Ronald R. Charpentier
(charpentier@usgs.gov)
Troy A. Cook
(tcook@usgs.gov)
U.S. Geological Survey
Box 25046, MS 939
Denver, CO 80225

Variability of Oil and Gas Well Productivities for Continuous (Unconventional) Petroleum Accumulations

By Ronald R. Charpentier and Troy A. Cook

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Abstract

Over the last decade, oil and gas well productivities were estimated using decline-curve analysis for thousands of wells as part of U.S. Geological Survey (USGS) studies of continuous (unconventional) oil and gas resources in the United States. The estimated ultimate recoveries (EURs) of these wells show great variability that was analyzed at three scales: within an assessment unit (AU), among AUs of similar reservoir type, and among groups of AUs with different reservoir types.

Within a particular oil or gas AU (such as the Barnett Shale), EURs vary by about two orders of magnitude between the most productive wells and the least productive ones (excluding those that are dry and abandoned). The distributions of EURs are highly skewed, with most of the wells in the lower part of the range.

Continuous AUs were divided into four categories based on reservoir type and major commodity (oil or gas): coalbed gas, shale gas, other low-permeability gas AUs (such as tight sands), and low-permeability oil AUs. Within each of these categories, there is great variability from AU to AU, as shown by plots of multiple EUR distributions. Comparing the means of each distribution within a category shows that the means themselves have a skewed distribution, with a range of approximately one to two orders of magnitude.

A comparison of the three gas categories (coalbed gas, shale gas, and other low-permeability gas AUs) shows large overlap in the ranges of EUR distributions. Generally, coalbed gas AUs have lower EUR distributions, shale gas AUs have intermediate sizes, and the other low-permeability gas AUs have higher EUR distributions.

The plot of EUR distributions for each category shows the range of variation among developed AUs in an appropriate context for viewing the historical development within a particular AU. The Barnett Shale is used as an example to demonstrate that dividing wells into groups by time allows one to see the changes in EUR distribution. Subdivision into groups can also be done by vertical versus horizontal wells, by length of horizontal completion, by distance to closest previously drilled well, by thickness of reservoir interval, or by any other variable for which one has or can calculate values for each well. The resulting plots show how one can subdivide the total range of productivity in shale-gas wells into smaller subsets that are more appropriate for use as analogs.

Data Sources

IHS ENERGY, INC., MONTHLY PRODUCTION DATA FOR U.S. WELLS

- 50,000+ wells in continuous deposits studied
- Estimated ultimate recovery (EUR) by decline-curve analysis
- Decline-curve analysis done by hand or by automated procedures

USGS ASSESSMENTS OF CONTINUOUS RESOURCES IN THE UNITED STATES

- 132 assessments conducted from 2000 to 2011
- Input forms give the estimated EUR distribution for the undrilled part of each assessment unit (AU)
- EUR given as a shifted, truncated lognormal distribution
- For most AUs, the EUR distribution for the undrilled portion of the AU is close to that for the drilled portion of the AU
- EUR distribution from the input form takes into account geologic differences of undrilled versus drilled portions

Estimated Ultimate Recovery (EUR)

For each AU, tens to thousands of hand-fit decline curves to individual wells were used to create a distribution of EURs (Cook and Charpentier, 2010).

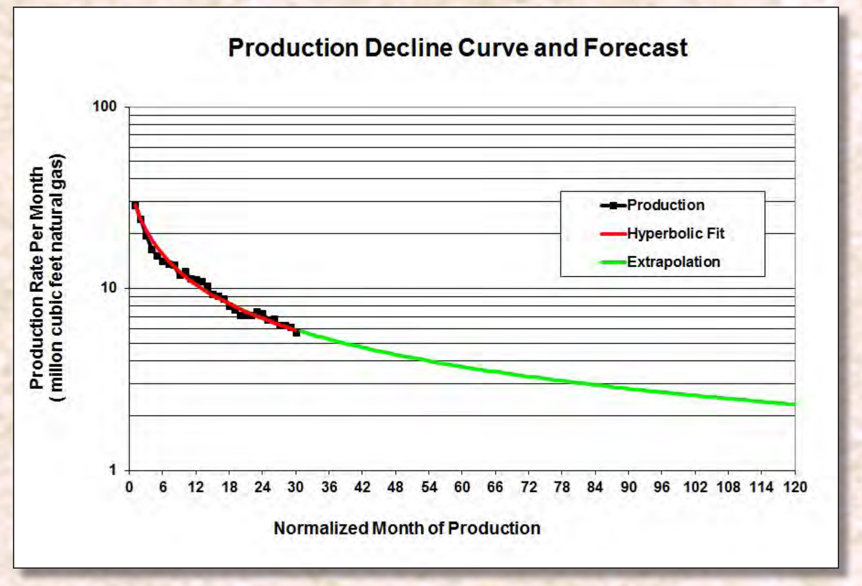

Figure 1. Example showing best-fit decline curve and extrapolation of decline to estimate EUR.

