Summary

There are two main themes of this poster.

The first theme is to provide an update on the stratigraphy and sedimentology of the Tensleep/Casper Formation of Southeast Wyoming (and parts of Northern Colorado), and oil production from these rocks. We incorporate new measured sections, stratigraphic analysis and petrophysical work by the authors. To this end we created a new database in ArcGIS (geographic information software) of ups and other data that updates the historical database of the Wyoming Oil and Gas Commission archived in Casper. This new database has been used to create Common Risk Segment (CRS) maps of the Upper Tensleep oil play in Southeast Wyoming. These CRS maps indicate the potential of an eolian reservoir to create a new source of oil. We believe that eolian cross bedding and cross strata, and other sand depletions serve to increase sweep efficiency in rocks that, on standard seismic data, have low to moderate permeability. This is illustrated in the two figures above. The “Fountain” inter-bedding with Tensleep occurs mainly in the Lower Tensleep, close to pre-Permian uplifts. Oil production in SE Wyoming occurs in a variety of stages from primary through tertiary (EOR), as well as various states of IOR (mechanical upgrades). There may be development opportunities in existing fields.

The State of Wyoming well database is a valuable asset. EORI has used this trove to create a digital database of tops and other data that updates older (historical) tops in the State of Wyoming database, using modern stratigraphic concepts. This database will be made public, and may lower informational barriers to oil industry activity in Southeast Wyoming.

Much oil in the Tensleep may be trapped in microscopic, or very small stratigraphic traps created by primary eolian strata and flow units derived from small dunes. EORI is working on ways to calculate oil trapped by eolian primary strata, and devise strategies to produce it. We are using seismic analysis, and seismic techniques along with novel seismic and field studies. We hope this will help to guide field studies and other strategies in order to improve recovery of oil from Wyoming fields.

Conclusions: Petroleum exploration, production and sedimentology Southeast Wyoming

Common Risk Segment analysis of SE Wyoming Tensleep oil shows structure and reservoir quality has identified four regions near existing production that may still have opportunities for further exploration using improvements in exploration technology.

Oil production in SE Wyoming occurs in a variety of stages from primary through tertiary (EOR), as well as various states of IOR (mechanical upgrades). There may be development opportunities in existing fields.

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Conclusions: Tensleep Stratigraphy Southeast Wyoming

The Tensleep and Casper Formations comprise the same rocks in SE Wyoming.

The Tensleep Formation can be divided into a mainly eolian Upper Tensleep member and a carbonate-rich, paralic and eolian Lower Tensleep Member.

The Upper and Lower Tensleep in this study, provides contrast to the Rhyolite (Upper Tensleep) and Medicine Lodge (Lower Tensleep) Members of the Big Horn Basin, although this is not confirmed by this study.

The Upper Tensleep is mainly Permian, the Lower Tensleep is Pre-Permian. Lithostratigraphic change between Upper and Lower Tensleep was probably driven by climate changes from Upper Carboniferous time into Permian times.

The Upper and Lower Tensleep Members are no longer present regionally in SE Wyoming.

The “Fountain” inter-bedding with Tensleep occurs mainly in the Lower Tensleep, close to pre-Permian uplifts.

Oil Production is mainly from the Upper Tensleep in structural traps.

Shallow marine carbonates inter-tongue with the Upper Tensleep (Permian) across the Laramie Range.

Reservoir heterogeneity caused by eolian primary strata

After R.H. De Bruin, 2005

Flat Top

White Rocks

Paradise Valley

Sand Creek

The Permian Upper Tensleep Formation at Flat Top Anticline near Medicine Bow, Wyoming. Several measured sections here are being used to create a model of the outcrop as a petroleum reservoir. Our observations on heterogeneity are helped by the fact that the lower half of the outcrop is oil saturated, which makes variation in oil-saturation visible. Unsatuarated laminations and beds tend to be red or white, whereas oil-saturated portions of the outcrop are brown beneath a thin “whitish” layer of degraded oil.

The Inglewood Formation (Casper-Tensleep correlatable) at Owl Canyon, Colorado. Two sections were measured in this area for comparison with nearby Wyoming outcrops. View to the east.


