Field Guide

20th Caribbean Geological Conference (2015)

Port-of-Spain, Trinidad and Tobago

Moruga:

Modern Deltaic Processes

May 17, 2015

Trip Leaders: Dr. Hasley Vincent, Mr. Richard Coutou and Ms. Dana Tankoo

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Trip Objectives:

To assess the relative interaction and preservation of tidal, fluvial and wave-induced sedimentary structures across the Moruga river delta.

Field Itinerary:

Pick up & Return times for each trip

Moruga river field excursion and core workshop
6:00 a.m. : Departure from Hyatt Regency, POS
9:00 - 10:00 a.m. : Tour of the study area, the Moruga river delta
10:00 a.m. - 12:00p.m. : Workshop and Lunch
12:30 - 1:30 p.m. : Visit to the Moruga Museum
2:00 p.m. : Depart Moruga to Port of Spain

Trip Locations

1A. Day 1: Moruga – Modern Deltaic Processes

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Keywords: Foreshore sedimentology and geomorphology, unconsolidated sands, deltaic processes, sedimentary structures, Moruga river

Access and Safety

The drive from Port of Spain to Moruga is approximately two hours. The route passes Barrackpore and Basse Terre before arriving in Moruga, a drive that includes several rural communities, forested areas, oil fields and cultivated lowlands. Moruga is located along the southern limb of the Southern Range anticline where sandstone beds dip up to 70 degrees at the coast forming steep cliffs and generally hilly topography. The coast at Moruga, adjacent to the Moruga River mouth, is the sole stop for this field trip. Easy access to the site along with flat and sandy terrain allow for a relatively easy traverse. To fully participate in the traverse however, participants will be required to cross shallow (30 cm) streams and a change of footwear is recommended. No attempt will be made to cross the deeper Moruga River that is located at the eastern end of the delta platform. After approximately 1 1/2 hours at the coast, the group will retreat to an enclosed area for a core workshop discussion.

For safety and comfort, participants are encouraged to wear comfortable, stiff-soled footwear with toes enclosed in order to minimize the risk of lacerations from litter and broken bottles that may be present at the site. Drink lots of water (provided) to avoid dehydration and walk with sunscreen, hats and sunglasses (not provided) for protection from the sun. There will be toilet and seating facilities at the core workshop venue; refreshments and lunch will be provided there.

Executive Summary

The Moruga River is one of the larger rivers within the Southern Basin of Trinidad that debouches along the coastline at Moruga where the wave-cut platform significantly increases in width forming a small coastal delta approximately 1km x 0.5 km dimension. The delta is attributed to both the sediment output from the Moruga and smaller Moroquite rivers, and the sheltered embayment created by Moruga Point to the east. The Moruga river meanders for approximately 250 m along the intertidal zone where sands are distributed west by longshore, wave, fluvial and tidal processes. Arial photographs and surface bedforms suggest an interesting interplay of these sedimentary processes across the delta.

Nineteen shallow cores ranging from 30 – 200 cm length were taken across the delta platform in order to examine the lithology and relative preservation of sedimentary structures. The aim was to examine the relative influence of

the varying sedimentary processes (waves, tides, fluvial discharge and longshore currents) in the redistribution and preservation of sedimentary bedforms that occur adjacent to the river mouth.

Four facies can be differentiated along the delta platform and includes (1) rooted and organic rich muds; (2) coarse, structureless and cross-bedded bioclastic sands; (3) fine-grained well sorted sands and (4) plane parallel laminated sands. Fluvial discharge is stongly reworked at the coast by tidal, wave and longshore processes to form a series of north-migrating oblique bedforms. Current orientation and velocity is variable at the surface, though only the larger bedforms are being preserved into the shallow surbsurface as cross stratified sands with occasional silty drapes indicative of tidal processes. The various subsurface and surface observations collectively suggest that longshore currents (wave-induced) is the primary control on the platform morphology, while tidal currents are secondary. This study is one of the first documented attempts to acquire and study shallow sediment cores across sandy bedforms around Trinidad and certainly along the Moruga river mouth.

Introduction to the Moruga coast

The Moruga River, together with the smaller Moroquite River, drains an area of approximately 240 km^2 (Fig. 1). The watershed bedrock comprises deformed Miocene and Pliocene consolidated sandstone and clays with bed dips as much as 70 degrees where they crop out at the coast. The deformation is largely related to the position along the flank of the Southern Anticline that parallels the southern coastline. Locally, northwest and northeast-trending high angle faults occur along the coastline and together with the general structural setting, determine the coastal topography and indentations in the vicinity of the Moruga River. The fluvial discharge rates and sediment concentration at the mouth of the Moruga River are unknown. At the southern coastline, river discharge is subjected to longshore-induced westerly currents which are an extension of the north-west equatorial flow known along the Guyana shelf to the south (van Andel and Postma 1954; Warne et al., 2002). Locally, the oblique wave crest approach at the mouth of the Moruga River suggests longshore sediment transfer from the east (drift-aligned coasts of Masselink et al., 2011) which may be a significant source of additional sediment at the river mouth. van Andel and Postma (1954) suggests there is always a surfacial westerly flowing tidal current along the Serpents Mouth (Fig. 1 for location) that may vary in deeper water (~9 m) to south easterly flows at low tide. The coastline experiences micro-tidal conditions with a diurnal range of approximately 150cm which at spring low tide exposes a 400m foreshore that diminishes to approximately 30m east and west of the river mouth. The coastal bathymetry increases gradually to approximately 60m from the coastline into the Serpents Mouth, creating a likely depocentre for sediments extruded from the Moruga River.

