Rapid Export of Organic Matter to the Mississippi Canyon

Coastal margins, where rivers serve as the dominant control on productivity and delivery of dissolved and particulate materials, have been understudied. The potential importance of certain river-dominated margins (RiOMars), such as those of the Mississippi River plume, to the global carbon budget is garnering increased attention because of their disproportionate role in transporting terrigenous materials to the ocean [*Dagg et al.*, 2004; *McKee et al.*, 2004].

This study concludes that labile (readily open to chemical, physical, or biological change) sedimentary organic matter, produced by in situ diatom production in the Mississippi River plume, is rapidly transported to the Mississippi Canyon. Despite the notion that canyon sediments are typically unstable and lack adequate food resources to support significant macrobenthic communities, this study suggests that productive RiOMars are important conduits for transporting fixed carbon from highly productive plume waters on the shelf to deeper benthic communities.

The Louisiana Shelf as a RiOMar

The Mississippi–Atchafalaya River delivers 60% of the total suspended matter and 66% of the total dissolved materials transported from the conterminous United States to the ocean. Particulate organic carbon (POC) introduced by the river or biologically fixed on the Louisiana shelf is carried along-shelf, decomposed, buried, or transported to deeper regions in the Gulf of Mexico. Vertical fluxes of organic carbon (OC) in the Mississippi plume as high as 1.80 grams carbon (C) per square meter per day have been observed during spring [*Redalje et al.*, 1994], but are lower during other seasons (0.29–0.95 grams C per square meter per day) and away from the immediate plume (0.18–0.40 grams C per square meter per day). Much of the in situ plume productivity supporting carbon flux is composed of diatoms [*Lohrenz et al.*, 1999], as reflected in surface sediments below the plume.

Finally, a unique characteristic of this passive margin, where the Mississippi River discharges into the Gulf of Mexico, is the relatively short distance to the Mississippi Canyon; this setting may allow for the rapid transport of shelf-derived primary production to the canyon floor. In fact, there is evidence that layers of increased suspended matter and resuspension events are important advection mechanisms in this setting (C.A. Burden et al., unpublished data, 2006).

Source-to-Sink

Understanding the connectivity between coastal systems and the deep sea has received considerable attention in recent years. A primary goal of the U.S. National Science Foundation (NSF) MARGINS Source-to-Sink program (http://www.nsf-margins.org/S2S/S2S.html) is to develop a quantitative understanding of margin sediment dispersal systems, including OC export from river mouth and shelf regions. Similarly, the global importance of the coastal ocean has been recognized in national and international efforts, for example the Land-Ocean Interactions in the Coastal Zone (LOICZ), the European Union's European Land-Ocean Interaction Studies (ELOISE), Shelf-Edge Exchange Processes (SEEP I and II), Coastal Ocean Processes (CoOP), Ocean Margins Program (OMP), and RiOMar (http://www.tulane.edu/~riomar/).

Many RioMARs export a relatively small volume of river-derived particulates seaward of the shelf break due to (1) their location on wide, passive continental margins where deltaic sedimentation is confined to the inner shelf and (2) along-shelf dominated coastal currents. However, other RioMARs are characterized by high export to the lower continental margin (e.g., Sepik, Ganges-Brahmaputra, Eel) due to a narrow (active continental margin) shelf and/or landward incision of the associated subma-

