Chapter 9
Geochemical and Faunal Characterization in the Sediments off the Cuban North and Northwest Coast

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Abstract This chapter provides a summary of the scientific knowledge about sediments and fauna in the margin of northwest Cuban shelf. Little scientific information is publicly available, and so much of what is discussed here is the result of the scientific expedition to the region in May 2017 on board the *R/V Weatherbird II* as part of the GoMRI consortium, C-IMAGE (see Foreword, this book). The goal was to set broad environmental baselines against which to evaluate the impacts of any potential future oil spill or other disturbance in the Gulf of Mexico (GoM). The chapter is organized in three parts: (1) overview of the geographical setting of Cuban margin of GoM; (2) sediment characterization including texture, composition, and geochronology of sediment cores; and (3) characterization of key bioindicators of oil impact: mollusks, meiofauna, and foraminifera.

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9.1 Introduction

This chapter provides a summary of the scientific knowledge about sediments and fauna in the margin of northwest Cuban shelf. Little scientific information is publicly available, and so much of what is discussed here is the result of the scientific expedition to the region in May 2017 on board the *R/V Weatherbird II* as part of the GoMRI consortium, C-IMAGE (see Foreword, this book). The goal was to set broad environmental baselines against which to evaluate the impacts of any potential future oil spill or other disturbance in the Gulf of Mexico (GoM). The chapter is organized in three parts: (1) overview of the geographical setting of Cuban margin of GoM; (2) sediment characterization including texture, composition, and geochronology of sediment cores; and (3) characterization of key bioindicators of oil impact: mollusks, meiofauna, and foraminifera.

9.2 Geographical Setting and Sampling

Cuba constitutes the southeast limit of the Gulf of Mexico (GoM) and determines the connection of this large marine ecosystem with the Caribbean Sea through the Yucatan Straits and with the North Atlantic Ocean through the Florida Straits. The northwestern region of Cuban island is the terrestrial border of the Cuban GoM and is characterized by a relatively narrow shelf. The Cuban margin is essentially different from the other borders of the south GoM which are bordered by the extensive shallow banks of Campeche to the west and Florida shelf to the north (Locker and Hine 2020). As result of the *R/V Weatherbird II* expedition to northwest Cuba, thirteen sites were sampled along eight transects (SL37 to SL44) using a multicorer between 316 and 1670 m depth (Table 9.1 and Fig. 9.1). Transects included sites at several nominal depths (300, 500, 1000, and 1500 m), but the steep slope of the margin and the scant amount of deposited sediments limited our successful retrieval of cores to only those at the deeper sites (usually 1000 and 1500 m).

9.3 Sediment Characterization

Sediment cores analyzed for sediment texture, composition, and short-lived radioisotope chronologies reflected the spatial and temporal variability in sedimentation patterns offshore of northwest Cuba (Table 9.1 and Fig. 9.1). Sediment texture, represented as % gravel, % sand, % silt, and % clay, generally reflects energy related

Table 9.1 The sampling sites off NW coast of Cuba sampled during the expedition of R/V Weatherbird II

Site code[a]	Location	Latitude (N)	Longitude (W)	Depth (m)	Cores retrieved (analyzed)
SL 37-250	San Antonio Cape	22 09.068	84 49.579	530	
SL 37-500	San Antonio Cape	22 11.094	84 52.245	1209	7(3)
SL 38-750	Gulf of Guanahacabibes	22 28.735	84 41.568	1670	11(5)
SL 39-750	Jutía Key	22 48.324	84 06.538	1296	14(6)
SL 40-750	Levisa Key	23 00.151	83 40.771	1580	16(6)
SL 41-750	Honda Bay	23 05.135	83 11.824	1513	15(6)
SL 41-500	Honda Bay	23 02.263	83 11.240	974	3(3)
SL 42-500	Cabañas Bay	23 03.703	82 58.732	1156	9(5)
SL 42-750	Cabañas Bay	23 05.849	82 59.035	1420	14(6)
SL 43-750	Mariel Bay	23 07.735	82 43.916	1535	15(6)
SL 44-150	Havana Bay	23 09.388	82 22.132	316	8(4)
SL 44-500	Havana Bay	23 11.799	82 21.067	970	8(4)
SL 44-750	Havana Bay	23 14.373	82 20.357	1430	15(6)

