Reconstruction of global biogeochemical cycle of Silicon in the geologic past from ocean sediment core records

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BACKGROUND
1. Opal (an amorphous form of Si from marine Si-secreting organisms) content in marine sediments can be informative of paleoecology and paleoceanography and palaeoproductivity on both short and long time scales.
2. Box-model is used to simulate the changes in the Si mass and isotope in the seawater [Fig.2]

QUESTION TO BE ADDRESSED
- Model the global biogeochemical cycle of silicon mass and isotope dynamics to reconstruct seawater Si changes and paleoecology of Si-secreting organisms since Last Glacial Maximum (LGM).
- Major drivers of the cycle are temperature, pH, and biocycling.
- Comparison to sediment core records
- Applicable to the future, the better the model

CONCLUSION
1. Model Si mass and isotope change is possible utilizing box-model, though more complexity should be added.
2. Temperature-dependent change may not be enough to yield a 0.6% difference between LGM and present.
3. The variations ofopal sedimentation and burial rates over the last 1 Myr are controlled by Si input and biocycling.

FUTURE WORK
- Global Si BIOCYCLE: Use global opal and Si-shelled biota biogeochemical and stratigraphic records to restore Si biogeochemical cycle.
- Part II: marine Si isotopic modeling of paleoceanography and future climate changes.

REFERENCES

Fig.1 Temperature profiles from LGM (10 °C) to pre-industrial times (~15 °C) used in the simulation. Temperature is directly related to bioproduction and dissolution by Q10 factor and Arrhenius equations, respectively.

Fig.2 (bottom) Biogeochemical cycle of Si in Last Glacial Maximum.

Fig.7 Zonal river discharge of water, DSi and particulate Si in modern global watered surveys and literature values.

Fig.8 Model setup used for future projections, under climate and human controls.

Fig.9 Coastal Domain

Tab. 2 Literature range of δ30Si references listed in the end.

PART I MARINE SI ISOTOPE BALANCE MODEL AND LINEAR TEMPERATURE INCREASE EXPERIMENT
To extend from the Si mass-balanced model, a marine Si isootope balance model is established (Fig.3). The isotope value of each reservoir satisfies the steady-state equations

First a linear increase of temperature case is used to study the behavior of the model, assuming LGM–10 °C and increase to pre-industrial time T=15 °C linearly (blue curve in Fig. 1).

Fig.9 Marine and land biogeochemical budget

Fig.10 Temperature change contributed to about almost 50% bioproduction on land but less effective in the ocean productivity. The warming climate and enhanced hydrological cycle also drove the chemical weathering of continental silicate rocks and phylolith remineralization that increased riverine input of dissolved Si (Fig.6).

The increase in the continental, diatom, and radiolarian Si is largely affected by temperature, resulting a 'flat' variation in deposition, on the other hand radiolarian change is more monotonic.changes and impact on land and marine Si cycles.

The isotope changes indicate the Si paleocycling is to a large extent closed and Si-limiting. Isotope signature is largely affected by paleoproductivity.

Fig.11 Coastal and oceanic Si budget

To an extent, the model successfully resolves the Si water chemistry and isotopic changes.

However, there are some DISCREPANCIES in the field data and simulation results. Possible reasons are:
1. The model is not a closed system as assumed in the regional sea studies, thus the ocean DSi is not as strongly enriched in heavy Si isotopes during opal production.
2. The dynamic between radiolarian, a cold water heterotrophy and marine diatom may be more complicated than competition over available DSi and better constrain on fluxes, isotope values and fractionation should be obtained.
3. Other factors, chemical weathering, erosion changes, hydrological settings, coupled with bioproduction, etc.

Fig.1 Data from De La Rocha, 1998. Arrows indicate the level of δ30Si in the core as determined from radiolarian C. davisoni counts, δ 0 Corg measured from diatom organic matter.

Fig.12 Coastal and oceanic temperature change.