- Interactive Well Path Planning with Integrated Geoscience and Cultural Data

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  (* Speaker)

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Speaker Bio

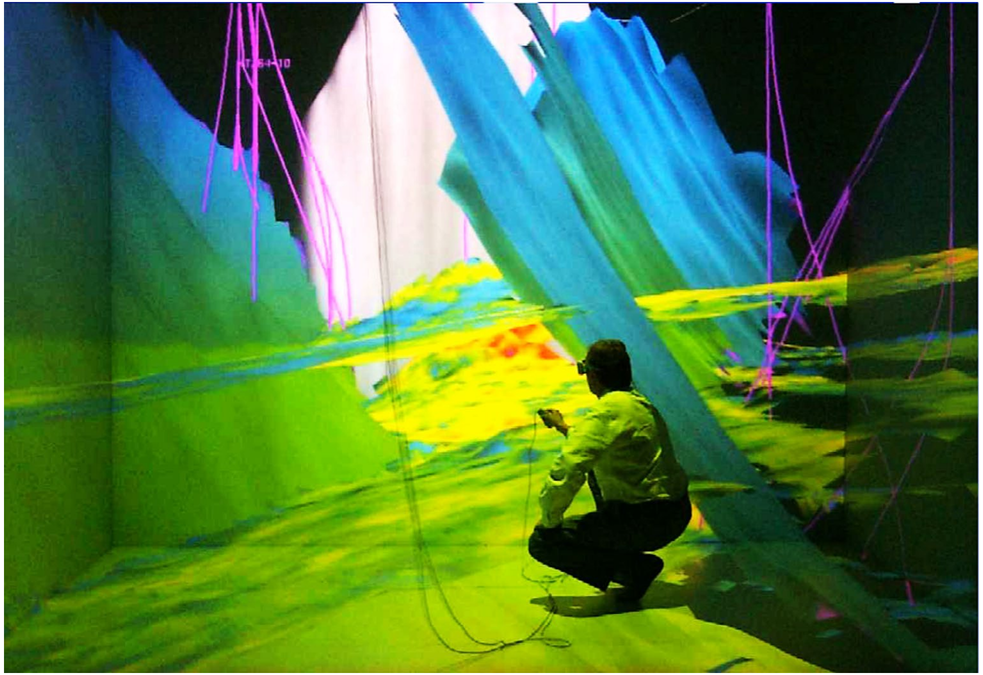
CGG
Passion for Geoscience
GeoSoftware

- Introduction
  - Employer: CGG GeoSoftware
  - Experience: ARCO, Univ. of Colorado, TerraSpark GeoSciences, CGG GeoSoftware
  - Education: PhD in Eng. Geoscience, UC Berkeley
  - Location: Denver, Colorado, USA
  - Focus: Seismic Interpretation, 3D Visualization Integrated Geoscience & Well Path Planning

Integrated GeoScience & Well Path Planning

3D Integration and Visualization of:

- G&G Data
- Existing Wells
    - Paths, Logs, Tops
- Planned Wells



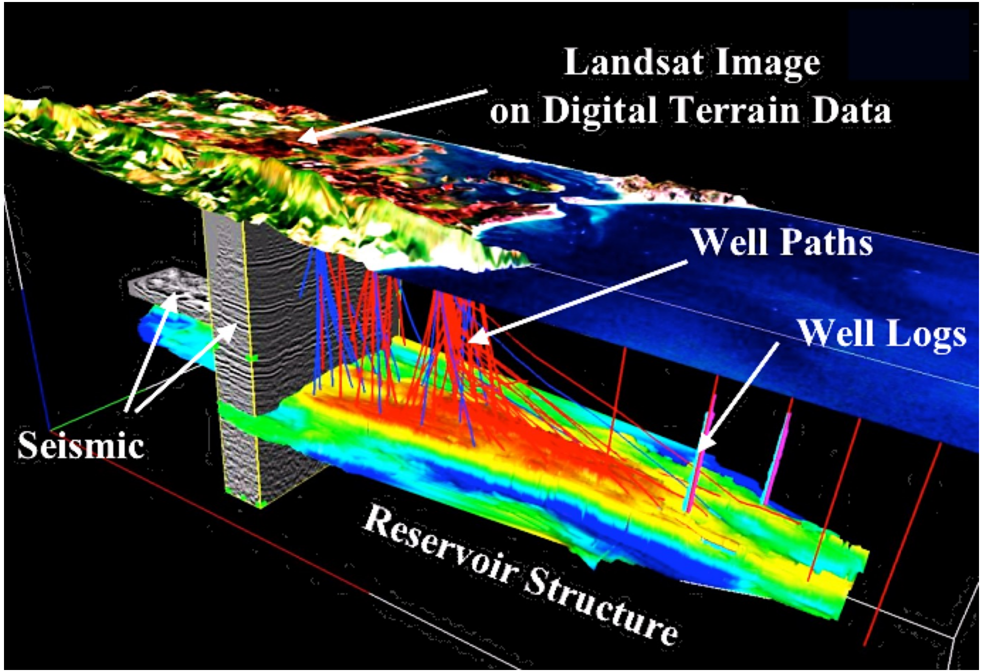
(1997 ARCO)

Integrated GeoScience & Well Path Planning

3D Integration and Visualization of:

- G&G Data
- Cultural Data
- Existing Wells
  - Paths, Logs. Tops
- Well Path Planning
  - Conventionals

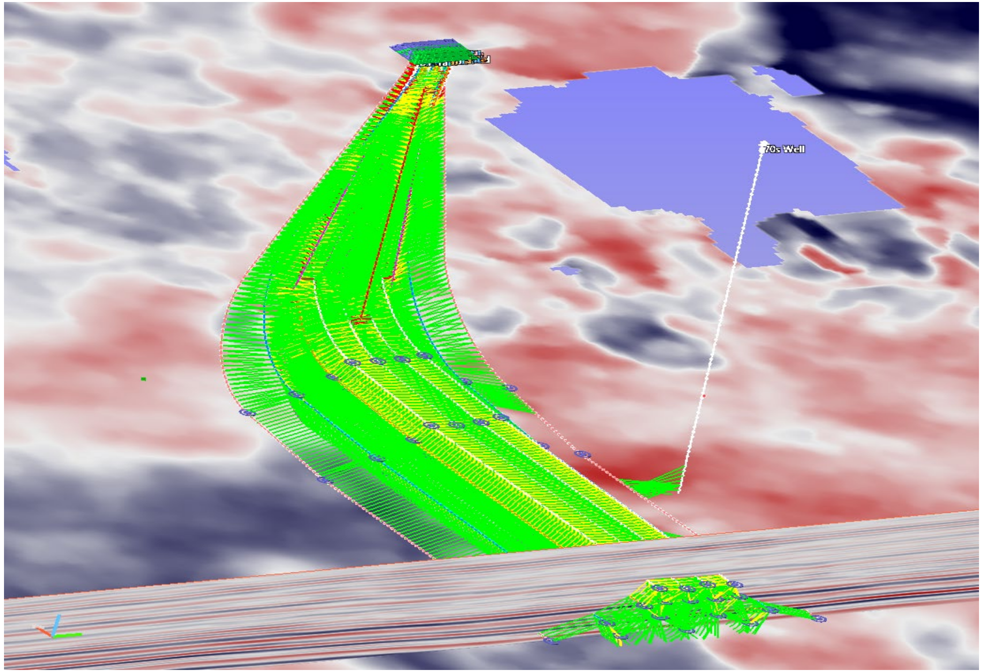
(2005 BP Center, Univ. of Colorado, Boulder)



