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Editorial

Editorial for Special Issue "Characterisation of Mudrocks: Textures and Mineralogy"

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Mudrocks are a volumetrically important part of many sedimentary basins, both in the present day and across geological time. Although often considered to be somewhat simple, or even of little research interest, recent research has indicated that mudrocks are highly heterogeneous in terms of texture and mineralogy at the micron to decimetre scale. Mudrocks are economically significant as seals for oil, gas, water, CO_2 and H storage, as source rocks for unconventional oil and gas plays and as an important engineering material in their own right. The characterisation of mudrocks in terms of texture and mineralogy is, therefore, important in determining variation in porosity, permeability and structural rigidity as well as the environment of deposition and diagenetic history. Techniques used in characterising mudrocks include, amongst others, scanning electron microscopy (SEM), transmission electron microscopy (TEM), X-ray tomography (XRT), neutron micros-copy/diffraction, X-ray fluorescence (XRF) and X-ray diffraction (XRD). This Special Issue on "Characteristics of Mudrocks: Textures and Mineralogy" contains seven papers, representing the works of 32 researchers in aspects related to the field of mudrock research. Areas covered include petroleum exploration [1], carbon capture and storage [2], diagenesis [3], environmental interpretation [4,5] and new techniques [6]. These papers should be of interest to all those interested in the field of mudrocks.

Wang, Long, Peng and Ju present an SEM-based study of organic matter and organic-hosted porosity in the high- to over-mature important shale gas reservoir of the deep-water Ordovician to Silurian Longmaxi-Wufeng Shale, Eastern Sichuan Basin, China [1]. With a collection of over 500 images, four types of organic particle are recognised: (1) weakly or undeformed porous pyrobitumen; (2) moderately to strongly deformed pyrobitumen; (3) nonporous kerogen and (4) mineral-enriched amorphous kerogen. The authors argue that organic porosity from the study area is affected primarily by original chemical composition and the degree of deformational stress. Areas having undergone higher levels of deformation in the south of the study area have much lower organic porosity, with up to three times lower organic-hosted porosity compared to less deformed parts of the basin to the north.

In Buckman, Aboussou, Esegbue, Wagner and Gambacorta, the authors present a new technique for the visualisation of heterogeneity in fine-grained mudrocks, gathered from backscattered (BSE) large area SEM automated image acquisition surveys (producing montaged BSE images) [6]. They illustrate examples from pyrite distribution within Jurassic mudstones (UK), and organic content from Cretaceous deep-water mudstones (Southern Atlantic Margin). In both cases, the use of image analysis of individually collected image tiles allowed the construction of coloured distribution maps, making it possible to visualise micron- to millimetre-scale heterogeneity over relatively large areas. Problematic areas such as user bias, the selection of tile size and the practicality of the separation of phases using BSE imaging are discussed.

Bankole, Buckman and Stow's paper, entitled "Unusual components within a fine-grained contourite deposit: significance for interpretation of provenance and the contorite budget", looks at the distribution and significance of particles from deep-water Pliocene to

Quaternary contourite deposits from the Gulf of Cadiz [4]. These include tunicate spicules, micro-bored shell fragments, the presence of the coccolithophore *Braarudosphaera biglowii*, micro mudclasts and the degree of fragmentation of bioclasts. It is argued that such components can aid in calculating the contourite budget, with spicules, micro-bored shell fragments and *Braarudosphaera biglowii* representing sourcing from shallow waters, while micro mudclasts and the high fragmentation of bioclasts indicate re-working and transportation within contour parallel-flowing bottom waters.

Buckman, Mahoney, März and Wagner's contribution features a novel examination of what happens to foraminifera from a Colombian Cretaceous black shale, and their potential for deriving information on diagenetic and deformational history [3]. Foraminifera body chambers can act as significant repositories of authigenic calcite, baryte, sphalerite and iron sulphides (pyrite and marcasite), which need to be taken into account when using Ba, Zn and Fe as geochemical proxies of environmental parameters such as productivity and redox conditions. In addition, the use of the SEM charge contrast imaging technique is used to illustrate high levels of foraminifera test lateral dissolution due to structural foreshortening during orogenesis.

Worden, Allen, Faulkner, Utley, Bond, Alcalde, Heinemann, Haszeldine, Mackay and Ghanbari describe and discuss the characteristics of two important North Sea mudstone units that will act as top seals for the underlying storage of CO_2 in planned carbon capture and storage (CCS) schemes (Acorn and East Mey CCS) [2]. Wireline logs, geomechanical tests, special core analysis and mineralogical and petrographic techniques are used to demonstrate the potential of wireline logs as a predictor of Young's modulus and thus the susceptibility of top seals to brittle fracture and the development of fracture leakage pathways. Both planned CCS scheme top seals are characterised as good for CO_2 storage with column heights of nearly 400 m, although the Lista Shale may develop fracture permeability by injected CO_2 due to the presence of locally quartz-rich horizons. In addition, they develop a model with four theoretical end-member shale top seal types, which can be used to predict likely seal integrity in terms of CO_2 storage, and is a useful tool in the consideration of other CCS projects.

Atar, Aplin, Lamoureux-Var, März and Wagner examined thirty-nine thin sections of Kimmeridge Clay Formation (KCF), from a 50 m Tithonian section of the Cleveland Basin, using optical microscopy and SEM, with additional data from total organic carbon analysis, XRF and stable carbon isotopes [5]. Six mudstone facies were identified, based on proportions of detrital clays, quartz, lithic clasts, organic matter, biogenic components, authigenic minerals as well as sedimentary textures and bedding characteristics. These mudstones were deposited under shallow marine conditions, with periods of high productivity (promoting organic matter preservation) and intermittent input of fines from fluvial systems. Deposition fluctuated between background sedimentation and current and/or storm-influenced sedimentation. As such, conditions were comparable to those previously noted for time-equivalent deposition in the Wessex Basin. The study warns that the careful consideration of facies and their environments of deposition is important in the interpretation of geochemical data.

Li, Zeng, Cai, Wang, Mu and Zhang examine the lacustrine mudrocks of the Shahejie Formation in the Dongpu Sag, which is an important petroleum basin in East China [7]. Optical microscopy of thin sections, XRD, major and trace element concentrations and pyrolysis were all used in the characterisation of the examined mudrocks. The authors record three facies types: (1) silt-rich massive mudstone; (2) homogeneous massive mudstone and (3) laminated mudstone. Facies one to three pass from shallow lake, dysoxic, low salinity and terrigenous-dominated to deeper lake, higher salinity, reducing environments, with authigenic sedimentation and higher organic matter preservation. Organic content is therefore controlled by facies, with the highest occurrence in the laminated mudstones. This explains the nine times higher hydrocarbon content in the northern part of the Dongpu Sag, which has much higher levels of laminated mudstone facies.

These seven papers demonstrate the range and depth of research currently being carried out on mudrock characterisation, which it is hoped will inspire further work into an area that is often overlooked.

Conflicts of Interest: The author declares no conflict of interest.

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