BIOGEOCHEMICAL DYNAMICS AT MAJOR RIVER-COASTAL INTERFACES

Linkages with Global Change

This volume provides a state-of-the-art summary of biogeochemical dynamics at major river-coastal interfaces for advanced students and researchers. River systems play an important role (via the carbon cycle) in the natural self-regulation of Earth's surface conditions by serving as a major sink for anthropogenic CO_2. Approximately 90 percent of global carbon burial occurs in ocean margins, with the majority of this thought to be buried in large delta-front estuaries (LDEs). This book provides information on how humans have altered carbon cycling, sediment dynamics, CO_2 budgets, wetland dynamics, and nutrients and trace element cycling at the land-margin interface. Many of the globally important LDEs are discussed across a range of latitudes, elevations, and climates in the drainage basin, coastal oceanographic setting, and nature and degree of human alteration. It is this breadth of examination that provides the reader with a comprehensive understanding of the overarching controls on major river biogeochemistry.

Thomas S. Bianchi is a Professor in the Department of Geological Sciences at the University of Florida, Gainesville, where he holds the Jon and Beverly Thompson Endowed Chair of Geological Sciences. His general areas of expertise are organic geochemistry, biogeochemical dynamics of aquatic food chains, carbon cycling in estuarine and coastal ecosystems, and biochemical markers of colloidal and particulate organic carbon. He has published more than 130 articles in refereed journals and 4 books, including *Biogeochemistry of Gulf Mexico Estuaries* (1999, lead co-editor with Pennock and Twilley), *Biogeochemistry of Estuaries* (2007), *Hypoxia in the Northern Gulf of Mexico* (2010, co-author with Dale et al.), and *Chemical Biomarkers in Aquatic Ecosystems* (2011, lead co-author with Canuel). In 2012, he was elected as a Fellow of the American Association for Advancement of Science.

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To our families for their unending support and patience through the years.

"No man ever steps in the same river twice, for it's not the same river and he's not the same man."

– Heraclitus

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Preface

Approximately 87% of Earth's land surface is connected to the ocean by rivers. Over the past 60 years, increases in the human population have had severe, globally significant effects on large-river systems through enhanced fertilizer usage, damming, deforestation, and many other land-use changes. Many countries in the world are experiencing potable and agricultural water shortages, particularly in Asia, which contains 30% ($13{,}500\times10^9$ m^3 yr^{-1}) of the world's ($42{,}700\times10^9$ m^3 yr^{-1}) renewable water resources. The world's 25 largest rivers drain approximately half of the continental surface and transport approximately 50% of the freshwater and 40% of the particulate materials entering the ocean. Moreover, it has been estimated that 80% of the total organic carbon preserved in marine sediments occurs in "terrigenous-deltaic" or large delta-front estuaries (LDEs).

Organic carbon (OC) burial in marine sediments is only second to silicate weathering and subsequent carbonate precipitation as sink of atmospheric CO_2, and much of this occurs in deltaic regions of the world. Thus rivers play a vital role, delivering a large flux of OC from the continents to the oceans. Recent work has also documented global decreases in water and/or sediment discharge to the coastal ocean in numerous LDEs such as the Mississippi, Nile, Indus, Changjiang, and Huanghe systems. Although humans have increased riverine sediment transport within the continents through soil erosion by an estimated 2.3 ± 0.6 Pg yr^{-1}, the actual amount reaching the ocean has decreased by 1.4 ± 0.3 Pg yr^{-1}, mainly as a result of dams and reservoirs. These reductions play an important role in deltaic coastal retreat, where a large fraction of the human population lives, and which, due to their low elevation, are highly susceptible to rising sea levels. Consequently, there has been increased interest in understanding how the flux of materials from rivers to the ocean have been altered, including global community programs such as the International Geosphere Biosphere Programme (IGBP) and its major project, Land Ocean Interaction in the Coastal Zone (LOICZ). A number of investigations have demonstrated relationships between fisheries' yields and the high nutrient loads and freshwater inputs associated with LDEs. For example, a great fraction of the harvested secondary production in the Gulf of Mexico "fertile crescent" is derived from estuarine ecosystems, including areas on the shallow shelf influenced by the Mississippi-Atchafalaya river plumes, as has been found for other fisheries linked with plumes from rivers such as the Nile, Mekong, and the Changjiang, just to mention a few.

