Determination of the sediment inputs from the upper shelf towards the beaches and dunes of Maspalomas (Gran Canaria) by foraminifera analysis.

I. Sánchez-Pérez††, I. Alonso† and J. Usera‡
†Dept. of Fisica
Univ. Las Palmas de Gran Canaria
35017 Las Palmas (Spain)
ialonso@dfis.ulpgc.es
‡Dept. of Geologia
University of Valencia
46100 Burjassot, Valencia (Spain)
isora.sanchez@uva.es
usera@uv.es

ABSTRACT

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In this paper the coastal dynamics of the sedimentary system of Maspalomas (Gran Canaria) has been studied by means of micropaleontological tools. To achieve this goal, the analysis of the foraminiferal content in a group of sedimentary samples from 3 different environments was carried out. A total of 19 samples have been studied, 6 of them corresponding to submarine sediments up to 45 meters depth, 10 to beach sediments from the foreshore and 3 to sediments from recent eolian dunes. Results show that the foraminiferal content in submarine samples is much more elevated, both in number of individuals and species, compared to samples from the foreshore and the dunes, which seems to indicate that sedimentary inputs from the upper shelf towards the beach, and from the beach to the dunes are very weak.

ADDITIONAL INDEX WORDS: Coastal erosion, Micropaleontology, Sediment transport, Canary Islands

INTRODUCTION

The southern end of Gran Canaria has a very important sedimentary system called Maspalomas. It has been declared Natural Special Reserve in 1994 and the shoreline of the adjacent beaches has been catalogued as Ecological Sensitivity Area. The natural values of Maspalomas constitute the impulse of the tourist development in this region (Figure 1).

Recent studies in this area reveal that there is an important deficit in the inputs of sand that has produced a significant increase in vegetal cover, which at the same time is responsible of the fixation of dunes. Furthermore, the lack of sediment inputs has originated the expansion of deflation areas, the reduction of the height of the dunes and the withdrawal of the first transverse ridge with regard to the beach line (Hernández et al. 2003).

Several studies have been carried out in Maspalomas mostly referring to the landscape, the ecologic aspects of the Reserve and the socioeconomic issues relative to the development of tourist resorts in the area. Nevertheless, there have been just a few of them relative to the sedimentary aspects of the system. Some of them have been associated with the dune field (Martinez et al., 1986; Hernandez, 2002), while some others are relative to the coastline (Martinez, 1990; Alonso et al., 2001a). All of them have considered the dynamics of the system based on its sedimentology or geomorphology. In this paper we focus on this problem from a very different approach, by means of micropaleontological tools.

The main goal of this paper is contribute to the study of the sedimentary inputs towards Maspalomas dunes by means of the analysis of foraminiferal tests. To carry out this study we have used a series of samples from three different environments i.e. upper shelf, beaches and dunes.

The use of foraminiferal analysis in coastal dynamics processes is a useful tool because foraminiferal shells behave in an equivalent way as any other particle, and therefore, foraminifera can be used as tracers of sediment transport. In this context, they have been used as natural tracers in a wide range of coastal systems (Gaio and Collins, 1995; Aledo et al., 1999; Hippensteel, 1999; Williams, 1999; Leduc et al., 2002).

STUDY AREA

Figure 1. Aerial view of Maspalomas dune field and adjacent beaches looking eastwards. Note tourist resorts at the back.
Sediment inputs at Maspalomas

The dune field of Maspalomas has a total extension of 4 km² and is located at the southern end of Gran Canaria over Quaternary fluvo-marine terraces, which were mostly formed due to the alluvial sediments pulled down by the Fataga valley. The principal beaches surrounding the dune field are El Inglés and Maspalomas beaches, with a total length of 6 km, located both eastward and southward the dune field. Both beaches meet in Punta de la Bajeta (Figure 1).

Sediments on the beaches are mostly coarse and medium sand (ALONSO et al., 2001b), while those from the dunes are medium and fine sand (MARTÍNEZ et al., 1986). According to these authors, nearly 50% of sand from the dunes is composed by carbonate derived from marine organisms, and the rest are minerals and fragments of rocks from terrestrial origin. Sediments from the upper shelf in this area are quite similar, since depending on the area 30-80% is also carbonate from marine organisms (CRIADO et al., 2002).

