Impact of organic matter on rheological behavior of fine-grained sediment

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Introduction: The presence of organic matter in fine-grained sediment usually hinders the settling of particles and eventually results in the formation of fluid mud layer, in addition to the natural wave motion or human intervention. There are two common sources of organic matter in sediment: (i) natural and (ii) anthropogenic. The natural sources include eroded terrestrial topsoils, plant litter and benthic and planktonic biomass while surface runoff and sewage effluents contribute towards the anthropogenic source of organic matter [1]. The existence of organic matter in fine-grained sediment can significantly influence the rheological and cohesive properties [2, 3].
In addition to the content of organic matter, its extent of degradation can also significantly affect the rheological properties of fine-grained sediments. The aerobic degradation (i.e., in the presence of oxygen) of organic matter usually results in the production of carbon dioxide while the anaerobic condition produces methane as well, in addition to carbon dioxide [1]. The entrapped gas bubbles can significantly decrease the strength of fine-grained. Our study is aiming to quantify the effect of organic matter on rheological behavior of fine-grained sediments and to analyze the systematic changes in rheological behavior of mud triggered by organic matter degradation.

Methods: In this study, sediment core samples were collected in the Port of Hamburg using one-meter core sampler. The samples were divided into suspended particulate matter, fluid mud, pre-consolidated sediment and consolidated sediment based on the visual differences in their consistency. The density, particle size distribution, organic matter content of sediment samples were determined in the laboratory. The samples were incubated in glass bottles under aerobic and anaerobic conditions. C release was quantified from the CO_2 and CH_4 concentrations measured in the headspace by gas chromatography and the pressure increase in the bottle head space. Aerobic and anaerobic degradation of organic matter experiments were conducted as reported in [1].
Rheological behavior of fine-grained sediment samples was analysed using HAAKE MARS I rheometer (Thermo Scientific, Germany) with Couette geometry. Different rheological experiments including stress ramp-up test, amplitude sweep test, frequency sweep test and thixotropic test were performed for fresh and degraded mud samples in order to quantify the rheological behavior of incubated sediment samples during long-term (>250 days) organic matter degradation experiments.

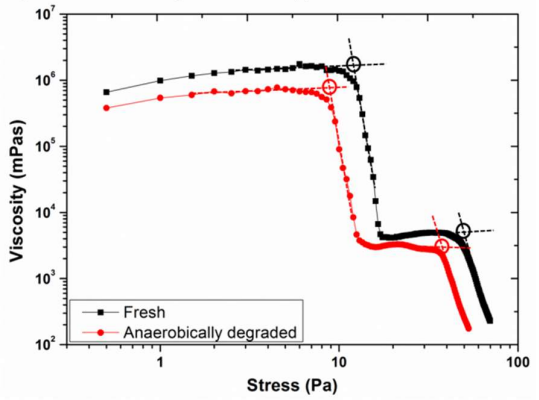

Fig. 1: Apparent viscosity as a function of shear stress for fresh and anaerobically-degraded sediment samples at the same densities. Circles represent the two yield points (i.e., static and fluidic).

Results: Our rheological analysis conducted on fine-grained sediment samples revealed the following:
1) The strength of anaerobically-degraded samples decreased systematically during organic matter degradation experiments. This decrease can be attributed to either loss of organic matter due to degradation or entrapment of gas bubbles in samples.
2) Fresh and anaerobically-degraded fine-grained sediment samples with the same densities have scientifically different rheological properties. As it is shown in Figure 1, the fluidic yield stresses (indicated in circles) were 37 Pa and 58 Pa for degraded and fresh samples, respectively.

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