Integrated GeoScience & Well Path Planning

3D Integration and Visualization of:

- G&G Data
- Cultural Data
- Existing Wells
  - Paths, Logs, Tops
- Well Path Planning
  - Conventionals
  - Unconventionals (2018 CGG)



Integrated GeoScience & Well Path Planning

Why do we need need software that integrates Well Path Planning with all available data?

Not a good outcome

REALLY Not a good outcome

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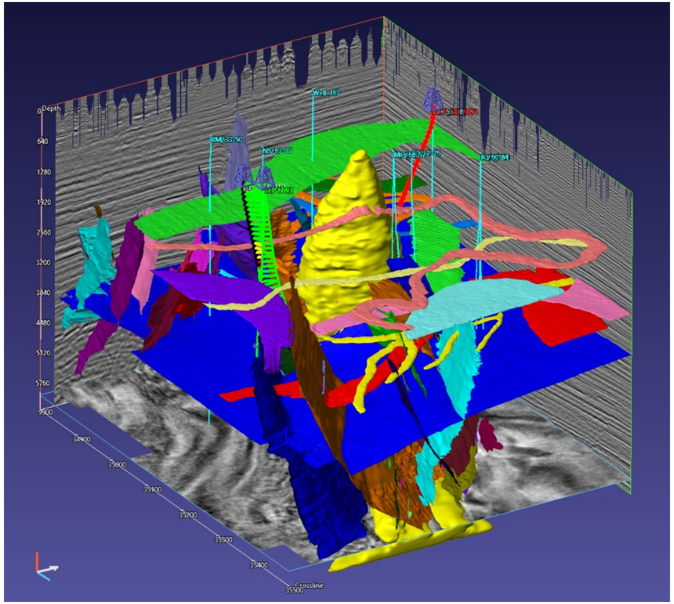
The Exploration and Development Goal

- Whether you are a Drilling Engineer, Well Planner, Geophysicist, Geologist, Well Log Analyst, etc., the goal is to **find, develop and produce reserves as efficiently, effectively and safely as possible**.

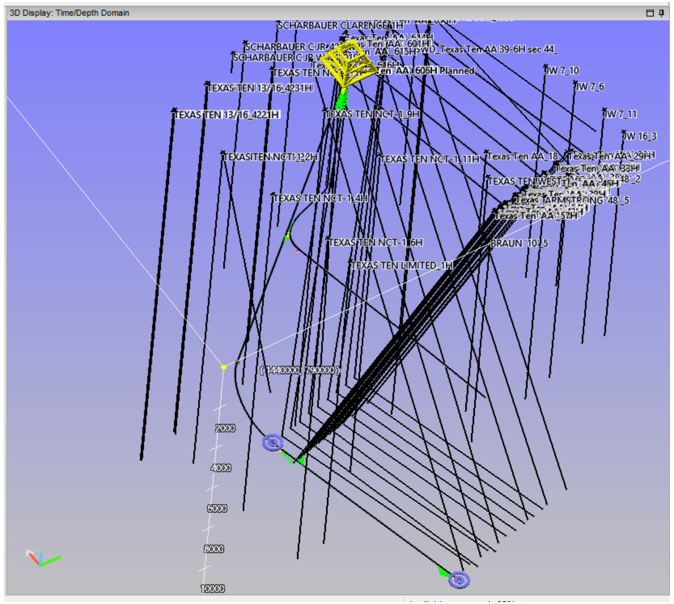
- This can be most effectively accomplished by having all of the spatially referenced data properly registered and displayed in one place.

- InsightEarth WellPath is a step down this path.

Well Path Planning in 3D



A: Geology is 3D



B: Wells are 3D

You need A and B together to Plan in 3D

Planning in 3D

Early Experience using Geophysics to support 3D Well Path Planning

- "Deep geothermal exploration in New Mexico using electrical resistivity"
  (Proceedings of the Second United Nations Symposium on the Development and Use of Geothermal Resources, 1975)

  - **Well Path #1:** Drill into the hot-dry rock of a KGRA in New Mexico
  - **Create Fracture(s)**: Frac the hot-dry rock
  - **Geophysics:** Use electrical resistivity measurements to determine the orientation/location of the fracture
  - **Well Path #2:** Intersect the Fracture with a second borehole to allow circulation of injected water.

Permian Basin Examples

- Shallow Drilling Hazards
- Water Source or Water Problem
- Planning in Mature Drilled areas
- Optimize Path and Completion Plans for Natural Fracture Swarms
- Plan for Multiple Stacked Reservoir Zones

Permian: Shallow Drilling Hazards

Mapping near-surface karsts:

- Affects pad placement, well placement and well path
- Ignoring this results in bit drops, equipment loss, pad loss, environmental impact …

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Permian: Water Source or Water Problem

Understanding the water table:

- Identify potential sources of drilling water
- Help avoid near surface geology anomalies that might impact drilling
  - Dissolution/collapse features (e.g., karsts)
  - Mapping of velocity inversions
  - Improved statics in problem areas