Gran Canaria, as well as the rest of the Canary Islands, is under the influence of trade winds, which flow steadily from the NNE with quite high velocities since April-May until October. The rest of the year winds are much more variable both in direction and speed (ALCANTARA-CARRIO, 2004). Nevertheless, to the south of the island trade winds change in direction due to refraction processes originated by the island topography. As a result of this change, winds at Maspalomas are mostly from ENE and WSW, being those from ENE the prevailing ones.

Resulting from this wind pattern, the net aeolian sediment transport is towards the WSW, which is also the direction followed by dunes while moving pulled by winds. The dunes move with speeds ranging between 0.8 and 12.3 m/year depending on the area (HERNÁNDEZ, 2002).

With regard to waves, there are no specific studies about the wave climate in the area, but having a look into Puertos del Estado web page (see literature cited), it is clear that prevailing waves are northeasterly seas ($H_s=1-1.5$ m, $T_p=6-9$ s), while the most energetic ones are southwesterly swells ($H_s=2.6$ m, $T_p=11.3$ s, direction $244^\circ$ N) and northeasterly seas ($H_s=2.3$ m, $T_p=6.9$ s, direction $44^\circ$ N).

As a result of this wave pattern, during the last decades the coastline both at El Inglés and Maspalomas beaches has changed the position back and forward around 50 m, but the greatest changes have taken place at Punta de la Bajeta (approx. 300 m). No erosional nor accretional trend has been detected in any case (ALONSO et al., 2001a).

**METHODOLOGY**

An amount of 19 samples from the upper shelf (6), beaches (10) and dunes (3) have been considered in order to analyze its foraminiferal content. In order to get a distribution not only restricted to Maspalomas area, but also considering the most probable source areas, some of the shelf and beach samples were taken eastwards and southwards Maspalomas (Figure 1). Shelf samples were collected by means of a Shipeck grab from a boat. Beach samples were taken from the foreshore by using a hand-held core 15 cm long, while dune samples correspond to the upper 3 cm of the dune surface in order to account for the more recent aeolian transport. All of them were positioned with GPS.

A fixed volume of 3 cm³ per sample was separated and washed through a 63-microns sieve. The remaining dry sediment was floated using CCl4. Foraminifera were picked from the dried float, separated and classified following LOEBLICH & TAPPAN (1987). To carry out the statistical analysis of the data, a cluster
analysis was performed by using NTSYSpc2 program (Rohlf, 2002).

RESULTS

Nearly 3700 individuals were separated and classified into 76 species, 39 of them corresponding to Suborder Rotaliina, 27 to Miliolina, 3 to Textulariina and 7 to Globigerinina (planktonic foraminifera). Nearly 45% of all the identified shells correspond to sample Masp.73. Figure 3 shows three examples of the identified foraminifera.

The number of species and density (individual/cm³) for each sample are indicated in Table 1. Samples with greater foraminiferal content are Masp.73, Masp.67 and Masp.60 corresponding all of them with upper shelf sediments. Sample Masp.73 is the deepest one (45 m water depth) and presents the highest foraminifera density (Table 1). The dominant assemblage in this sample is constituted by Lobatula lobatula (Walker & Jacob), Cibicides refugens Montfort, Quinqueloculina berthelotiana D'Orbigny and Quinqueloculina quadrata Nörvang. Even though sample Masp.67 is poorer in biodiversity and number of foraminifera shells, its dominant assemblage is very similar.

Sample Masp.60 points out due to the presence of Trochammina inflata (Montagu) and Eggerelloides scabrum (Williamson), whose importance will be discussed later. In this sample the dominant assemblage is constituted by Ammonia beccarii (Linné), Asterigerinata mamilla (Willamson) and Q. quadrata.

On the other hand samples Masp.5, Masp.6, Masp.7, Masp.8, Masp.13E, Masp.19, Masp.25 and Masp.26, all of them from beaches and dunes, show very low values or even have no specimens. Referring to beach samples, it has to be pointed out that samples Masp.21 and Masp.23 (collected at Las Burras and El Cochino beaches respectively) show the greater density of foraminifera respect to the rest of beach and dune samples.

