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Environmental Impact of Artificial Nourishment of the Beaches of Cala Gonone (Central – East Sardinia)

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Abstract

A local project of littoral reconstruction was conducted from the autumn of 1994 to the summer of 1997 on two small sandy beaches near Cala Gonone (Central-East Sardinia) which are subjected to intense erosion phenomena. During this project 80.000 cubic meters of coarse sediments, composed of about 30 % of crushed limestone and the remaining 70% of scattered granite, have been distributed on the beaches, leading to a widening of approximately 10 m. For the following years the research groups of Cagliari and Firenze have systematically monitored the evolution of the emerged and the submerged beach, sampling in many places in order to measure grain size, sphericity and rounding of the sediments, beach and landscape quality was evaluated as well. These data allow to analyse the effects of the nourishment project on the beaches and the behaviour of the two different sediments used for nourishment. Results will be useful for the improvement of the techniques in the future and to contain impact over littorals and landscape, not only on the Sardinian coasts afflicted by coastal erosion, but also in the entire Mediterranean area.

1. INTRODUCTION

The littoral of Cala Gonone (Dorgali, Central-East Sardinia) has been subjected to beach nourishment between fall 1994 and summer 1997, with an interval between spring 1995 and fall 1996. After the first beach nourishment, that ended in spring 1995, several monitoring campaigns have been performed (Pacini et al., 1999; Atzeni, 1999), in order to define the geomorphologic and sedimentological evolution of the beach and to predict its stability, and these studies have continued after the second nourishment that ended in June 1997 (Arba, 2000; Pacini et al., 1999).

During these researches a total of 28 beach profiles have been measured up to a water depth of 4 meters and along these profiles sediment samples have been taken. The beach profiles have then been confronted and their evolution has been analysed. The sediment samples have been subjected to particle-size analysis emphasising on their grain-size evolution and their rounding due to wave motion, comparing them with the analysis performed on the original calcareous and granite sediments coming from nearby quarries and used during the beach nourishment in 1994-1995 (Pacini et al., 1999) and with the data obtained by Arba (2000) on beach sediments sampled in summer 1998 and winter 1999.

In this work the Authors resume the geo-environmental situation of the beaches of Cala Gonone five years after the end of the nourishment project, in order to define the stability of the beaches, the evolution of the sediments and their perceptive characteristics.

The impact on the landscape is particularly interesting for the presence of the granite material that was not present in the original beaches.

2. GEOGRAPHICAL AND GEOLOGICAL SETTING

The coast of Cala Gonone is primarly characterised by the outcropping of limestones, dolomites and basalts, and secondarly of conglomerates and sandy deposits (periglacial Pleistocene *éboulis ordonées*) (De Waele & Pisano, 1997; Ozer & Ulzega, 1980).

The littoral of Cala Gonone, together with most of the eastern coast of the Island, can be defined as a tectonic coast, characterised by high sea cliffs, generally related to main faults, locally interrupted by major streams forming canyons that end in the Sea creating beautiful beaches that, together with the many pocket beaches, represent major tourist attractions, e.g. Cala Fuili and Cala Luna (Arisci et al., 2000).

Together with many other spectacular morphologies, represented by caves, rock arches, beaches and canyons, this littoral is reputed as one of the most beautiful of Sardinia, and Cala Gonone one of the most visited coastal towns of the Island. It is also for this reason that the local communities take the coastal erosion under serious consideration, and since 1995 have made serious efforts in rehabilitating the beaches not only through beach defence systems such as groins and submerged breakwaters but also with beach nourishment.

The beach segments which have been subjected to nourishment are Central Beach (Spiaggia Centrale), Palmasera A, Palmasera B, Sos Dorroles and Abba Meica (Figure 1). All these are small pocket beaches that are naturally fed by the seasonal erosion of the cliffs composed of *éboulis ordonées* and ancient alluvial sediments.