The use of automation and probabilistic expression to create probabilistic type curves may allow similar well-level results for more wells with a smaller time investment (Cook and Charpentier, 2010).

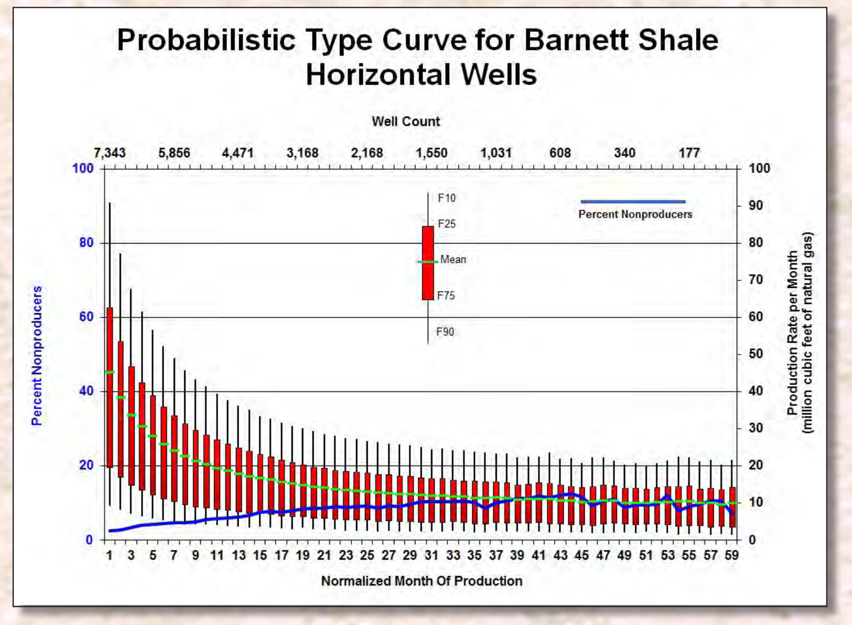

Figure 2. Example of a probabilistic type curve for Barnett Shale horizontal wells.

Either process delivers a single distribution of EURs for use in USGS continuous assessments.

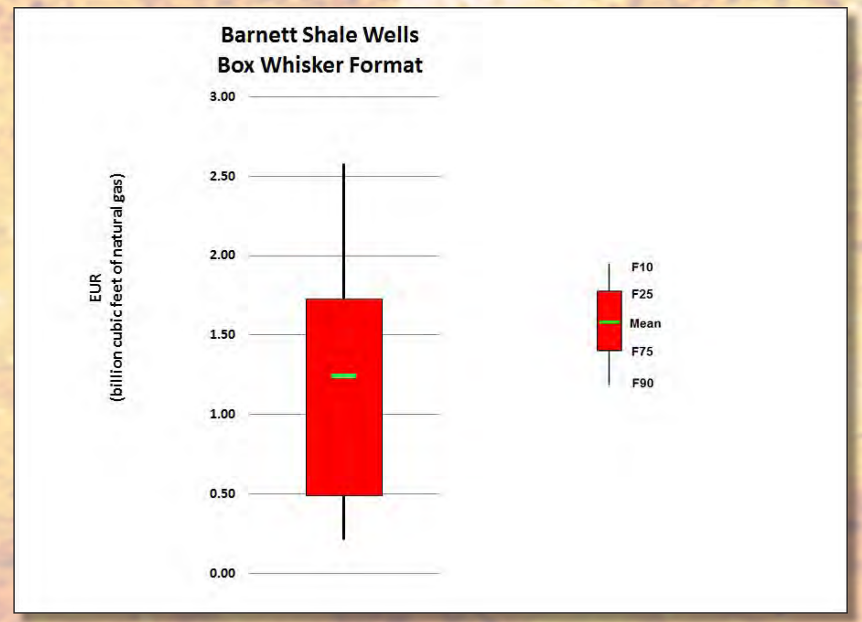

Figure 3. This box-whisker plot presents the EURs for all Barnett Shale wells drilled through October of 2009. (1 billion cubic feet equals approximately 28 million cubic meters.)