[a] Codes from Weatherbird II expedition. SL labels were removed from the text for simplicity

to sediment deposition (Folk 1965). Sediment composition, represented as % carbonate, % total organic matter (TOM), and % other (non-carbonate, nonorganic), indicates sediment source(s) with carbonate sediments reflecting marine source, organic matter reflecting biological productivity and/or terrestrial runoff, and the remaining fraction (% other) reflecting a terrigenous source (Milliman 1974). Short-lived radioisotope chronologies using excess ^{210}Pb (^{210}Pb$_{xs}$) provide age control and mass accumulation rates (MAR) to determine the timing of changes in deposition over the past ~100 years (Binford 1990; Swarzenski 2014). Cores were subsampled at 0.2 cm resolution (Schwing et al. 2016) and analyzed to determine baseline sedimentation patterns for northwest Cuba. This allows to compare with studies which describe the sedimentary impacts of the *Deepwater Horizon* (DWH) oil spill in the northern Gulf of Mexico (Brooks et al. 2015; Schwing et al. 2017a).

In the western portion of the study area (sites 37-250 and 38-750), sediments were dominantly carbonate (95–98%) and silts (82–95%) and have been consistently accumulating, with little to no variability over the past ~100 years (Fig. 9.2). The ^{210}Pb$_{xs}$ chronology for site 37-250 dated 1900 at 14 cm downcore with an average MAR of 0.125 g cm^{-2} yr^{-1}. The ^{210}Pb$_{xs}$ chronology for site 38-750 dated 1900 at 3.5 cm downcore with an average MAR of 0.027 g cm^{-2} yr^{-1}. This stable sedimentation pattern reflected the low-disturbed nature of the coastal region adjacent to these sites. The higher MAR at site 37-250 was likely due to exportation of sediments from the nearby Gulf of Guanahacabibes.

In the central portion of northwest Cuba, from Jutía Key (site 39-750) to Mariel Bay (site 43-750), sediments were still dominantly carbonate (78–92%) and silts (44–89%) but exhibited more variability over the past ~100 years (Fig. 9.3). There was an increase in accumulation of terrigenous sediments offshore of this region,

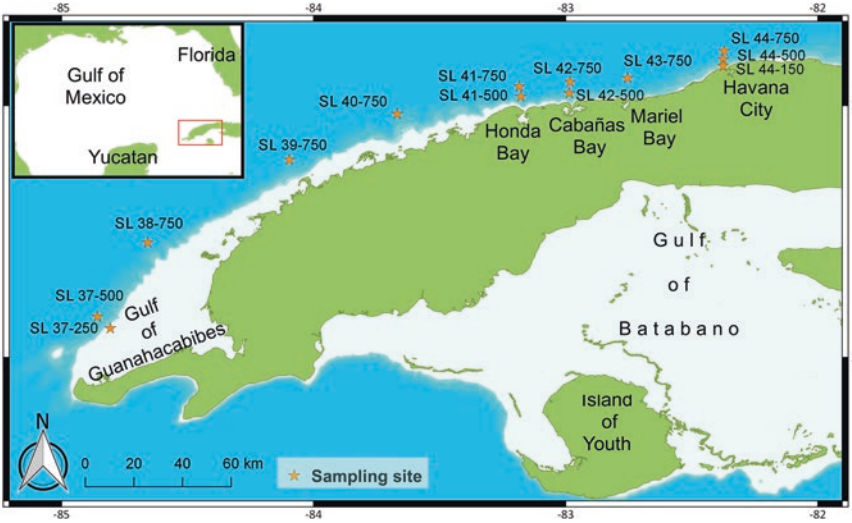

Fig. 9.1 Map of the NW region. The 13 sites sampled during Weatherbird II expedition in the shelf margin are indicated with starts

