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ORIGINAL PAPER

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The Belize margin revisited: 1. Holocene marine facies

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Abstract Belize is best known for its 260-km-long barrier reef and associated lagoon reef shoals, but also exhibits a complete transition from near-shore siliciclastics to pure carbonate deposits across a narrow shelf lagoon and, in addition, has three of the very few occurrences of Caribbean atolls. Published Holocene facies relationships on the Belize shelf have been semi-quantitative in that they are based on quantitative point count thin section data in the northern shelf lagoon and on qualitative estimates of thin section composition in the southern shelf lagoon. This contrast has been rectified by point counting southern shelf lagoon thin sections and incorporating the result with published point count data from the northern shelf, supplemented by additional information, to produce a modified factor analysis facies distribution for the entire shelf. The resulting nine facies are extended seaward to include previously published analysis of sediment on the three Belize off-shelf atolls, resulting in a total of 11 facies. In addition, the carbonate mud distribution has been mapped over both the shelf and atolls with the not unexpected result that, in places, the distribution pattern clearly indicates a barrier platform source of lagoon-deposited carbonate mud. Dunham's limestone classification terminology has been used as a basis for description to make these relationships more useful to those reconstructing ancient limestone depositional environments.

Keywords Atoll · Barrier reef · Belize · Carbonate sediments · Shelf margin

Electronic Supplementary Material Supplementary material is available for this article if you access the article at http://dx.doi.org/10.1007/s00531-003-0324-0. A link in the frame on the left on that page takes you directly to the supplementary material.

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Introduction

Objective

The purpose of this contribution is to update the Holocene facies distribution of the Belize shelf in a format compatible with that used for describing ancient limestones. Towards that end, we begin by describing salient onshore and offshore attributes.

Mainland and offshore framework

The country of Belize is situated at the south-eastern end of the Yucatan Peninsula and is bordered on the east by the Caribbean Sea, on the north by Mexico and on the west by Guatemala (Fig. 1). The 22,963-km^2 land area is characterized by considerable topographic and lithologic diversity. To the north, topographic relief is less than 60 m and developed exclusively on low-lying limestone and Quaternary deposits. To the south, the topography reaches elevations as high as 1,100 m in the Maya Mountains where it is developed on largely non-carbonate lithologies (Fig. 2). Paralleling these changes is an annual rainfall distribution pattern that increases from 124 cm in the north to more than 380 cm in the south near the Guatemalan border (Purdy et al. 1975). Belize lies within the trade wind belt with the winds blowing most consistently and strongest from the north-east and east (Fig. 2).

The offshore shelf area is bordered by a well-developed barrier reef that extends from the northern border of the country southward for approximately 260 km, terminating in a hook-like configuration (Fig. 2). Shelf bathymetric relief parallels land topogra-

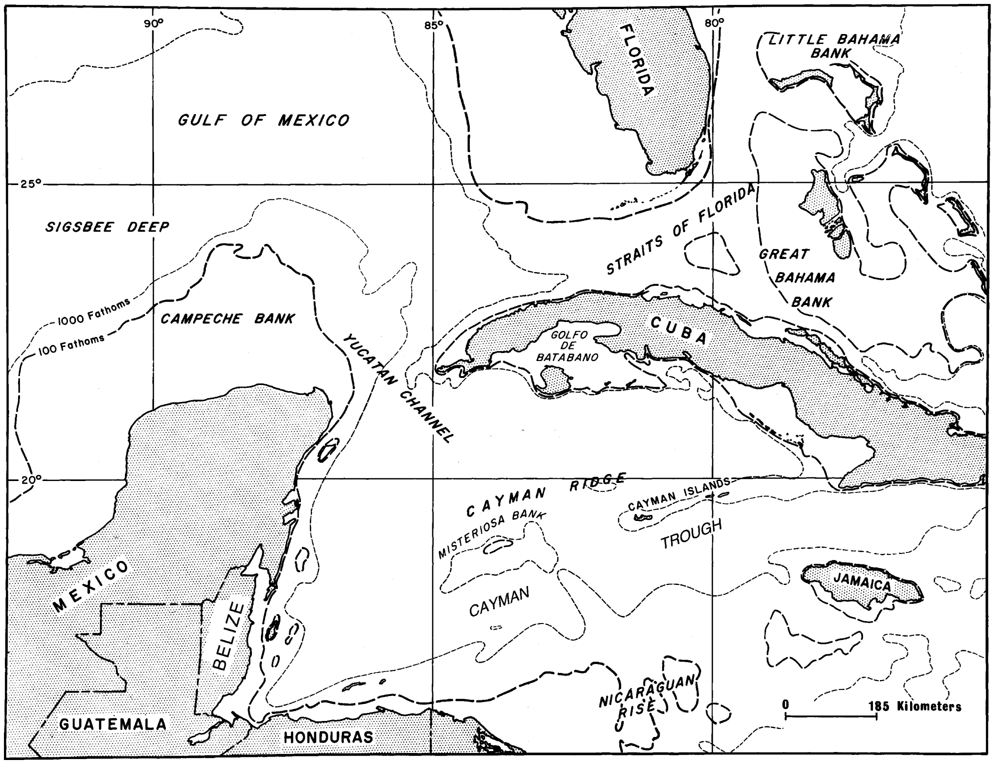


Fig. 1 Regional Caribbean location of Belize

phy in that it increases from less than 5 m in the north to more than 46 m in the south (Fig. 2). As in other areas, the barrier reef provides wave shelter for the adjoining lagoon. In the north, this shelter takes the form of a barrier rim that broadens in width to the south to become a barrier platform. Unlike the barrier rim, the barrier platform is characterized by an abrupt increase in depth into the adjoining shelf lagoon that increases in magnitude toward the south. A similar depth relationship is common in reefs throughout the world and we propose that the same barrier platform terminology be applied to these examples as well. To refer to them simply as backreef is misleading, as it does not discriminate the marked change in depth toward the lagoon, which, strictly speaking, is also backreef. The increasing depth of the Belize shelf lagoon toward the south allows the further distinction of a northern and southern shelf lagoon. Marine influence in the northern shelf lagoon diminishes northward into Chetumal Bay due to the marine circulation restriction imposed by Ambergris Cay and the fresh water influx into the bay from streams and rivers, mainly the Rio Hondo and New River (Fig. 2). We have used the Bulkhead mud shoal (Fig. 2) as the boundary between Chetumal Bay circulation and the more marine influence in the northern shelf lagoon based on the distribution of bottom and surface water salinities (Purdy et al. 1975, their Figs. 5 and 6). The barrier platform makes its appearance approximately at the latitude of Belize City, and separates the northern shelf lagoon from a central shelf lagoon that is for all practical purposes devoid of carbonate shoals with the exception of those that occur adjacent to the deeper water English Cay Channel through the barrier platform. Still farther south, the shelf lagoon becomes characterized by a multiplicity of carbonate shoals including shelf atolls that are sometimes collectively referred to as the rhomboid shoal area because of their individual shapes. The occurrence of these shoals marks the boundary between the central and southern shelf lagoons. To the south, the southern shelf lagoon includes the relatively flat bottom area of Victoria Channel as well as innumerable carbonate shoals and extends southward to include the hook-shaped termination of the barrier reef. The southern shelf lagoon is bordered by the deeper Gulf of Honduras that lacks the protection of a barrier reef and generally deepens toward the shelf edge, although there are some deeper water shoals within it. The Port of Honduras is a curious indentation in the coastline characterized by a multiplicity of large coral colonies of *Siderastrea siderea*, low surface water salinities (approximately 26‰) and higher, but still relatively low, bottom water salinities (30‰, Purdy et al. 1975).

Previous and present database

A Belize Holocene facies map was first published by Purdy (1974) and was based on approximately 250 surface samples taken along E–W traverses across the Belize shelf. Subsequently, a more comprehensive account of the composition, texture and mineralogy of these samples was published by Purdy et al. (1975). Composition was based on the amount of insoluble residue and texture was based on the wet sieve weight per cent of silt

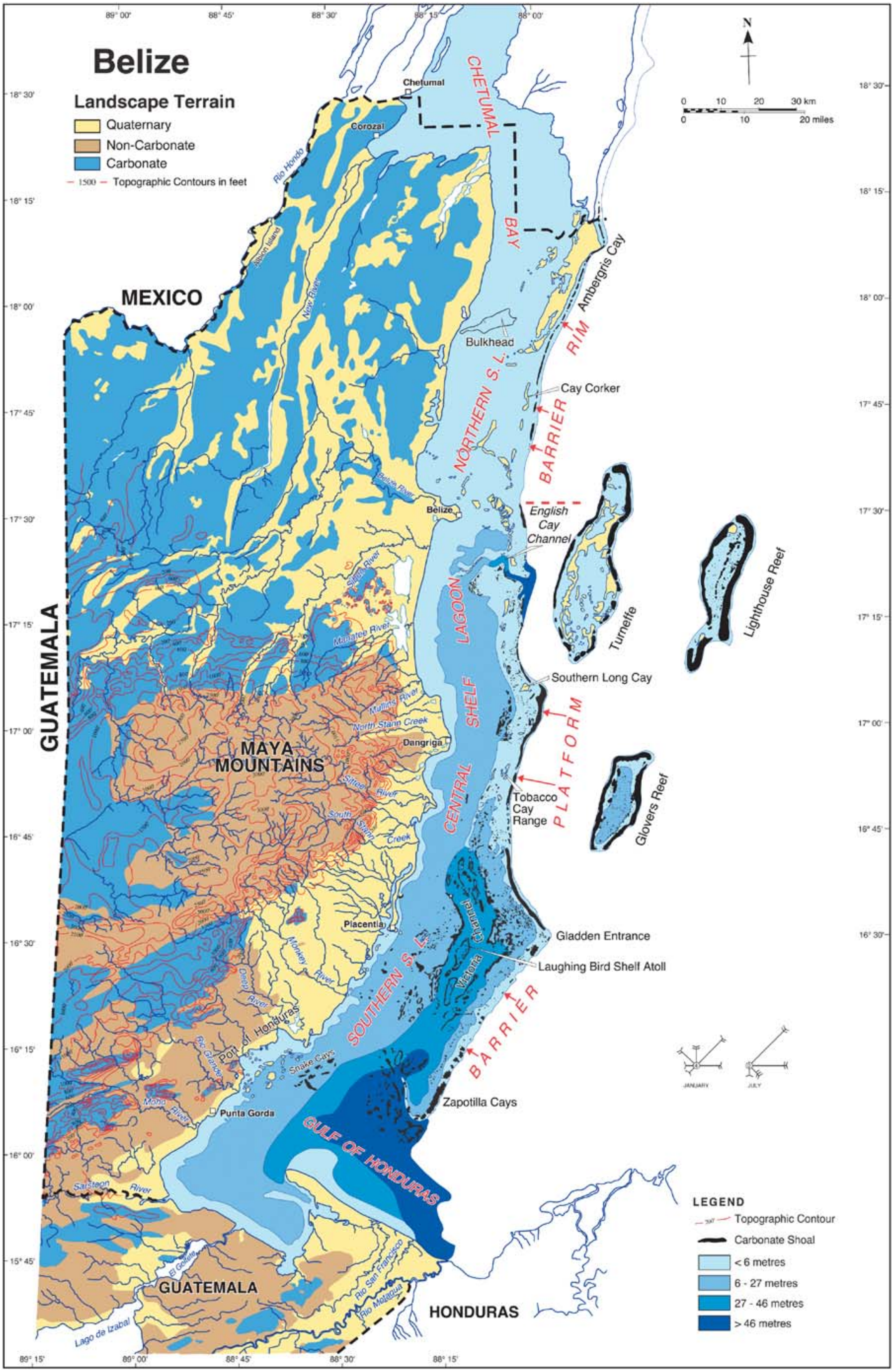


Fig. 2 Topography and bathymetry of Belize with mainland terrain lithologies and names of major shelf subdivisions (i.e. northern, central and southern shelf lagoons, barrier rim and barrier platform). Carbonate shoals are mainly reef complexes

+ clay (mud) in each sample. To this extent, both northern and southern shelf samples were treated identically. The constituent composition of the sediment fraction coarser than 1/16 mm, however, was determined differently for the northern and southern samples. Both were based on relative abundances in thin section, but, whereas the northern shelf estimates were based on point-counts of thin sections, the southern ones were based only on visual estimates. Nonetheless, the composition, texture and differently determined constituent composition of each sample were used collectively to describe Holocene facies on the shelf.

