The Effect of Salinity and Clay on Wettability

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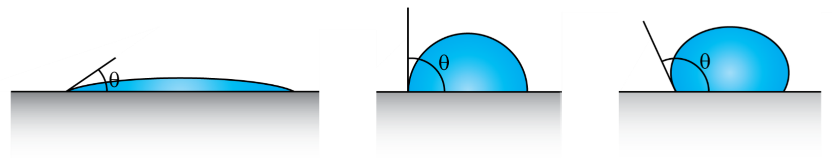
Introduction

- Without additional effort, the average oil recovered from a well is <20%, but Enhanced Oil Recovery (EOR) can increase this by an additional 20 – 40% (1)
- There are many different EOR methods
  - One of the simplest, and the method assessed in this study, is low-salinity EOR, where the injected water is at a lower salinity than the formation water
- Problems may occur near injection wells due to changing the salinity of the fluids in the formation
- Will the change in fluid salinity, and the presence of fine clay particles in the fluid, affect the wettability?

Background Concepts

- The wettability of a surface is a measure of how it will interact with water



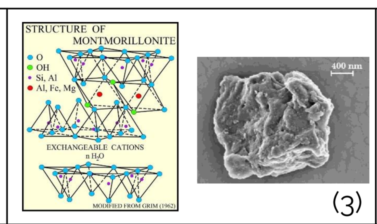
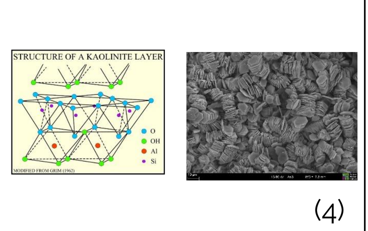
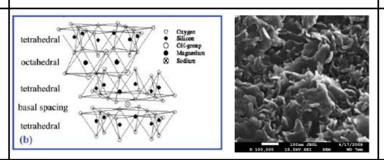
Water-wet | Neutral-wet | Oil-wet

- The surfaces generally encountered near the injection well are water-wet, but different minerals may exhibit different wettabilities
- Measurements of wettability are generally made with distilled water on a clean, flat surface; how will these measurements change when salts and clays are added to the water?

Materials tested

Clays

- The first two clays tested represent clays which typically might be found in an oil-bearing sandstone. Laponite was chosen as a highly controlled synthetic clay.

Bentonite (Wyoming bentonite, ex Steetly)	 (3)	Main mineral: Sodium Montmorillonite. Ellipsoidal tactoids typically 320-400 nm long/250 nm wide and 1.2 nm thick (2)
Kaolinite (Kaolinite KGa-1b, The Clay Minerals Society	 (4)	Hexagonal in shape with lateral dimensions of the order of 1-2 µm and a thickness of about 0.05-0.1 µm
Laponite (Laponite XLS, Byk)		Disc-shaped crystallites with a diameter of ca. 25–30 nm and a thickness of approximately 1 nm (5)

