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Stabilization of organic carbon in salt marsh sediments: A physical protection perspective

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Overview

Salt marshes are globally significant repositories of organic carbon (OC), and have received attention as potential locales where anthropogenic CO_2 could be sequestered through marsh production and accretion. However, unlike organogenic (peaty) marshes that only receive OC input from local production, minerogenic marshes receive OC from both autochthonous and allochthonous sources, complicating the relationship between local CO_2 fixation and OC burial. Therefore, our project addresses the following questions: What is the relative importance of autochthonous and allochthonous OC buried in minerogenic salt marsh sediments, and what are their likelihoods for preservation during burial?

To help distinguish allochthonous OC from autochthonous OC, we: (1) separate bulk sedimentary OC according to density; and (2) examine OC dynamics in areas dominated by C4 production. Density fractionation allows gross separation of low-density organic detritus (dominated by autochthonous OC) from mineral associated OC (assumed 100% allochthonous at time of deposition). Conducting the work in zones under C4 macrophyte cover (in this case *Spartina foliosa*) allows use of $\delta^{13}C$ signatures as tracers for autochthonous from allochthonous OC (predominantly C3).

Summary of progress made during the reporting period

FIELD WORK: In January and February of 2018, we collected 6 additional sediment cores from two sites in San Francisco Bay: Don Edwards Wildlife Refuge, and in a marsh along Gallinas Creek, immediately north of China Camp State Park. At both sites, three cores were collected along a transect that ran perpendicular to the coastline. Two cores were retrieved from within the *Spartina* zone, and one from the mudflat.

LABORATORY WORK: We (1) processed three more depth intervals from the first sediment core collected in Yr-1 for bulk chemical analyses; (2) processed samples from the Yr-1 core for $\Delta^{14}C$ analyses; (3) processed a subset of low-density filter samples collected in Yr-1 for isotopic signatures; and (4) density fractionated 24 depth intervals from the 6 new sediment cores sampled in Yr-2. We also collected, dried, and pulverized >2-mm detritus from all sediment intervals for further analyses.

FINDINGS THUS FAR: Results to date are all from the Yr-1 core retrieved from the *Spartina* zone adjacent to Gallinas Creek; data from the 6 new cores collected in 2018 are not yet available.

Results reported herein involve the following density isolates: **f-LF** (particles with density of ≤1.6 g/mL that are largely unassociated with minerals); **m-LF** (particles with density of ≤1.6 g/mL that are obtained only after disrupting mineral disaggregates by ultrasonication); **t-MAF** (total mineral-associated fraction obtained by removing f-LF from the bulk sample); **s-MAF** (stable mineral-associated fraction obtained after removing m-LF from t-MAF); **CF** (particles with density between 1.6 and 2.5 g/mL presumably rich in clay minerals); **HvF** (highest density with density >2.5 g/mL).

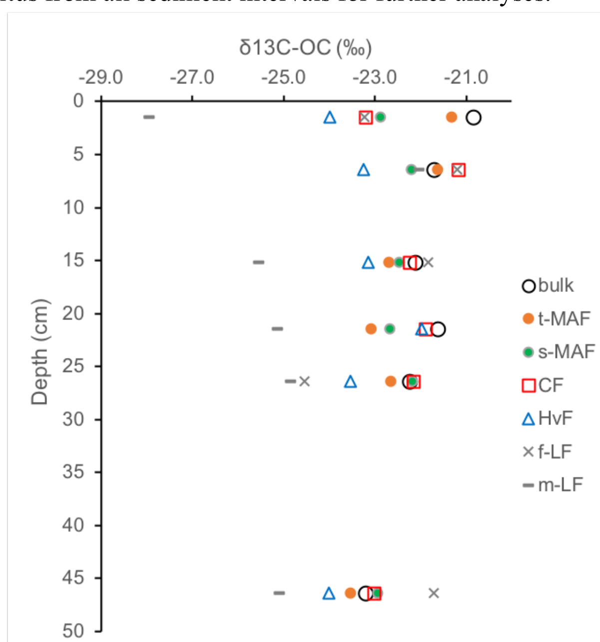

Figure 1. Depth profiles of $\delta^{13}C$ signatures of bulk sediment and its density isolates collected from the *Spartina* zone adjacent to Gallinas Creek, San Francisco Bay.

At the bulk level, sediments accumulating in the *Spartina* zone adjacent to Gallinas Creek show $\delta^{13}C$ values that are intermediate between $\delta^{13}C$ values reported for estuarine seston and for *Spartina* in San Francisco Bay (~-25‰ and ~-15‰, respectively[1]; Fig. 1). Density isolates exhibit distinct $\delta^{13}C$ values, and this spread is most pronounced at the sediment surface and attenuates with depth. In particular, $\delta^{13}C$ values of bulk sediment and t-MAF decline with depth, while $\delta^{13}C$ values of CF and HvF increase within the top ~20 cm (within the root zone; Fig. 1). We hypothesize that this convergence in $\delta^{13}C$ values across density isolates with increasing sediment depth are due to combined effects of: (a) degradative loss of autochthonous OC during burial; and (b) slow incorporation of ^{13}C-rich autochthonous OC into the mineral-associated pools. The f-LF isolate was expected to show $\delta^{13}C$ values similar to those reported for *Spartina*, but this is not observed (Fig. 1). Preliminary mass balance calculations suggest that, at least for the surface sediments, there is enhanced loss of autochthonous OC during density fractionation, lowering the $\delta^{13}C$ values of the density isolates (Fig. 2).

