

# Morphological and morfometric analysis of bed forms in the Bonifacio channel (Mediterranean occidental)

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**Abstract** – During the oceanographic cruise, “BOCCHE 2003” (Project: Geologia e geomorfologia terrestre e marina dell’insieme Corsica-Sardegna e della Toscana e applicazioni” PIC- INTERREG III) and “Sardegna 2010” ( Project MAGIC – Protezione Civile Italiana”), *Multibeam, Side Scan Sonar and GeoChirp* data were obtained and samples of superficial sediment have been taken.

The analysis of data highlighted on mobile funds, the presence of complex bedforms associations, typical of continental shelf environment affected by high flow rate currents, both mono or bidirectional. Integrated analysis of sismostratigraphic, Multibeam, Side Scan Sonar and sedimentological data, performed in a GIS environment, allowed to define, the distribution of sedimentary structures and the relative dominant bottom currents. Furthermore, a general circulation pattern of currents that highlights the existence of bottom currents flows westward, opposed to surface flow was assumed.

## I. INTRODUCTION

The Bonifacio Strait have been studied within the Project “Geologia e geomorfologia terrestre e marina dell’insieme Corsica-Sardegna e della Toscana e applicazioni” - PIC- INTERREG III – Italia –Francia - Isole Sardegna – Corsica e Toscana, Asse 3 – Scambi transfrontalieri; Misura 3/1 scambi e cooperazione nel campo della ricerca(Campagna oceanografica “Bocche 2003”); the area was also studied under the MAGIC Project- Marine Geohazard Along Italian Coasts - financed by Italian Civil Protection (Campagna oceanografica “Sardegna 2010”.

Numerous studies in literature refer to interpretation and classification of morphologies on sediments [1], [2], [3], [4], [5] and on their close relationship with speed, direction, persistence of bottom currents flows and availability of sediments [1], [2], [6], [7], [8].

These studies mainly concern areas of the North Atlantic, both continental shelf, characterized by strong tidal range, and continental slope.

Similar morphological associations have been described in the Mediterranean, particularly in the Strait of Messina [9], in the straits between the Cycladic Islands in the Aegean [10], in the Strait of Gibraltar [11], [12]and in the continental shelf in front of the Nile delta [13].

This study proposed a circulation pattern of bottom currents and migration of sediments, through the geomorphological and sedimentological study of the bedforms.

## II. GEOLOGICAL SETTING

The Bonifacio Strait area is within the domain affected by the geodynamic events that characterized the Sardo-Corso block in the context of convergence between the Africa plaque and that of Eurasia, [14], [15], [16], [17], [18]. The oldest lithotypes emerging are attributable to the metamorphic-crystalline paleozoic basement and they are widespread both on the slope of Corsica and on the Sardinian slope [19].Above the acoustic basement, cenozoic carbonate deposits are detected, upper bounded by an erosional surface [20], [21], [22].

The western limit of the Bocche continental shelf is engraved and eroded during the regressive Messinian phases. On this surface of erosion, also observed on Burdigalian deposits, the sedimentary prism of the plio-quaternary succession rests, that closes the observable deposition series on the continental shelf [15], [23]. Holocene and current sediments cover the entire shelf



Fig. 1 – Bonifacio Strait – Study area location.

with variable thicknesses [24].

### III. SEDIMENTARY STRUCTURES

The analysis of acquired geophysical data has allowed to identify longitudinal, transverse and intermediate sedimentary structures compared to the direction of the flow. The dimensional limit of the observed forms, imposed by the methods used for data acquisition and processing, is decimetric; bottom areas apparently smooth, could also contain structures smaller than this dimensional limit such as ripple marks. The areal distribution of the bedforms is shown in fig. 6.

#### 1 - Longitudinal structures- Comet marks

In sonograms, behind the isolated obstacles in relief on the mobile substrate, erosion structures have been observed, interpreted as comet marks [2], [3], they are caused by a unidirectional flow with speed  $>75$  cm/s [25]. The trace of comet marks is depressed compared to the surrounding seabed (fig. 2). The inner part of such structures consists of granulometrically larger materials [26] than those of the surrounding seabeds, in accordance with that observed by [2], [3]. The most significant forms can reach lengths of 1800 m and width of 100 m; they develop at depths greater than 70 m on medium and coarse sands. The obstacles are represented by isolated rocky outcrops, which give rise to single and obvious trace or by sequences of small crests, arranged transversely to the current. They can be detected off the Muccia, along the limits of the depression of P. Falcone's Piana, West of Capo Testa, at the passage between the homonymous Piana and the South Channel (fig. 6).