The coastal ocean is a dynamic region where the rivers, estuaries, ocean, land, and atmosphere interact. Although relatively small in area, this region, having 30% of the total net oceanic productivity, supports as much as 90% of the global fish catch. In particular, LDEs have historically played an important role in the advance of human civilizations (via trade, transportation, and food resources). This relationship between humans and rivers began some 5,000 years ago with the demands of

hydraulic power in Mesopotamia, as well as in the Nile, Huanghe, and Indus valleys. It has been estimated that approximately 61% of the world population lives along the coastal boundary. By 2025, an estimated 75% of the world's population is expected to live in the coastal zone, with many of the remaining 25% living near major rivers. One of the most challenging issues concerning large river fluxes is to better understand the presumably major changes that they have undergone over the Anthropocene as a result of land-use changes (agriculture and urbanization) and river basin and delta alterations, and the resultant impact of these changes on the land-ocean material transfer term, both quantitatively and qualitatively.

Our main objectives in this book are to provide the reader with a comprehensive overview of what is known about the biogeochemical processes of the major LDEs around the world – the natural and anthropogenic factors that control and regulate them, in the western and eastern hemispheres. Thus we have divided this book into the following four sections: Section I. Introduction; Section II. Water and Sediment Dynamics from Source to Sink; Section III. Eastern Hemisphere Systems; and Section IV. Western Hemisphere Systems. In Section I we provide the reader with an overview of how we define these regions, why they are important to the global carbon cycle, and how climate change may be impacting these systems as they are changing rapidly in the Anthropocene. In Section II, the chapters primarily address the physical processes that determine how fluvial inputs of water, sediment, carbon, and nutrients are modified by tidal modulations, ocean wave incursion, wind-driven currents, estuarine circulation, and passage through wetlands and shallow water bodies and are then distributed along and across the upper continental margin. These chapters address how these processes control the fate of nutrients, sediments, and plume waters, including hydrodynamic sorting processes that control the fate of particulate and dissolved organic carbon sources (e.g., terrestrial, marine, and black). Section III, which focuses on LDEs in the Eastern Hemisphere, provides a comprehensive view of the biogeochemical dynamics of major rivers that drain the Himalayas, such as the Changjiang, Huanghe, Pearl, Ganges-Bramaputra, and Mekong, and empty in a range of coastal settings from tropical to temperate. These systems are being rapidly urbanized, owing to the highest rates of population growth in the world, and also are experiencing the most rapid rates of dam building; these factors are discussed in the context of comparing natural versus anthropogenic factors and how these processes are likely to be modulated by climate change. Finally, Section IV, focused on LDEs in the Western Hemisphere, is the largest section of the book, because there they have been the focus of considerably more biogeochemical research. Once again, the chapters provide the reader with an excellent overview of what is known about the biogeochemical dynamics of LDEs such as the Nile, Mississippi-Atchafalaya, Yukon, Congo, Reine, Seine, and many Arctic systems. We believe this is the most comprehensive presentation to date of how large-river systems are being altered globally due to human and climate change and also provides important information on the role of these systems in understanding the global carbon cycle.

Our special thanks go to the authors of each chapter, who supported our overall goal of providing the most comprehensive view of the biogeochemical cycling of the large-river LDEs across the globe. We would also like to thank the editors we worked with at Cambridge University Press, Amanda O'Connor, and Adrian Pereira at Aptara Inc., for their invaluable guidance through this effort.