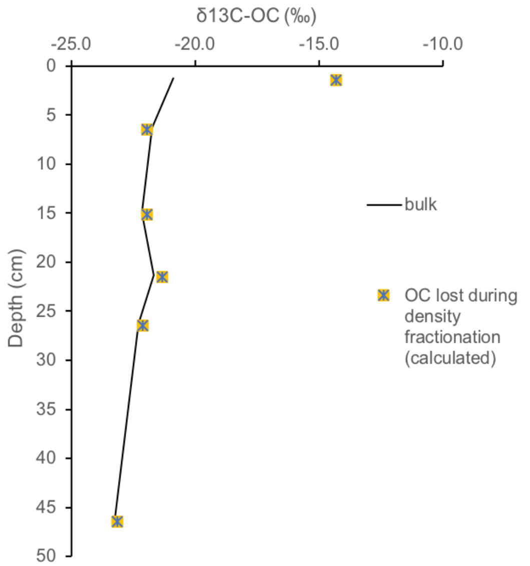

Figure 2. Depth profiles of $\delta^{13}C$ signatures of bulk sediment and the OC that was lost during density fractionation (calculated from mass balance).

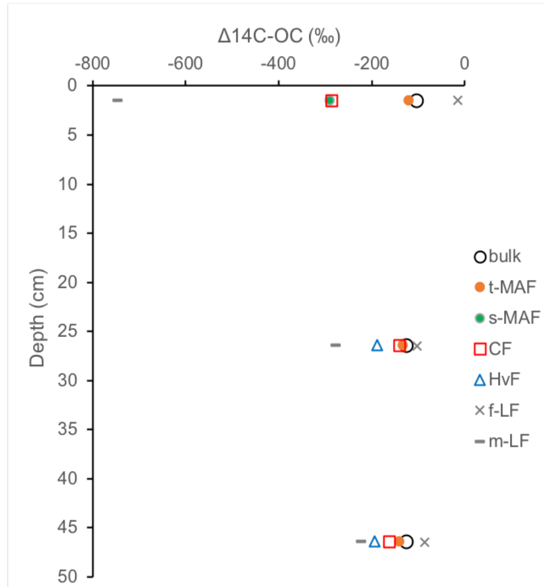

Figure 3. Depth profiles of $\Delta^{14}C$ signatures bulk sediment and its density isolates collected from the *Spartina* zone adjacent to Gallinas Creek, San Francisco Bay.

$\Delta^{14}C$ values show that mineral-bound OC in these sediments is on average significantly older than what is expected of autochthonous OC [2,3], pointing to presence of pre-aged, imported OC (Fig. 3). f-LF shows the highest $\Delta^{14}C$ values at all depths indicating that this fraction is relatively rich in recent OC. Consistent with the $\delta^{13}C$ data, $\Delta^{14}C$ values of CF show a large increase with depth, suggesting incorporation of autochthonous OC. The $\Delta^{14}C$ and $\delta^{13}C$ values of m-LF are both considerably lower than the other isolates, possibly due to occurrence of petroleum-derived black carbon in this fraction[4].

Impact on students and PI

STUDENTS: This project provided robust research experience and professional training for a number of students. The fact that this project is accessible (includes many laboratory procedures that are readily mastered by undergraduate students), and requires teamwork (laboratory procedures that are best done in pairs; field work) promoted camaraderie and helped create an environment conducive to student learning. During this reporting period, 4 undergraduate students and one graduate student actively participated in the project. Mr. Bravo (undergraduate) and Ms. Brinkmann (graduate) presented their work on this project at the SFSU College of Science and Engineering Student Project Showcase in May 2018, and both won 2nd place in their respective categories. Mr. Bravo also won a travel award to attend the 2018 SACNAS conference in Texas in October 2018 where he will present his findings from this project; this will be his first professional conference. In addition, this project provided a robust summer research experience for Ms. Wong (NSF-REU scholar). This experience has strengthened Ms. Wong's intent to pursue a Ph.D. in STEM. Finally, this project formed the foundation of Ms. Brinkmann's MS thesis which she completed in Aug 2018. Ms. Brinkmann presented her MS work at the ASLO conference in Victoria, British Columbia in June 2018.

PI: This project has impacted the PI in two major ways. First, it has allowed the PI to explore a new research direction. As a sediment biogeochemist interested in carbon cycle processes, the PI has primarily focused on offshore sedimentary environments in her research to-date. This project provided an opportunity to expand her scope of work by applying her area of expertise to a new system: tidal wetlands and marshes. These vegetated habitats are arguably much more complex than offshore depositional environments, and so far, this project has proved to be a positive learning experience for the PI. Second, this project has allowed the PI to begin to establish connections with wetland scientists, opening doors for new, and potentially fruitful, collaborations. Publications that will result from this project will help the PI obtain a footing in a field that is currently dominated by ecologists.

References

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3. Komada T., Polly J. A., Johnson L. 2012, 57, 567–581.
4. Wagai, R., Mayer, L. M., Kitayama, K. *Soil Sci. Plant Nutr.* 2009, 55 (1), 13–25.