3-D Imaging Helps Researchers Understand Fluid Movement Through Shale Formations

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-PSIEE Highlights


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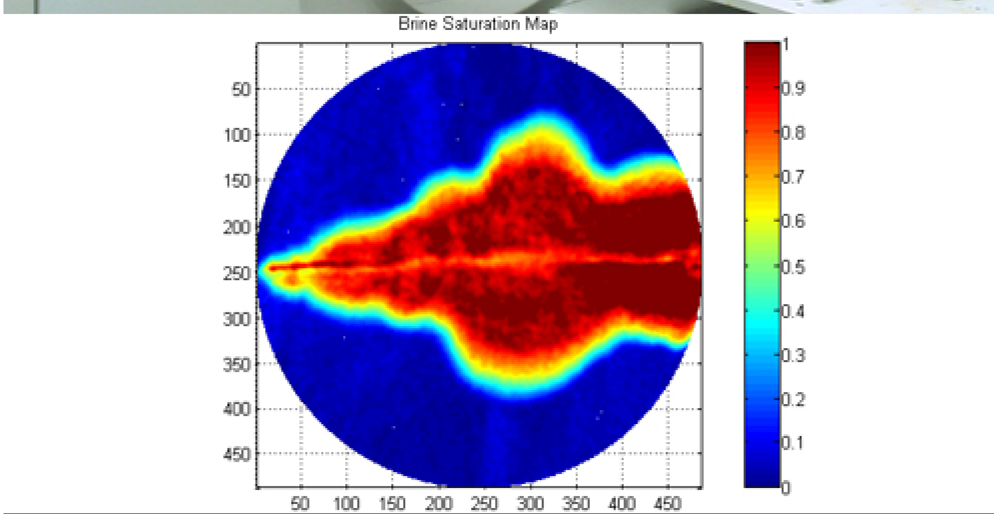

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Imagine dipping a napkin in a glass of water and watching the paper slowly draw up the liquid. Now picture an underground rock formation drawing liquid in the same way. The surface tension responsible for this phenomenon is referred to as capillarity. While capillarity is often ignored for traditional rocks, it could have significant implications for gas extraction from tight rock formations (i.e. formations with low permeability), such as the Marcellus Shale region.

Zuleima Karpyn, associate professor of petroleum and natural gas, is currently working to better understand these surface forces and how they might contribute to the retention of hydraulic fracturing fluids in extremely tight rock formations, such as gas shales and tight sands, where fluid can?t flow through the rock. Working above ground with the help of a modified medical computed tomography (CT) scanner, Karpyn is gathering three-dimensional images of these forces in action.

?Because these formations have such a low permeability?the idea that hydraulic fracturing fluid is going to go into the rock is inconceivable for a lot of people,? Karpyn said. However, because the pores in these rocks are so small, there is more surface area available, making capillarity much more prevalent than in large-pore rocks like sandstone.

Karpyn and her group focus their research efforts on understanding fluid flow within geologic structures and porous materials. In addition to studying capillary forces for natural gas drilling, the group has several ongoing projects related to CO_2 sequestration, looking at rock properties for the purpose of trapping gas.

?The overarching theme of all of these projects is to understand how fluids and rocks interact, from the point of view of facilitating flow or inhibiting flow,? Karpyn explains.

An important aspect of her research is the use of X-ray computed microtomography to characterize structural properties of rock and monitor fluid-rock interactions. The work is done in the Center for Quantitative Imaging (CQI) at Penn State, which houses an industrial high-resolution X-ray CT scanner and a medical X-ray CT system. These systems provide a nondestructive method for observing the interiors of objects in three dimensions, similar to X-ray CT and MRI images of the human body.

In Karpyn?s current project she is using the X-ray CT scanner to directly observe how hydraulic fluid moves through a tight sand sample. The goal, Dr. Karpyn said, is ?to understand whether surface properties are actually as relevant as we think they could be.?

To understand the importance of this research, we need to understand a bit about the natural gas extraction process. Unlike conventional oil and gas wells, natural gas located within shales or tight sands will not naturally flow when a well is drilled. Therefore, these wells need to be stimulated, and the preferred method is hydraulic fracturing, or pumping water-based fluid into the well under high pressure to release the gas from the rock.

Ideally, most of the fluid would be recovered from the well. Among other things, leaving it in the ground could block the flow of natural gas and affect the productivity of the well. Unfortunately, it is very hard to predict how much fluid will return.

To illustrate the drilling and fracturing process, Karpyn drew a well with two perpendicular lines, like wings, reaching out through the formation to represent the fracture. While she continued to draw concentric ovals around the two lines, she explained that the longer the fracturing fluid sits in the ground, the further it moves into the rock, away for the initial fracturing site.

?We don?t know how far into the rock [the fluid] is going to go, and we don?t know what happens if you leave it there for a little while before you put the well into production,? Karpyn said.

She explained that not waiting long enough to put a well into production can mean that all of the fluid is concentrated in a very small zone, which can restrict gas flow. However, waiting too long means the same amount of fluid is spread over such a large area it becomes much harder to recover.

So, with tight sand samples, water, and nitrogen Karpyn and her team are replicating the process inside a scanner to visually monitor the fluid movement through the rock and determine the optimum wait time between drilling the well and putting it into production.

By answering two questions: how much of the original fluid can be recovered, and does the remaining fluid restrict the flow of nitrogen, which would indicate low well production, researchers will better understand how to design a process to minimize the amount of fluid left behind and maximize the reservoir?s productivity.

Zuleima Karpyn is an associate professor of petroleum and natural gas in the John and Willie Leone Family Department of Energy and Mineral Engineering. She can be reached at zkarpyn@psu.edu [2]. For more information on the Center for Quantitative Imaging, visit www.cqi.psu.edu [3].

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