



Jonah and the Wells



THE SETTING

- Jonah Field, Wyoming
- Tight Gas
- Stacked Fluvial Channel Sands
- Multiple Frac Stages (8–12 per well)
- Optimize staging and well placement



THE BACKGROUND

The historical account says that Jonah was in the belly of a whale for 3 days before he was freed. Pinnacle assisted BP in trying to free natural gas locked in their wells in Jonah for more than 65 million years!

The Jonah Field is located in Sublette County, WY approximately 70 miles north of Rock Springs. The field is a large, structurally complicated wedge shaped fault trap located in the northwestern part of the Green River Basin. Production is primarily from over-pressured and tight sandstones in the Cretaceous Lance Formation. The Lance formation in Jonah Field is composed of a stacked sequence of 20 to 50 fluvial channel sands inter-bedded with associated over-bank siltstone and floodplain shale deposits. Gross interval thickness ranges from 2,800 ft to more 3,600 ft. Within this interval the net-to-gross ratio varies from 25% to 40%. Sandstone bodies occur as individual 10 ft to 25 ft thick channels and stacked channel sequences greater than 200 ft in some cases.

The main reservoir issues are low permeability and small pay sections across a large gross interval. Hydraulic fracturing is required to sustain commercial production in these low permeability reservoirs and wells in the Lance are stimulated in multiple fracture stages. Each fracture stage may target three to six sand bodies with eight to twelve stages per well.

PINNACLE PERFORMS

Microseismic and tiltmeter mapping were used to estimate fracture azimuth, fracture geometry, stage height coverage and fracture complexity on about 100 frac stages in two pilot areas (East and West). Results from the East area are presented here and more detail on both areas can be found in SPE 102528.

Microseismic Mapping Results for the East Area

Figure 1 shows the composite map view of the microseismic events for all eighteen stages mapped in four wells. Fracture azimuth varies from about N18°W to N64°W. Stages 3, 6, 7 and 8 in well EAST 3 have a fracture azimuth of N44°W. In stage 9 it was difficult to determine fracture azimuth as half-lengths were relatively short. Fractures in stages 6 and 7 of EAST 3 grew into and past the observation well EAST 1. Fracture azimuth ranged from N18°W to N64°W for EAST 4. The fracture azimuth for EAST 5 was approximately N42°W and it was approximately N43°W for all stages in EAST 6.

Fault Interaction

It appears that several treatments encountered faults or open natural fractures. Figure 1 shows a plan view for all stages mapped in the East Area. Microseismic events considered to be fracture related events and faults events are indicated on the map showing three possible faults. These were imaged during stage 3 in EAST 4, stage 3 in EAST 3 and stage 3 in EAST 6. These were identified by the number of events generated, linear nature of these features and the event magnitudes compared to typical fracturing events. Surface seismic imaging did not detect these faults but they are being integrated with 3-D seismic and local structure maps to better characterize the reservoir.

Figure 2 shows the side views of microseismic events for the EAST 3 (stages 3, 6, 7, 8 and 9), and respectively. Created fracture half-lengths range from 700 ft to 1,100 ft (except for stage 9). The created fracture is assumed to be symmetric, with observation well location biasing results to the northwest. Fracture heights range from 150 ft to 350 ft and out-of-zone growth appears to be common with overlap between stages.

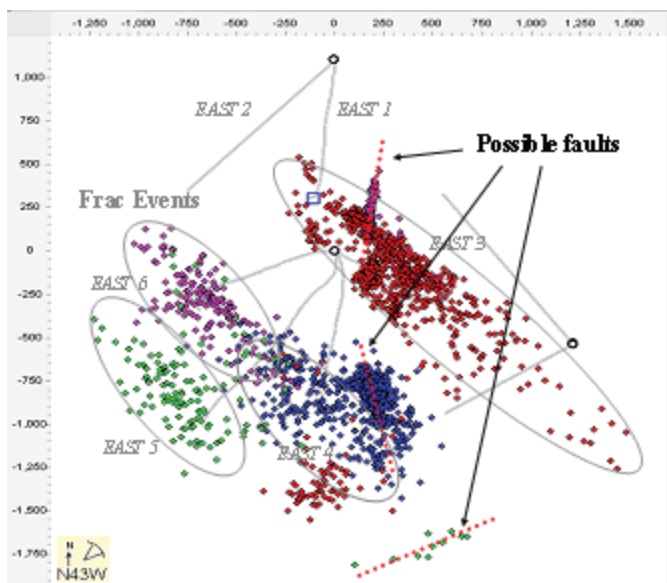


Fig. 1 Plan view showing microseismic events for all stages mapped in the East Area showing frac events and possible fault related events.

