Improving Production in the Emerging Paradox Oil Play

DE-FE0031775

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U.S. Department of Energy
National Energy Technology Laboratory
Oil & Natural Gas
2020 Integrated Review Webinar

Acknowledgements

NATIONAL ENERGY TECHNOLOGY LABORATORY

U.S. DEPARTMENT OF ENERGY | Fossil Energy

OFFICE OF OIL & NATURAL GAS

ZEPHYR ENERGY

Program Overview: Key Aspects

- Funding (DOE and Cost Share)
  - $8M Federal, up to $3M Cost-Share, $11M Total
- Overall Project Performance Dates
  - October 1, 2019 – March 31, 2024

Project Participants:

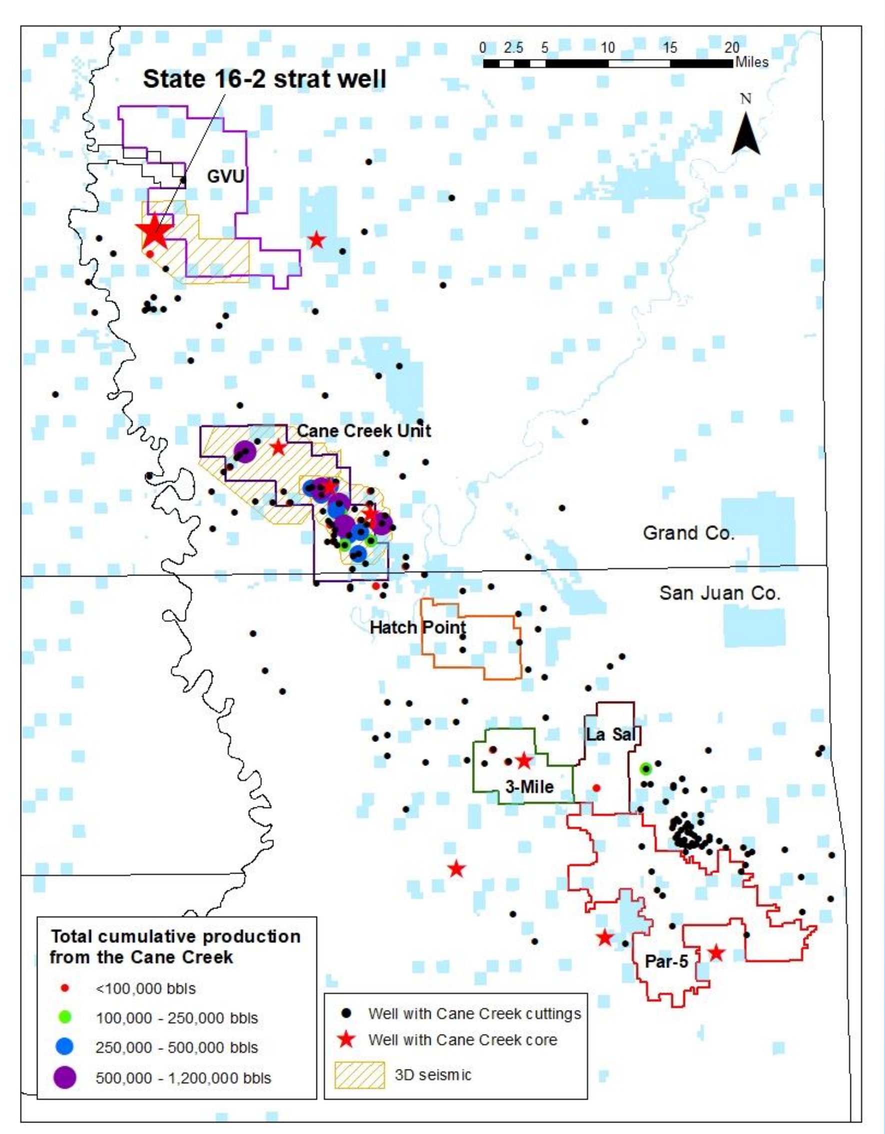
Statistical Petrophysics LLC

Program Overview: Objectives

- **Overall Objective**: determine / test best strategy to drill emerging unconventional northern Paradox Basin Play – maximize production, minimize impact

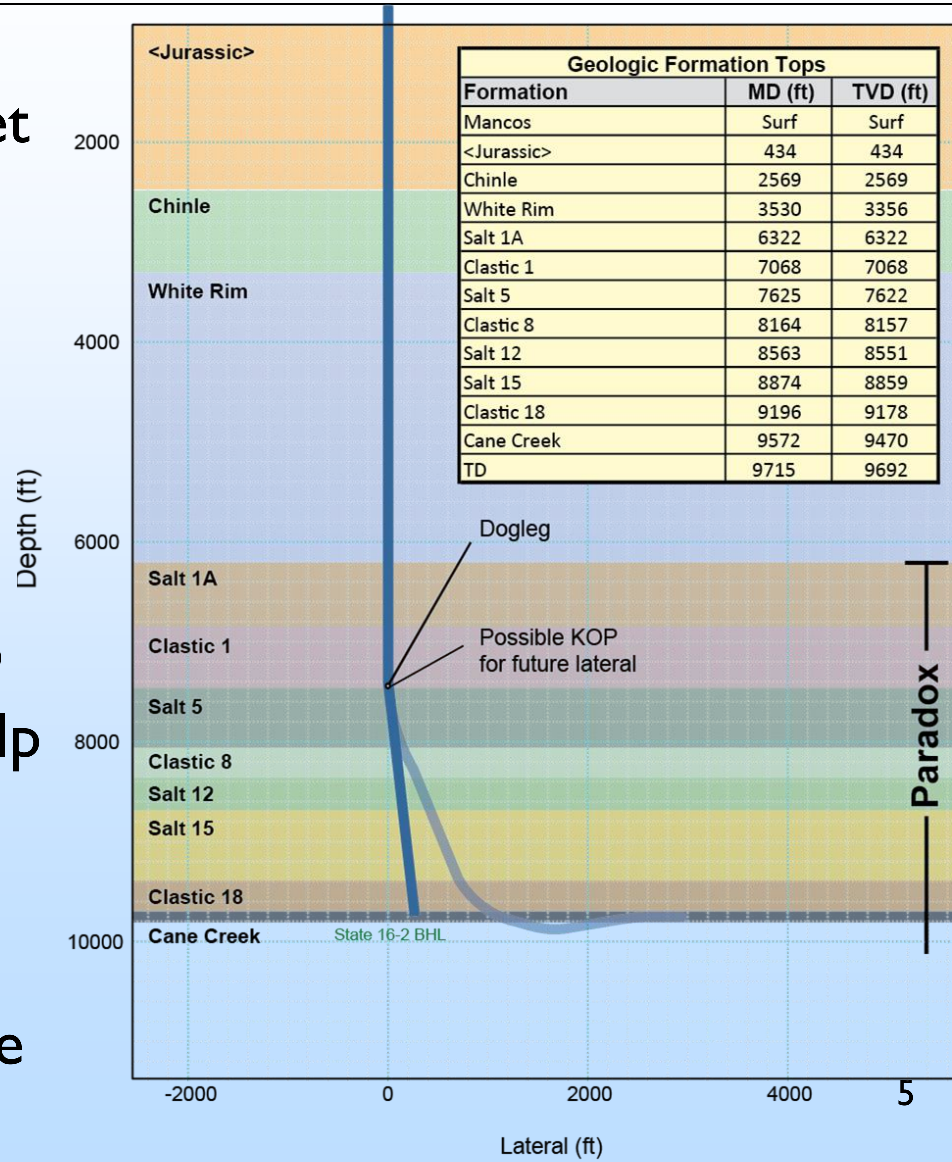
- **Key Tasks**: characterize, quantify, and interpret the geology, structure, hydrodynamics, petrophysics and geomechanics of the northern Paradox oil play

