Formation of Crenulated Clinoforms on Continental Shelves

P. Puig
Institut de Ciències del Mar (CSIC)
Passeig Marítim de la Barceloneta, 37-49
Barcelona 08003, Spain
phone: +34 93 230 9518 fax: +34 93 230 9555 email: ppuig@icm.csic.es

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http://www.icm.csic.es

LONG-TERM GOAL

The long-term goal of this research effort is to improve understanding of sediment transport in a region of crenulated clinoform development on a shelf adjacent to a mountainous coast drained by rivers with episodes of high discharge.

OBJECTIVES

Our principal objective is to establish relationships between active sediment dynamics, cross-shelf transport and accumulation of sediment, and preservation of the stratigraphic record in the crenulated clinoforms that characterize large portions of the late Holocene prograding mud wedge in the Apennine shelf. Several specific objectives are being pursued: (1) identify the principal transport mechanisms acting in the topset and foreset region of a crenulated clinoform, (2) determine if, at present, seabed crenulations can be created and/or maintained by a specific sediment transport process, (3) provide information on the relative importance of gravity-driven flows versus current-driven sediment transport in the formation of clinoforms along the Apennine shelf, and (4) evaluate the role of internal waves in transporting sediment and inducing the formation of crenulated clinoforms.

APPROACH

The proposed approach consisted in measuring sediment transport process across a crenulated clinoform by means of deployments of a boundary-layer tripod in 20 m water depth and a mooring in 50 m water depth, off the Pescara River mouth. Another tripod provided by Dr. Andrea Ogston (U. of Washington) was deployed in the topset region of the crenulated clinoform in 12-m water depth. The boundary-layer tripod was equipped with a pressure sensor, three electromagnetic current meters and three optical backscatter sensors. Additionally, an Aanderaa RCM-9 current meter, equipped with turbidity, pressure, temperature and conductivity sensors was placed at the tripod frame. The mooring line was equipped with two RCM-9 current meters placed at 1 meter above the seabed and at 20-m water depth, in intermediate waters. Thermistors provided by Dr. Dave Cacchione (Coastal & Marine Environments) were mounted on the mooring line at numerous heights above the seabed to asses the presence of internal waves. Observations took place from late October 02 to early May 03 in two consecutive three-month deployments, following the EuroSTRATAFORM timeline plan for the Apennine field study. Instruments were retrieved and re-deployed in early February 03.

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14. ABSTRACT
The long-term goal of this research effort is to improve understanding of sediment transport in a region of crenulated clinoform development on a shelf adjacent to a mountainous coast drained by rivers with episodes of high discharge.

15. SUBJECT TERMS

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WORK COMPLETED

During FY04, data collected during an early phase of this grant was synthesized and research papers were written and submitted for publication. In addition, the results obtained during this study were presented among the scientific community in scientific meetings.

RESULTS

Analyses of sediment transport measurements collected off Pescara during autumn/winter 2002-2003 provided a view of how the western Adriatic clinoform feature may have been formed and is presently maintained, as well as provide an explanation for the generation of the crenulated features found on the foreset of the clinoform. The results obtained during this study support the following conclusions:

1) Sediment-resuspension events in the central Adriatic shelf are associated to the occurrence of Bora and Sirocco storms, during which wave-orbital velocities and current velocities, and hence sediment fluxes, increase considerably. Combined maximum wave-current shear stresses in the shallow topset region (12 m) reached values of 1-3 Pa, mainly induced by waves, and decreased about one order of magnitude close to the clinoform roll-over point (20 m), where maximum values were 0.2-0.4 Pa and shear stress induced by currents alone became as larger as those induced by waves. In the foreset region (50 m) maximum shear stresses were ~0.1 Pa and were mainly induced by currents.

2) Sediment resuspended on the shallower parts of the topset region is transported towards SE, parallel to the bathymetric contours and to the direction of the Western Adriatic Coastal Current (WACC), but close to the clinoform roll-over point and in the foreset region, near-bottom currents have a significant offshore component associated with an intense bottom Ekman transport (Fig. 1). This process is not observed in the shallow topset region because in very shallow waters the role of Coriolis force diminishes, the bottom Ekman spiral cannot be formed and the near-bottom currents become more aligned with the direction of the surface current. As suspended material typically occupies the lower part of the Ekman layer, the depth-integrated sediment transport occurs at an angle with respect to the depth-integrated water flow, favoring the suspended sediment transport from the topset down the foreset region. The across-shelf transport is particularly intense during Bora storms, due to enhanced wave shear stresses causing sediment resuspension and to the strengthening of the WACC. This process contributes to the development and maintenance of the Adriatic clinoform feature, and appears to be the major mechanism in present-day conditions.

3) Near-inertial internal-wave activity associated with storm events also contributes to the offshore transport of suspended sediment across the crenulated clinoform feature. The spatial distribution of the Adriatic seafloor crenulations, the decrease of their wavelength and dimensions in the onshore direction and their long, linear crests, suggest that internal waves may play a major role in the formation and/or maintenance of the Adriatic crenulated clinoforms.

