QUARTERLY TECHNICAL PROGRESS REPORT

Intelligent Computing System for Reservoir Analysis and Risk Assessment of the Red River Formation

Cooperative Agreement DE-FC26-00BC15123

Luff Exploration Company
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Disclaimer

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Abstract

Integrated software has been written that comprises the tool kit for the Intelligent Computing System (ICS). Luff Exploration Company is applying these tools for analysis of carbonate reservoirs in the southern Williston Basin. The integrated software programs are designed to be used by small team consisting of an engineer, geologist and geophysicist. The software tools are flexible and robust, allowing application in many environments for hydrocarbon reservoirs. Keystone elements of the software tools include clustering and neural-network techniques. The tools are used to transform seismic attribute data to reservoir characteristics such as storage (phi-h), probable oil-water contacts, structural depths and structural growth history. When these reservoir characteristics are combined with neural network or fuzzy logic solvers, they can provide a more complete description of the reservoir. This leads to better estimates of hydrocarbons in place, areal limits and potential for infill or step-out drilling.

These tools were developed and tested using seismic, geologic and well data from the Red River Play in Bowman County, North Dakota and Harding County, South Dakota. The geologic setting for the Red River Formation is shallow-shelf carbonate at a depth from 8000 to 10,000 ft.

Executive Summary

Improvements and additions were made to the Entrapment Tool. An algorithm has been added that simulates oil migration and oil accumulation along the reservoir pressure surface. ICS evaluations of reservoir characterization and oil potential were tested using 2D seismic at two fields. It was found that the well control and normalized seismic attributes at 3D surveys can be satisfactorily used for evaluation of 2D seismic surveys. There were a cumulative total of 11 Red River B Zone and three D Zone demonstration tests covered by ICS evaluation through the second quarter. The project website is being modified to highlight software capability, no cost and a feedback form.

Summary of Technical Progress

ICS Program Development

There are now two options for estimating entrapment potential with the Entrapment Tool. One method uses the residual of the pressure surface from the trend and the second method simulates oil charge from an iterative solution of oil migration along the pressure surface. The original method for estimating entrapment pressure uses the difference of the pressure trend and pressure surface. The greater the difference of the pressure at a point on the pressure surface from the pressure trend, the greater the entrapment potential.

The Entrapment Tool has been revised to include an algorithm to simulate flow or migration of oil along the reservoir pressure surface. The oil migration feature is an iterative grid-based calculation, which attempts to model where oil accumulates as a result of movement along this pressure surface. Initially, one unit (or "drop") of oil is assigned to each grid cell of the calculated pressure grid. The minimum pressure is investigated in the surrounding eight cells. If this pressure is at least one psi less than the pressure in the source cell, the adjacent minimum-pressure cell becomes the destination cell, otherwise the oil drops do not move. The user specifies a pressure factor which controls how the pressure surface changes as drops move. At the completion of the iteration process, a map is created that shows the pressure charge resulting from the oil migration.

In either method, the pressure surface can be modified by capillary pressure as inferred by rock type. An output file can be created from the output map of either routine. This file may be used with other data for predictions of oil-cut and productivity by the neural solver tool.

ICS Calibration

The main calibration efforts for predictions of reservoir potential from ICS have been focussed on entrapment. Predictions of reservoir interval thickness and porosity from seismic attributes have been very good. At the present time, there are three structural related attributes that have been found to be most useful for entrapment.

The Entrapment Tool is used to calculate the structural residual and oil migration pressures. In addition, a residual height from the regional-depth trend is being used in ICS evaluations. It has been found that determining local structural relief is insufficient in predicting the potential for oil-charge. Correlation for predicting oil-cut and oil productivity is greatly improved when the regional structural height is included in the data file.

A specific example comes from one of the demonstration wells drilled during the third quarter of 2001. The well penetrated excellent porosity and permeability reservoir rocks at a depth that was slightly higher than had been predicted from the seismic data. The apparent local structural closure was 60 feet; however, the structural height relative to regional was minus 10 feet. The Red River B and D zones were found to be wet from drill-stem testing and the well was plugged. This result raised questions in regard to the previous methodology and evaluations that had been done with ICS. Subsequent to the results from this well, inclusion of the regional depth in ICS training for prediction of oil-cut and oil productivity has produced better correlation.

The methodology for reservoir characterization and prediction of producibility (oil-cut and oil rate) has been developed by training at six 3D seismic surveys and two areas of 2D seismic coverage. Initially, training and prediction were done using all well data in the 3D seismic surveys. Subsequently, well control from each individual 3D survey was rotated out of the training process to compare

consistency of results and predictions. In the last quarter, training from the 3D seismic survey well control was applied to the 2D seismic areas. A follow-up training from the well control in the 2D seismic was then performed. Similar results for reservoir properties and producibility were obtained from the 3D well control and the 2D well control at the 2D seismic study areas.
A simplified summary of the most common application of ICS to the Red River in the Bowman area is described in the following steps.