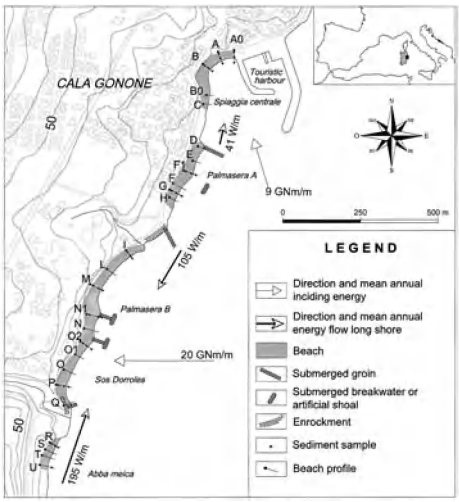

Figure 1: The four beaches of Cala Gonone, the coastal dynamics and defences, the monitoring profiles and the sediment samples.

3. PREVIOUS WORK

Many coastal areas in Sardinia are the subject to erosion due to human intervention (Atzeni et al., 1999; Di Gregorio et al., 1999). The erosion of the sandy beaches near Cala Gonone has become a serious problem already since the early 70's, when sea-storms repeatedly menaced the coastal road of the village (Viale Palmasera). In order to protect the beach, the conglomerate cliff and the road above from erosion, the beach was partially re-constructed and two groins were built at Sos Dorroles A and Palmasera B, but these artefacts did not have the desired effect (Pranzini & Mania, 1988; Arba, 2000).

Another small attempt of beach nourishment and protection was performed in 1988, when 3,000 cubic meters of fine granite sand, taken from the entrance of the Bue Marino Cave, was distributed on the Palmasera beach. But this fine sand was lost in less than one year.

In 1988, a larger project of beach nourishment and protection started. After 6 years of studies and experimenting, 23,000 cubic meters of a mixture of calcareous and granite, mainly coarse, pebbly gravels were distributed between fall 1994 and spring 1995. In the second phase of this project, between fall 1996 and spring 1997, and other 57,000 cubic meters of predominantely weathered granite granules were deposited.

Finally, in 1999, a small amount of the same granite gravel has been deposited at the small beach of Abba Meica (Pacini et al., 1999; Arba, 2000). To prevent erosion and transport of the newly deposited sediments several partially submerged breakwaters and groins, designed as artificial shoals (Figure 1), were constituted with basalt blocks put at a sea-bottom depth of 3-4 meters.

4. GRAIN-SIZE PARAMETERS OF THE BEACH SEDIMENTS

Particle-size analyses have been performed on samples taken on twelve beach profiles on the backshore (a), on the beach face (b) and on the foreshore (c), using an interval of ½ phi and sieves between –3.5 phi (greater than 11 mm–medium pebbles) and 4.5 phi (coarse silt). The sediments are essentially constituted of two grain-size components: gravel (pebbles and granules) and sand (very coarse and coarse).

Where gravel prevails (Ac, A0c, Bc, F1a, Gc, N1b, O2b, Pa, Rb) limestone normally occurs in pebbles while granites compose the granules. Where the coarse component is less abundant (F1b, Ic, Mc, N1a, O2a, Pb, Ra) the sediments are mostly composed of coarse to very coarse granite sands with a limited tail of finer material, also granite.

In the four beaches a general grain-size decrease from North to South is observed; particularly along the profiles A, A0, B, F e G a pebbly and poorly sized beach has formed. In the profiles from I to U (excluding profile P) the backshore beach is composed of coarse sands. Along the beach face the grain size is analogous from A to G, except for profile F1 and from I to U, except for profiles N1, O2 and R.

Comparing these data to the ones of 1998 the beach face sediment samples are very much alike, except for profile O2 which seems to have become coarser in 2002.

On the 12 samples of the beach face the rounding of the pebbles and granules has been estimated using a visual method (Pettijohn et al., 1972). The limestone granules and pebbles have a value of 0.6-0.7 on average, while the granite ones only reach 0.4.