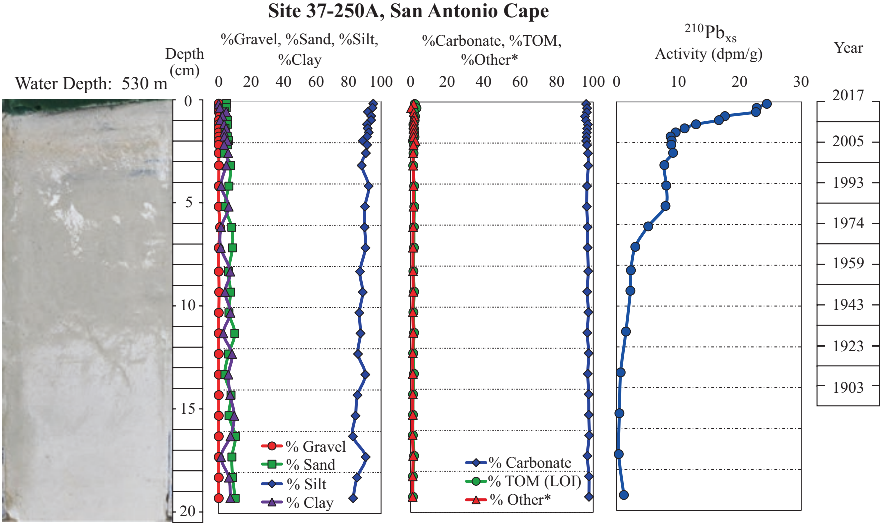

Fig. 9.2 Sediment core log for site 37-250 in the western portion of the study area, showing core photograph, sediment texture, sediment composition, 210Pbxs profile, and 210Pbxs chronology. Note the stable consistent sedimentation of carbonate silt over the past ~100 years

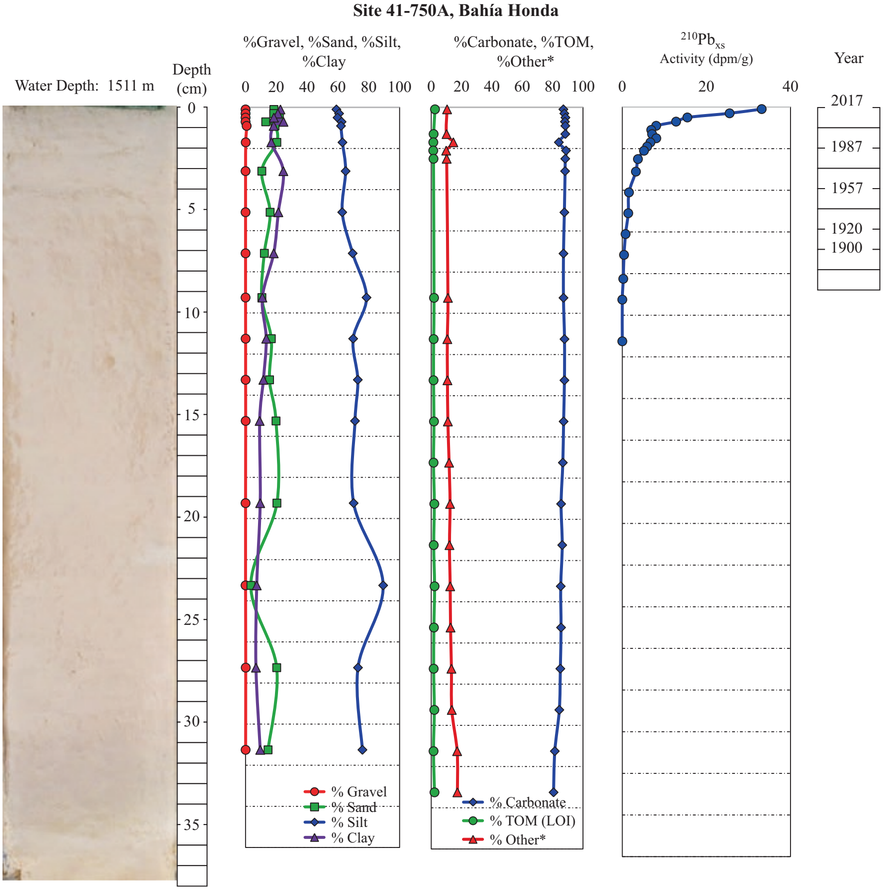

Fig. 9.3 Sediment core log for site 41-750 in the central portion of the study area, showing core photograph, sediment texture, sediment composition, 210Pbxs profile, and 210Pbxs chronology. Note the decrease in % silt upcore with no changes in composition over the past ~100 years

