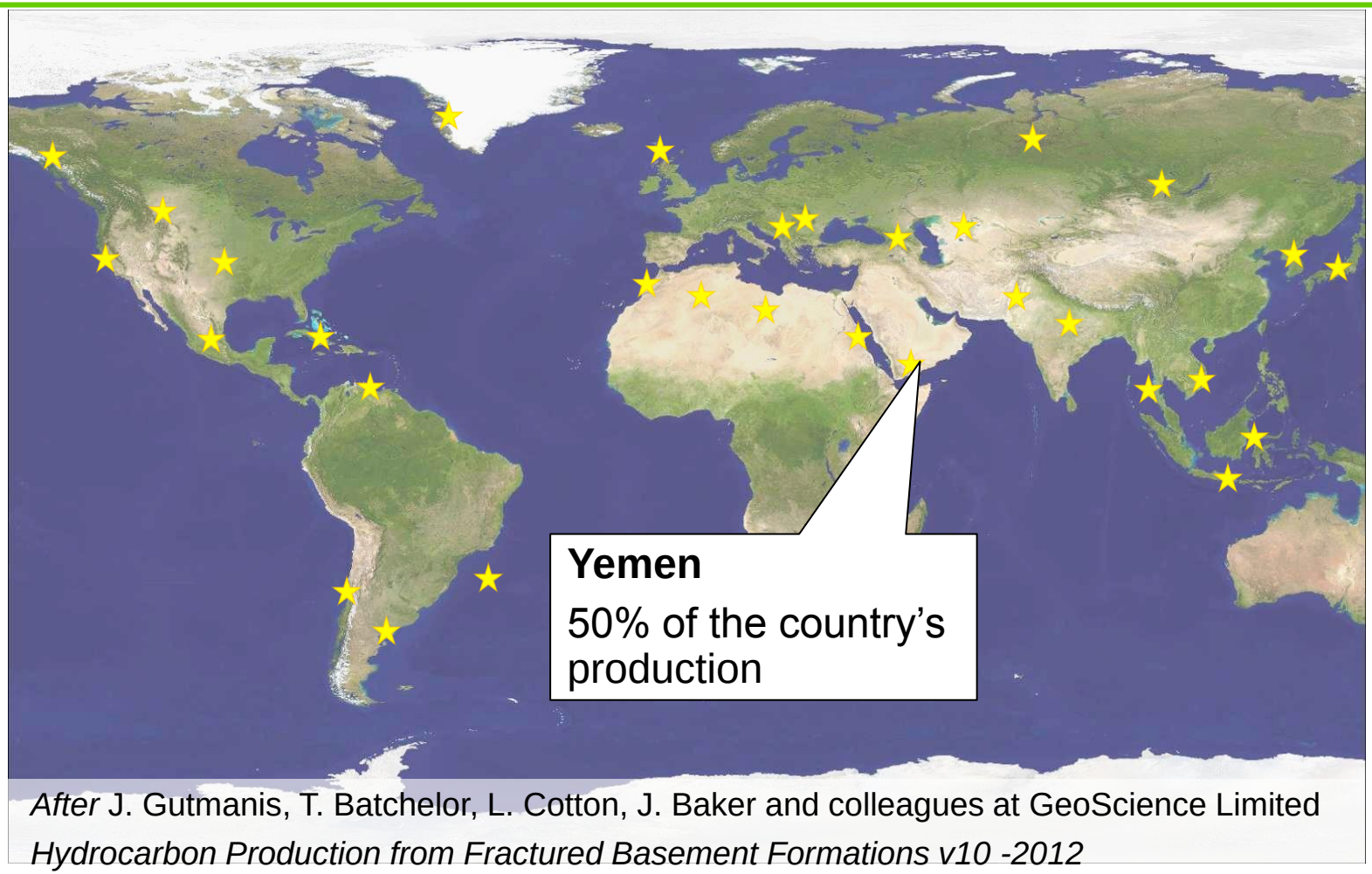

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Hydrocarbon Production from Fractured Basement Formations v10 -2012

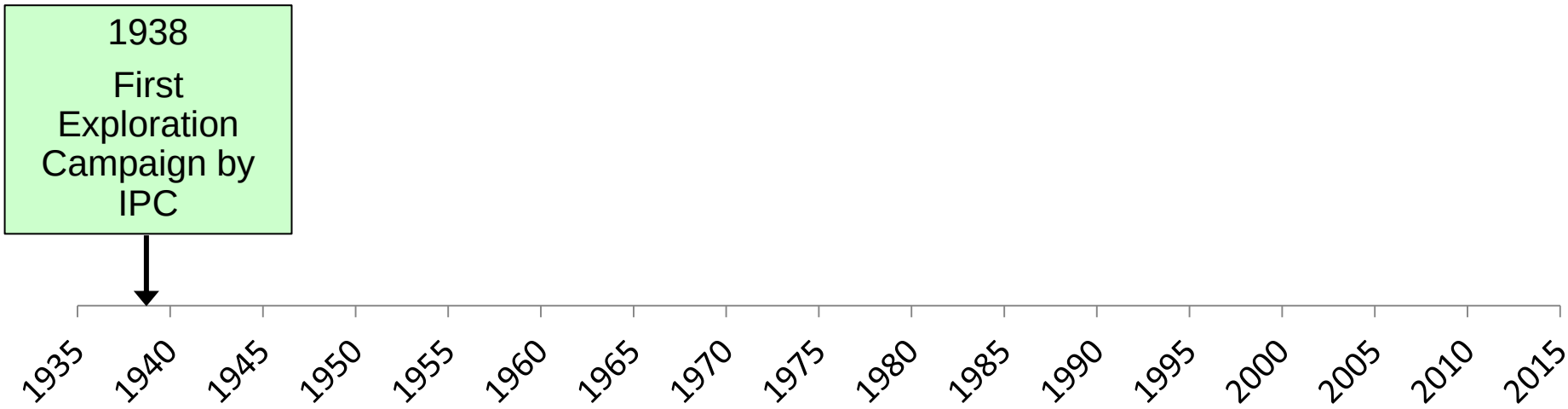
Outline

Basement play around the world

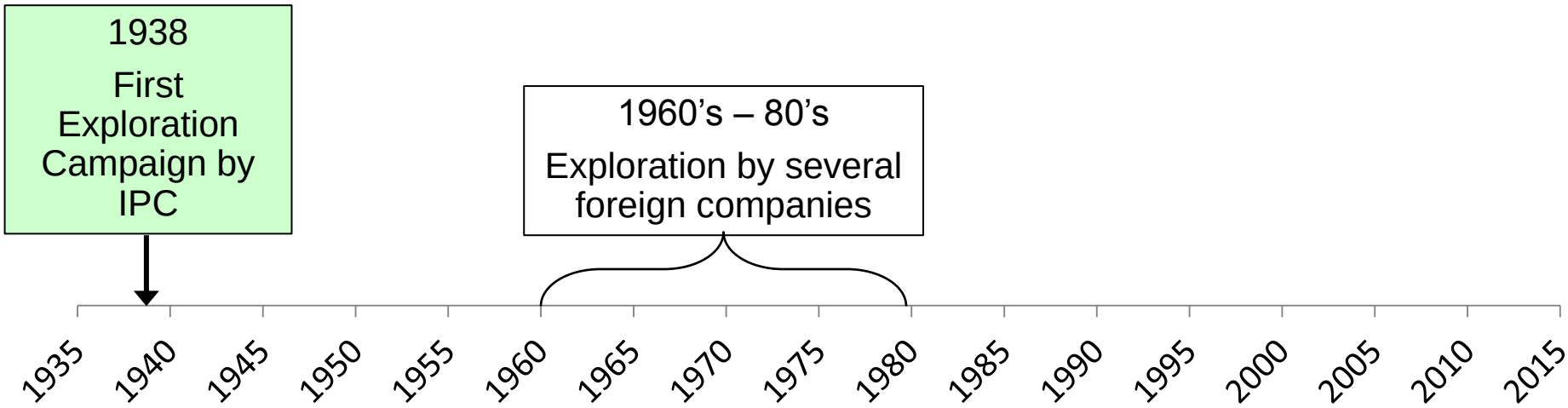
- Some facts about the Basement play in Yemen

Block S2 – Habban field

Yemen – Oil Discovery History



Yemen – Oil Discovery History



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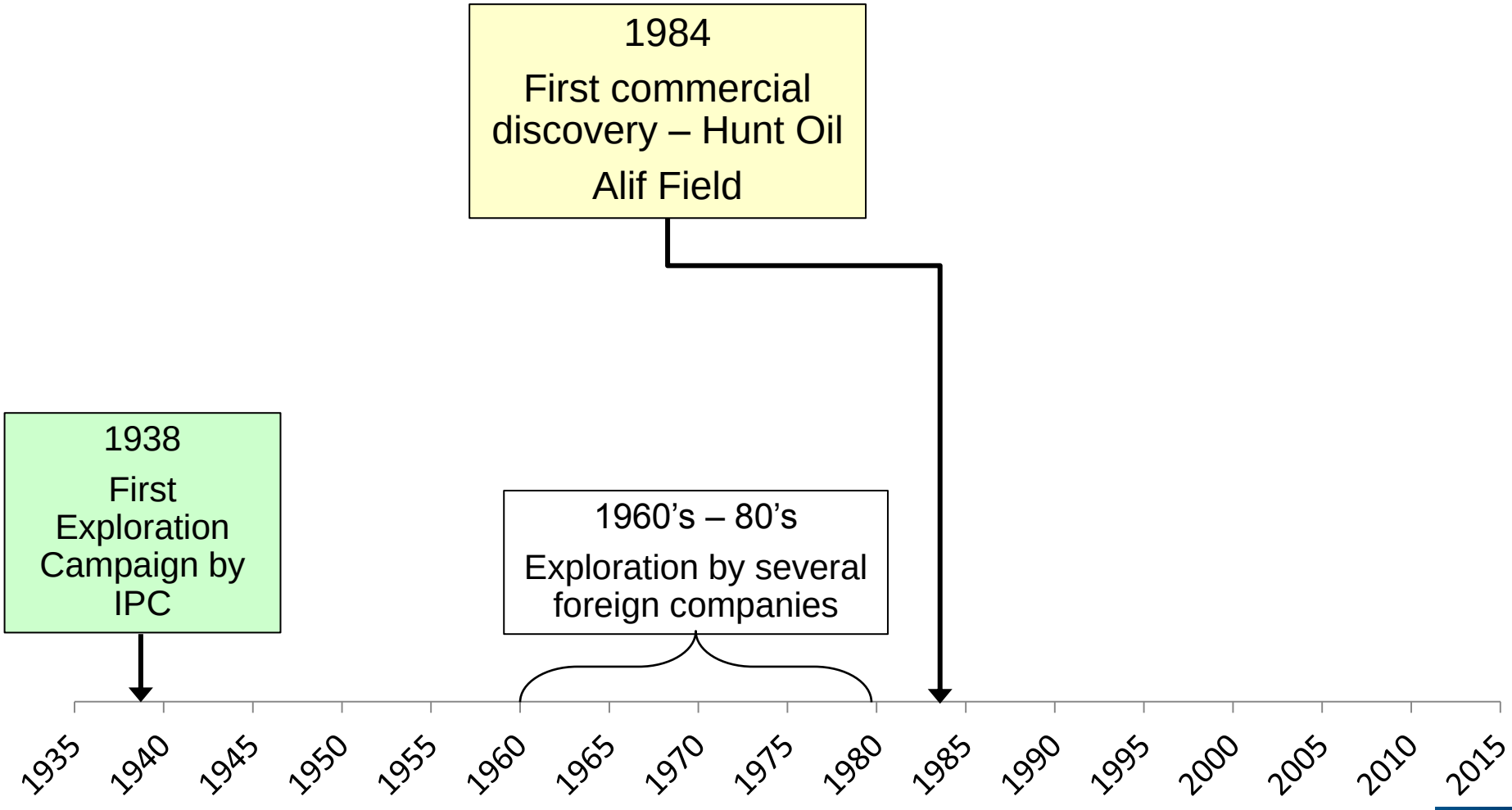

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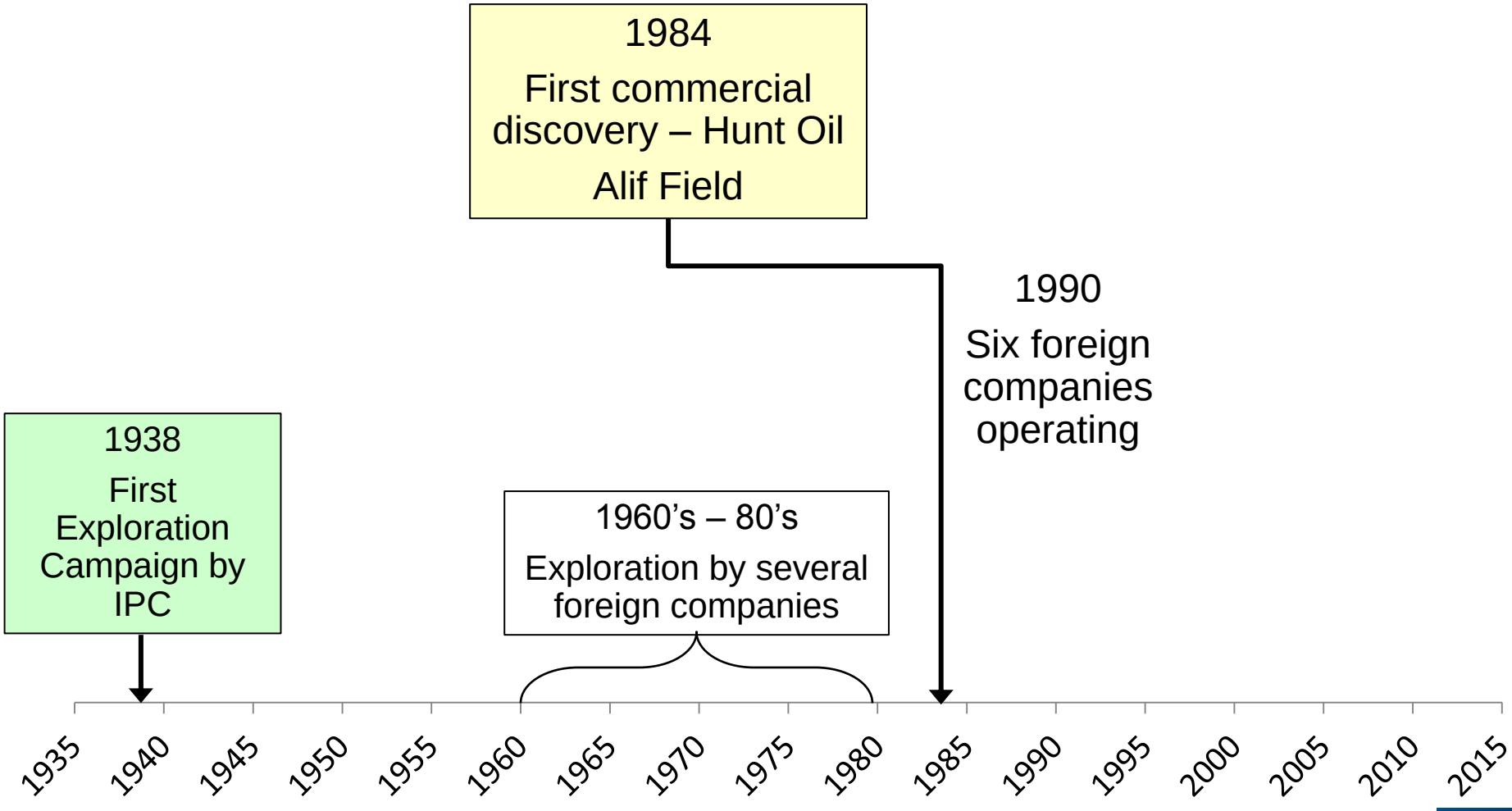

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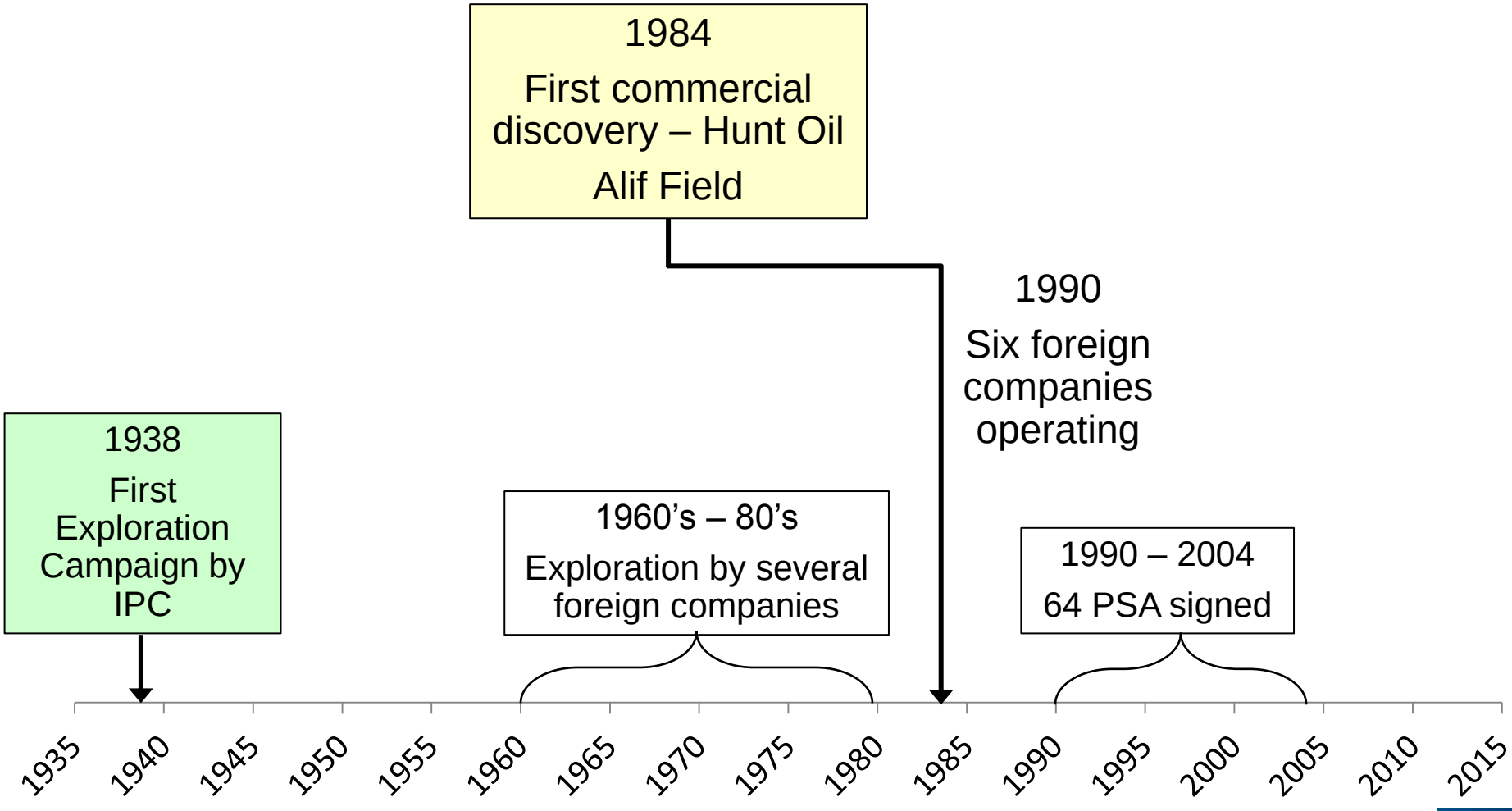