- **Major Outcomes**:
  - detailed facies analysis of core
  - core-to-log petrophysical integration
  - Fully coupled fracture model
  - innovative 3D seismic interpretation
  - THMC basin model for forecasting



Technology Background: Operation

- ❑ A 9,850 ft stratigraphic well = comprehensive scientific dataset in northern Paradox Basin:
  - ✓ matrix reservoir potential
  - ✓ petrophysical model
  - ✓ geomechanical properties
  - ✓ hydrodynamic model
  - ✓ natural fractures and in situ stress regime = fracture model
- ❑ well will be co-located with 3D to ground truth seismic and help with drilling (reduces drilling risk)
- ❑ Some overpressures; mostly hydrostatic; typical temperature gradients (~30° C/km)



Geologic Formation Tops		
Formation	MD (ft)	TVD (ft)
Mancos	Surf	Surf
<Jurassic>	434	434
Chinle	2569	2569
White Rim	3530	3356
Salt 1A	6322	6322
Clastic 1	7068	7068
Salt 5	7625	7622
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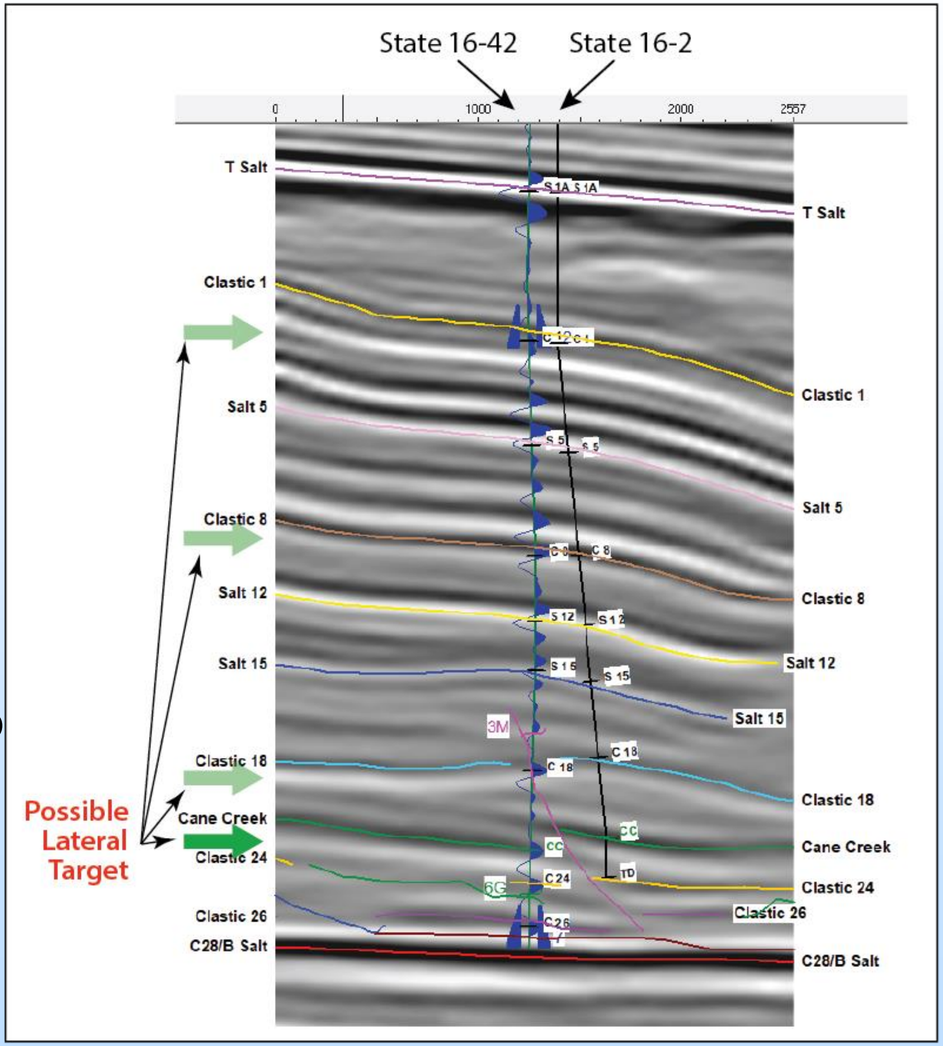
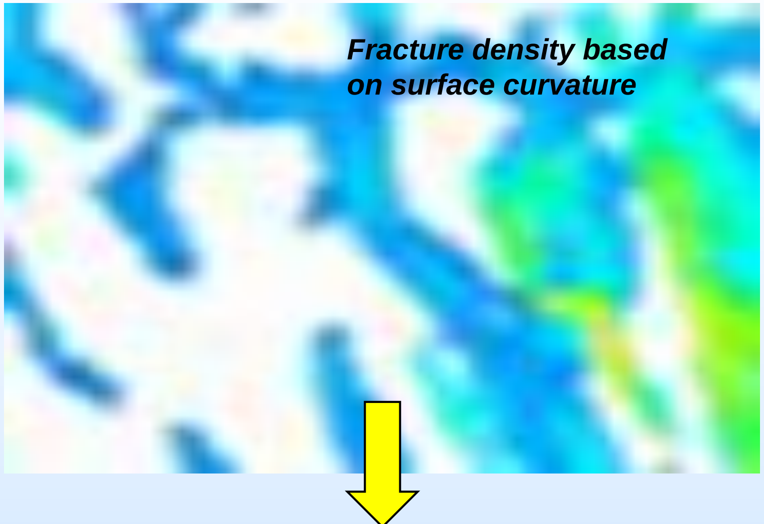
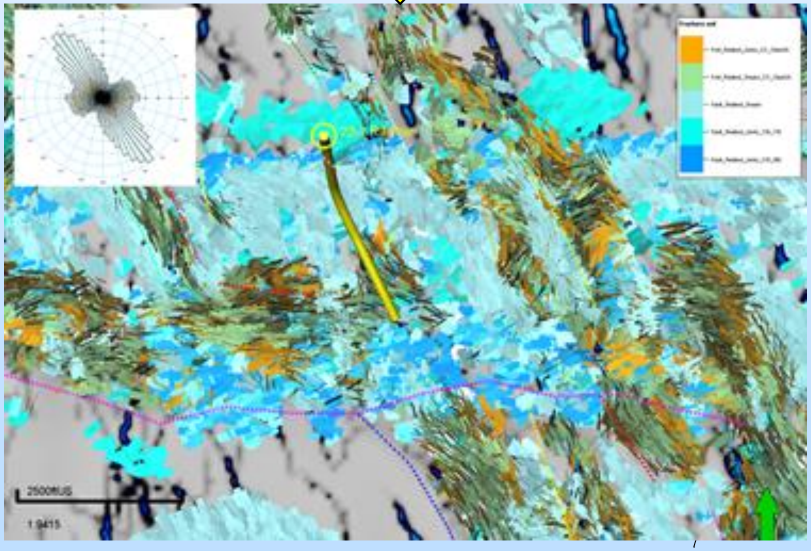


