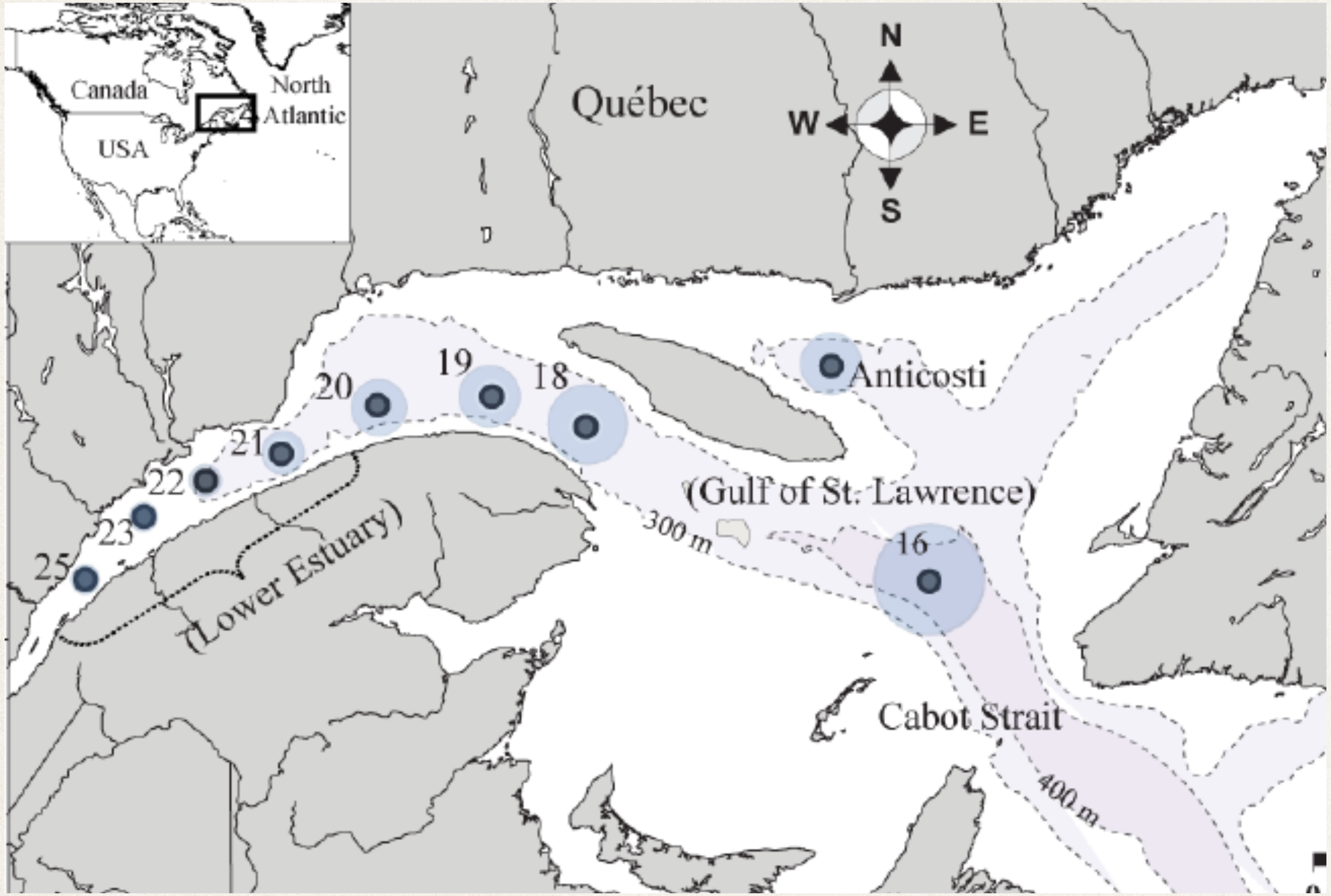
The Priming Effect in sediments of a cold temperate estuarine system

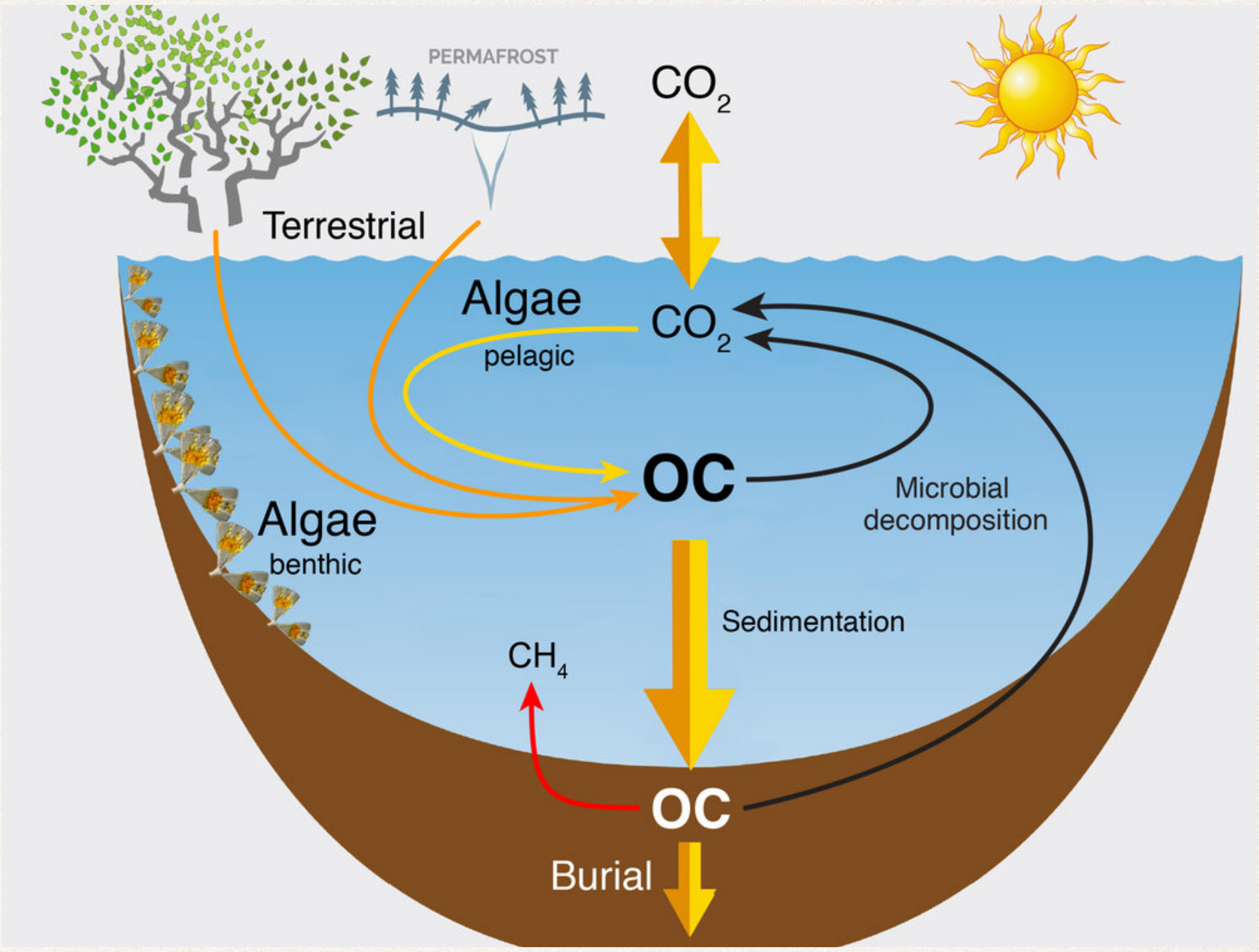
An Assessment using Compound Specific Stable Carbon Isotope Measurements of Bacterial Fatty Acids