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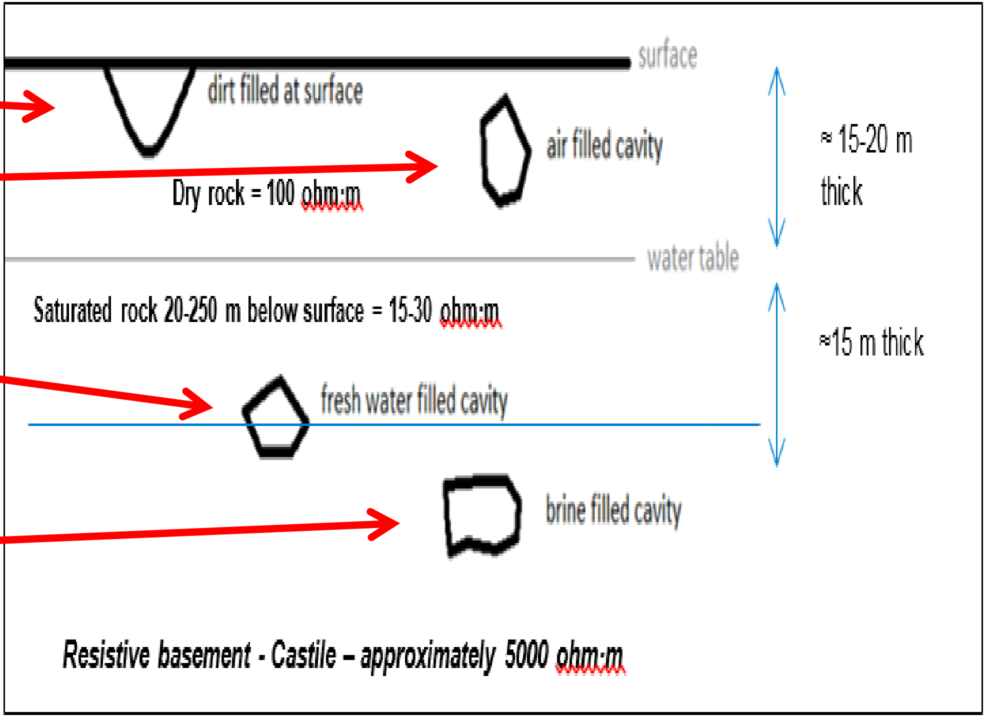
Examples of EM Responses

- Dirt filled sinkholes
- Air filled cavities
  - above water table – ~0-20m below surface
  - more resistive than the dry host rock
- Fresh-water filled cavities
  - 20 - 35m below surface
  - may have little contrast with resistivity of the limestone.
- Brine-filled cavities
  - lower resistivity than surrounding rock.



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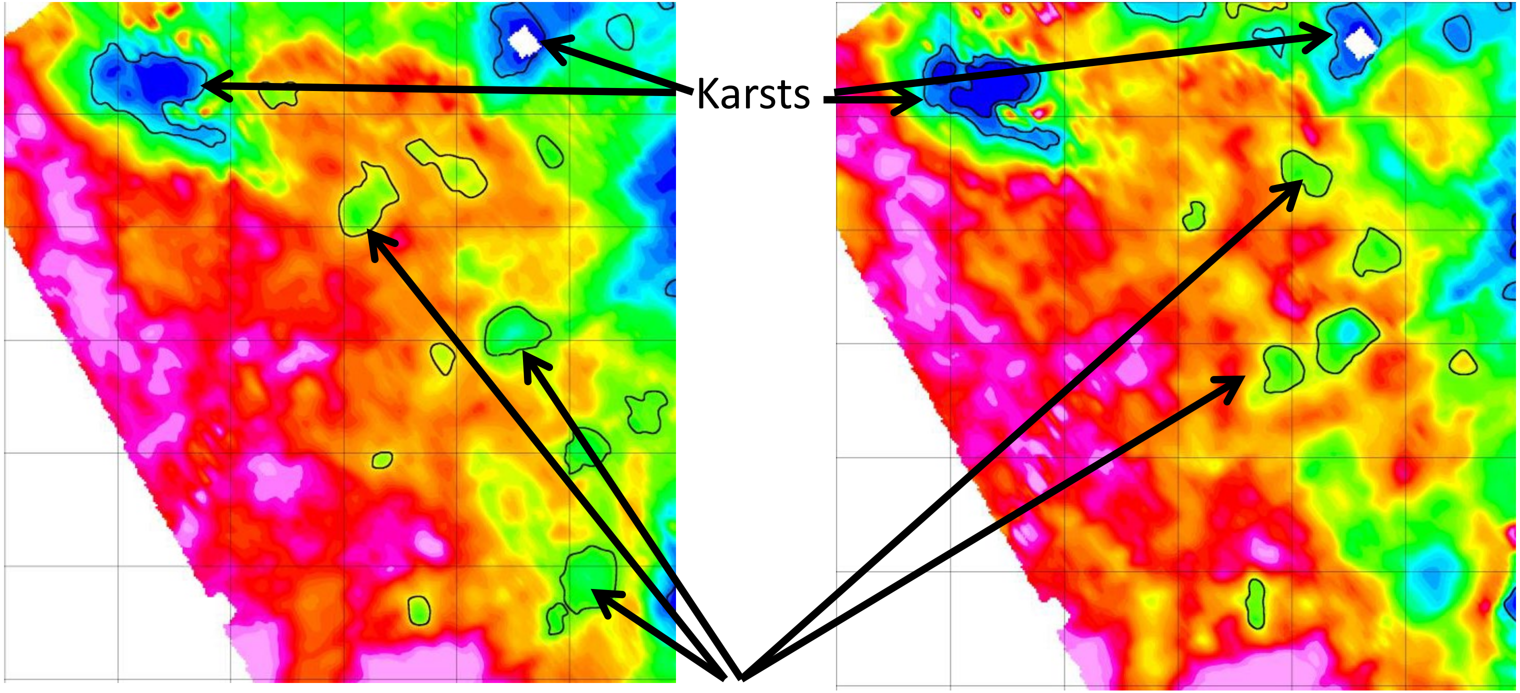
Permian: Airborne EM Data Showing Possible Karsts



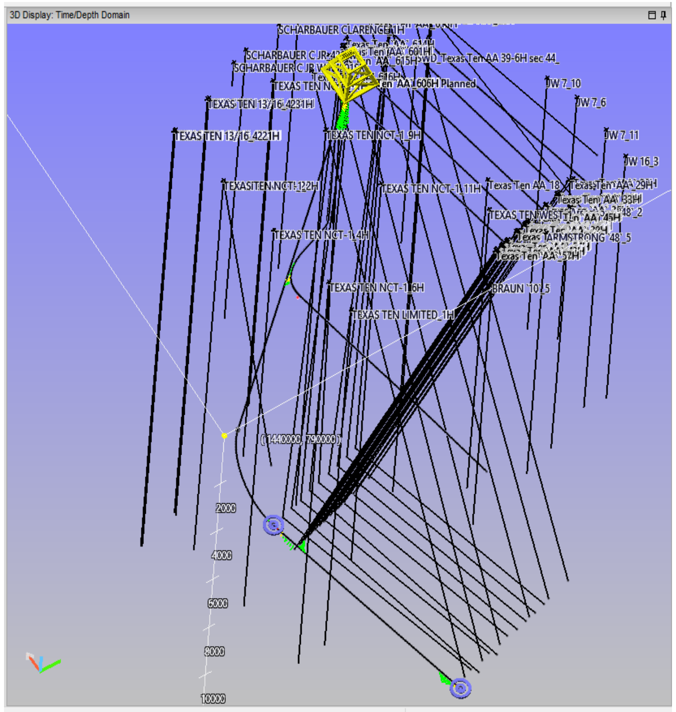
Depth: 50 m

Features of “concern”