1. Export from geophysical software any relevant macro seismic attributes of time and computed depth. Also, export micro (reservoir level) seismic attributes of amplitude, frequency, interval time, etc. See Figure 1 for a map display of computed reservoir depth.
2. Create a database from well data for thickness, porosity, permeability, production etc.
3. Transform seismic micro attributes to reservoir attributes (thickness, porosity etc.) with cluster, neural or multiple linear-regression tools. See Figure 2 for a map of transmissibility from transformed seismic micro attributes.
4. Use the entrapment tool for migration pressure and residual pressure. See Figures 3 and 4 for examples of migration pressure and residual pressure.
5. Compute regional depth trend. See Figure 5 for a map of height above regional trend.
6. Concatenate a map file of transformed seismic attributes (reservoir, structure, entrapment, etc.) to be used for predicting production potential across the 3D seismic survey.
7. Extract transformed seismic attributes at well locations and create a training file.
8. Apply training file with the neural solver tool to the map file for prediction of oil-cut and oil productivity. See Figures 6 and 7 for oil-cut and oil rate predictions from neural solver.

Well Activity

During the second quarter, there was activity at three demonstration wells. Two wells were re-entered for lateral drilling in the Red River B Zone. One well was a vertical test for both the Red River B and D Zones. There were a cumulative total of eleven Red River B Zone and three D Zone demonstration tests covered by ICS evaluation through the second quarter. For the remainder of 2002, five Red River B Zone and one D zone tests are planned.

Project Website

During the second quarter, April-June 2002, there were 569 visitors to the project website. The average page views per visitor were 5.0 with an average duration of 5 minutes. From the file-type counter, the number of visitors who have downloaded the software during the second quarter appears to be 53. Figure 8 is a screen capture of the website monitor for April through June. We have concluded that the website is an excellent tool for technology transfer with the recorded activity from the website monitor. However, the number of software downloads appears low compared to the total website traffic. Also, there has been only one e-mail response to the project feedback form. The website will be modified to stress that the software is available without cost, a bullet format to summarize the software and a request for generic information from the potential user. Additionally, an option for requesting the software on CD ROM will be provided for those viewers with 56K modem connections, since the download time may be uncomfortably long. With these website changes, it is hoped that more downloads and requests for the software will be generated and there will be a more definitive count and demographic profile of interested parties. In the next quarter, we also plan to improve the website traffic by focusing on key words and key word positioning with Yahoo and other major directories.

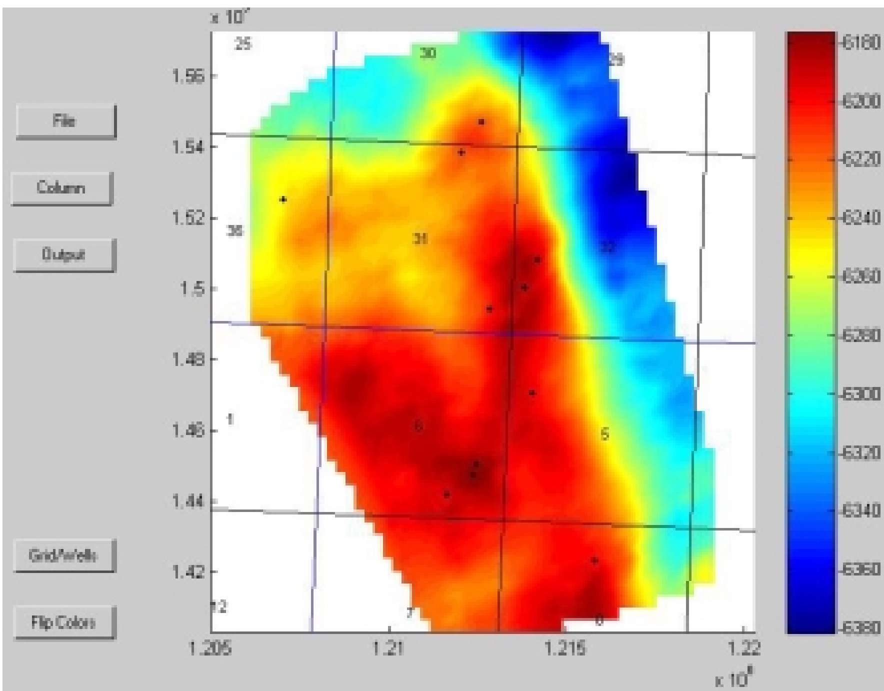

Figure 1. Map view of reservoir depth (feet) from a file computed by the project geophysicist.

