Estimating Major and Minor Natural Fracture Patterns in Gas Shales Using Production Data

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Introduction

Tight-gas sands and shales may contain up to 460 trillion cubic feet (Tcf) of gas in the U.S. alone (almost three times the amount of currently proven gas reserves).

The U.S. Geological Survey
Introduction

Identification of infill drilling locations has been challenging with mixed results in gas shales.

- Natural fractures are the main source of permeability in gas shales.
- Natural fracture patterns in shale has a random nature.
Introduction

The most common data that engineers can count on is **PRODUCTION RATE DATA**.
Objective

To develop a methodology to increase the probability of drilling more productive wells in the shale reservoirs by using just production rate data.
Methodology

- Wells are drilled in the WV and KY.
- Wells are completed in sandstone and shale.
- Production data was available for 320 wells from 1991 to 2001.
- Wells drilled prior to 2000 were used to develop & calibrate the methodology.
- Wells drilled during 2000-2001 were used to test the methodology.
Methodology

Wells are divided into three classifications.

- **Tier-one (Exploratory) Wells**
- **Tier-two (Isolated) Wells**
  - No well in 1000 acre spacing
- **Tier-three (Infill) Wells**
  - At least one well 640 acre spacing
Methodology

Two different tools and methodologies were used in this analysis:

1. Geographic Information System (GIS)

2. Intelligent Production Data Analysis (IPDA)
Methodology
Geographic Information System

Steps used in the GIS approach:

- Using stream network concept.
- Using existing trend concept.
Methodology

Geographic Information System - Stream Network

Analogy: Natural fracture patterns in a hydrocarbon reservoir are like rivers on a stream network.

- Points on stream network have lower elevation than the surrounding points.

- Wells that have been drilled on natural fracture path have higher production rate than those that have not.
Methodology

Geographic Information System - Stream Network

Procedure to create the stream network:

- Create the surface model form the points data.
- Create the flow direction.
  - Shows the direction of flow through the natural fractures.
- Create flow accumulation.
  - Represents the accumulation of gas into a cell that has been directed to the designated cell by a network of natural fractures.
- Create stream network.
Methodology

Geographic Information System - Stream Network

Import data for selected production indicator (First Year Cumulative).
Methodology
Geographic Information System - Stream Network

Reverse the value of production indicator.

First Year Cum:
- Very Bad (<18000)
- Bad (18000 - 26000)
- Average (26000 - 30000)
- Good (30000 - 35000)
- Very Good (>35000)
Methodology

Geographic Information System - Stream Network

Create a digital surface based on the reverse value of production indicator.
Methodology

Geographic Information System - Stream Network

Create natural fracture pattern (stream network) based on digital surface.
Methodology

Geographic Information System - Stream Network

Finding the maximum distance that a stream network has from a well in order to be considered.
Methodology

Geographic Information System – Existing Trend

- High quality wells are drilled most probably on the natural fractures’ path.
- The quality of a well is calculated based on operator’s yard stick. The operator’s yard stick used in this study is the first-year cumulative production.
- Based on first year cumulative the wells were clustered into five groups (very bad ... to .. very good).
- In order to identify an existing trend, there should be at least three average wells in a line without having any bad or very bad wells in between.
- The trend considered to be a minor if at least one of the wells belong to the group of average wells.
- If all the wells in trend belong to good and very good groups, the trend considered as a major trend.
Methodology

Geographic Information System – Existing Trend

Finding the maximum distance that an existing trend has from a well in order to be considered.
Methodology

Geographic Information System

Three data sets were used in order to calibrate the methodology:


Methodology
Geographic Information System

Based on Calibration results:

- **Stream Network:**
  - Production indicators:
    - First year cumulative
    - Initial decline
  - Spacing: 160 acre

- **Existing Trend:**
  - Production indicators:
    - First year cumulative
  - Spacing: 640 acre

**Rules:**

<table>
<thead>
<tr>
<th></th>
<th>Drill</th>
<th>Don’t Drill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tier III Well (has at least one well in 640-acre spacing)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Has an existing trend</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Stream flow network exist for production indicators (PIs) in 160-acre spacing</td>
<td>At least for one PI</td>
<td>For both PIs</td>
</tr>
</tbody>
</table>
Methodology

Intelligent Production Data Analysis (IPDA)

- Superimposing the trends of the production indicators on the field based on latitude and longitude of the wells, using fuzzy pattern recognition method.

- The zone ranking is represented by Relative Reservoir Quality Index (RRQI).

- RRQI is a number 1-5 (Very high - Very low potential).

- The process was repeated for each Main Zone Separately.

- Sub RRQI is calculated.
Methodology

Intelligent Production Data Analysis (IPDA)
Methodology

Intelligent Production Data Analysis (IPDA)

Based on Calibration results:
(Same as GIS method)

- Production indicator:
  - First year cumulative

- Combining Main and sub zones RRQI:
  \[ Comb \ RRQI = 2 \times Main \ RRQI + Sub \ RRQI \]

Rules:

<table>
<thead>
<tr>
<th>Combine RRQI</th>
<th>Drill Less than 8</th>
<th>Don’t Drill Grater than 10</th>
</tr>
</thead>
</table>

Results

Geographic Information System

Stream Network based on first year cumulative (wells drilled prior to 2000).
Results

Geographic Information System

Stream Network based on Initial Decline (wells drilled prior to 2000).
Results

Geographic Information System

Existing trend based on first year cumulative (wells drilled prior to 2000).
Results

Geographic Information System

Predicted 95% of wells
With 92% accuracy
Results

Intelligent Production Data Analysis (IPDA)
Results
Intelligent Production Data Analysis (IPDA)

Predicted 52% of wells
With 100% accuracy
Results
IPDA + GIS

Predicted 96% of wells
With 92% accuracy
Conclusion

- A new strategy for increasing the probability of drilling more productive wells in the shale reservoir has been introduced.

- Two different methods have been introduced for analysis: Geographic Information System (GIS) and Intelligent Production Data Analysis (IPDA).

- It has been shown that both methods have potential to determine optimum infill drilling locations in shale reservoir.
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