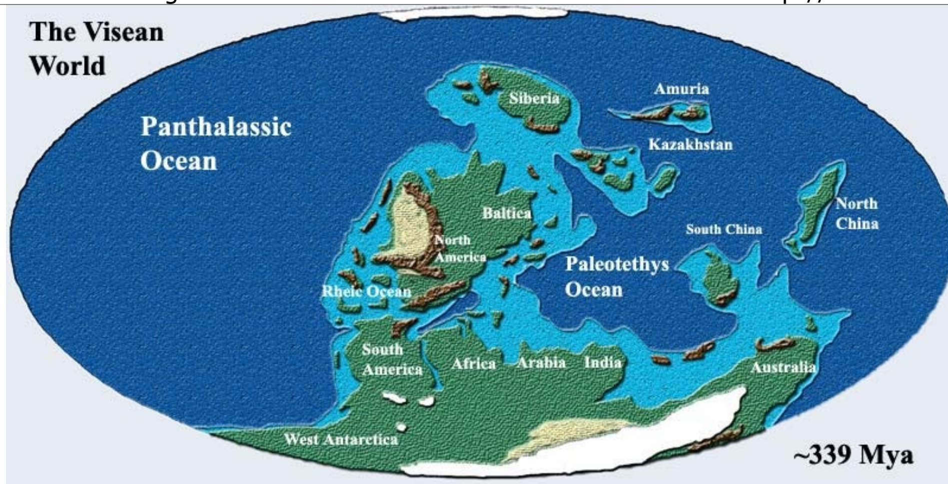
Shales and the gas within them

Posted by Heading Out on November 8, 2009 - 9:26am
Topic: Supply/Production
Tags: natural gas drilling, shale gas [list all tags]

This is Sunday, so this is a "tech talk" about getting fossil fuel out of the ground. While some previous posts have dealt with sandstone and carbonate deposits I'm going to be talking about getting gas out of shale for a couple of weeks, and so, before I started talking about Horizontal Wells, we'd better chat for a minute or so about shale. And when I don't give an alternate reference for the information, I am likely quoting from the Primer on Natural Gas in Shale, from the Department of Energy.

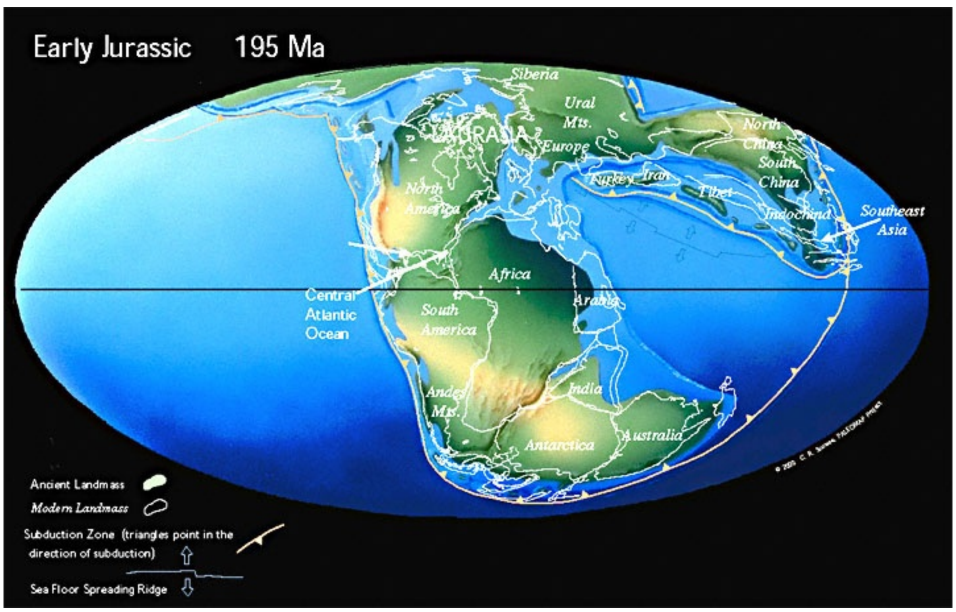
Folk who live near rivers, or along their outlet to the sea are familiar with the large mud flats that can develop around the outlet. These flats, which extend out into the sea, can cover large areas. When I was in school at Lancaster in the UK, we went to Morecambe Bay when my parents came to visit, and the large areas exposed when the tide ebbed remain a lasting memory. Through geological time these beds of mud have lain under large stretches of water, and so, as the algae that floated in the water died, they fell, and were caught in the mud. The mud is largely made up of clays, which in very small sizes are shaped a bit like a plate, and so as they settle, capturing and covering the algae remains, they tend to create layers (which can later tell us some of the conditions at the time they were deposited). When conditions are right – generally with a relatively warm sea containing a lot of nutrients – the sea can host vast colonies of algae, and over geological time the death of these algae built up considerable organic matter in the mud on the sea bed.