5. THE BEACH EVOLUTION

Monitoring of the beaches has been performed before beach nourishment in 1988 by the Studio Volta which took preliminary control of the beach (in Arba, 2000) and in 1993 by Atzeni (1999). After the end of the nourishment project the monitoring was continued by Atzeni in 1997 (Atzeni, 1999), by Arba in 1999 (Arba, 2000) and by the Authors in 2002 (Figure 2). Monitoring comprised seasonal measurement of the shoreline, the survey of 20 beach profiles, and the sampling of sediments on the backshore, the beach face and the foreshore.

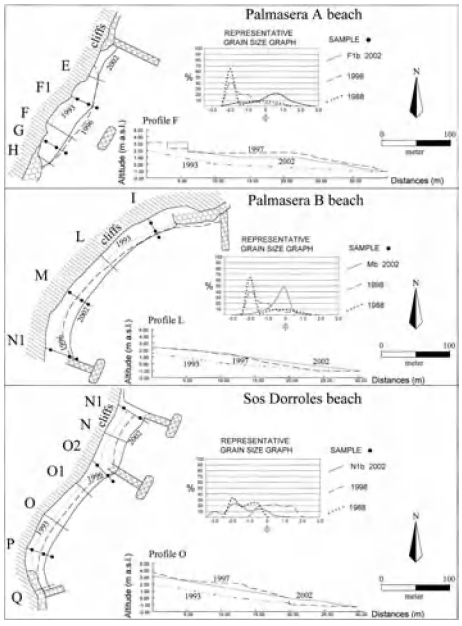

Figure 2: Plan of the beaches (Palmasera A, Palmasera B and Sos Dorroles with shoreline, beach profile and sediment evolution before and after beach nourishment.

These data shaw that the new sediments on all beaches have been redistributed in a more uniform way. Most of the sediment seems to have remained on the beaches demonstrating that the coarseness of the granules, together with the existing coastal defences (groins and breakwaters), have for the moment prevented erosion. Small amounts of the finer granules have been eroded and transported to deeper water, but the main sedimentary body, constituted of coarse and pebbly sediments, is essentially stable, in line with the observations done by the authors in many other pebbly beaches of central-East Sardinia.

The beach profiles also show that the initial slopes have been attenuated considerably, still showing a steep beach face and a sometimes pronounced berm in the central part of the beach.

Only in Palmasera A beach the sediment shows stratification with a succession of pebbly strata with coarse sand layers.

6. CONCLUSIONS

The monitoring data, the sedimentary balance and the grain size analysis show that the four pocket beaches of Cala Gonone have preserved most of the nourishment sediments carried on these beaches in the years 1994-1997, due to the protecting groins and breakwaters, that have nevertheless been partially destroyed by the wave action.

The two types of materials used (weathered granite and limestone) have evolved in a different manner and represent two clearly distinguishable grain size populations, pebbles (limestone) and coarse sands (weathered granite), that are distributed on the beaches according to the prevailing energy fluxes. The limestone granules are relatively well rounded and have slightly diminished in mean diameter, while the granite granules instead are less rounded and have decreased their dimensions significantly due to disintegration of the different mineralogical constituents.

Five years after the end of the nourishment project of the Cala Gonone pocket beaches, it appears that the limestone granules have better resisted wave action than the weathered granite material. The limestone granules have maintained their coarseness and, after seven years of wave action, have become well rounded, and will be identical to the original calcareous material of the beaches after approximately a dozen years. The weathered granite material, instead, has fragmented into single mineral granules, decreasing its grain size considerably and becoming more susceptible to erosion.

Furthermore these quartz and feldspar grains have not rounded very well even after several years of wave action. This weathered pinkish granite sediment is extraneous to the natural environment and, even though its colour could be appreciated, it gives the beaches an "artificial" aspect, putting them outside of the natural local landscape context and differentiating them from all the natural beaches of the Gulf of Orosei, that are characterised by calcareous sediments.

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