Depth: 63 m

Permian: Planning in Mature Drilled Areas

- The mature basin is a "pincushion" of legacy wells.
- Planning in the presence of legacy wells requires flexible anticollision and uncertainty capabilities:
  - Between Planned Wells and Existing Wells
  - A Variety of uncertainty models (conservative – liberal)
  - Methods to evaluate options

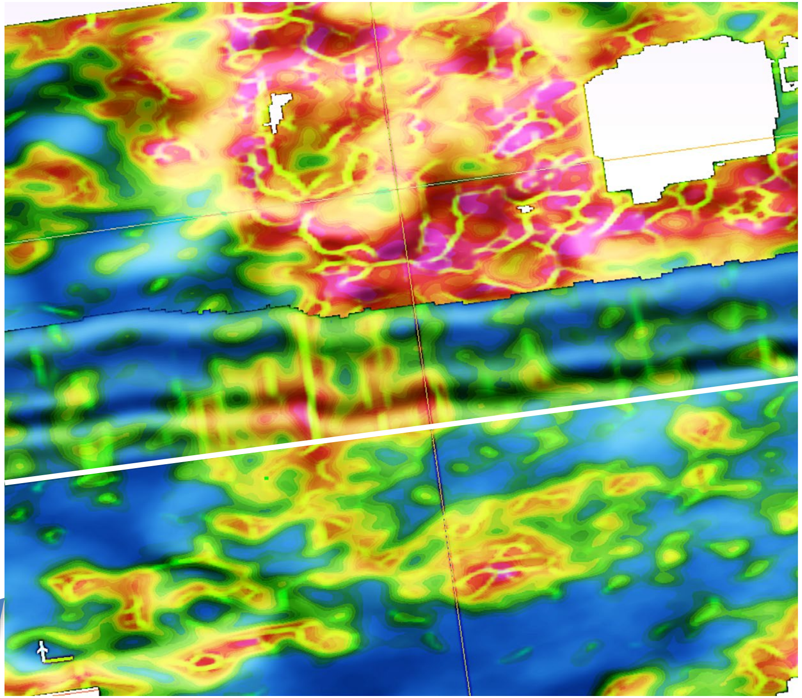


Permian: Optimize Path for Natural Fracture Swarms

Understanding the Effects of Fracture Swarms:

- Co-render four seismic attributes to understand communication problems

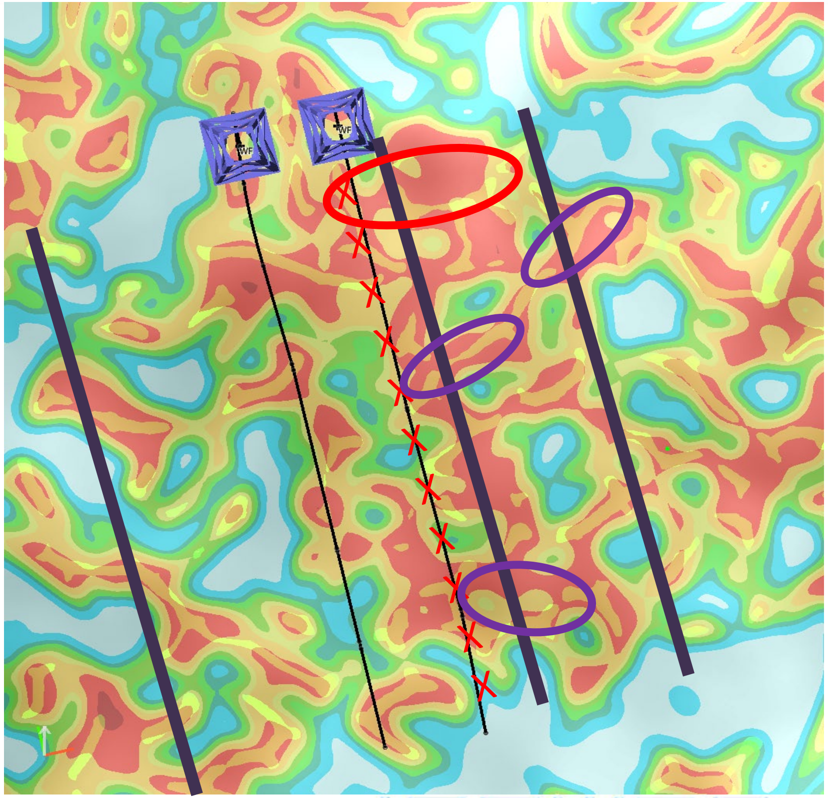
- In Increasing resolution:
  - Seismic Amplitudes
  - Fault Enhanced Volume
  - Discrete Fracture Network
  - Fracture Density



Permian: Change Completion Strategy

Change Completion Strategy Based on Natural Fracture Density

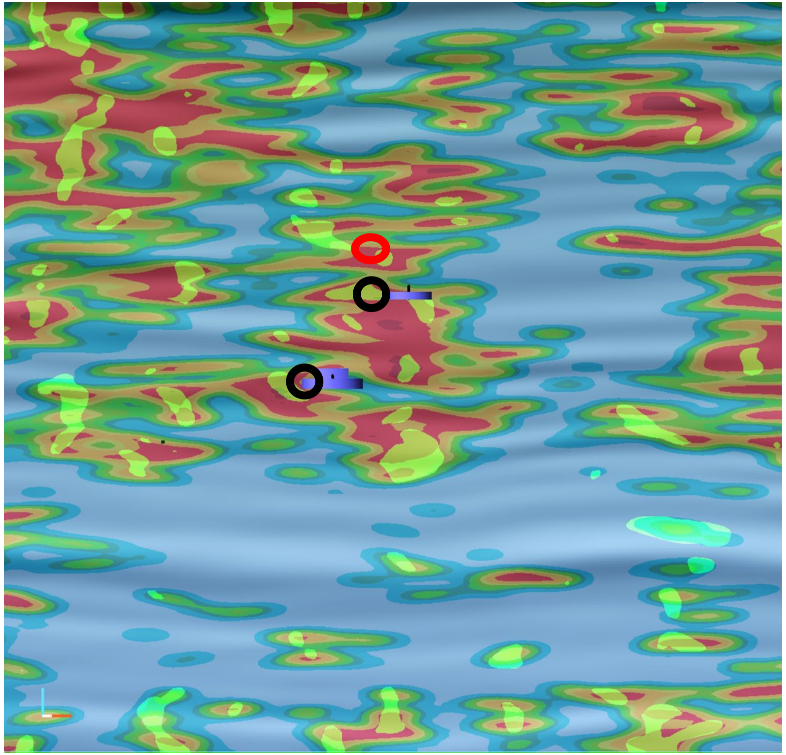
- Original Planned Laterals
- Recommended lateral placement
- Skip this stage
- Smaller Fracture Stimulation