Maria-Elena Radu, Yves Gélinas

LEGO LAB



Canada
North
Atlantic
USA
Québec
N
W
E
S
Anticosti
20
19
18
21
22
23
25
(Lower Estuary)
(Gulf of St. Lawrence)
300 m
16
Cabot Strait
400 m

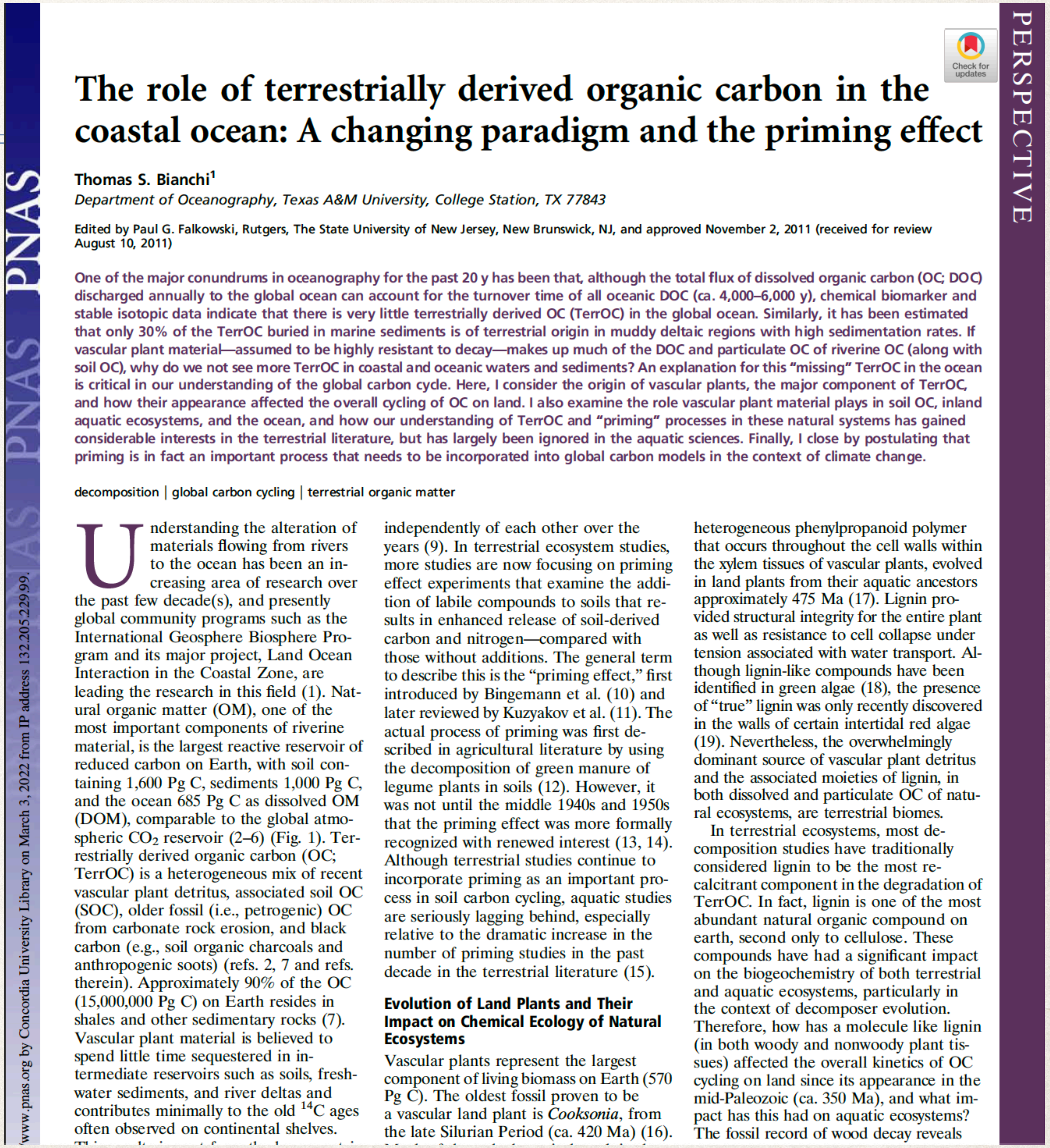


PERMAFROST
CO_2
Terrestrial
Algae
pelagic
CO_2
OC
Algae
benthic
Microbial
decomposition
Sedimentation
CH_4
OC
Burial


Priming Effect
Nutrients

Priming Effect (PE)

- Tested methods: analysis of CO_2 and carbon isotope ratio in seawater samples being produced in the system
  - e.g. variation in microbial respiration, reactivity of dissolved organic matter (DOM); changes in CO_2 efflux and N mineralization rate;
- Potential Method: analysis on bacteria (what is actively degrading), the type of preferred food
  - e.g., bacterial degradation through bacteria specific isotopes *isoC15:0* and *anteisoC15:0*.



PERSPECTIVE

The role of terrestrially derived organic carbon in the coastal ocean: A changing paradigm and the priming effect

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One of the major conundrums in oceanography for the past 20 y has been that, although the total flux of dissolved organic carbon (OC; DOC) discharged annually to the global ocean can account for the turnover time of all oceanic DOC (ca. 4,000–6,000 y), chemical biomarker and stable isotopic data indicate that there is very little terrestrially derived OC (TerrOC) in the global ocean. Similarly, it has been estimated that only 30% of the TerrOC buried in marine sediments is of terrestrial origin in muddy deltaic regions with high sedimentation rates. If vascular plant material—assumed to be highly resistant to decay—makes up much of the DOC and particulate OC of riverine OC (along with soil OC), why do we not see more TerrOC in coastal and oceanic waters and sediments? An explanation for this "missing" TerrOC in the ocean is critical in our understanding of the global carbon cycle. Here, I consider the origin of vascular plants, the major component of TerrOC, and how their appearance affected the overall cycling of OC on land. I also examine the role vascular plant material plays in soil OC, inland aquatic ecosystems, and the ocean, and how our understanding of TerrOC and "priming" processes in these natural systems has gained considerable interests in the terrestrial literature, but has largely been ignored in the aquatic sciences. Finally, I close by postulating that priming is in fact an important process that needs to be incorporated into global carbon models in the context of climate change.

decomposition | global carbon cycling | terrestrial organic matter

Understanding the alteration of materials flowing from rivers to the ocean has been an increasing area of research over the past few decade(s), and presently global community programs such as the International Geosphere Biosphere Program and its major project, Land Ocean Interaction in the Coastal Zone, are leading the research in this field (1). Natural organic matter (OM), one of the most important components of riverine material, is the largest reactive reservoir of reduced carbon on Earth, with soil containing 1,600 Pg C, sediments 1,000 Pg C, and the ocean 685 Pg C as dissolved OM (DOM), comparable to the global atmospheric CO_2 reservoir (2–6) (Fig. 1). Terrestrially derived organic carbon (OC; TerrOC) is a heterogeneous mix of recent vascular plant detritus, associated soil OC (SOC), older fossil (i.e., petrogenic) OC from carbonate rock erosion, and black carbon (e.g., soil organic charcoals and anthropogenic soots) (refs. 2, 7 and refs. therein). Approximately 90% of the OC (15,000,000 Pg C) on Earth resides in shales and other sedimentary rocks (7). Vascular plant material is believed to spend little time sequestered in intermediate reservoirs such as soils, freshwater sediments, and river deltas and contributes minimally to the old ^{14}C ages often observed on continental shelves.