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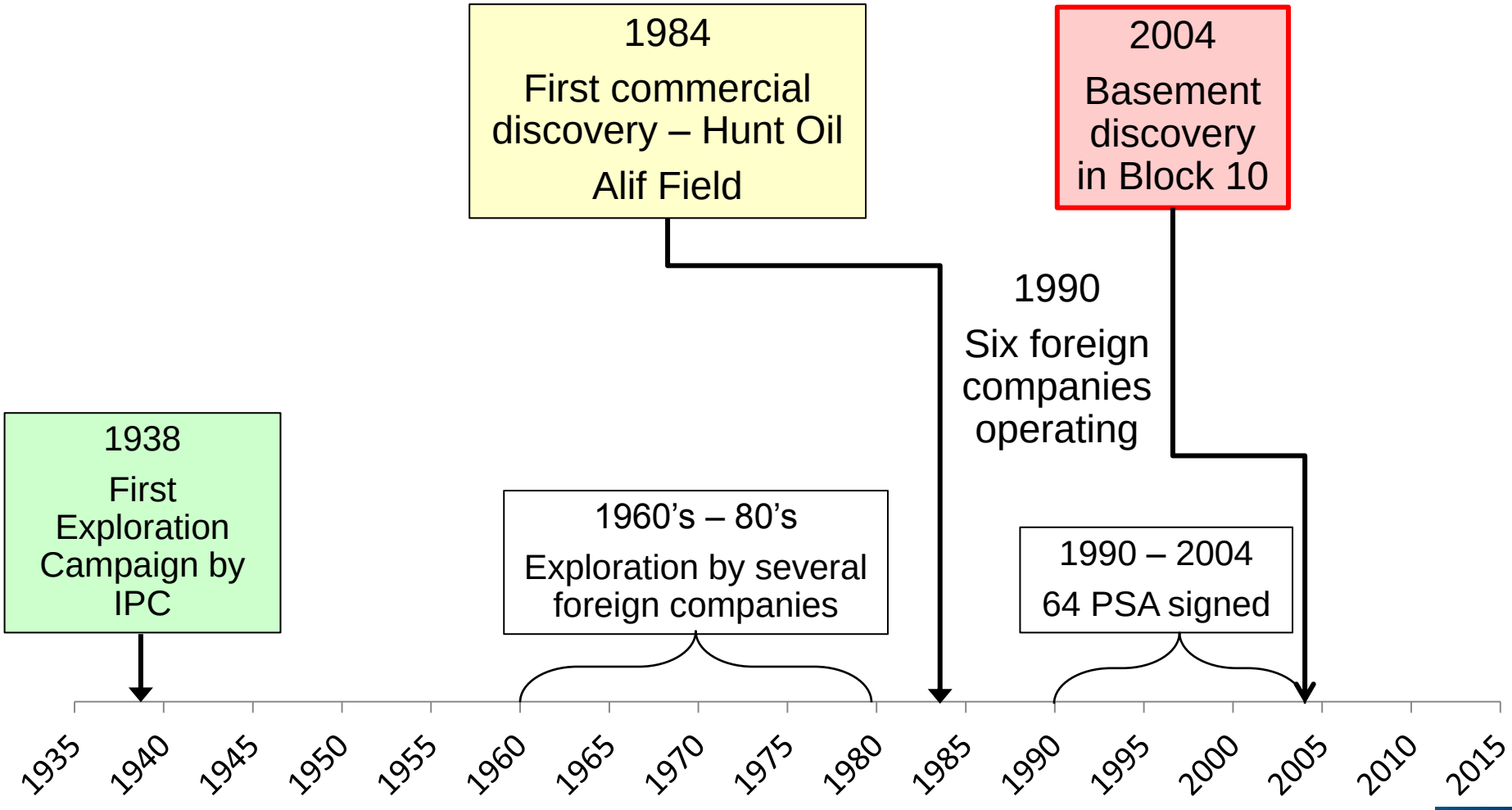

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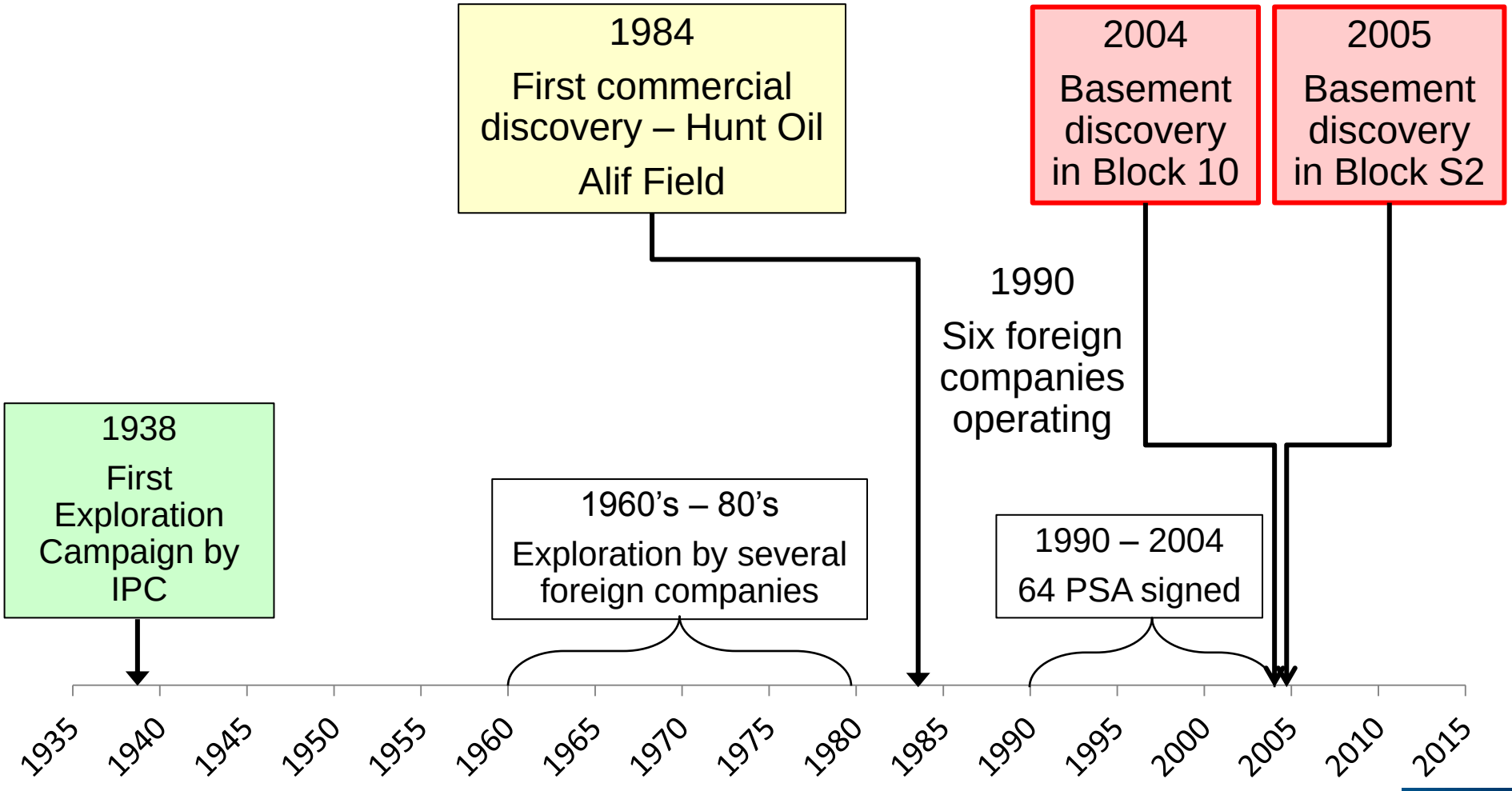


In 2009 – PEPA chairman Nasr Al-Humaidi

In Investment Magazine – June 09 2009 – Issue No. (27) Page 46

A Successful Project Heralds New Oil and Gas Discoveries and Huge Reserves…

Secret of The Oil Resources in Yemen Undiscovered Yet

Q: *What are the plans and programs for the exploration and production blocks?*

(…) Follow up and evaluate the performance of reservoirs, particularly basement rocks in Hadhramawt and Shabwah. (…)

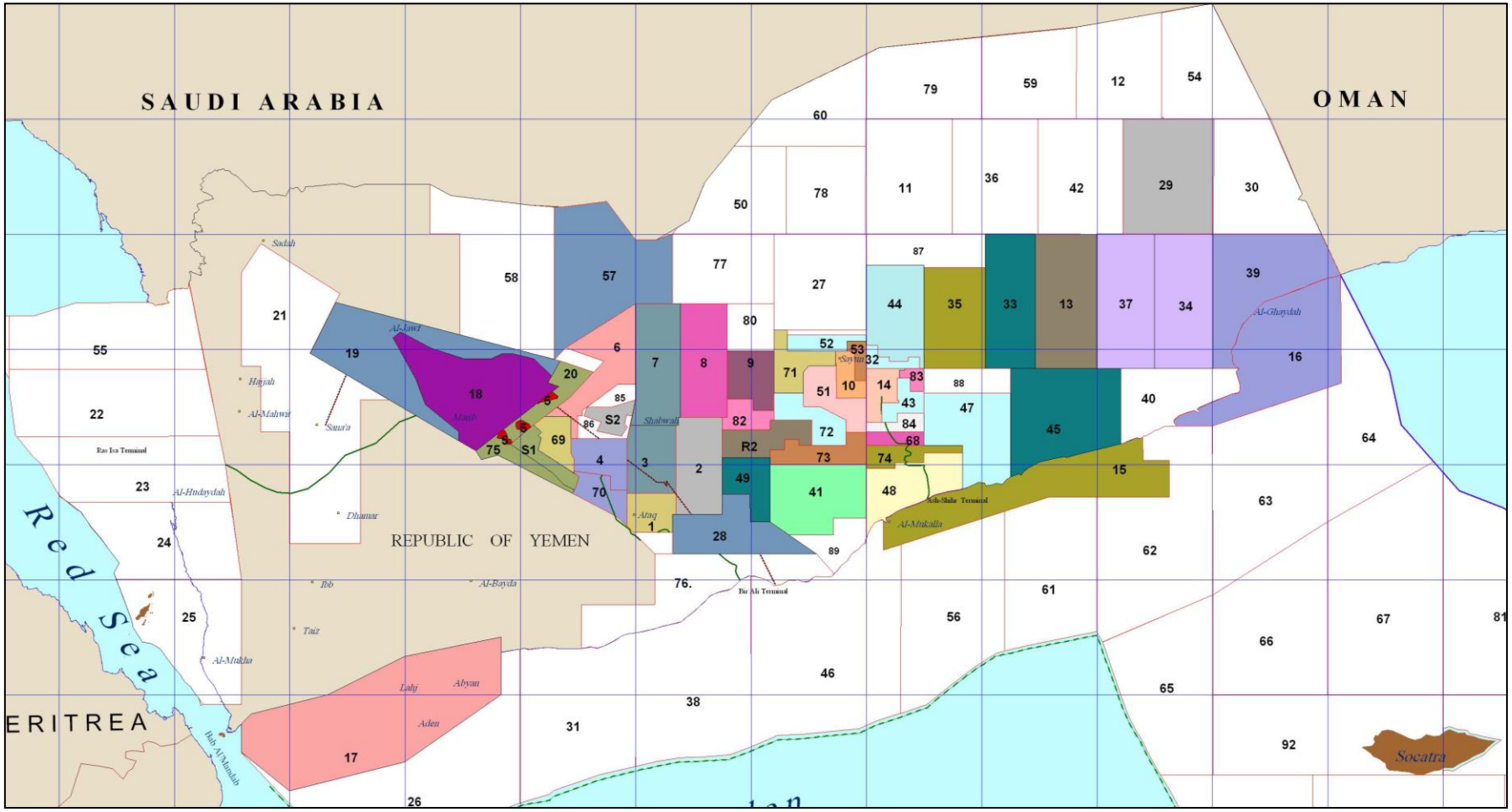
In 2014 – “Yemen Today”

“The FRACTURED BASEMENT is one of the most important targets in the recent exploration strategy.” […]

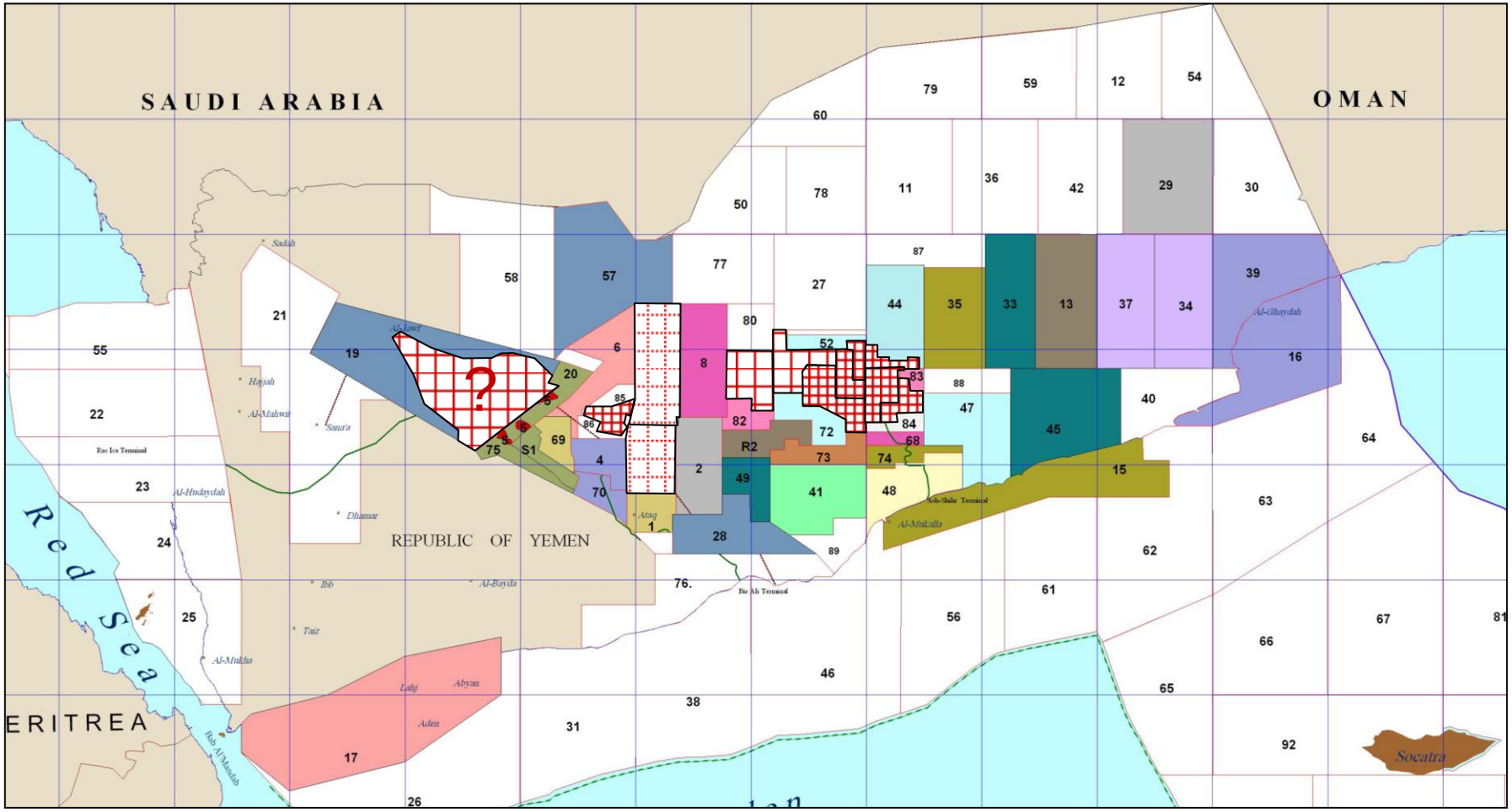
“A large proportion of YEMEN proven oil reserves are in the FRACTURED BASEMENT reservoirs “[…]” in many fields in two major sedimentary basins (Masilah and Sabatayn)”.

http://www.pepayemen.com/exploration%20facts.aspx

Yemen – Blocks



Yemen – Known Basement Blocks



OMV Yemen ⫟ Block S2, ∠The Habban Field and the fractured basement play in Yemen ⍈

