The Oil Drum
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

An oil production is more than turning a tap

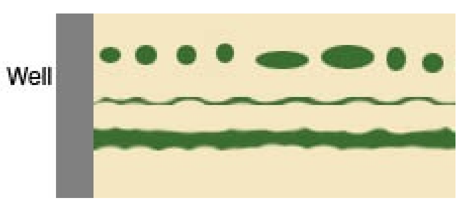
Posted by Heading Out on August 27, 2005 - 10:10pm
Topic: Supply/Production
Tags: tech talk [list all tags]

This is Saturday techie talk again, where we explain a little of the ins and outs involved in getting oil out of the ground. Please remember that this is a fairly simple description, and that there a lot of complexities that refine this initial explanation. Some of them I will post about in later parts of this series.

We got oil ! We put together the drill, the mud system, the derrick, the casing and the Christmas Tree and we found a layer of rock with the right porosity and it has oil in it. Hell-lo, Beverley Hills!

Ah, but hold on a moment gentle folk, aren't we forgetting that to get the oil out of the ground, it first has to get to the well. The basics of this aren't particularly complex, but within this topic of **oil well production** lies the scientific reason that production goes down in an oil field as the field gets older.

I'm going to begin by making a slight correction. Last time while I talked about sandstones and carbonates, I did not explain what the second group were very well. And because the structure of a carbonate field is often quite different from one that occurs in sandstone, I am going to put the production from carbonates off another week. Save only to say that the carbonates are usually limestones and dolomite, and that because these are very fine grained rocks, but easier to dissolve, the oil is more often found in the joints and cracks and dissolved holes in these rocks, than it is evenly spread through the rock. And often, with sandstone, the oil is spread throughout the rock, and so let's assume for now that's what we've got.



The sketch shows three different layers of oil lying next to a well. In the first case none of the little pockets of oil connects to another, nor do any reach the well. If the entire rock were like this, even though it had porosity, and a fair bit of oil, none of it could be extracted without making a path for the oil to get to the well. This **artificial stimulation** of the well is a secondary process that we will also leave until later. What we need is a clear path that connects all the oil that sits between the grains of sand to have a path to the well, similar, perhaps, to the second layer of green (for oil) in the sketch.

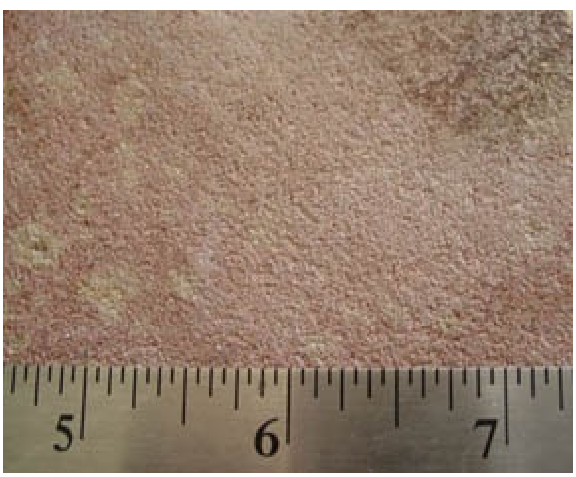
The existence of flow paths in the rock is known as the **permeability** of the rock. It is a measure of how easy it is for oil to move through the rock. The law describing the flow of fluid through rock is known as Darcy's Law. In simple terms it says that the volume of liquid flowing through a rock is going to be a function of the area over which the flow occurs multiplied by the pressure drop over the rock, a constant denoting the conductivity of the rock, and divided by the length of the rock path. Let's assume that the area is a constant (it's the side of the well).