Technology Background: Fundamental Science

- Natural fractures = key to **max** production and **min** env impact
- Alternatively…
- What is the contribution from matrix porosity? Can this be a resource play (not just a fracture play)? Where could it be a resource play? If no natural fractures, can the wells be stimulated? How do you stimulate wells without fracing into salt?
- Natural fractures related to:
  - ✓ intense structural deformation with salt movement
  - ✓ paleo-structural highs on top of Leadville
- Quality 3D seismic critical to fracture density and orientation
  - Curvature analysis
  - Core/FMI to ground-truth
- While Leadville "pop-ups" map using existing data, micro-structures via salt movement only identified with 3D seismic





Example DFN based on curvature and fault network inputs

Technology Background: Fundamental Science

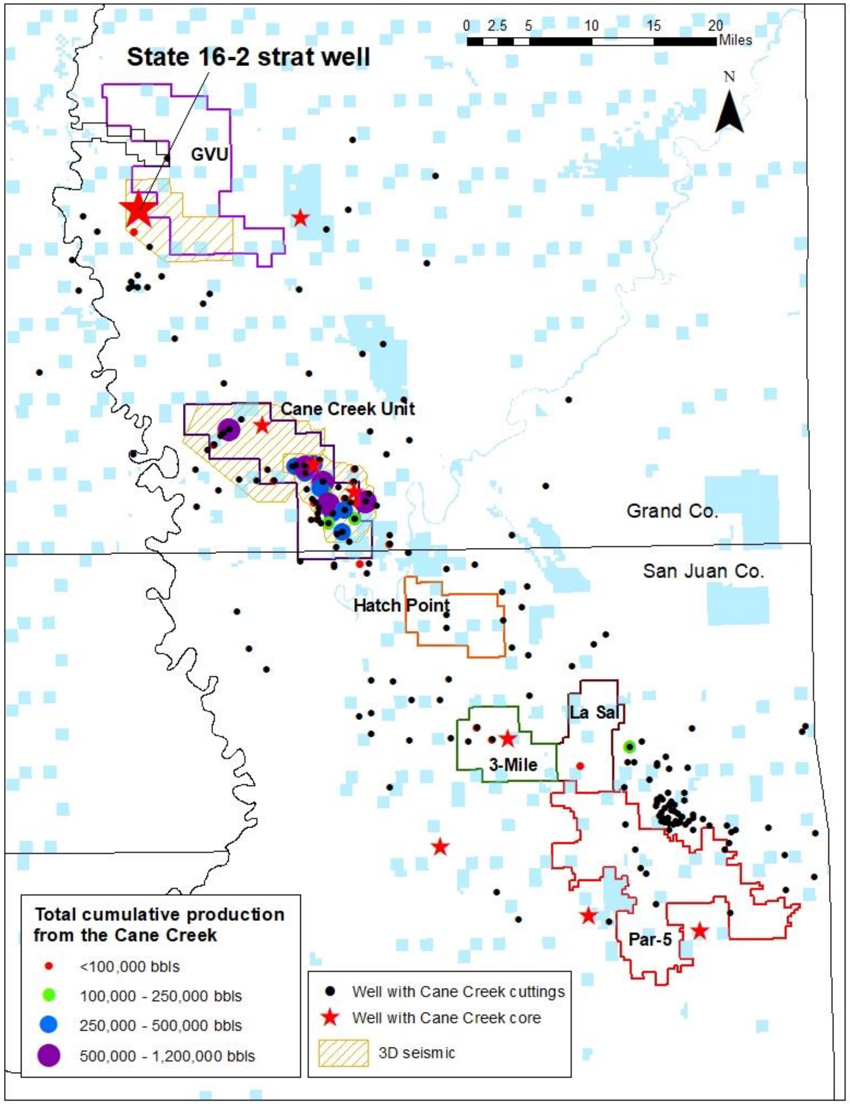
- Main outcome from **well logging**: first high-tier log suite in Paradox = robust petrophysics and geomechanics

  - detailed characterization of reservoir and bounding units:
    - ✓ Apply modern spectroscopy = mineral abundances, fluid saturation & porosity
    - ✓ Improve geomechanics characterization via scanner tools
    - ✓ Quantify (estimate) anisotropy: stress, seismic velocities (S), permeability
    - ✓ Characterize natural fractures with borehole image logs

  - High-tier logs to provide training data for ML algorithms
    - ✓ Machine learning calibration and application to legacy logs
    - ✓ Machine learning methods will improve core-log integration, and
    - ✓ Provide calibration data for seismic interpretation

