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Carbon Sink by Coupled Carbonate Weathering with Aquatic Photosynthesis: Control of Climate and Land-use Changes

LIU Zaihua*

State Key Laboratory of Environmental Geochemistry, Institute of Geochemistry, Chinese Academy of Sciences, Guiyang550081, China

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Abstract: Carbonate mineral weathering coupled with aquatic photosynthesis on the continents, herein termed coupled carbonate weathering (CCW, Fig. 1), represents a current atmospheric CO_2 sink of about 0.5 Pg C/a (Fig. 2). Because silicate mineral weathering has been considered the primary geological CO_2 sink, CCW's role in the present carbon cycle has been neglected. However, CCW may be helping to offset anthropogenic atmospheric CO_2 increases as carbonate minerals weather more rapidly than silicates. Here we provide an overview of atmospheric CO_2 uptake by CCW and its impact on global carbon cycling. This overview shows that CCW is linked to climate and land-use change through changes in the water cycle and water-born carbon fluxes. Projections of future changes in carbon cycling should therefore include CCW as linked to the global water cycle and land-use change.

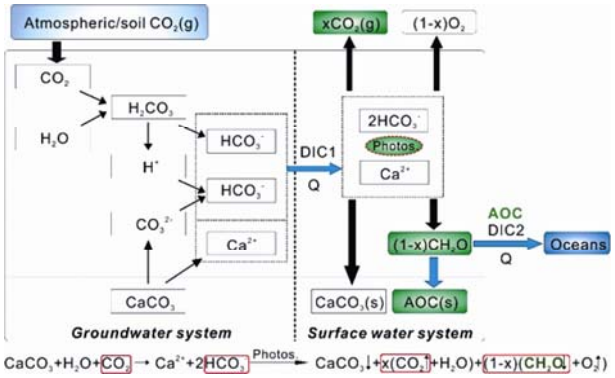

Fig. 1. Conceptual model of atmospheric/soil CO_2 uptake by coupled carbonate weathering (CCW, Liu et al., 2018).

Notes: 1. CSF (Carbon Sink Flux produced by CCW)=Q´(0.5[DIC2]+[AOC])/A+$F_{AOC(s)}$, where: Q is the discharge from the surface water system; the ratio 0.5 indicates that only one half of the HCO_3^- generated by carbonate mineral dissolution is of atmospheric origin; [DIC2] is the concentration of DIC (Dissolved Inorganic Carbon) in the surface water system; [AOC] is the concentration of AOC (Autochthonous Organic Carbon) in the surface water system transformed from DIC1 (DIC in the groundwater system) by submerged aquatic phototrophs via photosynthesis in the surface water system; and $F_{AOC(s)}$ is the sedimentary flux of AOC in the surface water systems over the watershed area (A). 2. Unlike the conventional carbonate mineral weathering carbon cycle model (Berner et al., 1983) (x=1 in the chemical reaction at bottom of the figure), which considers carbonate-H_2O-CO_2 interaction and ignores AOC production by aquatic photosynthetic uptake of DIC (Photos.=photosynthesis by autotrophs), this new conceptual model (0≤ x<1) helps to answer important questions such as whether CCW could be contributing to the long-term carbon sink (e.g., through sedimentation, burial of AOC), and thus, to a proportionate degree, controlling long-term climate change.

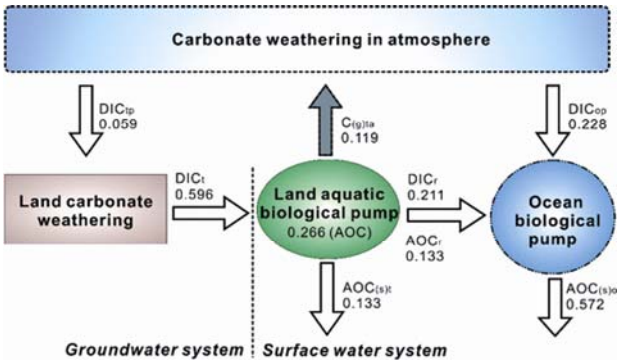

Fig. 2. Atmospheric carbon sources and sinks (Pg C/a) by coupled carbonate weathering (Liu et al., 2018).

DIC: Dissolved Inorganic Carbon; AOC: Autochthonous Organic Carbon; DICtp: Carbon sink resulting from precipitation on the land; DICop: Carbon sink resulting from precipitation in the ocean; DICt: Carbonate mineral weathering carbon flux on the land; C(g)ta: Carbon source flux from waters on the land; DICr: DIC flux from rivers to the ocean; AOCr: AOC flux from rivers to the ocean; AOC(s)t: AOC sedimentary flux in surface water systems on land (0.133=0.266x50%, i.e., assuming that half of the AOC was buried in terrestrial surface water system (Battin et al., 2009)); AOC(s)o: AOC sedimentary flux in the ocean. We attribute DIC and AOCr to short-term terms, while AOC(s)t and AOC(s)o may constitute long-term carbon sink by burial of AOC. Note: (1) The conventional carbon cycle model of carbonate mineral weathering (Berner et al., 1983) does not consider organic processes, i.e. x=1 in the CCW reaction (Fig. 1), and all CO_2 gas is returned to the atmosphere. Thus the carbonate mineral weathering does not form a net long-term carbon sink, and cannot influence climate change over extended timescales. The present CCW model took x=0.2, the mean release ratio of CO_2 from the surface water system to the atmosphere (with large variations from 2% to 30%, Liu et al., 2010), a net long-term carbon sink (AOC(s)t+AOC(s)o=0.705 Pg C/a) was derived, and may influence long-term climate change. (2) To fix the values of AOCr and AOC(s)t is more difficult because we are lack of systematic investigation of AOC formed by the biological carbon pump in the global terrestrial aquatic ecosystems. Therefore, more work is needed on this issue in future.

Keywords: CO_2 uptake, carbonate weathering, aquatic photosynthesis, global carbon cycle, climate change, land-use change

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* Corresponding author. E-mail: liuzaihua@vip.gyig.ac.cn

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About the author

LIU Zaihua, male, born in 1963 in Hunan Province; doctor; graduated from Bremen University of Germany; research professor of Institute of Geochemistry, Chinese Academy of Sciences. He is now interested in the study on the global carbon cycle. Email: liuzaihua@vip.gyig.ac.cn; phone: 0851-85892338, 13809404781.