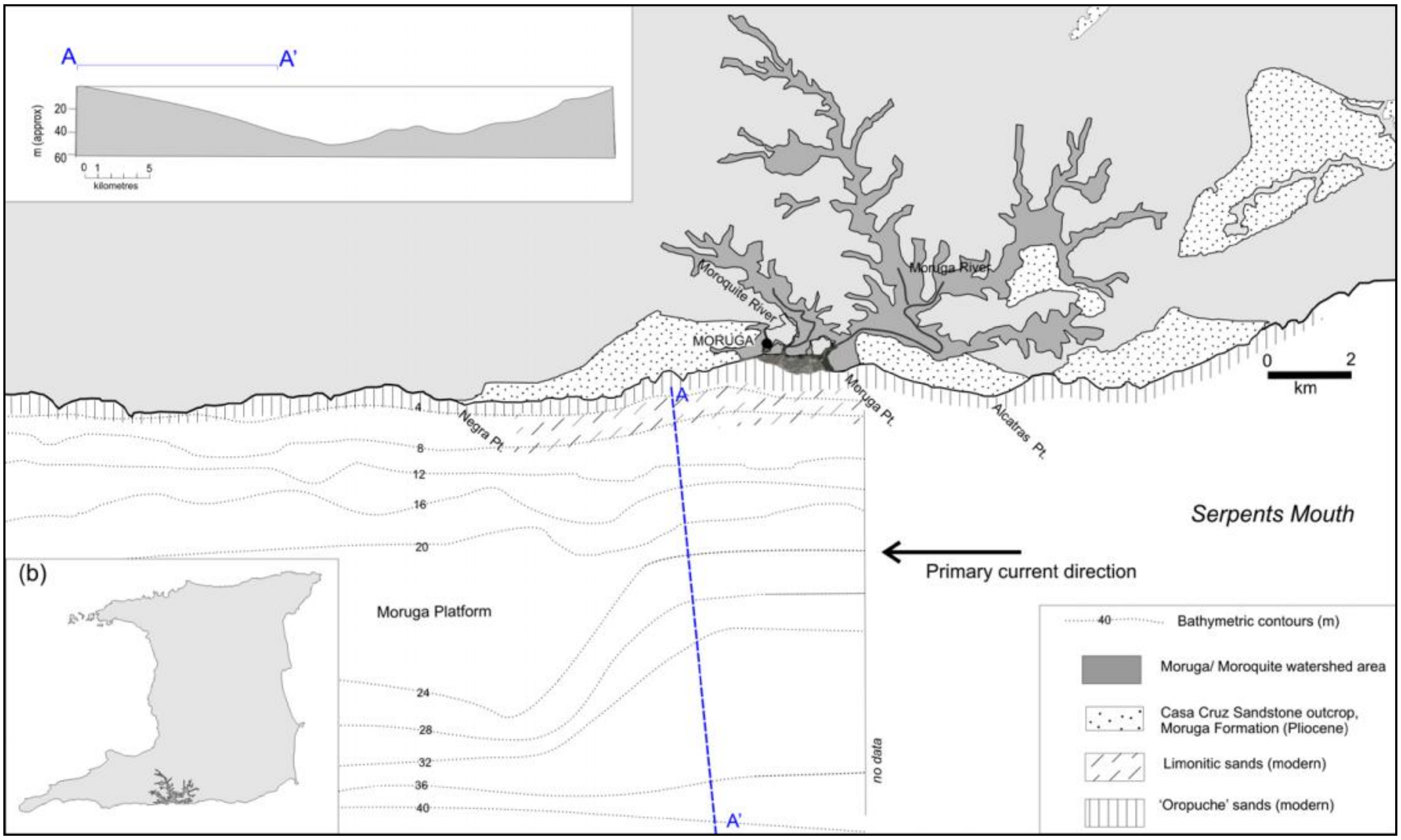


Figure 1: Southern coast line showing the Moruga River watershed, present-day bathymetry and general lithology. Inset **(a)** is a north to south cross section across the Serpents Mouth south of Moruga, and **(b)** shows the general location of the study area relative to Trinidad.

The sands along the Moruga River mouth can be classified within van Andel and Postma's (1954) "Oropuche Sands" represented by quartzose pink-yellow fine to medium grained variety that forms a band of 'beach sands' around the southern and western coast lines. This also includes limonitic sands west of the Moruga River mouth which has been attributed to local erosion. It is noteworthy that limonitic sands occur at the mouth of larger rivers around the southern and western coastlines and includes the Erin and Goudineau rivers to the west (van Andel and Postma, 1954, Map IV).

Methodology

This study arose out of a general desire to understand the sedimentology of modern sands around the Trinidad coastline and utilize the results as a teaching aid for geoscientists and researchers. The effort was entirely voluntary and part-time among the authors, which was arguably the most significant obstacle to its completion. Nineteen shallow cores ranging from 30 - 200 cm length were acquired across the Moruga River mouth over an eight month period between August 2014 and April 2015 (Figure 2). Sample locations were determined by a combination of ground measurements (distance, azimuth) and GPS coordinates. The cores were acquired by driving pvc tubing (2" or 3") into the unconsolidated sand, orienting the tube relative to north and extracting the core by creating a vacuum effect with pvc plugs towards the top. Following retrieval, cores were maintained in an upright position until dissection of the pvc tube with a grinder and separation into halves. This was accomplished through wire-slicing or manual pull-apart with the latter more suited to clay-rich zones and partially consolidated sands. Split cores were sealed in saran wrap in order to inhibit drying. Cores were described for lithology, grain size, physical and biogenic sedimentary structures and bedding relationships. Mineralogy was also examined by representative sample selection, using a transmitted-light binocular scope with up to 40x magnification. Much of the study remained qualitative as grain size variation and other standard statistical analyses were not carried out on the sands; these remain a subject for future research.

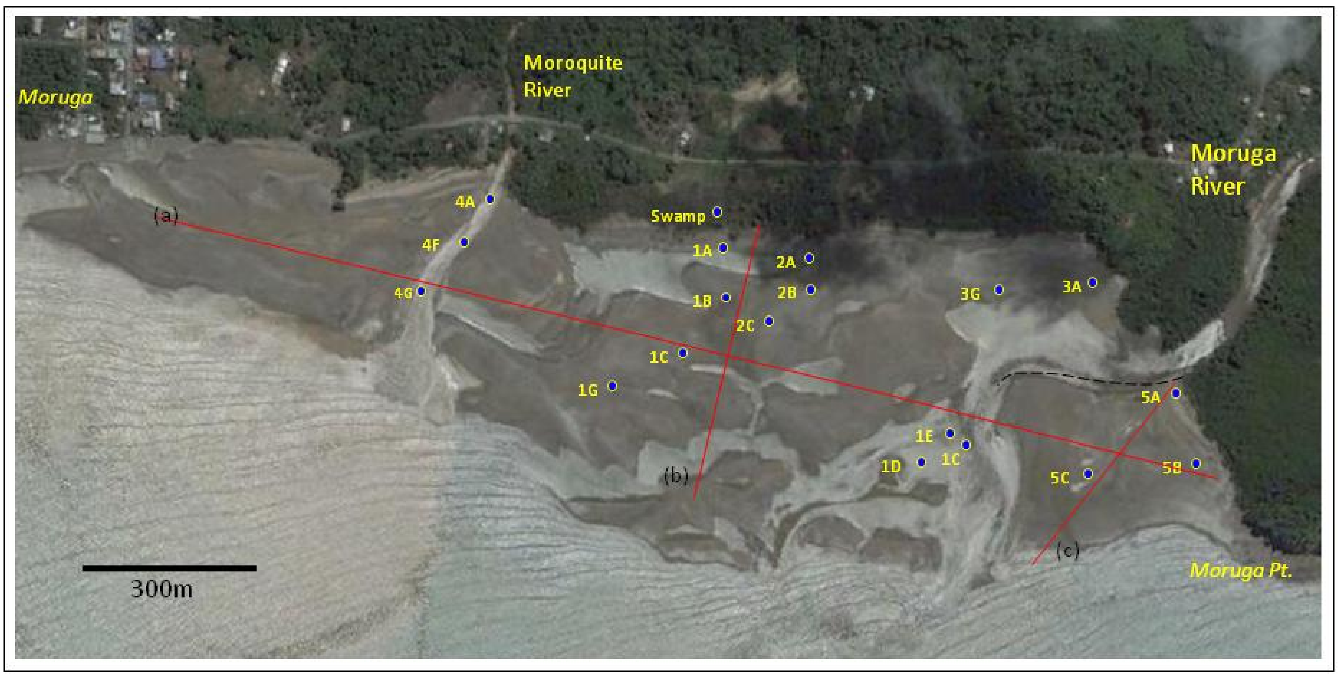


Figure 2: June 2005 Google aerial photograph at the mouth of the Moruga River showing core locations across the delta platform. Solid lines show locations of sections in Figure 3 and dashed line is the eastern bank of the river in April 2015.