The main gas shale deposits in North America are in the Barnett shale, the Fayetteville, the Woodford, the Haynesville, and the Marcellus while, in Canada, the large fields are in the Horn River and Montney deposits. Not that there are not others, but these are the ones that the Oil and Gas Journal calls "The Magnificent Seven." As an example the Barnett shale was deposited during the Mississippian Epoch, itself part of the Carboniferous Era, between 315 and 350 million years ago. At that time the map of the Earth looked at bit like this).



Shape of the Land and Seas at the time of the [Mississippean Epoch]

However not all the shales were deposited at that time. The Haynesville, for example is much younger, having been laid down in Jurassic Era, (remember the dinosaurs of Jurassic Park?) which was some140 to 200 million years or so ago, and when the globe looked a bit more familiar.

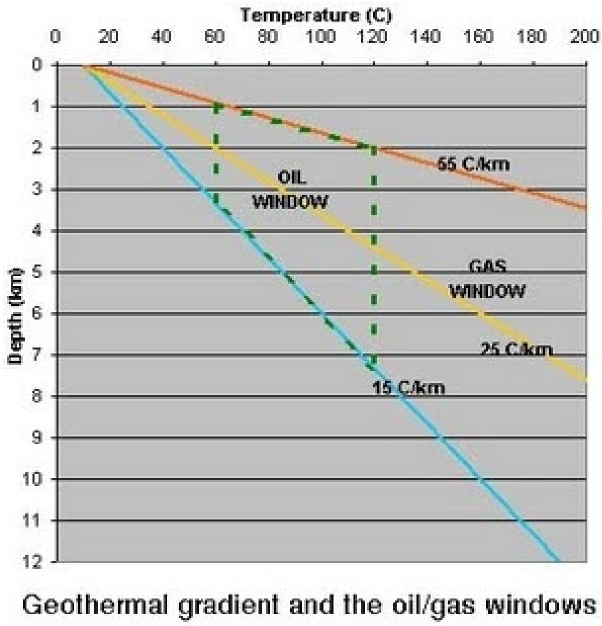


The map of the earth some 195 million years ago during the Jurassic

The mud that was deposited grew to be very thick – even after it was compressed by the weight of overlying additional sediments that turned into rock, the Barnett shale still can measure between 50 and 600 ft thick.

The individual particles that made up the mud were quite small, so that, as the material was compressed, the resulting rock became relatively impervious. Thus if the gas-generating algal remains were trapped, they were held in the shale, but dispersed throughout it, rather than concentrated in larger pore spaces, such as are found in sandstones. And, to be economic, there still needs to be a significant amount trapped within the pore space, which needs to be at least in the 5 – 12% range to hold enough gas to be worthwhile. Putting this into a different context, the Barnett, for example, is estimated to hold about 325 scf (cubic feet at a standard defined temperature and atmospheric pressure) of natural gas per ton of rock – or in about 13 cubic feet of rock. (Needless to say deep in the ground the gas is very compressed).

As the rock was buried deeper, so the temperature and the pressure also rose, gradually "cooking" the organic material over time. Depending on how deep the rock was buried, and the temperature, the material either turned into an oil, or if it were buried deeper and at a hotter temperature, it would turn into a gas. The relative conditions that set these bounds are sometimes referred to as the oil and gas windows for rock, and can be illustrated with a graph.