Salts

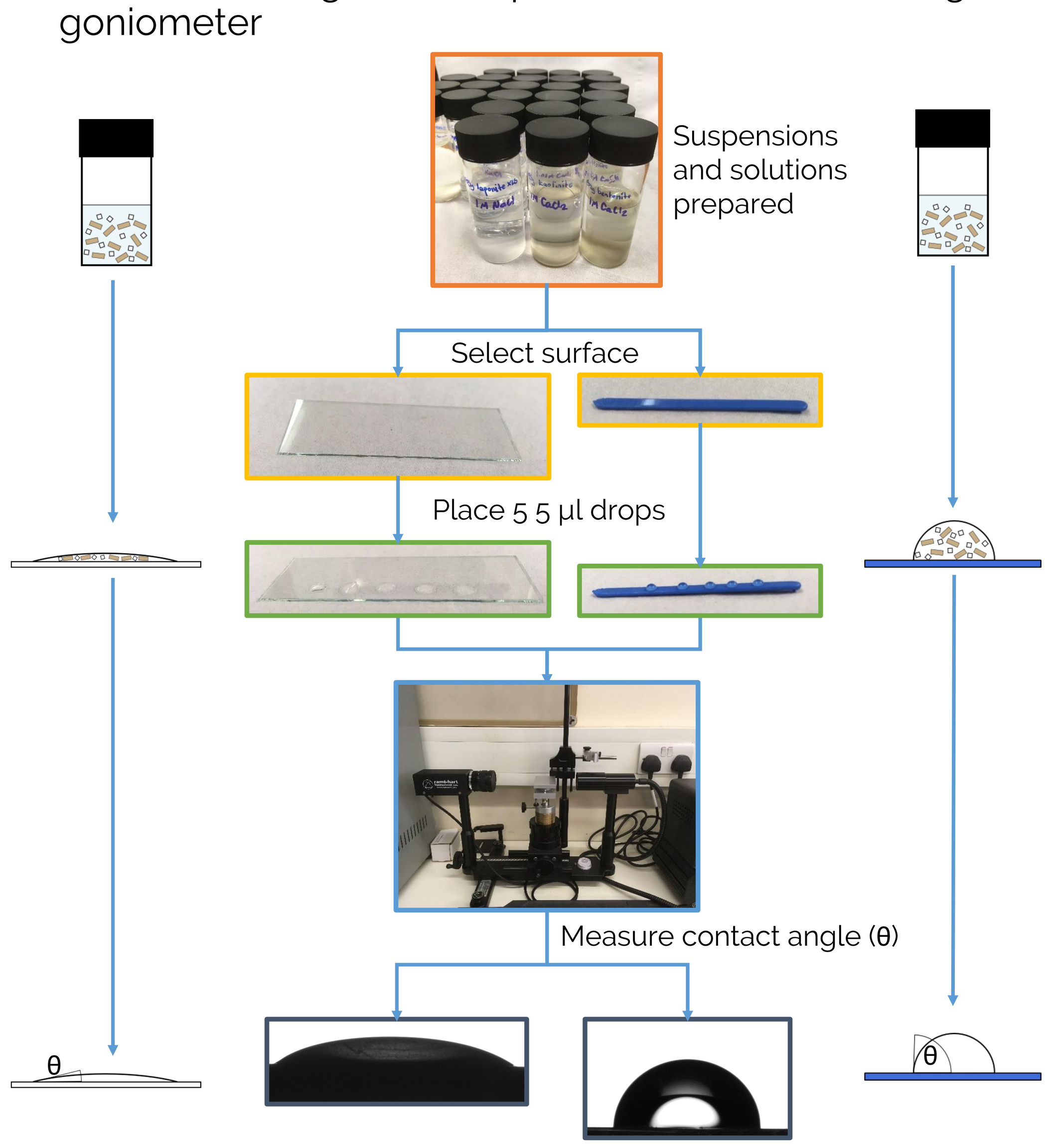
- NaCl and $CaCl_2$ to assess the effect of mono- and divalent cations
- 1M, 0.01M and 0.001M solutions of each single salt
  - These represent formation water salinity, intermediate salinity and low salinity

Methods

- Salt solutions with and without clay suspensions (2.5 g/l) were prepared as follows:

	Distilled Water	0.001M	0.01M	1M
Bentonite	No salt	NaCl or $CaCl_2$	NaCl or $CaCl_2$	NaCl or $CaCl_2$
Kaolinite	No salt	NaCl or $CaCl_2$	NaCl or $CaCl_2$	NaCl or $CaCl_2$
Laponite	No salt	NaCl or $CaCl_2$	NaCl or $CaCl_2$	NaCl or $CaCl_2$
No Clay	No salt	NaCl or $CaCl_2$	NaCl or $CaCl_2$	NaCl or $CaCl_2$

- Clay dispersion was ensured by treatment with pulsed ultrasound from an ultrasonic probe for 16 minutes.
- Two surfaces were used for taking measurements upon
  - Cleaned glass
  - PLA
- The PLA surface was prepared by melting onto glass to give a roughness close to that of glass, as roughness has a noticeable effect on wettability.
- 5 5 µl droplets of solution or suspension were placed onto a cleaned surface of interest
  - The droplets of suspensions were placed immediately after ultrasonic treatment, agitating for 5 seconds before drop placement.
- The contact angle the droplets was measured using a goniometer



Results

Figure 1: Repeated water measurements were made to give a range for the contact angle of water on the surfaces

