Fred Goldsberry

Reservoir Dimensioning and Energy Imaging

Reservoir geometry and volume can be determined early in the life of a well using a wave based pressure measurement and deconvolution technique. The geometry is detected by discrete events evident in constant rate pressure data during the initial production from a well. The events are produced by energy reflection from individual portions of the reservoir boundary as the cone of influence reaches it. These contact shapes can be assembled into an image of the reservoir using angle calculations from the radiating capillary arrays and accumulated elastic energy computations.

Wave mechanics have been a long neglected area of reservoir engineering theory. Energy and mass are transported by wave mechanics. There are various kinds of wave energy that pass through a reservoir. We think of seismic imaging where we supply energy from the surface that passes through successive layers of formation. Some of the energy is reflected back to the surface and recorded then processed. But what if we used the energy of well production to generate waves that can be detected by a sensitive pressure gauge to see waves of a different form reflected off the walls of the reservoir? In other words we would observe the reservoir from the inside out rather than from the topside down.

If we see features from a well bore in such circumstances then we see the connected geometry and volume of that reservoir compartment. Think of this process as a means for establishing geometry that can be compared with seismic but derived from a different geophysical process. The wave model “sees” the connected reservoir laterally. Think of a production log that has a depth of investigation of hundreds and yes, even thousands of feet. The interactions between two different types of waves interact to produce singularities in the pressure decline that can be used to produce an energy image of the reservoir during the initiation of production from a zone.