Technology Background: Prior Efforts are Strong Basis

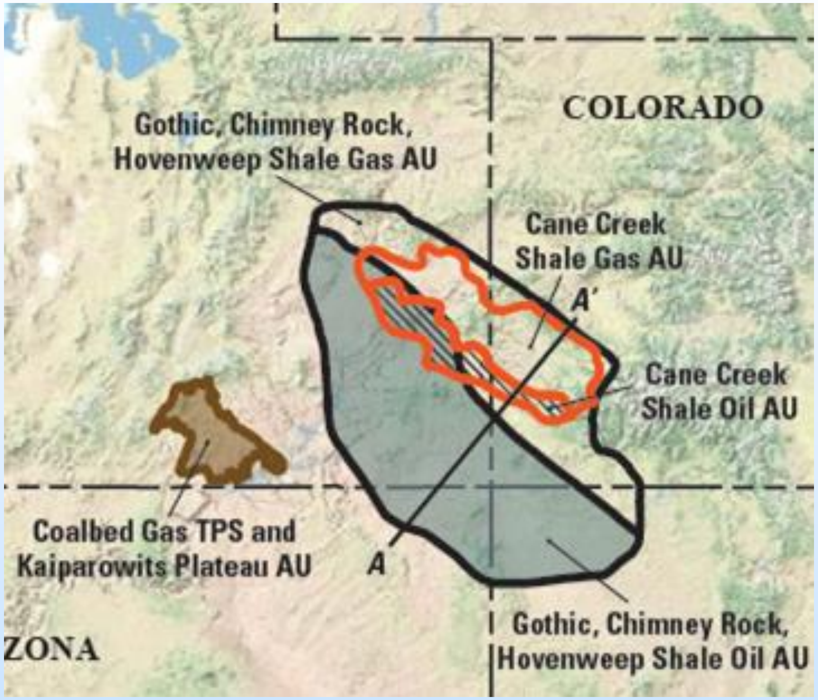
- Historic production/drilling concentrated in Cane Creek Unit
  - ✓ Limited success via blind natural fractures
  - ✓ Key conclusion of prior efforts: must know potential outside this area (north? south?)
- Key to this 2020-2024 Field Lab: prior DOE research project **DE-FE0010667** (UGS), completed in 2017
- Legacy geologic data include:
  - ✓ Core from 7 wells
  - ✓ Cuttings from 200+ wells
  - ✓ Logs from 300+ wells
- New core in north with quality 3D seismic will inform drilling strategies and tactical stimulation technologies



Technology Background: Advantages = Max Potential, Min Env Impact

- Cane Creek (cycle 21) economic potential
  - **1.2 billion BOE** (mean) undiscovered resources in the Cane Creek assessment unit *(USGS, 2012)*

- POTENTIAL → unproven upper clastic zones
  - Cycles 18/19, 9, 8, 7, 4
  - Hovenweep (cycle 2)
  - Gothic (cycle 3)
  - Chimney Rock (cycle 5) shale intervals = Additional **1.7 billion BOE**

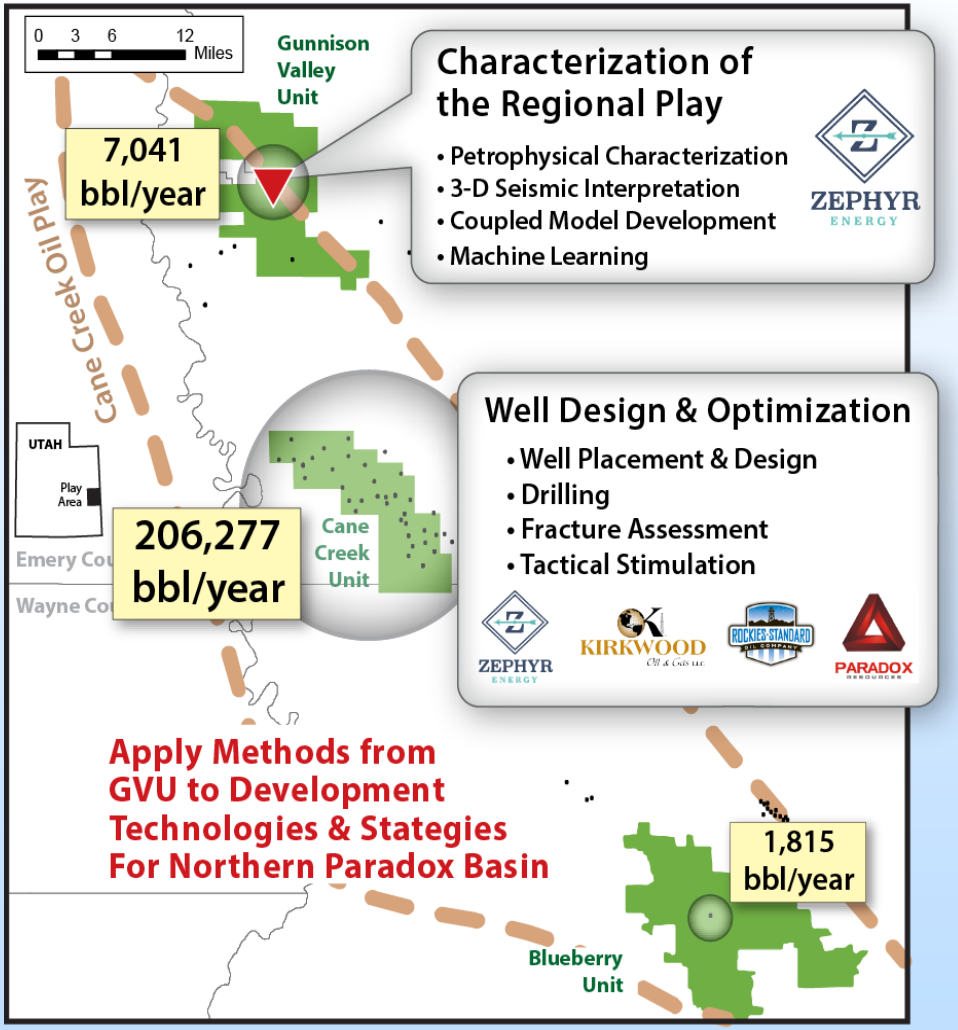


Total petroleum systems (TPS) and assessment units (AU)	Field type	Total undiscovered resources											
		Oil (MMBO)				Gas (BCFG)				NGL (MMBNGL)			
		F95	F50	F5	Mean	F95	F50	F5	Mean	F95	F50	F5	Mean
Cane Creek Shale Oil AU	Oil	103	198	382	215	84	175	364	193	6	14	31	15
Cane Creek Shale Gas AU	Gas					2,473	4,284	7,420	4,530	88	168	319	181

