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The role of dynamic topography in the global weathering carbon budget

DR. ALEX LIPP[1], MARK HOGGARD[2], MENGZE LI[3], SIMON STEPHENSON[4], PHILIPPA SLAY[5], HILDE CRONWRIGHT[4] AND ROBERT HILTON[4]

[1]University College London
[2]The Australian National University
[3]Chinese University of Hong Kong
[4]University of Oxford
[5]University of Cambridge

The erosion and weathering of rocks plays a major role in the geologic carbon cycle. Traditionally, enhanced erosion was assumed to result in a greater CO_2 sink by enhancing the weathering of silicate minerals in the presence of atmospheric derived carbonic acid. However, more recently it has become understood that elevated erosion rates can also result in a carbon source via coupled weathering of sulfide-carbonate minerals and oxidation of petrogenic organic carbon. These carbon sources are most significant in regions of uplifted sedimentary rocks. Because of the faster mineral kinetics of these carbon source reactions, recent work [1] has argued that the weathering CO_2 sink is maximised at “moderate” erosion rates, below the highest erosion rates where silicate weathering becomes kinetically limited. In summary, an emerging paradigm implies that continental areas with low levels of sedimentary rocks and moderate erosion rates may be optimised as carbon sinks in the geologic carbon cycle.

In this work, we argue that dynamic topography, the uplift of Earth's surface due to processes operating in the lithospheric and asthenospheric mantle, is a geodynamic mechanism to generate such areas. From a global lithological analysis we demonstrate that regions uplifted by dynamic topography show larger proportions of basaltic silicates and lower proportions of both siliciclastic and carbonate sedimentary rocks relative to areas created by plate tectonic processes. Moreover, topographically, these regions, whilst steeper than the "background" continents, are notably less steep than regions in orogenic belts. We next present detailed hydrochemical data from a case-study on the Macleay River, Eastern Australia which drains a region of dynamic topography. Here, we show that both silicate and sulfide weathering rates increase with erosion rates. However, unlike in highly erosive areas such as Taiwan, the magnitude of the silicate weathering sink always exceeds the carbonate-sulfide carbon source. We will also present results using the rhenium proxy to constrain variations in petrogenic carbon oxidation rates. Overall, our results suggest that dynamic topography ought be recognised as a geodynamic mechanism to produce a moderately sized, background sink in the geologic carbon cycle.

[1] Bufe et al. (2024) *Science* **383***,* 6687 pp. 1075-1080