4.1.74

Cycling and evolution of carbon within the shallow-water ocean environment since the Last Glacial Maximum

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In recent years, the shallow-water ocean environment (i.e., coastal regions, shelves, reefs and banks) has received increased attention in terms of its role in the global carbon budget and influence on climate. Although this region constitutes only about 10% of the surface area of the ocean, it is globally significant. Ten to 30% of global marine primary production presently occurs within the shallow-water ocean environment, and the area is a repository for more than 80% of the materials transferred from land to ocean. Because the region is well above the depth of the carbonate mineral chemical lysoclines, it presently serves as a sink of the C, Ca, and Mg in the form of calcareous shells, skeletons, and cements that are deposited and preserved there. In fact, on a time scale of tens of thousands to hundreds of thousands of years, the changes in locus of carbonate deposition between deep- and shallow-water ocean environments due to fluctuations in sea level explain to some extent the observed fluctuations in late Pleistocene atmospheric CO_2 concentrations. In addition, since the agricultural revolution 10,000 years ago and particularly in the post-Industrial Revolution modern era, human activities have had increasingly significant impacts on the shallow-water ocean environment. In an attempt to expand our understanding of the biogeochemical cycling and evolution of carbon and associated elements within the shallow-water ocean environment from the Last Glacial Maximum (LGM) to present day, we employed the biogeochemical box model *SOCM* (Shallow-water Ocean Carbonate Model) to conduct several numerical simulations of system behavior. Preliminary results demonstrated the changing importance of this region as an area of organic matter burial and biogenic $CaCO_3$ deposition. The net air-sea exchange of CO_2 was strongly coupled to the relative effects of net ecosystem production and calcification, and throughout the simulation the region served as a net source of CO_2 to the atmosphere. Changes in deposition and remineralization of organic matter also affected the carbonate chemistry of sediment pore waters and consequently the composition of the most soluble solid carbonate phase in metastable equilibrium with the pore waters and hence cement composition. Overall, the results of the numerical simulations showed that the rise of sea level since the LGM and the evolution of the shallow-water ocean environment have significantly affected the pathways of carbon cycling, thus having implications for global climate.

4.1.75

Advective controls on the distribution and composition of organic matter in marine sediments

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Although the burial of organic carbon (OC) is a key aspect of the global carbon cycle, there are still many unanswered questions regarding the exact origin and nature of the organic matter accumulating in marine sediments. In particular, the importance of terrestrial organic matter in marine sediments has been a longstanding subject of debate. For example, the relatively old ^{14}C ages of bulk OC commonly observed in surficial marine sediments is often attributed to relict terrigenous inputs, although other processes could also be responsible.

Using newly developed approaches that permit examination of ^{14}C variations at the molecular level, we have examined age relationships between source-specific biomarkers, bulk OC and planktonic forams isolated from sediments spanning a range of depositional settings. We have found a strong correlation between the ^{14}C ages of exclusively marine algal biomarkers (haptophyte-derived alkenones) and bulk OC in surface sediments. Moreover, planktonic foraminifera are often much (up to several thousand years) younger than alkenones and bulk OC from the same sediment horizon. These age offsets between foraminifera and alkenones are best explained by advective sediment transport by bottom currents as a function of grain-size.

These striking ^{14}C age relationships between sedimentary constituents have two major implications. First, the spatial and temporal decoupling of molecular and other proxies complicates the interpretation of paleoenvironmental signatures residing in different grain size fractions. Second, the correspondence between alkenone and bulk OC ^{14}C ages implies that redistribution of “old” marine OC rather than relict terrigenous OC derived from soils or sedimentary rocks may be largely responsible for old core-top bulk OC ^{14}C ages.

We argue that sediment redistribution may thus be an important consideration for understanding carbon burial in the marine environment and for correctly interpreting the marine sedimentary record.