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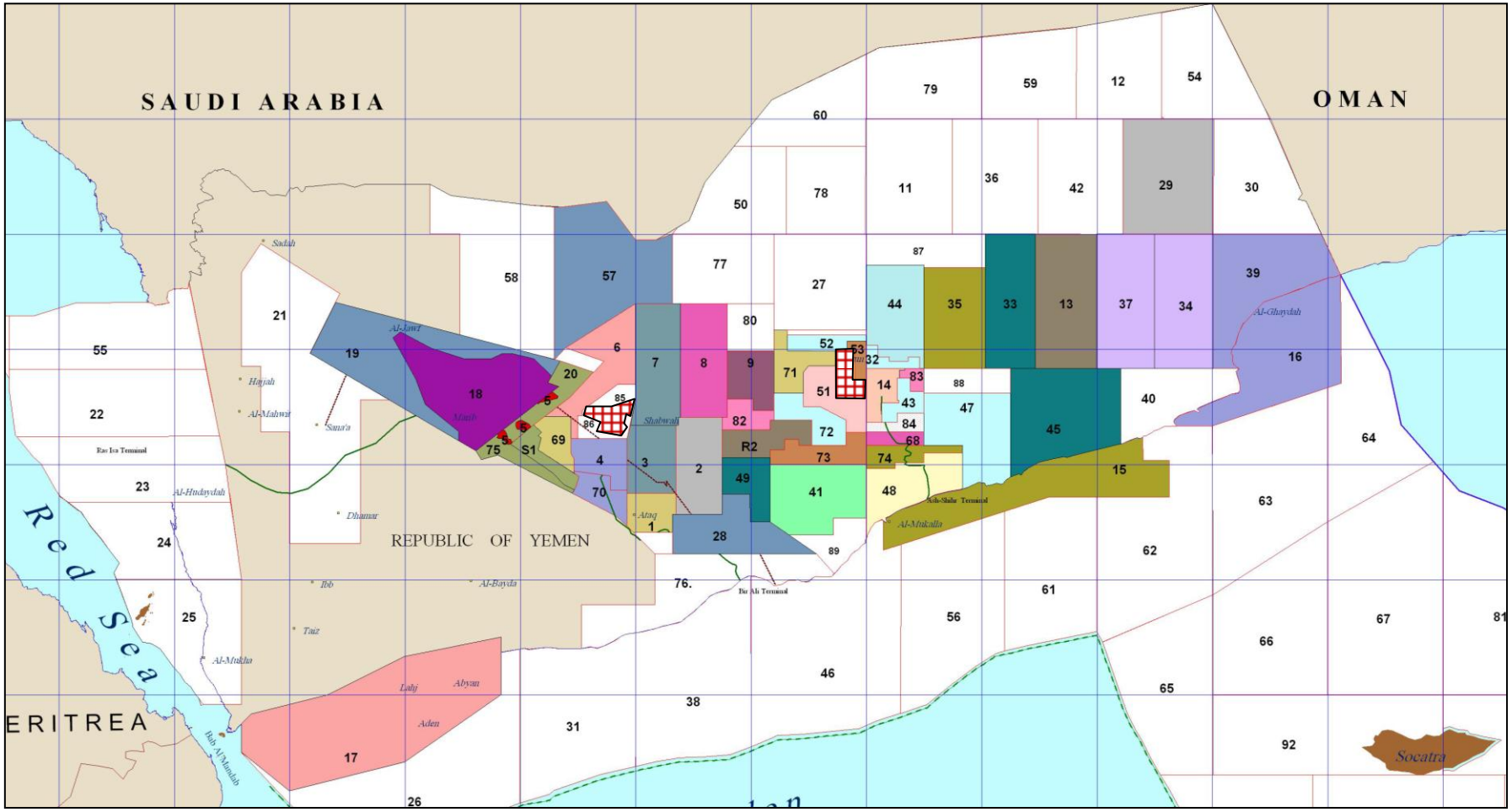
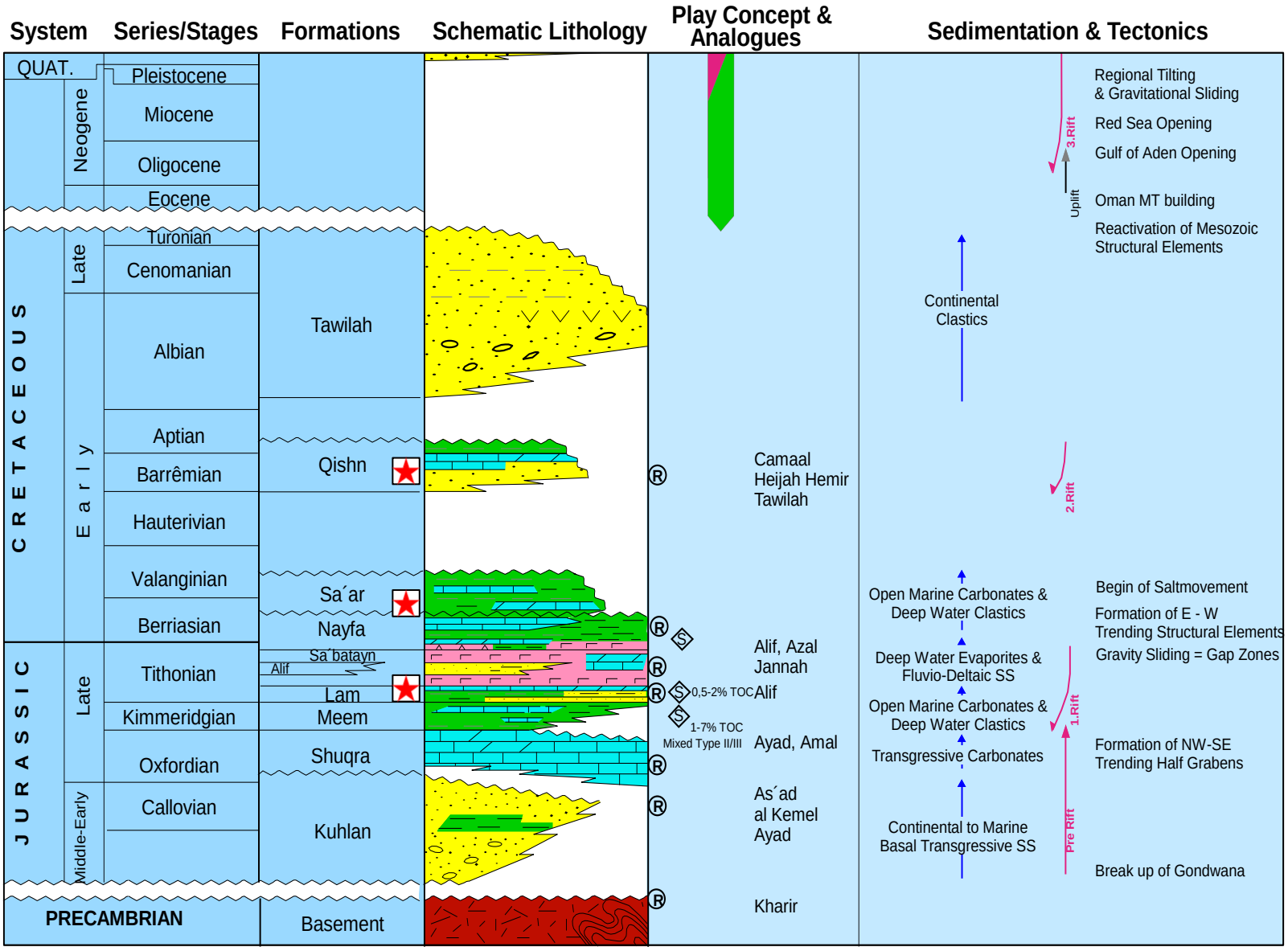
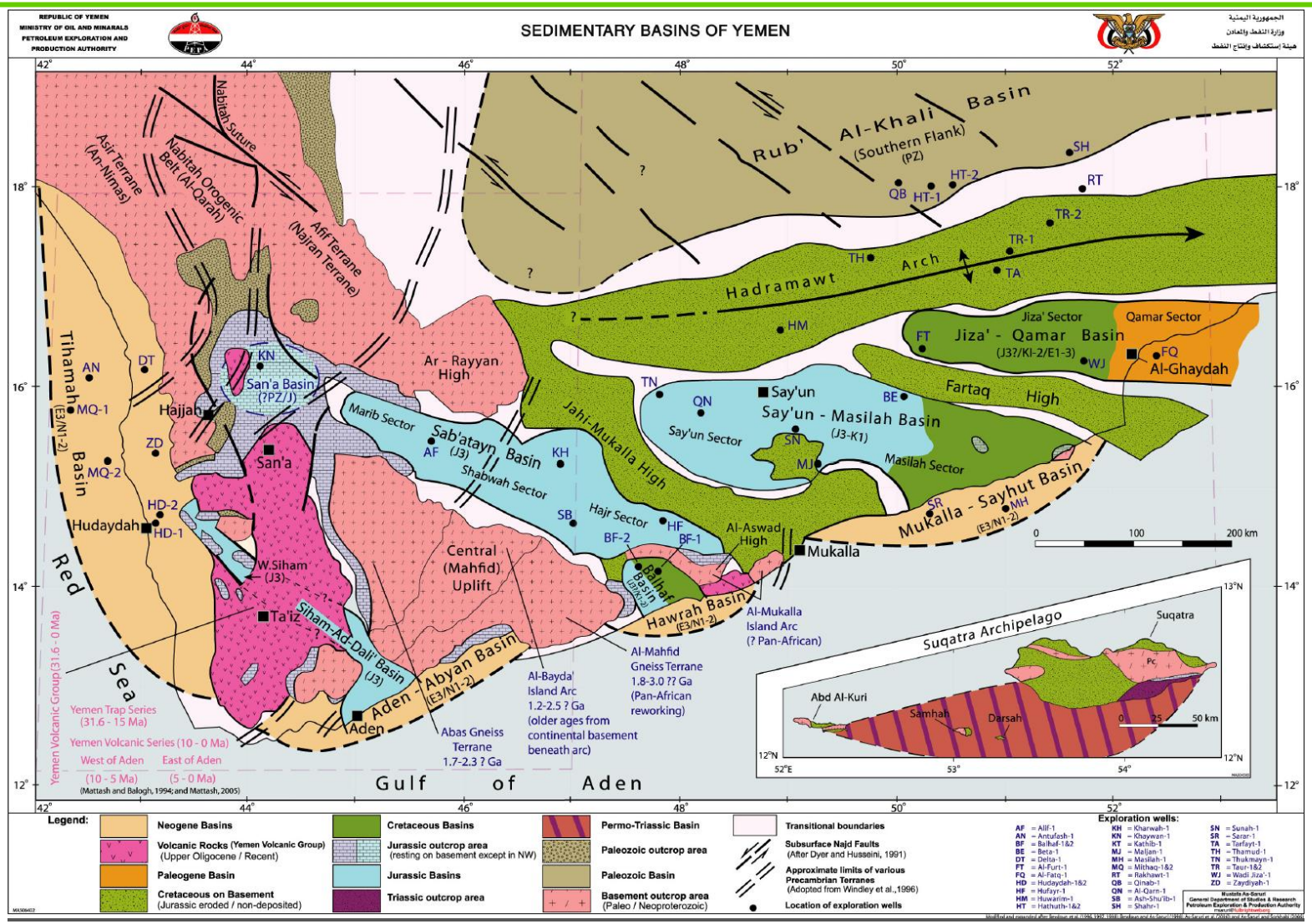


Yemen – Traditional Plays



Yemen – Productive Basins



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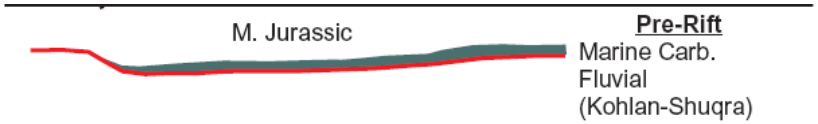
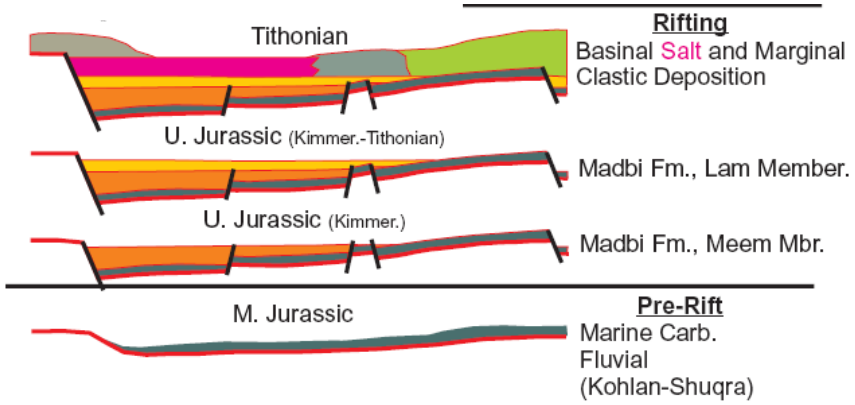
Sab’atayn Basin Evolution



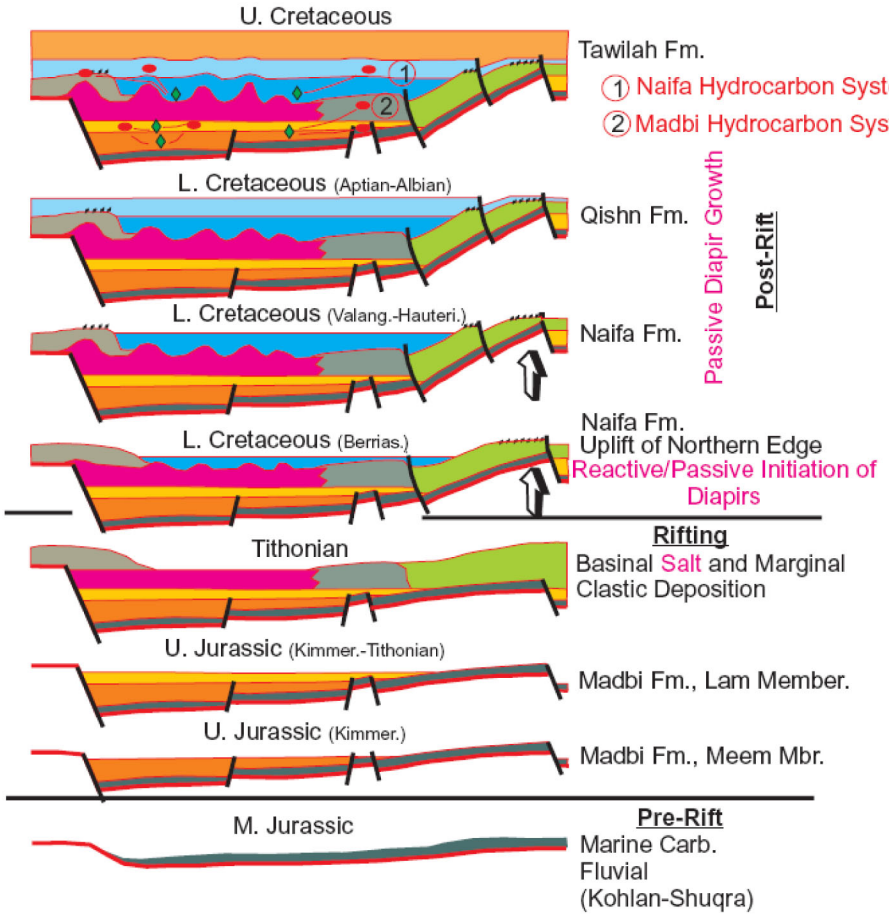
- Pre-Rift Phase (Paleozoic to Late Jurassic)
  - Paleozoic to Triassic
    - Area was uplifted and eroded
  - Early to Late Jurassic
    - General uplift with intermittent phases of subsidence (Kuhlan & Shuqra formations were deposited)

Sab'atayn Basin Evolution



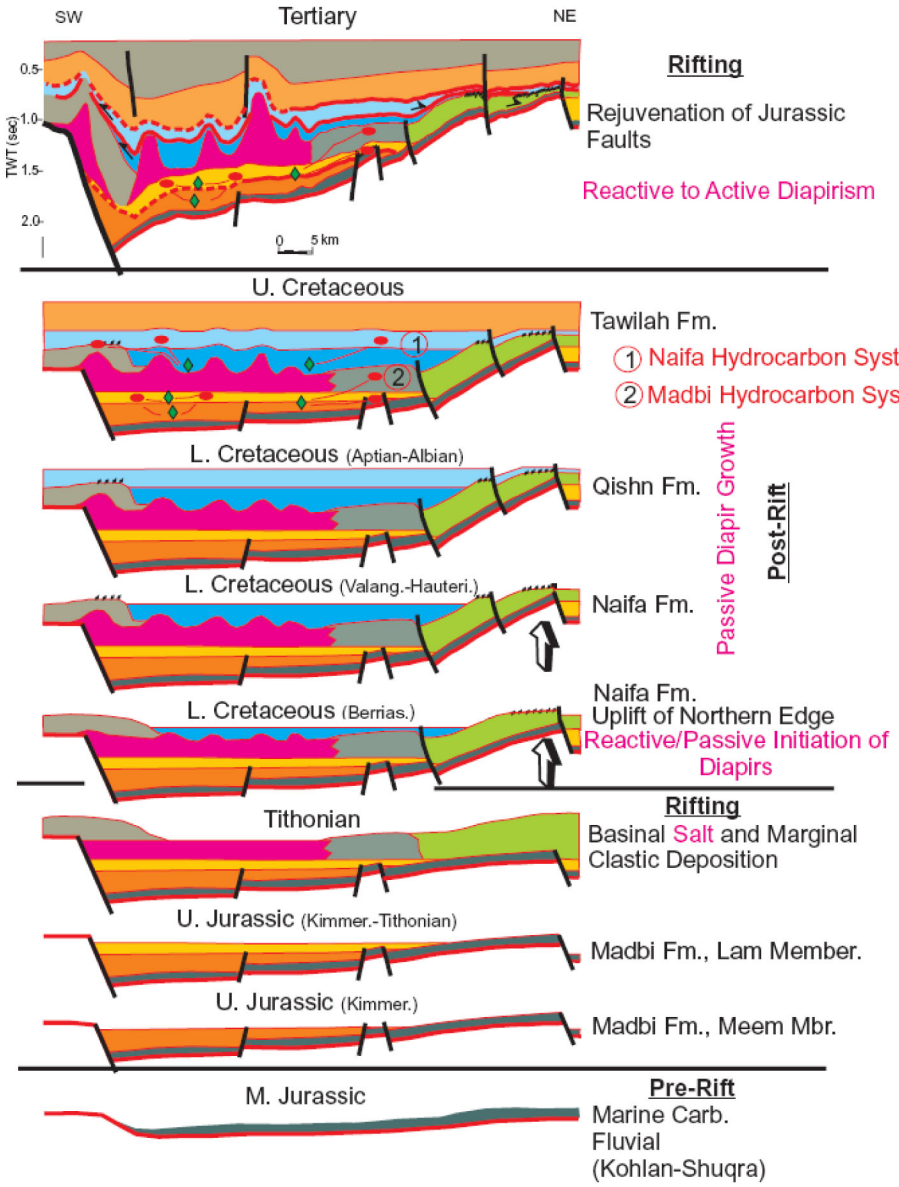
- Pre-Rift Phase (Paleozoic to Late Jurassic)
- Syn-Rift Phase: (Late Jurassic to Early Cretaceous)
  - Marked by extension, rifting and graben formation in Late Jurassic to Early Cretaceous
  - Kimmeridgian marked the peak of subsidence.
  - Central parts of the basin were filled with deep marine sediments of Lam and Meem members (Source rock)

Sab'atayn Basin Evolution



- Pre-Rift Phase (Paleozoic to Late Jurassic)
- Syn-Rift Phase: (Late Jurassic to Early Cretaceous)
- Late Syn-Rift to Post-Rift: (Mid- to Late Cretaceous)
  - Massive salt deposits (Sab'atayn formation) were formed in the restricted parts of the basin
  - Post-Rift - Moderate subsidence from Early to Late Cretaceous (Nayfa and Sa'ar formations were deposited in a shallow to deeper shelf in a normal marine enviornment)
  - Sa'ar Formation is unconformably overlain by Mid- to Upper Cretaceous predominantly clastic Tawilah Group
  - Sediment loading mobilized the salt of the Sab'atayn Fm. resulted in formation of salt diapirs/walls

