Fracture Models and Fractured Reservoirs*

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EDITORIAL NOTE: The reader is referred to a companion article, entitled "Using 3-D Outcrop Laserscans for Fracture Analysis," prepared by authors Ahlgren and Holmlund.

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Introduction

Ahlgren and Holmlund (2003) describe a new fracture detection method incorporating a portable laserscan unit to completely image analog outcrops in three dimensions. In this article, we explore how simple analysis of calibrated analog fracture models can enhance exploration and production in fractured reservoirs.

After collecting laserscan data from analog outcrops, semi-automatic processing extracts important fracture data such as geometries, intersections, trace lengths and orientation statistics. These statistical and spatial properties are extrapolated in three dimensions and used to generate synthetic fracture models at a scale consistent with existing or planned wells. The synthetic, three-dimensional fracture networks have similar statistical and topological characteristics of observed data, but offer distinct advantages over their natural counterparts. One important benefit is the ability to construct multiple realizations of the observed fractures quickly to test different hypotheses and perform sensitivity testing of the input parameters. Results also can be compared to well production volumes and modified to get good matches.

Technique

The new laserscan technique provides robust statistical data on fracture orientations, clustering and, to a lesser degree, fracture spacing. Parameters such as fracture trace length and shape (i.e., aspect ratio) also may be extracted from the laserscan data using techniques such as trace analysis, but with lesser certainty. Constructing multiple fracture networks using different parameters and analyzing them with a few simple tools may help to determine the relative importance of these less-constrained parameters. More importantly, the simple analysis may indicate whether a more detailed fracture investigation is truly necessary.

One technique is three-dimensional connectivity analysis, which determines how well connected or poorly connected fractures are within a natural or synthetic network. Parameters such as fracture volume and fracture area are extracted and may be useful for fracture modeling or well planning. Often, wells that intersect different components cannot communicate with one another, so defining the likely extent and volumes of the components is critical in making production estimates. For example, consider a simplified synthetic fracture network generated using orientation and length data extracted from a laserscan of a ~500m^2 outcrop face (Figure 1).

- Orientation data are extracted by orientation cluster analysis.
- The fracture length distribution is estimated using two-dimensional trace analysis. In this example, the length and aspect ratio (fracture length divided by fracture height) of the fractures are less constrained than other key parameters, reflecting a commonly encountered situation in three-dimensional fracture modeling.

