Finding the field can be a noisy business

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Topic: Supply/Production
Tags: gulf of mexico, oil production, seismic surveys, tech talk [list all tags]

One of my early "scientific" memories was being taught that, after you see a lightening strike, if you start counting the time in seconds until you hear the thunder, then divide by five, this tells you how many miles away the storm is. This is because the speed of sound in air is around 1,100 ft/sec (I say around since it depends on temperature and humidity). In the same way it was fun to stand in a place where you could get an echo when you yelled really loudly.

From which you may surmise that it is time for another techie talk. For those new to the site, this is a post on occasional weekends where I try and simply explain some of the aspects of getting oil and gas out of the ground. The full list of previous posts on the topic is given at the end of the post, and you are asked to remember that this is a relatively simplified discussion that is meant to briefly describe the fundamental ideas.

In the last post I considered that we had drilled into a reservoir, and showed how roughly one might find out how much oil was there. But I did not mention how we found out how large the reservoir was (I used a 200 ft thick, block of rock that measured 1,000 ft in length and width to make the calculations easy and obvious). So this week perhaps we can talk about why we think the field is a thousand ft wide and long. (We ultimately physically measure the 200 ft dimension).

When oil was first used, the way you found it was by finding where it was seeping out of the ground. However most oil fields do not have this visible signature, because all the oil had been trapped in a reservoir rock. When oil is first formed it comes from a source rock, that will have contained the biological material (mainly algae and plankton) as well as the muds and sand that accumulate with the dying organisms. As this material sinks deeper into the earth the pressure of the overlying material, and the growing heat at greater depth will slowly turn it into initially oil, and if it gets hotter, into gas.

However as these fluids are formed, they can be squeezed out of the original rock, and being lighter, will then start to move up through the ground. They will continue to flow up until the nature of the rock above them stops them going any further. This has usually been because the rock above is impermeable, and so the oil, gas and often associated water, cannot continue flowing up to the surface. Over the course of time the rock that the oil and gas is passing through will have been tilted, and bent by the movement of the Earth's crust, so that, in a favorable case, when the oil gets stopped by an overlying impermeable layer (the cap rock) that rock and the reservoir rock will have been previously shaped so that the oil cannot just move over to the side to find another way up.

The result of the shaping of the ground has therefore been to form a trap for the rock. One might think of a series of hills underground where the oil has risen inside the hill and having reached the top cannot go further up or out because the rock above the hill is not permeable. The oil then lies in that hill, and forms an oilfield. (There are many other shapes that also help to trap the rock - the layers can have been tilted, for example, and then an impermeable rock, say a salt, or a granite) can have been pushed up through the layers forming a wall which stops the oil movement and forms a trap for it). There are some pictures of possible traps here.

So what we now need to do is to find a way of looking through the Earth so that we can see the shapes of the layers of the ground at different depths beneath our feet. It would be nice if we could use a form of radar for this and there is such a thing as Ground Penetrating Radar . However because the energy that this uses is very rapidly reduced as it moves through the ground, this technique is only really useful close to the surface, where it can be used to find water pipes, graveyards, and is proving very useful for archaelogy and other searches at shallow depths. It doesn't have enough power however to look as deep as we want to.

To look deeper we need to use a more powerful signal. And we also use the same ranging idea that helps see how far away a storm is. The speed at which sound moves, but in this case it is through the rocks. By setting off a very load noise - that used to be a stick of dynamite, or a gun but is now more often the impact of a heavy hammer on a plate. Heavy trucks are used that drive this signal into the ground. They come in a variety of sizes. At sea, the sound can be generated by an air gun

When the hammer hits the plate a sound wave is sent into the ground. This radiates out, in the same way that happens when you drop a pebble into a still swimming pool, except it does it in three dimensions. (Trying this in a coffee cup or sink doesn't work since I just discovered that it happens too fast to see what happens). When the wave that moves out hits a layer of rock that is different, then part of the wave energy bounces back rather than going deeper. By laying out a string of microphones (called geophones because they listen to the rock) instruments can hear when that part of the signal bounces back to the surface, and by listening at different points they can combine the signals to give what is known as a reflection Seismic survey of the underground layers. You can get information both from the speed of the wave, and the distance that it has traveled. This can then be used to provide a map. The initial signals are enhanced and analyzed by computer programs to provide pictures of the structure of the ground, whether on land, or at sea.

For many years the survey was carried out by a single line of geophones that were stretched along a single path, giving a two-dimensional (2D Seismic) slice through the ground. Increasingly the surveys now use a grid of geophones so that the pictures that are recovered give a picture that has 3 dimensions (3D Seismic) that makes it a lot easier to understand the information. (The technical term is interpret the data). Columbia University has an example that includes a fairly comprehensive set of information on the Gulf of Mexico as the pdf file entitled Prospectivity of the Ultra-Deepwater Gulf of Mexico. There is also an animated 4D example that shows how effective a tool it can be.

By shooting a survey repeatedly over a period of time, the intent is

> 4D seismic is a reservoir management tool based on carrying out a series of repeatable 3D seismic surveys at regular intervals over a producing reservoir in order to 'image' the movement of hydrocarbon fluids. The information derived from comparing different surveys over time will allow petroleum engineers to focus production drilling and other hydrocarbon recovery measures which can hopefully net millions of dollars from additional reserves.

By identifying where, for example, the oil:water interface is moving to, one can better site subsequent infill wells. And by knowing the thickness of the oil layer, and its relative position in the well, which one can then mark (or have the computer color into the projection) one can estimate what the size of the actual oilfield is that you have hit.

This is part of an ongoing weekend series on technical aspects of oilwell (and natural gas) drilling. Previous posts can be found at::
the drill
using mud
the derrick
the casing
pressure control
completing the well
flow to the well
working with carbonates
spacing your well
directional drilling 1
directional drilling 2
types of offshore drilling rigs
coalbed methane
workover rigs
Hydrofracing a well
well logging

As ever, if this is not clear, or if there is disagreement then please feel free to post, and I will try and respond.