Surface Description

The period of study enabled observations of the foreshore profile between the wet and early dry seasons. The intertidal to proximal supratidal zone was the focus of this study (equates to the upper foreshore and proximal backshore (Fig. 3). The low cliffs of the Casa Cruz Sandstone Member of the Moruga Formation (Kugler, 1959) form a rocky backdrop to the study area and are the bedrock upon which the delta platform is built. The backshore area adjacent to these cliffs is a variably vegetated zone that includes common mangroves and other rooted trees and grasses. It consists, in part, of brown clay and silt at the surface that transitions laterally into wetland areas. The backshore is separated from the foreshore by a well-developed, but low-relief sandy berm (Figs. 3b, 4h) that was best developed during the wetter months with clear erosion during the later dryer period. Wind-formed asymmetric ripples were observed at its crest. The upper foreshore comprises relict rooted logs and fallen trees that quickly transition into a ridge and runnel system oriented sub-parallel to the shoreline. East of the Moruga river (adjacent to Moruga Point), the foreshore area is of a relatively higher relief because of well-developed and sandy bedforms that abut the concave bend of the river (Fig. 3c). A gentle foreshore slope in this area is attributed to the absence of the ridges and runnels; instead small-scale strandplain-like ridges are suggested from aerial photography (Fig. 2). The higher topography to the east produces an overall asymmetric longitudinal profile across the river mouth. This study did not examine the distal exposed foreshore though it appeared to be a relatively smooth and gently sloping platform into the subtidal zone.

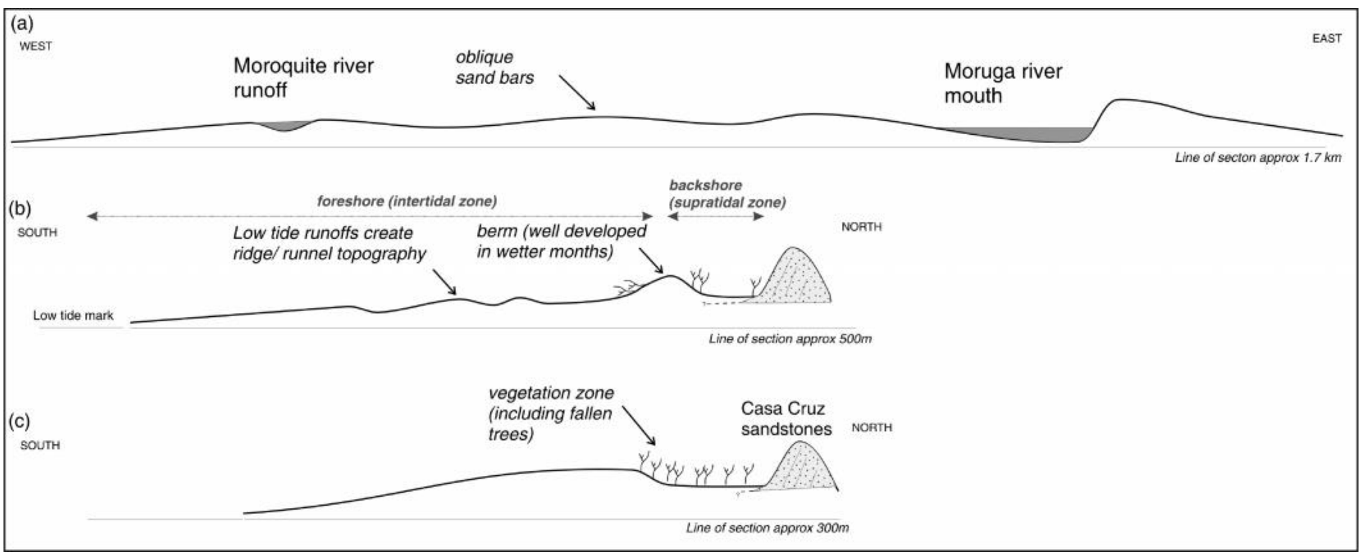


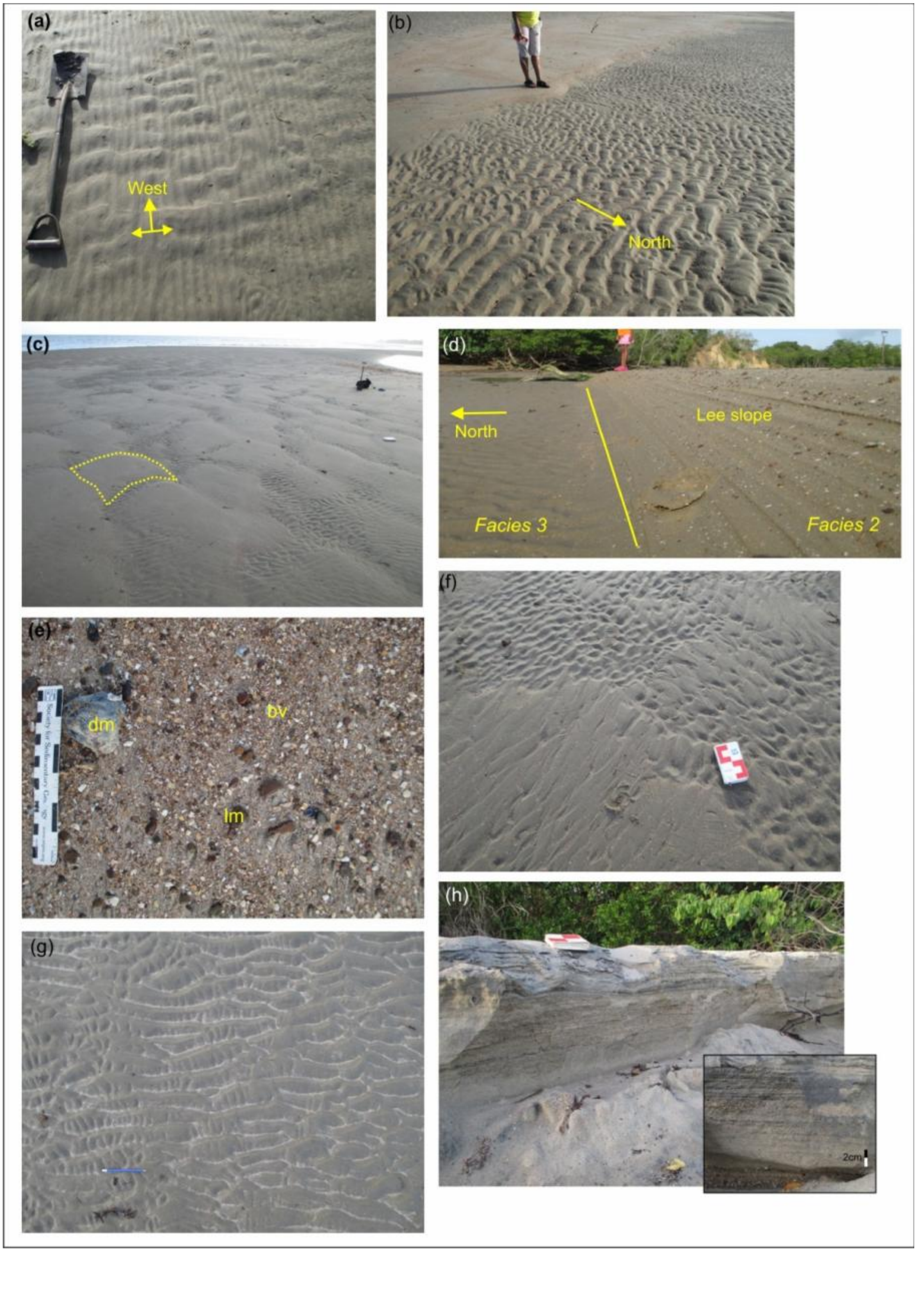
Figure 3: Schematic profiles across the Moruga delta platform showing relative variation in topography that can be observed at low tide. No vertical scale is intended and approximate locations are shown in Figure 2.

