Changing Tides: Phosphate Desorption from Calcite in Freshwater-Seawater Mixing Zones

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Introduction

Coastal estuaries, like the Florida Everglades (Fig. 1), are rich in biodiversity and require specific conditions in order to thrive.

Coastal estuarine environments are phosphate-limited, meaning the availability of phosphate (P) determines the ecological structure of the ecosystem as well as the productivity.

Fig. 1: Florida Bay, part of the estuarine ecosystem in the Florida Everglades.

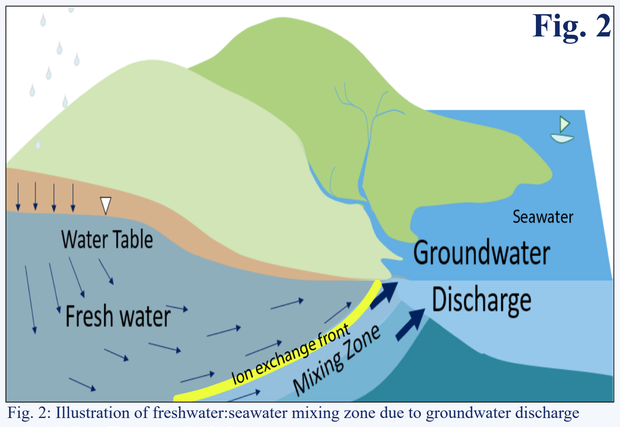

Fig. 2: Illustration of freshwater:seawater mixing zone due to groundwater discharge (adapted from Flower, et al. 2015).

One crucial source of phosphate is the release (desorption) of phosphate from mineral surfaces due to freshwater and seawater mixing (Price et al. 2006). In coastal aquifers, freshwater and seawater mix and this creates a continuum of increasing salinity, starting from the freshwater side (Fig. 2). Due to groundwater discharge, desorbed P will be brought to the overlying estuary.

Adsorption of P is more favorable in freshwater, while an introduction of seawater causes desorption (Fig 3).

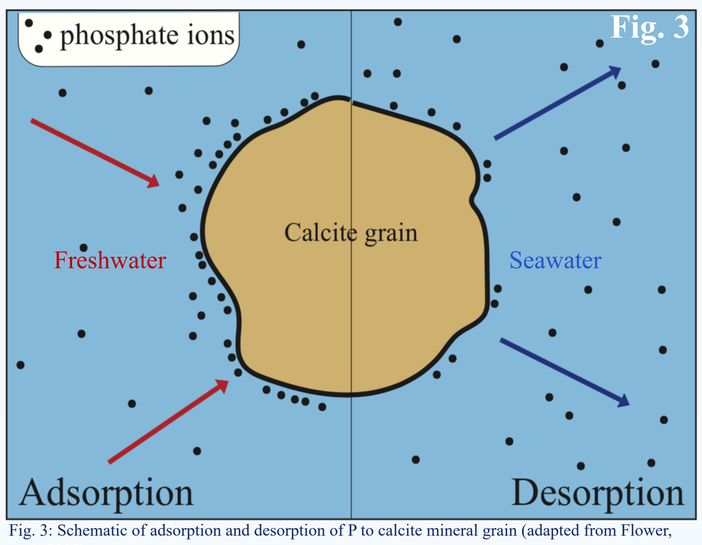

Fig. 3: Schematic of adsorption and desorption of P to calcite mineral grain (adapted from Flower, et al. 2015).

Overall Questions

Does seawater cause phosphate release from calcite?

If so, what percentage of seawater is needed to increase P release from calcite?

Results

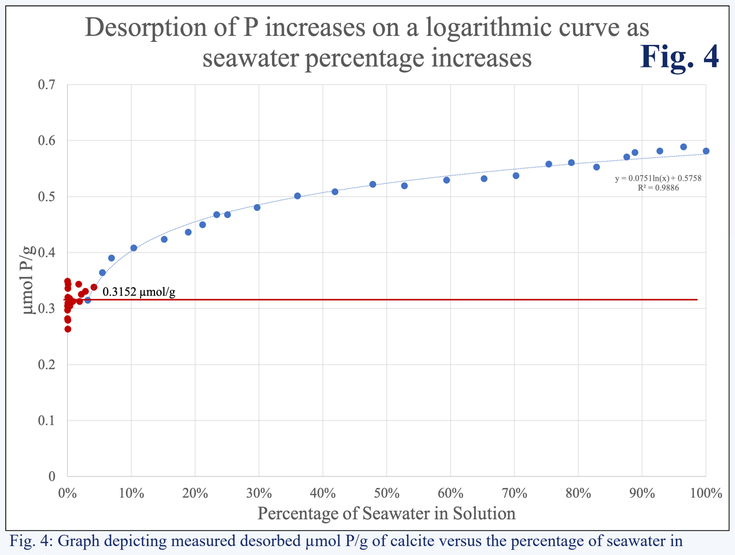

Fig. 4: Graph depicting measured desorbed µmol P/g of calcite versus the percentage of seawater in solution