potentially associated with coastal anthropogenic activities and/or export from the adjacent bays (Honda, Cabañas, and Mariel). With the exception of site 39-750 (offshore Jutía Key), $^{210}Pb_{xs}$ chronologies were comparable to sites to the west, with dating the year 1900 for site 40-750 at 6 cm, site 41-750 at 6.5 cm, site 42-500 at 6 cm, site 42-750 at 4.5 cm, and site 43-750 at 5.5 cm depth downcore. MARs for these sites were also similar with site 40-750 at 0.034 g cm^{-2} yr^{-1}, site 41-750 at 0.045 g cm^{-2} yr^{-1}, site 42-500 at 0.052 g cm^{-2} yr^{-1}, site 42-750 at 0.032 g cm^{-2} yr^{-1}, and site 43-750 at 0.049 g cm^{-2} yr^{-1}. Site 39-750 had the deepest $^{210}Pb_{xs}$ profile (12.5 cm) and highest MAR of 0.112 g cm^{-2} yr^{-1} for this portion of northwest Cuba. Site 39-750 also showed a shift in sedimentation patterns over the top 0–1 cm with an increase in sand content from ~10% to 50%, concurrent with a decrease in silt content from 80% to 45%. This recent shift in sedimentation pattern was present in all other cores in this portion of the study area, although magnitudes were generally lower. There were no detectable changes in sediment composition (% carbonate, % TOM, % other) indicating no significant changes in sediment source(s).

The eastern portion of the northwest Cuba resided offshore Havana Bay with sites 44-150, 44-500, and 44-750. Sediments were the most variable in this region with % carbonate for site 44-150 ranging from 50% to 75%, site 44-500 ranging from 28% to 50%, and site 44-750 ranging from 39% to 86% (Fig. 9.4). Sediment

