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Trace element and isotope proxies in paleoceanography: Starting a new synergic effort around marine geochemical proxies

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Reconstruction of past ocean states relies on the use of "proxies" (indicators or tracers), since it is impossible to directly measure variables such as water temperature, biological production and ocean circulation. In order to clarify the ocean's response to natural and anthropogenic forcings, it is essential to improve our knowledge of proxy behavior and the associated uncertainty. This task will be most efficiently achieved by the synergy between marine geochemists and paleoceanographers, as well as proxy and climate modelers. The first joint workshop of GEOTRACES-PAGES (geotracespages.sciencesconf.org) was such an occasion to identify open questions and scientific gaps of proxies used in paleoceanography. We focused mainly on trace elements and their isotopes (Fig. 1) that are targets of the GEOTRACES program (geotraces.org). These proxies are preserved in biogenic phases and/or bulk sediments and can be used to compare with simulated distribution to quantify physical and biogeochemical processes (Fig. 1). Sixty-four researchers and students from 11 countries from four continents gathered for this objective. The workshop consisted of a series of keynote talks and discussions around working groups with the following subjects: biological productivity, oceanic circulation, particle flux and sedimentation rate, and physical and/or biogeochemical modeling.

The keynote talks pointed out some recent findings, including the importance of recycled iron for biological productivity on seasonal-to-ice-age timescales (Rafter et al. 2017), and complex biomineralization processes of silicifiers and their impact on the silicon isotopic ratio (Hendry et al. 2018). Multi-tracer analysis of the same water sample is one of the strongest strategies of the GEOTRACES program, and multi-proxy reconstruction provides the most reliable results. However, different proxies sometimes tell us distinct stories. Since each proxy has its own advantage and potential bias, decoupling them can provide additional information. One of the most interesting examples of this decoupling is deep water circulation in the Atlantic Ocean during the last glacial maximum (LGM, 23-18 kyr BP). Three of the most frequently used geochemical proxies in paleoceanography do not tell a single, simple story: benthic foraminiferal carbon isotopic ratios ($^{13}C/^{12}C$ or $\delta^{13}C$) suggest weaker and shallower glacial North Atlantic deep water circulation with a dominant contribution of the southern source water (Lynch-Stieglitz et al. 2007), whereas the neodymium isotopic composition ($^{143}Nd/^{144}Nd$ or ε_{Nd}) recorded in authigenic oxides of planktonic foraminiferal calcites indicates a significant proportion of northern component waters in the North Atlantic over the LGM (Howe et al. 2016). The particle-reactive radionuclide ratio $^{231}Pa/^{230}Th$ suggests persistent southward transport of ^{231}Pa during the LGM (Bradtmiller et al. 2014). Reconciliation of these proxy reconstructions will be achieved by improved spatial coverage of tracer data in the modern ocean and proxy-enabled model experiments (Menviel et al. 2017; Muglia et al. 2018) with well-constrained parameters (e.g. particle concentration and partition coefficients according to the chemical composition of the particle), which can be obtained by process studies of the modern ocean, for example, from GEOTRACES.

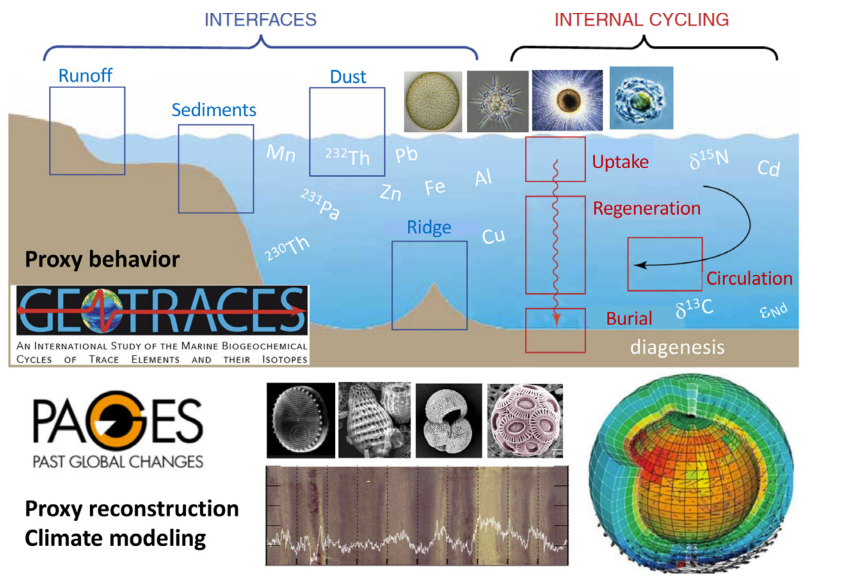

Figure 1: A schematic diagram presenting possible areas of interaction between the GEOTRACES and PAGES communities: targeted geochemical proxies, factors affecting their distribution, and paleoceanographic approaches associated with the proxies.

The workshop identified the necessity to reinforce the study of the water-sediment interface and early diagenetic processes. Benthic fluxes from the water-sediment interface may affect proxy distribution in the water column, and early diagenesis could modify the signature acquired in the upper-water column. More systematic and coordinated sampling of surface sediments and pore waters with samples collected in the overlying water column would help to scrutinize proxy behavior across this interface and promote core-top calibration.

The workshop was a great occasion to trigger coordinated actions that will be further developed in coming years. We identified products such as a compilation database of core-top samples suitable for proxy development and calibration, sensitivity tests and model-data comparisons, a synthesis paper on trace elements and isotope proxies used in paleoceanography and particle flux, intercalibration of methods used to analyze core-top sediments, and an outreach piece on paleo productivity.

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