When we had reached the rock just above the oil reservoir we had a break while we discussed the difference in pressure between the fluid in the well and the fluid in the rock. At the time we set the well pressure at 3,000 psi and the pore pressure, the pressure of the oil in the rock, at 6,000 psi. The difference in pressures, that 3,000 psi is the driving pressure that will push/pull the oil to move it to the well. This is the pressure drop in the rock. The **hydraulic conductivity** is a measure of the resistance that the rock gives to the oil moving through it. (You might think of it as a reverse friction, in other words the higher the number the less resistance there is to flow). A wide crack in the rock, with almost smooth sides (the third row above) has a higher conductivity than the second where the gap is narrower and more tortuous. And let us just say for now that the length is the distance from the well to the point that the oil pressure is equal to the original **pore pressure**.

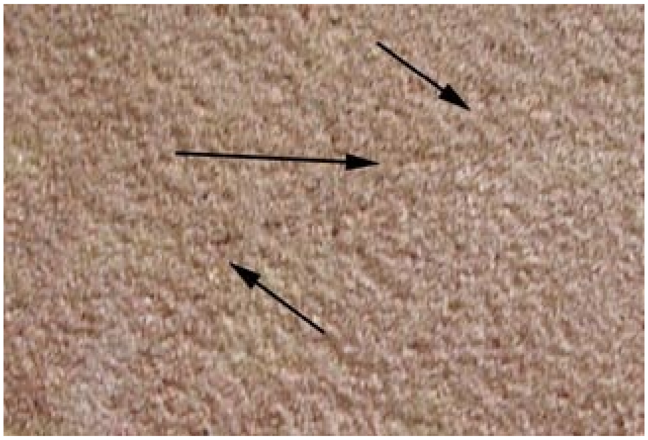
Now you might think that with this big a difference between the pore pressure and the well pressure that the oil would really gush from the well. And yes it might - but we don't want that and so we tighten the choke to reduce the difference in pressure between the well and the pore pressure, and the flow slows down.

However, as the flow develops, it does not happen evenly. Think of watching rain hit a pile of freshly dumped earth. At first, as the rain falls it runs evenly over the surface. But as it does it finds some layers of soil are weaker, and others have been compacted a bit more. And so the water erodes the softer, less compacted soil, and the water near those channels finds it easier to flow into them. And so after a while the water coming off the pile is no longer evenly flowing but is cutting grooves in the soil and all the water is coming out of those channels.

In many ways the rock carrying the oil acts the same way. The two channels in the picture above are in the same rock, with the same oil, but it is much easier for oil to flow through the bigger channel, and it will at much less pressure drop than it takes to get oil to flow out of the thinner crack. And with the flow of the oil the channels in which it does flow well get bigger, reducing further the flow from the narrow channels, and trapping, or **stranding** the oil that is left in them.



Now you might think that this has, initially to be a great difference. Well here is a picture of a piece of sandstone I had in my office. It is at first glance made up of grains of about the same size and were it full of oil you might think that oil would flow evenly through it. (It has no oil in it - oily rock looks black and it is hard to make out the features I am talking about due to lack of contrast.)



But if you look more closely (and I have zoomed in a bit on one area above the 6-inch marker) you might see a thin connected path wandering through the sandstone. (I have marked it with arrows). That line is one of higher permeability. I have been on a site where the ground was supposed to be as evenly sized and permeable as this sandstone, if not more. A test was being run in which my hosts had pumped some fluid into the rock. Since they did not get the result they wanted, they dyed the next batch of water a bright color and pumped it into the ground. They then dug a hole over the site, and looked down the side to see the thick colored layer that they expected to find. They needed a magnifying glass, all the fluid (hundreds of gallons) had gone into a single flaw, about the size of the one shown in the two pictures, and none anywhere else.

The converse can be true if one is not careful in drawing the oil from a well. The initial production can create flow paths through the rock, leaving isolated patches of oil that are not recovered on either side.

But hold-on you say surely if we just keep dropping the pressure (by opening the choke) then eventually we will have enough difference to move even that oil. Well, No! (You may have noticed I am becoming a relatively negative person).