independently of each other over the years (9). In terrestrial ecosystem studies, more studies are now focusing on priming effect experiments that examine the addition of labile compounds to soils that results in enhanced release of soil-derived carbon and nitrogen—compared with those without additions. The general term to describe this is the "priming effect," first introduced by Bingemann et al. (10) and later reviewed by Kuzyakov et al. (11). The actual process of priming was first described in agricultural literature by using the decomposition of green manure of legume plants in soils (12). However, it was not until the middle 1940s and 1950s that the priming effect was more formally recognized with renewed interest (13, 14). Although terrestrial studies continue to incorporate priming as an important process in soil carbon cycling, aquatic studies are seriously lagging behind, especially relative to the dramatic increase in the number of priming studies in the past decade in the terrestrial literature (15).

Evolution of Land Plants and Their Impact on Chemical Ecology of Natural Ecosystems

Vascular plants represent the largest component of living biomass on Earth (570 Pg C). The oldest fossil proven to be a vascular land plant is *Cooksonia*, from the late Silurian Period (ca. 420 Ma) (16).

heterogeneous phenylpropanoid polymer that occurs throughout the cell walls within the xylem tissues of vascular plants, evolved in land plants from their aquatic ancestors approximately 475 Ma (17). Lignin provided structural integrity for the entire plant as well as resistance to cell collapse under tension associated with water transport. Although lignin-like compounds have been identified in green algae (18), the presence of "true" lignin was only recently discovered in the walls of certain intertidal red algae (19). Nevertheless, the overwhelmingly dominant source of vascular plant detritus and the associated moieties of lignin, in both dissolved and particulate OC of natural ecosystems, are terrestrial biomes.

In terrestrial ecosystems, most decomposition studies have traditionally considered lignin to be the most recalcitrant component in the degradation of TerrOC. In fact, lignin is one of the most abundant natural organic compound on earth, second only to cellulose. These compounds have had a significant impact on the biogeochemistry of both terrestrial and aquatic ecosystems, particularly in the context of decomposer evolution. Therefore, how has a molecule like lignin (in both woody and nonwoody plant tissues) affected the overall kinetics of OC cycling on land since its appearance in the mid-Paleozoic (ca. 350 Ma), and what impact has this had on aquatic ecosystems? The fossil record of wood decay reveals

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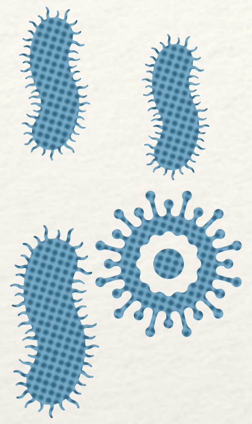
Bacteria specific fatty acids (*isoC15:0* and *anteisoC15:0*)

