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Do Montmorillonite Particles form Gels in Aqueous Suspensions?

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Introduction

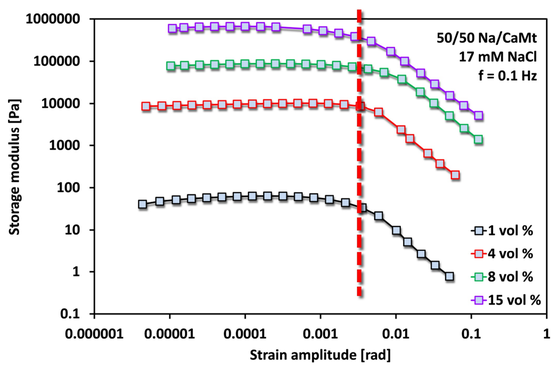
Clay mineral particles are considered to form gels at very low solids content in aqueous suspensions.[1] New evidence suggests that the solid-like consistency of clay suspensions may be due to steric or frictional forces between particle clusters rather than volume-filling bonded networks. This finding would suggest that clay mineral suspensions can be characterized as viscoelastic liquids instead of gels, as is commonly accepted.

Experimental

Rheological measurements were performed on purified (from Volclay MX-80 bentonite) and ion exchanged (Na, Ca) montmorillonite.[2] A TA Instruments DHR-2 rheometer equipped with plate-plate geomtery was used in all measurements. Optical Coherence Tomography[3] (OCT) was used for in situ imaging of clay samples emplaced within the measurement geometry.

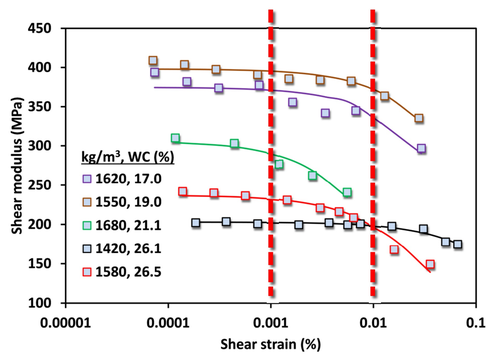
Length-scale: *strain sweep measurements and optical imaging*

~30 ← Effective strain (µm) → ~20 ~220

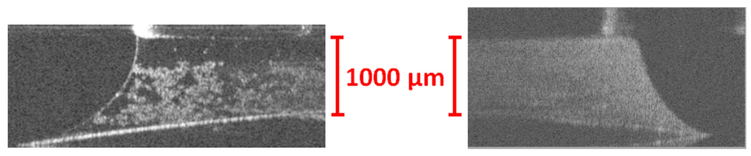


Dilute samples

The critical strain is on the same order of magnitude for dilute and compacted samples, thus indicating similarity in long-range structure.



Compacted samples[4]



0.1 vol % **5 vol %**

OCT images yield information about aggregate size and the macroscopic structure of montmorillonite suspensions. The structural length-scale perceived from OCT imaging corresponds very well to the critical strain.

material

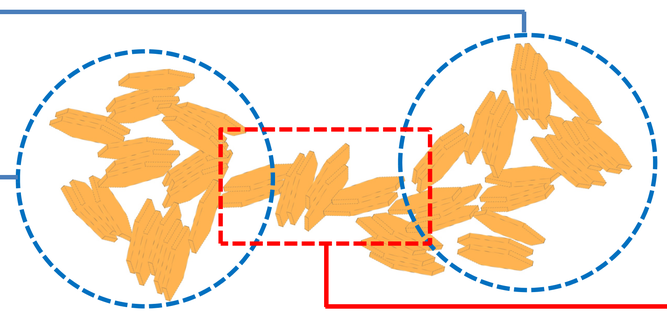
Montmorillonite
Generic formula: $(Na, Ca)_{0.6}(Al, Mg)_4Si_8O_{20}(OH)_4$
Single montmorillonite platelet:

height ~1 nm

width ~20 – 500 nm

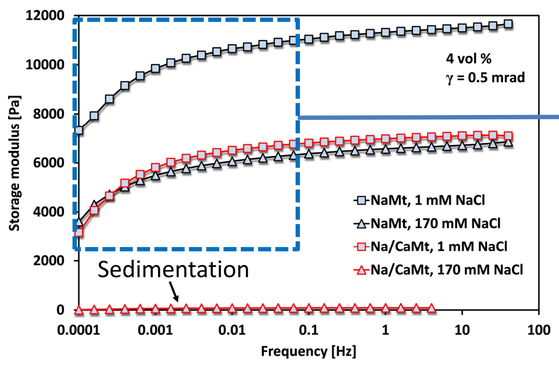
hypothesized structure and response to strain

Flocs / domains of higher density.
These deform under strain but do not break even above the critical strain.

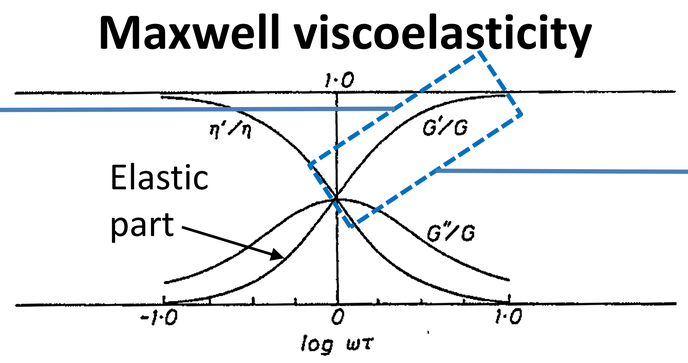


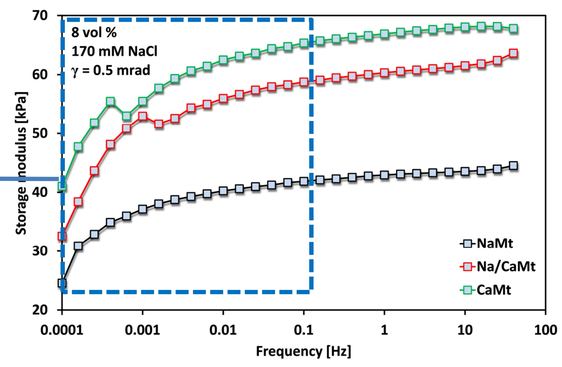
Bridges / domains of lower density
These deform under strain and normally break at the critical strain.

Time-scale: *frequency sweep measurements*



Maxwell viscoelasticity





Substantial relaxation at low frequencies indicate structural rearrangements, which is contrary to typical gel-like behavior.

Conclusion

The mechanical response of montmorillonite suspensions that have been allowed to swell freely seems to be governed by frictional forces between aggregates rather than inter-particle chemical bonds. This indicates that montmorillonite suspensions behave like highly viscous liquids instead of gels. Based on rheological data and OCT images the solid material (montmorillonite) is organized into domains of higher density (flocs) on the order of a few tens of microns which are interspaced by domains of lower density. Surprisingly, similar length-scales are found for highly compacted bentonite. It is worth noting that true gel-like behavior can be achieved for montmorillonite suspensions in controlled lab-environments, but it is highly unlikely to occur for free swelling montmorillonites (or bentonites) in natural environments. There are no stirrers in a nuclear waste repository.

Acknowledgements

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References

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