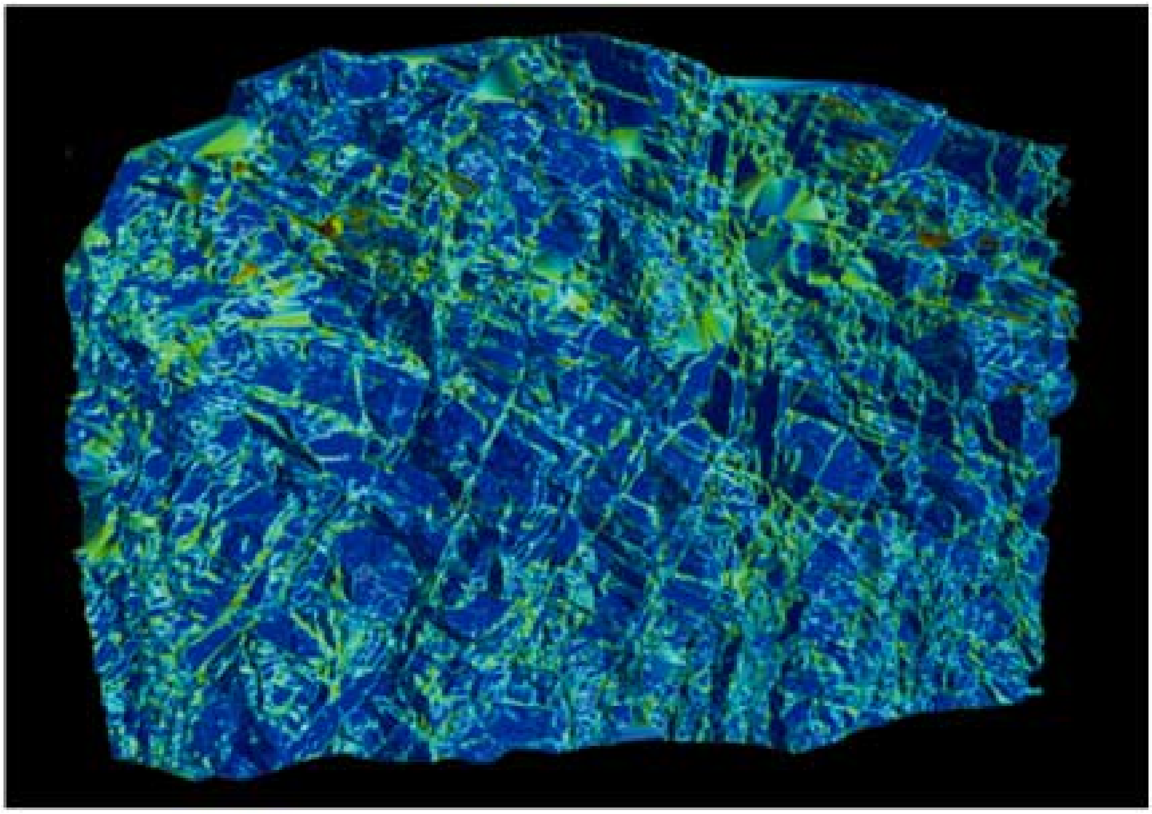

Figure 1. Meshed laserscan image of a fractured outcrop on Mt. Lemmon, Ariz. The face measures 28m x 18m.

The resulting scale model of the fracture network contains four fracture sets, each with a similar statistical signature as those interpreted from the outcrop laserscan data (Figure 2). A synthetic well is “drilled” into the model and used as the basis for connectivity analysis. The analysis quickly reveals that the well intersects a number of fracture clusters with relatively small drainage volumes (Figure 3).

Since the fracture lengths and aspect ratios are not uniquely defined, sensitivity testing of this fracture model might include changing the aspect ratio and lengths of one or more of the fracture sets, and re-analyzing the model for connectivity. To this end, a new model is constructed using one fracture set with twice the length and aspect ratio as in the first model. Connectivity analysis shows that the model is indeed sensitive to these changes, as reflected by the difference in drainage volumes intersected by the synthetic well (Figure 4).

Although both fracture models contain three primary drainage volumes of roughly equal size, the second model contains one volume (colored in yellow) almost 500x larger than in the first model. If the actual production volume for the well were known, it would be essential to compare these data with the new model to determine if a more detailed assessment of fracture size is important.