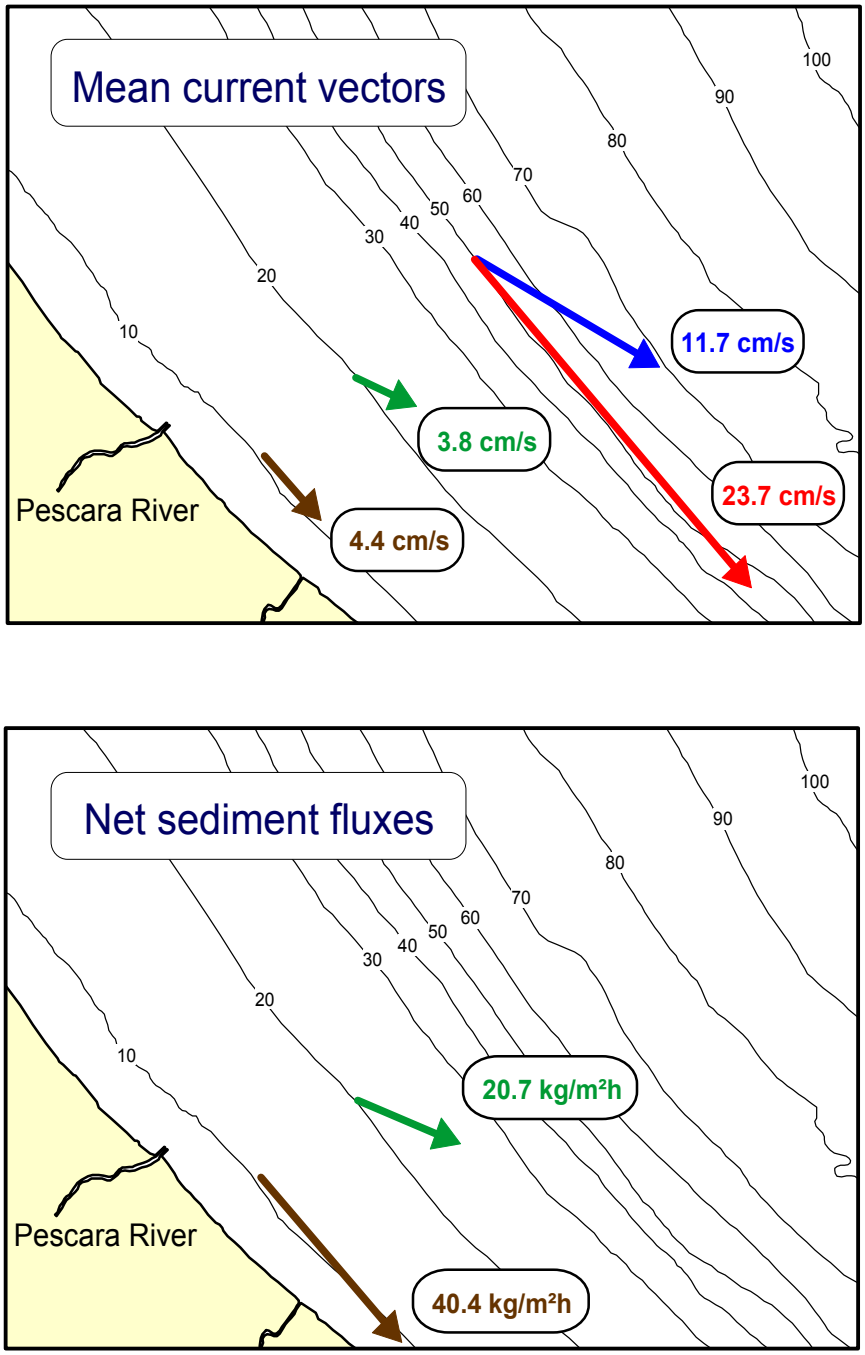

Figure 1. Mean current vectors (A) and net total sediment fluxes (B) during the study period at each instrumented site. Brown, green and blue arrows correspond to near-bottom measurements at 30 cmab (12-m site), 10 cmab (20-m site) and 1 mab (50-m site),respectively, and red arrow corresponds to measurements in mid-waters (30 mab) at the 50-m site. Close to the clinoform roll-over point and in the foreset region near-bottom currents and fluxes veer eastward due to frictional interactions with the seabed and the effect of bottom Ekman transport

IMPACT/APPLICATION

Sea-floor crenulations of complex and uncertain origin characterize large portions of mud-dominated continental slopes and prograding mud wedges around the world. The observed sediment transport processes in the Apennine shelf will provide key insight to understand the formation of crenulations in other continental margins.

TRANSITIONS

This effort will characterize the mechanisms responsible for the transport of sediment across crenulated clinoforms on the western Adriatic prograding mud wedge. Additionally, the data collected is being used for the interpretation of the sedimentary record on these crenulated fields, to characterize the Adriatic coastal current under different forcing regimes and to validate physical oceanographic and sediment transport models.

RELATED PROJECTS

EU-EuroSTRATAFORM (http://www.soc.soton.ac.uk/CHD/EUROSTRATAFORM/index.html). In addition, this observational effort will be a joint effort with other ONR funded researchers, Dr. Andrea Ogston (UW), Dr. Dave Cacchione (CME) and Dr. Charles Nittrouer (UW), as well as personnel at the Instituto di Geologia Marina (CNR) in Bologna, Italy (Dr. Fabio Trincardi and Dr. Antonio Cattaneo).

PUBLICATIONS

Printed

Puig, P., Ogston, A.S., Guillén, J., Fain, A., Palanques, A., submitted. Sediment transport processes from the topset to the foreset of a crenulated clinoform (Adriatic Sea). *Continental Shelf Research*

Cattaneo, A., Trincardi, F., Asioli, A., Puig, P., about to be submitted. Clinoformation on Mediterranean Margins. *Oceanography*

Abstracts

Puig, P., Guillén, J., Palanques, A., 2003. Sediment transport processes across a crenulated clinoform. *COMDELTA meeting*, Aix en Provence, France.

Puig, P., Guillén, J., Palanques, A., 2003. Sediment transport processes across crenulated clinoforms on the western Adriatic prograding mud wedge. *Eos Transactions AGU,84 (46)*, Fall Meeting Supplement, Abstract OS51D-02, San Francisco, California.

PATENTS

None

HONORS/AWARDS/PRIZES

None