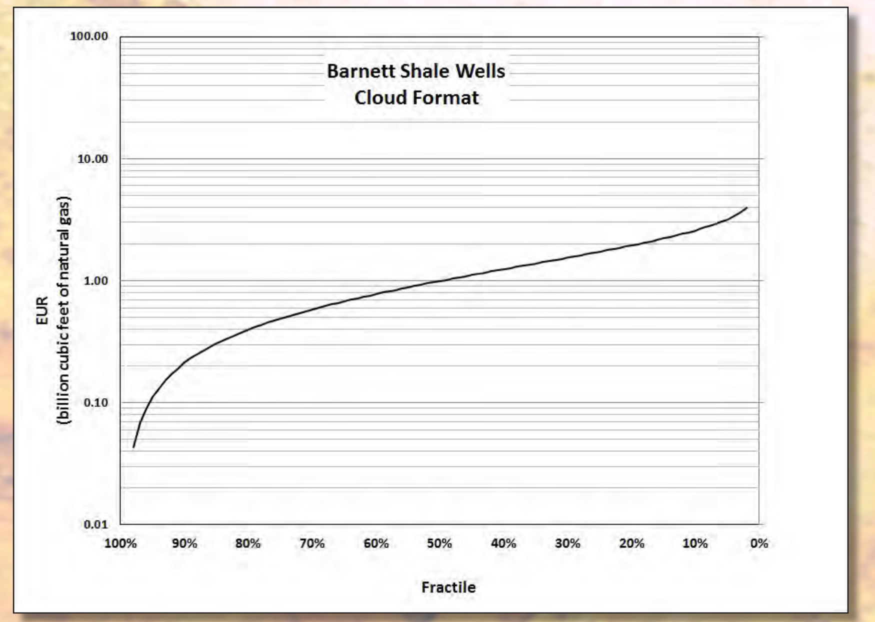

Figure 4. This cloud plot presents the EURs for all Barnett Shale wells drilled through October of 2009 (the same data used for figure 3). The fractiles indicate what percent of the wells have an EUR of at least the indicated amount. Note that the range of EURs is approximately two orders of magnitude.

Clouds:
Distribution of Distributions

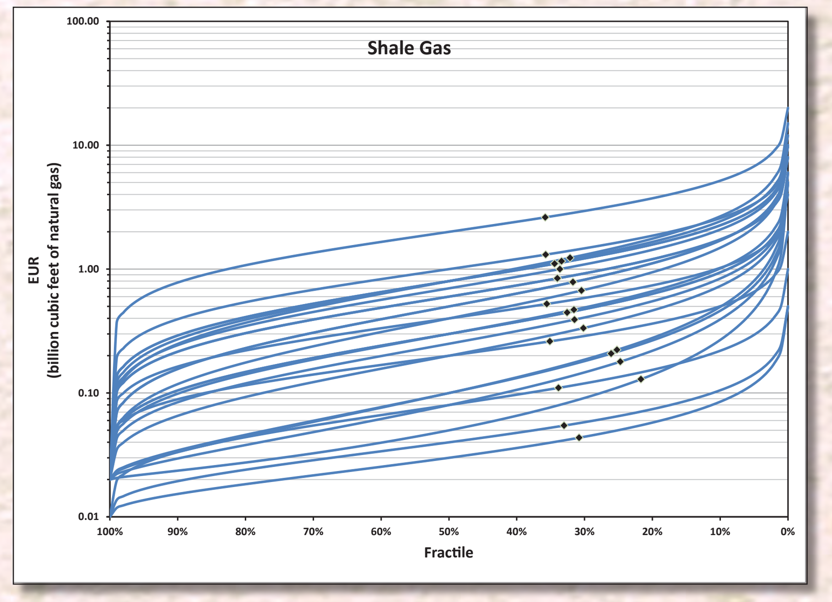

Figure 5. Here, the EUR distributions from 26 USGS assessments of shale-gas resources show the variation from AU to AU (U.S. Geological Survey Oil and Gas Assessment Team, 2012). Each distribution is a truncated shifted lognormal, and thus is a smooth curve. The black diamonds are the means for each distribution. The graph thus presents the "distribution of the distributions." Each distribution is a USGS estimate of the EUR distribution for undrilled productive cells of a particular assessment unit. This graph is termed a "spaghetti plot" which shows how EUR distributions vary for different shale-gas assessment units. The overall area defined by the variation in EUR distributions is termed "the cloud."

Are clouds built from different data sources comparable?