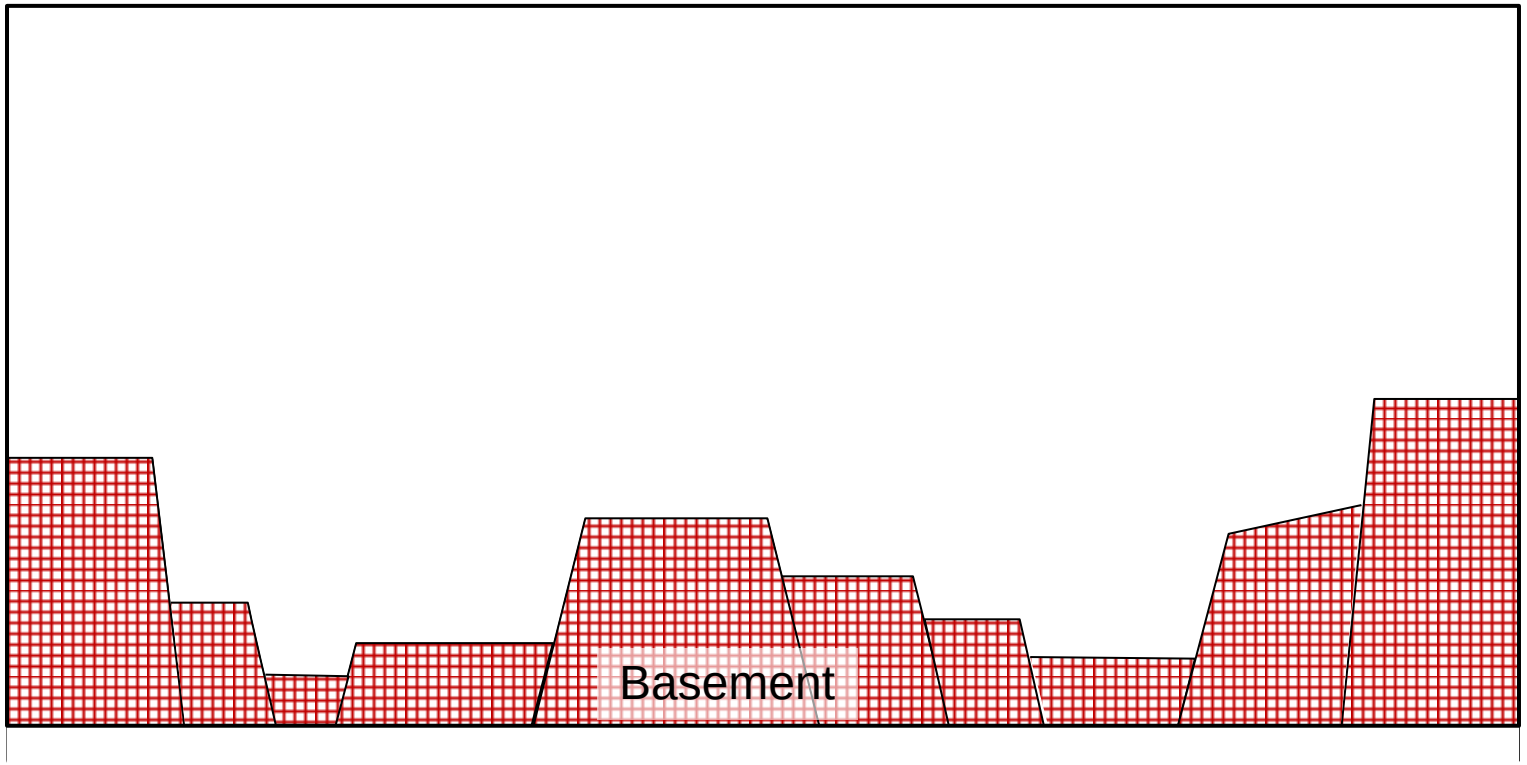
Sab'atayn Basin Evolution



- Pre-Rift Phase (Paleozoic to Late Jurassic)
- Syn-Rift Phase: (Late Jurassic to Early Cretaceous)
- Late Syn-Rift to Post-Rift: (Mid- to Late Cretaceous)
- 2nd Rifting : (Oligocene to Miocene)
  - Extension and rifting in the Red Sea and the Gulf of Aden occurred during the Oilgocene and Miocene

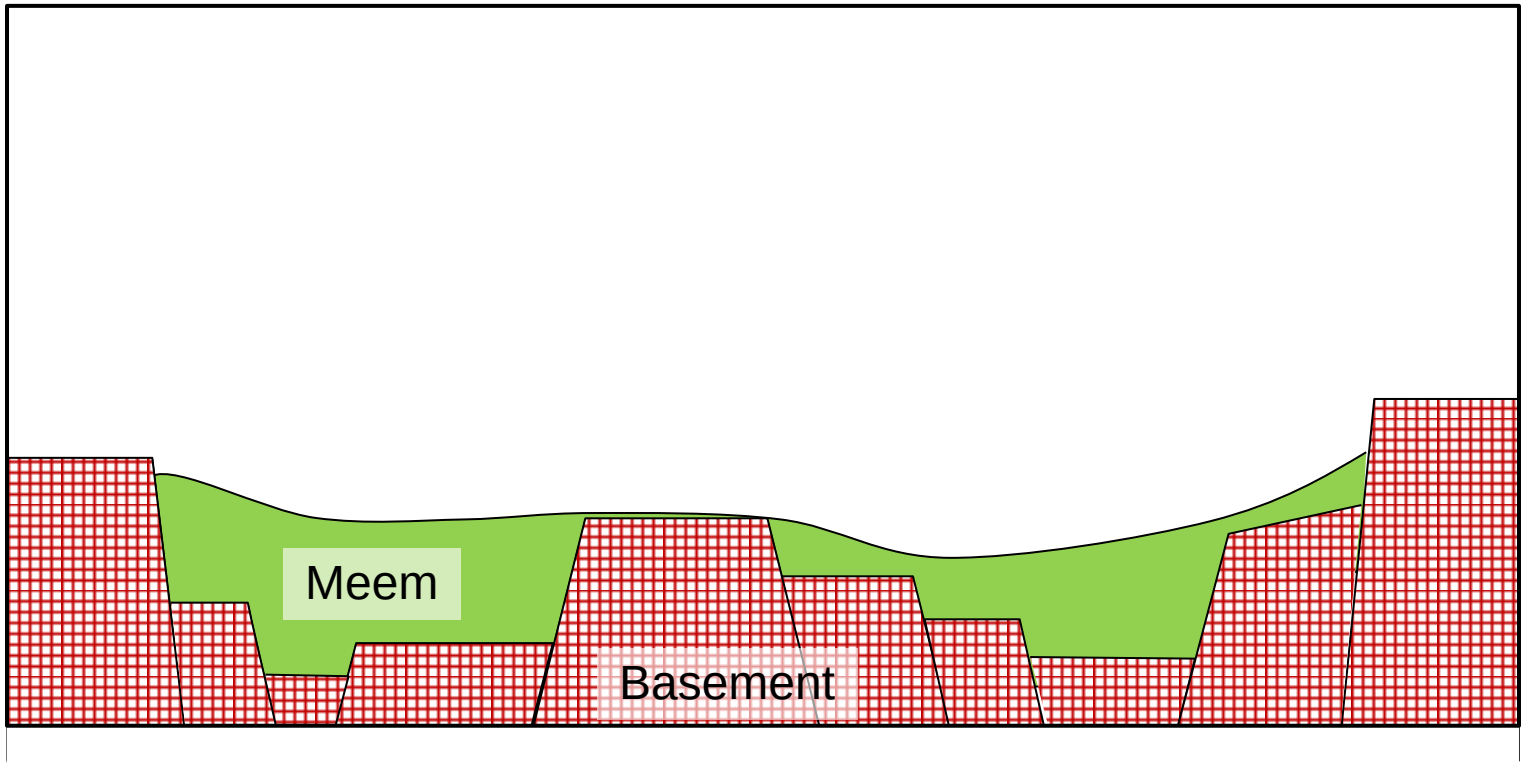
Yemen – Sab'atayn Basin
The Basement Play Elements

- Basement structure



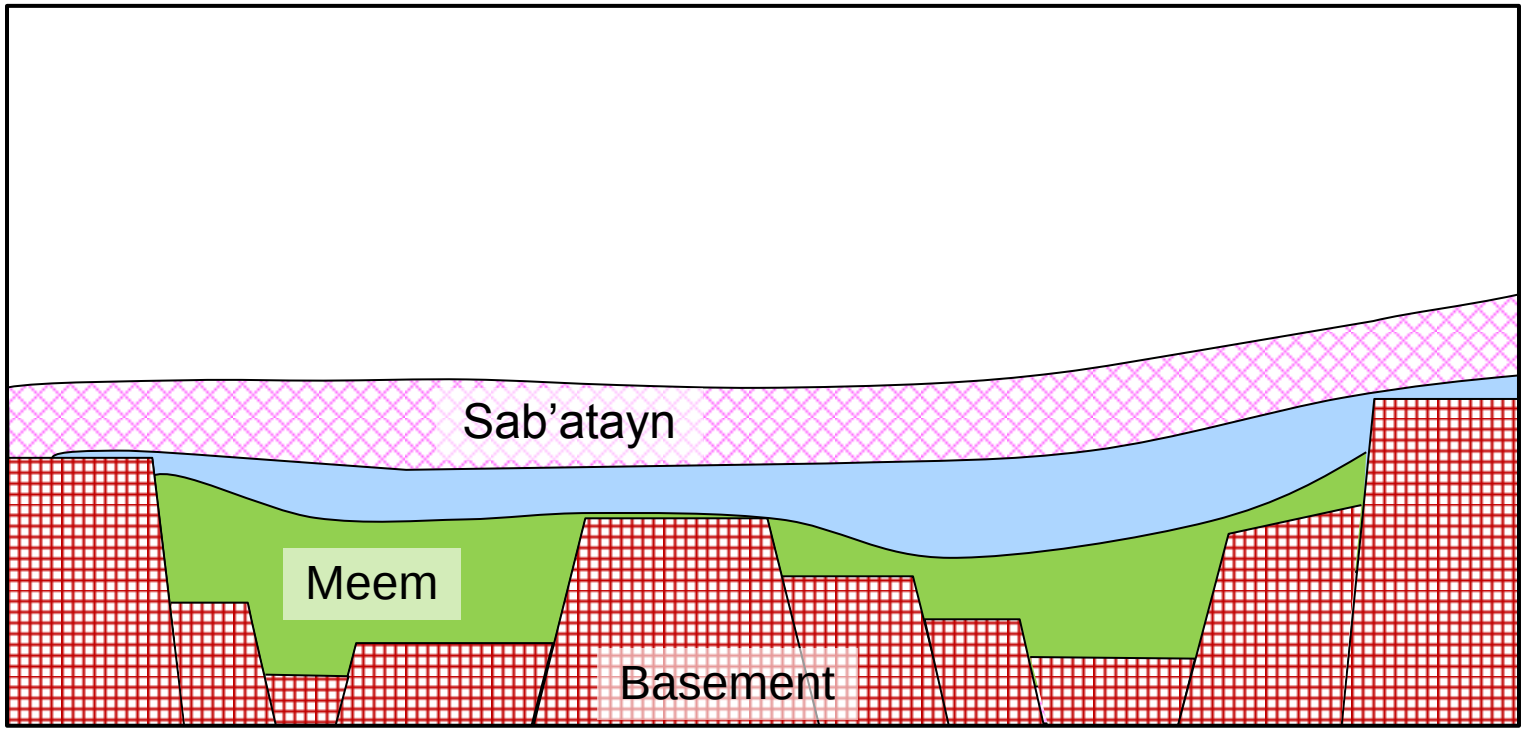
Yemen – Sab'atayn Basin
The Basement Play Elements

- Basement structure
- The source rock



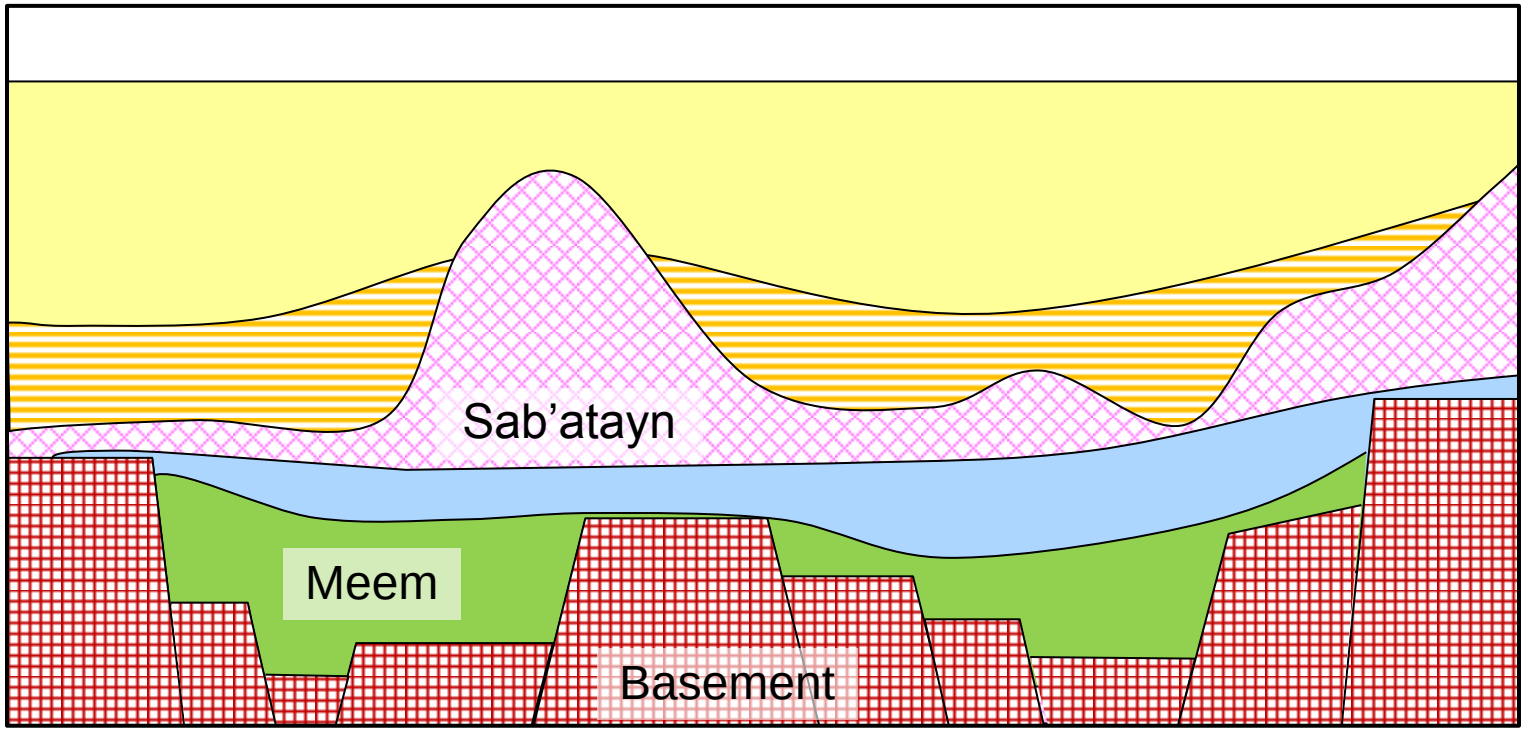
Yemen – Sab'atayn Basin
The Basement Play Elements

