Sedimentary Geology 269–270 (2012) 69–77

Contents lists available at SciVerse ScienceDirect

Sedimentary Geology

journal homepage: www.elsevier.com/locate/sedgeo

Unusual occurrence and stratigraphic significance of the *Glossifungites* ichnofacies in a submarine paleo-canyon — Example from a Pliocene shelf-edge delta, Southeast Trinidad

Sudipta Dasgupta *, Luis A. Buatois

Department of Geological Sciences, University of Saskatchewan, 114 Science Place, Saskatoon, Saskatchewan, Canada

ARTICLE INFO

Article history:
Received 17 February 2012
Received in revised form 7 June 2012
Accepted 7 June 2012
Available online 15 June 2012

Editor: J. Knight

Keywords:
Glossifungites ichnofacies
Submarine canyons
Paleo-Orinoco
Shelf-edge delta
Firmground

ABSTRACT

Sedimentary rocks belonging to the upper-slope shelf-margin delta of the Paleo-Orinoco River are present at the southeast coastline of Trinidad in the Columbus Basin. The Pliocene Mayaro Formation, exposed as foreshore cliffs, represents the wave-influenced delta front and mouth bar of this system. These deposits consist of thick to very thick hummocky cross-stratified sandstone beds and thin-bedded to laminated heterolithic sediments. They also contain abundant soft-sediment deformation structures and sparse well-preserved softground burrows (e.g. *Ophiomorpha nodosa*). Towards the north-central part of the outcrop, the delta front deposits are cut across by a paleo-canyon filled with younger mud-dominated prodeltaic sediments. The rare exposure of the canyon-wall exhibits an unusual occurrence of *Glossifungites* ichnofacies. Contrastingly distinct from archetypal examples, this monospecific suite contains a low abundance of firmground *Thalassinoides* filled with mud rather than sand. The tracemakers burrowed into a firm medium-grained sandy substrate of the delta front, and the burrows were subsequently passively filled by the mud from the overlying prodeltaic sediments filling the canyon. The deep-tier firmground *Thalassinoides* suite crosscuts the pre-existing softground trace fossils. Integration of ichnologic, sedimentologic and sequence-stratigraphic datasets indicates that the older delta front sediments are separated from the prodeltaic deposits by distinct episodes of fluctuating relative sea-level controlled by the basin-bounding growth-fault activities and the development of the canyon. Whereas the entire shelf-margin megasequence might have been deposited through a regional scale sea-level lowstand, the local fluctuations in accommodation space resulting from the growth-fault movements and the incision of the canyon were responsible for the shifting positions of the depositional architectural elements of the shelf-edge delta.

1. Introduction

The *Glossifungites* ichnofacies (Seilacher, 1967) is a substrate-controlled ichnofacies which has been extensively used in sequence stratigraphy to identify and characterize discontinuity surfaces (MacEachern et al., 1992; Pemberton et al., 1992, 2001, 2004; MacEachern et al., 2007; Buatois and Mángano, 2011). Development of the *Glossifungites* ichnofacies in siliciclastic sediments invariably involves erosional removal of sedimentary layers. The *Glossifungites* ichnofacies is commonly conspicuous in outcrops and cores, and is preserved at lithological interfaces, typically mudrocks overlain by coarser-grained clastic sediments. In such cases, the unlined burrows occurring in mudrock are passively filled with coarser grains from the overlying stratum. This reveals that the burrows remained open after the tracemaker relinquished the structure, thereby permitting sand grains from subsequent depositional events to pervade into the open, stable burrows. In a few cases, occurrences of burrows filled with sand and emplaced in compacted sand have been documented (Fig. 5 of Pemberton et al., 2004; Fig. 14 of Buatois et al., 2008). The *Glossifungites* ichnofacies develops in a wide variety of sequence-stratigraphic contexts (MacEachern et al., 1992, 2007; Buatois and Mángano, 2011), but the majority of documented case studies are from shallow-marine settings. Only a few examples are known from deep-marine contexts, such as incision of submarine canyons during relative sea-level falls (e.g. Hayward, 1976) or autogenic erosional episodes by turbidity currents and bottom currents (e.g. Savrda et al., 2001; Gérard and Bromley, 2008; Hubbard and Shultz, 2008).

