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Continental weathering rates and atmospheric CO_2 in the Quaternary: constraints from ocean chemistry

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Ice cores provide outstanding records of atmospheric CO_2 concentrations on glacial-interglacial timescales. The link between the variability they document and Quaternary climate is much debated but poorly understood, and the origin of the glacial-interglacial cycles in atmospheric CO_2 remains one of the most important unsolved issues in modern Earth system science. Continental weathering plays multiple roles in atmospheric CO_2. On long timescales chemical weathering of silicates acts as a sink from the atmosphere. On shorter timescales (10^4-10^5 years), the supply of both alkalinity (through its impact on the oceanic carbonate system) and nutrients (through their control on the strength of the biological pump) have both been invoked as contributors to glacial-interglacial changes in atmospheric CO_2. A key question for the long-term control of chemical weathering on atmospheric CO_2 is the degree to which the very particular Quaternary climate leads to slower (because of slower mineral reaction rates in a colder climate) or faster (through glacial grinding of rock by ice-sheets and subsequent rapid weathering during interglacials) chemical weathering. The lack of strong constraints on this issue means that even the sign of the feedback that weathering exerts on Quaternary climate dynamics remains an open question. In the shorter term, the exact nature and distribution of chemical weathering (e.g. silicate versus carbonate) represent key unknowns.

In a companion presentation (Foster and Vance, this volume) we present a new high-resolution technique to measure changes in the Pb isotope composition of the oceans on a 10-20 kyr timescale and we argue that this record contains information on chemical weathering rates on the continents. In brief we find that, in areas affected by Northern Hemisphere Glaciation, chemical weathering rates were around 2-3 times slower during glacials than during interglacials. However, on the long term, weath-

ering rates have speeded up during the Quaternary due to the continual supply of pristine, fine-grained material by ice-sheets coupled with rapid chemical weathering during interglacials. Here we concentrate on the implications of the new data. The long-term increase in weathering rates suggest that icehouse conditions may have an in-built positive feedback in that they lead to faster chemical weathering and greater CO_2 drawdown. Previous work[1] has suggested that chemical weathering rates, largely of carbonate material, may have increased by about 20% during glacial periods due to the exposure of continental shelves by sea-level drop. Our data suggest that this increase is largely offset by lower weathering rates in glaciated regions, largely of silicate material. However, the impacts of these two processes on atmospheric CO_2 are likely to be very different. The detailed implications of these processes on atmospheric CO_2 will be explored with the aid of numerical models.

[1]Gibbs, M. T. and Kump, L. R., 1994, Global chemical erosion during the last glacial maximum and the present: sensitivity to changes in lithology and hydrology, *Paleoceanography* **9**, 529-543.