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PERF Researchers Determine Key Mechanism Driving Sandstone Acidizing Performance in GOM Field

First laboratory study of HF acid for major operator perforates and stimulates cores at simulated formation and completion conditions

CHALLENGE
Determine the best-performing acid blend for enhancing perforation injectivity in a sandstone reservoir prior to hydraulic fracturing.

SOLUTION
Conduct sandstone acidizing experiments with different blends at downhole conditions, including the operator's first hydrofluoric acid (HF) studies, for extensive digital analysis.

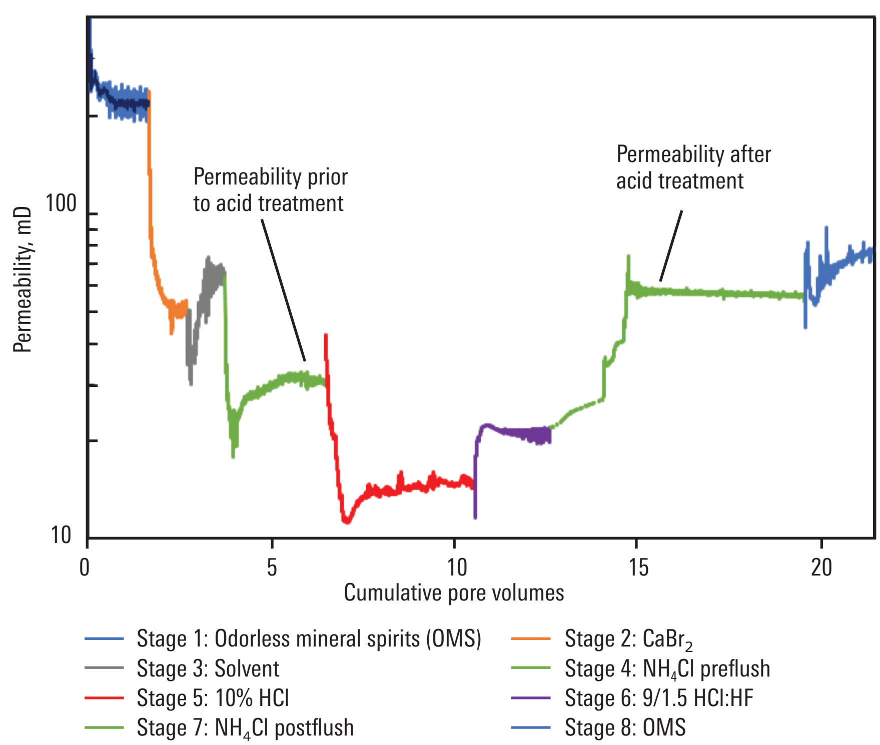
RESULTS
Revealed that use of HF is not necessary because the mechanism for permeability enhancement is primarily HCl dissolution of gun scallop and casing debris in the perforation tunnels.

No available data for evaluating stimulation fluids

An operator in the Gulf of Mexico (GOM) was employing stimulation treatments with HCl and organic acid blends to enhance the injectivity of perforations before conducting hydraulic fracturing. The operator was considering the use of alternative stimulation fluids containing HF to exploit its potential to dissolve siliceous damage in the crushed zone around the perforation tunnels. However, the high HSE risks associated with HF had discouraged the operator from conducting laboratory studies. As a result, no data on HF was available to evaluate its effectiveness for stimulating perforations in the field.

Field-specific sandstone acidizing tests—including HF

To provide the previously unavailable data on HF, researchers at the Schlumberger Productivity Enhancement Research Facility (PERF) laboratory designed and performed a series of first-of-their-kind laboratory experiments for the operator. Representative sandstone outcrop cores were perforated with big hole charges and then stimulated with HCl and HF acid blends at a test temperature of 200 degF. The test conditions were tailored to simulate the high-pressure formation characteristics and complex well completions. An injection sequence of eight fluid stages was pumped through the cores using a customized automated system.