Technology Approach: Scope

Experimental Design and Work Plan

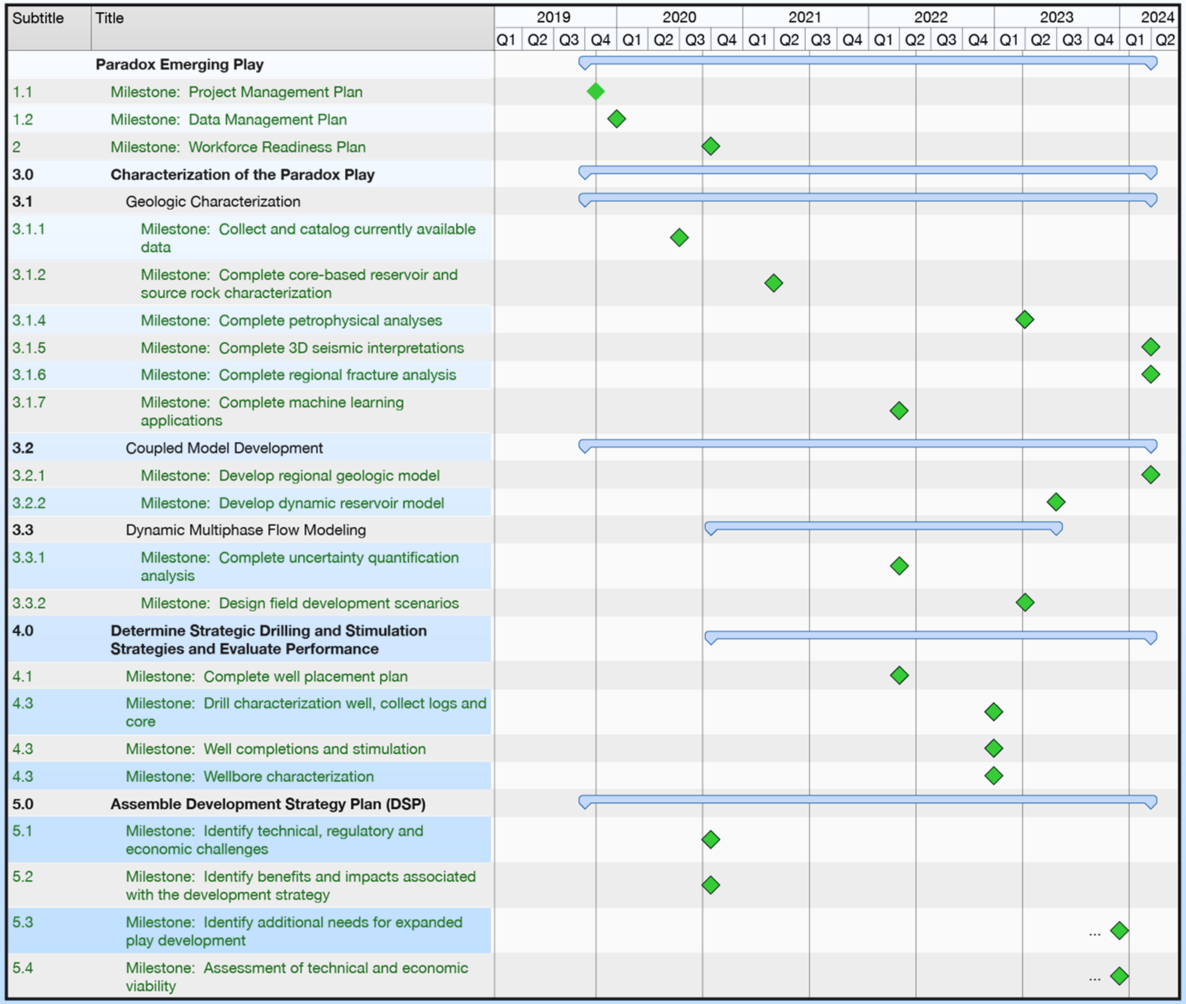
1. **Characterize fundamental geology, hydrology, and geomechanics**
2. **Forecast location, extent and mechanisms of natural fractures throughout the play** (Budget Periods 1 and 2);
3. **Develop drilling strategy to maximize intersection with (dominant) natural fractures** (BP's 2 and 3)
4. **Use high-resolution characterization data to develop a tactical stimulation strategy** (BP's 2 and 3)
5. **Test the best approach** (with the operator, determine whether (3) new drilling design or (4) the new tactical stimulation design will be more effective, and test in the field in new well(s) with strategic drilling and tactical stimulation (BP's 3 and 4).



Technology Approach: Schedule

Key Milestones

- Task 3: Complete characterization of strat well
- Task 3: Develop / execute models
- Task 4: Develop drilling design and stimulation strategy
- Task 5: Summarize challenges and benefits of Cane Creek development



Technology Approach: Success Criteria

Task/Subtask	Description	Date	Success Criteria
2.0	Workforce Readiness Plan	First continuation application	A detailed plan ready after reviewing the required skill sets and training/certifications (if any), and identifying the appropriate source or personnel for the workforce.
3.1	Geologic Characterization	Q4 2022	A geologically characterized basin model integrating 3D seismic data, well logs, core data, and production histories using machine learning algorithms.
3.2	Coupled Model Development	Q2 2023	A multi-continuum dynamic reservoir model, that combines the geological and discrete fracture network models, ready for simulating multiphase flow in the play.
4.3	Well Drilling	Q2 2022	Cased and cemented horizontal well that yield at least 50 feet of horizontal core to study the fracture network and its changes throughout the basin.
4.3	Well Characterization	Q4 2022	Fracture characterization and assessment of productive potential, reservoir properties, and stimulation treatment effectiveness.
5	Development Strategy Plan	Q4 2023	Develop a plan to effectively assess the technical and economic viability of further development of emerging UOG plays in the area and others across the US.

Technology Approach:
Risks and Mitigation Criteria

Risks associated with well operations	Risk Rating (Low, Med, High)			Mitigation/Response Strategy
	Probability	Impact	Overall	
Well drilling and completions are unsuccessful	Med	High	High	PI/team will determine cause of non-success; additional drilling partners will be solicited.
Well casing fails due to salt intrusion.	Med	High	High	PI/team will determine cause of failure; plan to recomplete or solicit other partners with available well(s).
Well stimulation fails due to salt intrusion	High	High	High	PI/team will determine cause of salt intrusion; additional partners/stimulation wells will be solicited.
Well stimulation fails due to formation damage	Med	High	Med	PI/team will determine cause of failure; additional partners/stimulation wells will be solicited.
Water flows in the shallow well section	Med	Med	Med	PI/team will identify cause of water flow.
Waste water disposal	Low	Med	Low	PI/team will identify waste water disposal services in area.

