RCP PHASE XVIII Proposal:

Chalk Bluff Development Optimization Project

Northern DJ Basin

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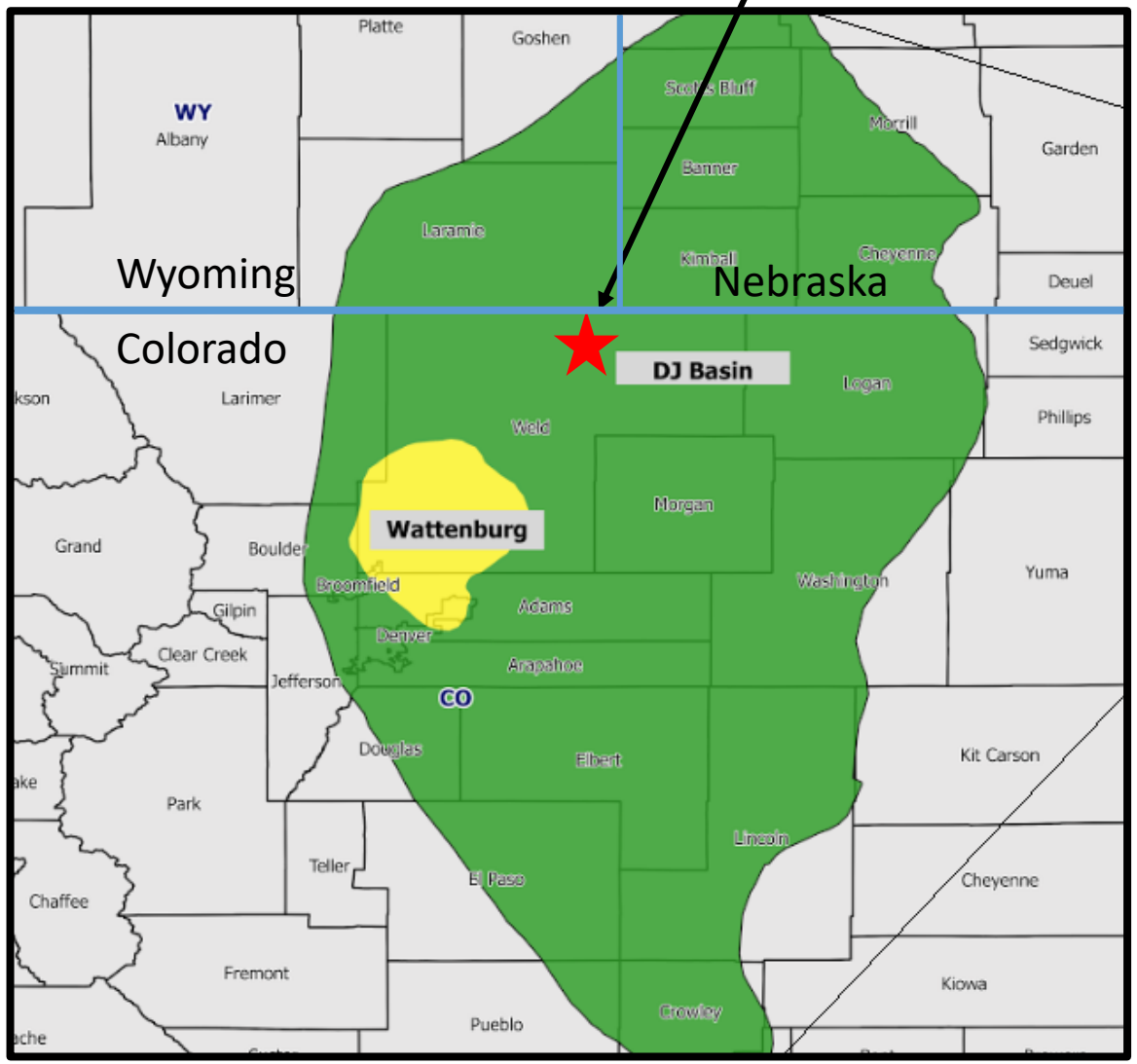
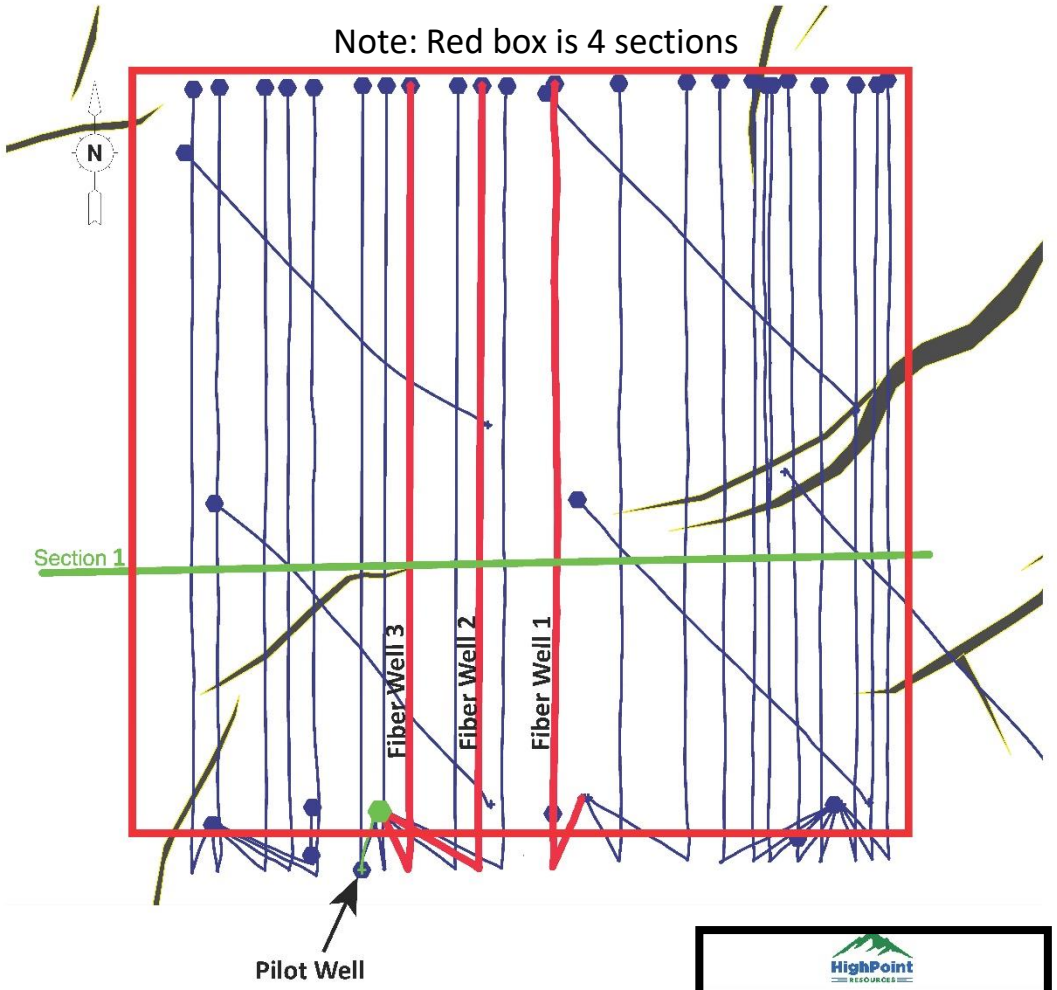
Colorado School of Mines Reservoir Characterization Project (RCP)