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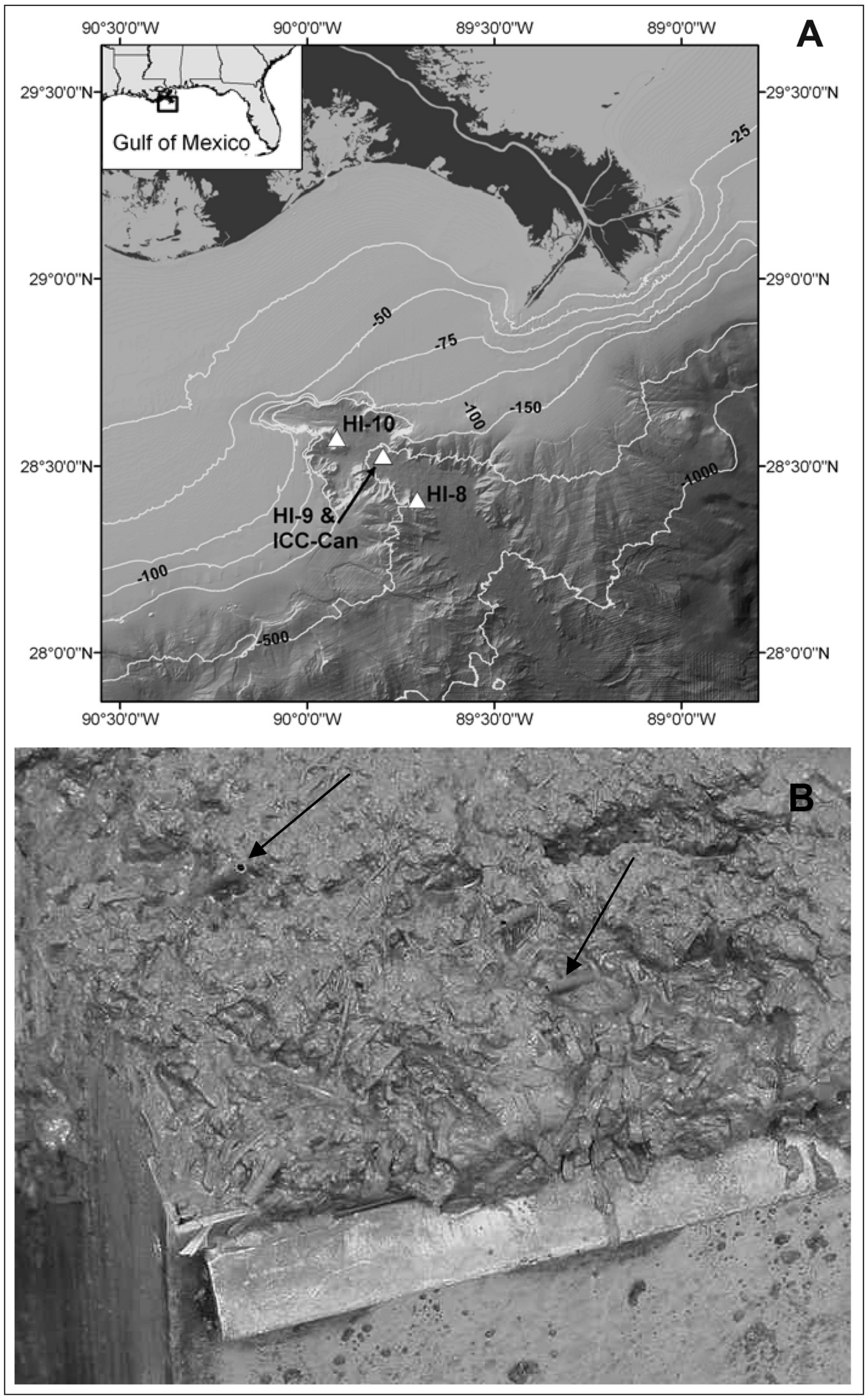

Fig. 1. (a) Map showing stations sampled in the northern Gulf of Mexico. Contour lines represent isobaths on a scale of meters. (b) Photograph of surface sediments in a box-core at station ICC-Can in July 2003; arrows show the presence of large tube-building macrofauna in sediments.