In samples from beaches and dunes there are no individuals corresponding to the Suborder Globigerinina, which are present in most of the upper shelf samples (Table 1).

DISCUSSION

In general, there is a significant gradient both in number of individuals and diversity (number of species) among the different environments the samples were collected from. Upper shelf samples shows the greatest contents in both indicators, while those from dunes present the lowest values both in number of individuals and number of species. Beach samples are in between previous groups (Figure 4).

The degree of relationship between different samples has been considered by means of a quantitative cluster analysis (Figure 5), which has been performed using the Manhattan Distance. Specific details are described in the following paragraphs.

Upper Shelf Samples

Even though sediments could have been reworked from adjacent areas due to dynamic processes, there is a quite clear relationship between water depth and the quantity and diversity of foraminifera in the samples. In this sense, the deepest sample (Masp.73) has the highest values in density of individuals and number of species, while the shallowest samples are the poorer ones (Table 1).

On the other hand, it has to be noted the amount of planktonic foraminifera in the samples. Once more the deepest sample shows the greatest number on planktonics, which is due to the necessity of these organisms of a significant water column to live in (Hemleben, et al., 1989; Arnold and Parker, 1999). In the study area, and considering the low number of upper shelf samples, it seems that there is a minimum water column of 12-15 m to find planktonics.

Table 1. Samples location and results of the foraminiferal analysis. (*) The number of species and individuals corresponding to planktonic foraminifera is shown in brackets.

<table>
<thead>
<tr>
<th>Sample Id.</th>
<th>Latitude (UTM)</th>
<th>Longitude (UTM)</th>
<th>Location (depth)</th>
<th>No. Species (*)</th>
<th>Density (*) (indiv/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Masp.13</td>
<td>458941</td>
<td>3078471</td>
<td>Upper shelf (17 m)</td>
<td>30 (3)</td>
<td>77 (3.3)</td>
</tr>
<tr>
<td>Masp.40</td>
<td>446409</td>
<td>3071658</td>
<td>Upper shelf (12 m)</td>
<td>22</td>
<td>34.6</td>
</tr>
<tr>
<td>Masp.50</td>
<td>450551</td>
<td>3073918</td>
<td>Upper shelf (11 m)</td>
<td>18</td>
<td>30</td>
</tr>
<tr>
<td>Masp.60</td>
<td>440744</td>
<td>3066306</td>
<td>Upper shelf (22 m)</td>
<td>27 (3)</td>
<td>252 (8)</td>
</tr>
<tr>
<td>Masp.67</td>
<td>444788</td>
<td>3070250</td>
<td>Upper shelf (16 m)</td>
<td>26 (3)</td>
<td>133.6 (8.3)</td>
</tr>
<tr>
<td>Masp.73</td>
<td>441476</td>
<td>3067475</td>
<td>Upper shelf (45 m)</td>
<td>54 (5)</td>
<td>560.3 (74)</td>
</tr>
<tr>
<td>Masp.26</td>
<td>447928</td>
<td>3072496</td>
<td>El Aguila Beach</td>
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<td>0.33</td>
</tr>
<tr>
<td>Masp.25</td>
<td>446897</td>
<td>3071890</td>
<td>San Agustín Beach</td>
<td>9</td>
<td>4.6</td>
</tr>
<tr>
<td>Masp.23</td>
<td>445781</td>
<td>3071501</td>
<td>Las Burras Beach</td>
<td>18</td>
<td>51.33</td>
</tr>
<tr>
<td>Masp.21</td>
<td>444903</td>
<td>3071098</td>
<td>El Cochino Beach</td>
<td>26</td>
<td>55.66</td>
</tr>
<tr>
<td>Masp.20</td>
<td>444245</td>
<td>3070402</td>
<td>El Inglés Beach</td>
<td>15 (1)</td>
<td>20 (0.3)</td>
</tr>
<tr>
<td>Masp.18</td>
<td>444035</td>
<td>3069544</td>
<td>El Inglés Beach</td>
<td>18</td>
<td>17.66</td>
</tr>
<tr>
<td>Masp.5</td>
<td>443943</td>
<td>3068589</td>
<td>Punta de La Bajeta</td>
<td>2</td>
<td>0.66</td>
</tr>
<tr>
<td>Masp.6</td>
<td>443467</td>
<td>3068144</td>
<td>Punta de La Bajeta</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Masp.8</td>
<td>442390</td>
<td>3068019</td>
<td>Maspalomas Beach</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Masp.15</td>
<td>441452</td>
<td>3068037</td>
<td>Maspalomas Beach</td>
<td>11</td>
<td>7.3</td>
</tr>
<tr>
<td>Masp.19</td>
<td>443955</td>
<td>306934</td>
<td>Dune</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Masp.7</td>
<td>443003</td>
<td>3068087</td>
<td>Dune</td>
<td>1</td>
<td>0.3</td>
</tr>
<tr>
<td>Masp.13E</td>
<td>441636</td>
<td>3068274</td>
<td>Dune</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Sediment inputs at Maspalomas