The outcrop of the walls of a paleo-canyon in the Pliocene Mayaro Formation from southeast Trinidad Island of Trinidad and Tobago (Fig. 1) serves as a unique example of the development of the *Glossifungites* ichnofacies, as the only known example of this ichnofacies developed on a canyon incision surface, which separates the underlying delta front sandy sediments from the overlying prodelta mudrocks. The incision surface identified on the basis of the development of *Glossifungites* ichnofacies marks a co-planar stratigraphic surface in the shelf-edge delta setting of the Pliocene Paleo-Orinoco River. It indicates striking changes in accommodation vis-à-vis changes in the loci of

* Corresponding author.
E-mail address: sudipta.dasgupta@usask.ca (S. Dasgupta).

0037-0738/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
doi:10.1016/j.sedgeo.2012.06.004

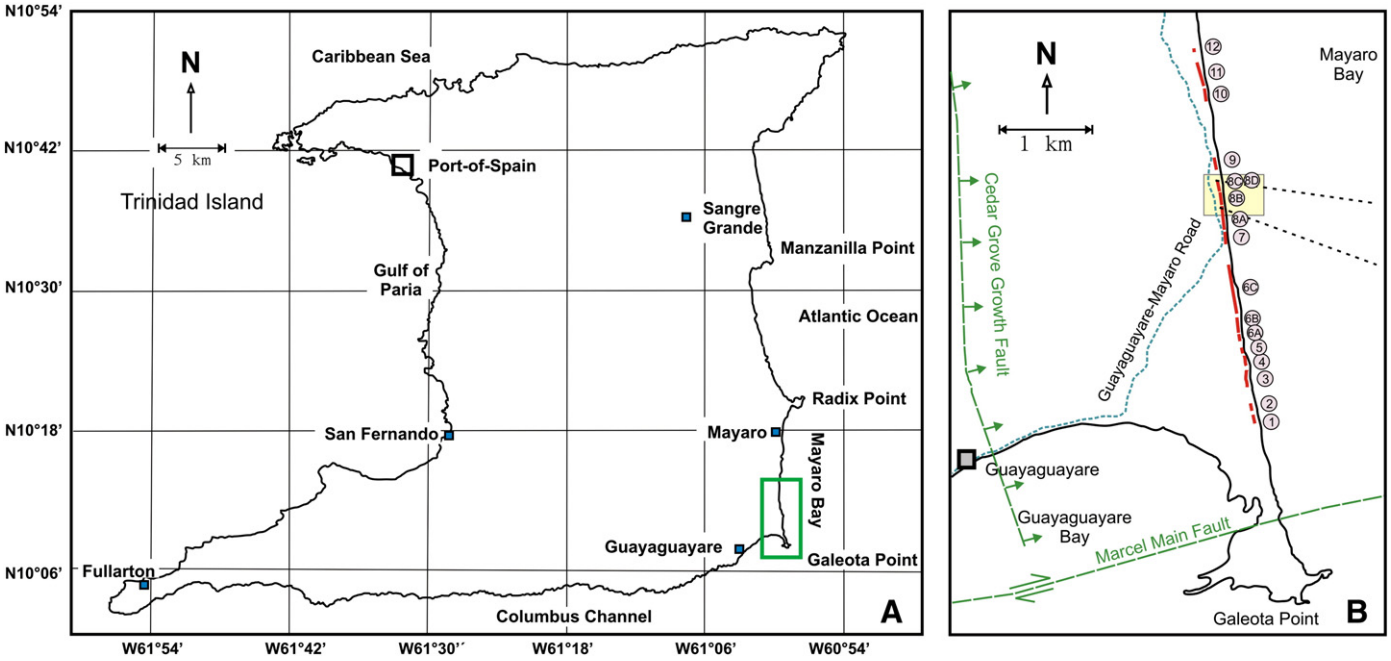

Fig. 1. Location maps. (A) Location of the Mayaro Formation outcrops along the southeastern shoreline of Trinidad Island shown with the green rectangle. (B) Locations of the Mayaro Formation outcrops as foreshore cliffs (marked by red) with the outcrop numbers (circles). The paleo-canyon incised within the delta front sediments discussed in this paper are delineated with a rectangle. Two dashed straight lines indicate the approximate orientation of the flanks of the canyon.

deposition for the sandy lithosomes of the shelf-edge delta system before and during the formation of canyon, colonization of the firm substrate exhumed by the incision and also during the subsequent filling of the canyon, involving the passive filling of the burrows. The aims of this paper are: (1) to characterize the major incision surfaces of the paleo-canyon in terms of sedimentary and ichnological characteristics; (2) to establish the relative chronological order of the series of ichnosedimentological events taking place in relation to the development of the paleo-canyon; and (3) to refine the sequence-stratigraphic context from the integration of ichnologic and sedimentologic datasets.