Sediment OM

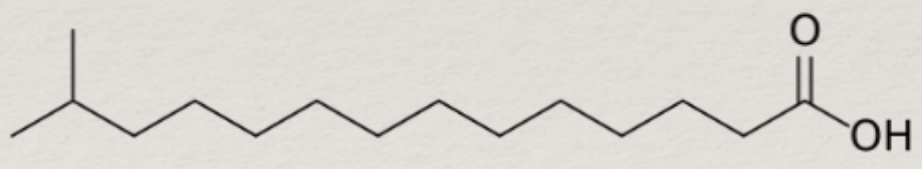
Fresh OM



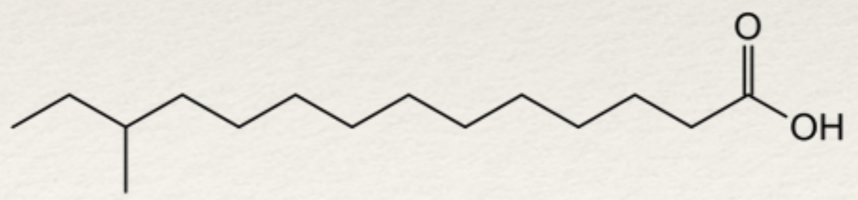
↑ *O_2 consumption*

Respiration (CO_2 production) → *Dissolved CO_2 and HCO_3^-*

Biomass incorporation → ***Fatty Acid (FA) synthesis***



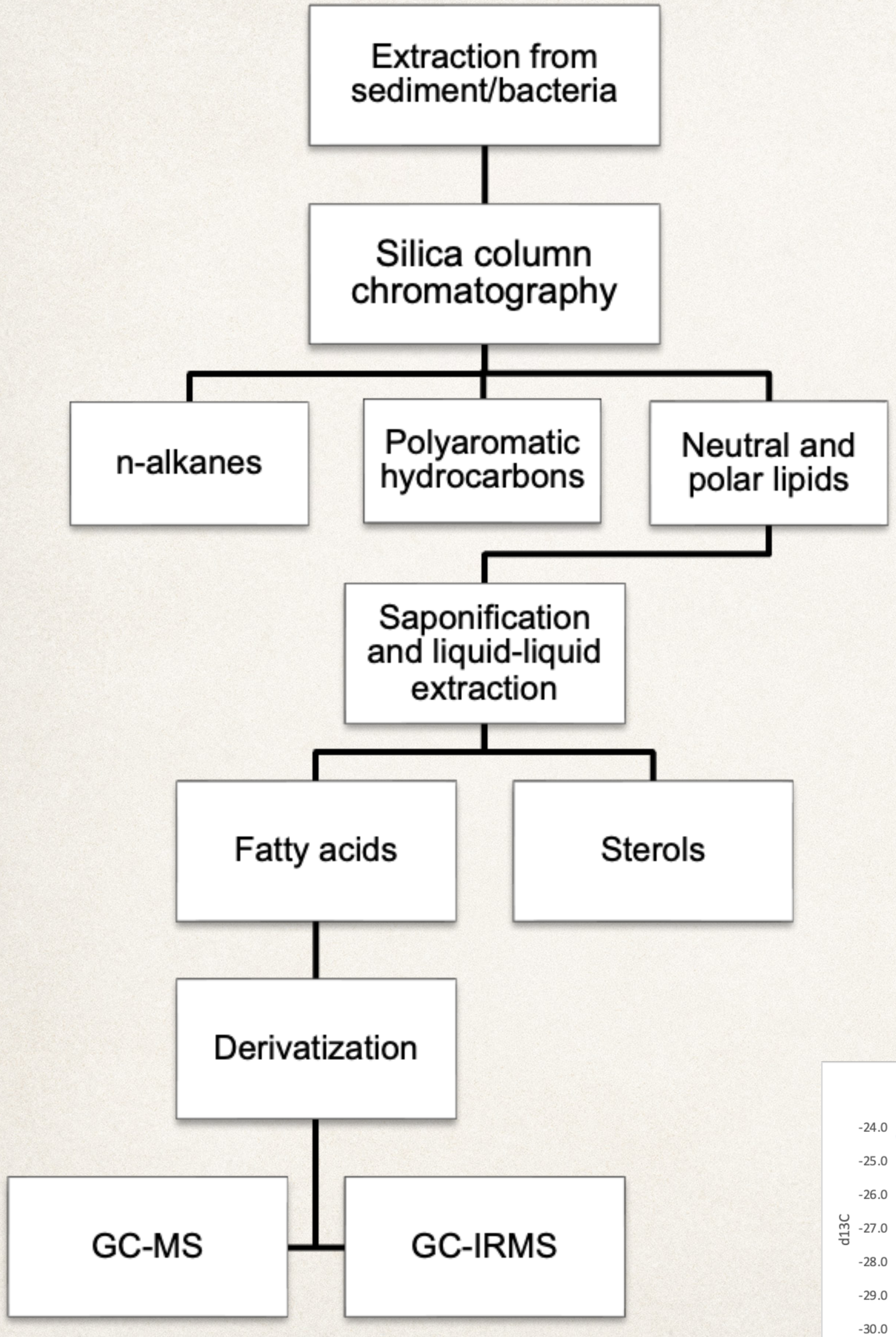
isoC15:0

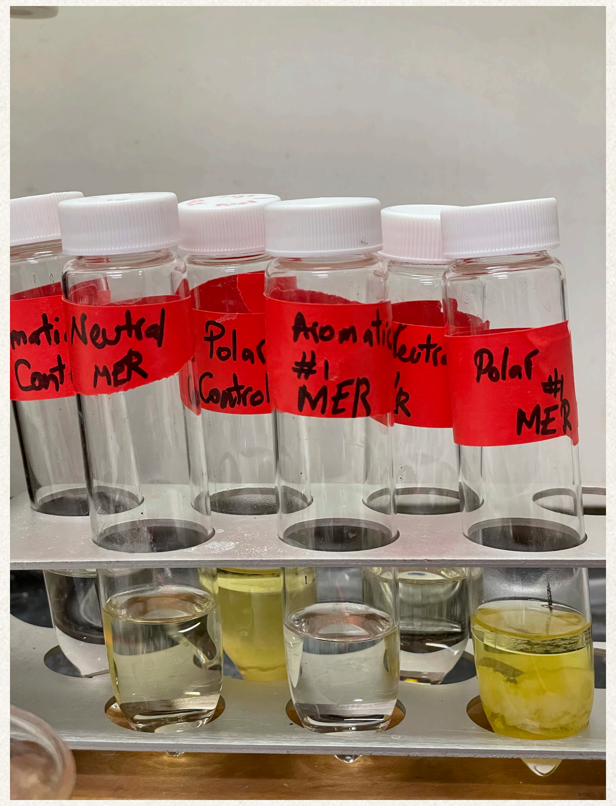


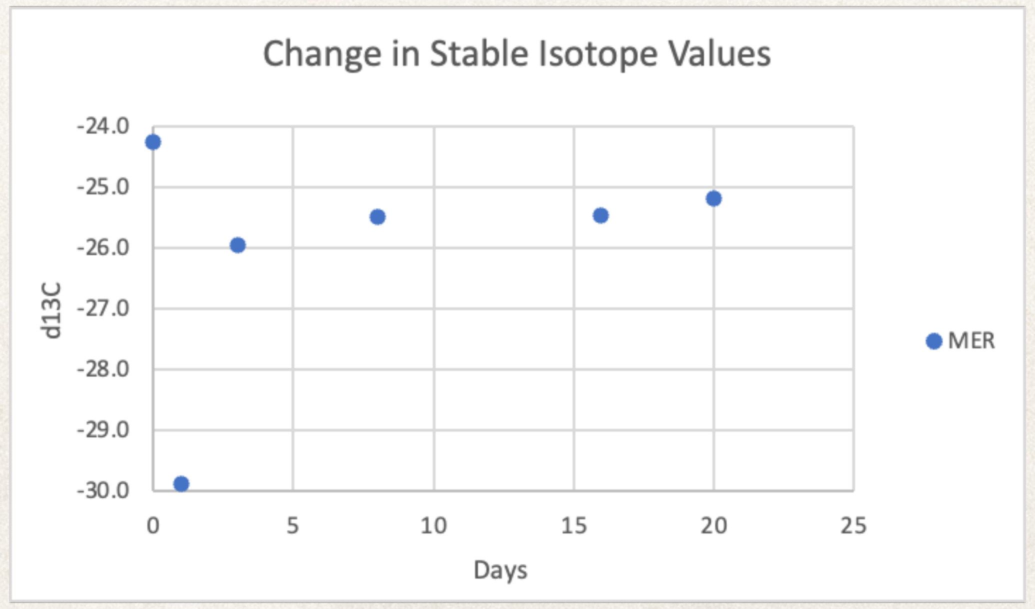
anteisoC15:0

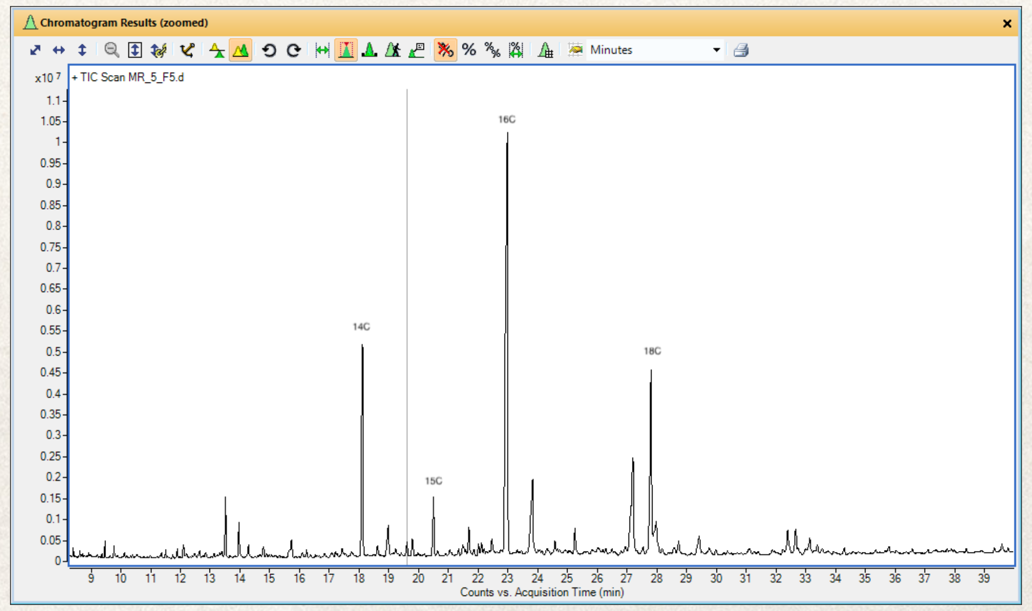
Tracking the source of OM
degraded by bacteria…