We have rectified this contrast in data analysis by point counting the constituent composition of 150 samples from the southern Belize shelf, at the limit of 200 points per thin section. Additionally, the samples have been reconstituted in the sense of looking at the constituent composition of each sample as a percentage of the total sample rather than the usual procedure of treating the total point-count constituents of each sample as equal to 100%. Thus, if the percentage of corals in a sample was 20% of the total 100% point count category, but the corresponding sieve fraction coarser than 1/16 mm was only 10%, the reconstituted coral percentage in the total sediment sample was correspondingly reduced to 2%. Not only does this make more sense from a purely depositional point of view, but it also serves to facilitate comparisons with ancient limestones in which the coarse fraction is seldom tabulated independently of the mud fraction. All these data have been electronically archived and can be found at http://dx.doi.org/10.1007/s00531-003-0324-0.

Sample preparation techniques were previously described by Purdy et al. (1975) and Pusey (1975) and it would serve no useful purpose to repeat them here. It is perhaps useful, however, to remind readers that recorded insoluble residue and wet sieve values in the data table are generally accurate to within 5% of the indicated values (Purdy et al. 1975).

Additional quantitative textural and compositional data of sediment samples from the three off-shelf atolls (Gischler 1994; Gischler and Lomando 1999) were used to extend the sediment maps to these areas.

Statistical analyses

The final data matrix for the Belize data set consisted of 207 sediment samples and 21 variables comprising compositional properties including total sample percentage of insoluble residue, wet sieve size fractions, point count data and calculated amounts of terrigenous and carbonate mud. Q-mode factor analysis (Imbrie and Purdy 1962) is a quantitative method that condenses large volumes of data such as this and objectively attempts to delineate natural groupings among samples based on a simultaneous consideration of all the variables. A coefficient that quantitatively measures the degree of similarity between all pairs of samples is required as input to the factor analysis. The cosine theta similarity coefficient (Imbrie and Purdy 1962) was used for this purpose as it defines similarity between samples on the basis of the proportionality of constituents and also mitigates against the influence of the large number of zeros that occur in these data.

Ed Klovan provided the factor analyses of these data using the Extended CABFAC method of Klovan and Miesch (1976). The analyses were made on both raw data values as well as on variable data converted to a percentage of their respective ranges. The percent range transformation is an attempt to give equal weight to all the variables regardless of their absolute values and range of variability. This approach proved ineffective, as the more common and abundant constituents were generally also those that were geologically more important; hence, the preference for the raw data factor analyses.

Results

A seven-factor solution, based on the raw data values, accounted for 98% of the data variability. Using the oblique solution of Miesch (1975), the seven compositionally most different samples were determined and the remaining 200 samples were treated as mixtures of these seven end members. Plotting the oblique factor loadings on maps provided a basis for plan view facies recognition. The seventh, and least significant factor, did not show a coherent geographic pattern and, therefore, was eliminated. The resulting six-factor case accounted for 96% of the data variability. The six extreme samples identified as end members were sample numbers 52, 74, 97, 88, 171A and 198. Among these, sample 52 had the lowest communality and, therefore, was the weakest choice among the six. The six factor results are recorded in an electronically archived table at http://dx.doi.org/10.1007/s00531-003-0324-0.

The factor analysis accomplished the objective of reducing the large amount of data to a more manageable form and provided a geologically meaningful sample classification. Acceptance of this analysis in its entirety, however, was negated by the need to emphasize certain sedimentary attributes in conjunction with plan-view patterns. Consequently, as noted in the following section, three additional facies were recognized within the factor grouping of six, making a total of nine facies. Among these were two terrigenous clastic facies.

The remaining seven shelf carbonate facies were given rock names following Dunham (1962) in anticipation of what they might be called when converted into limestones. In doing this, no attempt was made to judge what effect compaction might have in changing rock fabric. Additionally, the facies of the three offshore atolls were renamed from Gischler and Lomando (1999) to conform with the names of the shelf-related facies, but also resulted in the addition of two facies that appear to be atoll-specific in their occurrence. Total sediment composition for 19 shelf sample cross sections is shown in Fig. 3

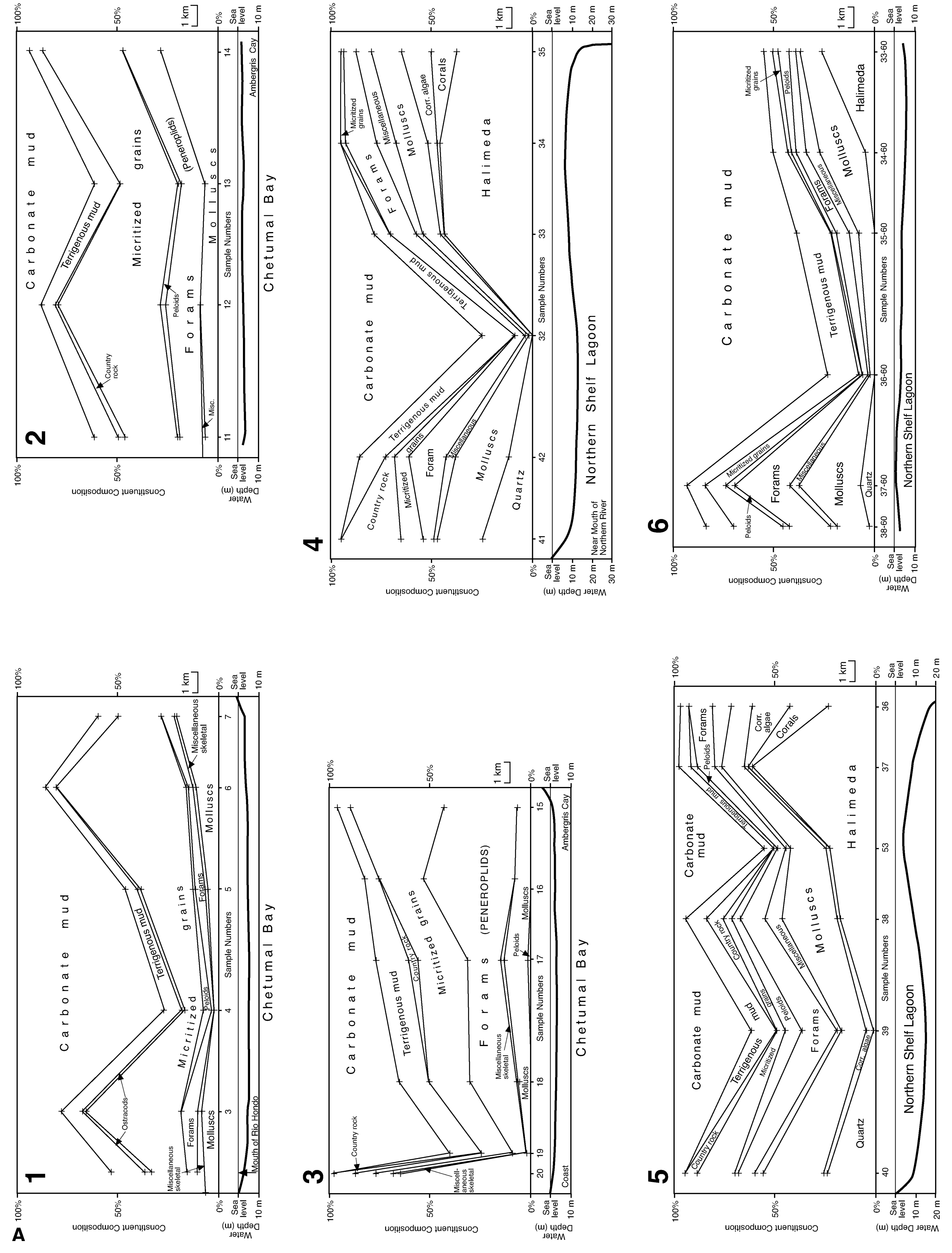


Fig. 3 Nineteen sediment composition cross sections across the Belize shelf. Location of all profiles is shown in **D**. The generalized bathymetric profile beneath each cross section is tied to the water depths recorded at each of the identified sample locations. Sample numbers in *parentheses* refer to instances where only sample water depth information was used. The peloid designation refers to what Pusey (1975) called fecal pellets. **A** Chetumal Bay and northern shelf lagoon profiles 1–6. **B** Central shelf lagoon profiles 7–12. **C** Southern shelf lagoon profiles 13–16. **D** Southern shelf lagoon, Gulf of Honduras and north to south strike section profiles 17–19. *Note*: the scale change for profile 19