2. Depositional setting of the Pliocene Mayaro Formation

The Pliocene Mayaro Formation of the Columbus Basin is exposed as foreshore cliffs along the north–south trending southeast coastline of Trinidad Island between two prominent headlands — Radix Point in the north and Galeota Point in the south (Fig. 1). The ca. 702 m thick Mayaro Formation outcrops represent an almost strike-parallel sliver of the growth-fault-bounded shelf-edge deltaic sediment belonging to the Pliocene Paleo-Orinoco River. The Columbus Basin is bounded towards the North by the Central Ridge-Darien Ridge Lineament, on the South by the Amacuro Platform of the present-day Orinoco Delta, offshore Venezuela, and on the West by the Cedar Grove growth-fault; towards the East, the basin continues into the hydrocarbon-rich offshore part of the basin on the present-day Trinidad shelf and deeper offshore (Wood, 2000; Sydow et al., 2003; Callec et al., 2010). The approximately north–south trending Cedar Grove growth-fault, which limits the Mayaro Formation sediments towards the west as its down-thrown side, passes parallel to the outcrops near Guayaguayare town within ca. 3 km away from the exposures (Fig. 1).

Bowman (2003) categorized the Mayaro succession into a hierarchy of complex five-level stratigraphic cycles — from (i) a hundreds to thousands of meter thick lower-order regressive shelf-edge delta megasequence, to (ii) hundreds of meter thick higher-order regressive–transgressive cycles and (iii) tens to hundreds of meter thick further higher-order progradational, aggradational or retrogradational subcycles, and to (iv) tens of meter thick progradational or retrogradational packages that intermittently comprise (v) less than a meter to several meter thick hummocky and swaley cross-stratified sandy strata. Uroza (2008) reinterpreted parts of the outcrop and constructed a conceptual depositional architectural model for this Pliocene shelf-edge delta.

As estimated by Porębski and Steel (2006), the present-day Orinoco delta is an accommodation-driven one, which implies that the delta front requires relative sea-level fall to reach the shelf margin. This suggests that the delta front of the Paleo-Orinoco River migrated towards and stacked up at the shelf-edge during the relative sea-level lowstand of the Pliocene icehouse and perhaps also during the following rise. The fluctuations of relative sea level in the Columbus Basin are both influenced by eustasy and tectonism, whereby the regionally extensive repeated growth-fault movements have always influenced the accommodation available for sedimentation of the north-eastward prograding Paleo-Orinoco delta (Wood, 2000).

The Mayaro Formation is interpreted to have been deposited by fluvially influenced hyperpycnal-flow sedimentation, and further remobilization of the sediments took place by wave-action. The sand-filled gutter-casted chutes of substantial thickness (up to ca. 2–3 m) bear evidence for hyperpycnal flow bypassing the areas of the delta front deeper onto the continental slope. The chutes are cut through the wave-remobilized sheet-like deltaic mouth-bar sediments characterized by stacked thickness of the hummocky cross-stratified medium-grained sandstone (comparable to the S2h hyperpycnite facies of Zavala et al., 2011), locally amounting up to 25–30 m in thickness, and intervening thinly laminated heterolithics composed of alternate laminations of silty sand and mud. The thickness of the delta front megasequence (ca. 702 m in outcrop) and the deeply incised large gutter casts suggest that sedimentation took place in a setup with substantially high delta front gradient and high accommodation space, which are characteristic of the transition from the outer shelf to the upper slope. Seismic data from the adjoining hydrocarbon fields also support a shelf-margin setup for the Mayaro Formation (Wood, 2000; Sydow et al., 2003).

The delta front is cut across by an ESE–WNW trending incised paleo-canyon, later filled by prodeltaic sediments. The southern wall of the paleo-canyon is exposed towards the northern end of outcrop 8A (Figs. 1B, 2). This southern cut-surface strikes approximately at S55°E, dipping ca. 58° north-easterly. The northern wall of the paleo-canyon can be located in outcrops 8 C and 8D and is more irregular, from gently