Permian: Change Completion Strategy

Change Completion Strategy
Based on Natural Fracture Density

- Avoid connected high fracture density
- Increase vertical spacing 200-300 ft



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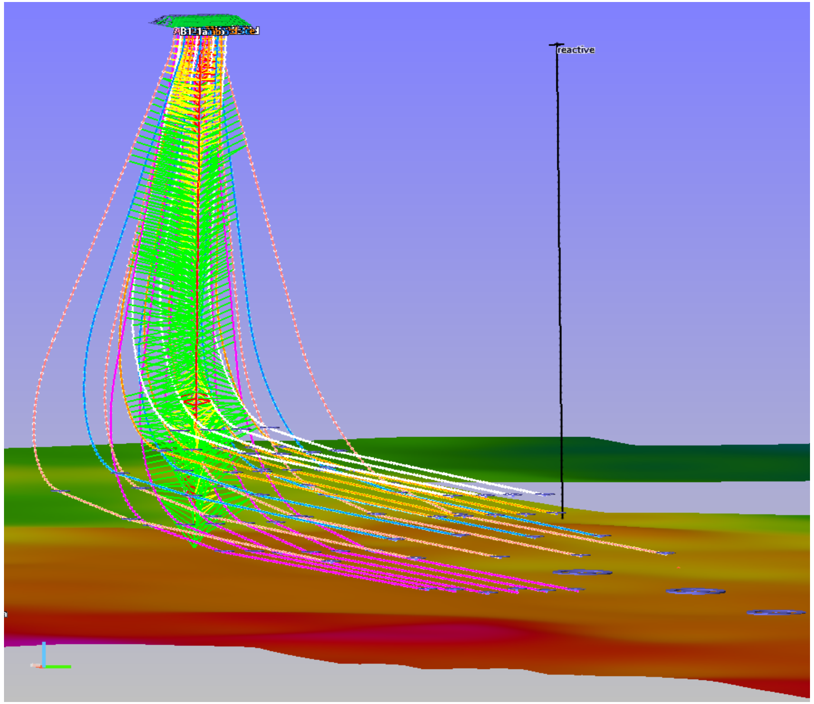
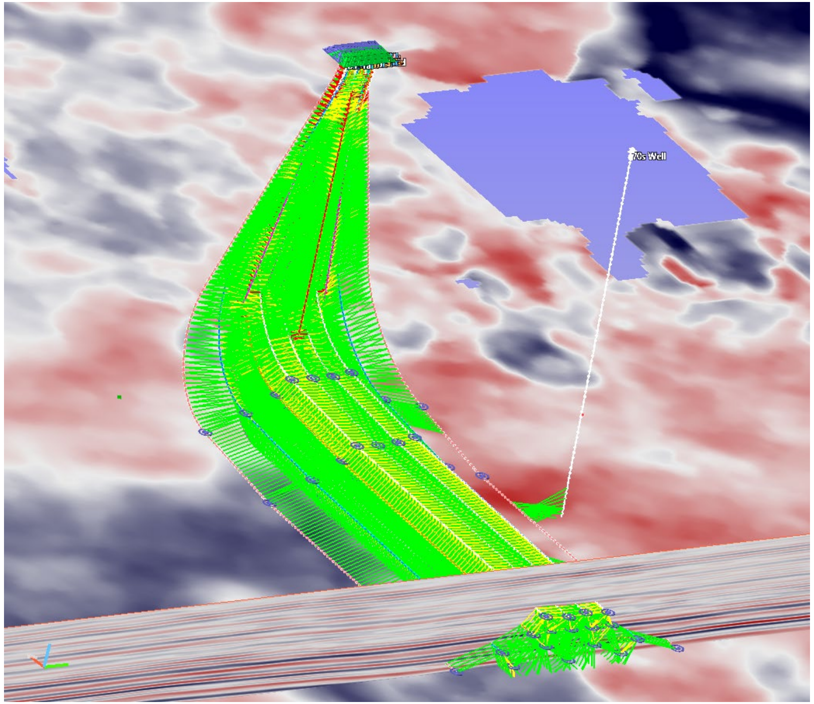
Plan for Multiple Stacked Reservoir Zones





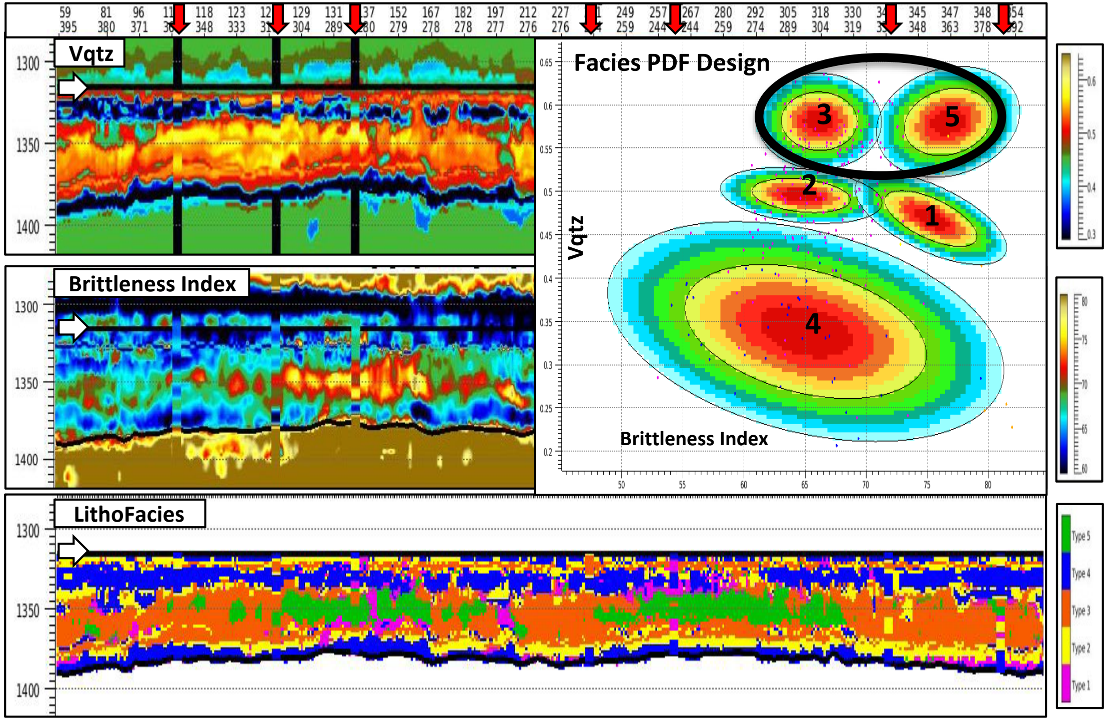
Barnett Shale Examples

- Optimize Path for Best Reservoir Facies and Fracture Swarms
- Optimize Path for Best Zone in an Interval

Barnett: Optimize for Best Facies/Rock Properties

- High Vqtz and Brittleness are desirable.
- Clay-rich rock inhibits fractures at the base of the formation.
- Facies 3 and 5 correlate to best production.

