Rock Physics Observations During Controlled Microbially Induced Precipitation

Ralf J. Weger, Mara R. Diaz, Peter K. Swart, and Gregor P. Eberli

Project Objectives

- To elucidate the involvement of microbes in ooid cementation processes and their potential effect on the acoustic properties of un-cemented ooid sandstone at low pressures.
- Compare the influence of microbially mediated versus inorganic precipitated cements on acoustic velocity and rock strengths of carbonates.

Project Rationale

Carbonates are prone to diagenetic alterations that sometimes result in drastic alteration of petrophysical properties. Small amounts of newly formed contact cement can create enormous changes in rock stiffness if deposited precisely at grain contacts, and can act to dramatically increase the stiffness of a particulate aggregate (Dvorkin and Nur, 1996). There is strong evidence that early microbial micritic bridging cements are the start of cementation processes that include fringing cements (Eberli et al., 2017). These cements are influential in determining the rock strengths both with regards to compaction and bulk and shear modulus. The question is whether these early microbial cements produce a significant increase in rock strength that increases velocity and is able to resist compaction.

In previous inorganic precipitation studies at the CSL we have shown that clean ooids can be cemented together by calcium carbonate crystal precipitation in only a few weeks (Fig. 1). Precipitation occurs preferentially at the ooid-to-ooid grain contacts, but sometimes overgrows the entire ooid surface with needle structures. The contact cements are responsible for increasing rock stiffness and thus acoustic velocity. Needle structured crystals on the other hand reduce porosity with very little increase in velocity. The rock undergoes apparent weakening creating a rock framework of lower stiffness for its lower porosity. This study aims to induce microbially mediated cements and test their influence on the elastic properties.

Project Objectives

In this project, experiments that quantify both the chemical changes in the fluids and the diagenetic and petrophysical changes in the rocks are designed to enhance our understanding of the effects of chemical rock-fluid interaction specifically focusing on the differences between microbial and inorganic precipitation. In particular, the study will capture changes in acoustic velocity and permeability during chemically controlled rock-fluid interaction that causes precipitation in experiments that deliberately enhance or inhibit microbial activity.

SCOPE OF WORK

In this project, experiments will be performed in order to:

Quantify the chemical changes in the fluids and the diagenetic and petrophysical changes in the rocks during different types of precipitation, including inorganic and microbially mediated precipitation. While inorganic precipitation experiments will be undertaken in incubation chambers inoculated with sterilized ooids – to discard any potential microbial involvement in calcification processes –, microbially mediated carbonate precipitation experiments will use an inoculum of freshly collected ooids supplemented with glucose for bacterial growth.

Determine the presence and potential involvement of biofilm extracellular polymeric substances (EPS) in carbonate precipitation at grain-to-grain contact loci and non-contact areas of the grains. The presence and development of EPS will be determined using fluorophore-conjugated lectins. This analysis, which uses confocal laser scanning microscopy (CLSM), will allow the visualization of EPS distribution in the grains via specific binding of lectins to EPS-carbohydrates.

Determine if ACC nanograins can act as precursors of cementation processes in ooids. Detection of ACC will use morphological attributes based on SEM image analyses

KEY DELIVERABLES

A data set will be generated that captures changes in acoustic velocity and fluid flow permeability generated by microbially induced precipitation. High-resolution images using SEM will provide insights regarding the precipitated material and its preferential location within the rock framework.

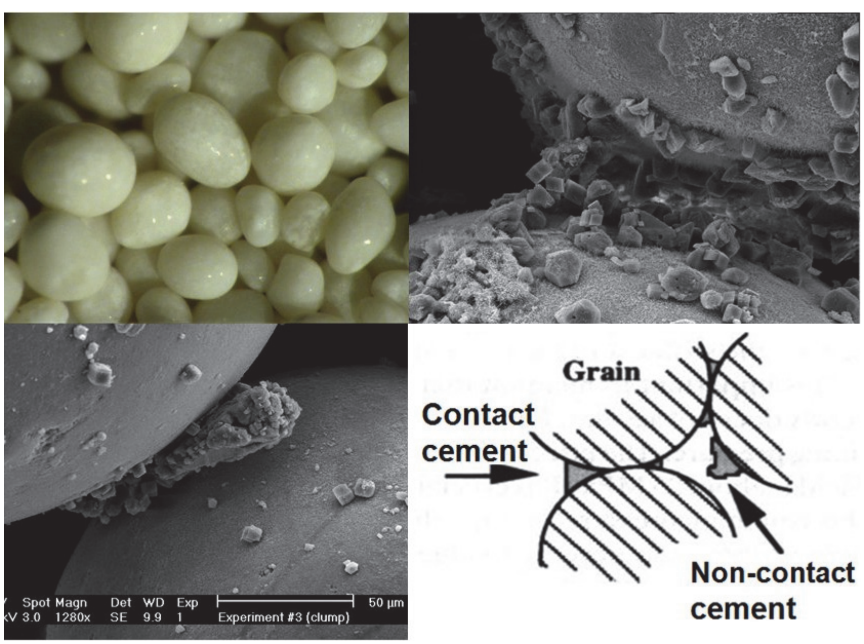

Figure 1: Results of precipitation study. Top right, clean ooids before experiment. Top right and bottom left, calcium carbonate crystals precipitated during the experiment. Precipitation occurs preferentially at the ooid-to-ooid grain contacts. Bottom right, illustration of contact vs. non-contact cement (from Dvorkin and Nur, 1996).