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Shallow marine carbonates inter-tongue with the Upper Tensleep (Permian) across the Laramie Range.
Cross section

Index map of Wyoming and counties, showing State database of Tensleep Penetrations (Tensleep, Casper, Minnelusa). Our study area is shown by red box with Upper Tensleep Thickneses posted. Not every Tensleep penetration was used in our regional study. Older wells with poor logs or little data were omitted, as well as dense grids intra-field wells such as those at Wertz and Lost Soldier.

Index map of the cross section shown on the right. Base map is the basement map of Wyoming, and Upper Tensleep thickness.
The Sand Creek measured section was chosen at a locality that shows the transition upward from the red siltstones and arkosic fluvial sands of the fountain to the eolian dunes of the Casper (Tensleep). The section is relatively complete, lacking only the upper 30 feet or so of Casper below the Satanta red beds. There is a major change in wind direction from northward to southerly and southwesterly at unit 16. The section is a whole in a classic “clearing upward” section, reflecting both the sorting of older fluvial sediments from the fountain, and in the end, the arrival of long-distance sand transported from the Permian sand sea to the north. To the north, at a nearby well, the Pennsylvanian formation has thinned and disappeared. This is typical of the Fountain in the Laramie basin, that does not seem to extend very far northward or westward of the old Pennsylvanian age uplifts.

### Sand Creek, Wyoming Measured Section

#### Eolian sediments

- **Sonic-GR log of the Upper Tensleep (Casper) in the Champlin 1-19 well (NESE sec 19, T15N R 75W) drilled north of the outcrops.** A thick section of eolian dunes, very porous and permeable comprises the Upper Tensleep sand and carbonate section. In the short distance northward to this well, most of the fluvial recycling at the east end of the measured section. The shallow sands are commonly the most porous and permeable eolian facies. Below, pink mixed source eolian and fluviatile sands.

- **View of dome-like weathering pattern of white, quartzose eolian dunes.** A fluvial channel filled with sandy red mud, cut into fluvial sandstones, in Tensleep (Casper). Base of channel is marked by white arrow. This sort of stratigraphy is typical of the lower Tensleep section.

- **Fluvial and pond sediments**
  - A carbonate pond deposit with very angular bedding. This is probably a local deposit within an arid zone. Soft rocks tend to collapse into the surface. Reddish but not direct evidence of evaporites. Found at about the level of sample SC-14 in the measured section.
  - A soil horizon in flat bedded (fluvial?) sands; with rhizocretions, bioturbation from plants and some clastic dikes. White arrow marks where soil zone is overlain by eolian dunes.
  - Eolian cross beds (red and white) in the upper part of the measured section. Immediately above the sabkha deposits on the cross beds (more sand). In this horizon the carbonate depositing peloids are the primary sediments, with some eolian sand that back along bounding surface. Sabkha above (flat bedded unit) was more extensive, as visible in this view. Eolian dunes (white) mark the boundary.
  - Several slightly disconformable sets of eolian avalanche strata in the Upper Tensleep (Casper) Formation, maybe part of invertebrate. A thick section of eolian dunes, very porous and permeable comprises the Upper Tensleep sand and carbonate section. In the short distance northward to this well, most of the fluvial recycling at the east end of the measured section. The shallow sands are commonly the most porous and permeable eolian facies. Below, pink mixed source eolian and fluvial sand deposition.

- **A color change purple to yellow-orange**

- **A view near the base of the measured section, showing mostly fluvial deposits of Upper Fountain-Lower Tensleep. View to the south.**

- **Matt Johnson pauses for scale in this image of the upper part of the measured section.** Behind him the eolian cross beds from which sample SC-12 was taken. A carbonate pond deposit (blue on the measured section). Behind the sample outcrop from which sample SC-14 was taken.

- **A view of a shearing parallel to the red mud pond deposits of the upper part of the measured section.** Matt's hand is on the top of a seated person.

- **Enlarged view of eolian avalanche and ripple primary strata in the Upper Tensleep (Casper) Formation, above the faulted sands.** This view is oriented to show representative ripple laminae from the top of the avalanche unit.

- **A view of domes-like weathering pattern of white, quartzose eolian dunes in the uppermost part of the measured section.** The unit is overlain by eolian dunes.

- **A view of a shearing parallel to the red mud pond deposits of the upper part of the measured section.** Matt's hand is on the top of a seated person.