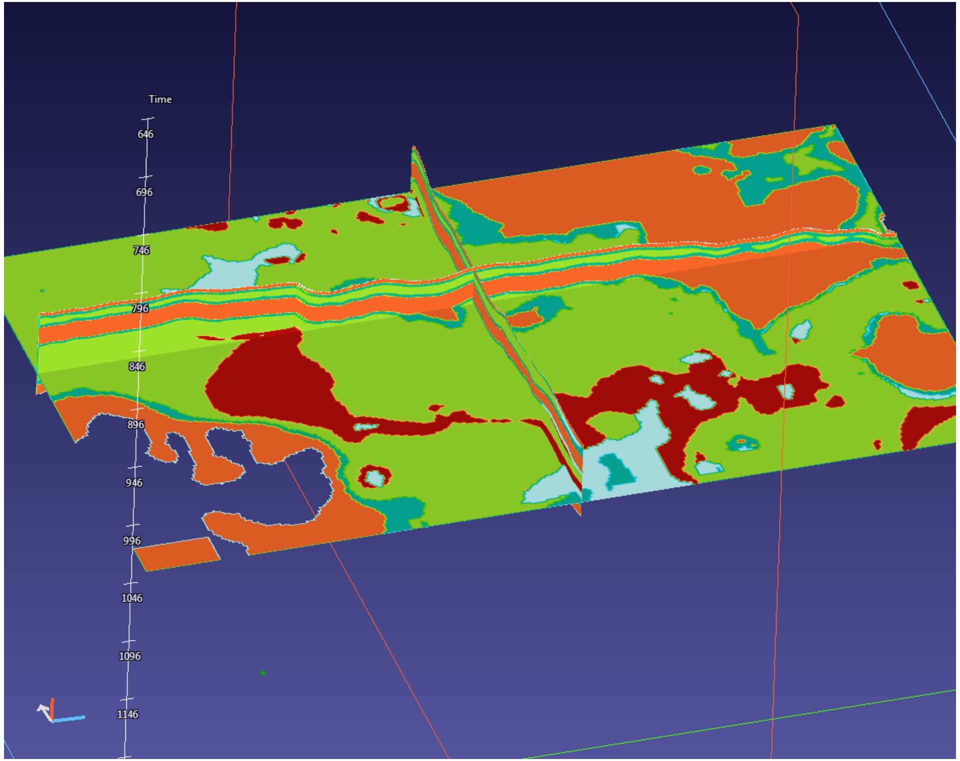
From Pendrel



Barnett: Best Facies Volume in Well Path Planner

Imported Facies volume defined by seismic inversion/rock properties model

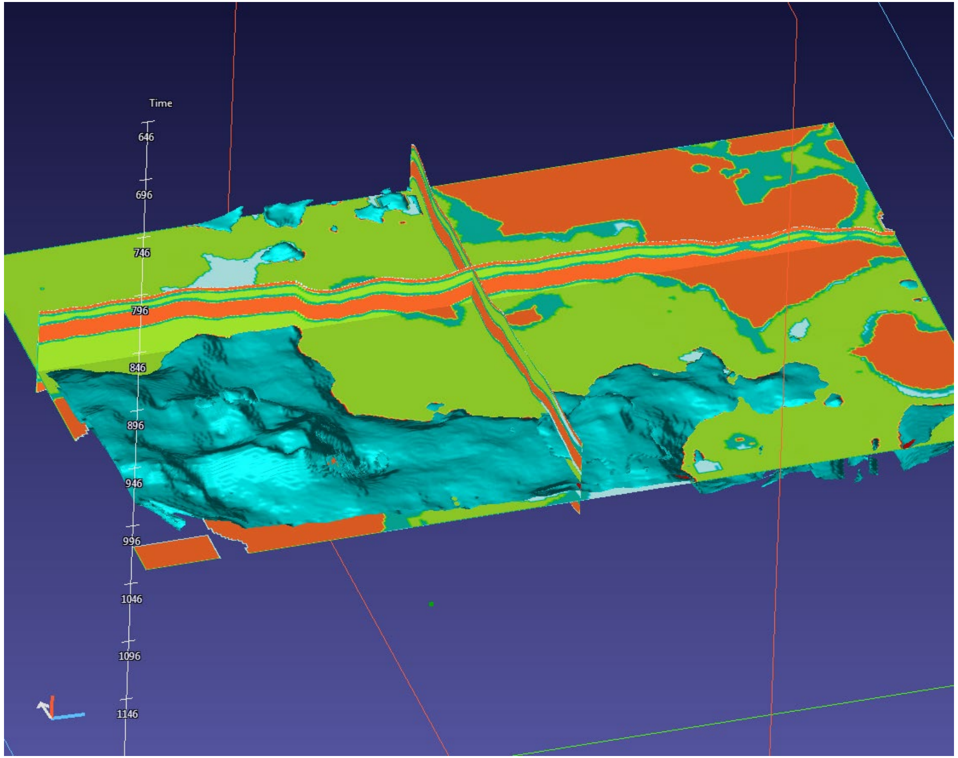
- Facies Type 5 (red)
  - Good reservoir quality
  - High brittleness
  - Good kerogen content



Barnett: Best Facies Volume in Well Path Planner

Extracted 3D boundary of best Facies

- Facies Type 5 (red)
  - Good reservoir quality
  - High brittleness
  - Good kerogen content



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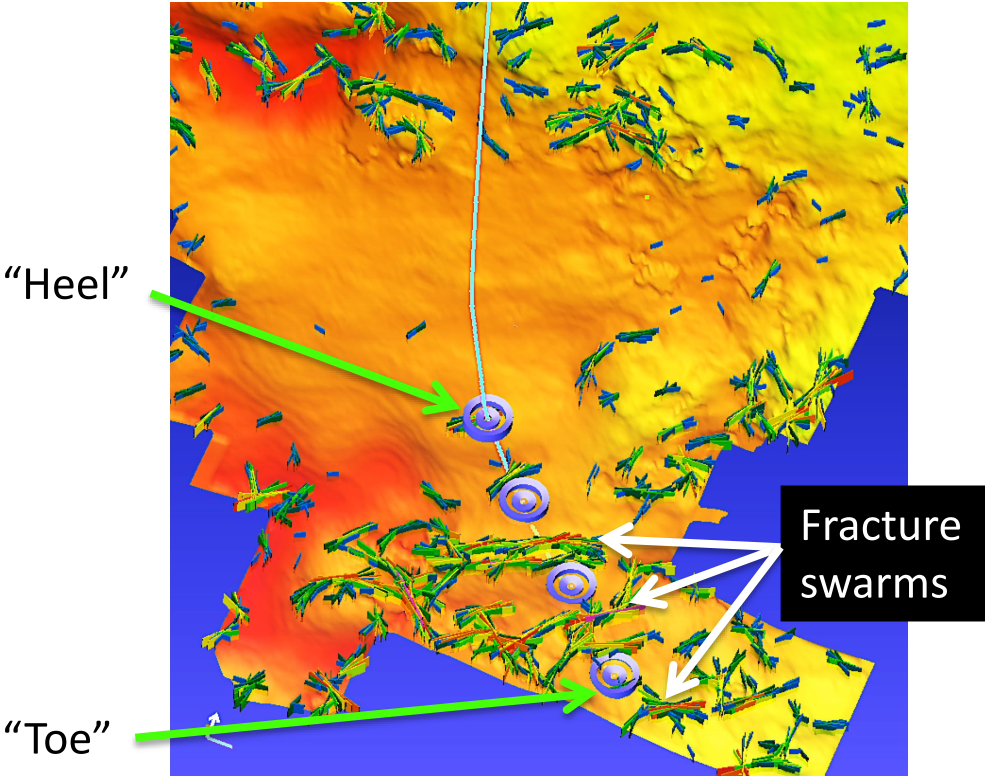
Barnett: Well Path planned on Best Facies & Fractures