- **Program would allow for various research projects designed to improve multi-faceted approaches to field development, and would include:**
  - Understand drivers of Vertical and horizontal subsurface connectivity at several scales
  - Characterize geologic heterogeneity and influence of natural & induced fractures on completions and production
  - Utilize integrated data to determine best well spacing both laterally and vertically
  - Understand legacy development effects & how to mitigate them
  - Determine Optimize Frac design including fluid volumes, type, sand loading, stage & cluster spacing
  - Understand frac energy & and its relationship to structure (e.g., faults & fractures)
  - Calculate stimulated reservoir rock volumes
  - Identify options to minimize interwell communication
  - Identify best practices completion strategies such as zipper fracing, bashing, stress shadowing

Project Location



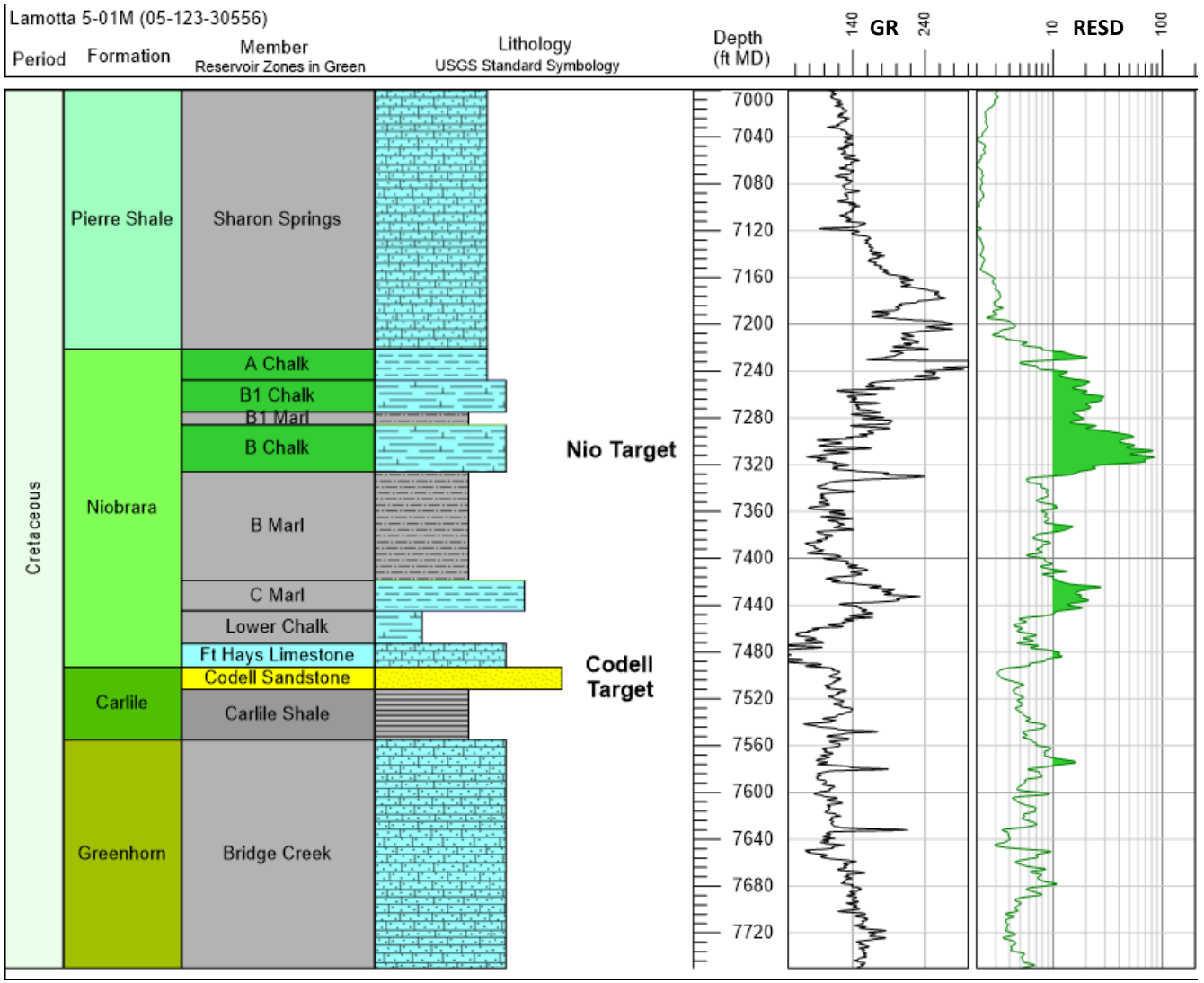


Chalk Bluff - Niobrara Formation in the Northern DJ Basin, Colorado

Primary Targets

Niobrara B Chalk →

Codell →



← Poor Quality Reservoir in the C Chalk

Chalk Bluff - Niobrara and Codell Development Optimization Project

- Seismic and surface microseismic
- Fiber: DAS and DTS technologies
- Pressure data
- Geochemistry data
- Log suites

Timing and Project Phases (Page 1)

- **Project work flow Phases I and II**
  - Drilling of 22 horizontal wells, long reach (10000’ laterals) underway.
  - Image log acquisition on fiber wells (two of three with CMI, Weatherford Micro-Imager)
    - Completed 4/8/2019
  - Fiber Installation Complete (cemented fiber, two single and two multimode fibers in each of three wells.)
    - Interrogators (2 DTS and 2 DAS) installation complete by 5/25/2019, currently have three of four on-line.
  - Pilot Well – Acquired Quad Combo, Sonic Scanner (oriented), 12/2018
  - Geochemistry – Cuttings, Mudgas collection, XRD and XRF complete.
  - Surface microseismic monitoring, tiltmeter monitoring and processing, and fiber microseismic monitoring underway, complete approximately 6/1/2019.
    - Fiber well completions 5/2019
    - All microseismic patches in place and recording. First half of zipper group one monitored in real time for QC purposes.
    - All tiltmeters in place and recording.