- **A soil horizon in flat bedded (fluvial?) sands; with rhizocretions, bioturbation from plants and some clastic dikes. White arrow marks where soil zone is overlain by eolian dunes.** A soil horizon in flat bedded (fluvial?) sands; with rhizocretions, bioturbation from plants and some clastic dikes. White arrow marks where soil zone is overlain by eolian dunes.

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- **A fluvial channel filled with sandy red mud, cut into fluvial sandstones, in Tensleep (Casper). Base of channel is marked by white arrow. This sort of stratigraphy is typical of the lower Tensleep section.**

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Stratigraphy, Exploration and EOR potential of the Tensleep/Casper Formations, SE Wyoming

Steven G. Fryberger, Nick Jones, Matthew Johnson and Curtis Chopping
Enhanced Oil Recovery Institute, University of Wyoming, 2016

Tensleep Sandstone at Flat Top Anticline
Carbon County, Wyoming (ft.)

Siltstone bedded sedimentary rock with minor dolomite and minor iron carbonate. The dolomite was precipitated as a result of chemical weathering of the Tensleep sandstone, which is rich in calcium carbonate. The iron carbonate was precipitated as a result of the oxidation of iron-rich sediments. The rock is grey in color and contains abundant evidence of bioturbation, including burrows and channels, and is thought to have been deposited in a shallow marine environment.

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Satellite view of the Flat Top Anticline surrounded by exposures of Permo-Triassic red bed formations. East Allen Lake Oil field (red dot) in the Tensleep is just south of the town of Medicine Bow.

Mixed ripple and avalanche strata in Unit 2 of the Flat Top measured section 1. Note the black lines of oil saturation on the ripple strata. These lines are due to an oil-saturated reservoir that has been partially swept by the encroachment of oil from the Goose Egg. Thus, there may be no immediate connection to marine shorelines in the Upper Tensleep at Flat Top.

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Density-OGR log of the Flat Top Anticline, which contains both the Upper and Lower Tensleep at nearby Allen Lake East (Tensleep) oil field. The sabkha encountered at Flat Top Anticline may be present in this well (arrow).
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White Rock Canyon

The Upper Tensleep Sandstone at White Rock Canyon is 226 feet thick, based on well control. The measured section begins in the Upper Tensleep, which is roughly 400 feet thick, based on well control. It was measured on the opposite (west) side of the cliff where access was easier. It begins about the middle of the Upper Tensleep and continues to the first carbonate in the Phosphoria (Goose Egg) Formation. Note the variety of genetic units in terms of thickness, shape and cross-bedding. This suggests that oil recovery factors from these genetic units would be equally diverse, mainly as a function of the arrangement of primary strata in each, as well as geometry, lithology etc. These faults zones of deformation do not all lie.

Fluvial channel (conglomerate, sandstones, siltstones) in unit 7. These sediments represent Upper Fountain Formation tongues that have pinched out a short distance northward at Pass Creek oil field. They are the product of runoff into the Upper Tensleep dune field from an ancient uplift to the south.

Fluvial channel with coarse reddish sandstone and irregular bedding (between dashed lines). It is enclosed by dune sands above and below. Unit 18. Steep cliff above goes to top of section units 19-23.

Fluvial channel with coarse sands and eolian sands. They form a complex body of strata. Unit 15. Sample WR-4.

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Paradise Valley Measured Section

**Paradise Valley Measured Section**

The measured section at Paradise Valley consists of an eolian sequence sandwiched between two marine carbonates. Base and top of the section are on marine limestones of the Tensleep (Casper). Dune sequence in this outcrop has largest dunes at base, smaller, more marine shoreline deposits including carbonates higher up. Dashed white line shows base of sabkha (Unit 5).

Lower part of the Paradise Valley measured section with dune bedforms, where Nick Jones is seated. Generally, bedforms become smaller up-section. This sequence (see measured section) would make a complex petroleum reservoir with numerous distinctive flow units – the best probably the dunes shown here at the base of the cliff below the dashed line.

A close up view of a set of avalanche strata on a dune slipface at the base of the measured section. This is Unit 1 of the measured section. Eolian bedforms and dunes consist of stacked sets of strata (Units 2-4), which overall has highest proportion of ripple primary strata – the best probably the dunes shown here at the base of the cliff below the dashed line.

The marine limestone that forms the base of the dominantly eolian rocks in the background. This limestone contained shell fragments.

The measured section at Paradise Valley. It displays an eolian sequence with isolated limestone beds and strata. Many of the coarse grains are light-colored.