Surface bedforms and lithology

During the months of August 2014 to February 2015 the area west of the Moruga River mouth comprised soft grey clays which became completely covered with sandy bedforms by April 2015. Two sand-prone lithologies were observed. The first comprised fine-grained, well sorted and silty quartzose sands with minute shell fragments (facies 3 described below). These occurred in runoff areas (runnels) and comprised almost entirely straight-crested and symmetrical ripples superimposed upon a north-flowing asymmetric ripple set (Fig. 4a). This was overlain by the second lithology of poorly sorted quartz, variably disaggregated shells and limonite pebbles (facies 2 described below) arranged within low relief oblique sand bars measuring approximately 100 m (parallel to the shoreline) by 10s of metres width (perpendicular to the shoreline) by approximately 30 cm height (Fig. 4 c & d). These bars reduced in height west from the river mouth (Fig. 3a) and are migrating towards the north with lee slopes up to 24 degrees dip. Bar troughs comprise a well-defined set of north-oriented, asymmetric and sinuous ripple trains that were cross cut by a variety of other ripple forms. North and west-directed rhomboid, lingoid and compound ripple and dune-scale features are also superimposed upon the oblique bars (Fig. 4 b, f & g).

It is apparent from the varying scale and orientation of surface bedforms and sedimentary structures that the platform is strongly influenced by unidirectional, complex and bi-directional currents. The largest bedforms comprising the coarse grained bioclasts and pebbles are clearly migrating northward (landward). The superimposed ripples demonstrate a range of flow orientations ranging from north-northwest to east. Complex ripple forms are attributed to ebb currents as they indicate flow within the runnels. Symmetric ripple forms are pervasive and demonstrate the influence of the wave-induced processes perpendicular to the shoreline. The variety in scale and orientation of sedimentary structures collectively demonstrate a complex interaction of sedimentary processes that may include tidal, fluvial and wave-induced currents. Their respective influence will be determined when the internal sand character are described from the cores.

Figure 4: Surface bedforms across the Moruga delta platform. **(a)** Pervasive straight crested symmetrical ripples are superimposed upon west-directed asymmetric sinuous ripples likely formed by tidal runoff. Double arrows show north-south direction of wave motion; **(b)** North-migrating sinuous asymmetric ripples within troughs of similarly-migrating dune-scale bedforms; **(c)** Lingouid megaripples exposed on stoss of north-migrating bedforms. One is highlighted and backpack and shovel for scale; **(d)** Lee slope of one of the dune-scale bedforms. Preferential runoff during slackwater periods occur to the left of the image (north); **(e)** Lithic fragments common to dune shown in (d) include limonite clasts (lm), bivalve fragments (bv), disarticulated and whole molluscs (dm) and gastrapods, algae and plant matter; **(f)** complex ripple forms indicate a variety of flow orientations upon mega-ripples; **(g)** Sinuous ladder ripples suggest multiple interference currents upon mega-ripple trains, pencil for scale; **(h)** Eroding berm crest showing internal parallel laminations (inset) that are well-defined by opaque mineral and coarse bioclastic concentrations (note backshore vegetation in background).


(a)
West
(b)
North
(c)
(d)
North
Lee slope
Facies 3
Facies 2
(e)
dm
bv
lm
(f)
(g)
(h)
2cm

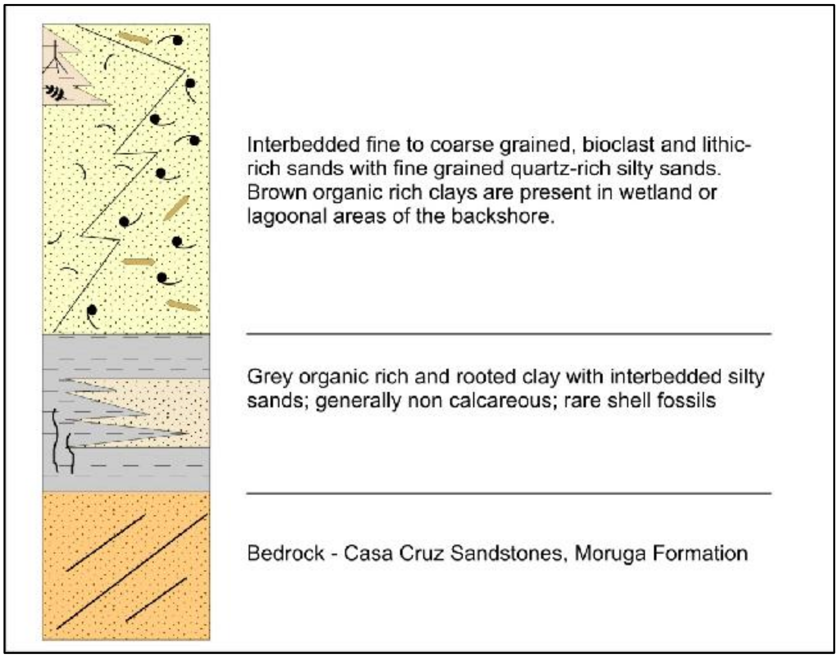


Figure 5: Moruga River delta stratigraphy (no vertical scale intended).

Facies from cores

The stratigraphy deduced from shallow cores across the Moruga River delta comprise unconsolidated clay and sands that rest upon consolidated sandstones of the Moruga Formation (Fig. 5). Four facies are described below.

Facies 1 - Grey organic-rich and rooted clays

This facies overlies bedrock and was obtained where the sand cover was thinnest or absent. It equates to the grey clays present within the runnels, as described from the surface lithology. It comprises non-calcareous clay with lesser fine sand laminae and abundant organic matter (Figs. 5, 6 & 7(a-c)). Dipping laminae-set contacts in the clay are common and can be quite high-angle with up to 40 degrees measured. Wavy laminae are also typical, sometimes with truncation of lower laminae sets. The quartz component comprises grey silty sands that occur either interlaminated/ interbedded with the grey shales or as 'floating' sand balls. The interlaminated sands are very fine to fine grained and are distinctively silty. They typically display wavy and divergent laminae contacts and common pinch-and-swell form. Coarsening and thickening upward intervals were described within 2 cores (3G and 4G) over a 30 cm interval that immediately preceded the onset of overlying structureless to trough cross stratified sands (facies 2). Overall, the laminated sands are distributed throughout this clay-prone facies which contrasts with the 'floating' sand balls which are distinguished by their highly irregular form and contacts. Where prevalent, these sand balls appear to increase in occurrence and amalgamation nearer to the contact with the stuctureless to trough cross stratified sands above, forming irregular sandy accretions. The sand balls also contain shell fragments, limonitic clasts and organic matter very similar to the overlying stuctureless/ trough cross stratified sands.