#### 2 - Great dunes 2-D e 3-D

The dunes are regular and parallel at 2-D profile (2-D large subaqueous dunes, sensu Ashley [5]) have an extension of 500 m to 800 m and with a wavelength of 30-40 m with a moderate relief estimated around the meter. Sometimes, the ridges can bifurcate, complicating the simple 2D morphology, with the tendency to assume geometries, asymmetry and regularity typical of the most complex dunes tend to a 3-D profile.

Big irregular dunes with 3-D profile are characterized by sinuous ridges, rounded and extended on average 450 m; the wavelength ranges from 60 m to 110 m and the wave amplitude, measured in Chirp seismic registrations, is about a meter. The presence of small rocky outcrops does not seem to affect the continuity of the dune fields [26]. Both typologies are indicative of conditions of great availability of sandy sediment and flow velocity of 70-100 cm/s [6], [27], [28]. They are found along the Bonifacio channel, in the depression between the Valle Sospesa mesas and West - Southwest of Capo Testa (fig. 6).

#### 4 - Association of longitudinal structures

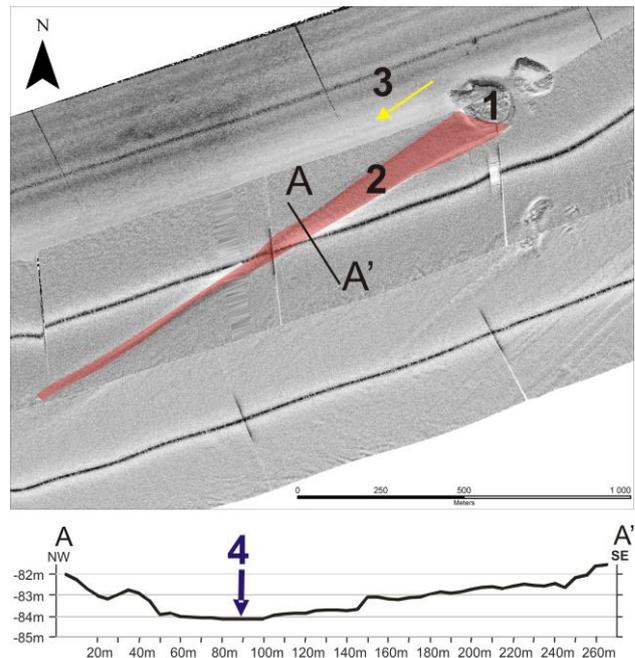


Fig.2 - Side Scan Sonar mosaic 100 Khz, Range 250 m, 3 miles west of Capo Testa (Fig.6); depth -80 m. 1 - Rocky obstacle high on the bottom of about 1,5 m; 2 - Comet marks; 3 - Direction of the bottom current by wavestorm from NE; A-A' cross section at comet marks; 4- Deep erosive depression of about 1 meter to residual coarse materials.

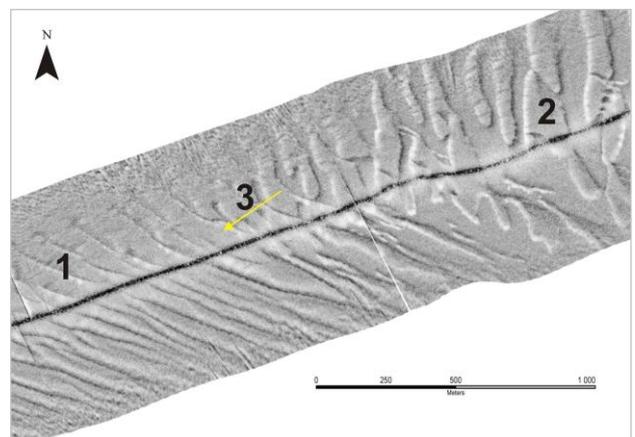


Fig. 3. Side Scan Sonar mosaic 100 Khz, Range 250 m 3,5 miles north of Capo Testa; depth - 65 m. 1 - dunes 2D with bifurcated endstending to evolve into more complex forms; 2 - Dunes 3D; 3 - Direction of the bottom current by wavestorm from NE.

As reported in literature [1], [2] also for the area studied, in association with small comet marks, other types of structures are present; the individual bedforms are difficult to observe separately, because they blend and overlap each other. In the Side Scan Sonar data, where comet marks are better defined and also the obstacle that

originated them. The light bands, slightly sinuous, parallel to each other and not immediately linked to an obstacle, were interpreted as medium sand ribbons, similar to the sand ribbons described by Kenyon[28] in the English Channel, alternating with dark bands, interpreted as residual coarse sediments or outcrops of rock. In the Bonifacio Strait, they are wide between 7 m and 40 m, stretched up to 500 m, in the Northeast - Southwest direction, and develop on sub-flat areas, to a depth between -65 m and -75 m. In presence of rocky outcrops of modest height, interpretable trace like sand shadows have been observed [26], [2], [3]. All these bedforms are generated in unidirectional flow conditions with speed  $>100$  cm/s, [6], [7] and low availability of sandy sediment [2], [3], [28]. This association of longitudinal structures in an area extending East - West; it extends westward within a relatively depressed area, from Plane of Razzoli, on the threshold of the Marmorata and the Plane of P. Falcone and beyond Testa Cape (fig 6).

