NATURE AND DISTRIBUTION OF THE SAND FRACTION COMPONENTS IN THE CADIZ BAY BOTTOMS (SW-SPAIN)

M. Achab [1] and J.M.Gutiérrez Mas [2]

[1] *Département de Géomorphologie et de Cartographie, Institut Scientifique-Agdal, Université Mohamed V, BP 703, Rabat-Maroc. achab@israbat.ac.ma*

[2] *Departamento de Geología Marina y Litoral, Facultad de Ciencias del Mar, Universidad de Cádiz, Apartado 40, 11510 Puerto Real (Cádiz). josemanuel.gutierrez@uca.es*

Resumen: Se analizan el contenido y distribución de los componentes terrígenos y bioclásticos presentes en la fracción arena de los sedimentos recientes de la bahía de Cádiz. Se han establecido sus relaciones y variaciones con las diferentes fracciones granulométricas. Los componentes de origen terrigeno presentan contenidos medios de 70%. El cuarzo es el mineral más importante con valores de 62%, y tiende a acumularse en las fracciones más finas, mientras que las fracciones gruesas están compuestas por componentes bioclásticos. La glauconita es el mineral autigénico más representativo en la fraccion arena, es de color verde oscuro. A pesar de su carácter siliciclástico, los sedimentos presentan un contenido medio de carbonatos del 23%, su origen es fundamentalmente biogénico. Los moluscos son los componentes mayoritarios, muestran un elevado estado de fragmentación. Su contenido disminuye en las fracciones finas donde son sustituidos por el cuarzo. Los foraminíferos presentan un buen estado de conservación, cuyos caparazones aparecen rellenos de glauconita. La presencia y la naturaleza de estos componentes está relacionada con la naturaleza petrográfica de las áreas fuentes, así como de las condiciones de erosión que afectan a los bajos rocosos y acantilados costeros presentes en la zona de estudio. Otro factor de control se relaciona con el comportamiento hidrodinámico de cada componente durante el proceso de transporte y depósito.

Palabras claves: Bahía de Cádiz, fracción arena, análisis morfoscópico, terrígenos, bioclastos.

Abstract: The content and distribution of the terrigenous and biogenic component in the sand fraction of Cádiz bay sediments were analysed. Their relation and variation with the grain size fraction were determined. The components of terrigenous origin represent an average content of 70%. The most important mineral is the quartz with 62%, and trends to accumulate in the finer sizes fraction, while the coarsest sub-fractions, are composed mainly by bioclastics components. The glauconite is the authigenic components more represented in the sand fraction, and appear in dark green colour. In spite of their siliciclastic character, the sediments show an average content of carbonates of the 23%, their origin is fundamentally biogenic. The mollusks are the majority components; its content diminishes in the finest subfractions where they are replaced by the quartz. The foraminifera display generally a good state of conservation, the test is of calcite and sometimes they appear fillers of glauconite. The presence and the nature of these components were found to be related to the petrographic nature of source area and to the condition of erosion affecting to rocky shoals and plioquaternary coastal cliffs present in the study area. Other control factor is related to the hydrodynamic behaviour of each component during the transport and deposit processes.

Key words: Cádiz bay, sand fraction, morphoscopic analysis, terrigenous, bioclasts.

Achab, M. and Gutiérrez Mas, J.M. (2005): Nature and distribution of the sand fraction components in the Cadiz Bay bottoms (SW-Spain). *Revista de la Sociedad Geológica de España*, 18 (3-4): 133-143

The grain size and morphoscopic analysis of the sand fraction are of great hydrodynamic and sedimentary interest. They allow the constitution of concepts relative to alteration, transport and deposit of the detrital sedimentary particles (Galloway and Hobday, 1983; Mack and Leislikow, 1996). Sediments in the littoral zone may be composed of any material that is available in significant quantities and is of suitable grain size to remain on the beach. Thereafter the sediments are selectively transported by wave and tidal action to the adjacent marine environment (Chamley, 1988; Komar, 1996). The composition therefore closely reflects various sources and their relative importance. The sand fraction components can be classified in two types based upon their source and composition (Watson, 1971):