Organic matter was in the form of scattered wood and plant fragments, organic laminae, leaf casts and vertical root structures. Root structures were measured up to 26 cm in vertical length and cross-cut all other fabrics within the clay beds. The leaf casts range from ordered (parallel to bedding contacts) to disorganized.

Interpretation

The highly dipping laminae contacts within the grey clay coupled with disorganized leaf casts suggest soft sediment deformation (slumping) within an otherwise quiet-water setting. This is also evident from the irregular sand balls which were likely formed from soft-sediment loading of the overlying sandy facies into the soft grey clays (ball and pillow structures). The laminated sand suggests occasional sand input via traction currents and ripple trains. Their random vertical distribution may represent sporadic depositional events along the shoreline as opposed a more cyclical control (e.g. tides). The thickening-upward trends near the top are interpreted to result from an increasing proximity to the overlying sandy facies which eventually prograded over the clay beds. The root structures are the most significant observation within this facies. They were cored at least 175 m basinward from the closest present-day occurrence of vegetation and rooting and are interpreted to indicate a relict vegetated horizon (backshore) now transgressed by marine waters in the foreshore zone.

Facies 2 - Structureless to trough cross stratified bioclastic sands

This facies equates to the bioclastic sands described from surface lithology (Fig. 4 d & e). The contact between this facies and the underlying grey clay was either sharp (e.g. core 4F) or gradational (e.g. cores 3G and 4G), the latter occurring with a zone of interbedded bioclastic sands and grey clays (Fig. 6). This facies is everywhere present across the platform and contains fine grained (occasionally coarse) sands within a lithic framework of shells and other bioclastic fragments, limonite pebbles and organic fragments. The coarsest quartz grains were described within these beds which measured up to 15 cm thick. North-oriented high-angle cross stratification was the primary sedimentary structure (Fig. 7 d & e) with the occurrence of increasing dip angle with height (typical of trough cross stratification) recorded in at least two cores (1C_west and 1B). Rare laminae of clay or silty very fine sand are present with a distinctive brown colour that contrasts with the grey clay beds below; this characteristic was useful to discern the onset of this facies. Lithic fragments comprise the framework component in many of these beds and displayed a wider variation in grain size than quartz. The coarsest fragments are up to granule sized shells and limonite and were often structureless, though bedding planes may have been disguised within this fabric. Disarticulated and whole gastropod and bivalve fragments, algae, and foraminifer tests comprise the bioclastic framework.

Interpretation

The common trough cross stratification suggests formation from unidirectional bedload and traction currents within mega-ripple or dune-scale bedforms. The landward-directed transport direction coincides with the transport direction of oblique sand bars observed at the surface. Landward-directed megaripples occur at river mouths where sediments are reworked by a combination of waves and tides with flood and/or swash-dominated sediment flux (e.g. McCubbin, 1982; Reading & Collinson, 1996). Swash processes may be dominant given the orientation and asymmetry of the sand bars relative to longshore currents and the relative absence of tide-induced characteristics such as clay drapes or reactivation surfaces among the bedforms. Tidal currents are instead evident from the wider variation in current direction and velocity described from the smaller-scale surface ripples, although these are not being preserved in the shallow subsurface (compare with facies 3, below). These bedforms are interpreted as swash (e.g. Masselink et al., 2011) or longshore bars (e.g. Reineck & Singh, 1973) related to wave-induced processes.

The structureless beds may represent lithic-rich debrites associated with local bedform collapse or lithic-rich flows as may occur during periods of greater sediment input (e.g. increased river discharge or longshore contribution).

Facies 3 - Homogenous well sorted fine grained sands

This facies equates to the well sorted and silty quartzose sands described from surface lithology (Fig. 4a). These sands were found either overlying the grey clays or interbedded with the trough cross stratified sands in the cores. They comprise very well sorted, very fine to fine grained quartzose sands with minute shell and other bioclastic fragments and limonitic clasts (Fig. 7 f-h). Sands are structureless within beds up to 15 cm thick with bed boundaries demarcated by clayey-silts. These silts vary from beds up to 5cm thick to individual wavy laminae. The thicker silt beds contain well-defined fine-grained sand laminae occurring at regular intervals which are also wavy in character.

Interpretation

The symmetrical ripple forms that were observed overlying this lithology at surface (Fig, 4a) were not observed in the cores and it is apparent that ripples are preserved in the subsurface only within clayey silt-sand couplets. The intervals of interspersed silt and regularly spaced wavy-fine sand suggest a more cyclical control that can be expected from tide-induced sedimentary currents. It is apparent therefore that these sands are influenced by a combination of wave and tide-induced sedimentary currents with the latter passing into the shallow rock record. This facies is therefore interpreted to represent a significant tidal influence on the delta platform.