**Tensleep/Casper Formation**

**Paradise Valley, Albany County Wyoming**

**Measured partial measured Section**

101 Feet

(June 4 2015) Fryberger and Jones

- Spl PV-3A
- Spl PV-3
- Spl PV-4
- Spl PV-5
- Spl PV-6
- Spl PV-2
- Spl PV-1
- Spl PV-4
- Spl PV-7
- Spl PV-8
- Marine transgression

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*1 Enhanced Oil Recovery Institute, University of Wyoming. 2016
Upper Fountain-Ingleside Fm Lien Quarry and Owl Canyon Northern Colorado

Measured section
Upper Fountain-Ingleside Formations
Lien Quarry, Colorado

Lien Quarry

Overview of the Owl Canyon Upper Fountain-Ingleside Formations measured section. This section begins in the Upper Fountain fluvial conglomerates and arkosic sandstones. It continues into mixed fluvial and eolian deposits. A thin gray limestone bed is exposed in the photograph taken north of the measured section proper. This unit shows evidence of shallow marine deposition.

Fountain-Ingleside measured along highway 287

Upper part of the measured section (mostly Permian Upper Tensleep Member, measured near Owl Canyon测点). This section begins in the Upper Fountain Formation. Transition to Ingleside is in the upper part of the section. This section shows evidence of shallow marine deposition, particularly in the upper part of the section. One of these units is marked by the arrow on the left.
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Tensleep stratigraphy

**Upper Tensleep thickness**

- Hanna Basin
- Lower Tensleep

**Upper Tensleep Hydrocarbon shows and Structure**

- Green areas on this map enclose regions with oil or gas shows in the Upper Tensleep, based on Wyoming Oil and Gas Commission records of production, drill stem tests and some limited core and sample data. This map also shows major faults in red from the state geological map, and structure contours subsea on the top of the Upper Tensleep. There are distinct, structurally-defined shows in Wertz, Atlantic Rim, Baggs, Medicine Bow and Quealy Dome regions.

**Total Tensleep thickness**

- Hanna Basin
- Southern Wyoming

**Satanka Shale thickness**

- Shape of Hanna Basin
- Photographer: Alph Agateaux, 1934

The thickness of the Upper and Lower Tensleep combined follows the pattern of the Upper Tensleep. It is clear that major Laramide upfolds of the Medicine Bow and Sierra Madre Mountains have stripped off the Tensleep. There are also more subtle trends related to local faulting.

**Satanka Shale thickness map** (overlies Tensleep regionally). Areas with Satanka eroded colored purple. Orange shading shows thick Satanka in southern Laramie Basin.

**Sybille carbonate-evaporite thickness**

- The Sybille carbonate-evaporite sequence of the Goose Egg Formation immediately overlies the Satanka Shale. The thickness is a good indication of post-Tensleep tectonics. Thick Sybille is present in the Lost Soldier-Wertz area, Hanna Basin and a NE-SW trending area defined by faults in the Laramie Basin. On this map, thicks are indicated by purple shading, thins by orange.
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Tensleep Formation Common Risk Segment Maps

CRS Overview

The maps on this page illustrate the stages in a “common risk segment” map, with the final product displayed immediately to the right. Not surprisingly, the CRS map finds existing production (red areas on map are oil fields). However, study of the other maps on reservoir, structure and charge (shown) reveal why the fields are where they are, and make visible certain trends that would not be obvious without this technique.

Qua]d dome occurs in an area of complex structures related to shear faulting. There may be uninterpreted or incorrectly mapped structures in this area based on older seismic data. Because Qua]d Dome has at more than a 300 foot oil column, this area is probably worth another look.

There is also a trend of shows and structures that extend from East Allen Lake, Big Medicine Bow and Pass Creek Tensleep oil fields. Big Medicine Bow and Pass Creek are still on primary production. If water bypassing can be identified, there may be room for additional injection or producing wells. There are strong oil shows in outcrops at Flat Top anticline, that suggest perhaps further exploration is worthwhile along NE-SW trending faults in this area north of East Allen Lake near Medicine Bow.

To the west, the Atlantic Rim area has considerable shows. More production may be found along the Sierra Madre trend and southward following shows including free oil in drill stem tests.

The Lost Soldier Wertz area, including Mahoney Dome has major production with big structures, good upper Tensleep Reservoir and charge presumably from down-dip Phosphoria source rocks.

