Benha University
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Geology Department

Reservoir Evaluation and Petroleum Production (G605)

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Model Answer

1- Reservoir models

The aim of building a reservoir model is to simulate what will happen in the real reservoir when it is put on production. A reservoir model built during the appraisal stage allows different development options to be tested before major expenditure is committed to drilling production wells and building facilities. During the production life of a field, the reservoir model will be calibrated and recalibrated to the production data. After some time, it may prove necessary to build a new reservoir model to simulate accurately past behavior of the field and so predict future performance. Thus the reservoir model built during the appraisal stage represents just the initial part of field life reservoir management. Reservoir engineers, not petroleum geoscientists, build "reservoir models." It is not the intention of this book to introduce reservoir engineering. However, it is important that the geoscientist does not simply hand over his or her geologic model to the reservoir engineer. If a robust reservoir model is to be produced, the two disciplines must work together. The geologic model apart, the geoscientist will have a better grasp of the spatial aspects of the reservoir going into development than will the reservoir engineer. In the initial attempts at reservoir simulation, it may be the geologist who has a better feel for the validity of the output, since he or she has a conceptual Earth model with which to compare that output; whereas at the appraisal stage the field has no production history with which the reservoir engineer can numerically compare the output of the reservoir model. The reservoir model is a numerical representation of the reservoir and its associated fluids. Like the geologic models described above, it comprises a 3D array of cells. However, each cell is significantly larger than its counterpart in the geologic model. Typically, the height of cells will be measured in a few tens of meters, although thin high-permeability streaks or low-permeability baffles and barriers of a meter or less can be modeled. Cell widths are commonly measured in many tens of meters and lengths commonly in hundreds of meters0If the oil- or gasfield is believed to have an active aquifer, this too will be modeled within the reservoir simulation. However, to reduce the computational complexity, the aquifer may be represented by a few very large (long) cells.

2- Reserves additions.

Reserves additions come from pools that were not originally considered to be part of the field development. Such reserves additions may come from small satellite fields close to the major development. Alternatively, secondary horizons, either above or below the main reservoir, may be produced. The quest for reserves additions commonly leads to a small phase of exploration in the areas surrounding the field. The key aspects of such exploration are that the new pools must either be within tie-back distance or, alternatively, it must be possible to reach them by extended-reach drilling from existing facilities. In introducing this section, it was emphasized how the cost of any new work would come under rigorous scrutiny. In order to sell an idea for a new well or a new set of perforations in an existing well to management, it will be necessary to demonstrate the value of that work. A number of measures, or "metrics" as they are commonly called, can be used. Typical measures can be as follows:

- The time to payback;
- the production cost per unit of petroleum (barrel of oil or million standard cubic feet of gas);
- the income per day.

In order to work out these figures, it will be necessary to calculate the following parameters:

- The cost of the work;
- the likely production rate from the new interval;
- the likely production volume from the new interval.

The drilling, production, and facilities engineers can supply the cost components for these sums. The petroleum rate data and volume data come, of course, from the geoscientists and reservoir engineers. Late in the life of a field, it should be possible to make fairly accurate estimates of the production rate and volume for a new well or perforated interval on the basis of experience in the field to date. Table 6.2 is an example of new well and new interval perforation opportunities for a gasfield in Asia. The field is mature and close to designed plateau production. The owners wished to extend the life of the field, and in consequence a small team of geoscientists, reservoir engineers, and a petrophysiscist investigated the possibilities for new wells, sidetrack wells, and perforation of hitherto unproduced sandstones in existing well bores. The background information is that the field produces principally from theE and D sandstones. The stratigraphically higher F and G sandstones are commonly thin and often of poor reservoir quality. Although most of these intervals are gas bearing, they had not been included in the original development plan for the field. The stratigraphically deeper C, B, and A sandstones, though of moderate to high quality, were also not included in the development plan because in many instances they are below the gas/water contact.

A combination of core data, log data, and experience from existing wells allowed estimates to be made oflikely production rates for the various sands across the field, whether the estimate was for new wells or new perforations in existing wells.

Similarly, the production history to date allowed calculation of the likely volume to be delivered from a well over its history. Thus it was possible to rank the opportunities in terms of cost, ultimate reserves, or time to pay back the cost of recompletion.

3- T ime-lapse seismic

.Repeat seismic surveys, sometimes called 4D or time-lapse seismic, are currently being developed as a methodology to examine changes in the reservoir and fluids during production.

The premise is that production of petroleum and possibly injection of cold water will alter the acoustic properties of the rock plus fluid. An examination of the difference in seis- mic response between surveys conducted at different times can then highlight these changes. In particular, the properties that might be expected to change during petroleum extraction include pore pressure, pore fluids (saturation, viscosity, compressibility, and fluid type), and temperature. There is also some evidence to suggest that mineralogical changes (precipitation) can also take place during petroleum production.

Reservoir pore pressure can drop during petroleum extraction, particularly around the wellbore. It can also increase around injection wells. Barriers to fluid flow can cause porepressure discontinuities either laterally at the same depth or vertically at the same locality.

Naturally, reservoir fluids change during production and injection. The fluid properties oflight oil and gas can be particularly sensitive to pressure changes. If the sonic properties of a reservoir are changed sufficiently by injection or by pressure loss (such that the petroleum fluid drops below the bubble point), it might be possible to follow water-flood fronts and identify areas of bypassed oil (Jack 1998; Koster et al. 2000; Fig. 6.18).

Temperature changes induced by injection of cold water, hot steam, or through *in situ* combustion can lead to changes in both the acoustic properties of the fluids (viscosity changes) and the rock (possible fracturing). Secondary effects of production include changes in the state of compaction of the rock, porosity reduction, and hence increase in bulk density and changes in the overburden stress.

