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Fluctuation of marine osmium isotope ratio during the Quaternary climate cycles

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The solid earth plays a major role in controlling Earth's surface climate. Volcanic degassing of carbon dioxide (CO_2) and silicate chemical weathering are known to regulate the evolution of climate on a geologic timescale (>10^6 yr) [1], but the relationship between the solid earth and the shorter (<10^5 yr) fluctuations of the Quaternary glacial–interglacial cycles is still under debate. We employed the paelo-seawater osmium isotope composition ($^{187}Os/^{188}Os$), as a proxy for the solid earth's response to the Quaternary climate change. The marine $^{187}Os/^{188}Os$ reflects the relative intensity of two dominant influxes to the ocean: radiogenic continental-derived materials ($^{187}Os/^{188}Os$ = ~1.4) and unradiogenic mantle-like materials ($^{187}Os/^{188}Os$ = ~0.126) such as hydrothermal fluids and cosmic dust [2].

Our analytical results of deep-sea sediments at ODP Site 834 in the South Pacific Ocean showed that the seawater $^{187}Os/^{188}Os$ has varied during the past 300,000 years in association with glacial–interglacial cycles [3]. We implemented marine Os isotope mass-balance simulations and revealed that the observed $^{187}Os/^{188}Os$ fluctuation cannot be explained solely by changes in global chemical weathering rate corresponding to the Quaternary glacial–interglacial climate cycles [3]. Instead, the fluctuation can be reproduced by taking account of short-term inputs of (i) radiogenic Os derived from intense weathering of glacial till during deglacial periods [4] and (ii) unradiogenic Os derived from enhanced seafloor hydrothermalism triggered by sea-level falls associated with increases of ice sheet volume [5]. Our results constitute the first evidence that ice sheet recession and expansion during the Quaternary systematically and repetitively caused short-term (<10^5 yr) solid earth responses via chemical weathering of glacial till and seafloor magmatism. This finding implies that climatic changes on <10^5 yr timescales can provoke rapid feedbacks from the solid earth, a causal relationship that is the reverse of the longer-term (>10^6 yr) causality that has been conventionally considered.

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