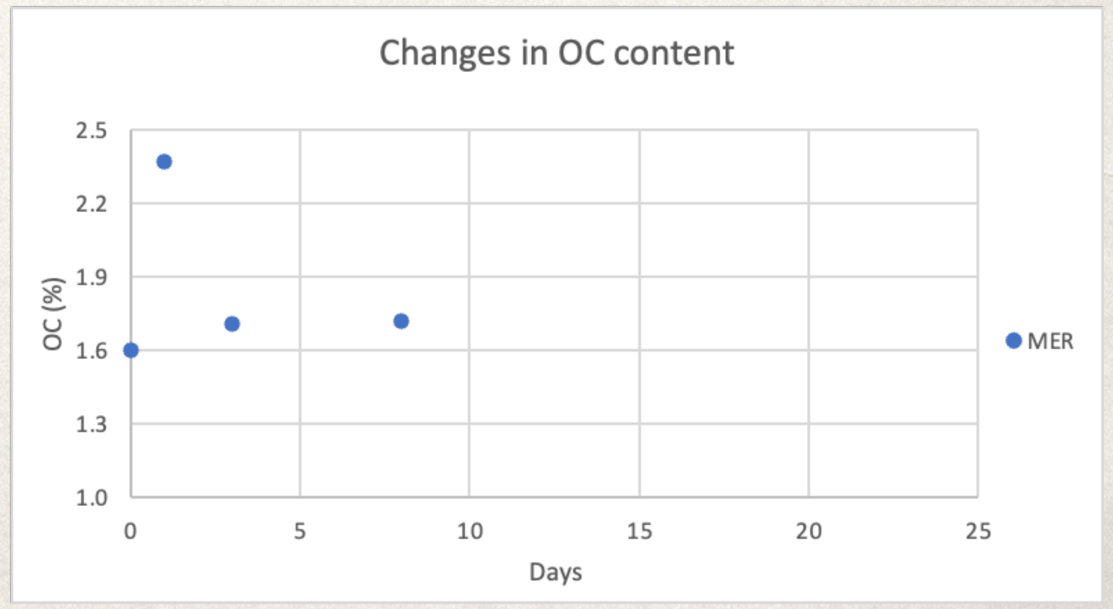
Methods


Extraction from sediment/bacteria
Silica column chromatography
n-alkanes
Polyaromatic hydrocarbons
Neutral and polar lipids
Saponification and liquid-liquid extraction
Fatty acids
Sterols
Derivatization
GC-MS
GC-IRMS



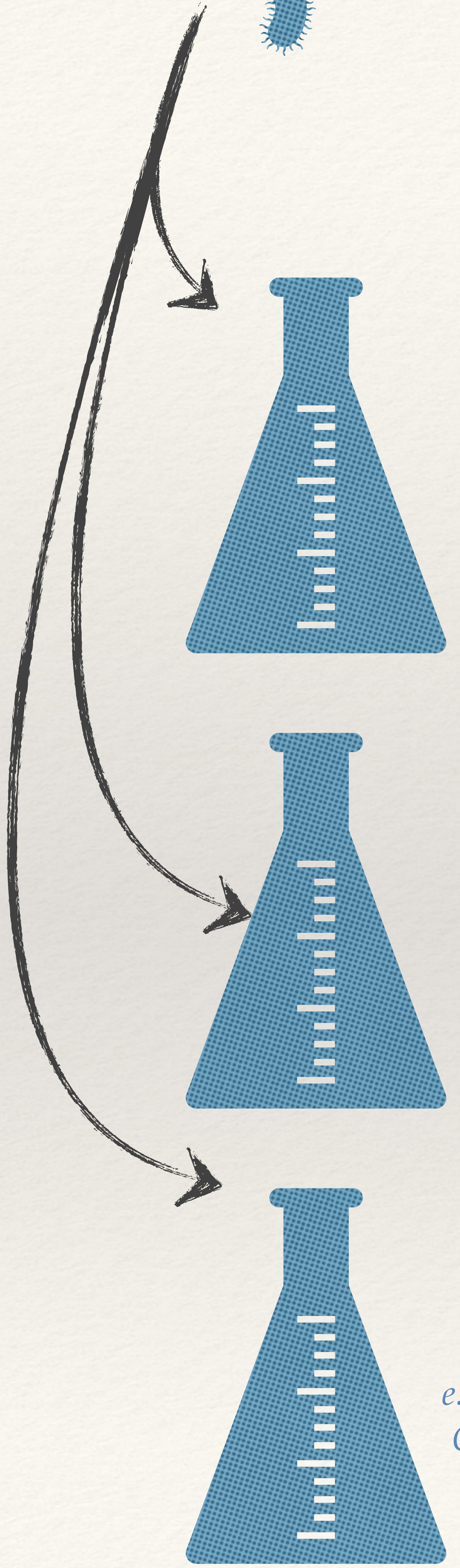

Change in Stable Isotope Values
d13C
-24.0
-25.0
-26.0
-27.0
-28.0
-29.0
-30.0
0
5
10
15
20
25
Days
MER




