Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.36135

The application of U-series laser ablation mass spectrometry in studying benthic mass flux variability in the late Quaternary

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U-series radionuclides (^{230}Th, ^{232}Th, ^{231}Pa, ^{238}U) are powerful tracers of particle fluxes, productivity, oxygenation, and sediment focusing in the ocean, yet their application in low-sedimentation-rate environments and heterogeneous archives has long been limited by analytical throughput and spatial resolution. Recent advances in laser ablation multi-collector ICP-MS now enable direct, micro-scale U-series measurements of various sediment archives, opening new opportunities to investigate benthic mass flux variability in the late Quaternary.

Here we synthesize recent developments and applications of U-series laser ablation techniques to investigate late Quaternary benthic mass flux variability. We then demonstrate in situ U–Th isotope measurements on hydrogenetic ferromanganese crusts from the oligotrophic North Pacific gyre. Micro-scale ^{232}Th records quantitatively track Asian dust input and closely match Chinese loess grain-size variability, extending reliable dust flux reconstructions to ~1.6 Ma. In contrast, paired ^{230}Th scavenging signals indicate that export productivity varied independently of dust supply, suggesting a dominant role of ocean stratification and nutrient redistribution rather than iron fertilization on orbital timescales.

We have also applied micro-domain U-series analyses to cold-seep carbonates, resolving spatial heterogeneity in U–Th systematics and directly constraining the timing and persistence of methane seepage. In situ determination of initial ^{230}Th/^{232}Th ratios improves U-series chronologies and reveals multi-phase seep activity linked to glacial–interglacial bottom-water changes. Finally, we highlight our recent applications, including rapid construction of ^{230}Th-based age models for large numbers of deep-sea gravity cores and combined ^{230}Th–^{231}Pa laser ablation analyses to trace past productivity changes in the North Pacific. Therefore, U-series laser ablation mass spectrometry offers a powerful technique for marine geochemistry and paleoceanographic flux reconstructions.