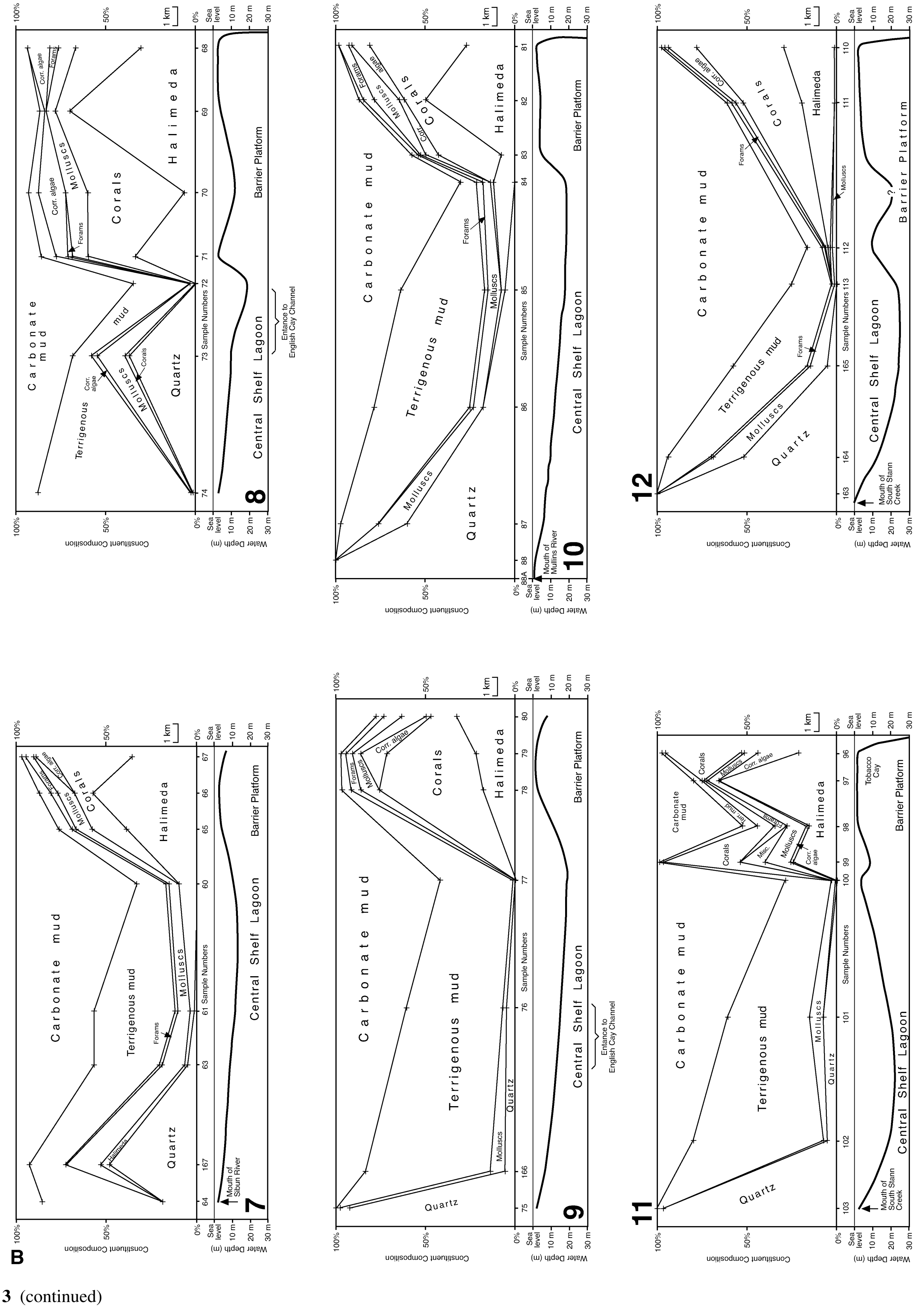
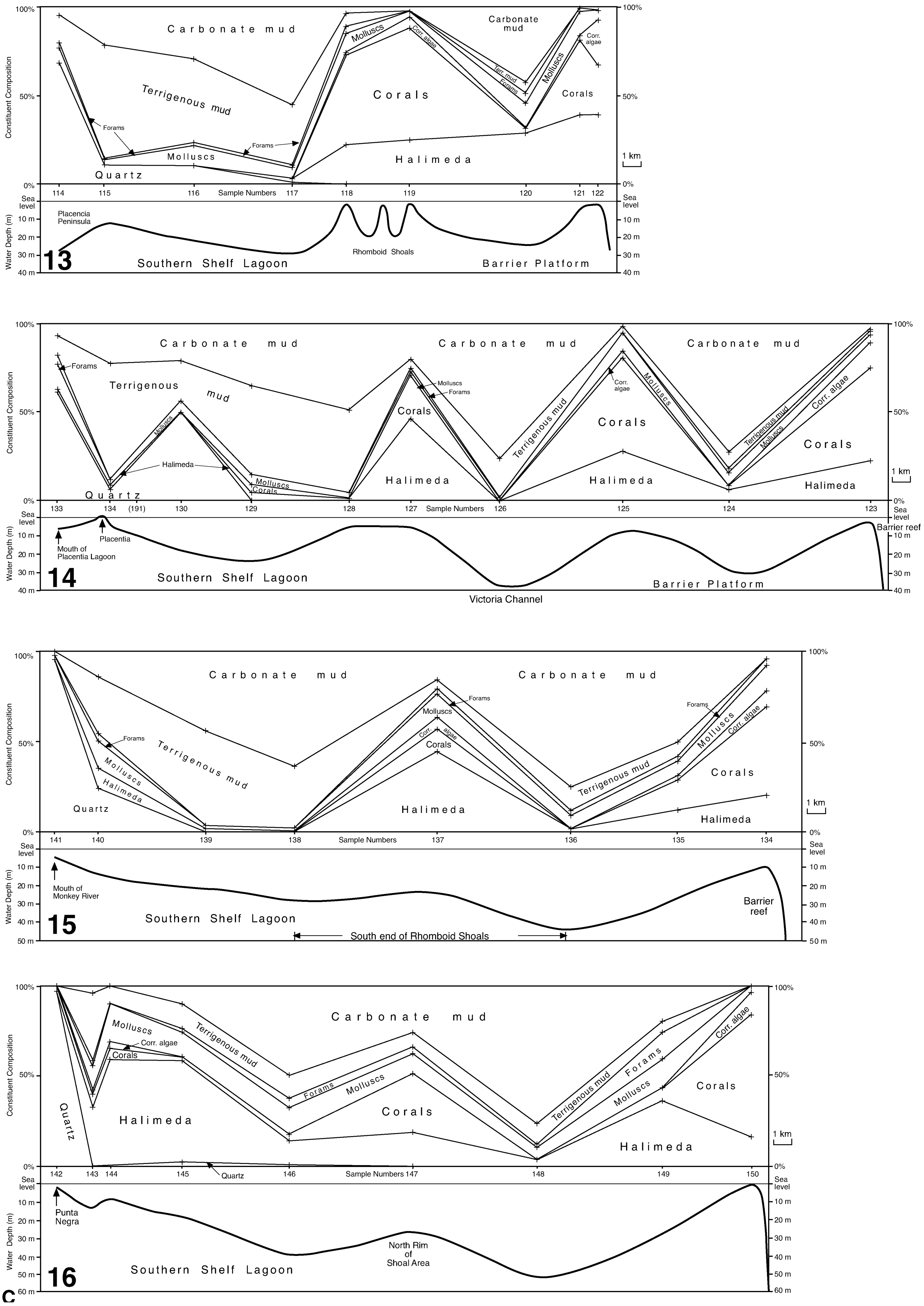


Fig. 3 (continued)



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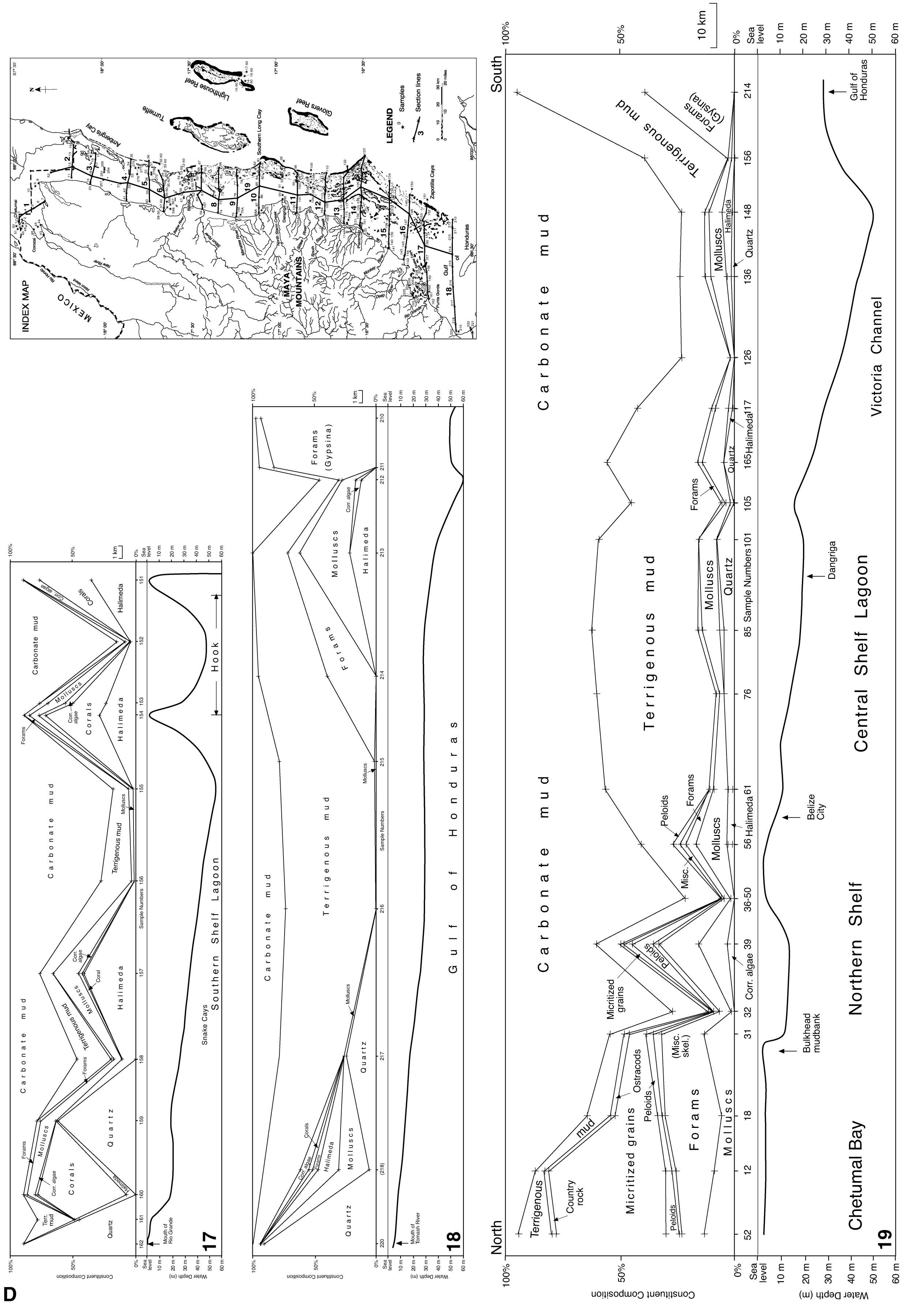


Fig. 3 (continued)

and all 11 facies are illustrated in Fig. 4 and introduced and described in a general west to east direction beginning with the terrigenous end member and ending with the carbonates. Specifically excluded from the facies discussions are Holocene dolomite occurrences in the supratidal flats of Ambergris Cay, in the mud shoals separating Ambergris Cay from Congrejo Cay and in Chetumal Bay. The reader is referred to Ebanks (1975), Mazzullo et al. (1995) and Teal et al. (2000) for a discussion of these occurrences.