We searched carefully for a reason to be hopeful about the relatively under-drilled Hanna Basin, however the deep burial appears to have reduced porosity in the Upper Tensleep and increased the risk of drilling tight reservoir even if structures could be defined. The high risk CRS along the Laramie range is mainly due to lack of structure. Reservoir in the Upper Tensleep is very good, however there are few shows this close to the Laramie Range. It should be noted however that our main information on shows came from drill stem tests and production, as well as a few lithological logs contributed by operators. We did not have complete sample descriptions (mud logs) for many wells, those sample shows may have been missed.

Upper Tensleep Trap Risk

Tensleep trap (structure) risk map. Contours show subsea top Upper Tensleep. Green shading is low risk; blue shading is moderate risk; purple shading is high risk. Regional faults shown by red lines, background is Wyoming Basement map. This map is based on distribution of known producing structures at Tensleep level, and structural setting. In Southeast Wyoming, there do not appear to be stratigraphic traps above intraformational (reservoir heterogeneity) level. High risk area near Rawlins is related to very shallow depth of Tensleep, with exposure of the formation in places along the ridge that runs from Sinclair north towards Mahoney Dome.

Upper Tensleep Charge Risk

Tensleep charge risk map. Green polygons enclose producing oil fields and oil shows from state records (posted on map). Broad areas extend shows along structural or stratigraphic trends (green hachures).

Upper Tensleep Reservoir risk (quality)

Upper Tensleep Combined CRS map

Combined Upper Tensleep CRS map. Green areas show regions of best chance to find new production (lowest risk). Blue areas show moderate risk. Red hachured areas show high risk areas, mainly regions such as the Hanna Basin with tight rock, or areas with insufficient evidence for robust structural traps. State of Wyoming basement map as background.

Southeast Wyoming seismic trade data

Availability of trade seismic data in the SE Wyoming region. Black lines show 2D data, red polygons show 3D surveys. Data are superimposed on the combined CRS map for the region based on this study (see maps on this page). Map at background is Wyoming Basement map. Seismic data courtesy of MEI Seismic. Exchange data brokers in Houston and Denver.
EOR status in Southeast Wyoming Examples

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Green shaded areas indicate regions of oil shows. Background: Basement map of Wyoming.

EOR status in Tensleep Fields in SE Wyoming.

Wertz 46
An Upper Tensleep genetic unit was not perforated, despite high oil saturation. Oil may have been swept by an adjacent injector producing water from Kapaska. Unit appears isolated stratigraphically from perforated units below.

Petrel static model showing Lower and Upper Tensleep at Wertz Oil Field

Petrel static model showing Lower and Upper Tensleep at Wertz Oil Field

Oil Fields in Tensleep - Laramie Basin and environs


Page Sandstone outcrop in Page, Arizona, viewed by geologists on a Shell Field trip.

Erosional bounding surface Dip direction and amount (现代) primary strata


Estimates of the proportions of modern primary strata type and abundance for each dune type. These are rough guesses based on the author’s experience and published literature. In detail, there will certainly be mixed associations consisting of some ripple strata and some eolian primary strata. The be-dune type is illustrated here. Modern sands in reversing dunes, especially those on eroding flanks, are associated with well-developed ripple strata, and thus these may represent the primary strata.

Oil Fields in Tensleep - Laramie Basin and environs


Petrel static model showing Lower and Upper Tensleep at Wertz Oil Field

Petrel static model showing Lower and Upper Tensleep at Wertz Oil Field

Oil Fields in Tensleep - Laramie Basin and environs


Petrel static model showing Lower and Upper Tensleep at Wertz Oil Field

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Oil Fields in Tensleep - Laramie Basin and environs


Petrel static model showing Lower and Upper Tensleep at Wertz Oil Field

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Petrel static model showing Lower and Upper Tensleep at Wertz Oil Field

Petrel static model showing Lower and Upper Tensleep at Wertz Oil Field

Oil Fields in Tensleep - Laramie Basin and environs


Petrel static model showing Lower and Upper Tensleep at Wertz Oil Field

Petrel static model showing Lower and Upper Tensleep at Wertz Oil Field

Oil Fields in Tensleep - Laramie Basin and environs


Petrel static model showing Lower and Upper Tensleep at Wertz Oil Field

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