Geothermal gradients defining the oil and gas windows as a function of depth and temperature. (From WVU)

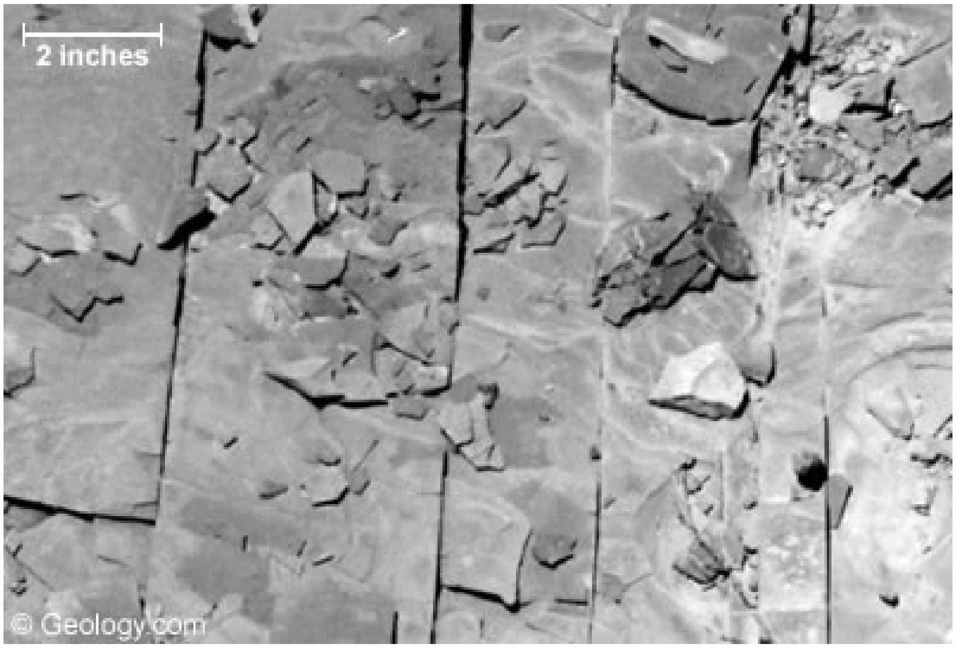
The current reservoir depths at which the different shales are now found can differ quite significantly from those at which the gas or oil was first formed, with depths for the Fayetteville being as little as 3,000 ft (0.9 km) to the Haynesville which can be at more than 14,000 ft. (4.3 km). The Barnett is around 6 - 8,000 ft (2.4 km).

Permeability, or the ease with which gas, oil or water can flow through a rock is measured in a unit called a Darcy, but it is sufficiently large that most rock permeabilities are measured in thousandths of a Darcy, or millidarcies (Md). As a point of reference for a rock with a good permeability such as the Ghawar oilfield in Saudi Arabia, Greg Croft quotes values in the 600 Md range.

A microdarcy is one thousandth of the value of a millidarcy, and it is this unit that the permeability of gas shales are often measured. Thus the permeability of the Marcellus shale can be around 20 microdarcy and the Barnett around 10 microdarcy. The density of the rock can be seen from the sample pieces shown at the Chesapeake Web site.

Illustration of gas shales from the Chesapeake web site.

These fine-grained rocks with low permeabilities mean that the producer has to rely on other paths within the rock to allow the gas to escape. Originally this was just the natural fractures that can be found in the rock. As the rock compresses vertical fractures often generate within the rock. These fractures can be quite consistent, though in contrast to the bedding, they normally occur vertically.



Shale fractures from Geology.com

The problem is that conventional vertical wells don't intersect a lot of these fractures, and thus, when the gas shales were first drilled the production was very low, and often uneconomic.

However when horizontal wells were developed it became easier to intersect a lot of these fractures as the well moved along the reservoir, and so it is time to introduce horizontal wells in the next post.

As usual this has been a very short description of a relatively complex topic, and so questions, and comments are appreciated.