In several cases, the use of Dunham's terminology is ambiguous in the sense that two, or in one instance three limestone rock names are used for a specific facies, for example: wackestone/mudstone or packstone/wackestone. Strict differentiation among these rock types would have led to a patchwork of facies patterns that obscured obvious regional trends. In this regard we notice that Enos and Sawatsky (1981) may have had a similar problem as the amount of mud in their Holocene Florida and Bahamian packstone facies ranges from 1.27 to 57.0%. It is doubtful whether compaction would have eliminated this patchwork tendency and, consequently, we suggest that while Dunham's classification may be optimal for reservoir descriptions, it leaves a lot to be desired in delineating meaningful regional trends, at least in terms of the Holocene.

Sediment mud fraction

The reconstituted approach also facilitates calculation of the amount of terrigenous and carbonate mud (silt + clay) in the samples. Terrigenous point count constituents are non-carbonate minerals, chiefly quartz, and are coarser than 1/16 mm as are all the point count constituents. Consequently, if the amount of reconstituted non-carbonate minerals is 10% and the insoluble residue total is 50%, the amount of terrigenous mud in the sample is 50−10=40%. Similarly, if the amount of terrigenous mud in the sample is 40% and the sieve fraction smaller than 1/16 mm is say 30% of the total sample, the carbonate mud in the sample is 30% (0.3×0.4)=18%. These calculations are the basis for the carbonate mud percentages recorded in the electronically archived table. The average error associated with the individual sample mud estimates is 2% and the maximum observed error is 10%. It is, of course, true that the insoluble residue percentages include non-carbonate skeletal material (e.g. siliceous sponge spicules) as well as organic matter, but the amount of this material would certainly fall well within the 5% analytical error recorded for insoluble residue percentages (Purdy et al. 1975) and probably within the above-noted average 2% error. Consequently, it seems reasonable to regard the insoluble residue percentages as essentially reflecting the abundance of siliciclastic material.

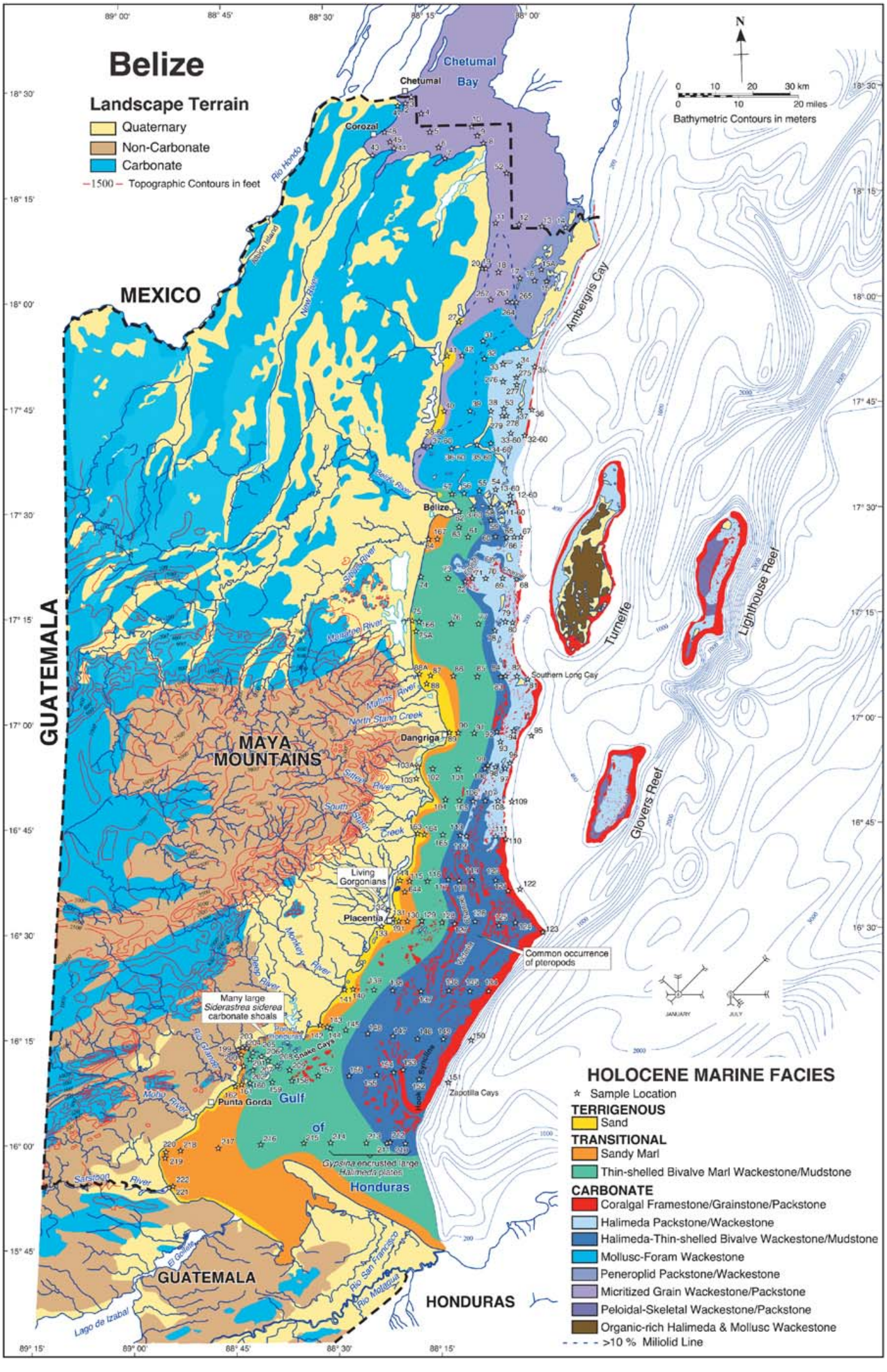
Terrigenous mud

The amount of terrigenous mud in the barrier rim of the northern shelf and the barrier platform and carbonate shoals of the southern shelf is generally less than 5%, and 1% or less in the barrier reef itself where it may represent the contribution of siliceous skeletal material (e.g. siliceous sponge spicules) rather than the amount of terrigenous mud. Within the shelf lagoon the percentage of terrigenous mud is generally minimized and less than 15% in Chetumal Bay and the northern shelf lagoon, reflecting the low-lying mainland provenance of largely carbonate rocks. Its extent increases markedly at the latitude of Belize City reflecting river drainage from the significantly greater non-carbonate relief of the Maya Mountains. In the central shelf lagoon, terrigenous mud values are generally greater than 40% and increase toward shore until replaced texturally by terrigenous sand. Correspondingly, terrigenous mud decreases in abundance toward the barrier platform through dilution by carbonate mud. The same general pattern is apparent in the southern shelf lagoon, but is modified by carbonate mud dilution in proximity to the innumerable carbonate shoals. Farther south, the seaward extent of terrigenous mud is maximized in the Gulf of Honduras, reflecting the relative lack of carbonate mud dilution as well as what must be a significant increase in land drainage occasioned by greater southern annual rainfall precipitation. There is also a corresponding north–south provenance difference in the distribution of clay minerals. The northern rivers mainly transport smectite whereas the southern rivers transport an abundance of kaolinite and illite relative to smectite (Krueger 1963). These differences are also reflected by the distribution of clay minerals offshore with the northern shelf dominated by smectite and the southern shelf by near-shore kaolinite and offshore smectite (Scott 1975).

Carbonate mud

The abundance of carbonate mud is highest in the shelf lagoon area adjacent to the barrier platform and in the

Fig. 4 Holocene marine facies on the Belize shelf and on the three off-shelf atolls. The miliolid line in the northern shelf lagoon-Chetumal Bay area encloses an area in which the miliolid content of the sediment exceeds 10% of the total sediment. The transitional marl facies are limited to the central and southern shelf lagoon, reflecting derivation from the Maya Mountains non-carbonate provenance. The wider seaward extent of marl facies in the Gulf of Honduras mainly reflects lack of carbonate dilution because of the absence of the barrier platform and the significant reduction in the number of shallow water carbonate shoals. Atoll-specific facies not occurring on the shelf are the peloidal-skeletal wackestone/packstones and the organic-rich *Halimeda* and mollusc wackestones. Note the usage of twinned limestone rock names for many of the facies (e.g. wackestone/packstone, etc.). Strict adherence to Dunham's (1962) classification scheme with respect to separation of these rock types would have led to a patchwork of facies that obscured significant regional relationships


Belize
Landscape Terrain
Quaternary
Non-Carbonate
Carbonate
–1500– Topographic Contours in feet
0 10 20 30 km
0 10 20 miles
Bathymetric Contours in meters
N
89° 15'
89° 00'
88° 45'
88° 30'
88° 15'
88° 00'
18° 30'
18° 15'
18° 00'
17° 45'
17° 30'
17° 15'
17° 00'
16° 45'
16° 30'
16° 15'
16° 00'
15° 45'
MEXICO
GUATEMALA
GUATEMALA
HONDURAS
Chetumal Bay
Chetumal
Corozal
Rio Hondo
Albion Island
New River
Ambergris Cay
Belize
Belize River
Sibun River
Manatee River
Mullins River
North Stann Creek
Dangriga
Sittee River
South Stann Creek
MAYA MOUNTAINS
Turneffe
Lighthouse Reef
Southern Long Cay
Glovers Reef
Living Gorgonians
Placentia
Monkey River
Deep River
Common occurrence of pteropods
Victoria Channel
Many large Siderastrea siderea carbonate shoals
Snake Cays
Rio Grande
Moho River
Punta Gorda
Zapotilla Cays
Hook Syncline
Gulf of Honduras
Gypsina encrusted large Halimeda plates
Sarstoon River
El Golfete
Lago de Izabal
Rio San Francisco
Rio Motagua
JANUARY
JULY
HOLOCENE MARINE FACIES
☆ Sample Location
TERRIGENOUS
Sand
TRANSITIONAL
Sandy Marl
Thin-shelled Bivalve Marl Wackestone/Mudstone
CARBONATE
Coralgal Framestone/Grainstone/Packstone
Halimeda Packstone/Wackestone
Halimeda-Thin-shelled Bivalve Wackestone/Mudstone
Mollusc-Foram Wackestone
Peneroplid Packstone/Wackestone
Micritized Grain Wackestone/Packstone
Peloidal-Skeletal Wackestone/Packstone
Organic-rich Halimeda & Mollusc Wackestone
- - - >10 % Miliolid Line