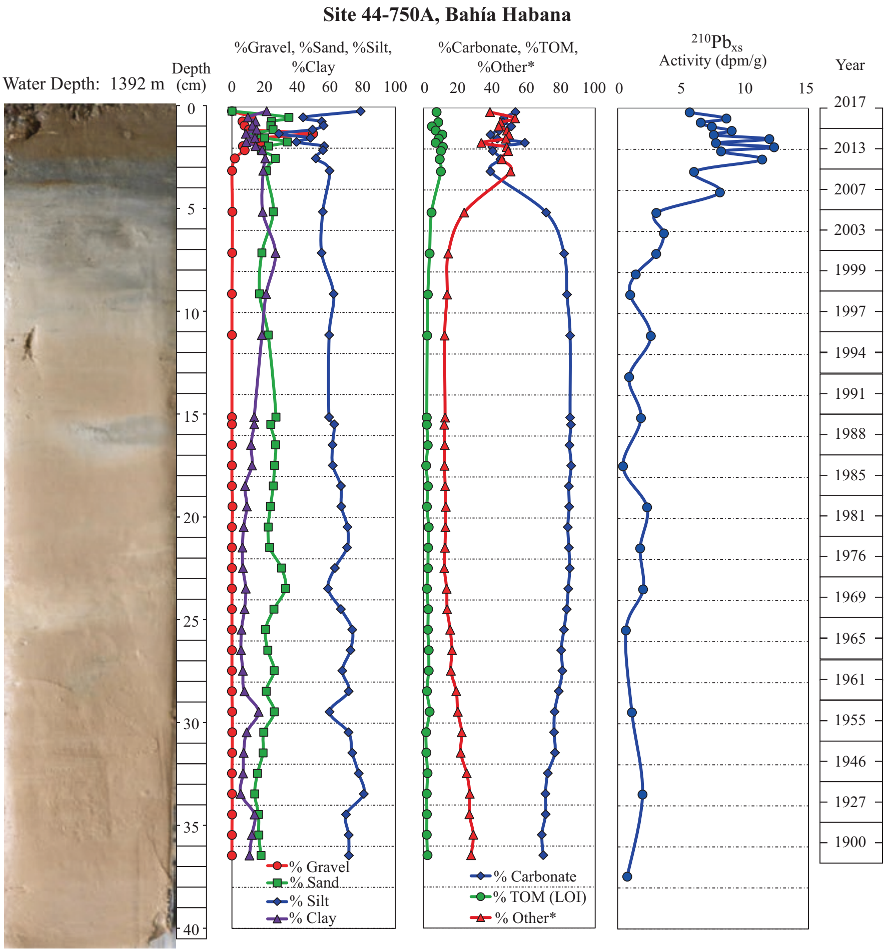

Fig. 9.4 Sediment core log for site 44-750 in the eastern portion of the study area, showing core photograph, sediment texture, sediment composition, 210Pbxs profile, and 210Pbxs chronology. Note the shifts in both sediment texture and composition in the recent portion of the sediment record

texture was also variable and coarser than the regions to the west, particularly with increased % gravel (0–50%), % sand (0–51%), and % silt (29–81%). This region also had the most variability in composition over the past ~100 years, with the highest % terrigenous (12–63%) and TOM (2–11%) indicating changes in sedimentation patterns and sources. $^{210}\mathrm{Pb}_{xs}$ chronologies were also distinctly different from the western and central regions of northwest Cuba, with site 44-150 dating 1900 at 19.0 cm, site 44-500 at 11.5 cm, and site 44-750 at 35.5 cm depth downcore. MARs for these sites were also higher, with site 44-150 at 0.229 g cm^{-2} yr^{-1}, site 44-500 at 0.111 g cm^{-2} yr^{-1}, and site 44-750 at 0.405 g cm^{-2} yr^{-1}. These MARs were coherent with those estimated inside Havana Bay (0.04-0.38 g cm^{-2} yr^{-1}) before 1900 (Diaz-Asencio et al. 2011). The higher sedimentation rates and increased variability in sedimentation patterns over the past ~100 years may be attributed to the close proximity to terrigenous sediment sources (narrow shelf), as well as potential changes in anthropogenic activities and influences on sediment input and distribution (Diaz-Asencio et al. 2011).

9.4 Fauna Communities

9.4.1 Mollusks

The decline in species richness is one of the most powerful indicators of environmental impact (Armenteros et al. 2016). The northwest Cuban margin harbors a diverse mollusk assemblage constituted by 129 species. Eleven species of pteropods (families Cavolinidae and Peraclididae) occurred in all the sites and in most of the samples in high dominance: *Cavolinia inflexa*, *Creseis acicula*, *Creseis virgule*, *Diacavolinia deblainvillei*, *D. deshayesi*, *Limacina bulimoides*, *L. inflata*, *L. lesueurii*, *L. trochiformis*, *Peracle reticulata*, and *Styliola subula.* Four species of heteropods (family Atlantidae) were also broadly distributed across northwest Cuban margin: *Atlanta inclinata*, *A. peroni*, *Oxygyrus keraudrenii*, and *Protatlanta souleyeti* (Fig. 9.5). These pelagic species were likely broadly dispersed by currents and deposited on the seabed at death. Thus, they have limited importance as a proxy for sediment quality although they may indicate potential impacts in the water column. *Benthonella gaza* was the only benthic species broadly distributed (Fig. 9.5). Fifty-seven other species were rare, occurring in one sample (43 species) or two samples (14 species). The decline of the bulk of rare species is another indicator of potential impact and can be used to assess environmental health.