Regarding specific samples, in Masp.67 and Masp.73 the some of the dominating species are *L. lobatula* and *C. refugens*. Both species are cosmopolitan ones, living in areas characterized by strong bottom currents and lateral organic matter transport (Mackensen et al., 2000). Both samples are located in front of Maspalomas beach where there are no foraminifera, indicating that there is no on-shore transport towards this beach.

Masp.60 sample, in front of El Ingles beach, is one of the keys in this study. According to Martínez et al. (1990) and Hernández (2002), El Ingles beach is the area where sediment inputs towards the dune system takes place. Therefore, the decrease of sedimentary inputs would represent a serious threat for the survival of all the system.

This sample has foraminifera shells corresponding to the Suborder Textulariina. It has to be noted the presence of *T. infrata* and *E. scabrum*, which have only been found in this sample. These species are very fragile and would not resist an intense transport. In our case, these shells are very well preserved, which clearly indicates that this is a low energy environment and that these are *in situ* individuals, so that they have not been transported from other places. The idea that this is a low energy environment is reinforced due to the small amount of *L. lobatula* and *C. refugens*.

Samples Masp.13, Masp.40 and Masp.50, located eastwards Maspalomas area, are quite similar between them in its foraminiferal content, as it can be observed in the cluster analysis (Figure 5). This similarity seems to be due to the similar orientation, shallow water depth and dynamic factors affecting them.

Beach Samples

There is a quite significant variability in the foraminiferal content of samples collected on the shoreline, since there are samples such as Masp.21 and Masp.23 with relatively high values of density and diversity, and samples like Masp.6 and Masp.8 where no shells were found. Reasons for these changes are mostly related to the dynamic characteristics of the sampling site.

Samples Masp.21 and Masp.23 where collected at El Cochino and Las Burras beaches, being both places sheltered by groins. These structures contribute to the accumulation of sand size particles, especially those of lower density such us foraminifera. Similarity between these samples is clearly recognised in the cluster analysis.

The low number of individuals in samples Masp.25 and Masp.26 indicates that these beaches do not receive sediments from the adjacent shelf (samples Masp.40 and Masp.50).

Regarding El Inglés - Maspalomas beaches, there is a clear NE SW gradient. As it was discussed before, there is a significant amount of foraminifera shells in the upper shelf samples located opposite both beaches. Nevertheless, there are individuals in samples collected at El Inglés beach (samples Masp. 18 and Masp.20), while on the contrary, samples collected at Punta de la Bajeta and Maspalomas beach (Masp.5, Masp.6 and Masp.8) have nearly no shells. This opposite pattern indicates the arrival of shelf
Figure 5. Cluster analysis using the foramiferal content of the different samples.

Figure 5. Cluster analysis using the foramiferal content of the different samples.

sediments at El Inglés beach, while there is no net on-shore transport at Maspalomas beach.

The presence of foraminifera shells in sample Masp.15 is probably related to the presence of alluvial boulders in this area, which promotes the accumulation of sediments.