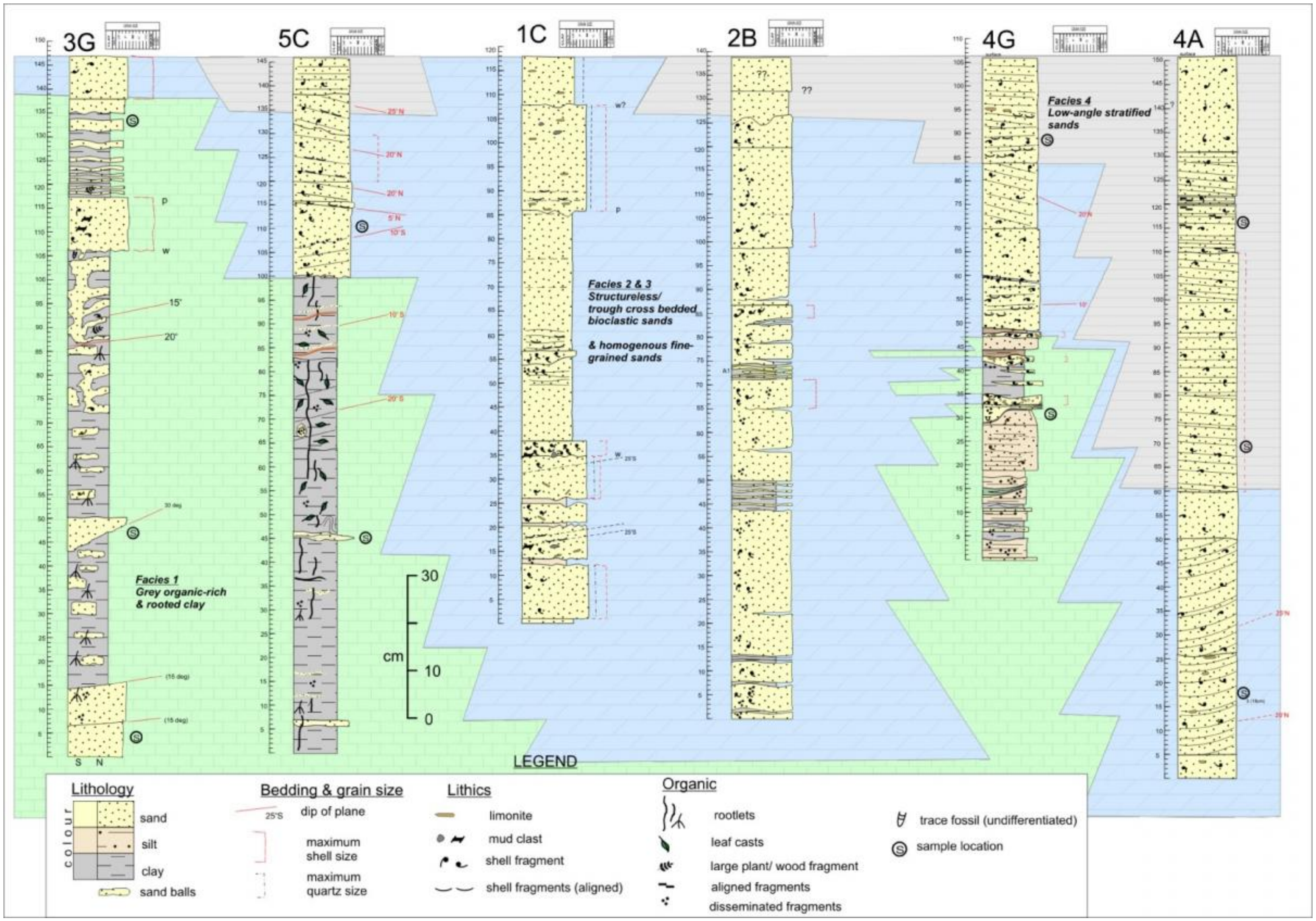


Figure 6: Representative cores showing four facies present along the Moruga delta platform. Cores are not arranged in any particular order; see Figure 2 for locations.

Facies 4 - Low angle cross stratified sands

This facies forms a relatively thick sand bank (berm) in the upper reaches of the foreshore and along the eastern flank of the Moruga River (transverse bar) where it overlies both trough cross stratified (facies 2) and homogenous sands (facies 3). Its lithology is very similar to that described for the structureless to trough cross stratified bioclastic sands. What differentiates this facies is the presence of parallel to low-angle cross stratification, and the exclusion of trough cross strata (Fig 7 i & j). Quartz is predominantly fine grained while lithic fragments show very poor sorting. Bioclasts are commonly aligned along the laminae planes and together with silt and opaque mineral concentrations, highlight the low-angle relationship between laminae sets.

Interpretation

The presence of low-angle strata is attributed to beach swash and backwash processes during constructive beach aggradation and formation of the berm (e.g. Reineck & Singh, 1973). This facies and its associated bedforms differ from the underlying trough-cross stratified sands by their orientation parallel to the shoreline and occurrence within the high tide swash zone. This zone extends farther into the foreshore on the eastern flank of the Moruga River because of a longshore current 'shadow' west of Moruga Point and this is suggested to account for the development of the transverse sand bar at that locality (this does not form elsewhere along the delta platform). As with the structureless to trough cross stratified sands, this facies highlights the reworking of fluvial sediment discharge by wave-processes at the mouth of the Moruga River.

Sand Mineralogy

A qualitative assessment estimates quartz content between 50 - 80% of the total sand composition (Fig. 8a). Quartz grains are sub-rounded to angular in shape and ranged from less than 0.1 mm up to 5 mm in size (Fig. 8 b & c). The sand matrix is often comprised of bioclastic grains with fragments less than 0.1 mm up to 3 mm, with varied angular to rounded texture. Bioclastic fragments occur as whole shells or disarticulated fragments of bivalve, molluscs and foraminifera (Fig. 8f). Limonitic clasts are also a significant lithic fraction, and ranged from less than 0.1 mm to pebble –sized and usually sub-rounded in shape.

Accessory minerals include apatite, zircons and pyrite. Zircons and apatite grains are sub-rounded to sub-angular and generally less the 1 mm in size. Hematite and pyrite occurred as fine grained, sub-rounded, slightly pitted grains (Figs 8c & e). The pyrite exhibited a greenish-gold colour while hematite had a typical reddish brown colour. No feldspars grains were seen in any of the samples.

