Reserve Growth in Oil Fields of West Siberian Basin, Russia

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ABSTRACT

Although reserve (or field) growth has proven to be an important factor contributing to new reserves in mature petroleum basins, it is still a poorly understood phenomenon. Although several papers have been published on the reserve growth in the U.S. fields, only limited studies are available on other petroleum provinces. This study explores the reserve growth in the 42 largest West Siberian oil fields that contain about 55 percent of the basin's total oil reserves.

The West Siberian oil fields show a 13-fold reserve growth 20 years after the discovery year and only about a 2-fold growth after the first production year. This difference in growth is attributed to extensive exploration and field delineation activities between discovery and the first production year. Because of uncertainty in the length of evaluation time and in reported reserves during this initial period, reserve growth based on the first production year is more reliable for model development. However, reserve growth models based both on discovery year and first production year show rapid growth in the first few years and slower growth in the following years. In contrast, the reserve growth patterns for the conterminous United States and offshore Gulf of Mexico show a steady reserve increase throughout the productive lives of the fields. The different reserve booking requirements and the lack of capital investment for improved reservoir management and production technologies in West Siberian fields relative to U.S. fields are the probable causes for the difference in the growth patterns.

Reserve growth models based on the first production year predict that the reserve growth potential in the 42 largest oil fields of West Siberia over a five-year period (1998-2003) ranges from 270 to 330 million barrels or 0.34-0.42 percent per year. For a similar five-year period (1996-2001), models for the conterminous United States predict a growth of 0.54-0.75 percent per year.

GEOLOGIC SETTING

The West Siberian Basin occupies a vast swampy plain between the Ural Mountains and the Yenisey River, and it extends offshore into the Kara Sea (Figure 1). The basin is the richest petroleum province in Russia. About six hundred oil and gas fields with original reserves of 144 billion barrels of oil (BBO) and more than 1,200 trillion cubic feet of gas (TCFG) have been discovered (Petroconsultants, 1996). The principal oil reserves and most of the oil fields are in the southern half of the basin; its northern half contains mainly gas reserves.

Sedimentary strata in the basin consist of Upper Triassic through Tertiary clastic rocks. Most oil is produced from Neocomian (Lower Cretaceous) marine to deltaic sandstone reservoirs although substantial oil reserves are present in the marine Upper Jurassic and continental to paralic Lower to Middle Jurassic sequences. The majority of oil fields are in structural traps, which are gentle, platform-type anticlines with closures ranging from several tens of meters to as much as 150 meters (492 feet). Fields producing from stratigraphic traps are generally smaller except for the giant Talin field (Figure 1) which contains oil in Jurassic river-valley sandstones. The source rocks for most of the oil reserves are organic-rich marine shales of the Volgian (uppermost Jurassic) Bazhenov Formation, which is 30-50 m (98-164 feet) thick. Bazhenov-derived oils are mostly of medium gravity, and contain 0.8-1.3 percent sulfur and 2-5 percent paraffin. Oils in the Lower to Middle Jurassic clastics were sourced from lacustrine and estuarine organic-rich shales of the Toarcian Togur Bed (Kontorovichand others, 1997). These oils are medium to low gravity, with low sulfur (less than 0.25 percent) and high paraffin (commonly to 10 percent) contents.

BACKGROUND AND RESERVE DATA

Previous studies are mainly limited to oil and gas fields in the U.S. (Marsh, 1971; Attanasi and Root, 1994; Root and others, 1995; Lore and others, 1996; Verma, 2005). Only a few studies have been published on other hydrocarbon-producing regions of the world: the North Sea by Sem and Ellerman (1999) and Watkins (2000); and the Volga-Ural Basin by Verma and others (2001). Limited studies of reserve growth show that the magnitude of growth is controlled by several major factors, including (1) the reserve booking and reporting requirements in each country, (2) improvements in reservoir characterization and simulation, (3) application of enhanced oil recovery techniques, and (4) the discovery of new and extensions of known pools in discovered fields.

This study is based on reserve and production data for 42 out of the more than 600 oil and gas fields in the West Siberian Basin (Table 1). In spite of the relatively small number of fields, the data include almost all of the largest fields in the basin with total reserves of about 80 BBO, based on a conversion factor of 1 ton equal to 7.3 barrels. All production and reserve values are as of January 1, 1998. Data used include year of discovery, year of first production, annual and cumulative production, and remaining reserves reported by Russian reserve categories (A+B+C1 and C2) in January of each year. Correlation of these Russian resource categories to U.S. categories of the Society of Petroleum Engineers classification is complex and somewhat uncertain (Grace and others, 1993; Nemchenko, 1996).