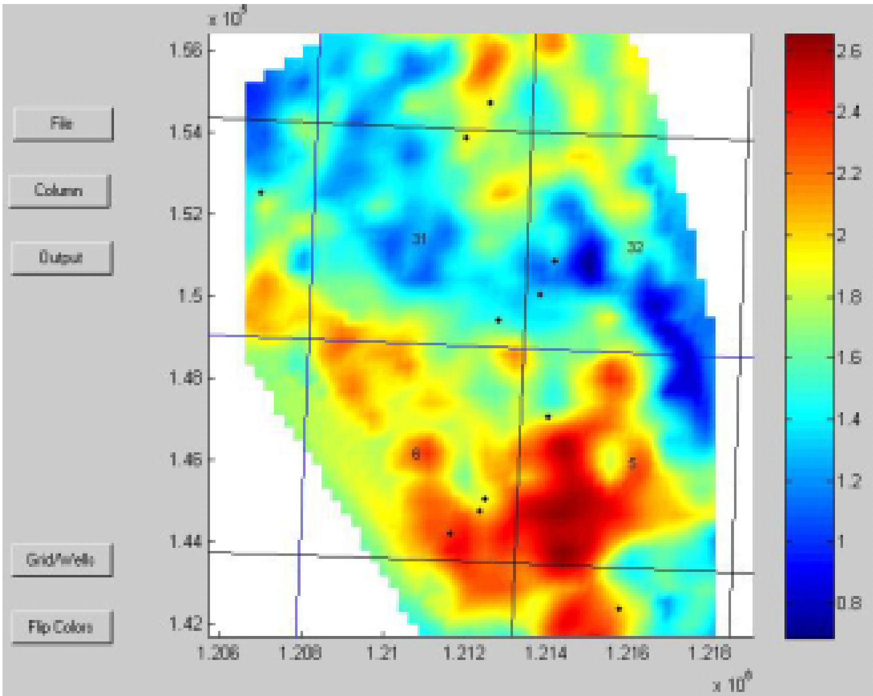

Figure 2. Map view of transmissibility (log of md-ft/cp) for Red River D Zone. Prediction was obtained from the Neural Solver Tool with seismic attributes and drill-stem test data from wells.

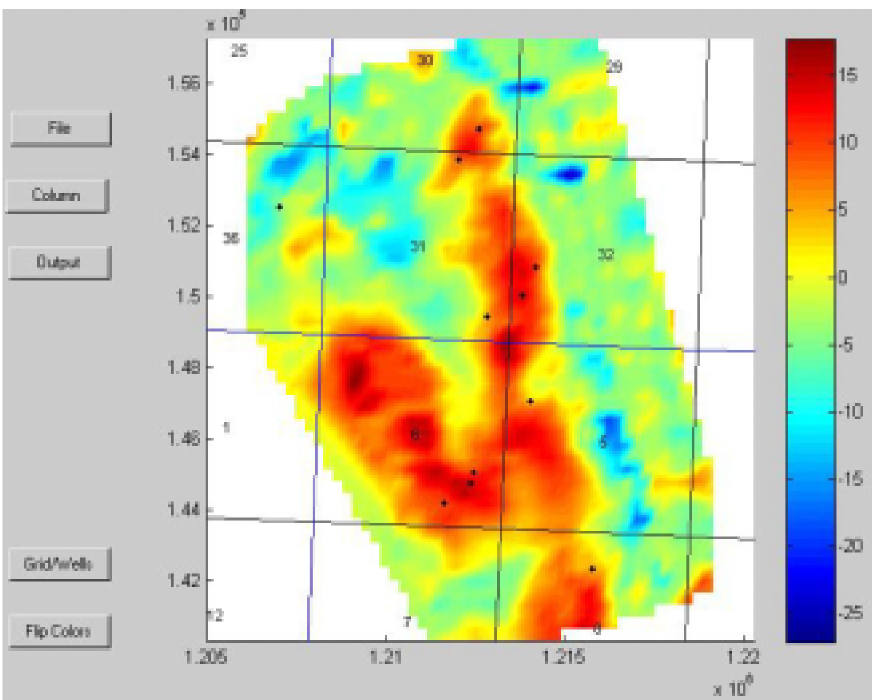

Figure 3. Map view of "oil charge" pressure (psi) from migration option of the Entrapment Tool for the Red River D Zone.