- Basement structure
- The source rock
- The cap rock



Yemen – Sab'atayn Basin
The Basement Play Elements

- Basement structure
- The source rock
- The cap rock



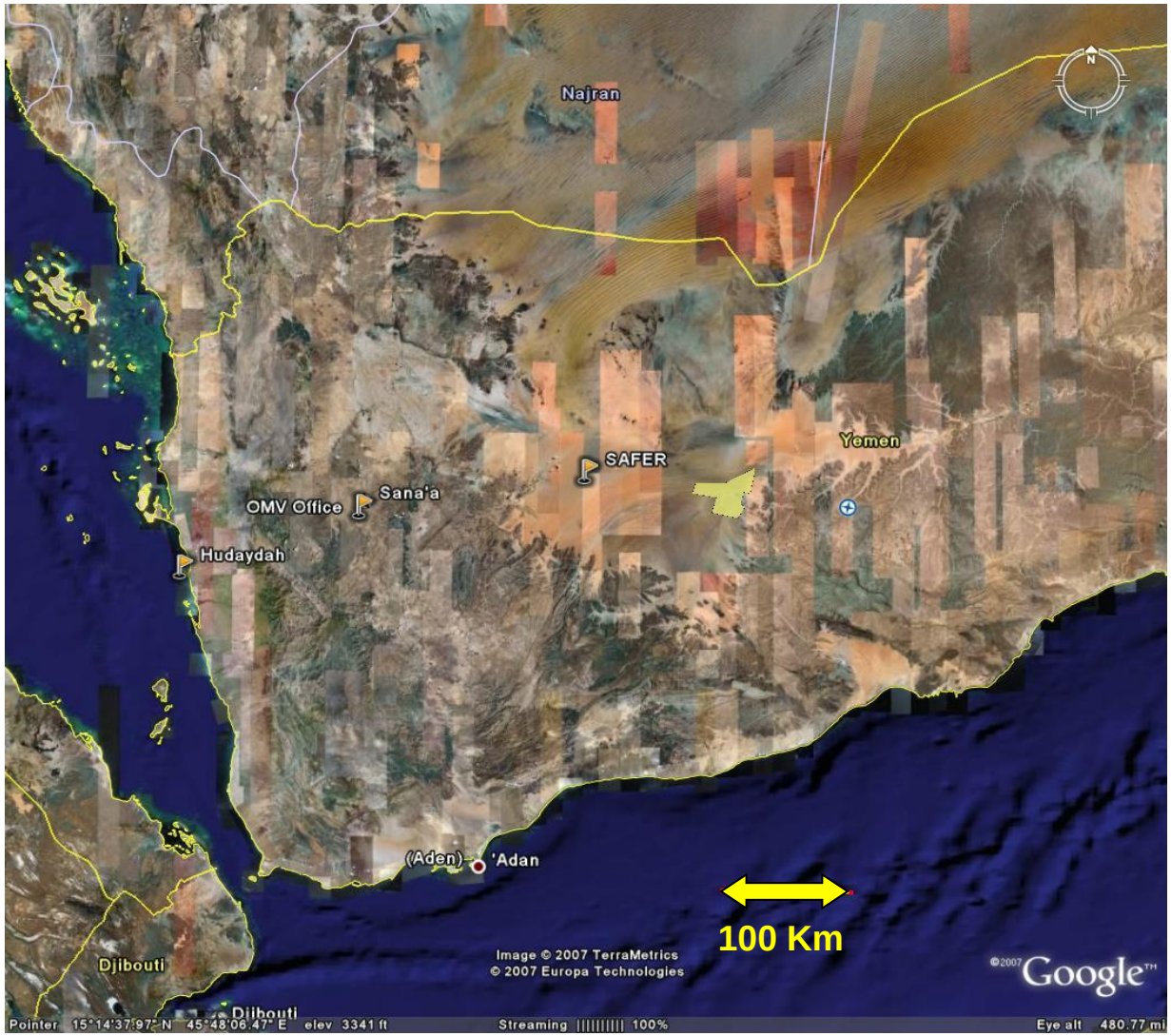
Outline

Basement play around the world

Some facts about the Basement play in Yemen

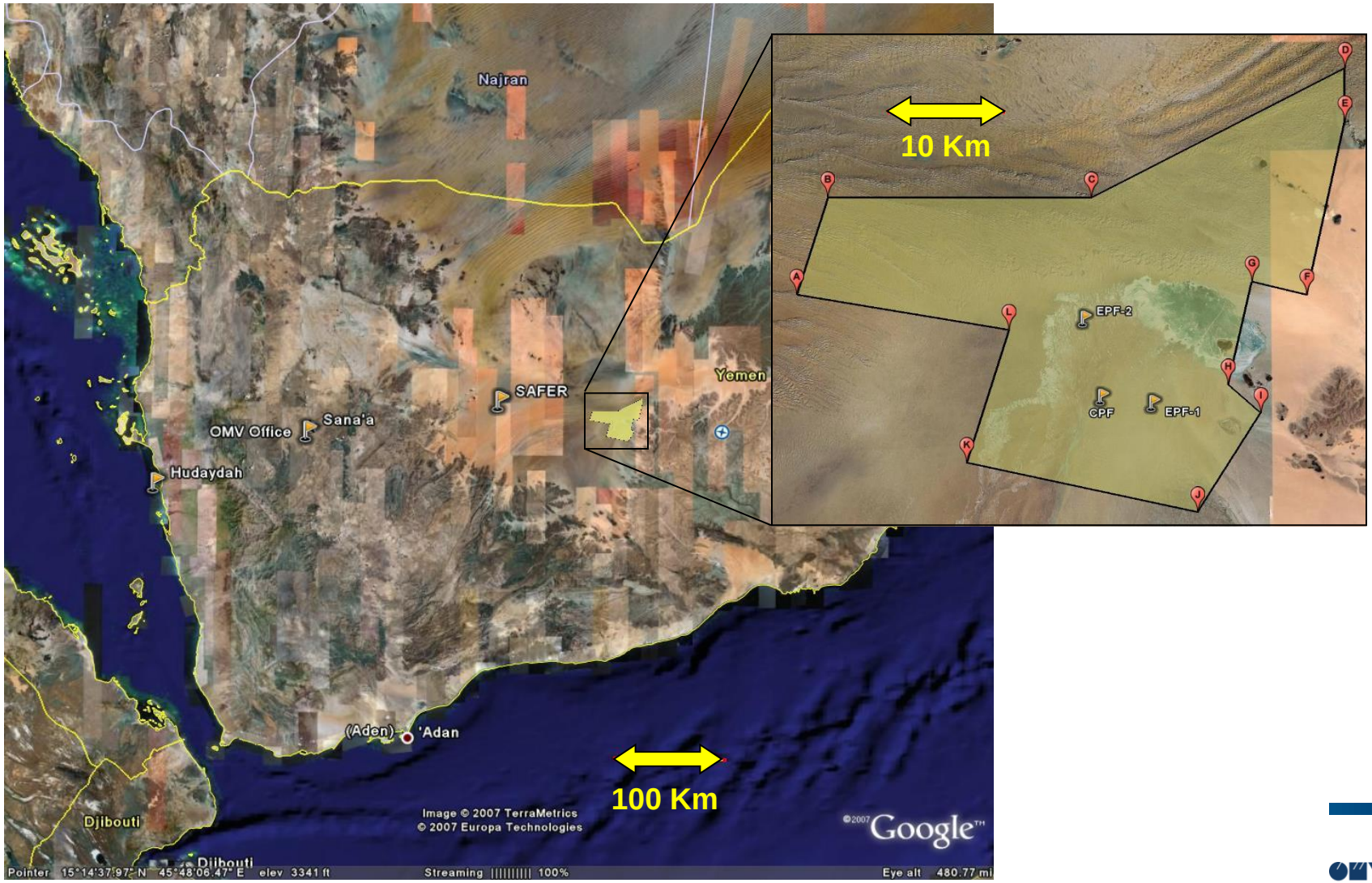
- BlockS2 – Habban field

Overview – Block S2 in Yemen



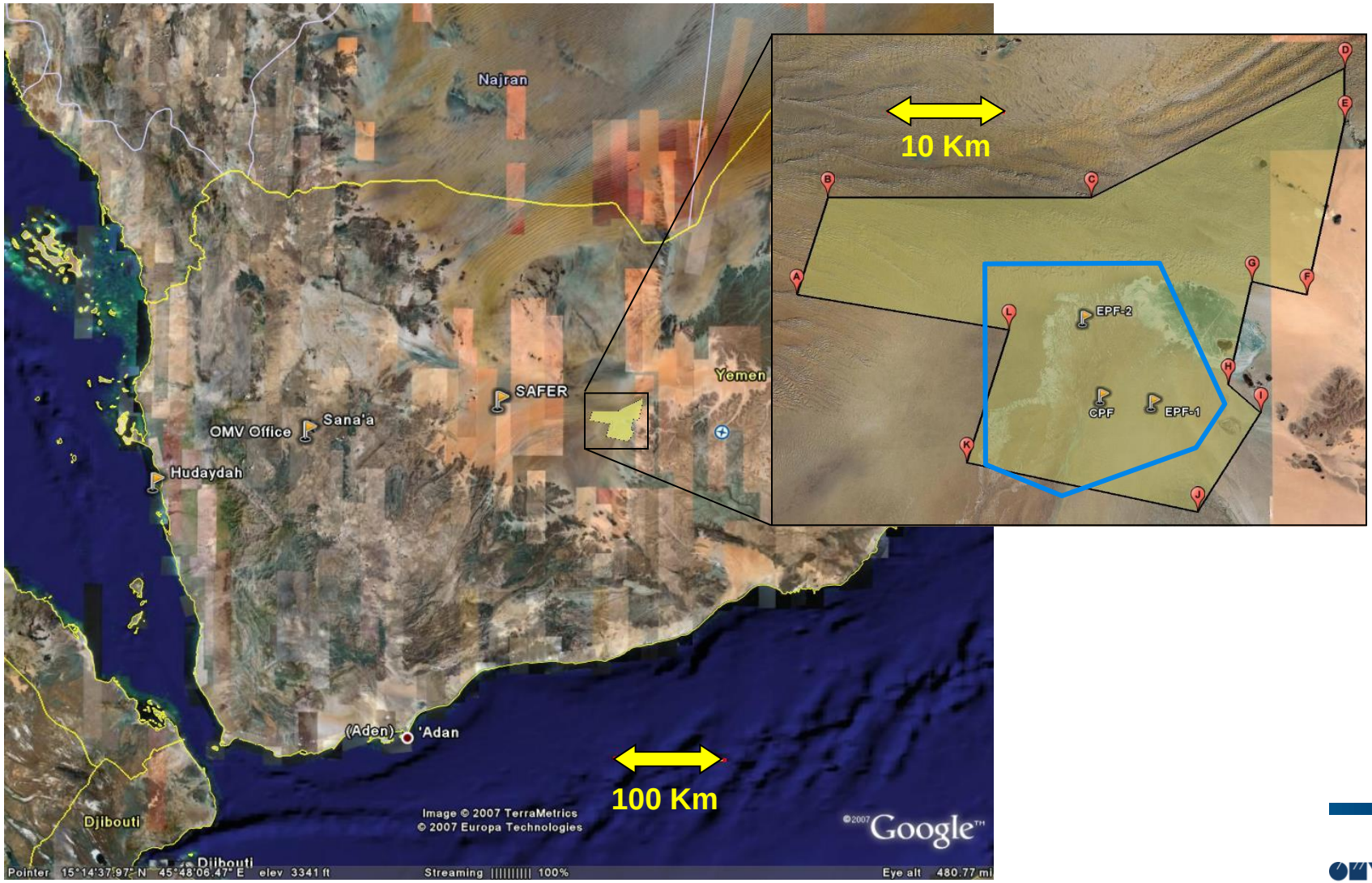
OMV Yemen ⌤ Block S2, ∠The Habban Field and the fractured basement play in Yemen ⍈

Overview – Production Facilities Block S2



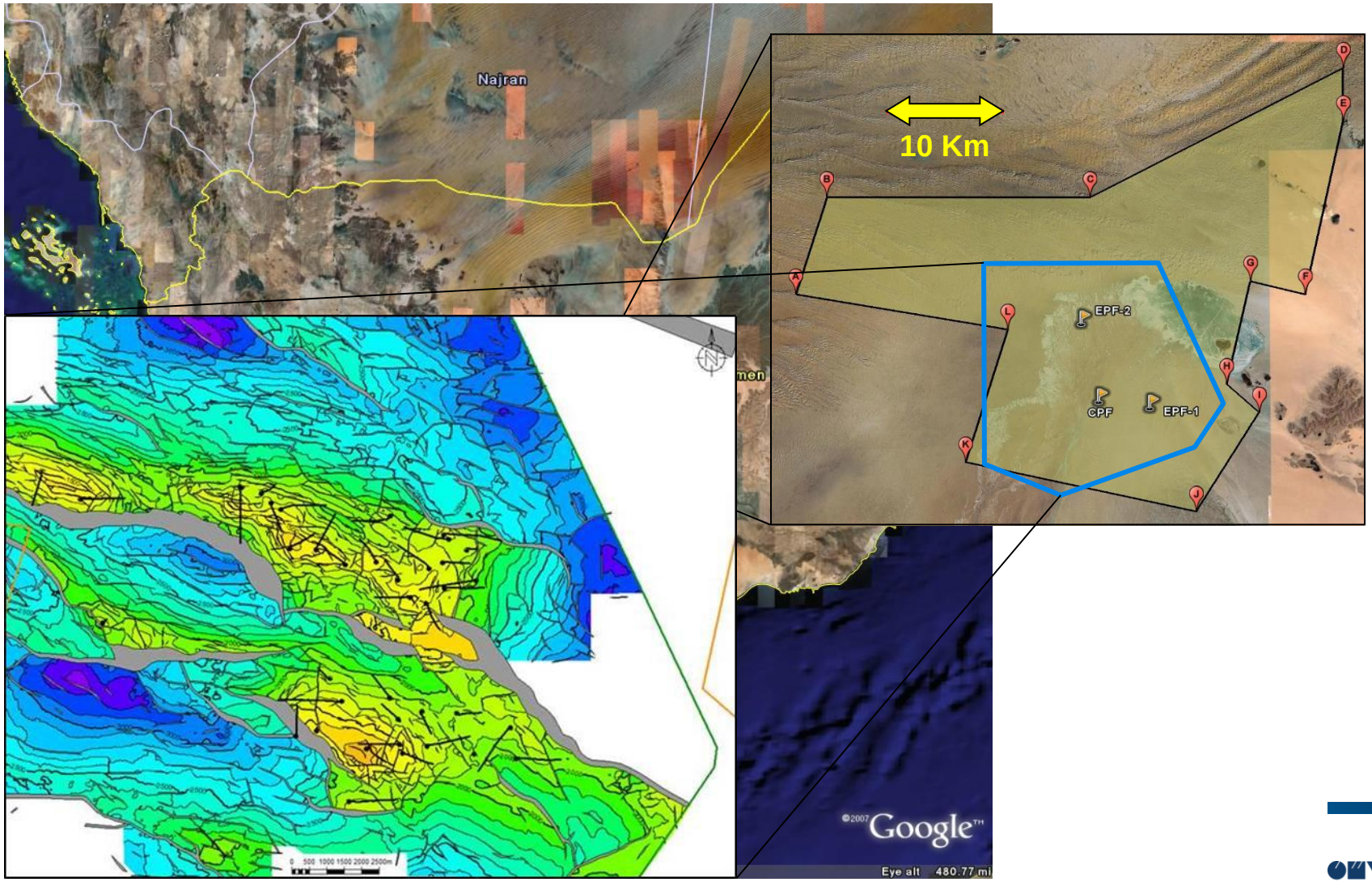
OMV Yemen ⫟ Block S2, ∠The Habban Field and the fractured basement play in Yemen ⍈

Overview – 3D seismic within Block S2



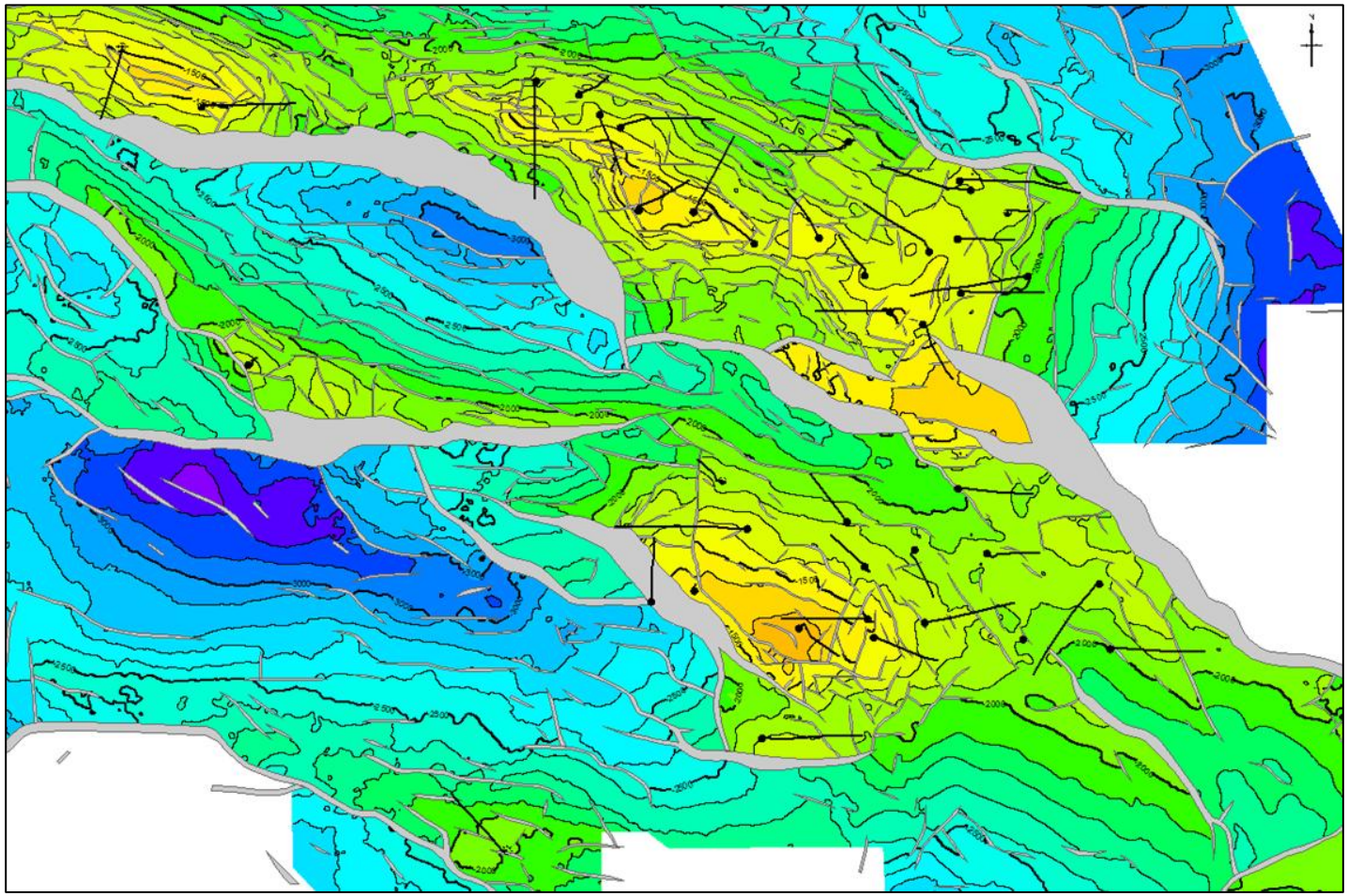
OMV Yemen ⫟ Block S2, ∠The Habban Field and the fractured basement play in Yemen ⍈

Overview

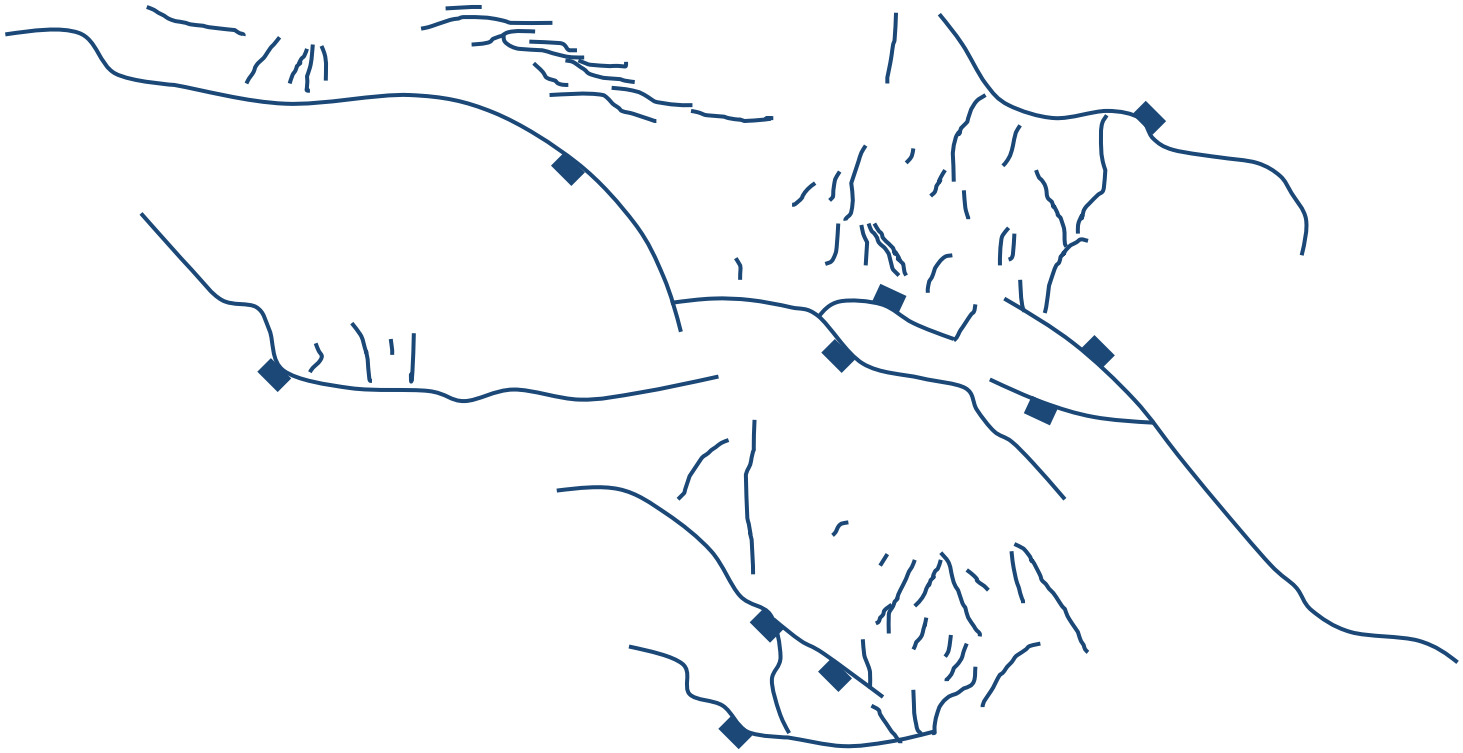


OMV Yemen ⫟ Block S2, ∠The Habban Field and the fractured basement play in Yemen ⍈

