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Cathodoluminescence Imaging on Sedimentary Rocks: Quartz Sandstones

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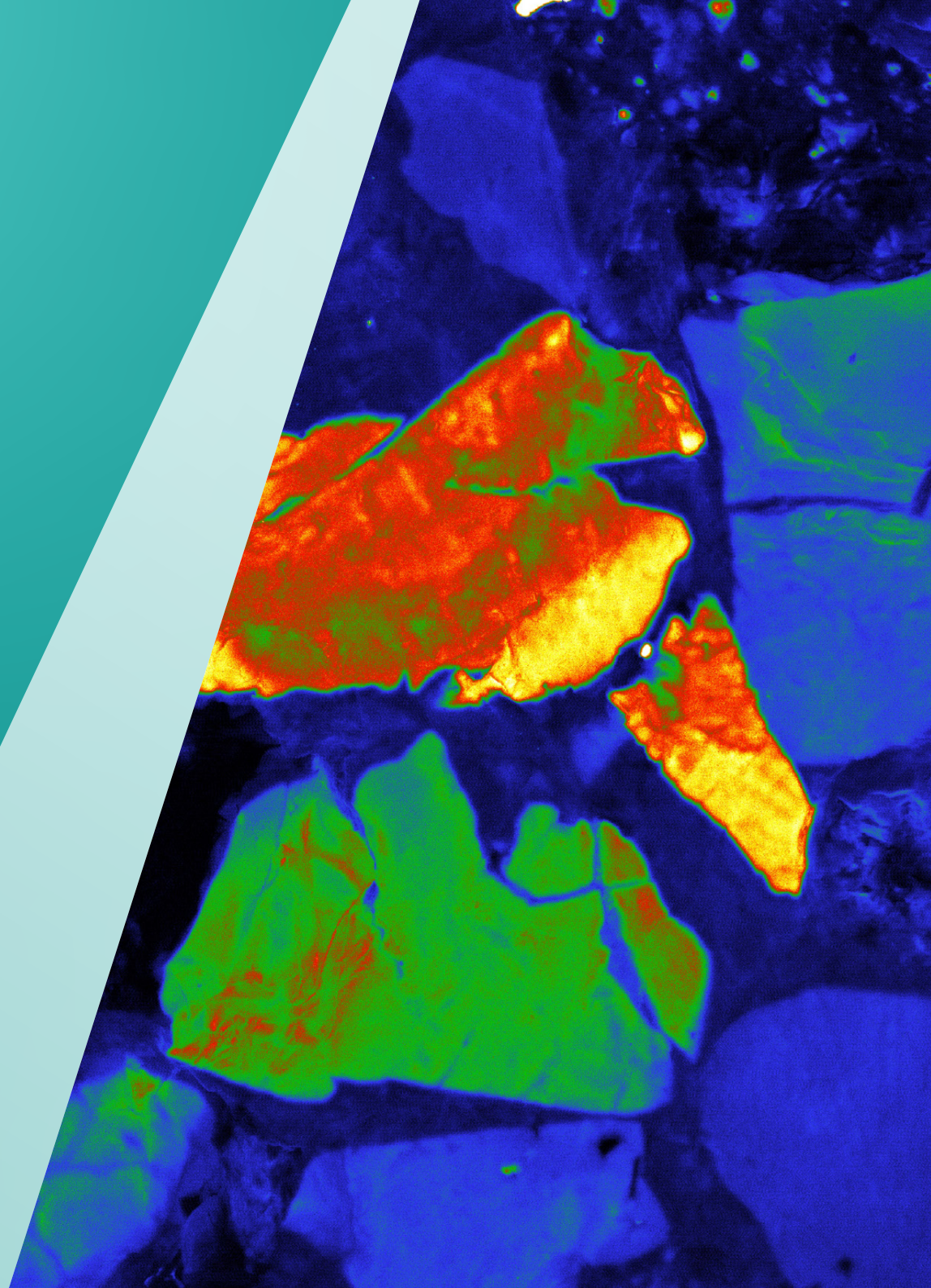

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Cathodoluminescence Imaging on Sedimentary Rocks: Quartz Sandstones

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Cathodoluminescence spectroscopy is a powerful tool for the micro-characterization of rocks and minerals, complementary to other electron microscopy-based techniques, such as backscattered electron imaging and energy/wavelength dispersive x-ray spectroscopy. In this white paper, we show how the technique can be employed to study quartz sandstone, a common type of sedimentary rock, which has gained both fundamental interest as well as practical interest in the form of fossil fuel exploration and extraction. In particular, we apply panchromatic (unfiltered), color-filtered, and hyperspectral cathodoluminescence imaging to reveal textures and contrasts of interest at the microscale which can aid in establishing the geological history as well as in porosity/permeability studies of such rocks.

Introduction

Sedimentary rocks are made up of a particular class of rocks which are formed by the weathering of the Earth's crust, the accumulation of shells secreted by organisms on the seafloor, and the precipitation of minerals from water. They are typically composed of granular material which has been lithified by pressure and temperature as the rock is buried deeper in the Earth's crust (if the deformations and changes in the material are too extreme the rock is classified as metamorphic.). The grain size can vary from less than 4 µm for clay materials up to more than 25 cm for some rudite materials.

Due to their granular structure, sedimentary rocks are generally quite permeable to fluids such as water. Minerals can precipitate from this infused water to form a cement that strongly binds the individual grains in the rock. Sedimentary rocks present a valuable source of iron and natural fertilizer. Furthermore, they form the main source of fossil fuels (oil, natural gas, and coal) and thus hold great practical value. In this case, the porous network in the rock determines the oil/gas holding capacity, as well as the transport properties which are relevant for the extraction of these resources [1].

Sandstone is a particular type of sedimentary rock which has strong relevance to the petroleum industry, as it presents one of the main rock types in which fossil fuels can be found. In sandstone, at least 50% of the grains must have a size between 60 and 200 µm. Sandstones often have a high quartz content, as quartz is more resistant to weathering compared to other common minerals such as feldspar and mica. Cement can also be present in sandstone which can strongly affect its porosity and permeability. The microscale/nanoscale topography and texture can be used to interpret the geological history of the rock. Furthermore, they directly affect the overall chemical, mechanical, and fluid transport properties of the rock and hence studying the rocks at those length scales is of high interest.

Over the course of the last decades, it has been demonstrated that scanning electron microscope (SEM)-based cathodoluminescence (CL) spectroscopy is a pertinent technique for the micro-characterization of sedimentary rocks [2-4]. In particular, it provides information that is complementary to SEM-based techniques, such as energy and wavelength dispersive x-ray spectroscopy (EDS, WDS), and electron backscattering imaging (BSE, EBSD). Typically the CL yield is high enough for rapid- and, in some cases, even video-rate scanning, allowing the fast inspection of relatively large areas. In the case of sandstone, CL imaging can be used to quantitatively map the quartz composition of the sample which enables, for instance, the rigorous segmentation of granular material and cemented material.