Species richness varied significantly among sites from 40 species at 42-750 (off Cabañas Bay) to 80 species at 40-750 (off Levisa Key) (Fig. 9.6a). Coastal mollusk species were well-represented in Mantua, Bahía Honda, and Mariel suggesting considerable transport of sediment offshore due to coastal circulation. Another anthro-

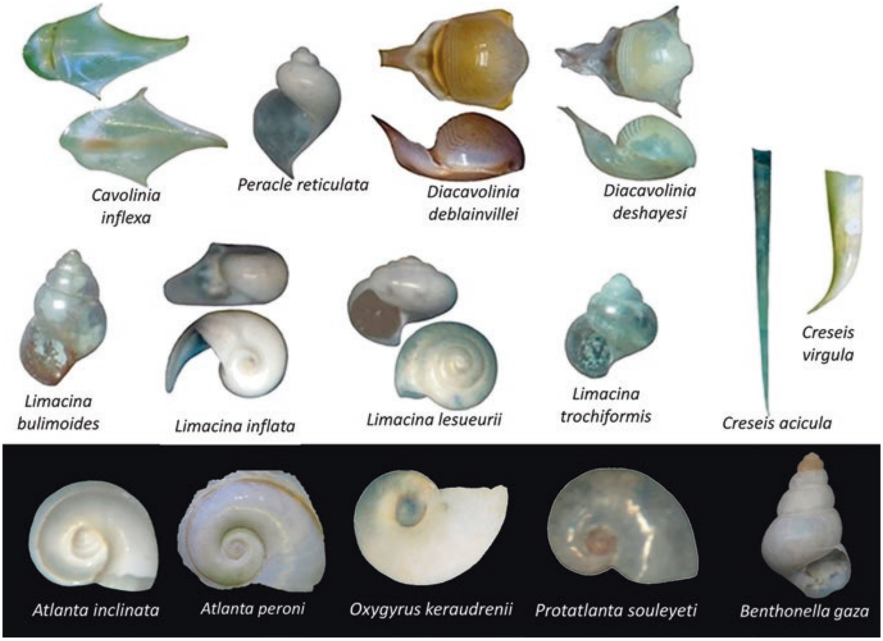

Fig. 9.5 The most broadly distributed species of mollusks from nine sites of the Cuban margin of GoM. Pelagic pteropods (families Cavolinidae and Peraclididae) in white background and pelagic heteropods (family Atlantidae) in black background. Note also to the single broad-distributed benthic species *Benthonella gaza* at bottom right corner

pogenic activity that may be responsible for the occurrence of coastal species in the deep-sea margin is the dumping of dredging material from nearby ports such as Santa Lucia (near to Jutía key) and Mariel (Fig. 9.6b).

9.4.2 Meiofauna

Meiofauna constitute one of the most used biological proxies for anthropogenic impact due to (i) relatively low dispersal capacity allowing the assessment of local impacts, (ii) high diversity represented by many species with different life histories (e.g., differential sensitivity to specific impacts), and (iii) tight association with sediment condition. Nematoda and Copepoda were the dominant groups of the meiofauna contributing to 66% and 12%, respectively, of the total abundance in the Cuban GoM; Halacaroidea and Foraminifera were also important (Fig. 9.7a). The meiofauna median density in the Cuban margin was 3.6 individuals/10 cm^{-2} (range 0–7 ind./10 cm^{-2}). This is one of the lowest values of meiofauna density ever reported for deep-sea environments in GoM (e.g., Baguley et al. 2006). Average estimates of meiofauna abundance in coastal habitats from northwest Cuban region