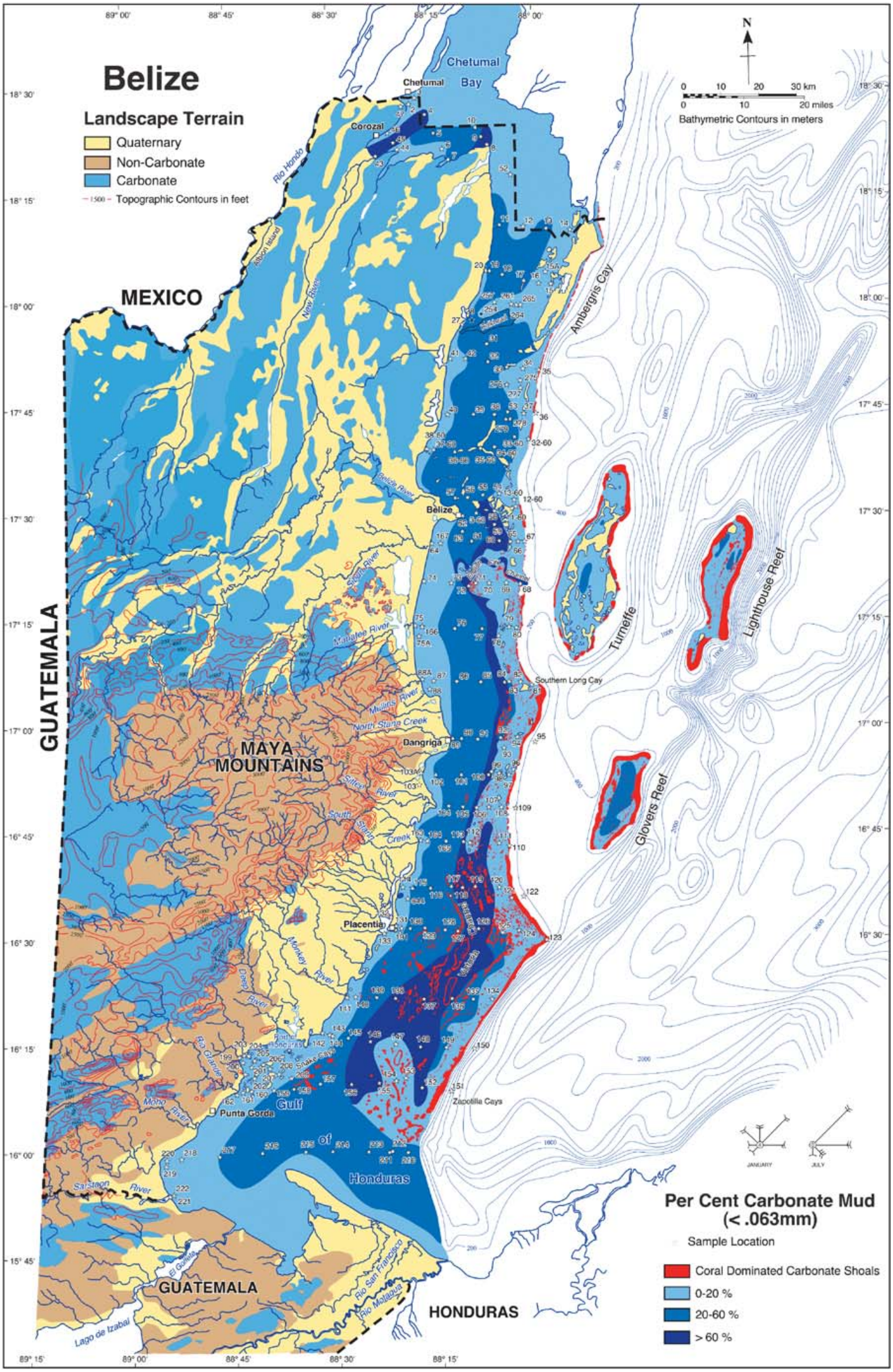


Fig. 5 Distribution of carbonate mud (<63 μm) on the Belize shelf and three off-shelf atolls. Note that in the central shelf lagoon in particular, the pattern of highest mud concentration in proximity to the barrier platform strongly suggests derivation from that entity

general carbonate shoal area of the southern shelf lagoon, including Victoria Channel. Carbonate mud percentages in these areas exceed 60% (Fig. 5). The central lagoon pattern in particular supports derivation from the barrier platform, since the highest carbonate mud values occur immediately adjacent to the barrier platform. The high concentration of carbonate mud in and around the carbonate shoals of the southern shelf lagoon suggests that the shoals themselves are an additional carbonate mud source. These patterns support the findings of Matthews (1966), who identified large parts of the 20–63-μm mud fraction on the southern Belize shelf as a product of physical abrasion and mechanical breakdown of skeletal carbonate grains. There is also an in situ shelf lagoon mud contribution by coccoliths (Scholle and Kling 1972), but the magnitude of that contribution does not affect the amount of mud Matthews believed was derived from the carbonate shoals and barrier platform (Purdy et al. 1975). Values exceeding 60% also occur in the deepest part of Glovers Reef and in the western main and northern lagoons of Turneffe Islands (Gischler and Lomando 1999) where SEM and geochemical analyses of mud also indicate a skeletal debris derivation (Gischler and Zingeler 2002).

Over large parts of the shelf lagoon and on the three offshore atolls, carbonate mud abundance is between 20–60% (Fig. 5). With the exception of the northern shelf lagoon, these mud percentages probably reflect derivation both as comminuted skeletal debris and as *in situ* deposition by pelagic organisms such as coccoliths. In the northern shelf lagoon and Chetumal Bay, however, the carbonate mud is sufficiently distinctive to require additional comment. There the carbonate mud contains no coccoliths (Scholle and Kling 1972) and is believed by Pusey (1975) to have been formed largely by abrasion of both skeletal and micritized grains. The micritized grains, in turn, may largely represent either recrystallized skeletal grains (Reid et al. 1992) or examples of precipitation in a multitude of crosscutting microbores (Reid and Macintyre 2000). The occurrence of whitings in the northern shelf lagoon (Fig. 6) may also indicate precipitation of some mud constituents, as it seems to do in the Bahamas (Macintyre and Reid 1992; Robbins and Blackwelder 1992; Milliman et al. 1993; Robbins and Tao 1996; Robbins et al. 1996). The occurrence of low Mg calcite muds in Chetumal Bay, however, remains enigmatic, especially in view of the fact that the overlying water mass is supersaturated with respect to aragonite (Purdy et al. 1975). There is a possibility that this too may be a precipitation phenomenon (Fig. 7).

Notwithstanding gaps in knowledge on the origin of specific mud components, it seems clear that the breakdown of skeletal debris is a major lime mud contributor. In this regard, it demonstrates the existence of a skeletal textural continuum from the widespread skeletal beach sands that occur on islands throughout the world to accumulations of skeletally derived lime mud where current velocities permit deposition. With this in mind it seems likely that much, if not most of the shallow water lime mud in the geologic record is of skeletal derivation, including not only products of skeletal abrasion, but also mud-sized skeletal constituents released through the decomposition of the organic tissues that bind them.

Fig. 6 Oblique aerial view of northern shelf lagoon ‘whitings’ southwest of Cay Corker. The two whitings are elongated toward the south-west by the prevailing wind, and their outline becomes distinctly less sharp in the same downwind direction. The ‘tail’ of a third whiting is just visible to the *left of the photograph*. Note that the ‘head’ of the middle whiting is slightly digitate, suggesting a composite origin for the downwind ‘tail’. Channel-like feature on the muddy bottom below the whitings is a drag mark from a boat. Longest whiting approximates 300 m in length. In the Bahamas similar features are interpreted as being associated with the biotically induced precipitation of aragonite needles (Robbins and Blackwelder 1992; Robbins and Tao 1996; Robbins et al. 1996), but in Belize their sedimentary significance is unknown although the water column is supersaturated with respect to aragonite (Pusey 1975). Similar features also occur near the southern end of the Australian Gulf of Carpentaria (Purdy, personal observation) where again their sedimentary significance is unknown

Holocene facies

Terrigenous sand

Terrigenous grains, represented overwhelmingly by quartz, but in places including minor amounts of feldspar and quartzite, average 72% in abundance and range in amount from 10–100%. Molluscs are the only other significant sediment contributor and average 9% in abundance (Table 1). With the exception of small occurrences in the northern shelf lagoon, terrigenous sands rim the shoreline within a narrow 2–3-km-wide area on the central and southern Belize shelf lagoons (Fig. 4). They project farther seaward off the mouths of rivers where they typically occur as cuspate deltas that show a marked depositional bias toward the south reflecting wind-driven southerly longshore drift (High 1975). The southern distribution of the facies is largely a reflection of

