



Tectonic forcing of global chemical weathering since the mid-Paleozoic

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Weathering of the Earth's surface has commonly been invoked as a driver of global cooling through geologic time. During the Phanerozoic Eon (541–0 million years ago, Ma), for example, the periodic onset of icehouse conditions has variously been attributed to enhanced weathering fluxes associated with mountain building (e.g. the Himalayas) (**1**), reductions in the global extent of continental arc volcanoes (e.g. the present-day Andes) (**2**), and uplift of oceanic crust during arc-continent collisions (e.g. present-day Indonesia and New Guinea) (**3**). These processes, tied to the global plate tectonic cycle, are inextricably linked. The resulting collinearity (i.e. independent variables are highly correlated) makes it difficult — using conventional statistical techniques — to isolate the contributions of individual geologic processes to global chemical weathering. An example of this is the Late Cenozoic Ice Age (34–0 Ma) that corresponds both to uplift of the Tibetan Plateau and Himalaya, and a gradual reduction in the extent of the global continental arc system.

We developed a machine learning framework to analyse the interdependencies between multiple global tectonic and volcanic processes (e.g., continental distribution, extent of volcanic arcs, mid-ocean ridges etc.) and seawater Sr composition (a proxy for weathering flux) over the past 400 million years. We developed a Bayesian network incorporating a novel algorithm that accounts for time lags for each of the predictor variables, and joint conditional dependence (i.e. how variables combine to influence the environmental outcome). Our approach overcomes problems traditionally encountered in geologic time series, such as collinearity and autocorrelation. Our results strongly indicate a first-order role for volcanism in driving chemical weathering fluxes since the mid-Palaeozoic. This is consistent with the strong empirical correlation previously observed between the strontium isotope composition of seawater and continental igneous rocks over the past billion years (**4**). Our study highlights how geologic processes operate together — not in isolation — to perturb the Earth system over ten to hundred million-year timescales.

References

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