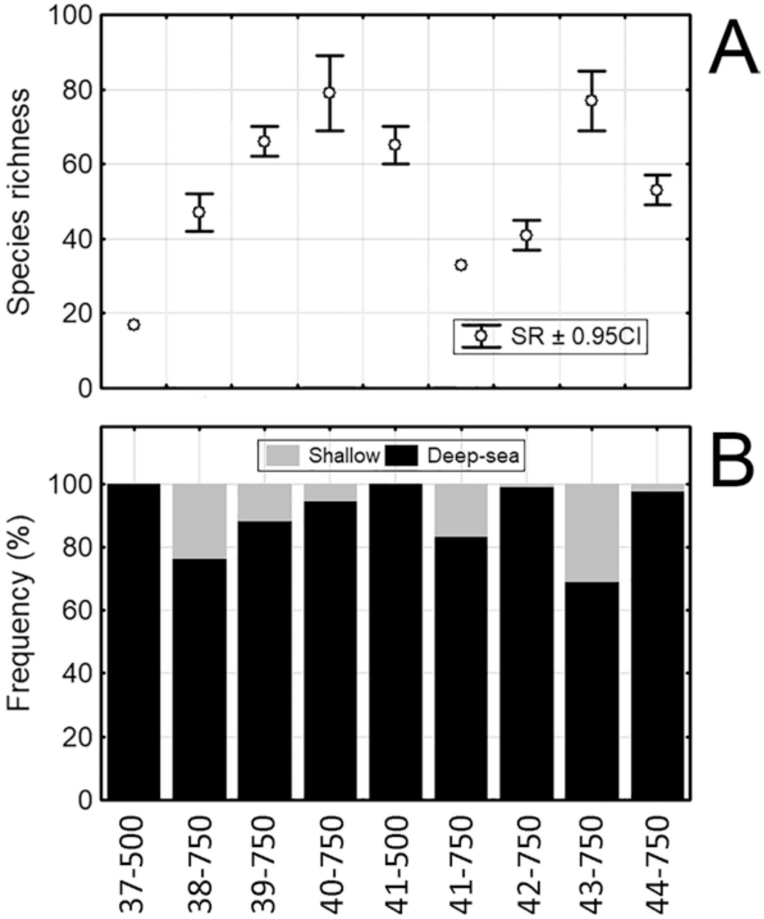

Fig. 9.6 Mollusks from nine sites of the Cuban margin of GoM. (**a**) The species richness with associated 0.95 confidence intervals (CI). (**b**) The frequency of shallow versus deepwater mollusk species

have been considerably higher (Armenteros et al. 2007, 2009): 24 ± 11 ind./10 cm^{-2} in mangroves, 148 ± 41 ind./10 cm^{-2} in seagrass meadows, and 243 ± 47 ind./10 cm^{-2} in spur and groove formations within coral reefs. The low abundance in deeper waters from the northwest Cuban margin is most likely caused by a combination of oligotrophic conditions in sediments and physical disturbance by water flows. The apparently natural low density considerably limits the use of meiofauna for environmental analysis since depletion in abundance is one of the main indicators of disturbance. Species composition of free-living nematodes, the most abundant taxon of meiofauna, could offer a potential baseline, but the analysis is still in progress.