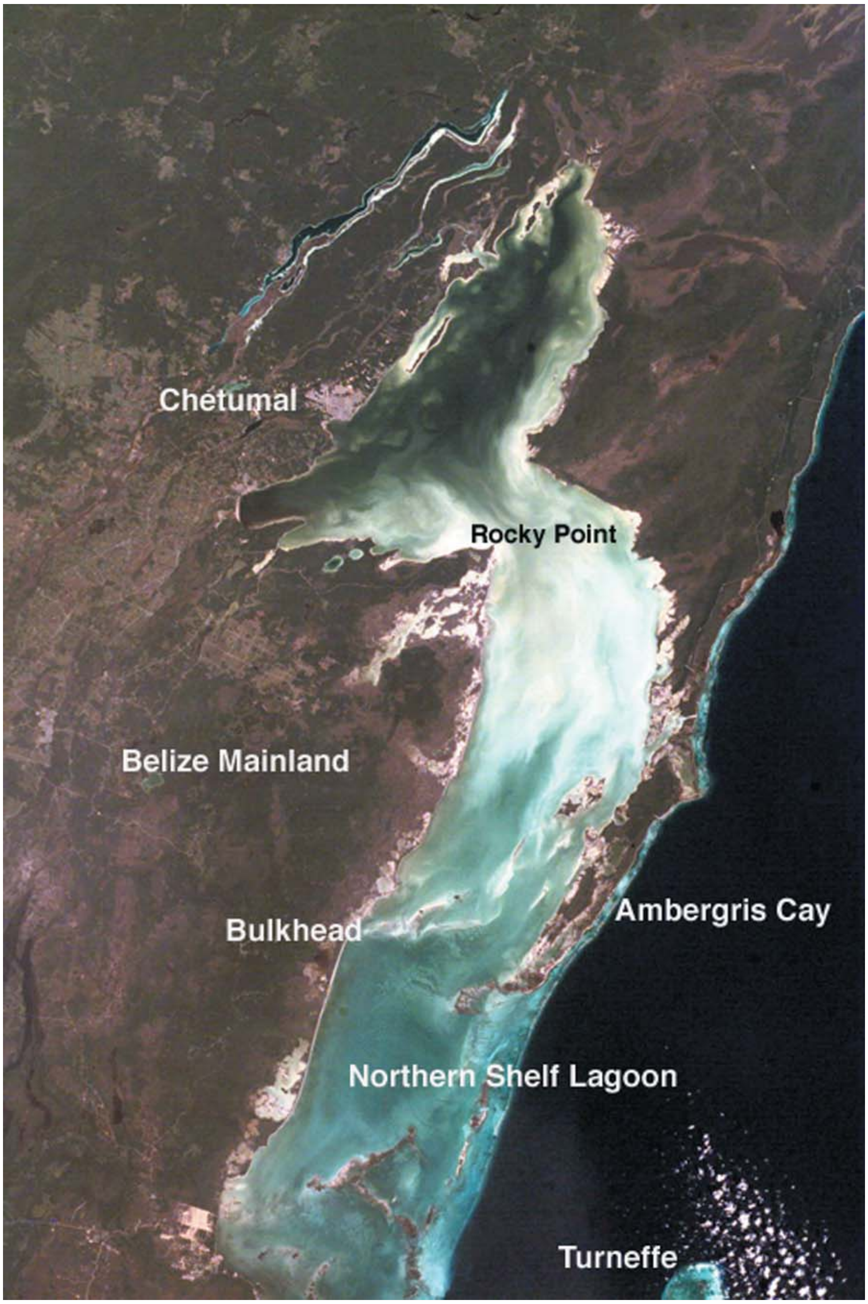


Fig. 7 Modified astronaut photograph of the northern Belize shelf (Image ISS001-ESC-5317 Courtesy of Earth Sciences and Image Analysis Laboratory NASA Johnson Space Center). Note the contrast between the 'white' water adjacent to Rocky Point and the clear water both farther north and in the northern shelf lagoon. The water bottom is clearly visible in the northern shelf lagoon and adjacent to the Mexican city of Chetumal where a number of bottom shoals can be seen. In contrast, turbid 'white' water obscures the water bottom in the general area adjacent to and south of Rocky Point. There is no obvious hydrographic reason for this difference as wind-induced waves from any quarter would not have been limited in their effect of 'stirring up' bottom muds to the area occupied by 'white' water. Consequently, the suggestion is that the 'white' water reflects general areas of carbonate mud precipitation, perhaps representing the dissipation and/or amalgamation of one or more whitings. Conceivably, the known calcitic nature of the bottom muds might reflect a microbial driven photosynthetic process in the water column similar to that reported from freshwater lakes and euryhaline lagoons elsewhere (Yates and Robbins 2001)

drainage from the non-carbonate Maya Mountains. In contrast, the small northern shelf lagoon occurrences are limited to isolated areas immediately offshore rivers or lagoon mouths where they result from reworking of onshore Quaternary sediment rather than a non-carbonate Maya Mountains source (High 1975; Pusey 1975).

Sandy marl

Terrigenous mud (fraction<63 μm) is the most important facies constituent with an average value of 45%. The amount of non-carbonate sand averages 24%, making the facies a sandy mud. The additional presence of 16% carbonate mud on average is the reason for the marl facies designation (Table 1). As in the terrigenous facies, only molluscs reach appreciable abundance (average 8.5%). Unlike the terrigenous sand facies, sandy marl sediments are restricted in occurrence to the central and southern Belize shelf where they constitute a narrow area seaward of the terrigenous facies. They are undoubtedly present on the northern shelf in proximity to the terrigenous sands there, but the rapidity of facies change seaward precludes their recognition relative to sample spacing. In any event, the facies map in the northern shelf lagoon conveys the correct impression of a rapid seaward change in sediment type from the terrigenous sands. In the Gulf of Honduras, sandy marl covers an area up to 20 km wide (Fig. 4) for

Table 1 Belize facies

	Water depth (m)	Terrigenous mud[a]	Carbonate mud[a]	Terrigenous grains[b]	*Halimeda*	Corals	Coralline algae	*Melobesia*[c]	Molluscs	Miscellaneous skeletal	Pteropods	Miliolids[d]	Peneroplids[e]	Other Foraminifera	Peloids[f]	Micritized grains	Country rock[g]	Ostracodes
Terrigenous sand: n=10 (shelf)																		
Mean	4.0	6.0	3.1	72.1	0.9	0.2	0.1	0.1	8.6	0.7	0.0	1.4	0.2	0.7	0.1	4.1	2.1	0.1
Standard deviation	4.2	9.6	5.3	32.7	2.8	0.5	0.2	0.4	9.6	1.3	0.0	3.0	0.6	1.0	0.3	11.1	7.1	0.2
Range	0–27.4	0.1–25.3	0.1–14.5	8–100	0–11.7	0–1.7	0–1.0	0–1.7	0–30.1	0–4.4	0.0	0–10.5	0–2.1	0–3.1	0–1	0–44	0–29.8	0–0.8
Sandy marl: n=18 (shelf)																		
Mean	11.7	45.0	16.1	24.4	3.1	0.5	0.7	0.0	8.5	0.3	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0
Standard deviation	6.5	16.3	13.6	16.0	5.6	0.8	2.2	0.0	8.3	0.7	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0
Range	2.1–21.9	18.8–66.2	7.9–31.9	10.5–49.7	0–11.7	0–1.7	0–1	0.0	0–19.1	0–2.1	0.0	0.0	0.0	0–3.1	0.0	0.0	0.0	0.0
Thin-shelled bivalve marl wackestone/mudstone: n=24 (shelf)																		
Mean	17.4	51.6	35.1	2.4	2.5	0.4	0.0	0.0	6.2	0.3	0.1	0.0	0.0	1.3	0.0	0.0	0.0	0.1
Standard deviation	9.9	14.7	16.1	2.7	4.8	0.9	0.1	0.0	8.3	0.5	0.2	0.0	0.0	1.9	0.0	0.0	0.0	0.3
Range	2.7–37.2	33.9–83.4	12.8–57.9	0–8	0–21.7	0–3.8	0–0.4	0.0	0.6–40.8	0–4.1	0–1.9	0.0	0.0	0.3-9.6	0–0.1	0–0.2	0.0	0–1.4
Coralgal framestone/grainstone/packstone: n=34 (shelf)																		
Mean	5.7	2.4	6.1	0.0	22.4	48.1	8.3	0.0	7.2	1.5	0.0	1.1	2.9	0.7	0.0	0.0	0.0	0.0
Standard deviation	6.8	1.4	11.1	0.0	8.9	11.5	6.8	0.0	4.7	2.4	0.0	1.5	2.1	1.8	0.2	0.0	0.0	0.0
Range	0–30.8	0–7	0.2–42.1	0.0	6.1–39.5	26.7–71.3	0–25.5	0.0	0.5–15.6	0–13.6	0.0	0–5.3	0–6.5	0–10	0–1.1	0.0	0.0	0.0
Coralgal framestone/grainstone/packstone: n=155 (atolls)																		
Mean	3.7	0.0	2.1	0.0	23.8	34.0	14.0	0.0	11.4	0.0	0.0	0.0	0.0	5.8	2.3	0.0	0.0	0.0
Standard deviation	5.4	0.0	3.4	0.0	11.9	14.0	7.1	0.0	7.2	0.0	0.0	0.0	0.0	4.6	5.2	0.0	0.0	0.0
Range	0–40	0.0	0–21.9	0.0	5–88.3	0–64.8	0–27.7	0.0	0–42.6	0.0	0.0	0.0	0.0	0–28.7	0–25.3	0.0	0.0	0.0
Halimeda packstone/wackestone: n=29 (shelf)																		
Mean	10.6	5.5	15.7	0.2	44.0	8.8	3.1	0.0	13.2	2.4	0.0	1.0	2.2	2.2	0.6	0.4	0.3	0.2
Standard deviation	9.0	7.1	13.6	0.5	14.5	9.4	4.7	0.5	5.6	2.9	0.0	1.1	2.6	2.6	1.4	1.1	1.6	0.5
Range	0.9–32.9	1–36.5	0.6–45.3	0–0.8	18.1–72	0–38.5	0–18.3	0–0.5	0.9–27.8	0–9.7	0.0	0–4.4	0–8.5	0–8.5	0–4.2	0–4.6	0–8.4	0–2.2
Halimeda packstone/wackestone: n=66 (atolls)																		
Mean	8.1	0.0	17.2	0.0	25.6	3.0	3.4	0.0	19.3	0.0	0.0	0.0	0.0	8.2	4.1	0.0	0.0	0.0
Standard deviation	4.8	0.0	14.6	0.0	18.7	4.3	4.7	0.0	6.9	0.0	0.0	0.0	0.0	5.0	7.8	0.0	0.0	0.0
Range	2.0–18.0	0.0	0.4–60.8	0.0	1.5–73.1	0–21.6	0–23.8	0.0	5.8–38.0	0.0	0.0	0.0	0.0	1–22.8	0–41.2	0.0	0.0	0.0
Halimeda thin-shelled bivalve wackestone/mudstone: n=37 (shelf)																		
Mean	31.9	18.4	64.2	0.3	5.5	3.1	0.5	0.0	5.5	0.4	0.2	0.3	0.2	1.4	0.0	0.0	0.0	0.0
Standard deviation	11.5	9.6	12.7	0.4	6.0	5.8	1.3	0.0	3.9	0.5	0.3	0.7	0.7	1.1	0.2	0.0	0.0	0.0
Range	8.2–59.7	1.3–35.9	19.1–83.3	0–1.4	0.1–23.2	0–27	0–6.1	0.0	1.3–16.1	0–1.8	0–1.0	0–3	0–3.2	0–4.6	0–0.9	0.0	0.0	0.0
Gypsina sub-facies: n=3 (shelf)																		
Mean	43.2	23.3	4.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	71.9	0.0	0.0	0.0	0.0
Standard deviation	12.9	28.6	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28.5	0.0	0.0	0.0	0.0
Range	28.3–51.8	3.0–56.0	3.8–5.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	39.5–93.1	0.0	0.0	0.0	0.0
Mollusk-foram wackestone: n=9 (shelf)																		
Mean	6.1	12.1	57.1	0.4	1.9	0.0	0.0	1.4	10.5	3.8	0.0	4.3	0.8	1.4	3.0	1.2	0.2	1.8
Standard deviation	5.0	3.8	14.5	0.4	2.4	0.0	0.0	1.7	7.4	3.0	0.0	5.1	0.8	0.8	3.1	1.2	0.3	1.2
Range	2.1–14	4.7–16	45.8–76.7	0–1.1	0–5.2	0–0.1	0.0	0–4.4	1.5–22.8	0.7–8.4	0.0	1.5–15.6	0.2–2	0.2–2.5	0–9.1	0.2–3.7	0–0.7	0.2–3.7

Table 1 (continued)