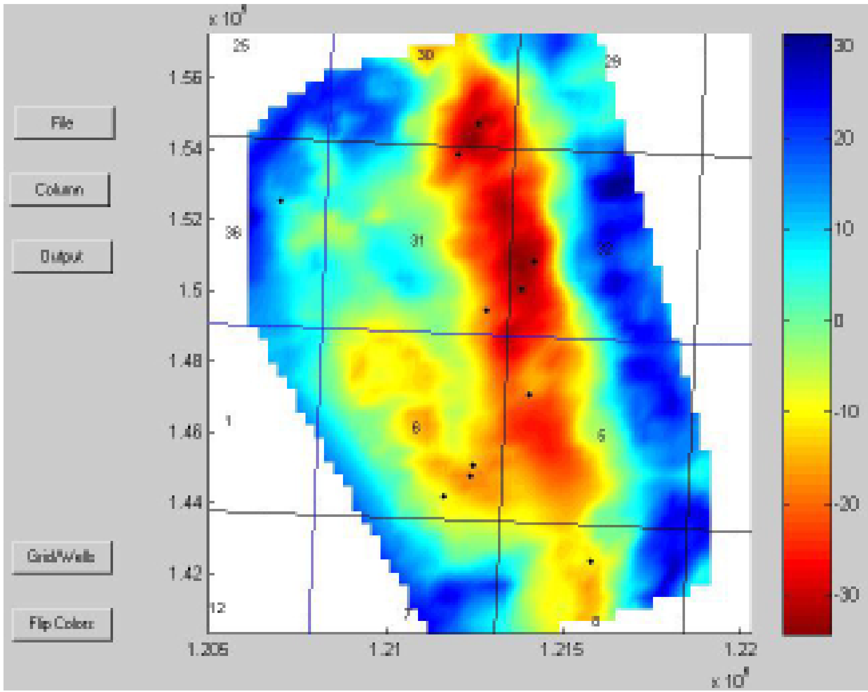

Figure 4. Map view of residual pressure (psi) from residual option of the Entrapment Tool for the Red River D Zone.

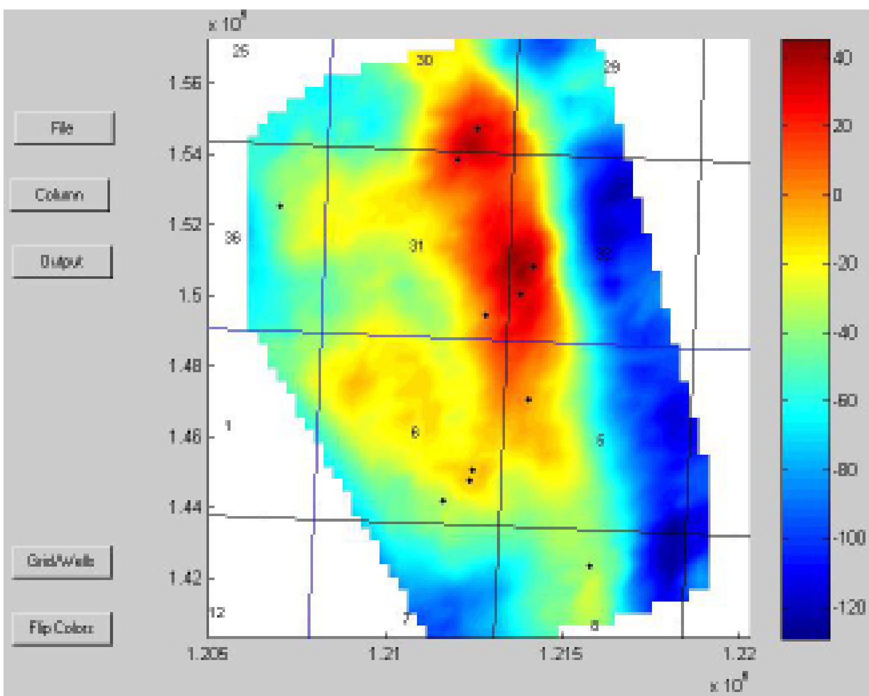

Figure 5. Map view of reservoir height (feet) relative to the regional trend for the Red River D Zone.

