Shale, gas, and water

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This is a short technical note as part of a series of tech talks that discusses some of the aspects of fossil fuel production. By the nature of the length of post that I think will hold people's interest, and what I think folk know and want to know, these posts tend to be very simplistic reviews of topics that are often, in detail, much more complex. I am very grateful to those who, in comments, help to illustrate that complexity.

One of the most promising sources of natural gas that has recently started to come into production is that from the shale deposits around the United States. Since it is possible that similar gas or oil-bearing shales occur around the world this provides a new potential source of energy that has some considerable promise, in the short term, for helping to fuel the world.

Shale, as a descriptive term, does not describe just a single rock, however, and there are a large variety of shale types. Consider, if you will, that much of the shale that contains the hydrocarbon started out as the mud at the bottom of a bay, as the algae bloomed, grew, multiplied and died, to be trapped within the mud and gradually buried with it. As the layer was further buried beneath additional layers of material, so the pressure, and increasing heat, gradually turned the oil in the algae into either oil or natural gas. Along the way the mud itself was compressed, largely dewatered, and baked so that it turned into what we now call shale. When these reservoirs are now tapped, they can produce large initial flows of natural gas, for example, in the Haynesville, the Garfield 25 H-1 just started production at some 20 million cu.ft/day at 7,700 psi delivery pressure.

There are other shale types that are found in producing fossil fuels. In the same way that the mud underlay the water where algae grew, it also pervaded the swamps where, during the Carboniferous era, the trees and vegetation grew that, in time, and to a degree under the same type of burial, pressurization and heating, led to the formation of coal seams. The mud underneath that was the soil in which the trees had been growing was also changed, and so it also formed the shale layer that remained under the coal through the eons. (In the North of England we sometimes referred to it as the “seat earth.”)

But while the term shale is used to describe a generic type of rock not all shales are the same, in the same way as not all soils are the same. By geological description the key part of the description lies in the bedded nature of the rock, and its high clay content. But is it the clay part of the content that I want to focus on in this piece.

> Geologists are strict with their rules on sedimentary rocks. Sediment is divided by particle size into gravel, sand, silt and clay. Claystone must have at least twice as much

> clay as silt and no more than 10 percent sand. It can have more sand, up to 50 percent, but that is called a sandy claystone. (See all this in the Sand/Silt/Clay ternary diagram.) What makes a claystone shale is the presence of fissility—it splits in more or less thin layers whereas claystone is massive.
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> Shale can be fairly hard if it has a silica cement, making it closer to chert, but usually it is soft and easily weathers back into clay. Shale may be hard to find except in roadcuts, unless a harder stone on top of it protects it from erosion.

The reason for stressing the point is that of weatherability, or how the shale holds up in the presence of water. Let me tell a small anecdotal story.

Back some years ago we used to test rock for different companies, and had been sent some samples of a shale, which we were asked to saturate in water before testing. Due to some confusion we did not get that message initially, and the rock sat – as received – over the weekend. First thing Monday we got a frantic call, don't put the samples in water. Turned out that two different sets of samples had been sent, and the other sample had been immersed in water over the weekend, and when the lab had looked in the bucket that morning, they had found a residual pile of particles as the shale had totally disintegrated in the presence of water. The shale was so sensitive that we ended up doing all the sample prep (cutting, coring, grinding etc) dry to make sure that we could keep the samples intact.

Testing different shale samples for their susceptibility to water attack, their durability if you will, is not that easy. One of the more common tests is known as slake durability, for which there is a standard test protocol. (Free version here. The sensitivity is also perhaps illustrated by the categories into which the results from another one of these tests (the jar slake test) can fall;

I_J	Behavior
1	Degrades into pile of flakes or mud
2	Breaks rapidly and forms many chips
3	Breaks rapidly and forms few chips
4	Breaks slowly and forms several fractures
5	Breaks slowly and develops few fractures
6	No change

Different responses to shale testing in the jar slake test.

The durability tests generally involve the tumbling of ten intact sample pieces of shale in water for ten minutes, oven drying it, and repeating the tumbling and drying. The amount of material retained on a screen afterwards as a percentage defines the durability. But bear in mind that the shale may still have fragmented or softened.

I am putting a little bit of emphasis on how sensitive the shales are, in general, to water, because, when the oil and gas shale reservoirs are developed, the drilling is usually performed with a water-based mud, and the resulting fractures that are driven into the shale to provide pathways for the gas to leave, are created using a water-based frac'ing fluid.

Now there are ways of stopping, at least temporarily, the wetting action of the water on the shale. One way of doing this is by adding more polymers to the water. Particularly at higher concentrations these (which also make the water "slick") can reduce wettability and stop the softening of the shale, but some of that work is still part science and part art. And part of the question is how the shale will behave in the longer term after it has been wetted.

Remember that to get the gas out the fractures through the rock have to be held open, and the way that this is done is to push small particles (called proppant, but similar to sand in nature) into the fracture to hold it open and still give a passage way through the fracture for the gas to get out.

But if the wetted shale along the edges of the fractures does soften with time, then under the pressures of the well, it may deform around the sand particles that are holding the fractures open, and slowly close the fracture, reducing production rate over that anticipated from a fully open fracture, and reducing the potential overall recovery of gas from the well. In that case, in order to sustain production from the well, it will need to be refrac'ed, perhaps more than once.