Well Path Plan

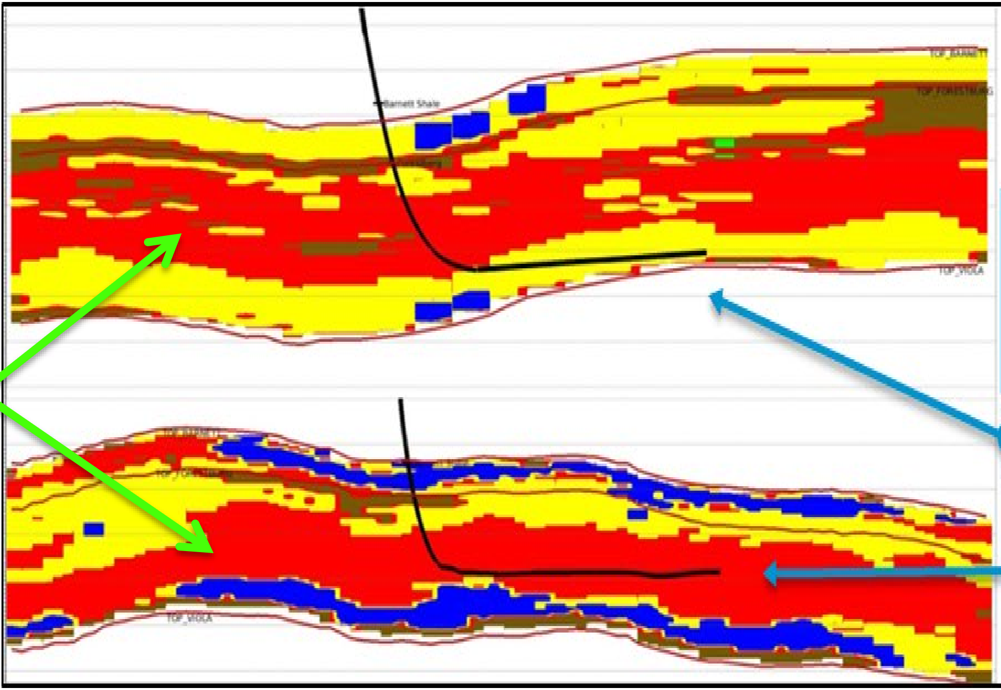
- Land path in Barnett 200 ft below top of best Reservoir Facies geo-body
- Traverse perpendicular to multiple fracture sets within best facies geobody
- Stays inside Best Reservoir Facies Geobody for entire length of lateral



Barnett: Optimize for Best Zone in an Interval

Minimize Cost and Maximize Return

Best Production Characteristics



Barnett Shale

Avg. mon. prod. * (mscf)	Total Frac (Bbl)	Prod. (mscf) per Bbl of Frac
43,000	85,036	0.5
60,000	4,724	12.7

* first 5 months of production

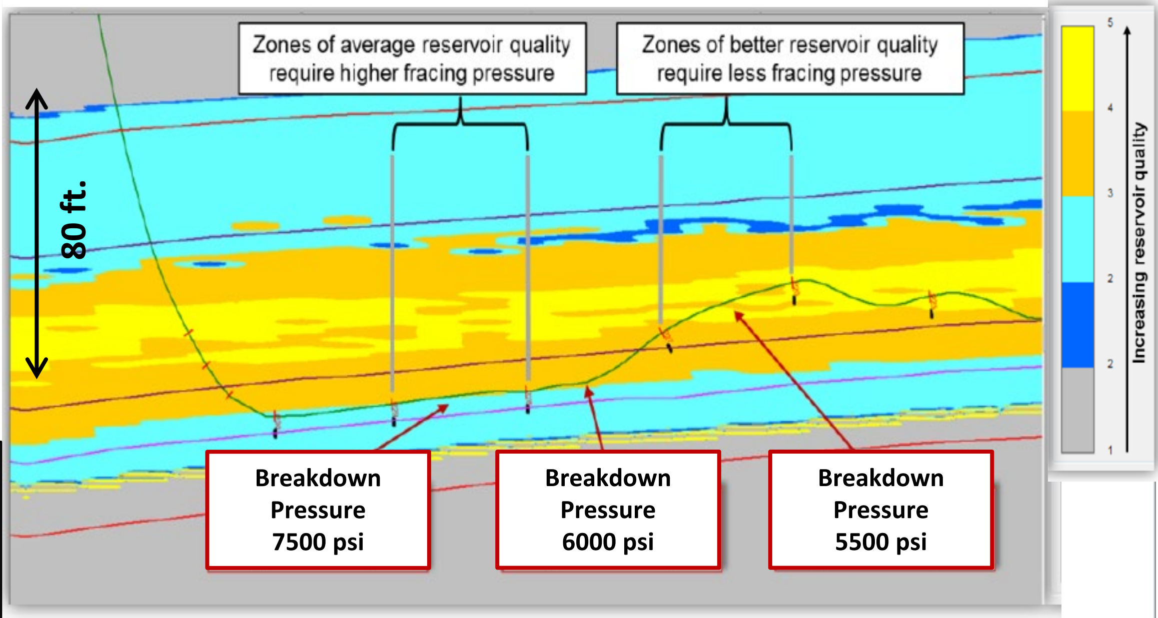
Barnett: Best Production Characteristics

- Detailed models
  - Image heterogeneity
  - Compartments in turbidites
  - Geomechanics
- Assess uncertainty
- Accurately estimate reserves