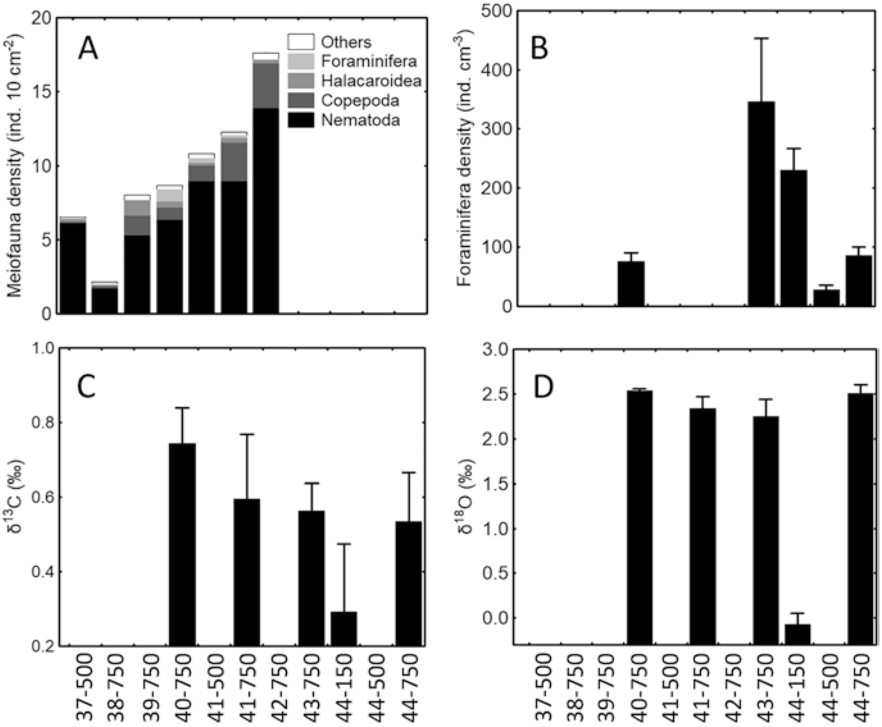

Fig. 9.7 Meiofauna in sampling sites of the Cuban margin of GoM. (**a**) Meiofauna (higher taxa). (**b**) Mean benthic foraminifera density (individuals/cm^{-3}). (**c**) Stable carbon (δ13C) isotope composition of benthic foraminiferal calcite. (**d**) Oxygen (δ18O) isotope composition of benthic foraminiferal calcite. Uncertainties are reported as standard deviation

9.4.3 Foraminifera

Benthic foraminifera density, diversity, and stable isotope composition have proven to be useful tools for assessment of impact, response, and recovery of the benthos in the event of an oil spill (Morvan et al. 2004; Lei et al. 2015; Schwing et al. 2015, 2017b; Schwing et al. 2018a, b). Cores collected at sites 44-150 (Havana Bay), 44-500, 44-750, 43-750 (Mariel Bay), 41-750 (Honda Bay), and 40-750 (Levisa Key) were analyzed for these variables to provide baseline measurements in advance of future perturbations.

The number of foraminifera species in the northwest Cuban margin was 261. Along the outer shelf (~300 m water depth), *Cassidulina* spp. was the predominant taxa. At sites ranging from 970 to 1590 m water depth, *Bolivina* spp. was predominant. *Bolivin*a spp. are widely abundant throughout the GoM continental slope

(Denne and Sen Gupta 1991). The total benthic foraminiferal density was highly variable and generally high relative to other regions within the GoM (Schwing et al. 2020) with a mean density of 163 ± 158 individuals/cm^{-3} (range 76–346 ind./cm^{-3}) (Fig. 9.7b).

The stable carbon isotope composition ($\delta^{13}C$) of benthic foraminiferal calcite was also highly variable between sites (mean 0.54‰ ± 0.51‰) and generally increased from near Havana Bay (44-150, 0.29‰; 44-750, 0.53‰) to the west (40-750, 0.7‰) (Fig. 9.7c). $\delta^{13}C$ was within natural variability throughout the northern and southern Gulf of Mexico continental shelf and slope (0.69‰ ± 0.46‰) (Schwing et al. 2020). However, the east-to-west enrichment is consistent with a decreasing terrigenous carbon source with distance from population centers such as Havana.

The mean stable oxygen isotope composition $\delta^{18}O$ (‰) of benthic foraminiferal calcite was 1.71‰ ± 0.13‰. $\delta^{18}O$ in the Cuban margin was generally higher than the northern (1.31‰ ± 0.08‰) and southern (0.73‰ ± 0.05‰) Gulf of Mexico. $\delta^{18}O$ varied primarily with water depth, which was likely due to changes in salinity (water mass) and proximity to sources of freshwater runoff. For example, a site near Havana Bay was depleted (44-150, −0.1‰) in contrast to sites farther offshore, which ranged from 0.22‰ to 0.25‰ (Fig. 9.7d).

9.5 Conclusions

In conclusion, offshore the northwest Cuban coast, there was a west-to-east sedimentation pattern as reflected by sediment texture, composition, MAR, and $\delta^{13}C$ of benthic foraminiferal calcite. This sedimentation pattern was likely caused by the combined increase of natural terrigenous influence and anthropogenic activities, which changed from west (almost pristine) to east (semi-enclosed bays with human development). Mollusk assemblages were dominated by relatively few pelagic species that distributed broadly along northwest margin suggesting strong connectivity due to oceanographic regime. Pelagic and coastal shells conformed large part of mollusk assemblages indicating deposition from both the water column and coastal sites.

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