4- Petroleum in place.

The methodology for calculation of oil and gas in place was introduced within Chapter 4 and its associated case histories. It is, of course, a simple volume calculation in which the total volume within the trap is multiplied by the reservoir fraction, then progressively by the net pay fraction, porosity, petroleum saturation, and the formation volume factor (or the gas expansion factor). At the exploration stage, the quantity of data available is often limited. As a consequence, the values used for net pay, porosity, petroleum saturation, and the formation volume factor are commonly either single figures or, more sensibly, most likely estimates with attached uncertainty ranges. More data are usually available for trap volume, although even here volume may be calculated from a sparse coverage of2D seismic data.
The same calculation of petroleum in place during or at the end of appraisal is quite a different process. The appraisal data will have delivered more information. Such information will undoubtedly show that spatial differences exist in reservoir properties across the field and that the geometry of the trap is more complex than could be appreciated during exploration. There are several ways in which the petroleum volume may be calculated using deterministic and stochastic methods.
Here, we will describe the basic deterministic approach, while stochastic methods will be examined in the following subsection.

5- Reservoir description from production data.

Reservoir description from production data is an essential part of maintaining production from a field on plateau and extending the life of a field in decline. There are few things about which there can be certainty when producing a field, and one of those certainties is that the field will not perform as the development plan suggested it would! The main factors of interest to the production geoscientist are establishing what petroleum has been produced from where, and how both petroleum and water reach the production wellbore. These two pieces of knowledge will allow the geoscientist, working with the reservoir engineer, production engineer, and drilling engineer, to target unswept oil and possibly reduce the unwanted water flowing into the production wells. Moreover, during production, information arrives very quickly and in large quantities. Most fields have many tens or even hundreds of wells and there may also be many layers within the reservoir. The production geoscientist needs to be able to capture and assimilate the data and then use it to guide further production of the field. In consequence, graphic and pictorial methods are often used to synthesize the mass of data into something understandable. In fields with many tens, hundreds, or even tl;ousands of wells, it will not be possible to understand the full details of field performance without a lot of work, which takes a lot of time. In such circumstances, time is often short and as a consequence it is commonly necessary to study just the anomalous wells, those that either overperform or under-perform. In doing so, it may be possible to understand about 80% of the field performance characteristics by working on about 20% of the wells.

6- Field rehabilitation and reactivation.

Rehabilitation of an oilfield is the process whereby production is improved in late field life. Reactivation involves much the same processes, but applied to a field that has been shut in o abandoned. Oilfield rehabilitation and reactivation became important parts of many companies' business during the latter part of the 1990s. There are several reasons why companies have chosen to reactivate and rehabilitate fields.

These include paucity of high-quality exploration acreage and expectations of early production, and hence early cash flow, from such activities. However, such drivers are not new What is new is that political changes have created opportunities in countries that were previously unavailable to Western companies. Areas with long production histories, such as those in the former Soviet Union, South America, and parts of the Middle East (Iran and Kuwait) are now open for investment. Many of the fields in these areas are old, have been developed without the benefit of modern technology, and have lacked reinvestment as they approached senility. However, despite the appearance of old age, recovery in many of these fields has been particularly low. Perhaps only 10% of the original oil in place has been produced. A similar field developed today might reasonably be expected to deliver 30-40% of its oil in place, perhaps more. So, while it may not be possible to replicate a new field development, it may be possible to dramatically improve upon the initial recovery of the field.

7- Geologic models.

Geologic models have already been introduced in the sense of trying to determine the depositional environment of a reservoir interval and then make some estimate of the reservoir architecture. The geologic model can be created deterministically by hand or with the aid of geologic modeling software. Alternatively, a computer-generated geologic model can be built using stochastic (statistical) data. Each of the computer-based methods, be they deterministic or stochastic, generates a model composed of a 3D tessellation. The cells within such tessellations are commonly oblate rectangular prisms. The height of each cell, perpendicular to stratigraphic surfaces, is commonly a few meters, while their widths and lengths are commonly between lOrn and a few tens of meters. Each of the cells is assigned rock and fluid property attributes. Geologic models for large fields may contain more than one million cells. Quite clearly, a subset of the property data contained within each cell can be used to calcu late the petroleum in place for that cell, and then by addition of all the cells in the model it is possible to calculate the petroleum in place.

8- Reservoir visualization.

It is important that the geoscientists and those working in other disciplines share a common understanding of the petroleum accumulation under development and production.
Most fields are complex, be that complexity in structure, reservoir architecture, or fluid flow behavior. Reservoir visualization techniques provide an opportunity for all of the technical and managerial disciplines to share a common understanding of the field. Most of the visualization techniques that we report in the following paragraphs have already been mentioned earlier in the book, usually in the context of the way in which they are used as part of the geoscience component of exploration, appraisal, and development. Here, we will concentrate on the visualization characteristics.

9- Reserves revision.

Upward revision of reserves can be achieved in a number of ways. In the Heather Field, much of the increase was achieved through a combination of OPEX reduction and identification of areas within the field from which oil had not been swept. The effect of OPEX reduction is to allow the field to produce economically at a diminished oil production rate. In consequence, the field lasts longer and the recovery factor increases.

The integration of production data and the reservoir description information derived from either the geologic model or the reservoir model allows analysis of the relatively productive and relatively nonproductive parts of the field. This should allow identification of areas from which the oil has not been swept. Such areas may then be developed into targets for infill wells. For example, much of the late field life exploitation of the giant Forties Field (North Sea) has been concerned with the identification of unswept oil. In this instance, much of the remaining oil in the field occurs in inter-channel areas within the Paleocene submarine-fan complex that forms the reservoir.

With best wishes

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