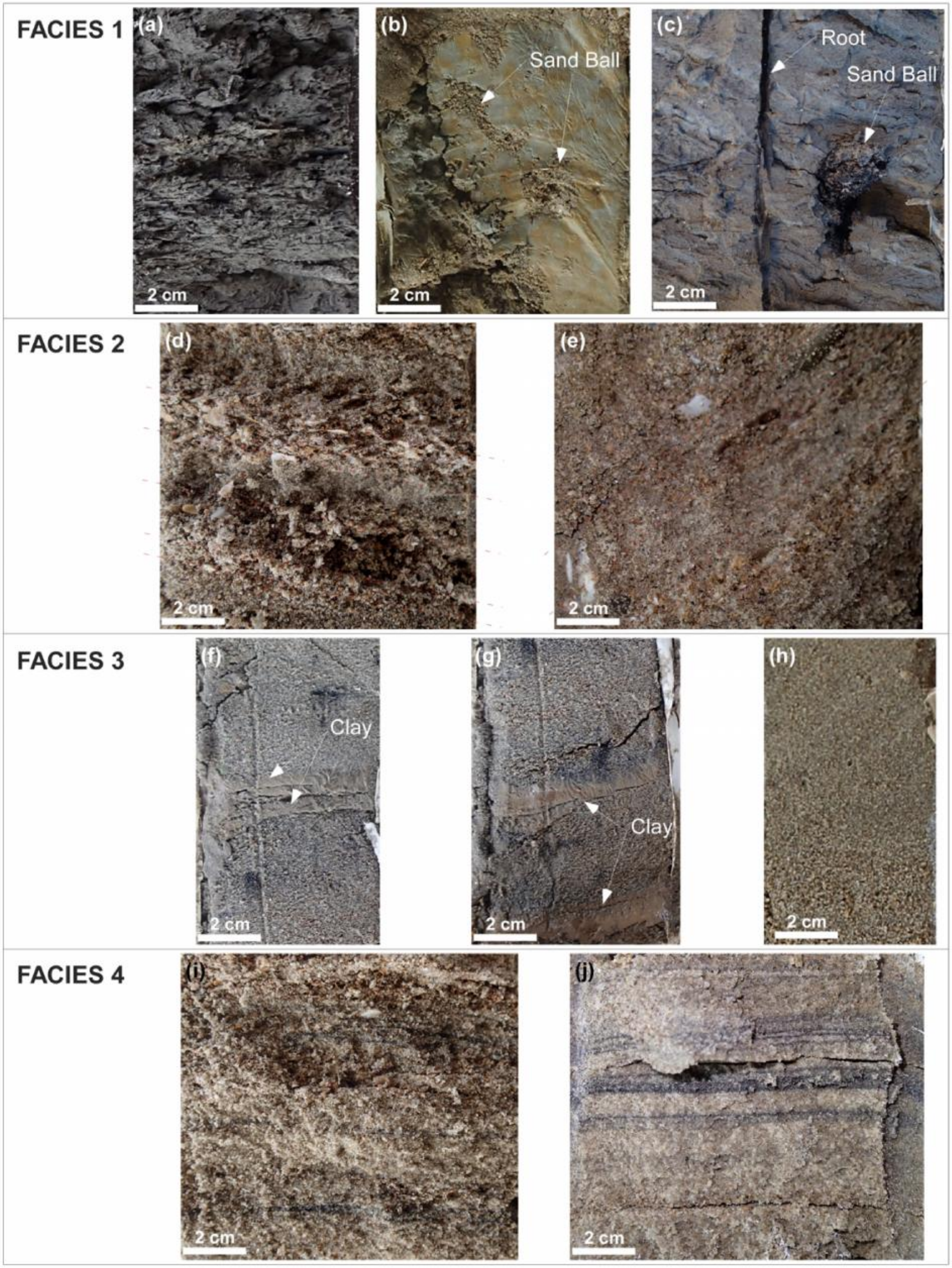


Figure 7: Facies identified from core: Facies 1 comprise **(a)** grey organic rich clays, **(b)** 'floating' sand balls, **(c)** laminated sands and rootlets. Cores 4F, 1B & 5C; Facies 2 with **(d)** & **(e)** high angle cross stratified sands. Cores 1A and 4A; Facies 3 with

characteristic well-sorted fine sands and clay laminae **(f)**, **(g)** & **(h)**. Cores 2B & 1G; Facies 4 with characteristic low angle cross stratified sands and opaque mineral concentrations across laminae **(i)** & **(j)**. Cores 1A & 4A.

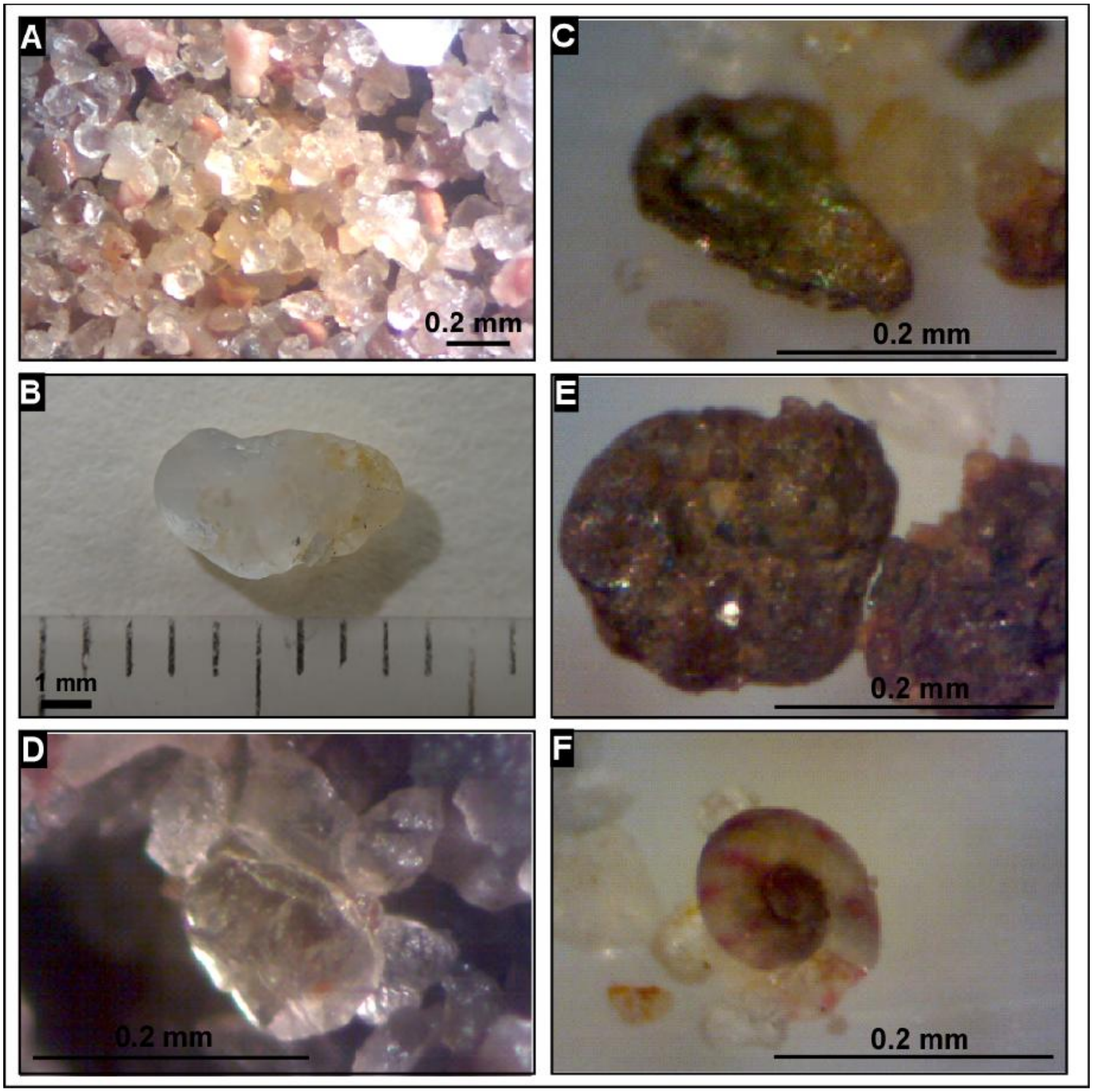


Figure 8: Representative mineralogy of sands across the Moruga delta platform. **(a)** Quartz aggregate; **(b)** single sub-rounded coarse quartz grains; **(c)** pyrite; **(d)** Angular quartz crystals are very common; **(e)** Hematite; **(f)** minute gastropod.

Discussion

The core and surface descriptions enable the lateral and vertical partitioning of the primary sedimentary processes over the delta platform (Figs. 9 & 10). Laterally, wave-induced sedimentary processes are everywhere-evident with varying styles of preservation. The eastern transverse bar is attributed to swash and backwash reworking of sand accumulating adjacent to Moruga Point. Correlative sedimentary processes on the western flank of the river are limited to the upper foreshore and instead sediment discharge is additionally reworked by longshore and subordinate tidal currents within the lower foreshore. The deflection and reworking of limonite-rich sediment discharge from the Moruga River by longshore currents results in a series of landward-migrating bedforms (swash bars) that diminish in height towards the west (Fig. 9); the swash bars are not apparent approximately 2km to the west. The vertical partitioning of primary sedimentary processes involves the superposition of low-angle cross stratified sands attributed to swash and backwash processes, over the migrating swash bars (Fig. 10). These bars are well-preserved in the subsurface together with the common asymmetric ripples associated with tidal runoffs. Conversely the prominent symmetrical ripples across the surface of the delta platform (Fig. 4a) are not evident in the subsurface. Wind-formed asymmetric ripples are common to the berm crest and backshore areas but were not sampled in the subsurface.