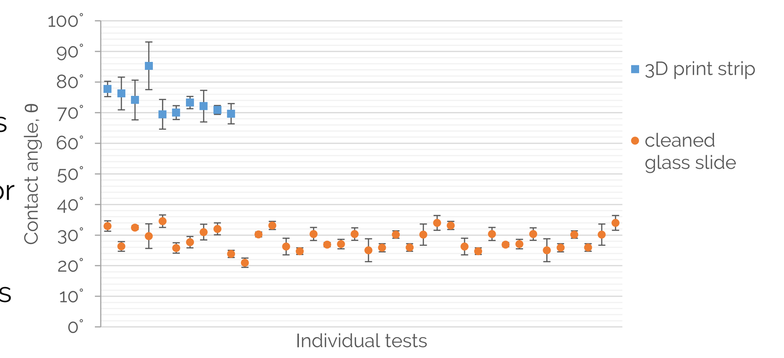


Figure 2: Comparing different NaCl concentrations for all clays on 3D print strip

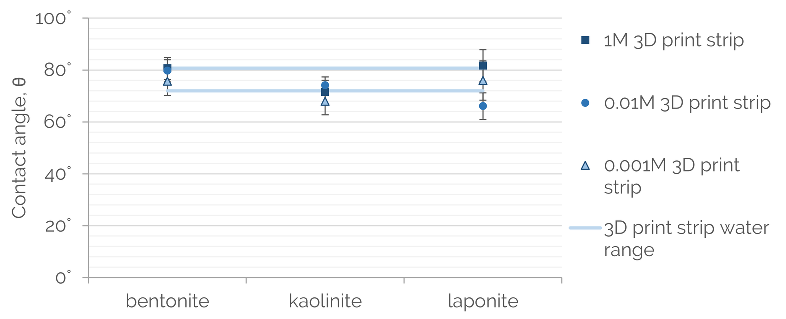


Figure 3: Comparing different NaCl concentrations for all clays on cleaned glass slide

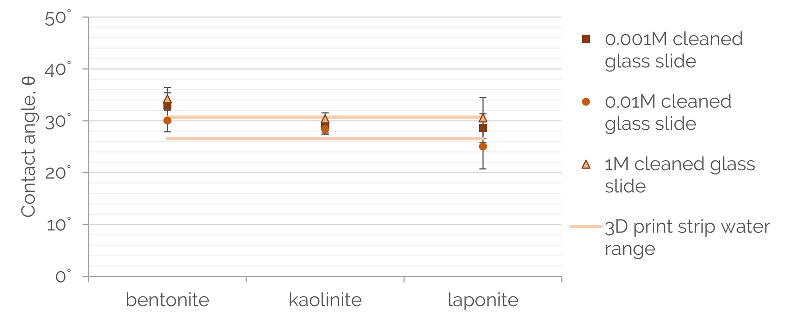


Figure 4: Comparing different $CaCl_2$ concentrations for all clays on 3D print strip

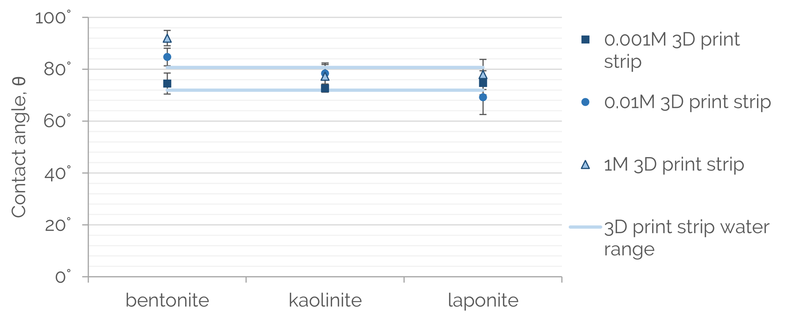


Figure 5: Comparing different $CaCl_2$ concentrations for all clays on cleaned glass slide

