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Maximising information on mudrock microstructure through high-resolution scanning electron microscopy

Shereef Bankole, Buckman Jim, and Dorrik Stow
Heriot-Watt University, Institute of Petroleum Engineering, United Kingdom (sab6@hw.ac.uk)

Mudrocks are the dominant sedimentary rocks in the Earth's crust and are well noted for their heterogeneity at several orders magnitude. The microstructure of mudrocks is an important control on other petrophysical properties (e.g. porosity and permeability) and hence also on fluid movement within them. Due to the extremely fine-grained size of mudrocks, high-resolution measurement is required to reveal their microstructural characteristics. High-resolution scanning electron microscopy has advanced knowledge about microstructure of mudrocks but further development of fast and reliable methods to accurately determine the micron-submicron features of mudrocks is still on-going.

In this contribution we have used scanning electron microscopy to provide data on grain size, grain-orientation, mineralogy and porosity and pore size distribution. The method involves multiple large-area, high-resolution scans from polished thin-sections, coupled with automated acquisition and stitching of backscattered images (BSE). This is combined with machine learning segmentation and energy dispersive X-ray analysis (EDX). The mudrocks analysed are deep-water identified as hemipelagites from the New Zealand Continental Slope (IODP Expedition 317) and Iberian Peninsula (IODP Expedition 339).

Grain size analysis shows that all the samples are within silt-mud class size. Orientation analysis indicates that randomly representative areas within each sample are heterogeneous; displaying a combination of preferred and random orientation. The samples were differentiated into clay (siliciclastic) dominant and calcite dominant based on EDX analysis. Porosity of representative areas for individual samples reveals small-scale heterogeneity, reflecting areas of low, medium and high porosity. Calcite dominated samples showed tighter porosity compared to clay dominated samples. However, there is no significant difference among representative areas per sample in terms of pore size distribution.

Automated image analysis of large area, high-resolution montages presented herein, is fundamental to revealing mudrock microstructure characteristics and its heterogeneity. The process minimises human subjectivity and bias. However, limitations to the workflow are the time involved for individual runs and large amount of computer memory required. In addition, cracks in the sediment samples resulting from drying, preparation of polished thin-section as well as stress relaxation during coring, restrict the area available for high-resolution large-area imaging to that between the cracks. This method is very significant for improved understanding of subsurface mudrocks and their capacity for fluid movement and storage