The bedforms described upon the delta platform are influenced primarily by longshore, wave and tide processes. Fluvial and tidal channel orientations are strongly aligned parallel to the swash bars though fluvial channels were observed to occasionally dissect these larger bedforms (e.g. western river flow in Fig. 9). It is likely there would be associated fluvial mouth bars within the subtidal zone, not sampled in this study. The fluvial impact was most strongly reflected in the volume of sediment discharge that formed the delta platform.

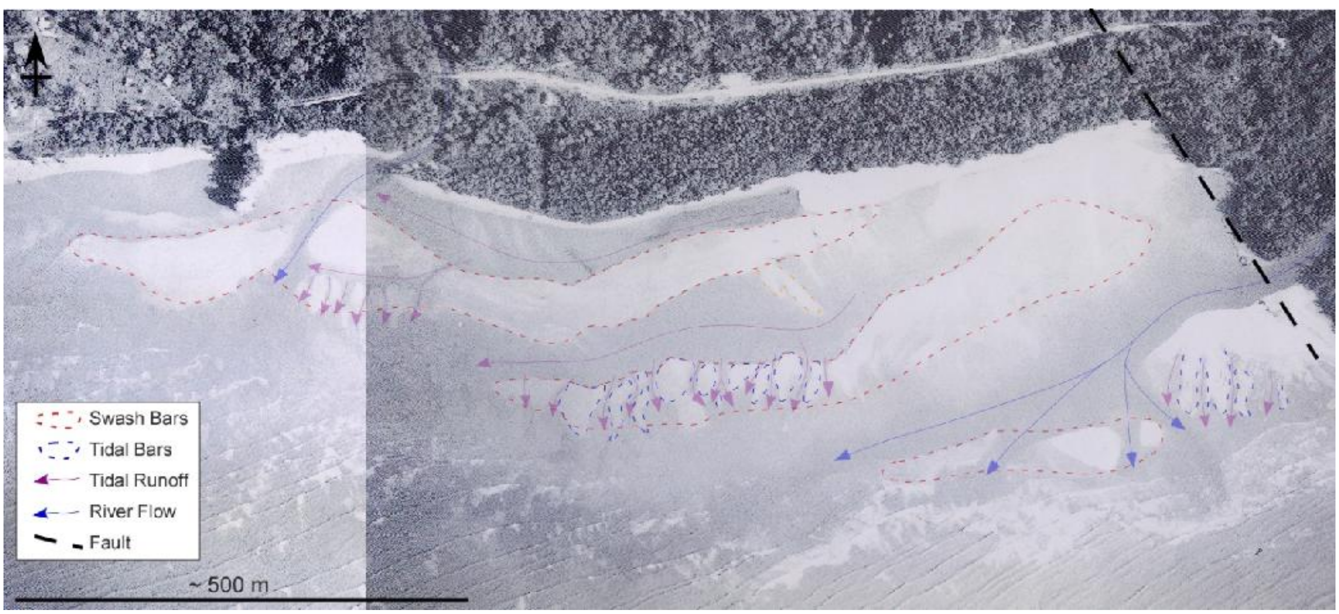


Figure 9: 1970 Air photograph of the Moruga delta platform showing well-defined swash bars and intervening runnels. The swash bars are dissected by tidal runoff chutes. The Moruga river mouth is to the right of the image.

These bedforms collectively demonstrate the wholesale transgression of the Moruga coastline as they overlie organic-rich and rooted muds that are interpreted to be relict lagoonal and soil horizons. The sandy bedforms are being deposited over an eroding shoreline with the preserved interface being a series of bioclastic debrites and soft sediment deformation (loading) into the soft clay. It is difficult to ascertain the longer-term rock record because of the dramatic seasonal changes in the beach profile. It is postulated that these bedforms will successfully pass into the rock record so long as sediment flux remains positive along the coastline. This record may be punctuated by large erosional events that may result from periods of destructive wave activity or large storms of a greater intensity and impact than the typical seasonal erosion. No attempt was made to date the sediments, though the occurrence of relict lagoonal muds over 175m away from the present-day shoreline suggest longer time intervals than initially anticipated (tens of years minimum as opposed to seasonal). Carbon dating these clays may provide useful insights into the rate of coastal retreat. In this respect, the Moruga River mouth is a modern estuarine complex.

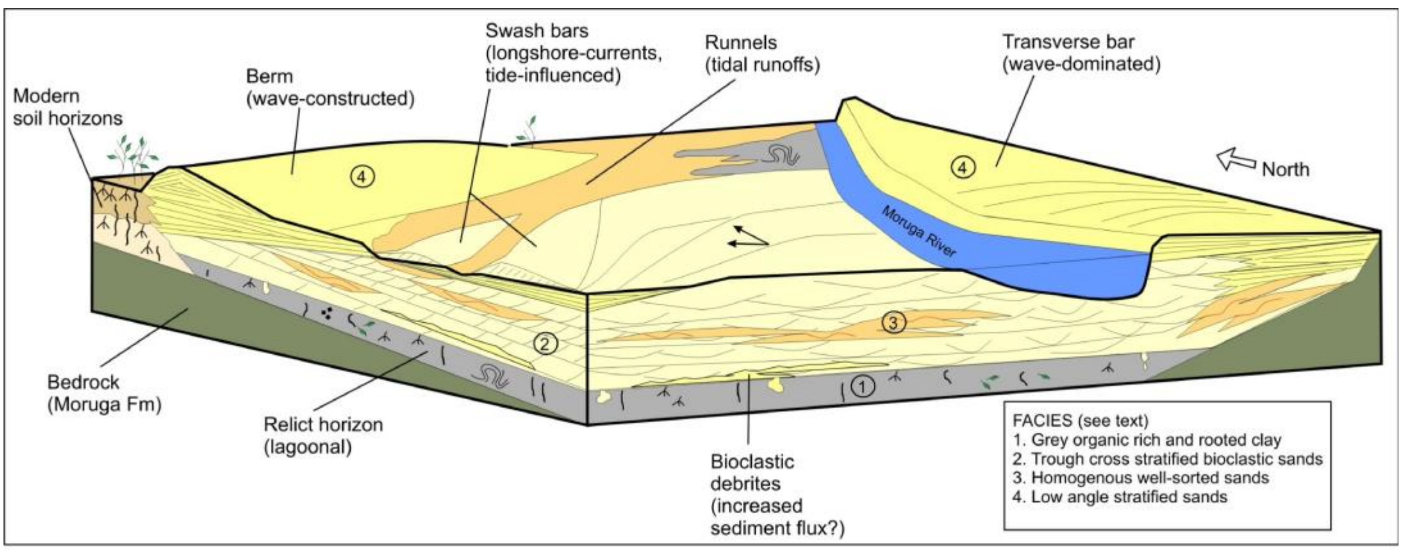


Figure 10: Schematic illustration of sedimentary bedforms and processes across the Moruga River delta. Fluvial discharge is reworked by wave and longshore currents into a series of swash bars, giving an overall asymmetry to the delta platform. Arrows indicate the migration direction of the swash bars. Not drawn to scale.