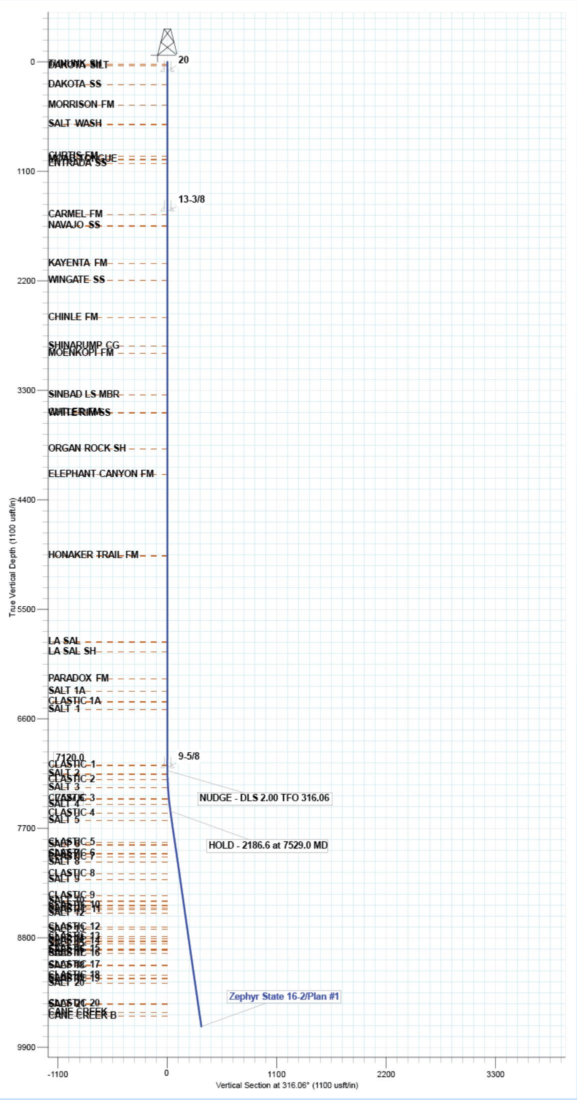
Technology Approach:
Risks and Mitigation Criteria

Risks associated with play	Risk Rating (Low, Med, High)			Mitigation/Response Strategy
	Probability	Impact	Overall	
Seismic fails to resolve regional faults and structure.	Low	Med	Med	Fracture and structural model will be developed from core/log data only.
Poor data quality for Machine Learning.	Med	Med	Med	PI/team will assess minimize data quality requirements for future projects.
Poorly defined model for natural fracture prediction leading to variable economic well performance.	Med	High	High	PI/team will identify cause of failure; plan to perform additional modeling or acquire new data.
Poor historical results from hydraulic stimulation leading to an inability to deliver more stable, economic performance.	High	Med	Med	PI/team will assess historical data quality; additional partners/stimulation wells will be solicited.

Progress and Current Status

- State 16-2 Strat Well Description
  - Well owned and operated by Zephyr Energy
  - Bottom Hole TVD: 9850' (Cane Creek)
  - 35 days of drilling
  - Current cost estimated close to $3M, including - 60-100 ft of core
- logs (Triple combo (TCOM), lithoscanner/ECS, dipole sonic and UBI)
- ultimate costs expected to be significantly less as negotiations with vendors continue.

  - Well to be temporarily abandoned with possible re-entry and drilling of lateral in project budget period 3 or 4 with Field Lab testing of proposed methods, stimulation and monitoring activities.

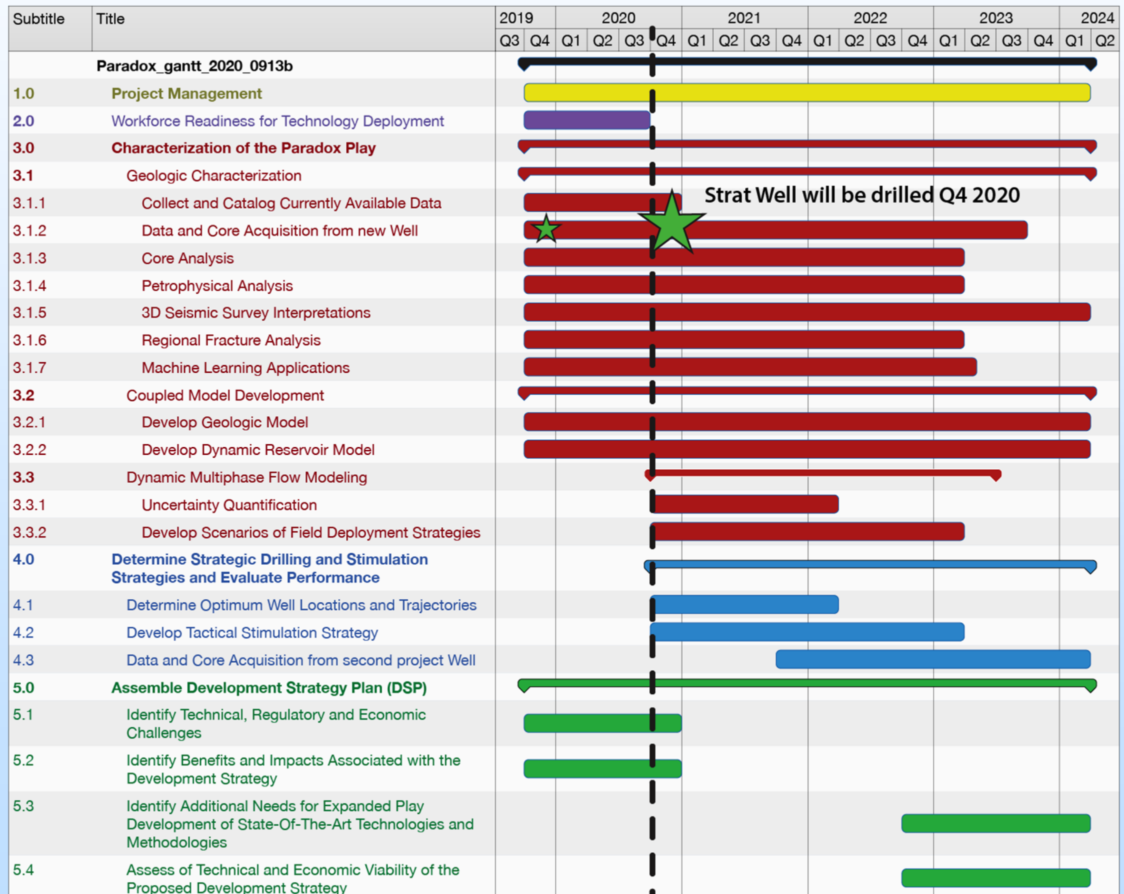


Progress and Current Status

- **Significant accomplishments and how they tie to the technology challenges**
  - Assembled limited wellbore data on fractures, mostly from core data
  - Most legacy seismic data (from recent years) assembled and are being tied to log due as much as possible
  - Collected all available legacy image logs and are identifying fractures within the Cane Creek and surrounding units
  - Collected and archived suite of available legacy logs in the basin; log-modeling (interpretation) under way
  - Developed engineering drill design and assembled all permits for drilling: spud date to be late November, 2020

Progress and Current Status

Deep science well drilling is approximately one year behind anticipated progress due to significant drop in price of oil and COVID-19. However, the delay gave the project time to identify another willing industry partner.



