The role of silicate weathering of intra-oceanic subductions on the atmospheric CO2 budget through geological time

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Résumé

One efficient driver for atmospheric CO2 removal over 10-100 Ma timescales is silicate-rich rock weathering, which is notably favored in the context of arc magmatism (Gernon et al., 2021). The modeling of the past evolution of atmospheric CO2 therefore requires to finely reconstruct the evolution of past subduction zones, which is challenging due to the permanent recycling of oceanic lithosphere. One difficulty notably resides in the reconstruction of intra-oceanic arcs, which leave almost no direct imprints in the geological record, although they could significantly contribute to the atmospheric CO2 removal through silicate weathering, especially in the tropics (Gaillardet et al., 2011). We propose to test how the variability of intra-oceanic arcs can affect the amount of CO2 removed from the atmosphere through supercontinent cycles. To do so, we use 3D numerical models of whole-mantle convection self-generating Earth-like plate tectonics in order to quantify the temporal evolution of the number and length of intra-oceanic arcs, in a fully-dynamic context, independent of any plate reconstructions. We use the automatic plate tessellation algorithm MAPT3 based on the open-source library Topology ToolKit (Janin et al., in rev.) to detect subduction zones. We show that the total length of intra-oceanic arcs varies significantly depending on the continental configuration in the models. We then test the sensitivity of atmospheric CO2 absorption level through silicate weathering to the latitudinal distribution of the intra-oceanic arcs, their width and fraction above sea-level, and the potential effect of True Polar Wander.

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Finally, we compare the amount of weathering produced in our geodynamic models with Earth's estimates deduced from a one-billion-years plate reconstruction (Merdith et al., 2021) using the climate-enabled biogeochemistry box model SCION (Mills et al, 2021). We show that in a fully-dynamic model, it is possible to reach the amount of extra-weathering required to possibly explain the atmospheric CO2 and temperature drops observed, especially during periods of continental aggregation. Nevertheless, the amount of intra-oceanic subduction zones in the geodynamic models varies over longer timescales than in the plate reconstruction, and cannot explain alone, rapid cooling events, such as during the Hirnantian (Marcilly et al., 2022).

Mots-Clés: intra, oceanic arcs, mantle convection, silicate weathering