Investigating carbonate mineral chemical variations to improve oil recovery

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Dr. Igor Ivanishin, a postdoctoral researcher in the Harold Vance Department of Petroleum Engineering at Texas A&M University, has firsthand experience with the frustrations of oil production. He spent nine years as a hydraulic fracturing engineer with operating and service companies in Russia. A few years ago, he came to Texas A&M to get his doctoral degree while delving into a recurring recovery problem in carbonate reservoirs: Why don't they produce oil as predicted?

Ivanishin is investigating variations in the chemical composition of dolomite and calcite minerals to prove why a one-size-fits-all approach to well stimulation in carbonate reservoirs doesn't always work. Because these formations occur worldwide, his research has attracted the attention of several major oil and gas companies that want to collaborate with him and improve well stimulation operations.

The chemical crystalline lattice of ideal dolomite has regularly alternating layers of calcium and magnesium. When dolomites naturally form in sedimentary rock, extra calcium ions can substitute for magnesium ions. This modification expands the crystal lattice and makes it less stable. A similar situation happens in calcite, a mineral that doesn't contain magnesium or other ions in pure form but can in reservoirs.

Such variations are typical in sedimentary rocks but are not yet considered in well stimulation software models. Current modeling methods assume both dolomite and calcite have an ideal chemical composition that does not vary spatially within the carbonate reservoir. Thus, reservoir rock is thought to react at the same rate everywhere when acids are injected to dissolve the rock and form the channels or wormholes for oil and other hydrocarbons to travel through.

"I found publications that reported the presence of impurities in carbonates, but the authors did not think about variation in the chemical structure of these minerals," said Ivanishin. "These are angstrom-level tiny things, so it's difficult to imagine that such a small-size variation in chemical composition may affect the stability of the mineral, but it does."

As a doctoral student, Ivanishin consulted with geologists, mineralogists and chemical geologists on the subject. He received and personally collected dolomite samples from around the world. Initial chemical composition analysis of the different samples helped him to select dolomites with varying excess calcium contents. The reaction of these samples with hydrochloric acid revealed that having extra calcium, a calcium uptake, increased the rate dolomite dissolved up to five times greater than usual. He concluded that because the chemical composition of dolomite does vary spatially, injected acids would unevenly dissolve the rock in the target zone and not travel further into the reservoir, leaving some areas untouched.

For his postdoctoral research, Ivanishin is working

with a large collection of calcites from Japan. He wants to determine if magnesium ions in calcite also change the dissolution rate of this mineral in acids. If calcite behaves the same way as dolomite, this should affect the design of stimulation treatments and other operations in carbonate formations, such as CO_2 injection.

Ivanishin is currently working on creating computer simulations of these molecular variances and associated dissolution reactions so they can be easily shared and studied. His goal is to provide information to companies and consult with them on applications of this discovery in the field.

Though the investigation requires hard work and long hours, Ivanishin is glad the problem led him to College Station, Texas. Years ago, he talked with visiting international speakers at his former job about the carbonate recovery issue, including professors from Texas A&M. He decided to explore the university in person as a visiting student, then came back when he discovered it was the right place to be.

"I decided the next step in my career should be a Ph.D. from one of the best universities in the world," said Ivanishin. "The experience obtained here, talking with people from different companies, working with other engineers, exchanging ideas with experts from different fields and gathering information, is like a point of contact with the whole petroleum engineering world."

More information: Igor B. Ivanishin et al, Effect of calcium content on the dissolution rate of dolomites in HCl acid, *Journal of Petroleum Science and Engineering* (2021). DOI: 10.1016/j.petrol.2021.108463

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