Changes in OC content
OC (%)
2.5
2.2
1.9
1.6
1.3
1.0
0
5
10
15
20
25
Days
MER

Experimental Analysis

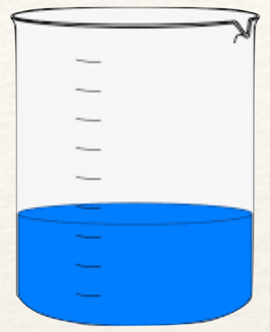
Phytoplankton (fresh OM) input



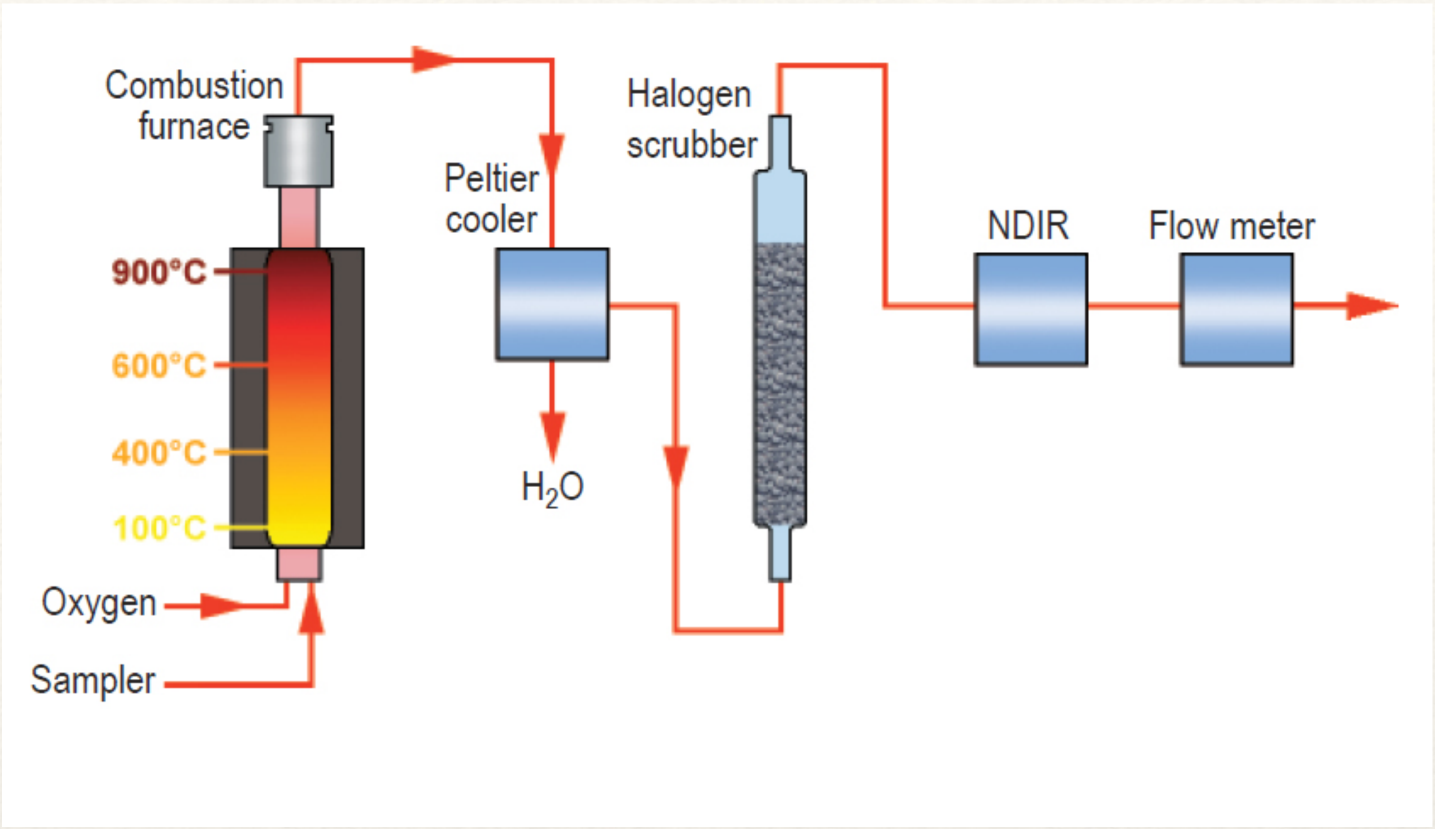
e.g., Day 1, Control Fresh OM

e.g., Day 1, Control Marine Sediment

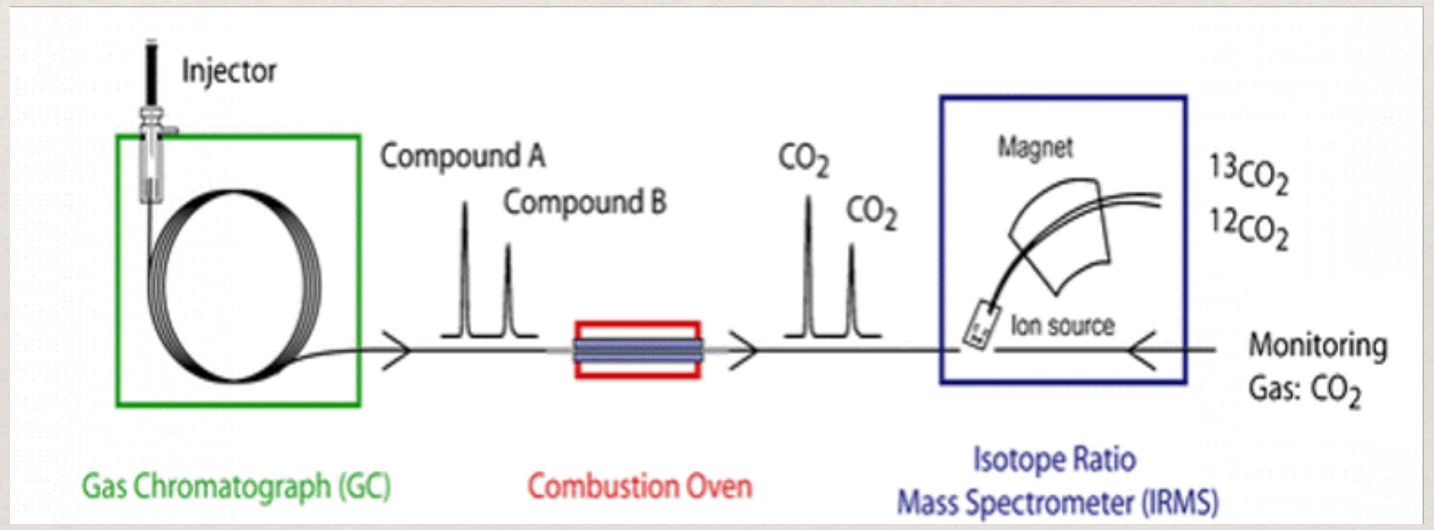
e.g., Day 1, Control Fresh OM + Marine Sediment ratio 1:1



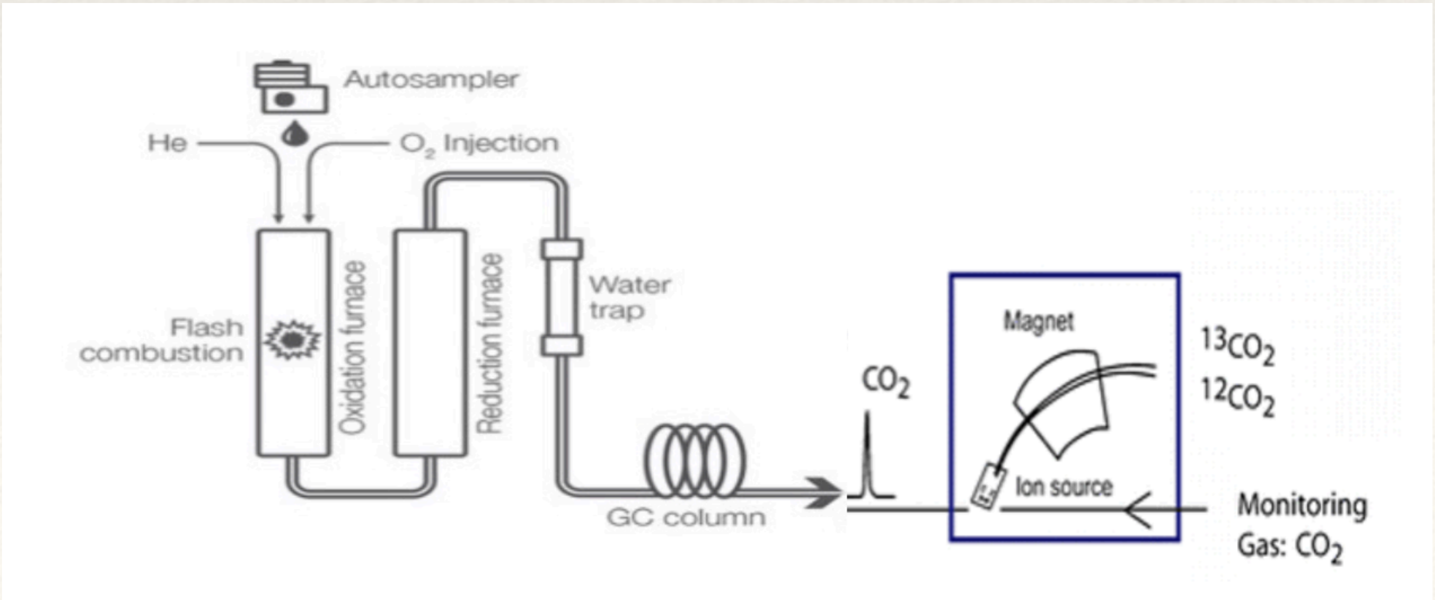
(Total Organic Carbon) TOC Analysis



Elemental Analysis (EA-IRMS)

