Slot-Shaped Borehole Breakout within Weakly Cemented Sand under Anisotropic Stresses

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RESEARCH OBJECTIVES

Boreholes drilled within weakly cemented sand can suffer excessive sand production that may hinder, or even stop, production of oil—and ultimately cause collapse. Further, in recent years, there has been increasing evidence of a unique, slot-shaped borehole failure within weak, high-porosity sandstones, which may have a significant impact on the stability and sand production of boreholes.

The primary objectives of this research are: (1) to establish quantitative relationships between grain-scale properties of weakly cemented sand and macroscopic properties such as failure mode and rock strength; (2) to understand the process and mechanism of fracture formation and failure of a borehole in a realistic stress and flow environment; and (3) to develop a predictive capability for borehole stability and sand production, through a series of laboratory experiments.

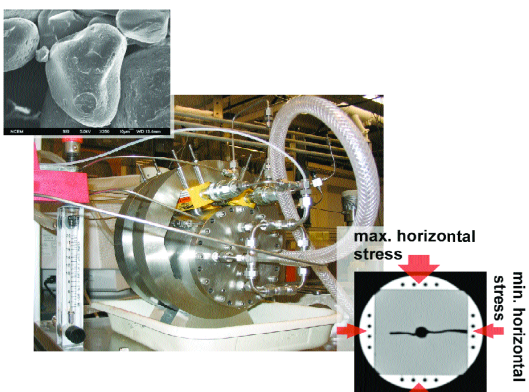

Figure 1. Block samples of weakly cemented sand (upper left, SEM photograph. Sand grain size~150 micrometers), containing a single borehole, are compressed anisotropically within a portable "true-triaxial" cell with fluid circulation through the borehole (middle). A slot-shaped borehole breakout develops in the direction perpendicular to the maximum horizontal stress direction around the borehole (lower right, x-ray CT image). The diameter of the borehole is approximately 1 cm (0.39 inches).

APPROACH

Because field cores of weakly cemented rocks are difficult to recover from oil and gas reservoirs, we developed a new laboratory technique to fabricate weakly cemented synthetic sandstone samples for our experiments. Using synthetic samples also allowed us to conduct parametric studies for a range of controlled sample properties, including the strength of intergranular bonds and porosity. These samples are made of pure quartz sand cemented together by a soda-lime glass micropowder melted under a high temperature. We also developed a "true-triaxial" loading cell (loads can be applied in the three perpendicular directions independently), capable of circulating fluid at a controlled rate through a borehole drilled in a rectangular block-shaped sample (3 inches x 3 inches x 6 inches).

ACCOMPLISHMENTS

Using the synthetic sandstone samples and the "true-triaxial" loading cell, we successfully produced a slot-shaped borehole breakout within the samples under anisotropic stresses and with fluid flow through the borehole (Figure 1). Experiments were conducted for a range of sample strength, borehole fluid flow rate, and stress anisotropy around the borehole axis. After each experiment, the geometry of the resulting breakout was examined via x-ray CT.

The results of the experiment showed that the width of the breakout decreased with increasing intergranular cohesion and strength of the samples, possibly because a larger zone of damage (process zone) formed near the edge of a breakout for weaker samples, which was subsequently washed away by the fluid flow. Further, for stronger samples, the growth of the breakout was rapid and catastrophic, while weaker samples exhibited the slow, stable growth of a breakout.

SIGNIFICANCE OF FINDINGS

Slot-shaped borehole breakout within well-cemented sandstone is commonly believed to form when the rock undergoes local compaction at the leading edge of the breakout, resulting in crushing of sand grains. In contrast, the slot failure within weakly cemented sand involves little grain failure, which indicates that compaction is not necessarily a critical mechanism of the failure. This indicates that the slot-shaped failure can occur at low stresses that do not involve grain crushing. Further, a numerical stress analysis based on a static boundary-element method indicates that, as long as the produced debris can be removed from the edge of the breakout, the growth of the slot-shaped breakout cannot be stopped, since the stress concentrations at the breakout-tip increases monotonically with the breakout length.

RELATED PUBLICATION

Nakagawa, S., and L.R. Myer, Mechanical and acoustic properties of weakly cemented granular rocks. 38th U.S. Rock Mech. Symp., Washington, DC, 3–10, 2001. Berkeley Lab Report LBNL-50814.

ACKNOWLEDGMENTS

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