Habban – Top Basement Depth Map

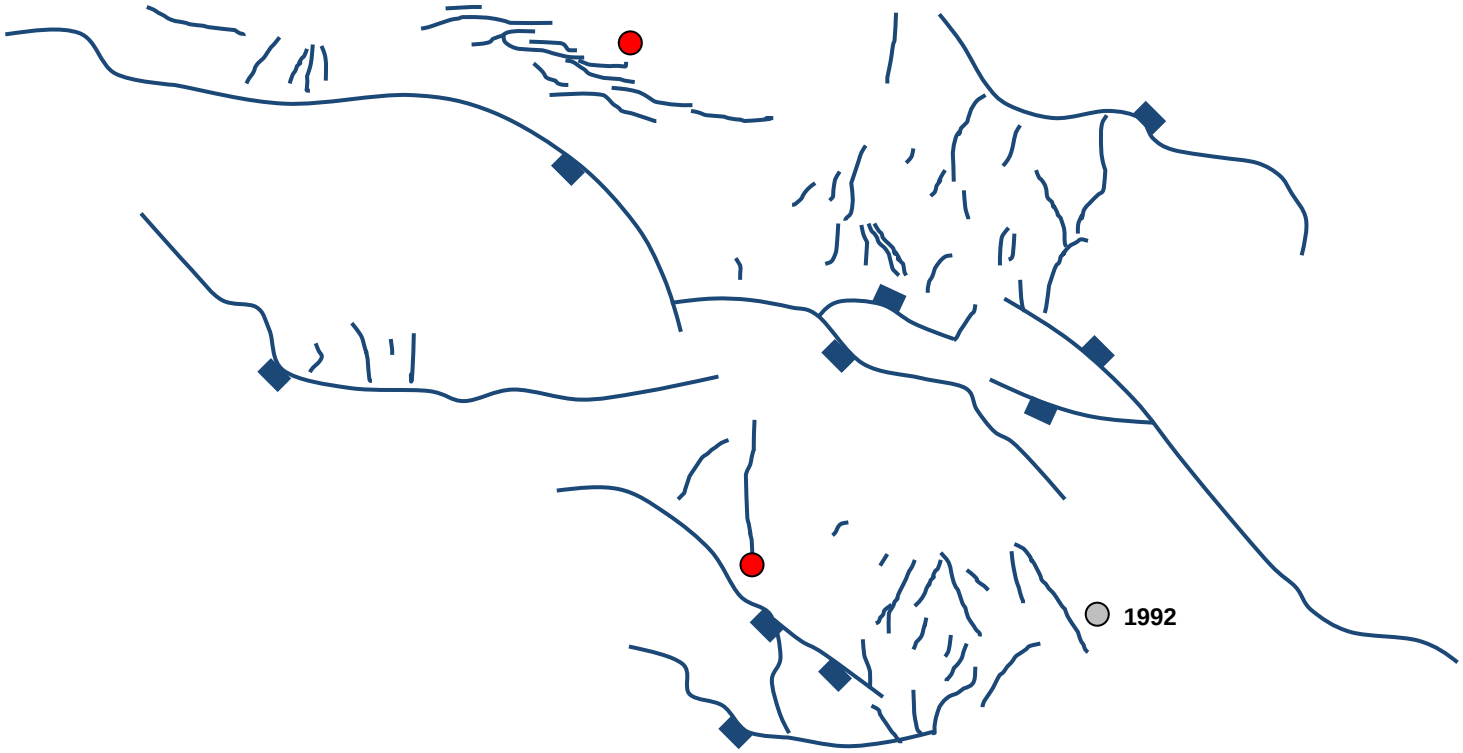


Main Structural Elements



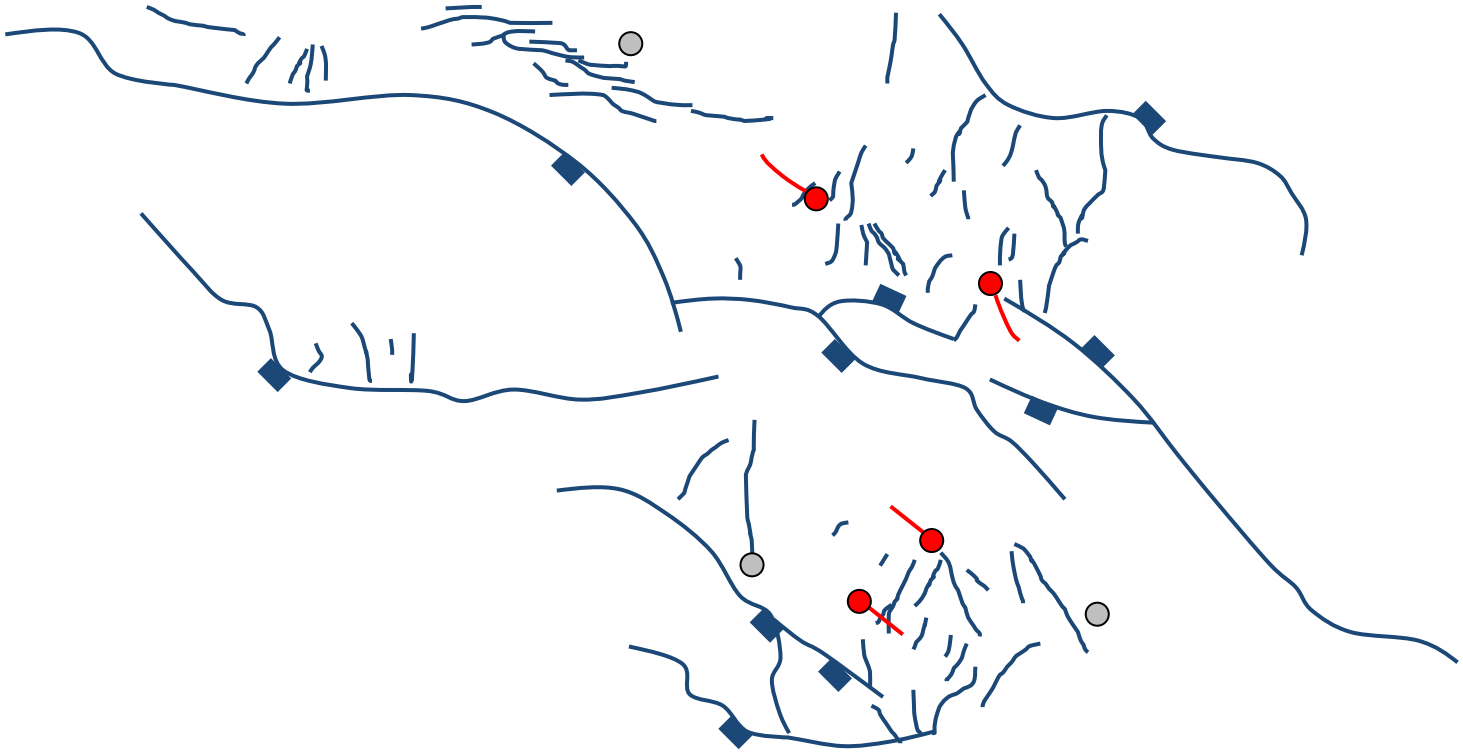
Wells Drilled Summary - 2005

Strategy: Before 2005 exploration wells targeted the sedimentary Fm. Overlying the Basement. In 2005, 2 crestal wells targeting fractured Basement, **planned on 2D seismic**



Wells Drilled Summary - 2007

Strategy: Crestal development of the fractured Basement, **planned on 2D seismic**



Initial Observations- Basement Lithology

Initial Observations

- No “stratigraphic” correlation observed between wells in Basement, except that granite might be found deeper in some areas. Majority of basement rocks are metamorphic.
- Metamorphic rocks can acquire porosity through fracturing and alteration (cataclasites, breccias).
- 2 major fault trends, the Najd fault trend (generally NW-SE) and the Hadhramawt fault trend (generally NNE-SSW) indicate 2 major distinct tectonic phases.

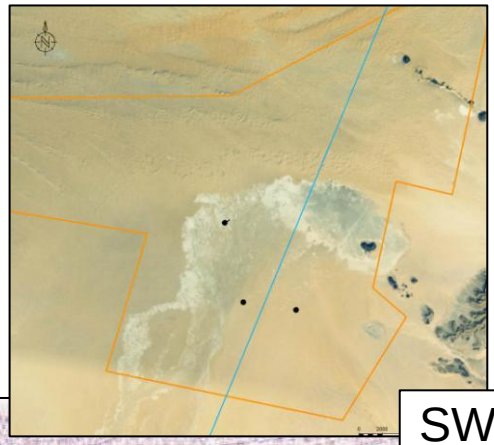

Cataclasite

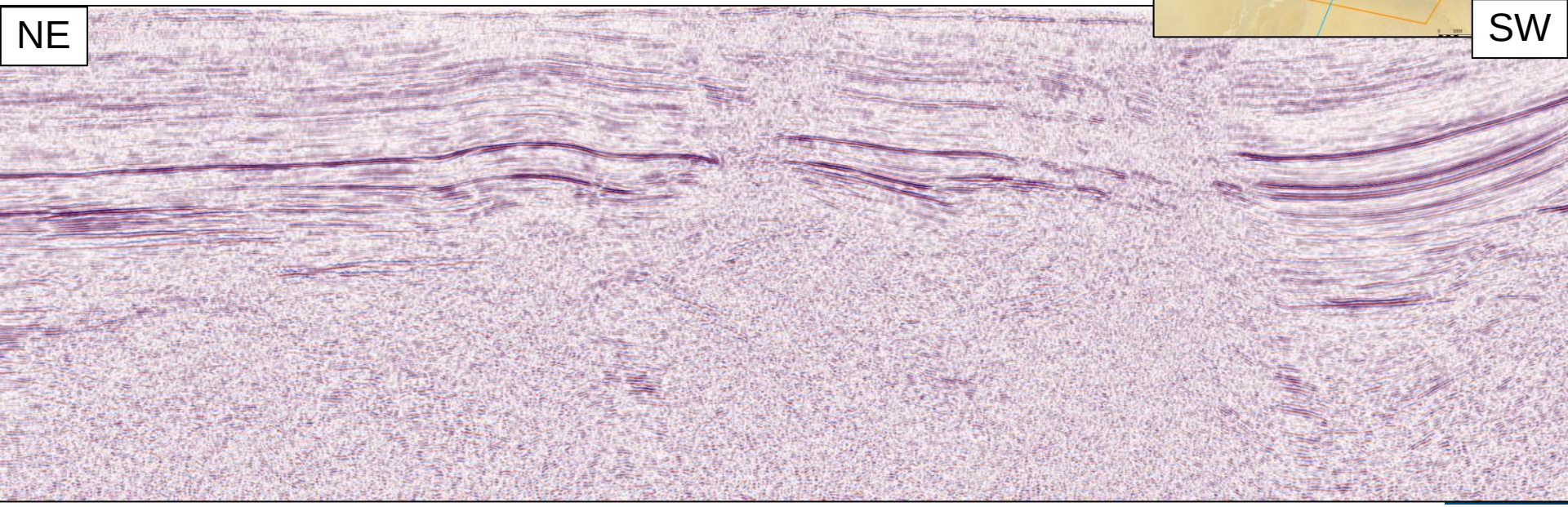

Corridor

Fractured Basement Characterization
Geophysics – 2D Seismic

- Reprocessing of the 2D seismic lines
  - Top Basement, barely interpretable

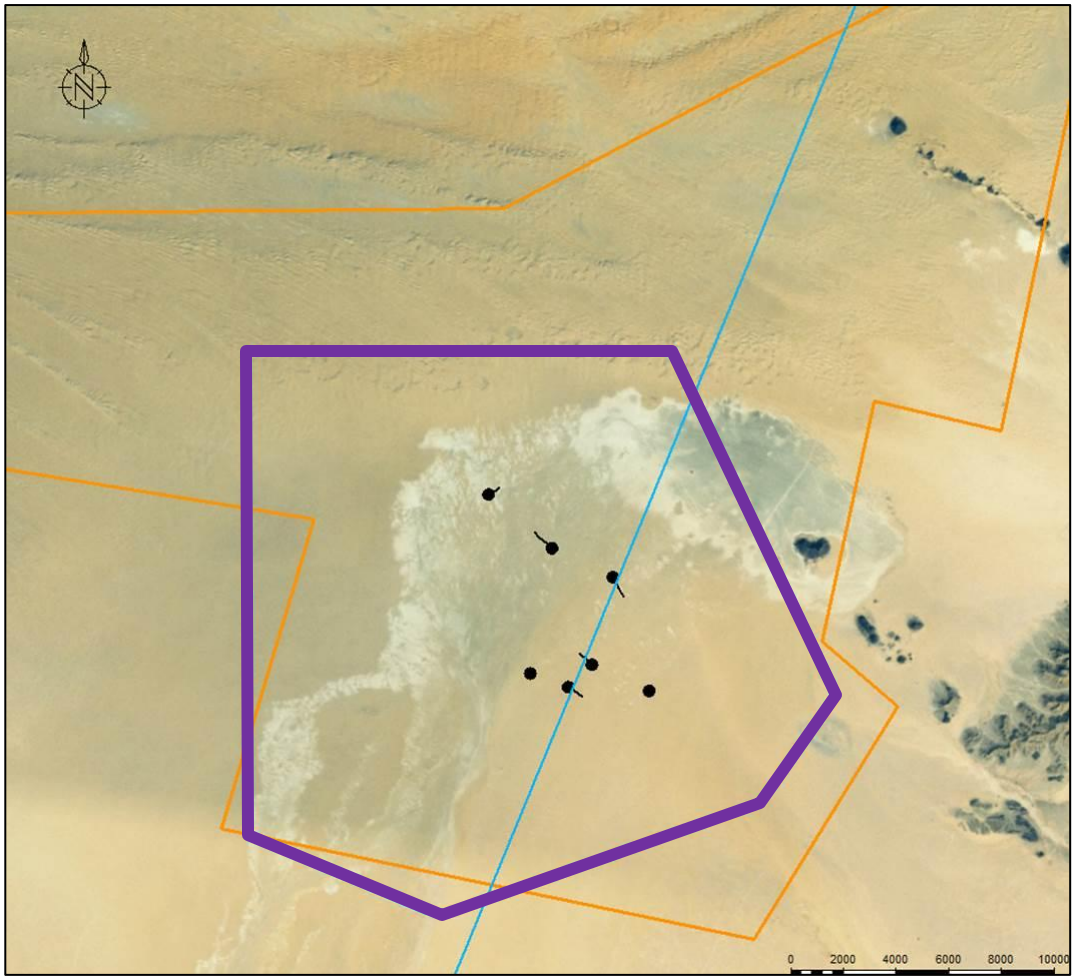
- 3D seismic mandatory to develop a Fractured Basement





Fractured Basement Characterization
Geophysics – 3D Seismic

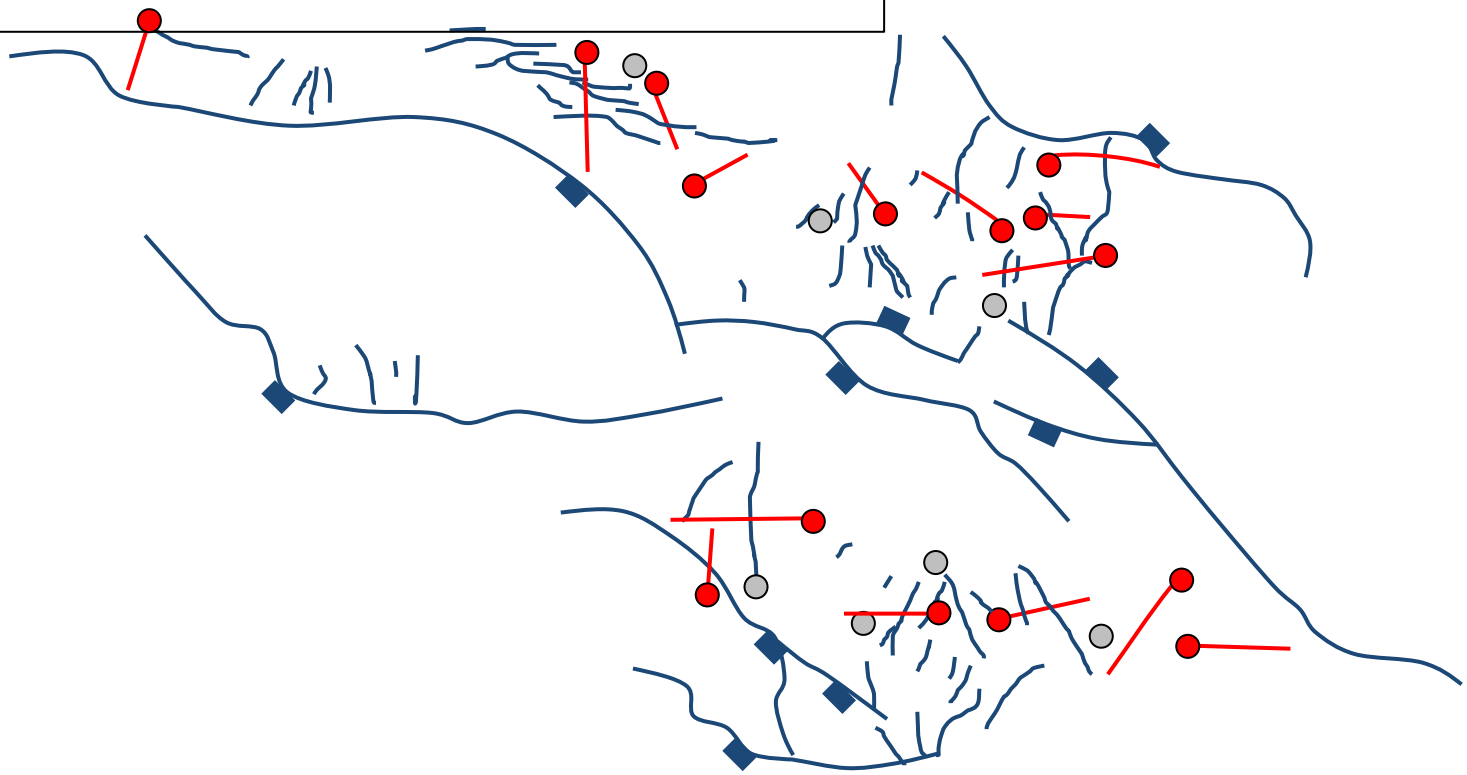
- 3D seismic acquisition - **Wide azimuth seismic**