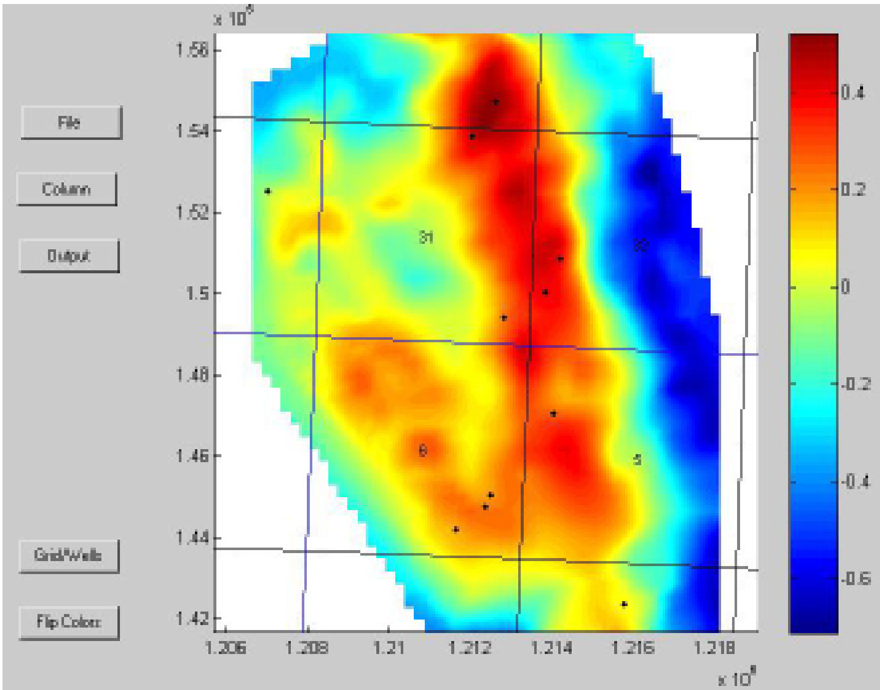

Figure 6. Map view of D Zone producing oil-cut predicted by the Neural Solver Tool from entrapment and rock properties. The maximum initial oil-cut is predicted at about 50 percent. Only one well, at the north end of the field, recovered significant oil from the D Zone on drill-stem test at 62% oil-cut.

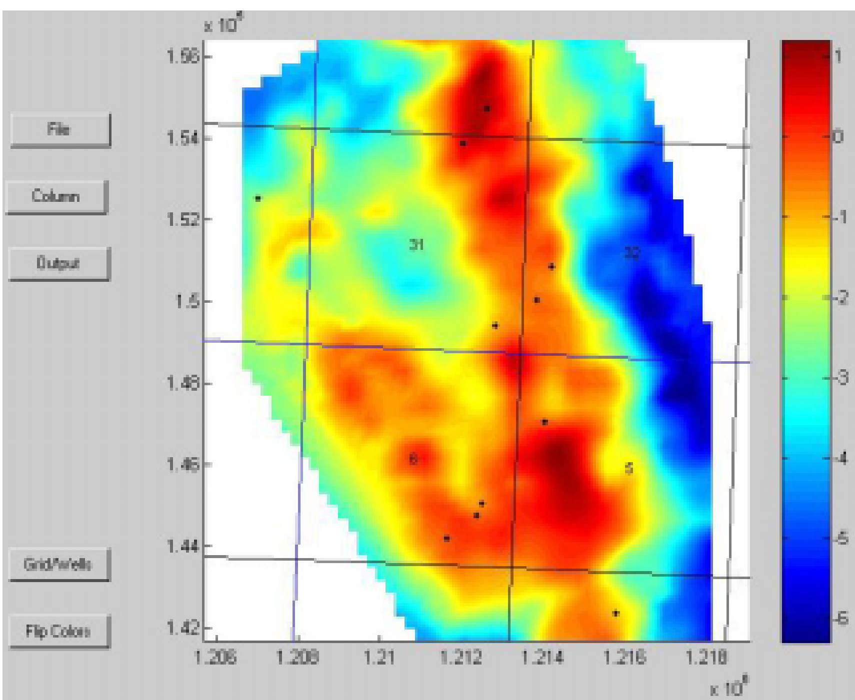

Figure 7. Map view of predicted oil rate (log of bbl per day) for the Red River D Zone. The maximum predicted oil rate is only about 10 bopd. Most oil production from the field is from the shallower Red River B Zone.

Report for: **stats.luffdoeproject.com**	**Date Range:** 04/01/2002 - 07/01/2002
Summary	
Total Visitors	569
Total Pageviews	2,857
Total Hits	9,768
Total Bytes Transferred	320.9MB
Average Visitors Per Day	7.2
Average Pageviews Per Day	36.16
Average Hits Per Day	123.64
Average Bytes Transferred Per Day	4.063MB
Average Pageviews Per Visitor	5.02
Average Hits Per Visitor	17.16
Average Bytes Per Visitor	577.6KB
Average Length of Visit (H:M:S)	00:05:13

Figure 8. Summary of website traffic for April through June 2002.