Total reserve, which is the same as estimated ultimate recovery, is defined here as the sum of cumulative production and the remaining reserve of A+B+C1 categories as of the date of reporting. Total reserves of individual fields in the dataset range from 313 million barrels to more than 25 BBO. Size distribution of these 42 fields is shown in Figure 2. The mode of the field size distribution is 0.5-1.0 BBO. Based on this distribution, the fields were divided into two categories ─ those with reserves of less than 1 BBO and those with more than 1 BBO. The data set contains 20 fields with less than 1 BBO and 22 fields with more than 1BBO.

METHODOLOGY AND DATA PROCESSING

The reserve growth estimates have been made on the basis of the discovery year or the reserve confirmation and (or) first production year.

The Group Growth method, developed at the U.S. Geological Survey (USGS), requires that the total reserve be added year-by-year for fields with equal length of reserve record starting with the discovery year or the first production year. Fields are grouped based on the number of years of reserve record. This criterion resulted in five sets (with number of fields ranging from 14 to 42) using discovery year as the basis, and four sets (with number of fields ranging from 9 to 42) using the first production year as the basis. Annual growth factor (AGF), which is the ratio of total reserves of two consecutive years, is calculated for each group of fields starting with the discovery or the first production year. The cumulative growth factor (CGF) is then calculated by multiplying the AGFs of all the previous years. The CGF data for all the sets of fields are presented as the multiple of the initial estimate of reserve. In each case, one set that best represents the overall growth is selected for studying the reserve growth sensitivity to field size and for developing the reserve growth models.

Table 1. List of 42 fields from West Siberia that have adequate data for reserve growth analysis.

Table 2. Summary of total reserves (in millions of barrels) for individual sets of fields based on discovery year or the first production year for the West Siberian oilfields. (Total reserve is the sum of cumulative production and $A+B+C_1$ category of reserves.)

Table 3. Reserve growth functions for the West Siberian basin, based on data from a group of 23 fields with 20 years or more of reserve data, yielding 19 years of growth values. Reserve growth functions are also shown for two subsets – one for fields with reserves larger than one billion barrels and one for fields smaller than one billion barrels. Reserve growth basis: first production year.

Figure 1. Map showing petroleum regions and oil and gas fields of West Siberian Basin. Modified from Maksimov, 1987.

Figure 2. Field size distribution of 42 oil fields in the West Siberian Basin: The mode field size is 0.5-1.0 billion barrels. The distribution is skewed to the right, implying fewer fields with increasing field size.

Figure 3. The number of fields in each of five sets ranges from 14 to 42, with the corresponding duration of the reserve record for fields in individual sets from 32 to 11 years since discovery (Table 2). The reserve growth ranges from 11- to 15-fold over a

period of 11-32 years; most of the growth occurs in the first 9-10 years. **Basis: Discovery Year**

Figure 4. A set of 32 West Siberian fields, with each field having at least 20 years of reserve record since discovery shows overall growth of 13-fold, while its two subsets - one for 18 fields with sizes larger than one billion barrels and one for 14 fields with sizes smaller than one billion barrel - show different growths. **Basis: Discovery Year**

Figure 5. The cumulative growth curves for four sets of fields are plotted. All 42 fields with each field having at least 9 years of reserve record since the first production; 30 fields with at least 14 years; 23 fields with at least 19 years; and 9 fields with at least 25 years of record (Table 2). Reserve growth for individual sets varies from 1.6- to 2.3-fold. **Basis: First Production Year**

Figure 6. The set of 23 West Siberian fields with 19 years of reserve record since the first production shows an overall growth of 1.9-fold, and the two subsets of the 23 fields - one for 16 fields with sizes larger than one billion barrels and one for 7 fields with sizes smaller than one billion barrels - show different growths, with large fields showing the most growth. **Basis: First Production Year**

Figure 7. A set of 23 fields with at least 19 years of reserve, is used to develop a model. Using power functions, the data were regressed in two different ways: one using all data points, and one splitting the data into two segments. Of the two, the latter shows a better match. **Reserver Growth Model: (Basis: First Production Year)**

Figure 8. Reserve growth functions are shown for the set of 23 fields and the two subsets, using a billion barrel reserves as the basis. Most of the growth occurred in the group with larger fields. **Reserve Growth Model for the set of 23 fields and its two subsets: (Basis: First Production Year)**

