CONTOURITE TERRACES vs MARGINAL PLATEAUS/PLATFORMS: CONCEPTUAL IMPLICATIONS

F. J. Hernández-Molina
Dept. Earth Sciences
Royal Holloway Univ. London (UK)
E-mail: javier.hernandez-molina@rhul.ac.uk
I. INTRODUCTION

II. OCEANOGRAPHIC PROCESSES

III. STUDY CASE: ARGENTINIAN & URUGUAYAN MARGIN

IV. OTHER EXAMPLES: MODERN & ANCIENT

V. CONCLUSIONS
Sediments deposited or substantially reworked by the persistent action of **bottom currents** (Stow & Faugères, 2008)

“I. INTRODUCTION

“Semi-permanent water-mass flows capable of eroding, transporting, and depositing sediments on the sea-floor”
CONTOURITE DEPOSITIONAL SYSTEM

Upper	
Middle	
Lower

Depositional features
Erosional features
Mixed features

Contourite Terrace - 1
Contourite Terrace - 2
Contourite channel
Erosional surface

(I. INTRODUCTION)

I. INTRODUCTION

Sediments deposited by contour-parallel thermohaline currents

Contourite channel

Contourite Terrace - 1

Contourite Terrace - 2

WATER MASS-II (INTERMEDIATE)

WATER MASS-III (DEEP)

Erosional surface

PRE-glacial margin deposit

Chaotic layer

WATER MASS-I (SUPERFICIAL)

Contourite channel

Erosional surface

Contourite Terrace - 1

Contourite Terrace - 2

WATER MASS-II (INTERMEDIATE)

WATER MASS-III (DEEP)

DEPOSITIONAL FEATURES

Very frequent in present marine basins

Length = hundreds of km
Wide = tens of km
Thickness = 0.2-3 Km

Present / recent depositional features
Depositional features in the ancient record
(Rebesco et al., 2014. Mar. Geol.)
I. INTRODUCCIÓN

Campaña ECOMARG 2004
Lander TFS-1
Fosa de Carrandi (Gijón moat)
Profundidad 600 m
15-04-2004
I. INTRODUCTION

TERRACES

(Harries et al., 2014)
“Marginal plateaus can be defined in the submarine morphology as flat (sub-horizontal) but deep (deeper than the shelf break) domains within the continental slope” (Mercier de Lépinay et al., 2016)

- Abut the margin
- Marginal plateaus (separate from the slope and form isolated, raised platforms)

Marginal plateaus are defined as a flat (sub-horizontal) surface within continental slopes bounded by large tectonic structures and controlled, in a long-term, by tectonic and sedimentary processes”.

BUT...

- At least one of its boundary represents a transform COB
- At least they had one period of rifting prior transform formation
- It represents and relative basement (CC and / or CO?) high

Total= 184 plateaus
Area= 18,486,600 km², or 5.11% of the oceans
(Harries et al., 2014)
An isolated (or group of) relatively flat horizontal or gently inclined surface(s), sometimes long and narrow, which is (are) bounded by a steeper ascending slope on one side and by a steeper descending slope on the opposite side” (IHO, 2008)

Total = 1230 terraces  
Area = 2,303,490 km$^2$,  
0.64 % of the oceans  
11.6 % of the continental slope (Harries et al., 2014)

- Are most common on the slopes of the Arctic and Indian Oceans (> 21% of the continental slope)
- Occupy < 6% of the slope in the Mediterranean and Black Seas, the North Pacific and the South Pacific Oceans.
- The largest terrace is on the NW Shelf of Australia (104,470 km$^2$)
"An isolated (or group of) relatively flat horizontal or gently inclined surface(s), sometimes long and narrow, which is (are) bounded by a steeper ascending slope on one side and by a steeper descending slope on the opposite side" (IHO, 2008)

They are sub-horizontal morphologic elements identified both at the present sea-floor and in the sedimentary record, which have developed over time in constructional and erosive phases.

(Faugères et al., 1999)
II. OCEANOGRAPHIC PROCESSES

Deep water circulation is influenced by a number of processes:

1. Bottom currents & thermohaline circulation
2. Overflows
3. Processes at the interface between water masses
4. Deep-water tidal & internal tides currents
5. Deep-sea storms
6. Eddies
7. Secondary circulation
8. Dense shelf water cascades
9. Internal waves & solitons
10. Tsunami-related traction current
11. Rogue- & cyclone-related traction currents
Sub-surface waves associated to interphases between water masses with different density

II. OCEANOGRAPHIC PROCESSES

Adapted from Shanmugan, 2012, 2013
Very common in all oceans!