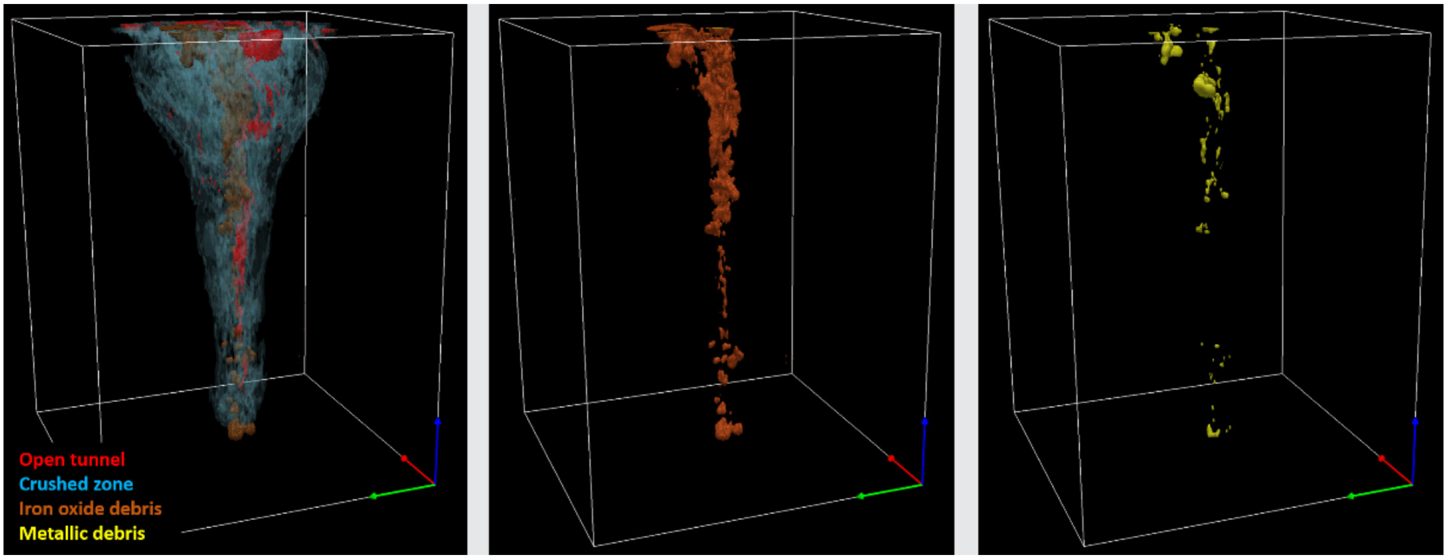


Permeability of the perforated core as a function of cumulative pore volumes pumped during the eight-stage multiphase injection sequence. The permeability in Stage 7 after the acid treatment was higher by about a factor of two than the pretreatment permeability measured in Stage 4.

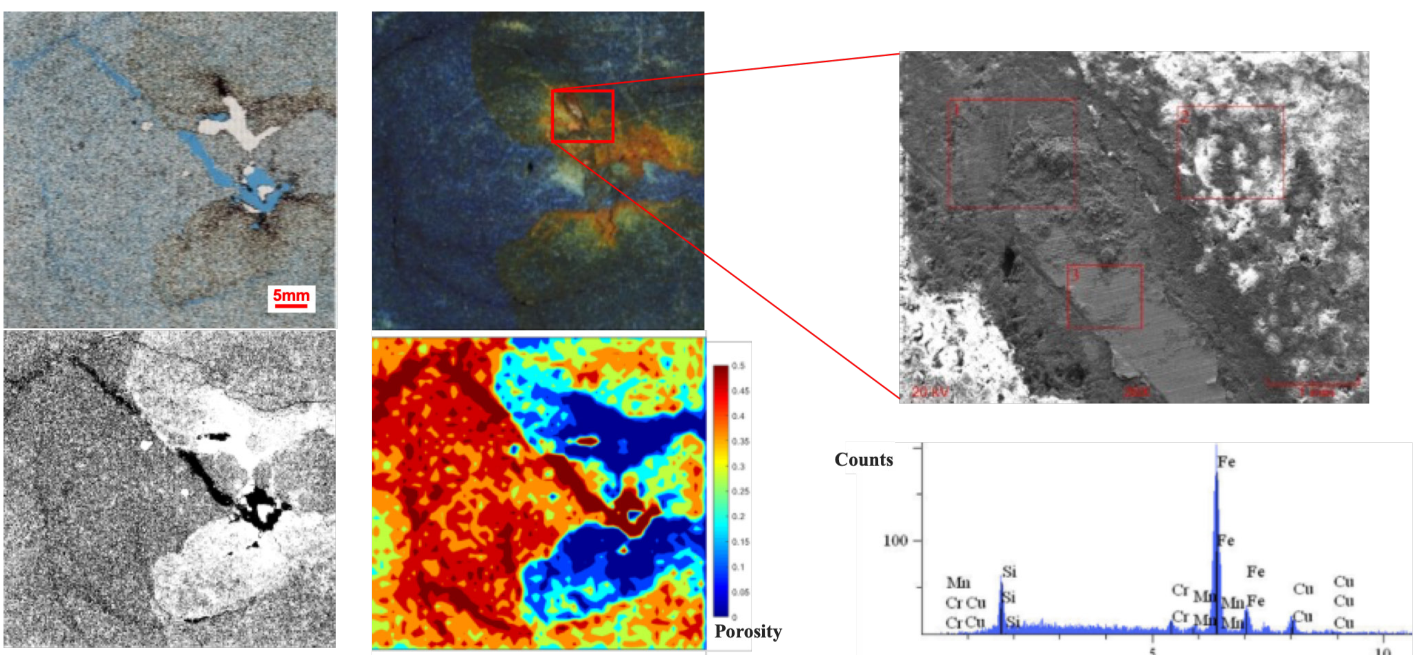
Quantified acid performance with unique insight to stimulation mechanisms

The sandstone acidizing experiments showed that a proposed mud acid blend (9/1.5 HCl:HF) increased the permeability of the perforated sandstone cores by about a factor of two. Surprisingly, comparable performance was obtained with the baseline acid currently used by the operator (10/10 HCl:acetic acid [HOAc]).

The digital analysis of the tested cores included computerized tomography (CT) scans, thin-section analysis, and scanning electron microscopy (SEM) with energy-dispersive spectroscopy (EDS) to understand the mechanisms underlying the stimulation results. The analysis revealed that permeability enhancement is dominated by HCl dissolution of iron oxide, gun scallop, and casing debris deposited in the perforation tunnels during the perforating event and is achieved irrespective of the use of HF.



Three-dimensional rendering of the big hole perforation tunnel reconstructed from CT images showing (left) the open tunnel, crushed zone, iron oxide debris, and metallic debris; (center) only iron oxide debris; and (right) only metallic debris.



Thin-section analysis (left) showing that iron oxide and metallic debris cause a strong porosity reduction in the crushed zone. SEM and EDS analysis (top and bottom right, respectively) of the metallic debris shows that it contains steel fragments from the gun scallop and casing. The steel fragments provide the likely source of the iron oxide.

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