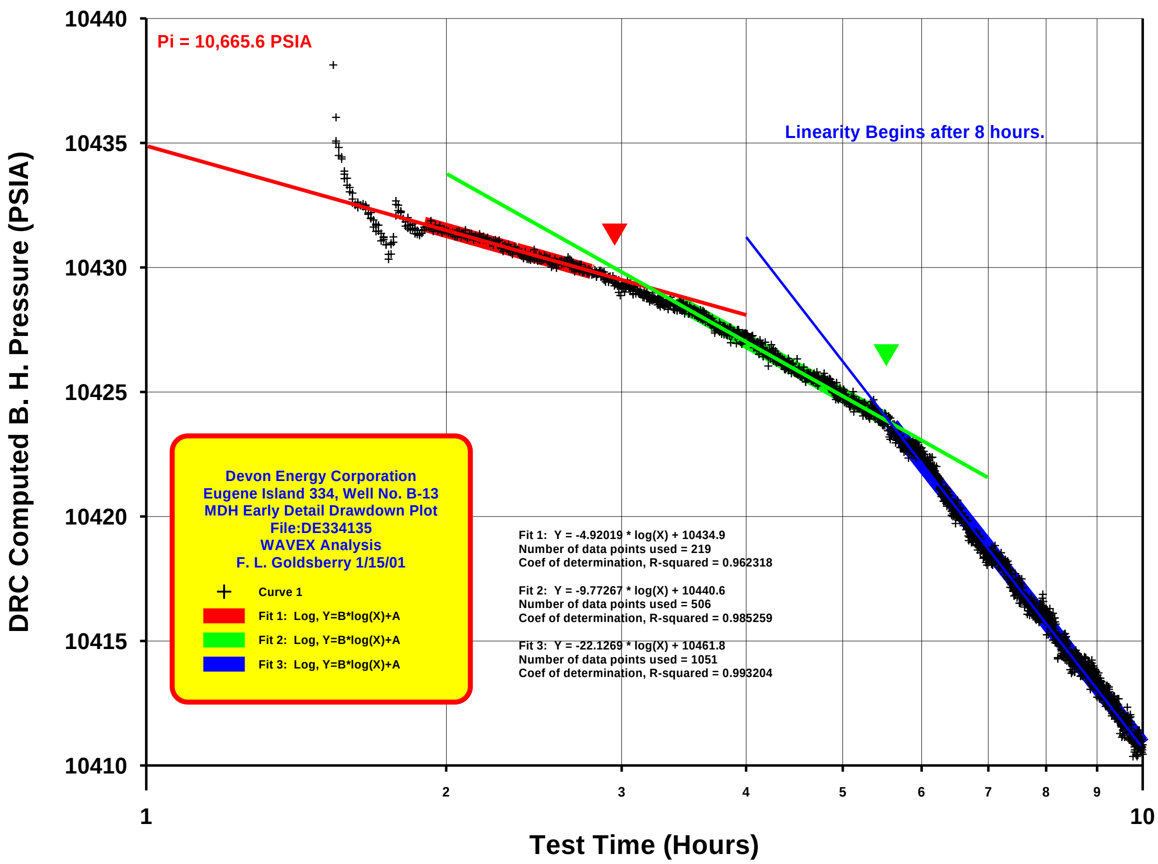

Figure 1. Semilog Plot of Initial Production Drawdown on a Fixed Choke

Figure 1 shows a typical drawdown data set. The three colored lines in red, green, and blue mark pressure decline segmentation that is associated with reservoir limits. Even though the rate does not change, the pressure decay rate does and does so abruptly. The red and green triangles mark the singularities in the data that mark a reservoir limit contact. At each contact we have two pieces of information. First is the time to the contact and the second is the new decay rate after the singularity or break in the data. The red contact is at 3 hours and the green contact is at 5.6 hours. Not shown is a third contact. These two pieces of information can be used to calculate the distance to the individual limit contact and the angular shape of the contact. These can be laid out along concentric circles and assembled into a series of relative limit dispositions. A decision tree is used to rank all of the possible maps using elastic energy integration for inplace volumes as encountered by the cone of influence. This is shown in yellow and appears as a cam follower type of diagram.

Figure 2 shows the most probable assemblage of relative limit positions around the well. Note that direction or orientation is not part of the solution. Everything is placed relative to the first limit contact then constructed relative to that position. Figure 2 is the most probable configuration based upon a points of conformity system. Part of that process is calculating a down range energy width for the reservoir boundary.

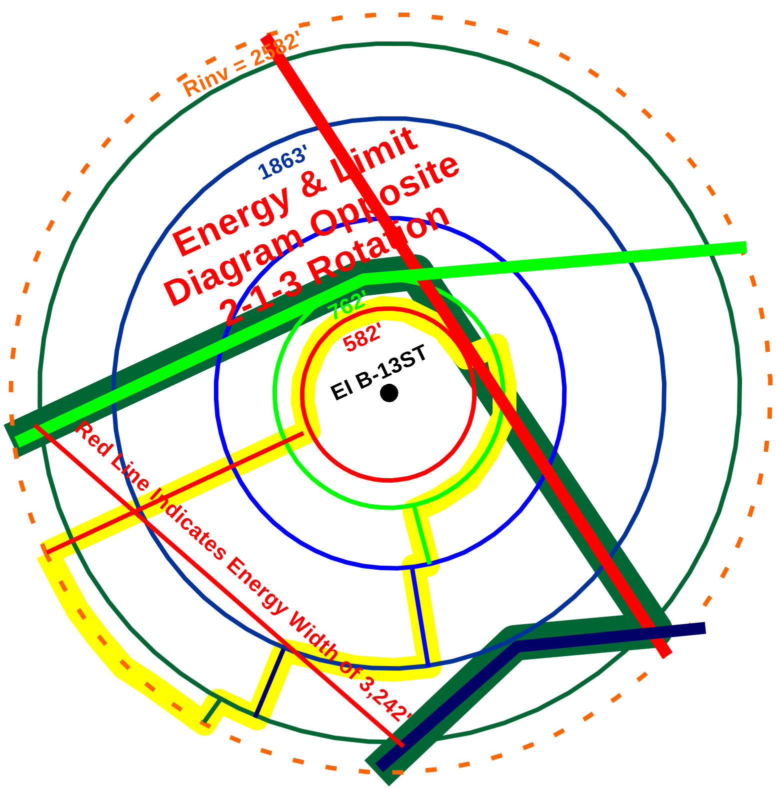

**Figure 2. Blind Energy Map Based Upon Energy Gained,
Boundary Contact Distances, Calculated Angles, and Down Range Energy Width**

Some examples of the energy map determination process will be shown. The method produces a snapshot image of the reservoir at the time of the test on a blind basis. There is no reference to the geologic map. The purpose of the method is to produce an energy image of the reservoir without reference to a geologic map or seismic amplitude. The utility comes from performing a blind overlay of the geologic map to confirm the structure and general shape of the reservoir.