Stage 3 grew very close to the observation well EAST 1 and this stage might have terminated at or near a fault. Stage 3 is well contained within the target interval. Fracture half-length was 710 ft and height was 200 ft. Stage 6 showed growth toward and past the observation well. Fracture half-length was 1100 ft and height was 320 ft. This stage may have intersected a fault allowing growth upward into the stage 7 interval. Much of the length development for this stage was solely in the stage 7 interval. Stage 7 also appears to grow very near the observation well. The fracture grew upward 50 ft but downward growth was contained. Fracture half-length was 920 ft and height was 215 ft. This treatment was asymmetric to the southeast possible due to growth from stage 6 into the northeast interval for stage 7. Stage 8 showed growth both upward and downward out of zone. Fracture half-length was 820 ft and height was 200 ft. Few events were recorded for stage 9 but they indicate upward height growth and a fracture half-length of 300 ft.

Surface Tiltmeter Mapping Results for the East Area

Figure 3 shows fracture azimuths from surface tiltmeter mapping with a dominant azimuth in the north-westerly direction (N43°W on average). However, some stages had a strong north-easterly component. These were seen in the EAST 3 (stages 3 and 6), EAST 4 (stages 1 and 2), EAST 5 (stages 2 and 3) and EAST 6 (stage 3). These

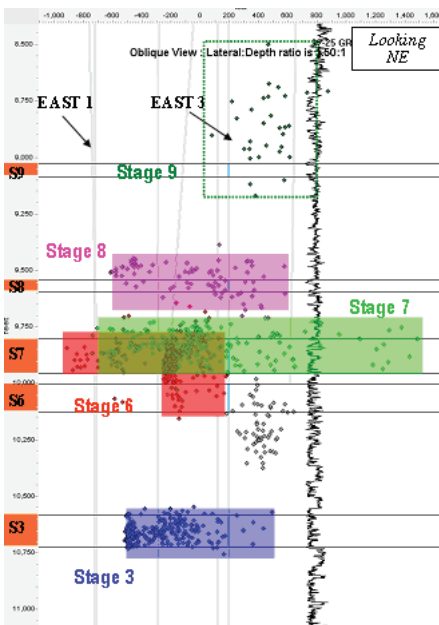


Figure 2. Side view showing mapping results for EAST 3.

north-easterly components could indicate far-field fracture complexity. In summary, about 15% of treatments show a significant north-easterly fracturing component indicating some degree of complex fracturing. The dominant fracture azimuth, however, is north-westerly, consistent with the microseismic mapping.

THE RESULTS

The primary fracture azimuth is north-west-southeast for these two areas. The microseismic azimuth agrees with the primary azimuth determined from surface tiltmeters. Evidence of fracture complexity was seen with surface tiltmeters showing some fracture volume in the northeast direction. Analysis of microseismic data indicated that faults were encountered on several stages. Surface seismic imaging was not able to detect these faults but they are now being integrated with 3-D seismic and local structure maps to better characterize the reservoir.

Fracture half-lengths varied from 300 ft to 1100 ft for the East Area. The long fracture half-lengths and fracture direction could indicate the possibility for interference between wells placed along the north-westerly fracture azimuth at distances of 1,000 ft or less.

Further production data analysis will also allow evaluation of effective fracture half-lengths and the tradeoff between tighter well spacing and larger treatment sizes. Measurements of fracture half-length and fracture azimuth can be utilized to more effectively select well locations to maximize recovery while minimizing well interference.

Fracture height was contained in some stages in both areas but many stages had out of zone height growth with overlap between stages. This means the number of treatment stages can be reduced in some instances where sands are fairly close together (< 100 ft). A calibrated 3-D fracture model was built and for use along with the mapping results to assist with future fracture staging and design. Fracture mapping provided the data necessary to determine future well spacing and placement as well as to optimize fracture design in these areas of the Jonah Field. Save the wells!

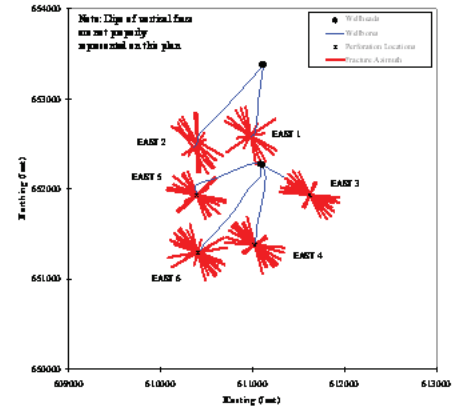


Figure 3. Surface tiltmeter mapping results for all wells in the East Area project.

Houston	281-876-2323
Denver	720-344-3464
Calgary	403-516-2260
Bakersfield	661-335-7711
San Francisco	415-861-1097
Dallas	972-401-0090
Delft	31-15-219-0062
Moscow	7-495-781-4820
Beijing	86-13838562150
Oklahoma City	405-604-5634
Midland	432-386-6791
Reynosa	52-892-42191
Cairo	2025283356-8

Pinnacle

WWW.PINNTECH.COM

©2007 Pinnacle Technologies, Inc. All Rights Reserved.

107