- The terrigenous components indicate continental origin; derive from non-living sources and pre-existing rocks through weathering and erosion processes. They are deposited by processes essentially mechanics. The common components are minerals and fragments of rocks resisting to the chemical weathering. Most of terrigenous sediments especially in the temperate zone are composed principally of quartz and feldspar grain derived from the weathering of quartzitic rocks that are abundant on the sources area (Clemens and Komar, 1988; Paskoff, 1985). In addition to the quartz grains, the terrigenous components generally also contain small amounts of heavy minerals. The specific heavy minerals present in the sand fraction of sediments reflect the types of rocks from which they are derived (Komar, 1998).

- The biogenic components correspond to rigid structures or to skeletal remains of plants and animals marine organisms. They are also called organic or biological components, because they come from the remains of organisms, which were once alive. Most biogenic components are composed of fragments or entire organism of molluscs (bivalves, gastropods, etc.), and foraminifera (Moberly *et al*., 1965). They also include other resistant biological fragments, such as echinoids and sponge spicules. The biogenic components are important in zone where biologic productivity is high and chemical weathering of the inland rocks tends to be intense (Watson, 1971). In most cases, the remains of these organisms are broken in to small fragments and accumulated in the sediment by wave action. The carbonate grains, especially shell fragments, are constituted by aragonitic and calcitic layers, with predominance of the first one (Leeder, 1982) that is transformed easily into calcite (Rehman *et al.,* 1994). These biogenic fragments are generally large in comparison with quartz grains, so they may be selectively transported and concentrated in the coarser-grained sediments by selective-sorting processes (Giles and Pilkey, 1965).

The study of these components allows to establish the characteristics and nature of the sediments, and types of sources areas (Melguen, 1974). In addition, the presence of some components and the relationship between them is very useful for the characterization of the sedimentary facies (Giro *et al*., 1984). In this work, we analyse the content and the distribution of biogenic and terrigenous components present in the sand fraction of Cádiz bay recent sediments. The purpose of this study is to recognise their nature, behaviour in the marine environment and their relationship with the granulometrics and hydrodynamics characteristics dominant in the study area.

Characteristics of the study area

The Cádiz bay is located in the southwest Iberian Peninsula (36° 3'N and 6° 10'W) (Fig. 1). From the geomorphologic point of view, the Cádiz bay can be defined as a mixed morphodynamics system constituted by a wide bay to the north (external bay), well connected to the continental shelf, and very affected by the action of surge (waves) and currents. A barrier-island-lagoon system to the South (inner bay); protected of the west and Southwest storms. An intertidal system of salt marshes to the south and Southeast, drained by complex system of tidal creeks.