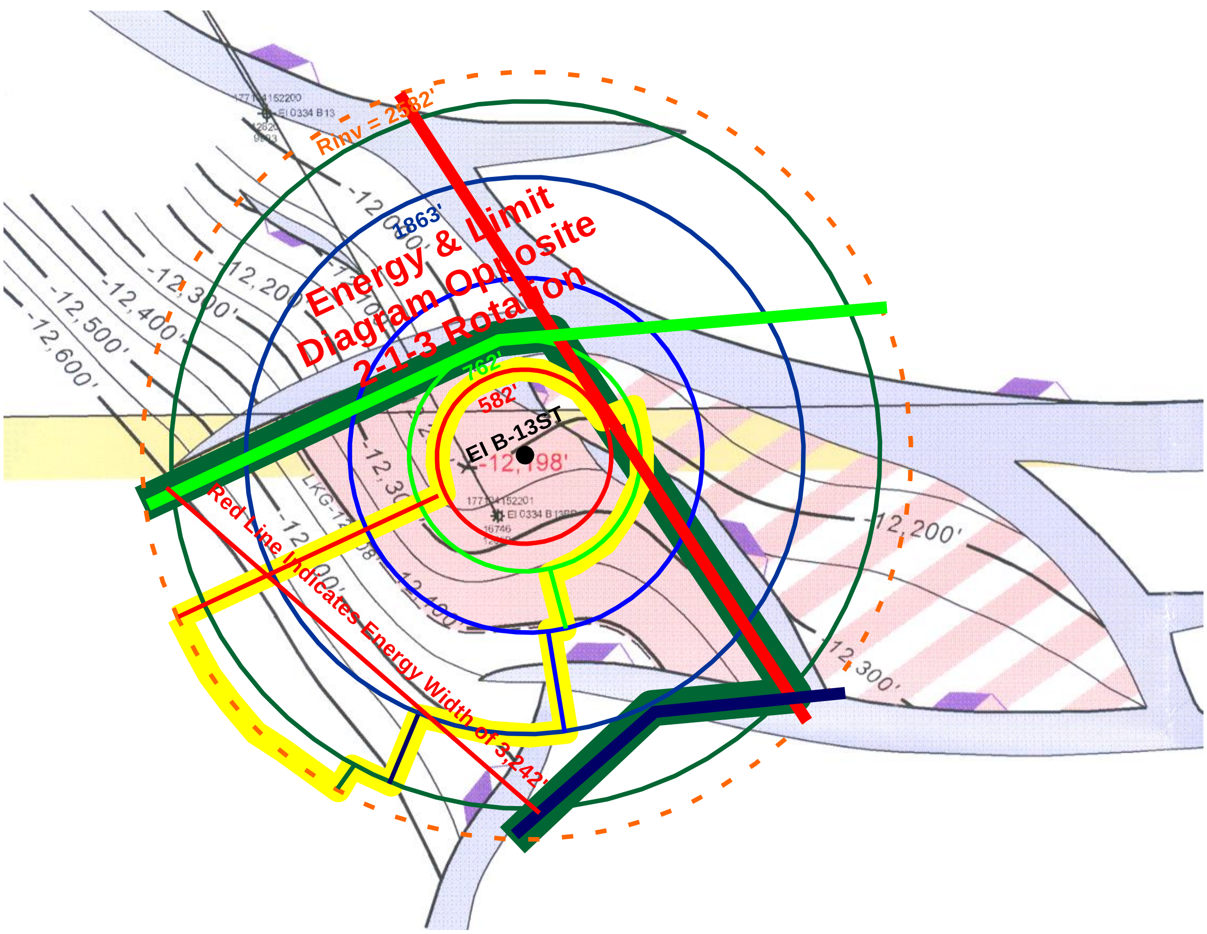

Figure 3. Energy Map and Geologic Independently Confirm Each Other

Figure 3 shows the results when compared with a seismic based structure map. Although the images are not exactly the same they provide enough conformance to enhance the certainty of the reservoir and the reserves being there as described independently by two different disciplines. The details of developing the energy image will be presented from the alternatives available. Other blind energy map examples will be shown and compared with seismic images to complement the explanation of the wave model.

BIOGRAPHY

Fred Goldsberry, President of WaveX, Inc., is a 1968 Honors graduate of Texas A&M University in Mechanical Engineering. He also earned and MSME (1969) and Ph.D. (1971) Degrees from Texas A&M as well as an MBA in 1992 from the University of St. Thomas. Fred was elected to the Academy of Distinguished Graduates of Mechanical Engineering at Texas A&M in 1996.

Fred holds eleven U. S. Patents in control systems, energy conversion systems, geopressured secondary oil recovery, nuclear waste storage, and transient well testing. He has worked in the E&P, chemical processing, electric generation, rocket motor, geothermal, and the nuclear industries. The bulk of his career has been spent in the Geothermal, Oil and Gas drilling and development business.

Since 1979, Fred has been employed successively as the director of the USDOE Geopressure Projects Office in Houston and later the Vice President of Operations for Zapata Exploration Company. Fred has functioned in every aspect of oil and gas exploration, drilling, completions, production, and pipelines both onshore and offshore.

Fred formed **WAVEX®, Inc.** in 1995 based upon his longstanding interest in the engineering mechanics of pressure transient phenomena and has practiced wave mechanics based reservoir mapping since that time as an independent engineering consultant. United States Patent: No. 6,041,017**, Method for Producing Images of Reservoir Boundaries** issued on March 21, 2000. The technology is patented in Canada and the EU.

Fred is a member of the ASME, SPE, and is active in the Society of Petroleum Evaluation Engineers. He was Houston Chapter President in 1999 and served on the SPEE Board 2005 to 2007. Fred became a member of SIPES in 2010.