Future Testing, Development and Commercialization

- Additional characterization and development of the larger Paradox Basin Play

- ML models will be used to "unify" basin models. For example, if we develop a ML-based N. Paradox Basin (electro)facies model, will assist application to adjacent areas within the Paradox or other similar unconventional resources

Future Testing, Development and Commercialization

- Hypothetical horizontal well scale-up plan for area covered with 3D seismic
- Opportunity for numerous horizontal wells in one small area targeting the natural fracture play, with countless opportunities beyond 3D area
- Further targets if commercial results can be achieved by hydraulic stimulation
- Multiple stacked pay opportunities beyond the primary Cane Creek reservoir

Summary

- **Overall Objective**: determine / test best strategy to drill emerging unconventional northern Paradox Basin Play – maximize production, minimize impact

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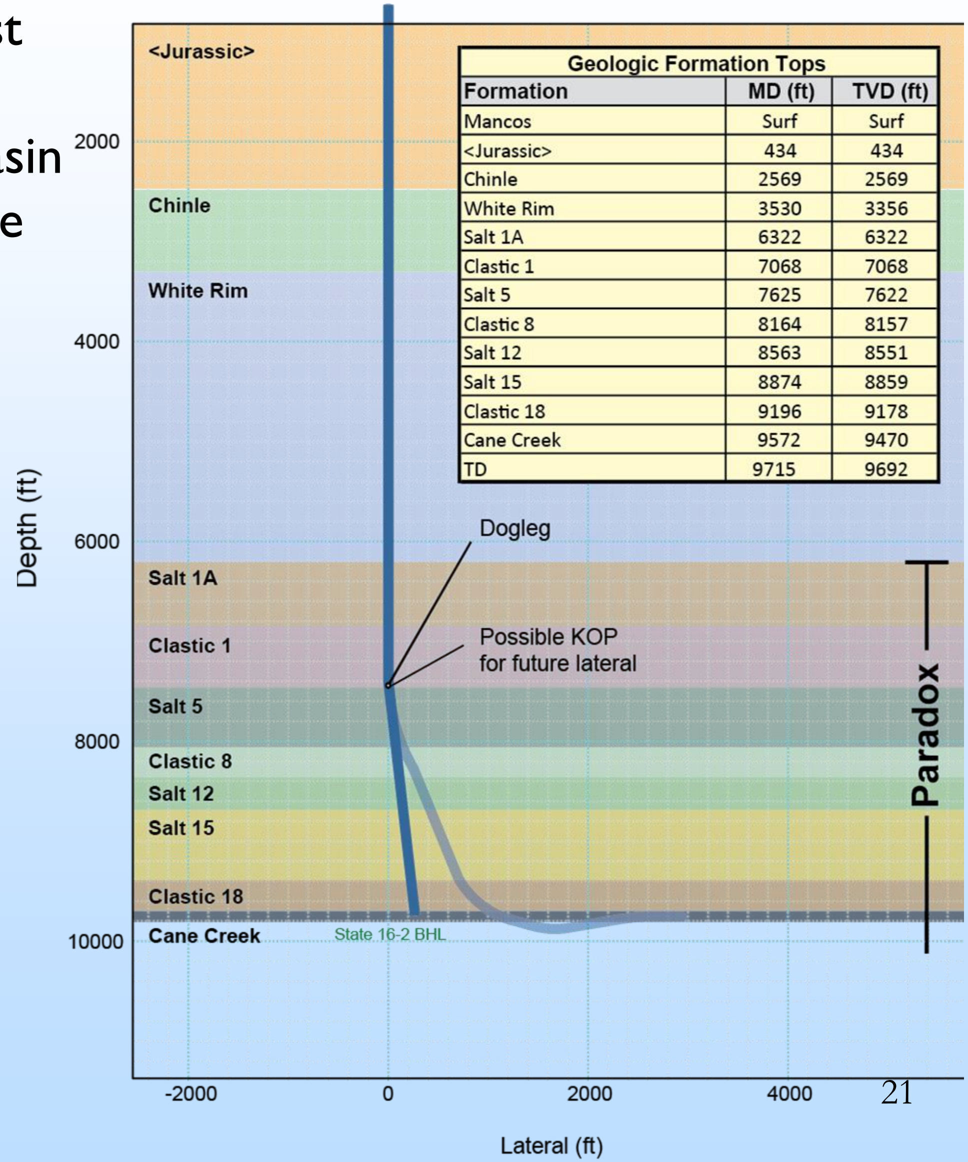

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Thanks!