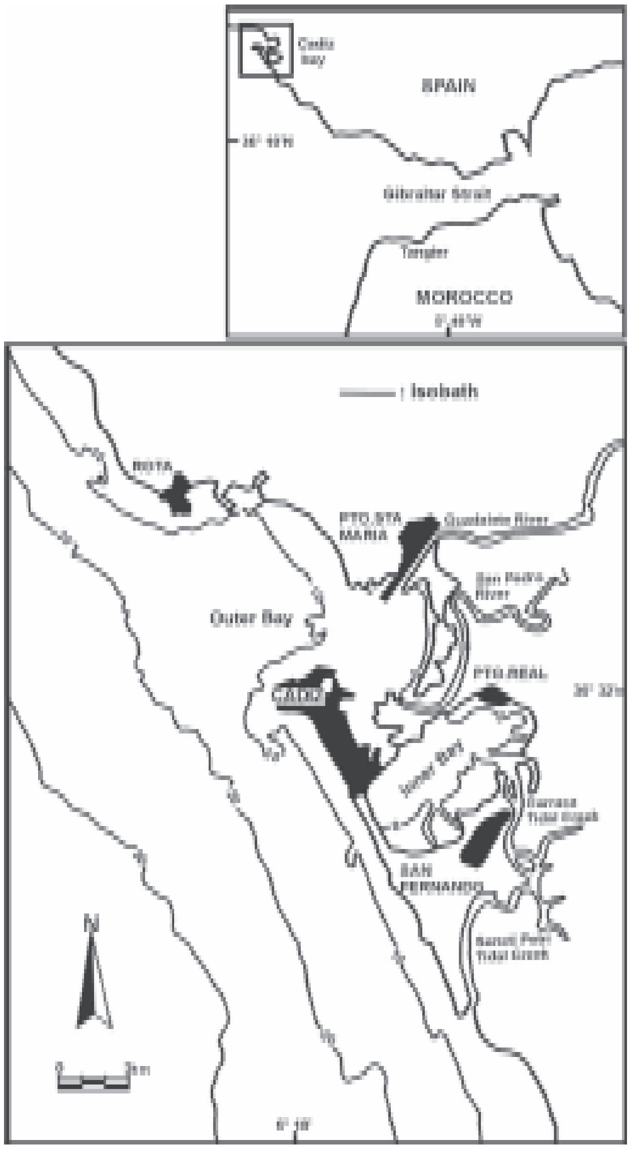

Figure 1.- Geographic situation of the study zone.

The coastal morphology of Cádiz bay is oriented from north-north-west to south-south-east, with east-west sectors, having a stepped aspect because of old and recent fractures (Baldy *et al*., 1977; Sanz de Galdeano, 1990). These are manifested by several systems of recent fault and diaclase, affecting so much to continental domain as marine bottoms (Fig. 2) (Gracia *et al*., 1999; Gutiérrez-Mas *et al*., 2003). The influence of tectonic structure and morphology of the coast, constitute an essential factor in the hydrodynamic control of the sedimentation and distribution of the facies in the Cádiz bay (Parrado *et al*., 1996; Achab *et al*., 1999b; Gutiérrez-Mas *et al*., 1999).

The tidal regime is mesomareal, with average amplitude of 2.18 m and maximal of 3.7 m. Wind and waves are essential factors of sedimentary dynamics. Western winds are the most frequent blowing with