	Water depth (m)	Terrigenous mud[a]	Carbonate mud[a]	Terrigenous grains[b]	*Halimeda*	Corals	Coralline algae	*Melobesia*[c]	Molluscs	Miscellaneous skeletal	Pteropods	Miliolids[d]	Peneroplids[e]	Other Foraminifera	Peloids[f]	Micritized grains	Country rock[g]	Ostracodes
Peneroplid packstone/wackestone: *n*=7 (shelf)																		
Mean	1.4	3.9	8.8	0.0	0.0	0.0	0.0	0.8	20.8	2.1	0.0	6.6	35.0	1.0	0.4	19.3	0.5	0.9
Standard deviation	0.9	2.2	7.7	0.0	0.0	0.0	0.0	1.4	13.4	1.2	0.0	5.4	20.6	1.1	0.7	17.5	0.7	1.1
Range	0.6–1.8	1.0–7.0	2-20.6	0.0	0.0	0.0	0.0	0–4.0	7.3–45.2	0.4–3.5	0.0	1.2–16.1	12.9–73.9	0.1–3.4	0–0.5	3.4–46.5	0–1.6	0–3.3
Micritized grain wackestone/packstone: *n*=25 (shelf)																		
Mean	3.6	11.2	39.9	0.9	0.0	0.0	0.0	0.3	9.7	1.2	0.0	5.6	1.9	1.5	1.2	24.7	1.3	1.0
Standard deviation	2.7	5.2	22.9	2.8	0.0	0.0	0.0	0.5	8.1	1.1	0.0	5.1	3.8	1.2	1.4	19.1	2.3	0.8
Range	0.6–12	4.0–26.0	6.2–78.6	0–7.1	0.0	0.0	0.0	0–1.2	0.1–31.3	0.2–4.1	0.0	0–21.4	0–14.9	0.2–3.3	0–3.7	0.2–68.1	0–9.2	0–3.3
Peloidal-skeletal wackestone/packstone: *n*=85 (atolls)																		
Mean	3.8	0.0	10.5	0.0	11.7	8.3	2.9	0.0	14.6	0.0	0.0	0.0	0.0	5.2	27.4	0.0	0.0	0.0
Standard deviation	2.7	0.0	8.4	0.0	6.9	10.5	3.4	0.0	6.6	0.0	0.0	0.0	0.0	3.9	14.3	0.0	0.0	0.0
Range	0.5–15	0.0	0–35.1	0.0	1.9–41.5	0–39.7	0–22.5	0.0	2.9–34.9	0.0	0.0	0.0	0.0	0–14.7	0–68.4	0.0	0.0	0.0
Organic-rich Halimeda and mollusc wackestone: *n*=46 (atolls)																		
Mean	3.4	0.0	12.0	0.0	48.9	2.7	0.4	0.0	17.1	0.0	0.0	0.0	0.0	6.2	0.0	0.0	0.0	0.0
Standard deviation	1.7	0.0	17.1	0.0	21.7	7.7	1.1	0.0	9.7	0.0	0.0	0.0	0.0	6.9	0.0	0.0	0.0	0.0
Range	0.1–9	0.0	0.5–75.2	0.0	0–85.8	0–44.9	0–5.7	0.0	0–36.9	0.0	0.0	0.0	0.0	0–41.1	0.0	0.0	0.0	0.0

[a] Particles smaller than 0.063 μm

[b] Largely quartz grains, larger than 0.063 μm, but also includes minor amounts of feldspar and quartzite

[c] Includes the genera *Melobesia* and *Fosliella*

[d] Includes the genera *Quinqueloculina*, *Triloculina* and *Articulina*

[e] Includes *Peneroplis* and the soritid foram *Archaias*

[f] Equivalent to the fecal grains category of Pusey (1975)

[g] Limestone fragments and caliche

reasons given previously in discussing the general distribution of terrigenous mud. The factor analysis results grouped the sandy marls with the adjacent seaward marls, but were separated from them because of their clearly transitional character relative to terrigenous sands to the west and more carbonate bearing muds to the east. Interestingly, the seaward extent of both the terrigenous sand and sandy marl facies increases markedly off the mouth of the Mullins River, reflecting both the high relief and areal extent of this river's non-carbonate drainage area.

Thin-shelled bivalve marl wackestone/mudstone

The facies is dominated by mud with average values for terrigenous mud of 52% and carbonate mud of 35% (Table 1). It is distinguished from the landward occurring sandy marl largely by the decrease in average amount of terrigenous sand grains to 2.5%. In addition, the occurrence of thin-shelled bivalves is also diagnostic although they only comprise some 6% of the sediment. The thin shells are thought to reflect increasing surface area relative to shell weight as an adaptation to prevent excessive sinking of these infaunal bivalves in the exceptionally soft substrate (Purdy et al. 1975). *Halimeda* fragments amount to 2.5% abundance. The facies is restricted in occurrence to the central and southern shelf lagoons where it covers an area up to 10 km wide area that widens into the Gulf of Honduras (Fig. 4). Incorporated within it are the *Halimeda* and *Gypsina* marl facies of Purdy et al. (1975). In both cases, the occurrence of *Halimeda* is in proximity to shoals, and in the case of *Gypsina* on or around deep-water shoals (Purdy et al. 1975). Thus, both distributions are shoal dependent, but their areal extent is unknown relative to sampling density as is the distribution of deep-water shoals within the Gulf of Honduras. Consequently we have grouped both occurrences within the thin-shelled bivalve marl facies with the caveat that the *Halimeda* content of the sediment increases in proximity to southern shelf lagoon carbonate shoals and the occurrence of *Gypsina* in the Gulf of Honduras is dependent upon the unknown distribution of deep-water shoals (Fig. 4). Even so, the sedimentary attributes of the few *Gypsina* samples that were collected are tabulated in Table 1 under the heading *Gypsina* subfacies.

Sample 73 is anomalous in that it contains approximately 38% terrigenous sand grains. There is no way these sand-sized constituents could have been transported from the shoreline across the intervening extremely soft marl substrate by traction or saltation and their size coupled with abundance precludes suspension transportation. A 0.5-m piston core taken at this locality is orange stained at 5.1 cm from the base of the core, indicating that the Holocene/Pleistocene contact is at or near this level. Notwithstanding the depth of the orange staining, the core's macroscopic appearance appears generally homogeneous from top to bottom, suggesting that the terrigenous grains reflect infaunal re-working of relict sand deposits associated with transport of sediment through English Cay Channel. In any event, the sample composition is so anomalous that it has been left out of the facies composition data recorded in Table 1.

Halimeda thin-shelled bivalve wackestone/mudstone

These sediments lie seaward of the bordering marl facies where they occur in the deeper parts of the central and southern shelf lagoons (Fig. 4). The sediment is dominated by carbonate mud, averaging approximately 65% and only 18.4% of the mud is terrigenous (Table 1). The most abundant sand-sized constituents are thin-shelled bivalve fragments and *Halimeda,* each averaging 5.5% in abundance. Pteropod shells are found in the rhomboid shoal/Victoria Channel area and these led Purdy et al. (1975) to delineate a pteropod marl facies based on visual abundance estimates. Point count data from the same thin sections used for the visual estimates proved these estimates to be grossly in error. The reconstituted point-count data further reduced pteropod abundance to an average of less than 1% (Table 1) thereby obviating the need for a separate pteropod facies. However, we have identified the area of relative pteropod abundance in Fig. 4. As noted previously, the distribution of carbonate mud, among other things, argues strongly for a barrier platform and carbonate shoal derivation through mechanical abrasion and decomposition release of organically bound skeletal constituents. The presence of thin-shelled bivalves is a carry-over from the marl facies and occurs for the same reason. The comparable abundance of *Halimeda* probably reflects transport of these constituents from the adjacent barrier platform and/or carbonate shoals. The occurrence of pteropods seems correlated with the presence of normal marine surface salinities far from the influence of mainland drainage (Purdy et al. 1975).

Mollusc-foram wackestone

The northern shelf lagoon facies equivalent of the southern shelf lagoon is a mollusc-foram wackestone that covers a 750-km^2 area (Fig. 4). The factor analysis results grouped these sediments with that of the southern shelf lagoon marls, but the differences between the two seemed sufficiently different to warrant the distinctions made here. The virtual absence of terrigenous mud is related to the low relief of the mainland limestone drainage area and that, combined with the quiet water depositional environment, insures a carbonate mud substrate that averages 57% in amount (Table 1). Common constituent particles are molluscs and Foraminifera; these average 10.5 and 9.5% in abundance, respectively. The consistency of the mud substrate is significantly greater than that of the southern shelf lagoon and, consequently, the bivalves are not thin shelled. The dominant forams are miliolids (a tabulation category that includes *Quinqueloculina*, *Triloculina* and *Articulina*) and these reflect lower than normal marine salinities of 26 to 34‰ although during dry spells the upper limit can be as high as 37‰ (Purdy et al. 1975; Pusey 1975). The facies is equivalent in part to Pusey's (1975) miliolid facies, but unlike Pusey (1975) and Purdy et al. (1975), we have split the miliolid distribution into two adjoining parts following the results of the factor analysis. This is illustrated by the greater than 10% miliolid line on the facies map of Fig. 4. Whitings occur within the environment (Fig. 6) and conceivably may reflect precipitation of some carbonate mud constituents, as they seem to do in the Bahamas (Macintyre and Reid 1992; Milliman et al. 1993; Yates and Robbins 2001).

Halimeda packstone/wackestone

South of the latitude of Belize City the *Halimeda* packstone/wackestone facies mantles the barrier platform over areas up to 10 km wide. North of the Belize City latitude, the facies occurs immediately lagoonward of the reefal barrier rim (Fig. 4). It also occurs, with slightly different amounts of constituent grains, in water depths of 5–18 m in the offshore atoll lagoons (Gischler and Lomando 1999). *Halimeda* fragments are the most common constituent (average 44% on the shelf; 26% in the atolls), followed by molluscs (average 13% shelf; 19% atolls) and Foraminifera (average 5.5% shelf; 8% atolls). The mud content of the sediment is on average 21% on the shelf and 17% in the offshore atolls (Table 1). The normal marine salinity depositional environment is generally sheltered from wave action by the seaward-occurring barrier or atoll reefs.

Coralgal framestone/grainstone/packstone

This facies is best represented in the barrier reef and offshore reef defining atolls, but also occurs on the innumerable carbonate shoals both within the southern shelf lagoon and within the offshore atoll lagoons (Fig. 4). Corals (average 48% on the shelf; 34% on the atolls) and coralline algae (average 8% shelf; 14% atolls) are the most diagnostic facies representatives (Table 1) along with a low percentage of mud (average 6% shelf; 2% atolls). *Halimeda* is not as abundant (average 22% shelf; 24% atolls) as in adjoining lagoonward facies, probably largely reflecting dilution by the increased abundance of corals and coralline algae; mollusc fragments are moderately common (average 7% shelf; 11% atolls). In terms of an energy spectrum, these deposits constitute the highest energy product of all the Belize facies with the barrier reef and reef defining atolls representing extreme energy conditions and the lagoon protected carbonate shoals illustrating less extreme conditions.

