Softening of organic matter in shales during heating measured with atomic force microscopy

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The elastic modulus of organic matter can impact the mechanical behavior of shales. Although recent advances have shed light on the properties of natural organic matter under ambient conditions, the elastic properties of kerogen and bitumen at reservoir temperatures remain poorly understood. Here we report on a novel atomic force microscope technique that enables us to directly map the nano-scale changes to organic matter during the heating of an organic-rich shale. Our experiments show that bitumen becomes significantly more compliant with heating; in an experiment during which the temperature was increased from 25ºC to 225ºC, the reduced elastic modulus dropped from 6.3 GPa to 0.8 GPa. In contrast to bitumen, we were unable to discern any measurable changes to the elastic modulus of kerogen with increasing temperature. Our results suggest that the temperature dependence of the elastic properties could be used as an additional method to differentiate between bitumen and kerogen in shales. Moreover, our analysis indicates that temperature should be taken into account when modeling the elastic properties of bitumen under reservoir conditions.

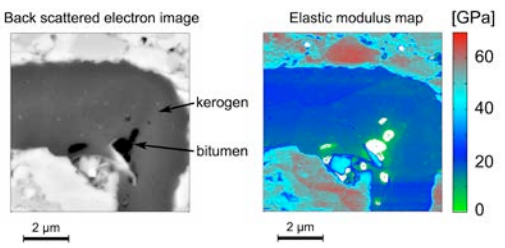

Figure 1: Kerogen in shale. The image to the left shows a backscattered electron image of kerogen (dark grey) containing bitumen inclusions (black). The map to the right shows the elastic modulus, which is measured as the sample is heated.