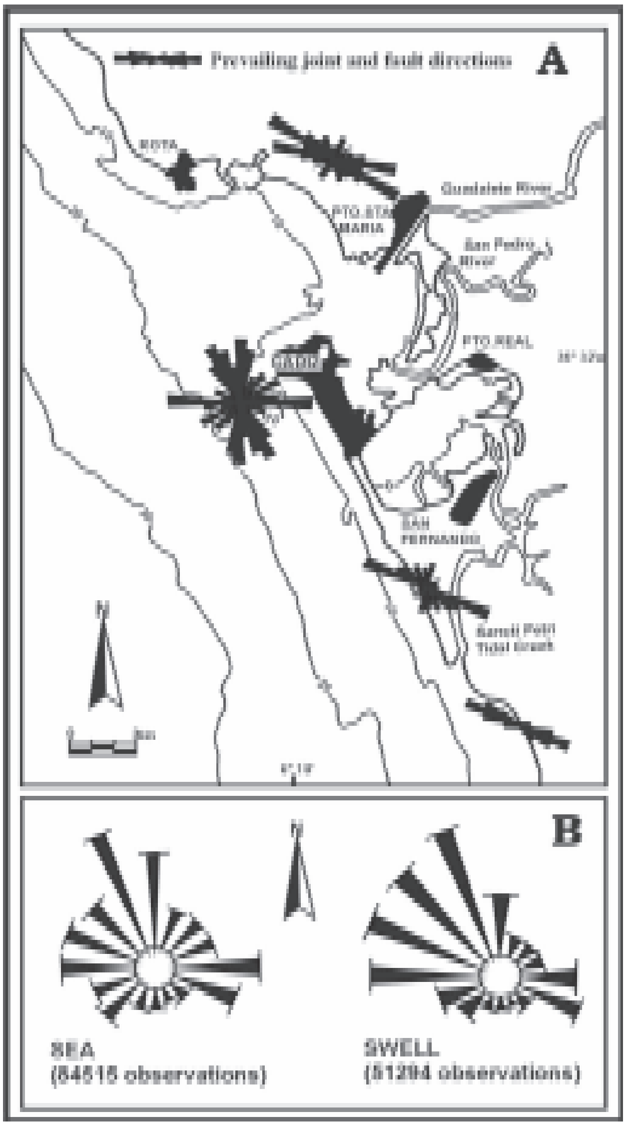

Figure 2.- **A)** Prevailing joint directions affecting plio-quternary and pleistocene units outcroping in the coastal zone, **B)** Circular diagram of Sea and Swell waves in Cadiz bay.

13.6% of average frequency. Eastern winds are also important with a frequency of 12.3% (Ramos, 1991). The Sea wave (mean frequency of 6.96%) presents a relative predominance of east component, while for the Swell wave (10.26%) dominates the west component (Fig. 2). The longshore currents are controlled essentially by NW surge, generating currents toward the SE, whereas the surge of SW makes it toward the North.

The geologic materials that constitute most of the bay, as much emerged as submerged, are fundamentally of sedimentary origin and plio-quaternary age (Fig. 3), being constituted by clay, marls, sands, sandstone and some limestone and conglomerate levels (ostionera rock). Other materials present in their surroundings are the calcarenites of the upper Miocene and the marls and gypsum of the Triasic. Upon all these materials, are others more recent and of quaternary age, constituted by muddy marshes, beach sands and continental

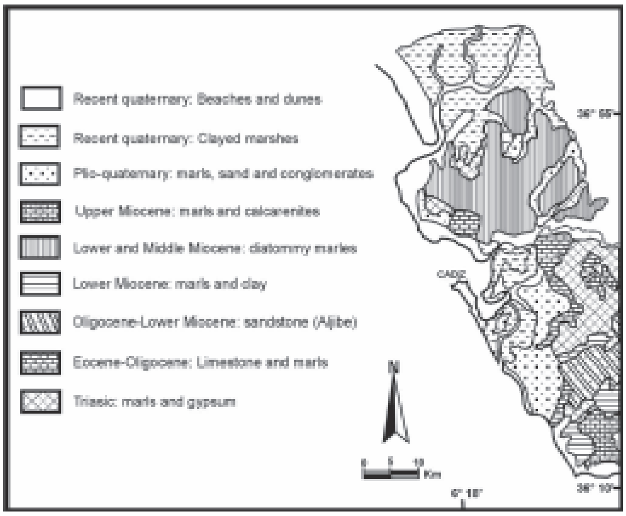

Figure 3.- Geologic map of Cádiz bay.

deposits (Zazo *et al*., 1983, Dabrio *et al*., 2000 and Achab, 2000).

Material and methods

The study of the sand fraction components has been carried out on 70 samples of seabed sediments of Cádiz bay, collected with a Van Veen drag and GPS positioning (Fig. 4). The granulometrics analysis consisted on the humid separation of the coarse and fine fractions using a sieve of 0.063mm (4 phi), the coarser material (sand and gravel) was dry-sieved during 15 minutes