Dune Samples

Results from dune samples show that some foraminifera have been found in sample Masp.19, collected in the former dunes close to El Inglés beach. This fact confirms the supply of sediments from this beach towards the dune field, as it has been stated by HERNANDEZ (2002) among others. On the other hand, samples collected in the southern dunes, close to Maspalomas beach (samples Masp.13E and Masp.7), have nearly no foraminifera shells. This result perfectly agrees with results from Maspalomas beach samples, where no individuals were found.

In addition, the aeolian sediment transport across the dunes is not very efficient, since sediments from the former dunes near El Inglés beach do not reach the dunes close to Maspalomas beach, 2-3 km away. Nevertheless, the difference between samples from both beaches could also be explained considering taphonomic processes, since foraminifera shells may be abraded, broken and eventually vanish off during this transport.

Dynamic implications

One of the hypotheses of HERNANDEZ (2002) to explain the deficit of sediment inputs in the dune field is the sediment transport decrease from El Inglés beach, which seems to be due to the scarcity of sediments in the upper shelf.

Previously exposed data corresponding to samples Masp.73, Masp. 67 and Masp.60, as well as results from CRÍADO et al. (2002) indicate that there are submerged sediments in the area. Furthermore, oceanographic conditions in front of El Inglés beach are good enough to accumulate sediments, which has been deduced from the presence of *T. inflata* and *E. scabrum*.

Nevertheless there is no disagreement between our results and HERNANDEZ (2002) hypothesis, since this author points out to a reduction of the submarine sand bank, but no to the total absence of sediments in the area. Obviously there are sediments in the upper shelf nowadays, and some of them are even being produced in recent times, but the on-shore transport towards El Inglés beach is much weaker than it was before. Assuming that the output of sediments from the dune field towards Maspalomas beach is in the same order as it used to be, results in an important sedimentary deficit in the dunes. Reasons that could explain the weakness of the net on-shore transport could be related to man made structures such as the groins adjacent to El Cochino and Las Burras beaches, as well as to natural phenomena (sea level rise, change in coastal currents, etc.) to which the effects of these structures would be added.

The presence of foraminifera in beaches and dunes is obviously conditioned by the existence of these materials in the upper shelf. Nevertheless, its presence in the shelf does not imply that they will be found the emerged environments, since there is a number of both dynamic and taphonomic processes that could determine that foraminifera shells will not reach them.

It has to be noted that currents along Maspalomas beach are mainly in the alongshore direction, both eastwards and westwards depending on dominant oceanographic conditions. On the other hand, at El Inglés beach coastal currents are determined by incident eastern waves, which determine a net cross-shore and alongshore transport, the latter one in the southward direction.

The practical absence of planktonic foraminifera in all the beach and dune samples, which agrees with Alonso et al., (2005) data from Fuerteventura Island, indicates that there is not an actual onshore transport from the deeper areas.
CONCLUSIONS

This work confirms the goodness of foraminiferal analysis in coastal dynamic studies, since it allows a better understanding of the sedimentary system after considering the upper shelf, beach and dune environments integrated as a whole.

Upper shelf samples show significant differences both in number of individuals and species depending on location and depth, as well as on the amount of planktonic individuals, which only have been found in the deeper samples.

Foraminiferal data of samples from El Inglés and Maspalomas beaches, as well as from adjacent dunes and submerged areas, points out different dynamic aspects: i) The upper shelf in front of Maspalomas beach has great number of L. lobatula and C. refugens, which indicates that this is an environment with strong bottom currents. ii) The presence of well preserved shells of T. inflata and E. scabrum, as well as the small amount of L. lobatula and C. refugens indicates very weak bottom currents in the shelf area opposite to El Inglés beach. iii) At Maspalomas beach there are no foraminifa, indicating that there is no on-shore transport towards this beach. iv) The low density of foraminifera in samples at El Inglés beach are due to prevailing eastern waves, which move the sediments from the adjacent shelf towards this beach, and v) It has been confirmed sedimentary inputs from El Inglés beach towards adjacent dunes.

On the other hand, samples of beaches protected by groins show a much higher values of foraminifera shells and diversity than any other beach sample, which is related to the sedimentary accumulation induced by these structures.

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