Defining the cloud by using USGS estimates of EUR distributions of undrilled cells gives a good approximation of the range of distributions. Assessments have been conducted over the last decade in a wide variety of reservoirs, using a variety of completion practices, and thus the present sample probably captures much of the range of distributions based on current technology. EUR distributions from decline-curve calculations for previously drilled wells show a consistent cloud pattern, as shown in figures 6 and 7.

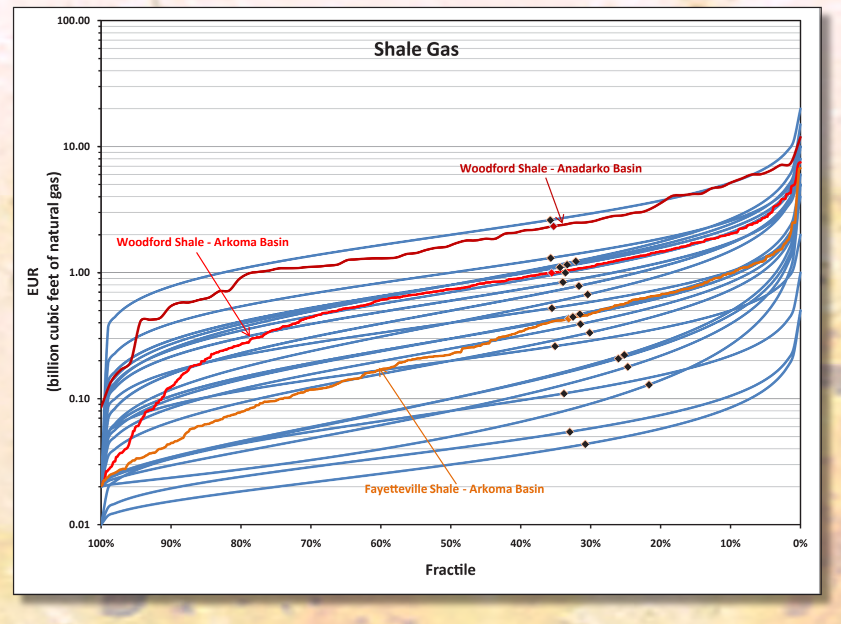

Figure 6. This graph adds the EUR distributions for three recent USGS sets of shale-gas wells, plotted against the cloud shown previously, to put the three distributions in context (Charpentier and Cook, 2010). The three additional curves are not smooth because they are based on actual well data and not on fitted distributions. The curves fall within the range of variability defined in figure 5.

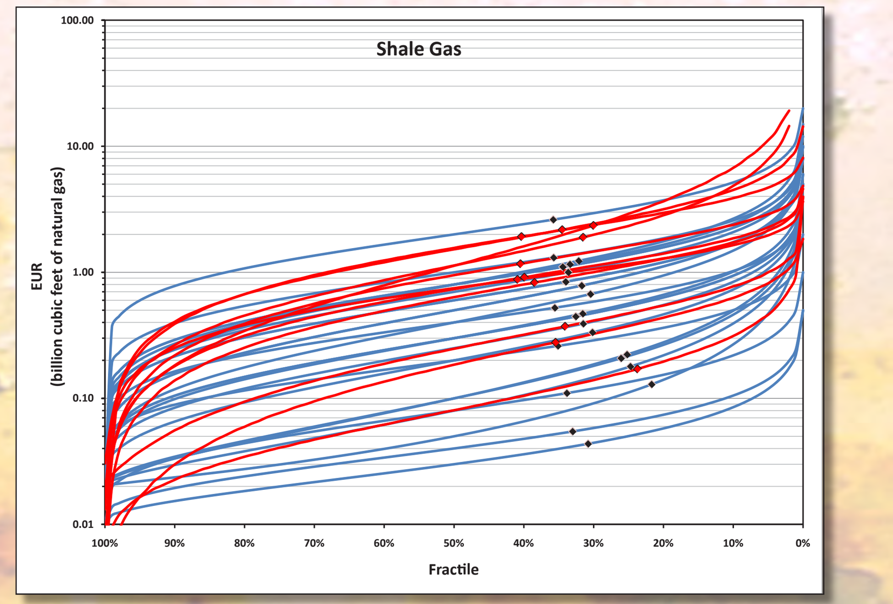

Figure 7. In this graph, the EUR distributions for eleven sets of shale-gas wells are plotted in red against the cloud to put them into context (Charpentier and Cook, 2010). Each of the eleven sets is a subset of the previously drilled wells within an AU. Horizontal and vertical wells are in separate subsets. These red curves are smooth because distributions have been fitted to each set of data. The distributions are of various types, not necessarily lognormal. Again, the data from previously drilled wells give a similar range of variability as from the estimates for undrilled wells.

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