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LA-ICP-MS as Tool for Provenance Analyses in Arctic Marine Sediments

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The hydraulic transport of sediments is a major geological process in terrestrial and marine systems and is responsible for the loss, redistribution and accumulation of minerals. Provenance analyses are a powerful tool for assessing the origin and dispersion of material in ancient and modern fluvial and marine sediments. Provenance-specific heavy minerals (e.g., zircon, rutile, tourmaline) can therefore be used to provide valuable information on the formation of ore deposits (placer deposits), and the reconstruction of paleogeography, hydrology, climate conditions and developments. The application of provenances analyses for the latter reason is of specific interest, since there is need for research on the progressing climate change, and heavy minerals represent good proxies for the evaluation of recent and past changes in the climate. The study of these fine particles provides information about potential regional or long distance transport paths, glacial / ice drift and current flows, freezing and melting events as well as depositional centers for the released sediments.
Classic methods applied for provenance analyses are mapping of the presence / absence of diagnostic minerals, their grain size distribution, modal mineralogy and the analysis of variations in ratio of two or more heavy minerals. Electron microprobe has been established to discover changes in mineral chemistry of individual mineral phases, which can indicate fluctuations or differences in the provenance. All these methods bear the potential of high errors that lower the validity of the provenance analyses. These are for example the misclassification of mineral species due to undistinguishable optical properties or the limitations in the detection / variations of trace elements using the election microprobe.
For this case study, marine sediments from the Arctic Ocean have been selected to test if LA-ICP-MS can be established as a key technique for precise and reliable provenance analyses. The Laptev Sea is known to be a "sea ice formation factory" and represents a perfect source area with numerous sediment loaded rivers draining into the Arctic Ocean. Mineral grains become trapped in the sea ice, which is transported to the Fram Strait, the outflow area of the Transpolar Drift System. Thus, minerals in the Fram Strait and in the Laptev Sea should have the same provenance. In both areas zircon, garnet, ilmenite, magnetite, tourmaline, pyroxene and amphibole were identified (amongst others). The vast majority of potential source areas and the widespread occurrence of these accessory and rock forming minerals result in the absolute need for a highly sensitive and precise method such as LA-ICP-MS. We report new data on the eligibility of selected heavy minerals for provenance analyses in the Arctic Ocean. Based on the individual trace element composition, REE-pattern and isotopic ratios, reflecting the conditions during formation, we report individual fingerprints for single mineral species. This enables us to allocate specific minerals from Fram Strait and from Laptev Sea to one provenance. Furthermore we evaluate the eligibility of different heavy minerals as a geochemical proxy in Arctic sediments for provenance analyses using LA-ICP-MS.