I was reading "*The Color of Oil*" by Michael Economides and Ronald Oligney this weekend. It is a very fast (even more so than this) spin around the world of oil, but I am going to use their numbers (page 32-33) for this next bit.

The oil inside the pores of the rock is initially assumed, for now, to be at the same pressure as the burial depth of the rock (due to geological movement this is a very very simplifying assumption, but let's make it). But as we let the oil flow out of the rock this pressure, which is caused by the oil and rock compression will get less. While the oil can expand and flow, the rock does not, and so after a while there is no pressure difference between the oil and the fluid in the well. The oil stops moving because the differential pressure has gone away. Professor Economides

> "Recovery of 3 percent or less of the initial oil in place can make the reservoir pressure equal to the pressure at the bottom of the hole. When this occurs, fluids are no linger driven into the well and 97% of the original oil is left "in place" in the reservoir. This defines primary recovery, the most elemental but generally unacceptable ending point in petroleum exploitation."

What else can we use as a driving force? Well, some posts back I mentioned the analogy of a bottle of champagne. Shake it, pop the cork, and the dissolved gas in the wine will fountain it out over the happy celebrants. But after the fizz is gone, there will still be some wine in the bottle. It is the same sort of thing that happens with the oil. Oil usually contains gas dissolved within it. As the pressure within the oil drops, this gas begins to come out of the liquid. (Slowly release the cap on a bottle of soda water and you will see the same thing). (Note that this does not change the pressure in the well, and thus reduces the difference or driving pressure moving the fluid to the well).

Professor Economides continues

> "A specific (lower) pressure level called the "bubble-point" pressure marks the onset of natural gas evolution, known as the solution gas. When this level is reached (the point at which this occurs depends on the specific crude), recovery can increase substantially to 15% or more."

Now let's go back to our example of the two layers of oil in the top sketch. The bottom one will flow oil faster and draw oil from further out, than the upper one. As the pressure in the larger channel drops, as it empties, the remaining oil in the channel will start emitting gas. While the gas will rise, overall, to give a gas layer above the oil, it will also flow more easily into the well than the oil in thinner channels. If the reservoir engineer is not careful at this point, all of a sudden he may find that all he is getting out of the well is gas. (Take a drinking straw and sucking gently move it down onto the top of water in a glass. Note that the straw has to be in the water before you can drink any. If you had machine strength suction and you don't so DO NOT TRY, you would find that if the straw was within half an inch of the water you might start to get a little, but effectively you won't get much). So it is with the oil well. You need to be drawing from the oil zone only to keep production going.

However, going back to Darcy's Law (in itself an application of Newton's Law) as the well has produced and the compression has come off the oil, the pore pressure has gone down, and thus the difference in pressure between the well and the rock is less. As a result the flow of oil from the well will also go down, and with no further stimulus, the oil will stop, now leaving about 85% of the well in the ground, and sometimes that happens.

If there is water under pressure below the oil, and there almost always is, then this water can percolate upward and provide an additional extra force to move the oil.

Professor Economides

> "If a large water aquifer is in contact with the petroleum reservoir, a natural drive mechanism can be provided by natural water influx. The larger the aquifer, the more effective and the more long-lived this drive mechanism tends to be. If a strong water drive is in effect, 10 to 25% of the oil in place can be recovered."

Once that is over, and with 25 - 40% of the oil recovered, then in a conventional well the oil is at the same pressure as the fluid in the bottom of the well, and no more oil will flow. To get the rest out will require some form of pumping. But to discuss that, and other steps is a topic for another day. But for now remember, it is not the oil in the reservoir that has been depleted, at this point, it is the force (the differential pressure between the oil and the well) that has been reduced, and finally gone away, and with it the oil production.

Unfortunately because driving pressure and permeability are so inter-twined this has been a long post. And yet I still may have glossed over some points too rapidly. So as usual if there are questions, please ask.

[ED I have corrected the title of the book, which I initially had wrong. My apologies.] Technorati Tags: peak oil, oil