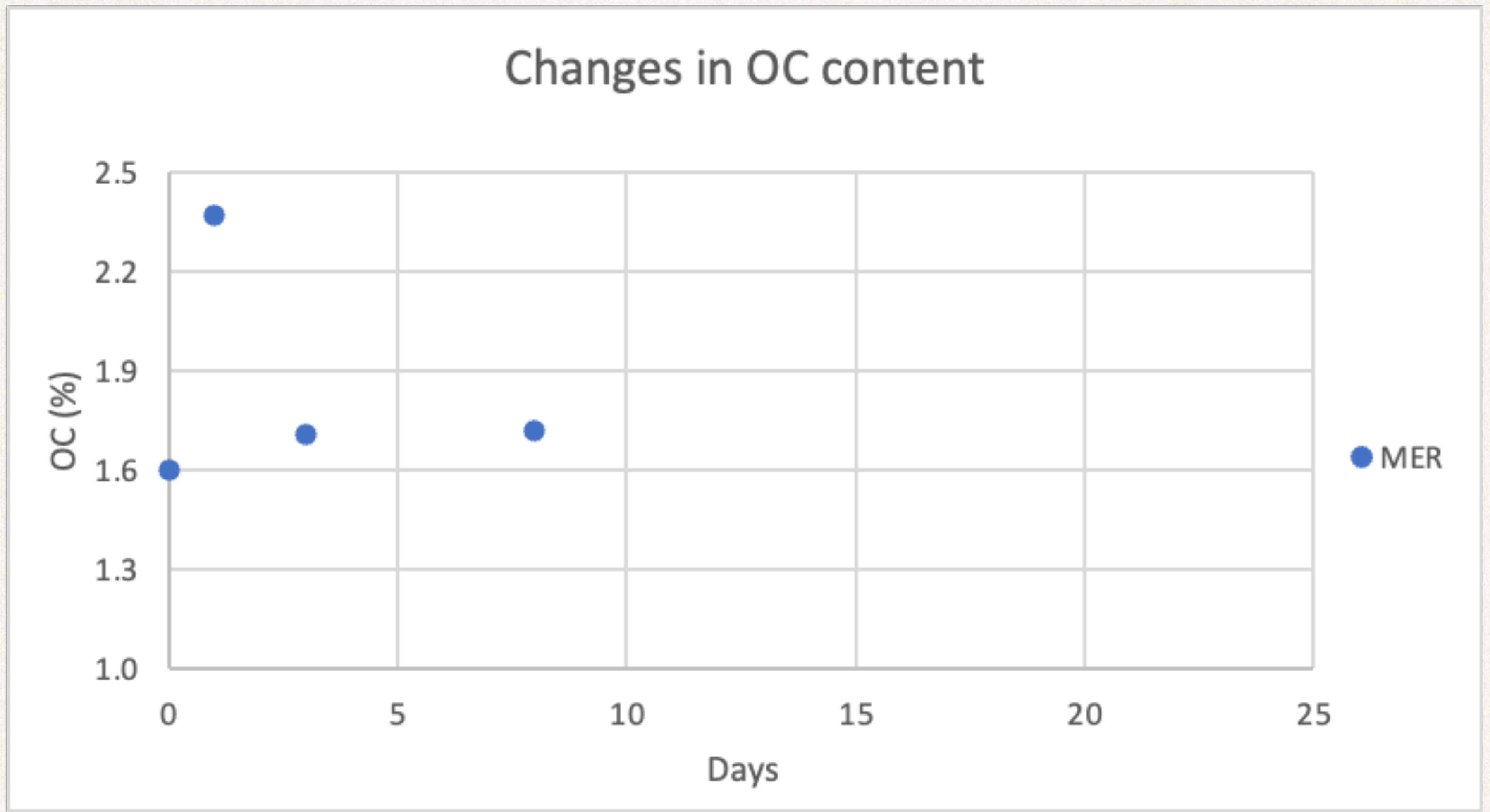


Gas chromatography isotope ratio mass spectrometry (GC-IRMS)