Figure 9. Curves (models) for the West Siberian and Volga-Ural provinces are based on the first production year and for the U.S. fields based on the discovery year. **Comparison of Reserve Growths - Russia and U.S.**

RESERVE GROWTH DISCUSSION

The plots in Figures 3 - 4 demonstrate a rapid reserve growth in the first 9-10 years, during which the reported reserves from the discovery year increased 11- to 14-fold. This stage of rapid reserve growth reflects annual booking of new reserves as step-out and delineation wells were drilled in the newly discovered fields. Reserve growth in the following years is much more moderate, reaching 13- to 15-fold growth over a 20-year period (Figure 3). The magnitudes of reserve growth in the two subsets of the 32-field set are significantly different; the larger fields grew 16-fold whereas the smaller fields grew only 5-fold (Figure 4).

Reserve growth based on the first production or reserve confirmation year for four sets of West Siberian fields ranges from 1.6- to 2.3-fold, most of which was during the first five years; slight growth ensued in the following years (Figure 5). The results of reserve growth for a representative group of 23 fields and their two subsets with 19 years of reserve record since the first production show that most of the reserve growth was in giant fields with reserves of more than 1 BBO (Figure 6).

The development of the predictive model of reserve growth requires a compromise between the number of fields and the duration of the reserve record for these fields. Based on the criteria defined earlier, the set of 23 fields with reserve record of 19 years since the first production was chosen for the development of the models. Of the various mathematical functions, the power function gave the best results.

A generalized equation for power function is: $CGF = \alpha*(Y^{\beta})$

After regressing data for the entire set of 23 fields, the data were divided in two segments: the first corresponds to the stage of rapid reserve growth during the first four years after the beginning of production; and the second to the gradual reserve growth that follows. Figure 7 shows two regression curves, using a power function, for the cumulative growth factors - one for all data, and one for the two segments of data. The α and β values for the two different approaches are given below:

		α	β
For all data points		1.3636	0.1258
Splitting data into two segments:			
First segment	1st year - 4th year	1.2823	0.1899
Second segment	5th year - 19th year	1.5230	0.0833

The two-segment curve (Figure 7) shows a much better match compared with the curve for all data. In addition to the two-segment model described above, two models were developed for the two subsets of the 23-field set, using production year as the basis: one subset has fields with reserves of more than one billion barrels and one has fields with reserves of less than one billion barrels (Figure 8). Regression of data for fields with reserves more than one billion barrels also required splitting the data into two segments for a better match. The values of constants α and β are:

Year of each segment	α	β
1st year - 4th year	1.3155	0.2060
5th year - 19th year	1.6665	0.0648

For the seven smaller fields, regression curve shows an unsatisfactory match with the data because of the smaller number of fields in this set.

The reserve growths for oil fields in the United States (Attanasi and Root, 1994; Verma, 2005; Lore and others, 1996) and two Russian provinces are compared in Figure 9. The three models for the U.S. conterminous and offshore fields show a similar rate of growth after the first five years from discovery. The model for the Volga-Ural Province (Verma and others, 2001), which is based on the first production year, shows a growth rate similar to the conterminous U.S. during the first three years and then diverges significantly in the following years. The West Siberian model (based on the first production year) shows the lowest growth, about 2-fold (Figure 9 and Table 3). This growth is similar to the reported reserve growth in North Sea fields, which are characterized by a 1.0- to 2.44-fold increase in reserves in the United Kingdom sector and 1.0- to 3.5-fold increase in the Norwegian sector over a 4-25 year period (Watkins, 2000). Both the U.S. and the West Siberian models show rapid reserve growth in the first 4-5 years, but they then diverge significantly in the following years.

CONCLUSIONS

1. West Siberian Basin reserve growth is similar to what has been reported for the North Sea fields; production start-up date is the basis for both the analyses.
2. All models show rapid reserve growth in the first five years, but the West Siberian models show much slower growth in the following years compared to the models for the U.S. fields. Slower growth in West Siberian fields is caused by different reserve booking requirements and probably by insufficient investment in improved production technologies.
3. The West Siberian model, using the year of first production, predicts potential reserve growth ranging from 270 to 330 million barrels, or 0.34-0.42 percent per year over a five-year (1998-2003) period, compared with 0.51-0.58 and 0.72-0.79 percent per year predicted by two models for U.S. onshore fields over a five-year (1996-2001) period.

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