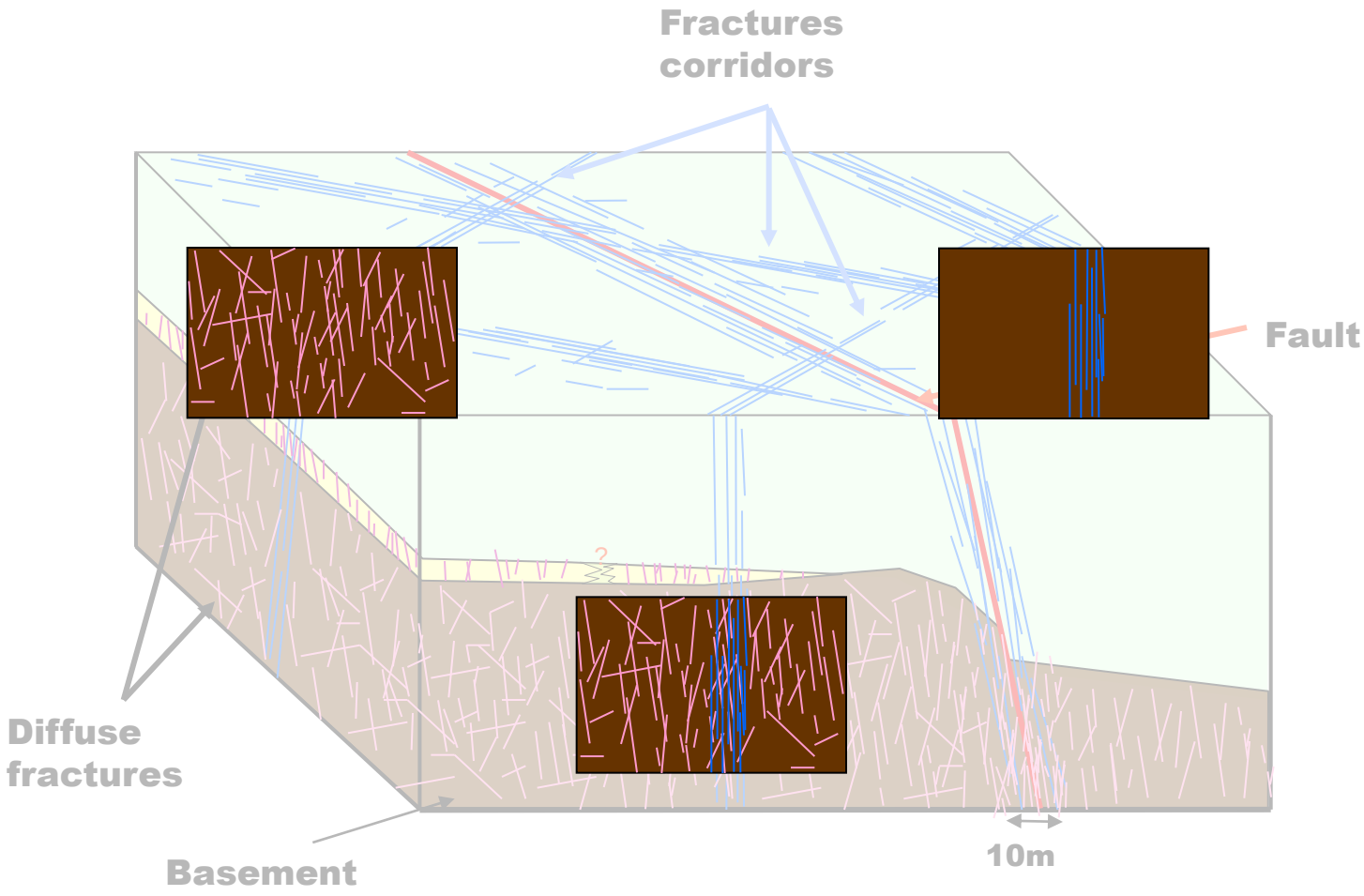
OMV

Wells Drilled Summary – 2008-2009

Strategy: Further crestal development of the fractured Basement. Then drilling moved to the periphery of the crestal fracture corridor, targeting large single faults. Optimum well orientation also tested. **Planned on 3D PSTM**



Basement Conceptual Model

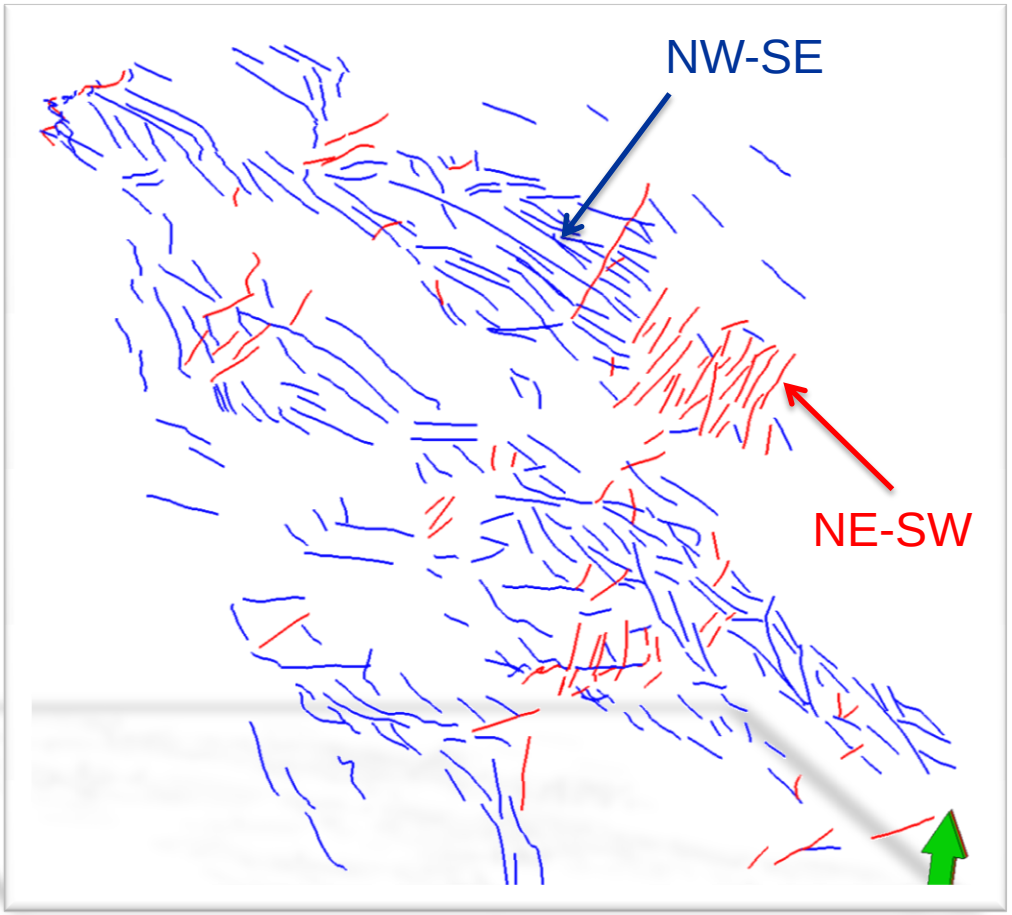


Fractured Basement Characterization

- Basement Fault/fracture system

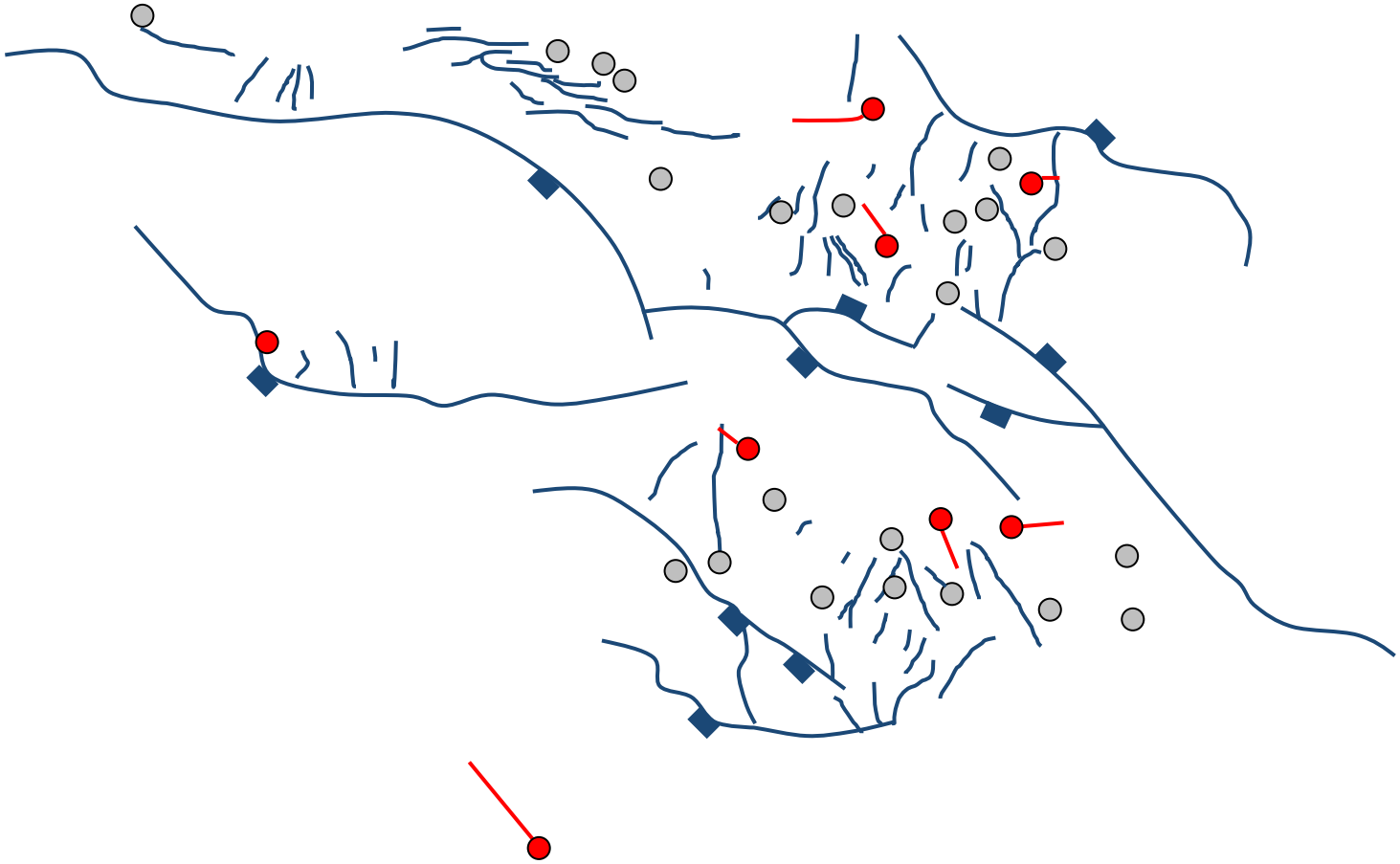
  Classification into two different fracture sets:

  - NW-SE
  - NNE-SSW



Wells Drilled Summary – 2010-2012

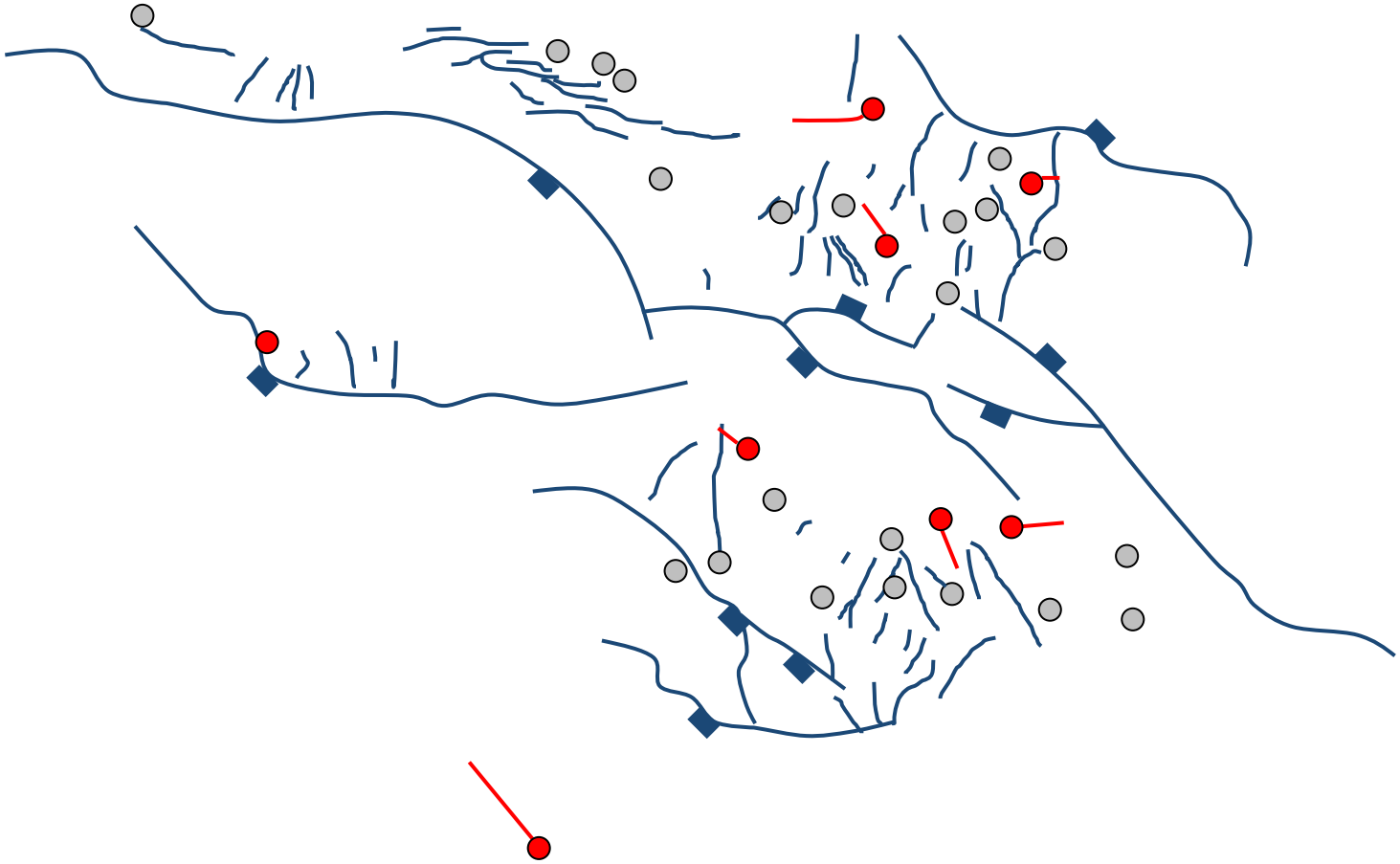
Strategy: Decrease in risk – development of Habban Central.
And 2 step-out appraisal wells “Higher risk”
Planned on 3D PSDM



Wells Drilled Summary – 2010-2012

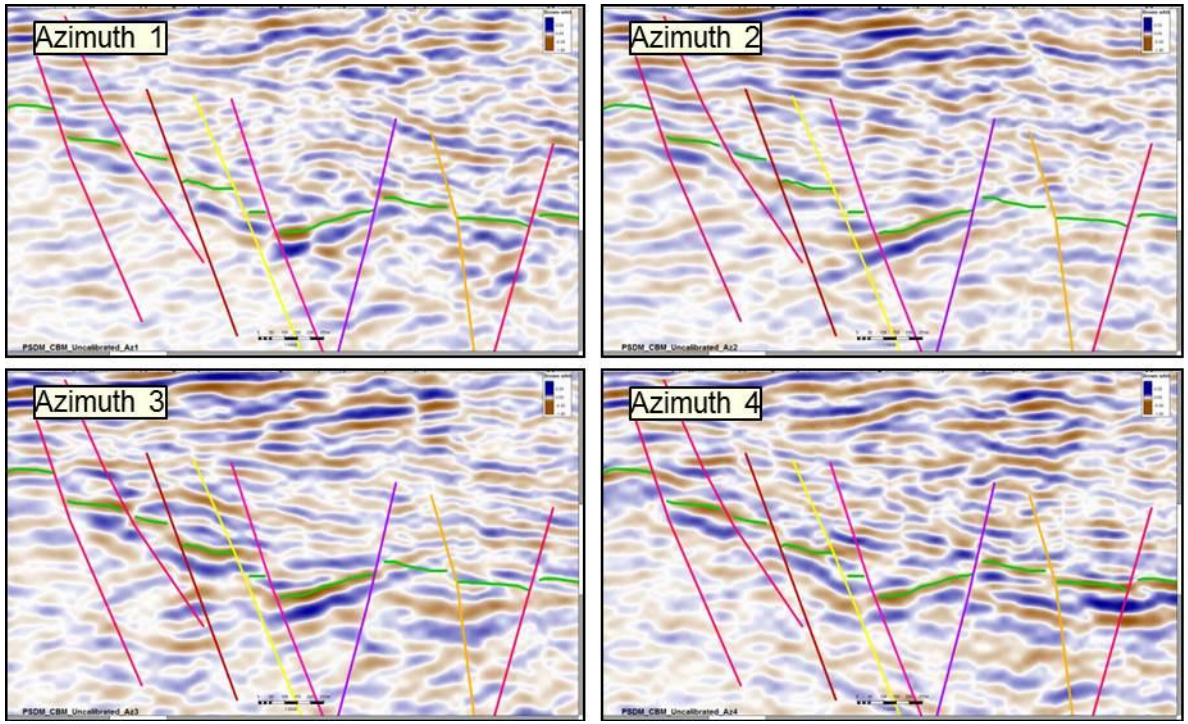
Strategy: Decrease in risk – development of Habban Central.
And 2 step-out appraisal wells “Higher risk”
Planned on 3D PSDM

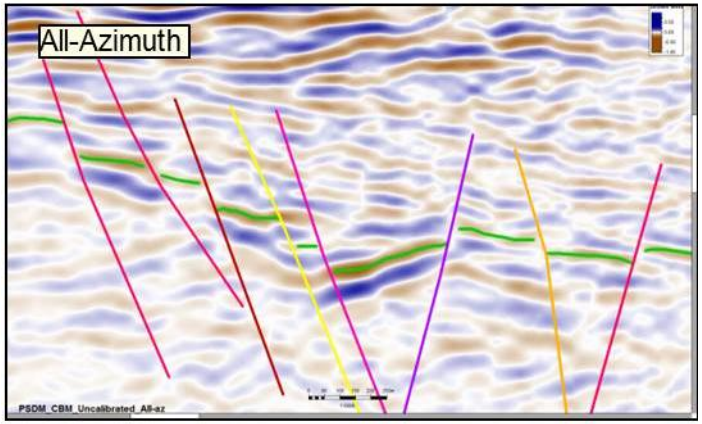
Mid 2011 Production and drilling suspended due to security concerns



Fractured Basement Characterization Geophysics

- **Post-stack Seismic Attributes generation for Fault/Fracture Characterization:**
  - Multi-azimuth 3D Seismic data was acquired over the Habban Field. This data has been used mainly for Seismic Anisotropy Analysis
  - For structural interpretation and fault characterization, CBM (all-azimuths) volume is used as this gives the best seismic image.