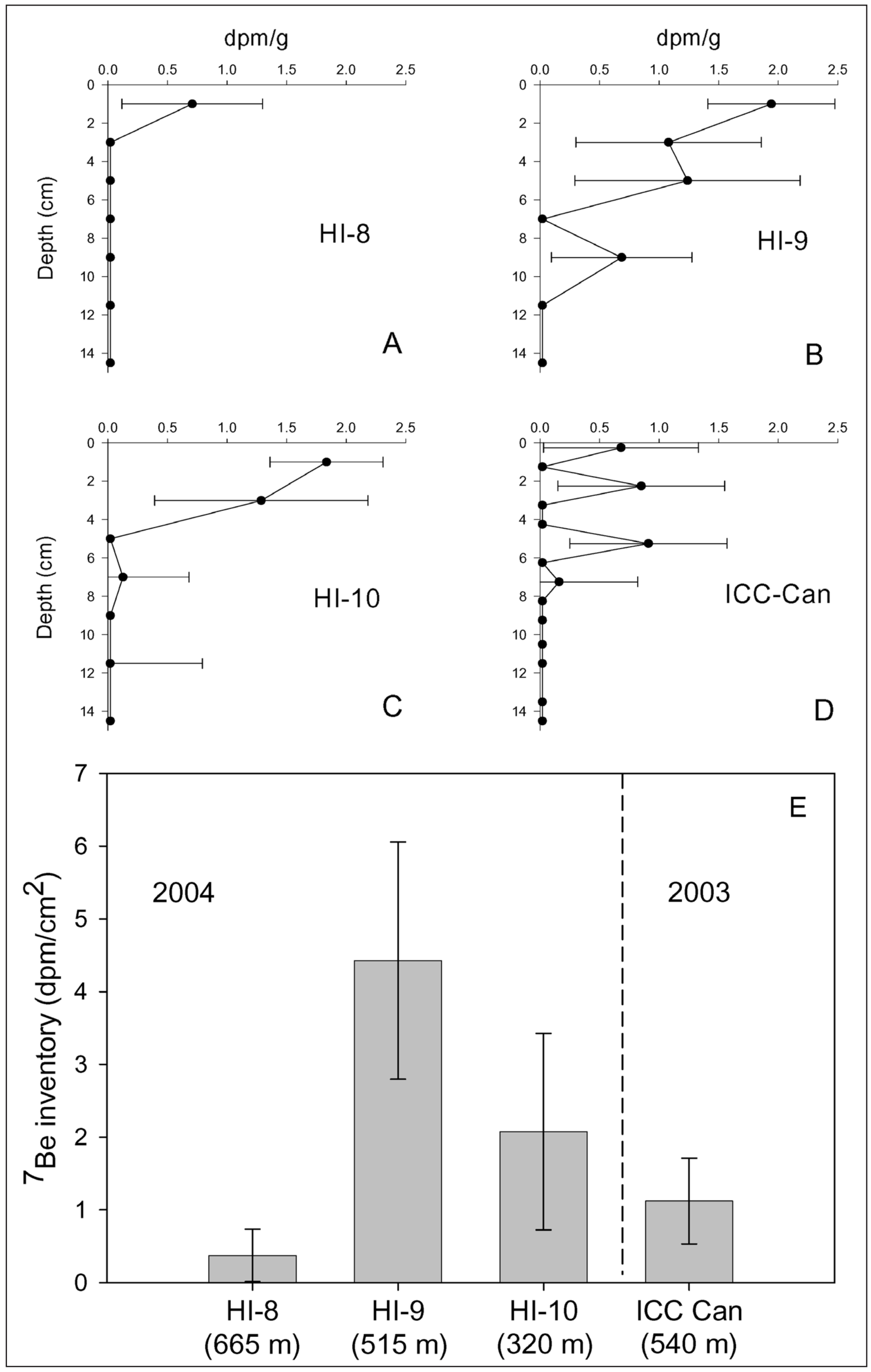

Fig. 2. (a–d) ^{7}Be activity profiles in sediments, measured in disintegrations per minute per gram (dpm/g), collected from four stations in the Mississippi Canyon in July 2003 (ICC-Can) and October 2004 (HI-8, HI-9, and HI-10). Sediments were collected using a box-corer. ^{7}Be measurements were made using techniques described by Corbett et al. *[2004]; horizontal lines represent counting errors. (e) ^{7}Be inventories (dpm/cm^2) were calculated using methods described by* Corbett et al. *[2004]. The values in the parentheses on the x-axis represent the water depth at each station in meters.*

rine canyon that intercepts along-shelf transport pathways.

Rapid OC Export From the Delta to the Mississippi Canyon

In this study, four box-cores from the Mississippi Canyon (Figure 1a) were investigated. Surface sediments from station ICC-Can (Integrated Carbon Cycle-Canyon were collected in July 2003, while Hurricane Ivan stations (HI-8, HI-9, and HI-10) were sampled in October 2004, one month following Hurricane Ivan. These samples are part of a series of funded studies that have been ongoing in this region for the past five to six years. This work is also relevant to research currently underway that examines post-Katrina effects. Water depths for these stations ranged from 320 to 665 meters. Sediments at all stations were fine terrigenous muds (<1% calcium carbonate at ICC-Can). The ICC-Can station had an extensive benthic macrofaunal assemblage of tube-dwelling polychaetes, something not commonly observed on the delta front, due presumably to the high sedimentation rates and mobile seafloor (Figure 1b).

The particle-reactive radionuclide beryllium-7 (^{7}Be; $t_{1/2}$ = 53.3 days) can be used as a tracer of recent river-derived inputs, and its presence in all surface sediments in the Mississippi Canyon (Figure 2) suggests that sediments are rapidly transported from the delta to the canyon. It is estimated that about 50% of the sediments delivered to this region are temporarily stored near the delta, with a large fraction transported along/across the shelf [*Corbett et al.*, 2004, 2006]. Winter fronts are most likely responsible for the resuspension and transport of sediments along and off the Louisiana coast [*Allison et al.*, 2000; *Corbett et al.*, 2004]. The ^{7}Be inventory at HI-9 is higher than at ICC-Can, its nearest site (Figure 2e). Since ^{7}Be inventories integrate inputs over time (~250 days), the passage of Hurricane Ivan between sampling at ICC-Can (July 2003) and HI-9 (October 2004) may explain this difference.

Sediment deposition following the passage of hurricanes Katrina and Rita was 6–19 times the typical annual accumulation at the 50-meter isobath and deeper [*Corbett et al.,* 2006]. The macrobenthos observed at station ICC-Can in July 2003 (see Figure 1b) was not present at station HI-9, or at the other canyon stations in October 2004 [*Corbett et al.*, 2006], indicating slow recovery of these deeper macrobenthic communities [*Corbett et al.*, 2006]. Gravity cores collected at ICC-Can also show evidence of mud turbidites at decimeters below the tube-dwelling community, indicating that hyperpycnal down-canyon transport is active at a lower frequency than storms and erosionally scours epibenthic communities. While there is a 25-meter difference in elevation between station ICC-Can and HI-9, inputs of ^{7}Be and chlorophyll to these sites are similar, which would not be the case if these sites were associated with a more sheltered versus a gravity flow region of the canyon floor.