Beginning at ~3%, there is a consistent logarithmic increase in P desorption from calcite as seawater content increases. Initial introduction of seawater has a greater effect on P desorption than do later, higher seawater percentages.

We observed that once seawater concentration hits the ~3% seawater mark, P will desorb from calcite at increasingly high levels.

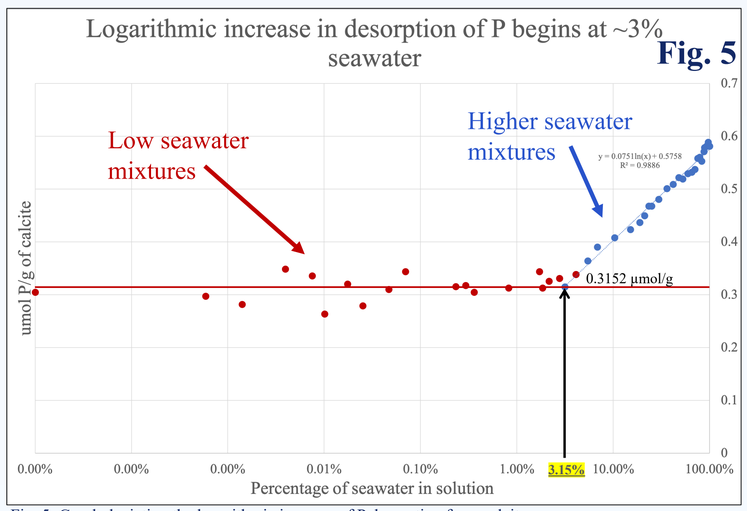

Fig. 5: Graph depicting the logarithmic increase of P desorption from calcite

Conclusions

- As seawater concentration increases, calcite will lose some adsorption affinity for P and release P into the ambient water
- Release of P by calcite is shown to occur in a logarithmic fashion, where initial seawater percentages induce more of a change in P desorption than higher concentrations of seawater (Fig. 4)
- A logarithmic increase in P desorption begins at ~3%, meaning that a threshold of ~3% seawater is needed to increase P desorption above baseline freshwater levels
- Our findings have potential to inform restoration and water management efforts in the face of rising sea levels (especially in regions with calcareous limestone like Apulia, Italy, Majorca, Spain, and the Florida Everglades)

Methods

1. Loaded 43 individual test tubes with P-loaded calcite
2. Dispensed 40 mL of a mixture of freshwater and seawater in various proportions into each tube
3. Equilibrated (shook) all samples on a tabletop shaker for three days
4. Water was filtered and analyzed for P

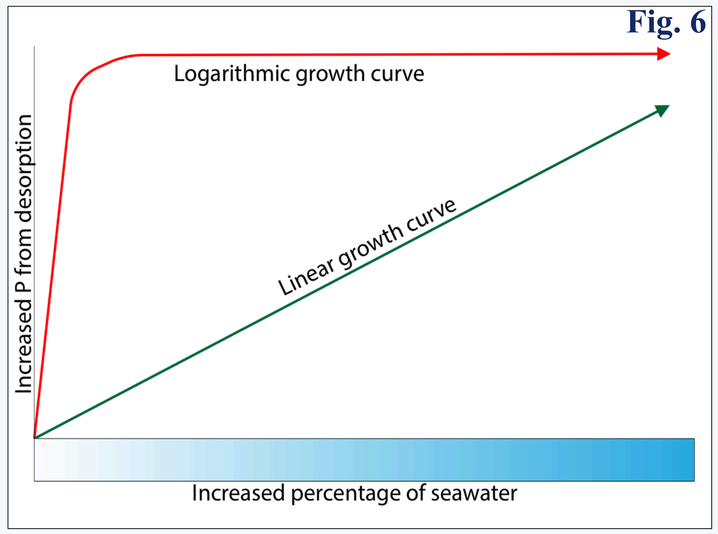

Fig. 6: Schematic of two hypothesized ways in how P desorption may occur with calcite (adapted from Flower et al. 2015).

References

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Acknowledgements

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