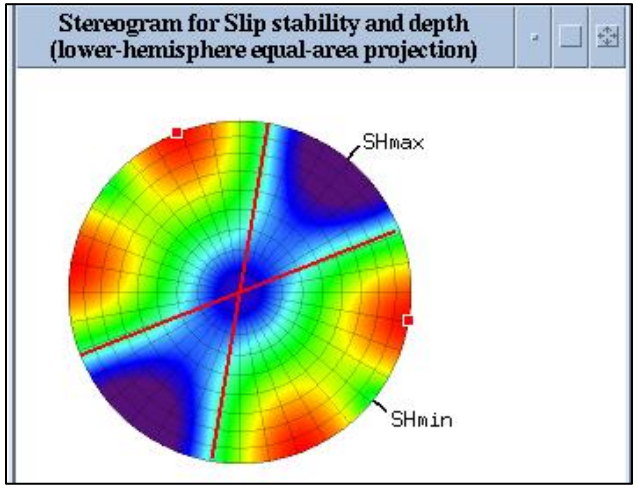


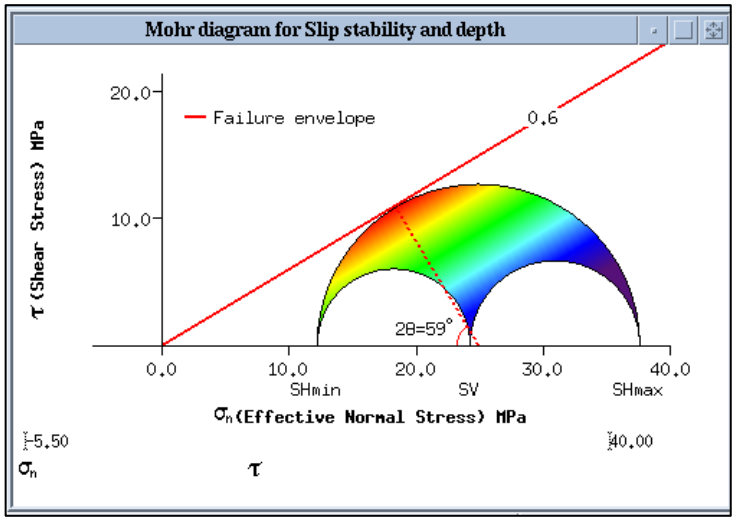


Fractured Basement Characterization Geomechanics

- **Objectives: Predict subseismic fractures pattern and assess the flow response to the in-situ stresses**

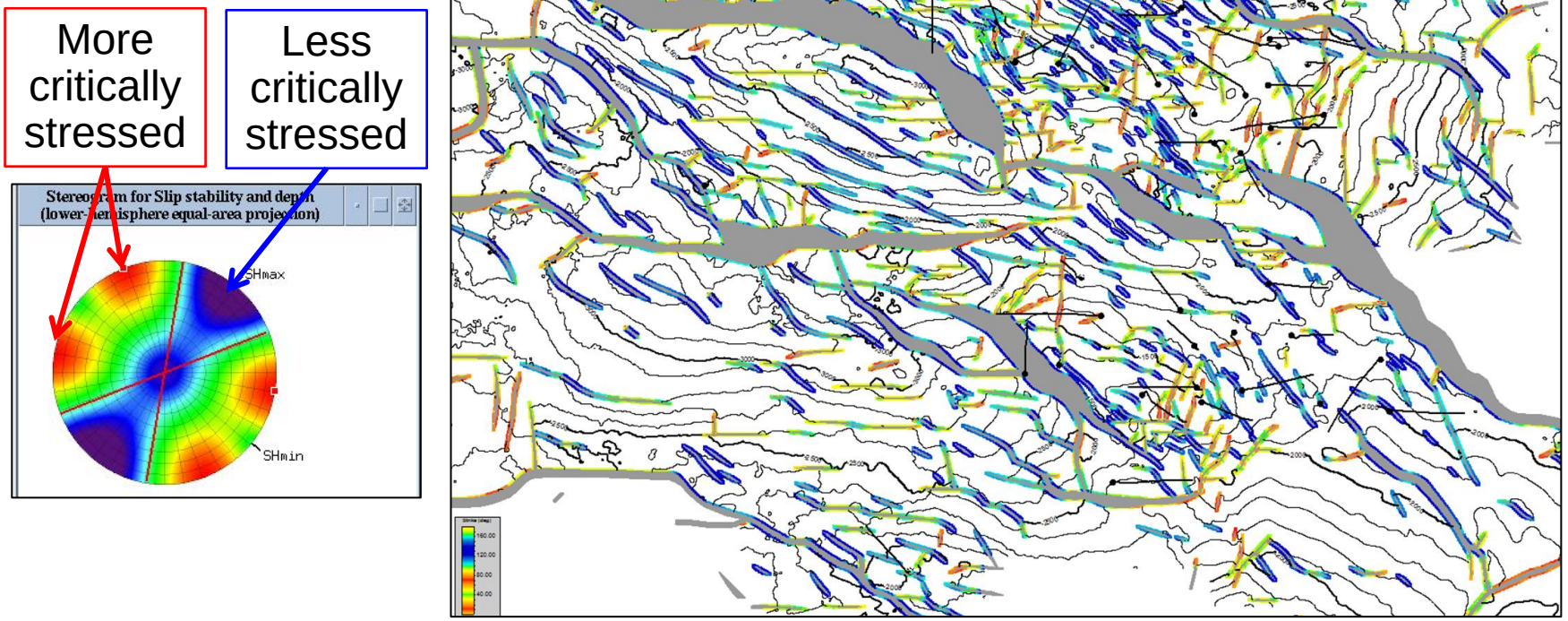
- Key findings:
  - Predicted orientation of failure planes (strongly dependent on the fault interpreted pattern and not sensitive to the material properties)
  - Faults and fractures in the in situ strike-slip faulting regime give a good explanation for the distinction between “open” and “closed” fractures





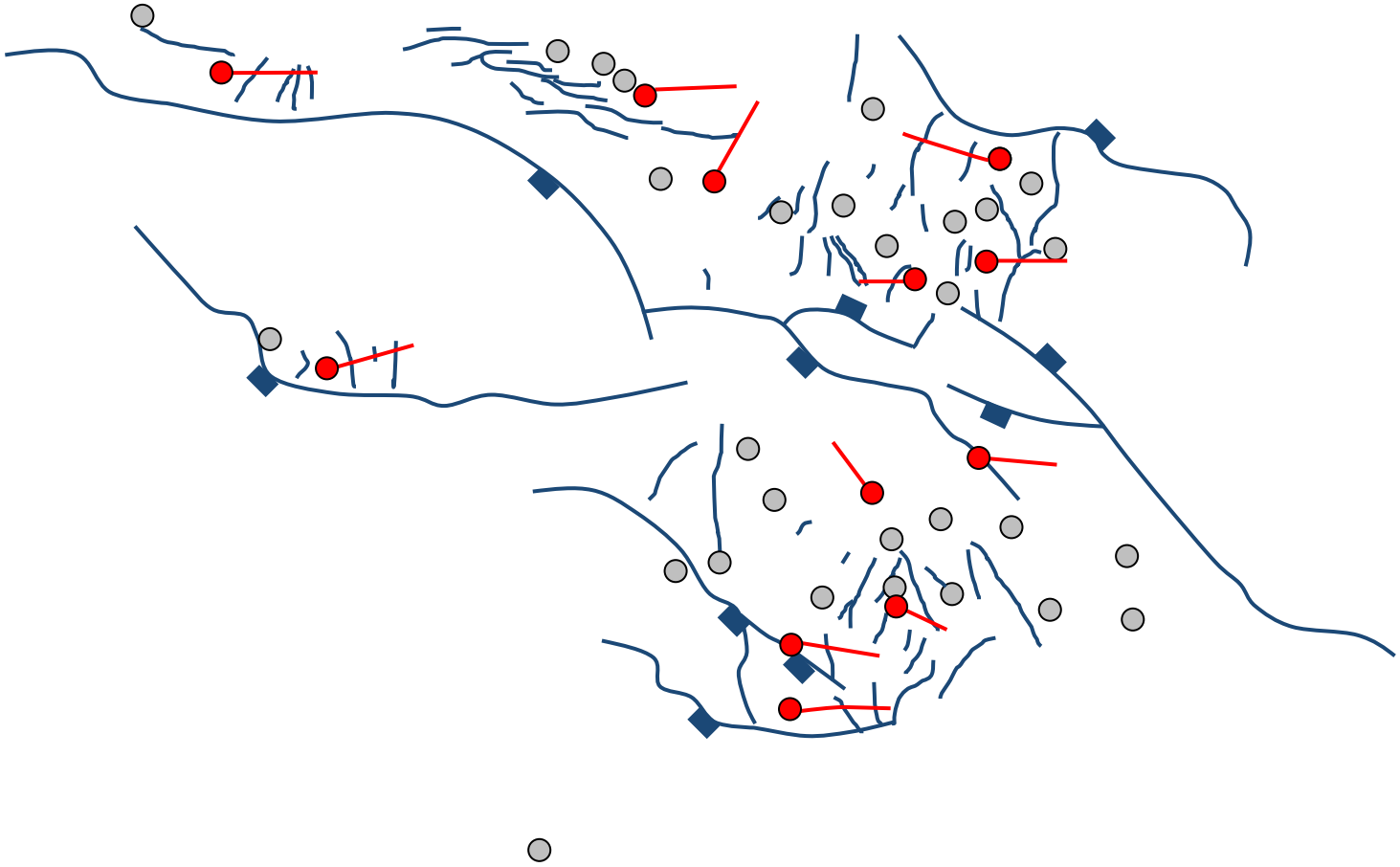
Fractured Basement Characterization Geomechanics

- Applying the strike-slip faulting regime deduced from the study to the orientation of the 2014 fault interpretation
  - More complex than the two set classification

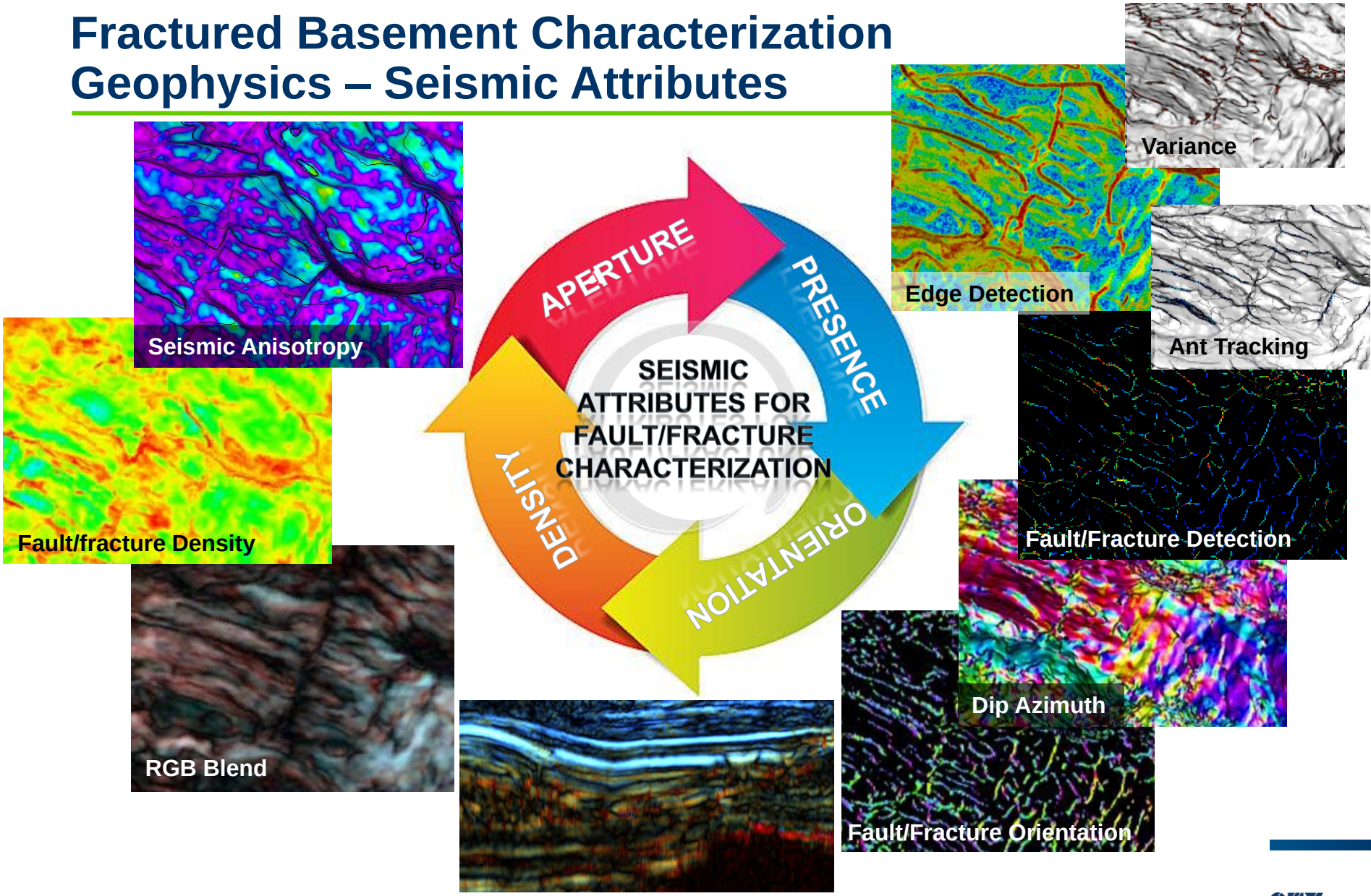


Wells Drilled Summary – 2013-2014

Strategy: Basement development wells target multiple “critically stressed” faults in search of well connected fractures. Re-appraisal of step-out structures. **New PSDM interpretation**.

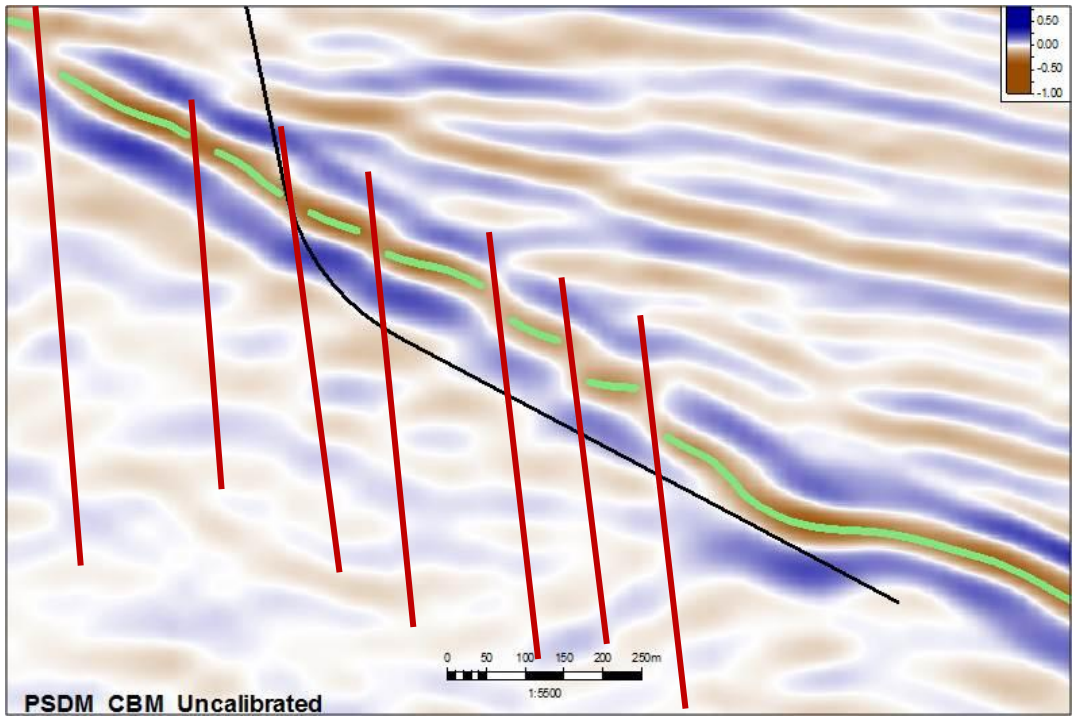


Fractured Basement Characterization
Geophysics – Seismic Attributes



Fractured Basement Development Continues

- Typical well plan
  - Maximize reservoir contact – maximize number of faults/corridors
  - Stay close to the top Basement



Conclusions

- Basement plays have often been overlooked or considered to be marginally economic.

- Basement reservoirs are challenging
  - Drilling challenges
  - Development challenges
  - Production challenges

- Keys to understanding the dynamic mechanisms
  - 3D seismic
  - Fault and fracture network characterization

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