Micritized grain wackestone/packstone

Chetumal Bay is covered by a facies in which micritized ('cryptocrystalline') constituent grains dominate and average 25% in abundance (Fig. 4). Carbonate mud is even more abundant, averaging 40% and consists largely of low Mg calcite whose origin is enigmatic considering the supersaturation of the overlying water mass with respect to aragonite (see Fig. 7 in Purdy et al. 1975). The mollusc average of 10% constitutes the only other sand-sized constituent present in significant amounts (Table 1). Ostracodes are uniquely present off the mouth of the New River and the adjoining unnamed river mouth immediately to the east, but unlike Pusey (1975) we have not designated them as a separate facies because of their small areal distribution combined with the fact that maximum abundance on a reconstituted sample basis is only 3.5%.

The facies occurs in shelf waters where the salinity is less than 30‰ and generally less than 26‰ and includes a narrow shoreline strip in the northern shelf lagoon. Following the work of Reid and Macintyre (2000), the micritized grain fabric is likely to be a product of microboring with concomitant precipitation of carbonate within the borings as the microorganism advances. Even if this is the case, the question arises as to why micritized grains should be particularly abundant in this facies. Complete grain mictritization obviously takes time and in this sense completely micritized grains must represent relatively older sedimentary constituents. The amount of time involved may not be great because Reid and Macintyre (1998) have demonstrated its occurrence in living examples of the miliolid foraminifer *Archaias* and the green alga *Halimeda*. Even so, this line of reasoning suggests that the micritized grain facies consists largely of older Holocene sand-sized grains.

The only other significant feature of the micritized grain facies is the occurrence of the Bulkhead mud shoal shown in Figs. 2 and 5. Pusey (1975) concluded that there was no correlation between the underlying antecedent topography and the position of the mud shoal. Subsequently, however, Ebanks (1975) modified Pusey's contours on the depth of the antecedent surface, and his map (his Fig. 25) shows an antecedent low beneath the general position of the Bulkhead shoal. This suggests that Chetumal Bay drainage would have experienced a decrease in current velocity over the depression resulting in the deposition, in this case, of mud. While this may explain the initial position of mud shoal development, it does not account for its position as a present-day bathymetric high nor for the laminated nature of the miliolid muds comprising the shoal, and the reader is referred to the detailed account of Pusey (1975) for further description and possibilities.

Peneroplid packstone/wackestone

Factor analysis grouped these Chetumal Bay sediments with the micritized grain facies, and certainly the micritized nature of the bulk of the sediment suggests a close affinity. Nonetheless, the average 35% abundance of peneroplid forams (a tabulation category that includes *Peneroplis* and the miliolid foraminifer *Archaias*) was deemed sufficiently unique to warrant recognition as a separate facies or, perhaps better, subfacies. Molluscs and micritized grains are next in abundance with averages of 21 and 19%, respectively, and the sediment contains a moderate average of 13% mud (Table 1). The facies is restricted in occurrence to a 10-km-wide area west of Ambergris Cay (Fig. 4) where its variable thickness generally overlies the antecedent limestone surface (Pusey 1975). The peneroplids are extensively micritized, possibly in the same microboring manner as described by Reid and Macintyre (2000). Unlike the aragonite microboring products described by these authors, however, the peneroplid micritization product is high Mg calcite (Pusey 1975).

There are few indications that the micritized peneroplids are living in the area in which they occur (Wantland 1975). The occurrence of similar current winnowed deposits on western beaches of Ambergris Cay and along the shores of intra-island lagoons within Ambergris Cay (Ebanks 1975) suggests that the peneroplid Chetumal Bay facies may represent drowned beach deposits of an earlier Ambergris Cay shoreline (Purdy et al. 1975).

Peloidal-skeletal wackestone/packstone

The facies is restricted to water depths generally less than 5 m deep in offshore parts of Glovers and Lighthouse atolls (Fig. 4). Peloids are the most common constituent and reach an average abundance of 27% (Table 1). They consist of cemented fecal pellets and, to a lesser extent, are represented by rounded, micritized skeletal grains, mainly Foraminifera. The average contribution of molluscs and Foraminifera approximates 15 and 5%, respectively. The mud fraction of the sediment averages around 10%. This facies clearly has affinities to the micritized grain wackestone/packstone facies of Chetumal Bay, the main environmental difference being the hyposaline environment of Chetumal Bay compared with the slightly hypersaline conditions (38–42‰) of Lighthouse and Glovers Reef lagoons (Gischler unpublished data). Presumably, the common denominator in both cases is the relatively older Holocene age of the micritized constituents, perhaps reflecting grain residence time at or near the depositional interface. In this regard it seems significant that two C^{14} dates from bulk sediment samples of this facies from Glovers Reef yielded ages of 1,380±40 and 1,400±50 years B.P., respectively, which were significantly older than other facies on the same atoll (Gischler and Lomando 2000, their Table 1).

Organic-rich *Halimeda* and mollusc wackestone

This facies is restricted in occurrence to the interior lagoons of Turneffe atoll (Fig. 4) where it is characterized by total organic carbon values as high as 15% with an average at 5.6% and a *Halimeda* content that averages 49%. The sediment is stained dark brown by the high amount of organic matter (Table 1). Molluscs and Foraminifera are common constituents with an average of 17 and 6%, respectively. The quantity of mud in the sediment is quite variable and averages 12%. The high organic content of the sediment reflects restricted lagoon circulation imposed by the surrounding rim of mangrove islands as well as organic debris from the mangroves themselves. The facies is similar to the Mollusk-foram wackestone of the northern shelf, but is distinguished from it by both its high organic content and the relative abundance of *Halimeda*.

Conclusions

The distribution and character of Belize Holocene facies is strongly conditioned by structural geology. Specific evidence of structural expression is reported in Purdy et al. (2003, this issue) and that evidence is used as the framework for the following conclusions.

Foremost in exercising offshore Holocene facies control is the uplift of the Maya Mountains and the consequent exposure of non-carbonate Maya Mountain lithologies, which are the source of the siliciclastic sediments that occur in the central and southern shelf lagoons. In an orographic sense that uplift also intensified rainfall toward the south, thereby accelerating mainland erosion in the same direction. Offshore, this first-order facies control is supplemented by structural control of Holocene antecedent topography. On a regional scale, the antecedent surface of the shelf and offshore atolls generally plunges southward, suggesting increased subsidence in the same direction. The result is a shallow northern shelf lagoon and a progressively deeper central and southern shelf lagoon.

On a smaller scale, the antecedent topography of the northern shelf lagoon consists of shallow karst depressions, similar to those exposed on the adjacent mainland, but these do not seem to have had much of a depositional effect on the present distribution of Holocene facies. A notable exception is the positive relief of Ambergris Cay. Here, the structurally influenced solution relief of Pleistocene limestone provides a barrier to marine circulation in Chetumal Bay. The resulting northern shelf lagoon facies, consequently, are a product of drainage from low mainland limestone relief, shallow offshore bathymetry and restricted marine circulation that is particularly pronounced in Chetumal Bay and is characterized by high amounts of micritized ('cryptocrystalline') grains and Foraminifera.

In the central and southern shelf lagoons, the smaller scale antecedent influence on the distribution of Holocene facies is more obvious. There, the barrier platform separation from the adjoining shelf lagoon represents the Pleistocene limit of antecedent lagoonward progradation of reef-derived material. There is also seaward progradation of reef-derived material as well, and in places the modern barrier reef is situated above the seaward limit of this antecedent progradation. These constructional aspects of antecedent topography have been modified by erosion during the last glacial sea-level lowstand. More specifically, the antecedent barrier platform surface is characterized by a nascent karst topography that is structurally influenced in its expression and increases in relief southward. The central shelf lagoon overlies a filled structural syncline that trends onshore to the south where the southern shelf lagoon marks its appearance with the occurrence of numerous carbonate shoals, including shelf atolls. The distribution of these shoals reflects underlying direct and indirect structural control, expressed in the form of both antecedent siliciclastic and carbonate topography. Indirect control is provided by the Esker et al. (1998) documentation of early southern shelf lagoon faulting, which created preferential sites for the development of both Quaternary reefs and river valleys that influenced the subsequent position of reefs and incised valleys in a feedback relationship. Within this antecedent framework, the central and southern shelf lagoons experienced the depositional influence of higher mainland non-carbonate relief, higher fresh water influx, reflecting the mainland southerly increase in annual rainfall precipitation, and the carbonate input of the barrier platform and innumerable carbonate shoals. The result is the present-day Holocene west-to-east transition from terrigenous clastics to marls to skeletal carbonates.

Toward the south, the barrier reef terminates in a hook-like plan-view pattern that represents fold geometry (Purdy 1998). The consequent absence of the barrier platform and paucity of carbonate shoals in the Gulf of Honduras ensures the predominance of shelf siliciclastic deposition there.

The sediments of the offshore atolls include not only skeletal carbonates similar to those of the shelf, but also non-skeletal peloidal grains as well as *Halimeda*-rich sediment with elevated amounts of organic matter (Gischler and Lomando 1999). The peloidal grains have some similarity to the abundant micritized grains of the markedly dissimilar environment of Chetumal Bay, suggesting that perhaps both reflect reduced sedimentation rates in which grain micritization is enhanced by time spent at or near the depositional interface. The atolls themselves overlie fault blocks.

It seems clear from the foregoing that the distribution of Belize Holocene facies is conditioned by antecedent topography, as is the case with many, if not most Holocene marine carbonates. But unlike other areas, the Belize facies distribution strongly reflects direct and indirect structural control, including mainland sediment provenance as well as offshore antecedent topography.

Future research potential

The Belize margin continues to offer the opportunity of providing constraints on a number of other unresolved problems. The distribution and origin of Holocene dolomite in the northern shelf lagoon continues to be investigated (Mazzullo et al. 1995; Teal et al. 2000) and those investigations have the potential of providing constraints on the occurrence of marine dolomite. Investigation of the possible chemical precipitation of carbonate mud outside the occurrence of the often-debated origin of Bahamian aragonite needles is provided by the occurrence of whitings in the northern shelf lagoon, not only with respect to aragonite, but also with respect to high and low Mg calcite. Additionally, the limestone that drains rivers of the northern shelf lagoon offer an opportunity of tracing what happens to dissolved river carbonate as it enters the hyposaline, supersaturated waters of Chetumal Bay. The cause of Belize micritization remains to be investigated with emphasis not only on the process, but also on the conservation of Belize mineralogy accompanying micritization from aragonite to aragonite and from high Mg calcite to high Mg calcite. The near-shore occurrence of reef communities south of the Placentia Peninsula and their virtual absence in the southern shelf lagoon north of that peninsula merits attention from the standpoint of contributing to an understanding of the little studied phenomena of fringing reefs. Collectively, it is the relatively small scale of the Belize margin combined with its logistical accessibility, distinctive onshore terrain and corresponding offshore bathymetric and environmental variability that offers remarkable potential for solving or at least constraining these and other problems.

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