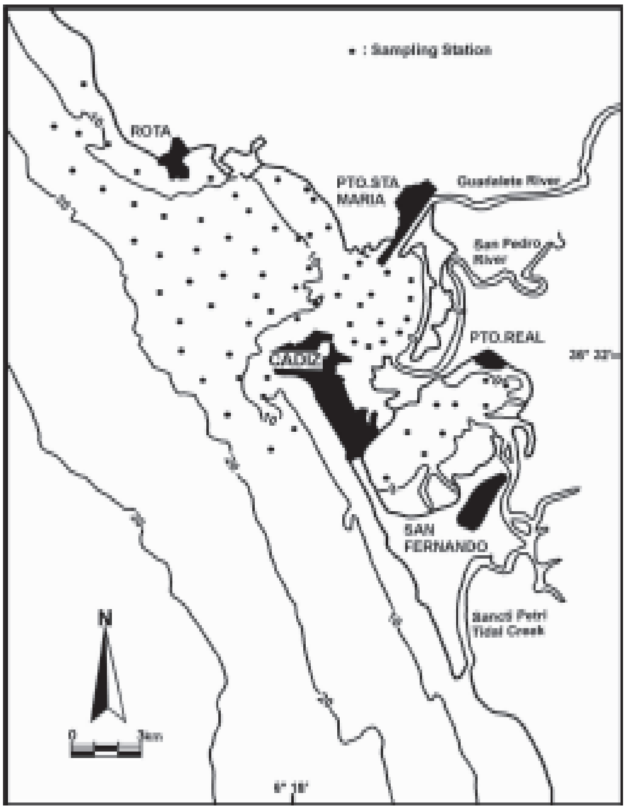

Figure 4.- Location of the sampling stations.

The microscopic analysis was made by means of observations with binocular loupe (x40) at each interval of the sand fraction, because each dynamics agent has the capacity to act on one or two fractions (Cailleux and Tricart, 1963). The main components of the sand fraction determined were quartz, shell, foraminifera, rock fragments and others (Folk, 1968).The recount of the components present in each fraction was made approximately in 500 grains on milimetric paper.

The statistical processing of data was carried out using the BMDP program. Multivariate Factorial Analysis was used to know the relations between components and measured variables, as well as between the individual samples. The association of sand fraction components obtained are based on those variables showing the highest scores in each factor; the factor scores represents the weight or influence of each variable and components within the corresponding factor (Reyment and Jöreskog, 1993).

Results

Sedimentary facies distribution

In Cádiz bay bottoms, the grain size distribution shows an enrichment of fine fractions, toward the more sheltered and internal zones of the bay. While the coarse fractions, appear in external zones, more opened to the sea and exposed to surge, swell and currents action (Fig. 5).

Figure 5.- Distribution of granulometric facies in the Cadiz bay bottoms.

Considering the relationships between grain size sediment and different environment of deposit, we can divide the area in two differentiated sectors (Achab *et al.,* 1999b): In the outer bay, the sand is the dominant fraction especially in the littoral zone, while the gravel appears near rocky shoals. The muddy-sand sediments occupy the central and oriental part of external bay. These sediments are oriented as a band that connects the internal bay with the mouth of the Guadalete River. They are prolonged until the inner continental shelf, where they reach depths between 20 and 30 m, being configured in two bands, one by the north margin of the bay and another one more to the South, bordering the city of Cadiz (Fig. 5). In the inner bay, mud and sandy-mud predominate, agrees with control factors of sedimentary processes present in this sheltered zone.

Terrigenous components

In the sand fraction, the components of terrigenous origin represent an average content of 75% (Table I), reaching concentrations superior to 80% in areas of the western external bay, especially in sandy bottoms (Fig. 6). The average concentrations (50-70%) occur in muddy bottoms of the inner bay and in areas of the oriental external bay among others. The lowest concentration (<50%), appear to the North margin of the bay in form of band oriented towards NW. These low contents are also given in the inner bay, near to Puerto Real city in bottoms where bioclastics facies predominate (Fig. 6).

PARAMETERS / COMPONENTS	MEAN VALUE	STANDARD DEVIATION	MAXIMUM VALUE (%)	MINIMUM VALUE (%)
Terrigenous	75	12	89	20
Quartz	63	14	85	17
Glauconite	<5	<5	10	<5
Mica	<5	<5	5	<5
Rock fragments	<5	<5	17	<5
Biogenic	23	12	79	10
Planktonic Fora	<5	<5	5	<5
Benthic Fora	<5	<5	6	<5
Ostracods	<5	<5	<5	<5
Bryozoans	<5	<5	<5	<5
Sponge Spicules	<5	<5	<5	<5
Echinoids	<5	<5	<5	<5
Mollusks	15	13	75	<5
Others	14	8	35	<5

Table I.- Statistical data of terrigenous and biogenic components of the sand fraction.