Timing and Project Phases (Page 2)

- **Phase III:**
  - Flowback and Production monitoring beginning 4/15/19 (first zipper group)
  - Fiber monitoring & geochemical sampling of produced fluids – monthly for 1st year after completions with quarterly reports – ongoing beginning 6/2019
  - Continuing integration of field data – revisions in drilling and completions parameters based on results to optimize field development.
  - Student Engagement – Fall Term Colorado School of Mines RCP
    - Envision multi-disciplinary team, engage all disciplines at the beginning of the project
      - Geophysics
      - Petroleum Engineering
      - Geology / Geochemistry

Project Goals:

- **Data Integration and cutting-edge research through the Reservoir Characterization Project**
  - Requires participation across Geophysical, Geological and Engineering disciplines
  - Opportunities for student interaction with HighPoint Mentors –
    - Tanya Inks (geophysics), tinks@hpres.com, cell (303-809-5520)
    - Ben Burke (geology), bburke@hpres.com, cell (860-655-6837)
    - Sean Stewart (primary engineering advisor), sstewart@hpres.com, 303-312-8582
      - Stephan Harpham, sharpham@hpres.com, 303-312-8544
      - Billy Sprague, bsprague@hpres.com, 303-312-8149

Chalk Bluff Niobrara and Codell Development Optimization Project

- **Data that we would make available for RCP study:**
- **Geophysical Data:**
  - Excellent quality seismic data acquired in 2009, and reprocessed in 2017. Data includes processed gathers, inversion volumes (utilizing pilot well sonic scanner and other full-wave-form sonics in larger project) and velocity anisotropy volumes. The proposed RCP project would include at least four square miles of full-fold PSTM data.
  - Surface microseismic – Currently being acquired in 14 to 18 wells (of 22 total wells) in 4 DSU's. Surface microseismic stations have been placed in patches over 20 sections.
  - Fiber has been permanently cemented in two Niobrara and one Codell well for DTS and DAS acquisition including DAS microseismic. Fiber VSP time-lapse is also being considered for evaluation of frac height and evaluation of Codell/Niobrara parent-child relationships.
  - Tiltmeter data is being acquired during the completions of all 22 wells in the study area.

Chalk Bluff Niobrara and Codell Development Optimization Project

- **Geological Data**
  - Full Quad Combo log suite in pilot well near SHL of western-most fiber well is within the full-fold seismic area, and includes sonic scanner data.
  - Geochemical data includes XRD, XRF, cuttings gas and mud gas data and oil and water data collected monthly after completions.
  - Two Weatherford CMR (micro-resistivity image log) in one Niobrara and one Codell fiber well.
  - LWD Gamma
  - Although there is no core in the study area, core (and corresponding FMI and logs) are potentially available from nearby wells in Hereford field.

Hereford Niobrara and Codell Development Optimization Project

- **Engineering Data**
  - DTS data in fiber wells – look at variability in production relative to legacy wells, faults and other identified rock property variations.
  - Pressure Analysis – (Pressure Gradient – one fiber well, ISIP)
  - Completion/Treatment data including well spacing and other completion variables in 22 2019 extra-long-reach horizontal wells.
  - Tracer Data (possibly, future)

Chalk Bluff Niobrara and Codell Development Optimization Project Scope (Page 1)

- **Specific Goals:**
  - Understand drivers and processes of vertical & horizontal connectivity. Tools Include:
    - Microseismic – vertical and horizontal spread of events relative to:
      - legacy wells (stress shadows)
      - Integration with Faults and Fracture systems identified on seismic and calculated seismic attributes (Fault Likelihood, Inversion Attributes)
      - Possible Long-distance stress or fluid pathways
    - Tiltmeter – integrated with microseismic, compare dilation versus propped SRV?
    - Seismic Inversion Attributes (Prestack SEI)
      - Legacy wells (parent – child relationships)
      - Changes is stratigraphy and rock mechanics

Hereford Niobrara and Codell Development Optimization Project Scope (Page 2)

- Understand legacy development effects & how to mitigate them. Tools Include:
  - DTS – Look at variability in production relative to position near legacy wells
  - Pressure analysis (pressure gradient, ISIP)
    - Poisson's Ratio from Inversion and ISIP to look at reservoir pressure variations
  - Microseismic - interpreted frac height and width
  - Tiltmeter – identification of depleted zones?

- Determine stage & cluster spacing that maximizes DSU economics
  - DTS
  - ISIP
  - Surface Microseismic and DAS microseismic – frac height, width, estimate SRV
- Examine how fracs respond to subsurface structural heterogeneity (e.g,. faults & fractures)
  - how to maximize Stimulated Rock Volume while minimizing bashing
  - Use microseismic to look at efficacy of seals, vertical and lateral effectiveness (and variations)

Potential Thesis Ideas

- Comparison of surface microseismic and DAS microseismic
- Integration of seismic geomechanical data with DAS/DTS data
- Fracture modeling and/or Geocellular modeling
- Stress Analysis – stress shadowing and affects on well and cluster spacing
- Vertical and horizontal communication between wells and reservoirs