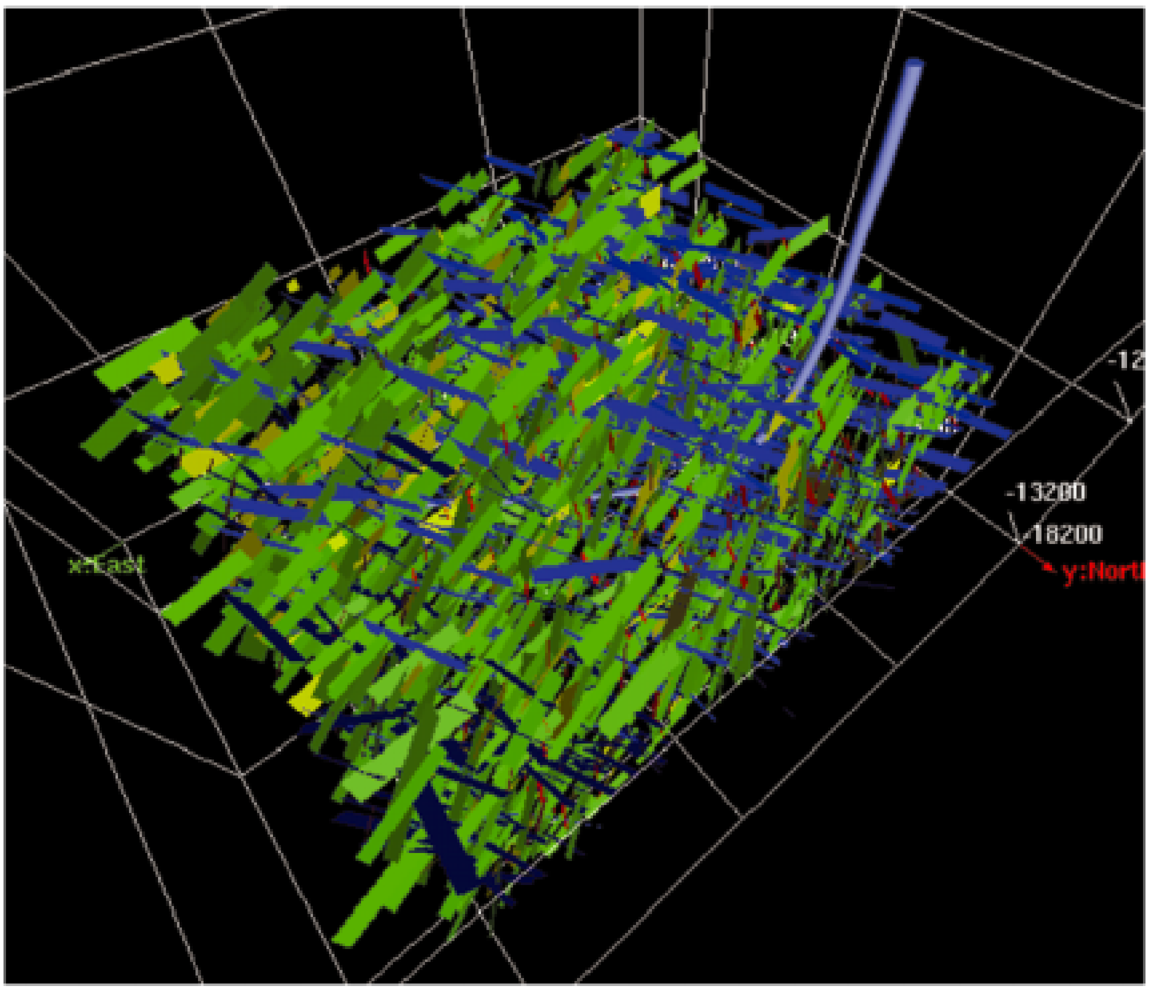

Figure 2. Synthetic fracture model with proposed well. The model contains four fracture sets interpreted from the laserscan data. A synthetic, deviated wellbore intersects the fracture network at the upper right side of the figure.

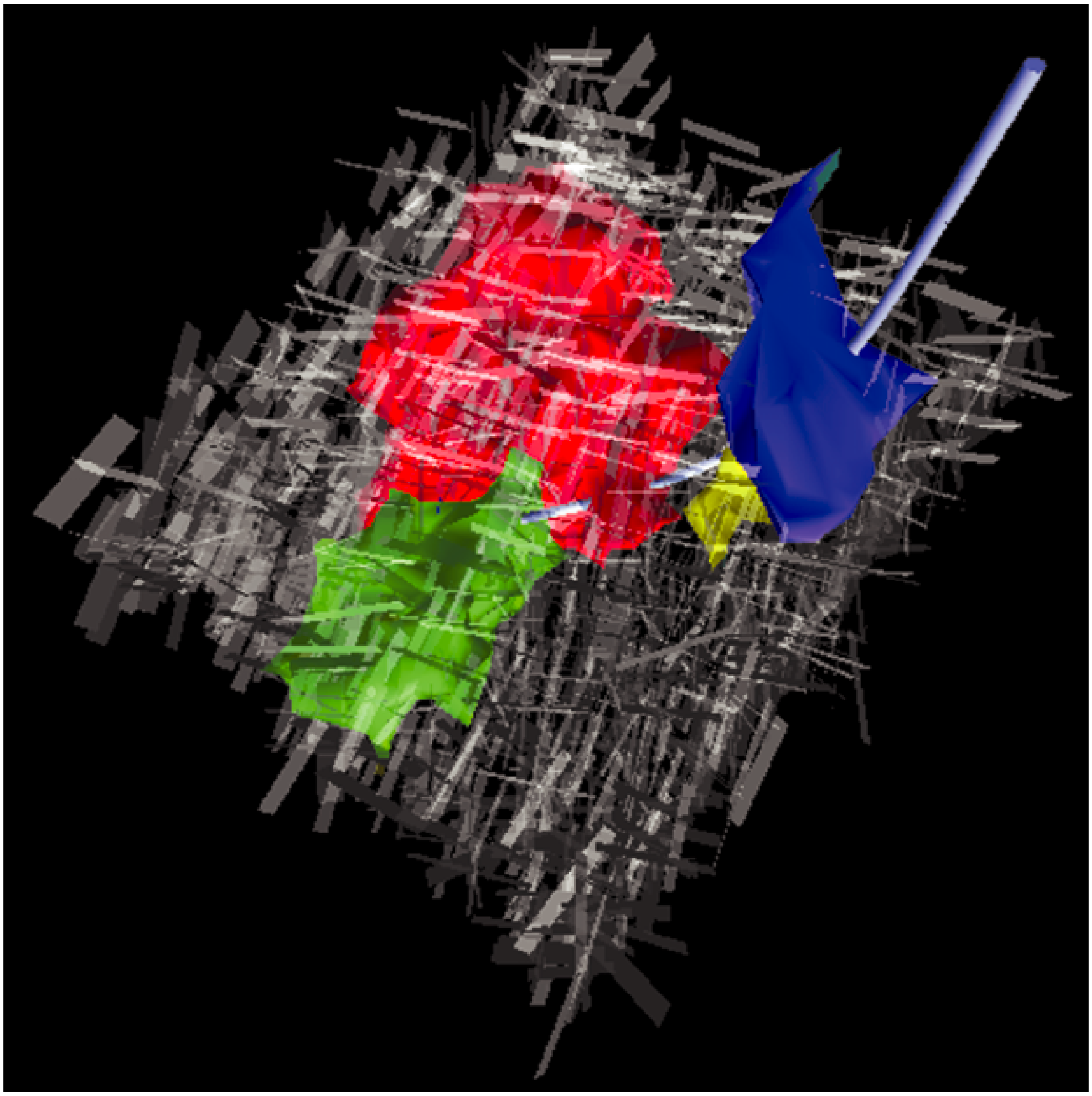

Figure 3. The synthetic well drains four distinct fractured volumes.