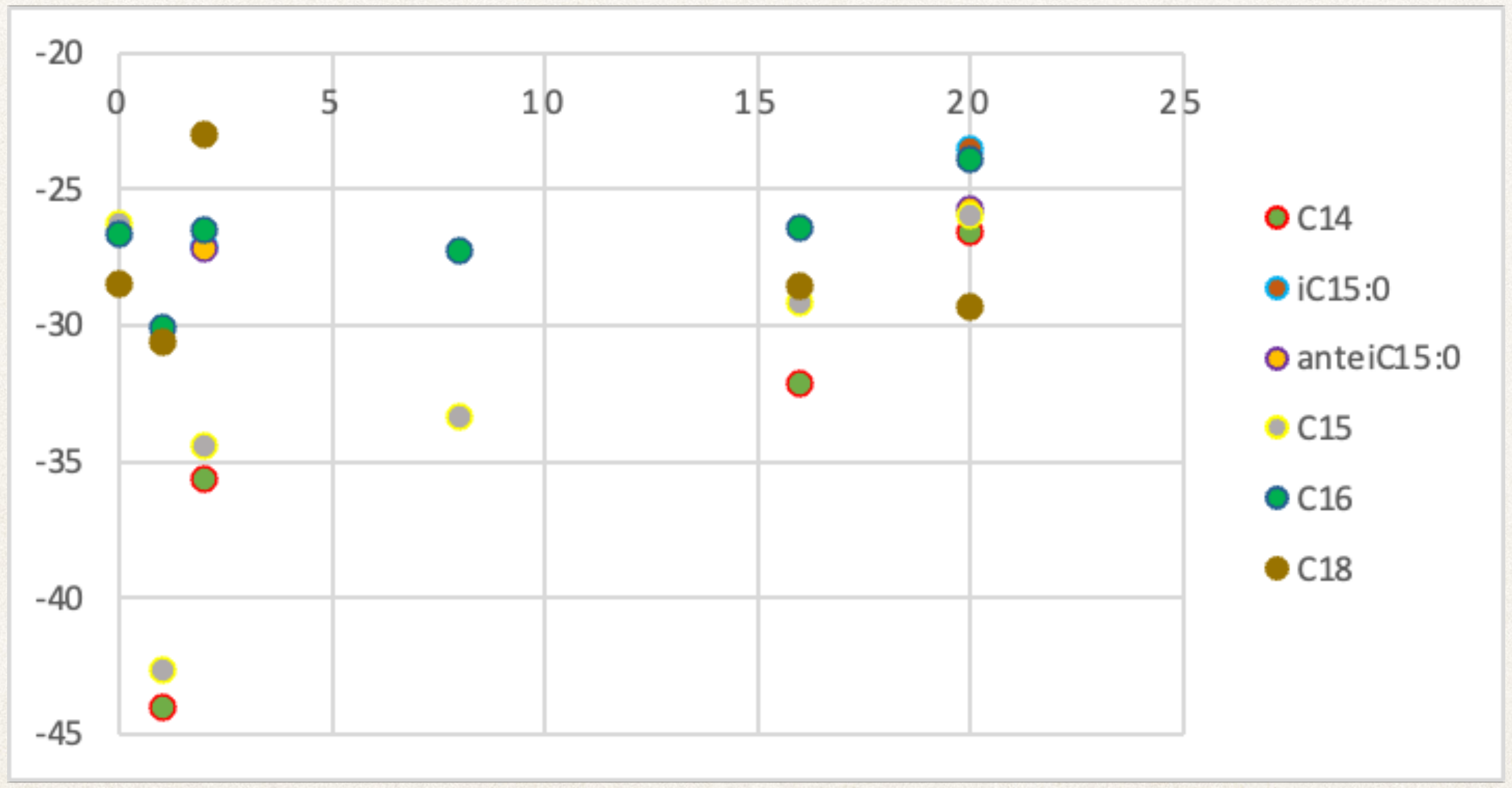


Current Results

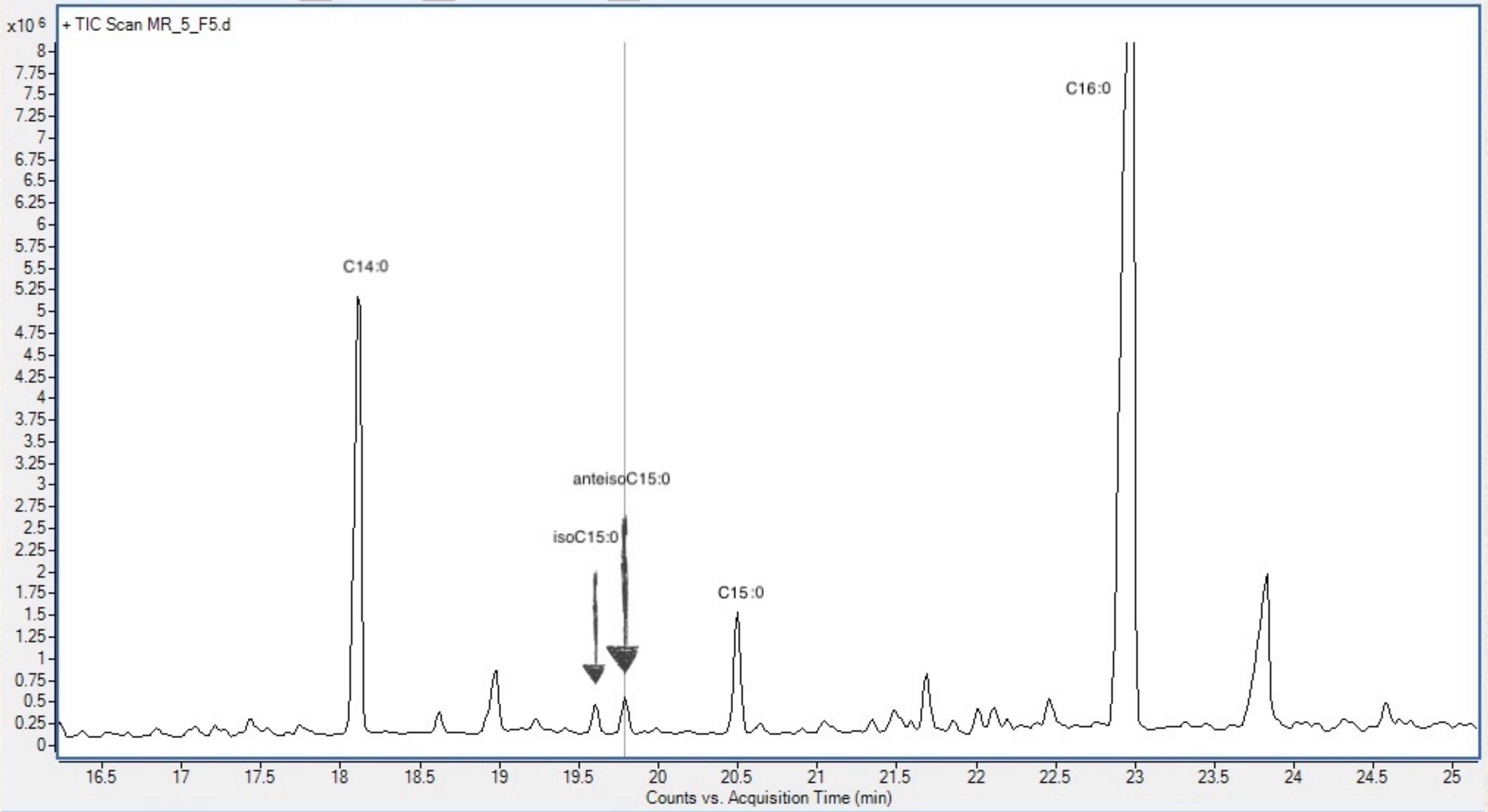
Elemental Analyzer

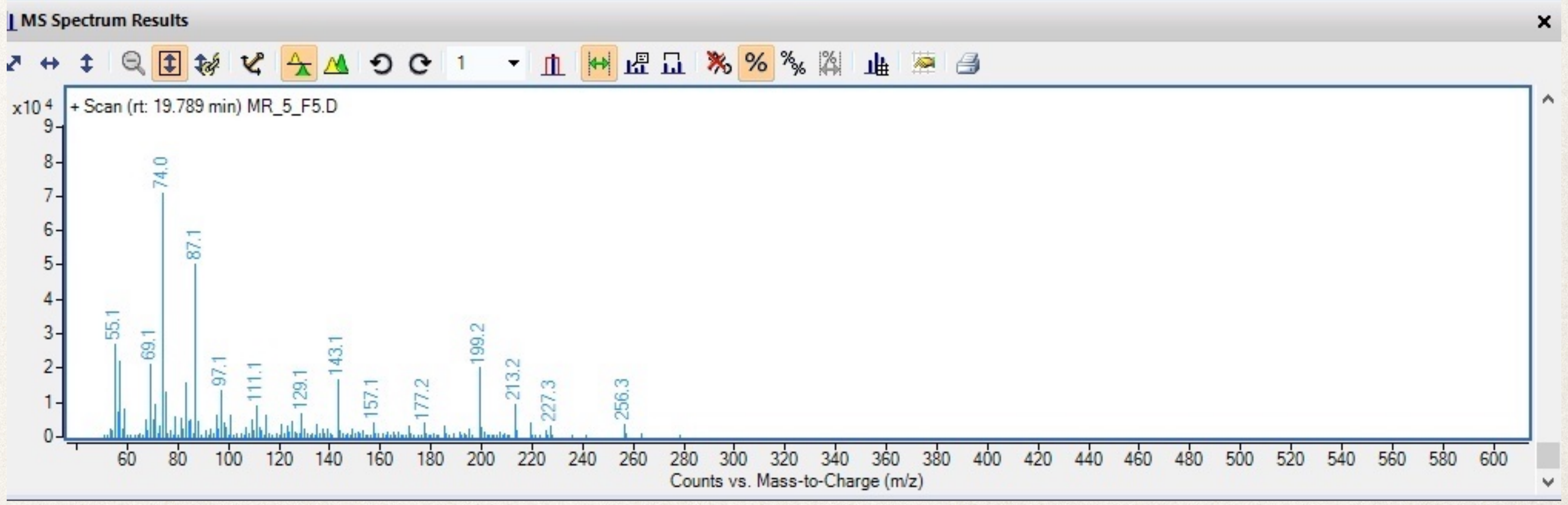


Gas chromatography isotope ratio mass spectrometry (GC-IRMS)



Elemental Analysis (EA-IRMS)





Thank you!