The majority mineral is the quartz with average contents of 63% (Table I), and reaching until 75% in the littoral and sub-littoral zone. It correlates positively with the total of terrigenos components (0.87) and negatively with gravel (-0.5), molluscs (-0.7) and rock fragments (-0.52). The quartz trends to accumulate in the finest sizes of the sand fraction, while the coarsest

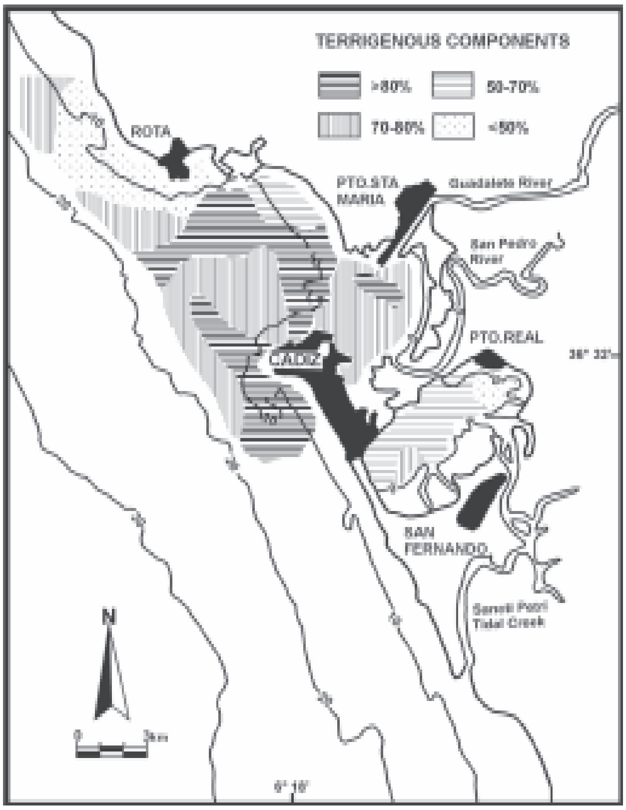

Figure 6.- Distribution of terrigenous components in the sand fraction.

sub-fractions, are composed mainly by bioclastics components (Fig. 7). According to the scale of Powers (Powers, 1953), three types of quartz grains have been differentiated (Table II): angular grains (49%), sub-rounded grains (48%) and rounded grains (5%). The two last morphologies tend to appear in the coarsest sizes of the sand fraction, whereas the angular ones prevail in the finest fractions (Achab and Gutierrez-Mas, 2002). The results of other morphologic properties considered in quartz grains, indicate that grains of high sphericity are also rounded, whereas the angular and sub-rounded ones display in general low sphericity. On the other hand, the sub-rounded grains tend to present dull/mat texture/aspect, whereas the shining ones are related to angular quartz grains.

Other terrigenous components are the mica and the rock fragments. The first one is not very abundant, with average contents <1%. It is concentrated in the finest sub-fractions and practically absent in coarsest ones (Fig. 7). The rock fragments corresponds to small cobble rocks grains of very diverse nature and lithology. Mainly fragments of «*Ostionera rock*» of plio-quaternary age come from the erosion of rocky bottoms and coastal cliffs. They are also present small rolled cobbles of quartzite and sandstone fragments. The rock fragments appear in very low amounts with average contents of 1% and maximums of up to 17% near to rocky bottoms, where they form part of the

PARAMETERS	Mean Value	Standard Deviation	Maximum Value	Minimum Value
Angular qtz	49	19.3	78.7	<5
Sub-rounded qtz	48	17.5	90	20.3
Rounded qtz	<5	5.3	29.4	0
Low sphericity qtz	97	2.2	100	91.7
High sphericity qtz	<5	2.2	8.2	0
Mate qtz	35	13	66.9	11.2
Brilliant qtz	65	15.6	85	32.9

Table II.- Statistical data of the morphologic characteristics of quartz grains.