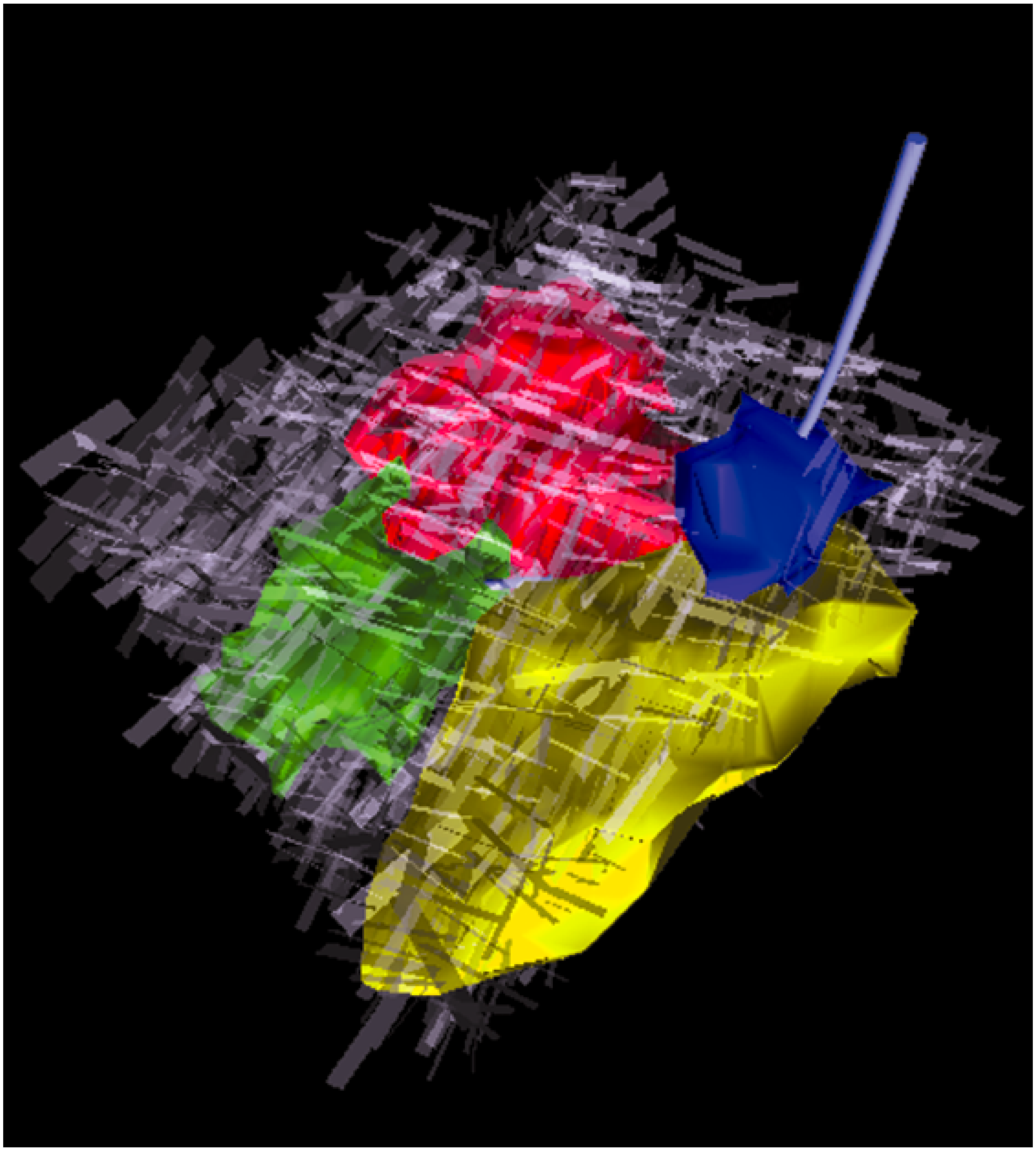

Figure 4. Changing the mean length and aspect ratio of one fracture set yields significant changes in the volume of one of the intersected components.

Conclusion

Laserscanning can be used to generate calibrated fracture models that enhance the understanding of a fractured reservoir. Models can be built around existing or proposed wells, and analyzed with simple techniques such as connectivity analysis.

Sensitivity testing may help to provide additional confidence in well planning and the fracture network interpretation.

Reference

Ahlgren, Steve, and Jim Holmlund, 2003, Using 3-D outcrop laserscans for fracture analysis: Search and Discovery Article #40099 (2003).

Acknowledgment

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