Locations (red dots) of observed oceanographic internal waves and tides in coastal seas and in the open ocean (from Apel, 2002; Jackson, 2004a).
Breaking of internal waves on sloping surfaces creates episodic high-turbulence events and consequently erosion and transport of sediments.
Impact in sediments: breaking internal waves

*based on laboratory experiments (Southard & Cacchione, 1973)*

Upslope, partly in suspension

**SWASH RUN-UP**

Downslope, as bedload

**BACKWASH**

deposition

Repetitive high energy events

*(Southard & Cacchione, 1973)*

*(Bádenas et al., 2011)*
The South China Sea is a unique, semi-enclosed ocean environment, characterized by strong tidal currents and internal solitary waves (ISWs). ISWs are generated by tidal forcing in the Luzon Strait and propagate across the deep basin with amplitudes regularly exceeding 100 m. These waves reach the continental slope, where their interaction with the seabed can generate significant sedimentary transport.

Materials and methods

Sediment gravity core and grab samples were collected from the continental slope from 200 m to 350 m at 5.5 km, with a sharp 80 m cliff from 120 m to 200 m at 5 km. The oceanographic study area is indicated by the solid line.

Data collection and analysis

Acoustic echosounder systems have been utilized for the study of the bathymetry and sediment structure. Figure 3 shows the ISW propagating along the slope, with long curved dark bands near 117.5°E, 119°E, and 120°E as surface expressions of the ISWs. The study area is indicated by the solid line.

Sand dune size and structure are shown in Figure 4, with sand dunes adjacent to the plateau from 5.0 to 5.6 km and smaller dunes further south. As the ISW shoals on the continental slope, it depresses the ocean bottom structure, which was initially suspected to be the ocean bottom structure, which was initially suspected to be the bottom boundary.

The samples at various locations, such as at 200 m, 300 m, and 400 m, were collected using bottom grab samplers. The distribution of sediment at all sites was bi-modal, with a peak at 40 m and another peak at 180 m, as depicted by the particle size distributions plotted in Figure 5. Given South China Sea ISW amplitudes regularly in excess of 100 m, full water column energy transport as indicated by isopycnal bifurcation was observed.
**OFF TIERRA DEL FUEGO**

**PATAGONIAN MARGIN**
- H1 -> Late Pliocene (~3.2 Ma)
- H2 -> Middle/Late Miocene
- AR5 -> Middle Miocene (~17 Ma)
- OUS -> Oligocene Upper Slope (~23 Ma)
- AR4 -> Eocene/Oligocene (~32 Ma)

**RÍO DE LA PLATA MARGIN**

**URUGUAYAN MARGIN**

(Modified from Koenitz et al. 2008 in Pérez et al., 2015. GML)

(Hernández-Molina et al., 2009. *Geology*)

(Preu et al., 2012. *DSR*)

(Hernández-Molina et al., 2016. *Marine Geology*)
• Their location can be correlated with the main interfaces of regional water masses.
III. ARGENTINIAN & URUGUAYAN MARGIN

(Hernández-Molina et al., 2017. Geology)
Erosional features:
  a) Regional discontinuities 
  b) Abraded surfaces 
  c) Contourite channels (\& moats) 
  d) Furrows 
  e) Marginal troughs 
  f) Scours 

Depositional features:
  a) 2D Sediment waves; 
  b) Barchanoid bedforms 
  c) Linear sand ribbons 

(Hernández-Molina et al., 2017. Geology)
- **Barchanoid bedforms** are convex to the SW with steep lee faces to the NW indicating a dominant NW-flowing current.
- They are typically around 1-4 km wide, 2.5-6 km long, and 14-60 m in height.
IV. OTHER EXAMPLES: MODERN & ANCIENT

CANADIAN MARGIN

(Miocene)

(Campbell & Mosher, 2016. Marine Geology)

Data EnCana Corp.
IV. OTHER EXAMPLES: MODERN & ANCIENT

BRAZILIAN MARGIN

(Schreiner et al., 2008. B. Geoci. Petrobras)
Sandy Contourites bedforms

• Large Sand-dune Fields
• Sand Waves
• Barchan dunes
• Sand Furrows
• Sand Ribbons
• Sand Waves

Geometry of barchan dune

(Mutti et al., 2014)

IV. OTHER EXAMPLES: MODERN & ANCIENT
• **UPPER JURASSIC SANDY-OOLITIC EVENTITES (RICLA, SPAIN)**

(Bádenas & Aurell, 2001; Bádenas et al., 2005; Bádenas et al. 2011; Pomar et al., 2012)

**Basic elements**
- thin sand lamina
- “down-dipping” crossbeds
- starved ripples
- thin sand lamina

**Occasional elements**
- “up-dipping” crossbed

**IV. OTHER EXAMPLES: MODERN & ANCIENT**
- **Jurassic - Cretaceous Kermanshah Radiolarite Complex, west of Iran**
The role of bottom water circulation and associated oceanographic processes in shaping the seafloor and controlling the sedimentary stacking pattern on passive continental margins has to be seriously reconsidered in future decades.