5 - Transverse structures - Small and medium dunes the wavelength of these structures is about ten meters and their heights have values of tens of meters. These structures are indicative of greater availability of sandy sediment than longitudinal forms and indicate flow velocity of 70-100 cm / s [27], [28]. They are found as dominant forms in marginal sectors compared to the axis of the strait, distributed around the association of longitudinal forms.

#### 6- Sand patches

They appear as an irregular mosaic of shapes, alternately in relief and in depression, lobed and elongated and tend to shrink. Typically the average spacing is around 20 m and the difference in height between the concavities and the highest sectors is about 30 - 40 cm; the asymmetry and regularity of the dunes were not found.

Depressed zones have a strong response to the Side Scan Sonar (dark tones) which is indicative of a substrate consisting of coarse sediments; the finer sediments (light tones) of the relief areas move on it, in accordance with what Kenyon & Stride [27] and Belderson et al [28] observed.

They are indicative of conditions of limited availability of sandy sediment and flow velocity  $< 50$  cm / s [27], [28]. They were observed along the western margin of Bonifacio Mesa in a depression open to the west and just south of the coast of Coarse, on the C. Feno Mesa (Fig. 6).

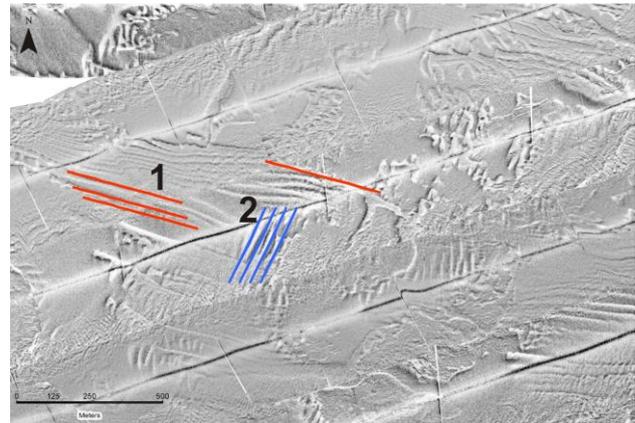


Fig. 4. Side Scan Sonar mosaic 100 Khz, Range 250 m 3,5 miles north of Capo Testa; depth - 65 m. Dunes field 2D where two dunes system diversely oriented can be observed: 1 - Dunes 2D with NW-SE oriented ridges; 2 - Dune 2D oriented to NE-SW.

Table 1. Main morphometric parameters of the bedforms.

type of structure	length min-max (m)	width min-max (m)	sediment type	current speed (m/s) [29]
Comet marks	40-1800	5-100	Medium or coarse sand	$> 0,75$
Dune 3D	400-500	60-100	Coarse sand and gravel	$0,7\div 1,0$
Dune 2D	500-800	30-40	Coarse sand and gravel	$0,7\div 1,0$
Association of longitudinal dunes	100-500	7-40	Medium or coarse sand	$>1$
Sorted Dune	5-12	1-3	Coarse sand and gravel	$0,7\div 1,0$
Sand Patches	===	2-50	Coarse sand and gravel	$< 0,5$

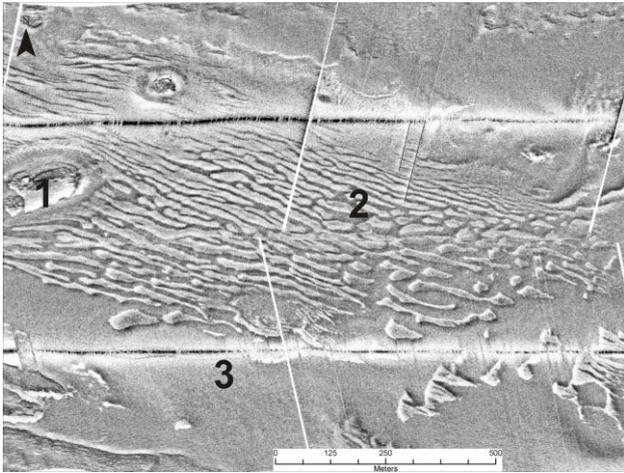


Fig. 5. Side Scan Sonar mosaic 100 Khz, Range 300 m 6,7 miles northwest of Capo Testa; depth - 80 m. 1- Rocky outcrop; 2 - Area with irregular structures, sand patches. 3 - Coarse sand cover and bioclastic gravel.