Business value

- High ROI
- Optimizing well planning program

Breakdown Pressure Summary

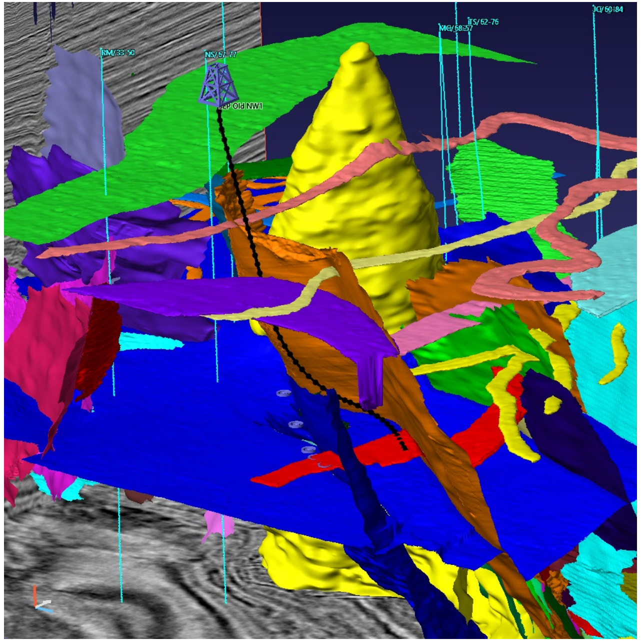


Use of facies could have improved well path design.

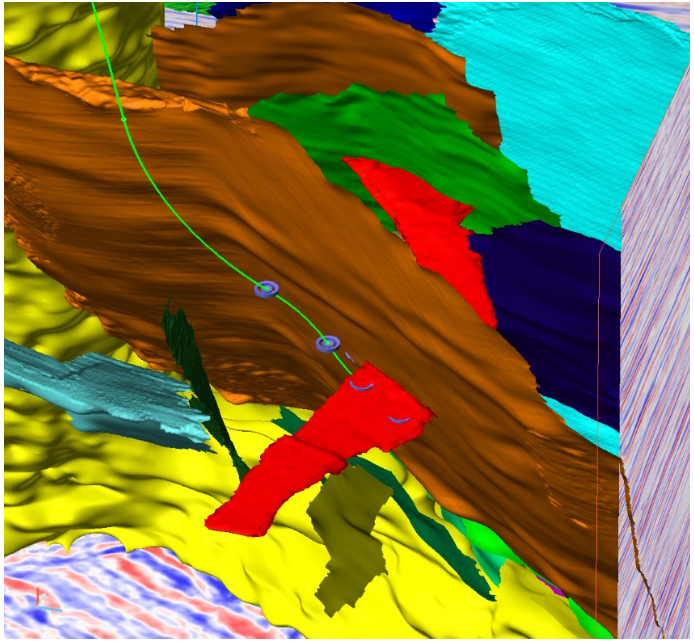
Gulf of Mexico

Optimized path to fault high-side channel
Optimized path to 3D salt body trap & reactive well plan

Planned Optimum Path to a Faulted Channel

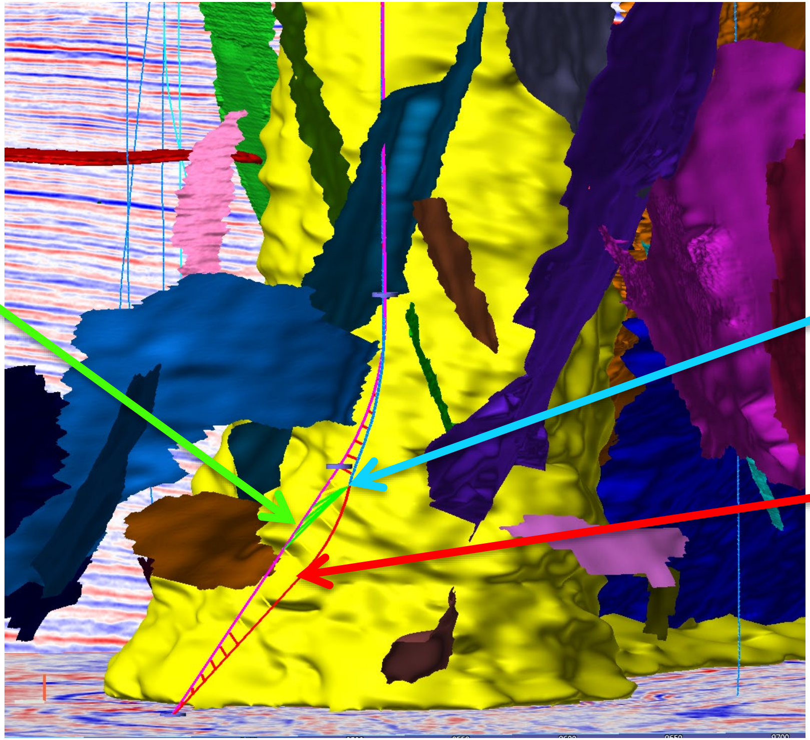


Planned Path



Close-up Planned Path

Planned Optimum Path to 3D Salt Trap



Benefits from Integration

- Safety
- Efficiency
  - The right well designs in the right place
  - Planning entire pad of wells at once
  - Plan and drill the potentially most productive wells first; fill in the the rest later after you have established cash flow
  - Save costs of unnecessary wells
  - Save costs by not drill a well if productive facies is not present
  - Avoid drilling or fracing wells in such a way that they interfere with each other.
  - Plan wells to maximize exposure to productive facies
  - Deliver plans that are drillable
- Accuracy and precision
- Design and adjust well paths efficiently with integrated Geoscience information supporting the design changes

InsightEarth WellPath

We are developing the tools to support Interactive Wellpath planning with integrated geoscience data:

- Data Import, Export and Display
    - Cultural Data (Topography, Bathymetry, Lease Boundaries, Satellite, …)
    - Geophysical and Geological Data
        - Seismic, Gravity, EM, ...
        - Interpretations (horizons, faults, geobodies, Geohazards, fracture density,...)
        - Earth models, inversion volumes, ...
    - Data Links/DataTransfer with major seismic intepretation systems
    - Existing Wells (Top hole locations, Well paths, Well logs and analyses, Formation Tops, …)

InsightEarth WellPath

- Well Path Planning:
  - Interactive Well Path Planning for Conventionals and Unconventionals
  - Targets, Target Sets – Interactive definition and editing
  - Anticollision and Uncertainty
  - Full range of curve types
  - Platform/Pad design
  - Sidetracks (incl. millout points, reachability cone)
- Constraints
  - Surface location and surface use constraints including lease offset
  - Formation well separation constraints
  - Design constraints (including dogleg severity, torque and drag)
  - Relative cost and complexity

InsightEarth WellPath

- Visualization:
  - 3-D Visualization of all Cultural, Geophysical, Geological, Well Data (Existing and planned wells, well logs, etc.)
  - 3-D Visualization of well paths, anti-collision and uncertainty (existing and planned wells)
  - Direct 3D interaction with pads, targets, well plans, …
- Seismic Interpretation (Optional)
  - Full capability to udate interpretation based on information obtained from drilling