http://paradox.play.unconventional.rocks

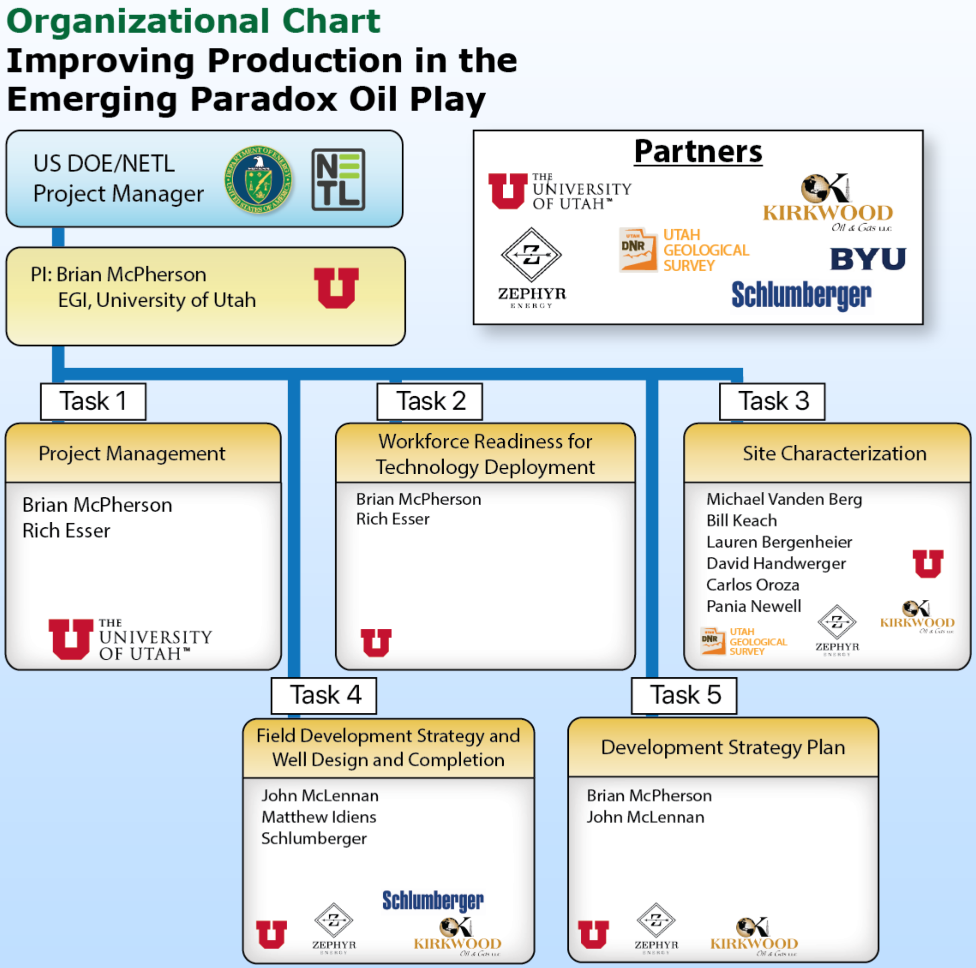
Appendix

– These slides will not be discussed during the presentation, but are mandatory.

Organization Chart

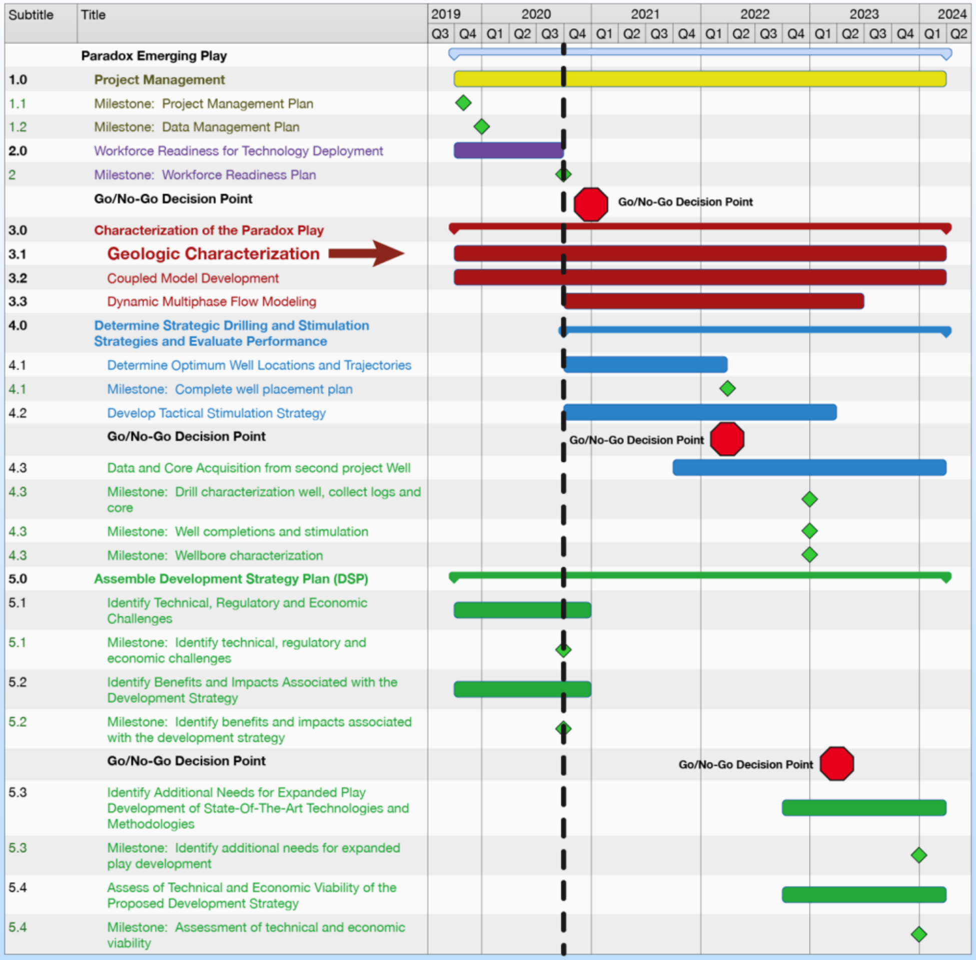
- Describe project team, organization, and participants.
  - Link organizations, if more than one, to general project efforts (i.e., materials development, design, systems analysis, pilot unit operation, management, risk/cost analysis, etc.).

- Please limit company specific information to that relevant to achieving project goals and objectives.



Gantt Chart

Provide a simple Gantt chart showing project lifetime in years on the horizontal axis and major tasks along the vertical axis. Use symbols to indicate major and minor milestones. Use shaded lines or the like to indicate duration of each task and the amount of work completed to date.



Program Overview: Key Aspects

No Zephyr "cost-share"	FY 2020		FY 2021		FY 2022		FY 2023		FY 2024		Total	
	DOE Funds	Cost Share	DOE Funds	Cost Share	DOE Funds	Cost Share	DOE Funds	Cost Share	DOE Funds	Cost Share	DOE Funds	Cost Share
Total	$480,431	$355,272	$3,919,759	$815,407	$2,652,201	$604,509	$595,457	$150,729	$327,153	$74,084	$8,000,000	$2,000,001
Total Cost Share %		42.5%		17.2%		18.6%		20.2%		18.5%		20.0%

$500K Zephyr "cost-share"	FY 2020		FY 2021		FY 2022		FY 2023		FY 2024		Total	
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Total Cost Share %		42.5%		25.1%		18.6%		20.2%		18.5%		23.8%

$1M Zephyr "cost-share"	FY 2020		FY 2021		FY 2022		FY 2023		FY 2024		Total	
	DOE Funds	Cost Share	DOE Funds	Cost Share	DOE Funds	Cost Share	DOE Funds	Cost Share	DOE Funds	Cost Share	DOE Funds	Cost Share
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Total Cost Share %		42.5%		31.7%		18.6%		20.2%		18.5%		27.3%

Statistical Petrophysics LLC