Sources of Labile Organic Carbon in Mississippi Canyon

Algal pigments and polyunsaturated fatty acids (PUFA) were observed in surface sediments at all four canyon stations. These algal biomarkers are labile compared with other biomarkers, so they, like ^{7}Be, reflect recent accumulation [*Canuel and Martens,* 1996]. The open waters of the Gulf are oligotrophic (poor in nutrients), and except for rare occasions when the Mississippi River plume extends farther southwest, vertical

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inputs of algal detritus over the canyon are small [*Lohrenz et al.,* 1999]. Rather, these biomarkers likely derive from sediments redistributed from the productive shelf region where diatom productivity and fluxes to sediments are high [*Dagg et al.*, 2004].

Furthermore, algal pigments and PUFAs decrease in concentration, whereas sterols (steroid alcohol found in plant lipids) increase in concentration between samplings before and after Hurricane Ivan (Figure 3b). Redistribution of sediments from the delta to the canyon associated with Hurricane Ivan may have promoted decomposition of labile compounds and/or resulted in their dilution by mixing with deeper (older) sediments depleted in labile compounds but enriched in more stable compounds such as sterols. Pigment and PUFA inventories at station ICC-Can confirm that labile phytodetritus (decomposing phytoplankton) is advected to the canyon, most likely during passage of winter fronts and sporadically by hurricanes [*Corbett et al.,* 2004, 2006]. It is likely that communities of macrobenthic polychaetes (a marine annelid worm) in the canyon are supported by shelf-derived sediments rich in diatom phytodetritus.

This study concludes that labile sedimentary organic matter, produced by in situ diatom production in the Mississippi River plume, is rapidly (day to weeks) shunted to Mississippi Canyon. Transport probably occurs during winter storms and hurricanes, and possibly by turbidites originating in the upper reaches of the canyon. The supply rate of this labile phytodetritus is temporally consistent enough to support macrobenthic polychaete populations that do not exist in nearshore waters off the Louisiana coast. Thus, despite the predominant notion that canyon sediments are typically unstable and lack adequate food resources to support significant macrobenthic communities, productive RiOMars can indeed serve as important conduits for transporting labile fixed carbon from highly productive plume waters on the shelf to fuel deeper benthic communities. Nevertheless, further work is needed to corroborate the importance of these food resources for macrobenthic communities.

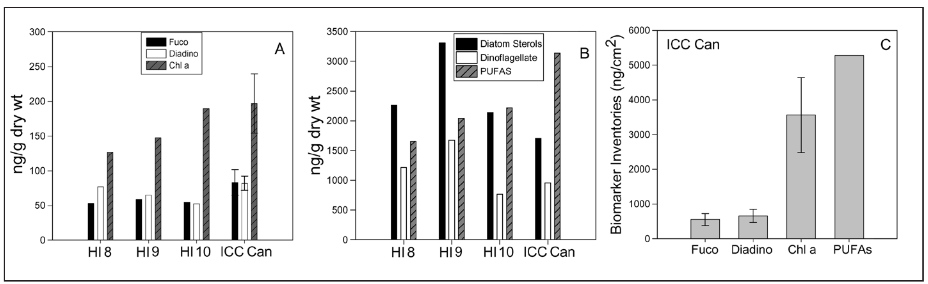

Fig. 3. (a) Concentrations (nanograms per gram dry weight of sediment) of algal pigment biomarkers fucoxanthin (Fuco), diadinoxanthin (Diadino), and chlorophyll-a (Chl a) in surface sediments from four stations in the Mississippi Canyon in July 2003 (ICC-Can) and October 2004 (HI-8, HI-9, and HI-10). Pigments were analyzed by high-performance liquid chromatography (HPLC) according to methods described by Bianchi et al. *[2000]. Values in parentheses on the* x*-axis are water depths at each station. Diadinoxanthin and fucoxanthin are biomarkers for diatoms. (b) Concentrations (nanograms per gram dry weight of sediment) of diatom sterols, dinosterol (from dinoflagellates), and polyunsaturated fatty acids (PUFAs) in surface sediments from four stations in the Mississippi Canyon. Sterols and fatty acids were analyzed using methods described by* Canuel and Martens *[1996]. The error values for these sterol and PUFA concentrations were in the range of ±10%. (c) Inventories of algal pigments and PUFAs (nanograms per square centimeter) at station ICC-Can collected in July 2003; downcore samples at the three stations collected in October 2004 were not available for biomarker analyses.*

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