#### IV. CONCLUSIONS

Through the integrated analysis of sismostratigraphic, ultrasound, and side scan sonar data the distribution of different bedforms facies was mapped identifying two main circulation pattern that overlap in the center of the Bonifacio Strait and they generate hybrid form of interference. The main morphometric parameters of each bedforms were detected, placing them in relation with the relative bottom currents.

This study may also have application aspects related to the dynamics of dispersion of any polluting materials in the seabed of Bonifacio Strait; putting emphasis on existence of an important dynamics of the flows in the seabed, locally in contrast with prevailing superficial flows [30].

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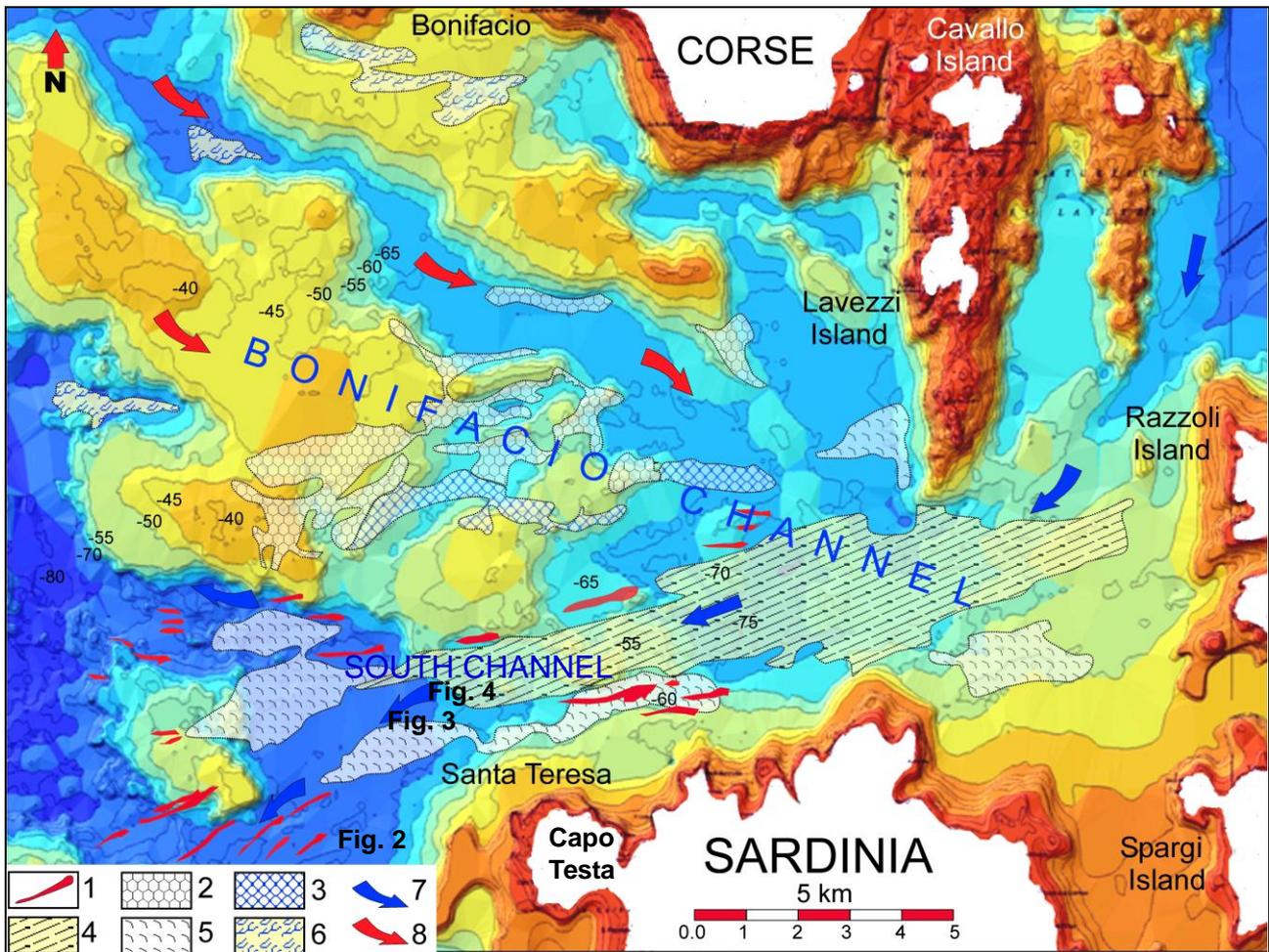


Fig. 6. Distribution of the different bedforms facies present in the Bonifacio Strait ( Italy-Corsica). 1- Bedforms, comet-marks; 2- Dunes 3D; 3 - Dunes 2D; 4 - Longitudinal structures; 5 - Sorted dune; 6 - Sand Pach. 7 - Bottom current by wavestorm from NE; 8 - Bottom current by wavestorm from NW.

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