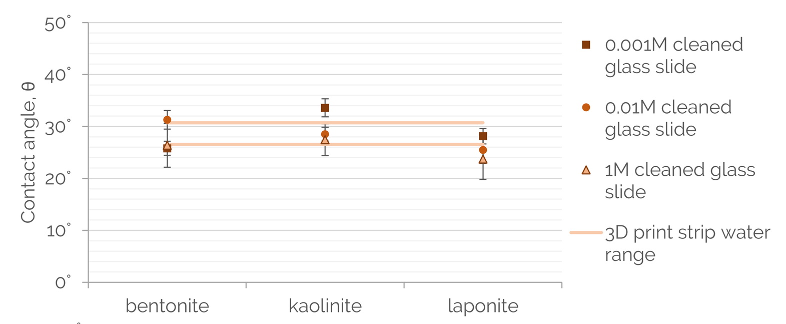


Figure 6: Comparing 1M salts and print surfaces

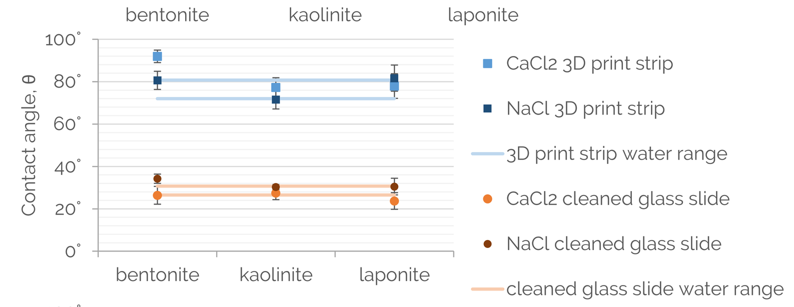


Figure 7: Comparing 0.01M salts and print surfaces

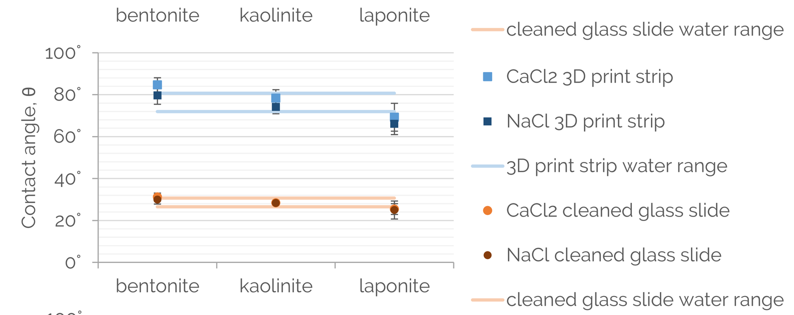
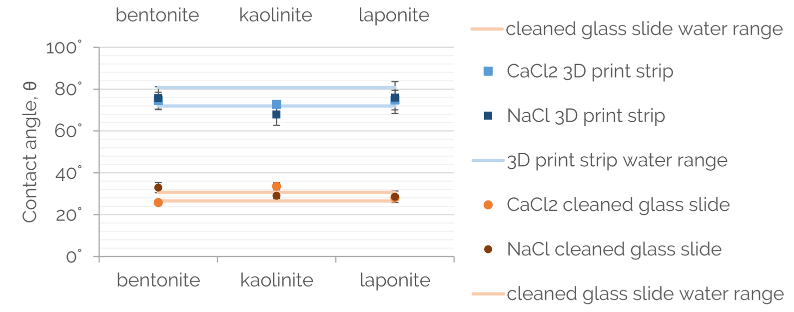


Figure 8: Comparing 0.001M salts and print surfaces



Conclusions

- Repeated measurements with distilled water on both print surfaces shows variation in the measured contact angle
- Variation of measured contact angle in suspensions of different NaCl concentration are generally within the range of distilled water measurement on each surface, with the exception of bentonite in 1M NaCl on glass
- Variation of measured contact angle in suspensions of different $CaCl_2$ concentration are generally within the range of distilled water measurement on each surface, with the exception of bentonite in 1M and 0.01M $CaCl_2$ 3D print and kaolinite in 0.001M $CaCl_2$
- Plotting the results by salt concentration for both salts and print surfaces shows the more significant variation at 1M salt concentration
- A trend can be seen in the contact angle measured in the different clays at 0.01M salt concentration, whereby bentonite gives consistently higher values than kaolinite, and laponite giving consistently lower values.
- In general, no significant effect can be seen when clay and salt is added to water at low concentration, which will prove useful for future work.

Further Work

- This work is to be taken forward into testing whereby these fluids are flowed in structures of variable wettability and monitored using micro-CT
- This work has shown that the fluids themselves do not significantly affect the wettability observed on the two different surfaces when salt or clay is added at low concentration
- This will thereby help to eliminate possible variables in the results obtained in the micro-CT experiment
- Further investigation may be needed into the variation in wettability seen between the different clays at 0.01M salt concentration

References

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3. Welti, André & Lüönd, Felix & O, Stetzer & Lohmann, Ulrike. (2009). Influence of particle size on the ice nucleating ability of mineral dust. Atmospheric Chemistry and Physics Discussions. 9. 10.5194/acpd-9-6929-2009.
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