A novel quantitative approach to sedimentary petrography: Next-generation SEM-EDS-based automated mineral mapping

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The dynamic evolution of the Earth`s surface systems is recorded in terrestrial and marine sedimentary archives. However, post-depositional processes, such as diagenesis, metamorphism and hydrothermal overprinting, can alter the primary sedimentary constituents, which limits our understanding of the identity, origin, composition and genesis of individual grains. A fundamental limitation of previous paleo-environmental and paleo-depositional reconstruction studies is their reliance on bulk mineralogical and geochemical techniques, which are unable to differentiate sedimentary constituents of various origin, such as detrital (physical vs chemical weathering) and authigenic (syn-depositional vs burial diagenetic) grains. We demonstrate that next-generation Scanning Electron Microscopy with Energy Dispersive Spectroscopy (SEMEDS) analysis can now reveal the petrological context of each grain. This advancement comes as a result of recent technological improvements, including fast spectral acquisition times and quantitative deconvolution of mixed-phase spectra to produce ‘mixels’, which greatly improves mineral identification in previously troublesome fine-grained lithologies and at mineral/grain boundaries. We show that SEM-EDS-based mineral mapping can provide fully quantitative mineralogical data comparable to conventional X-ray diffraction analyses of powdered bulk rocks ($R2 > 0.95$, $n = 268$), if (i) strict error minimization spectral matching approaches are used, (ii) region of interest (ROI) placement is correct (i.e., vertical segments perpendicular to bedding especially in laminated fine-grained rocks) and (iii) the volume of the imaged area is properly defined (~1 mm^2). We examine novel applications for SEM-EDS-based mineral mapping and quantification in the Earth Sciences via selected case studies, featuring 1) a precise differentiation of detrital vs authigenic clays in paleoenvironmental and diagenetic contexts and 2) the utility to identify and characterize target grains or mineral fractions prior to geochemical (sequential mineral leaching protocols) or in-situ geochronological (Rb-Sr dating via LA-ICP-MS/MS) analysis of clayey sediments.