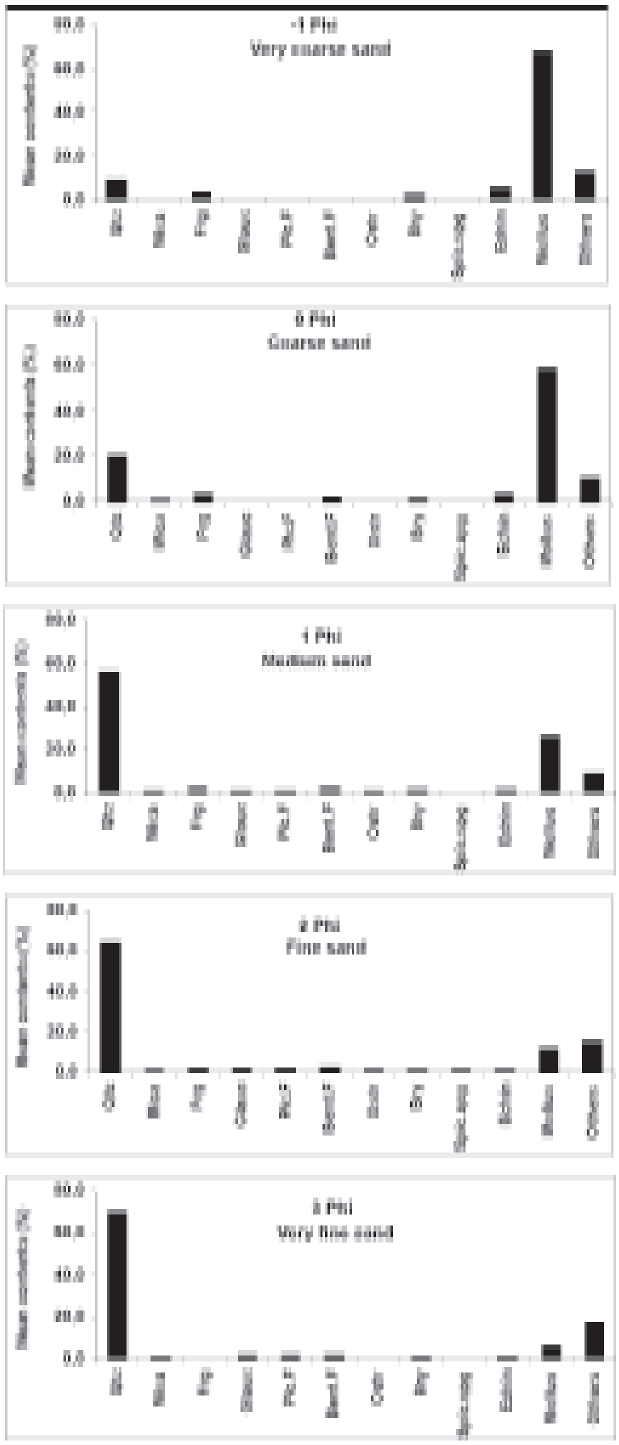

Figure 7.- Variation of the average contents of the terrigenous and bioclastics components in the sand fraction. Qtz: quartz; Frg: rock fragments; Glauc: glauconite; Spic.spg: sponge spicules; Plc.F: planktonic foraminefera; Bent.F: benthics foraminefera, Ostra: ostracods, Equin: echinoids, and Mollus: mollusks.

gravel fraction. Its relative content is important in the external bay. They concentrate in the coarser and very coarser sediment, and are mainly non-existent in the very fine sand (Fig. 7). Heavy minerals have been also observed specially in the finest fraction (very fine and fine sand), whereas the rest of vegetables (pieces of small trunks, small branches, etc.) are accumulated frequently in the coarser fraction (very coarse and coarse sand).

Biogenic components

The content of bioclasts is related with the growth rate of organisms in the environment, and with terrigenous supply (Burns, 1974). Its variety influences in the geochemistry and mineralogical heterogeneity of sediments (Morse and Mackenzie, 1990). In the study zone, the average content of bioclasts in the sand fraction is of 23% (Santos *et al.*, 1999 and Achab and Gutierrez-Mas, 2002) (Table I), although, in some areas values of 70% are reached. The intermediate values are located near the North margin of the external bay (30-50%) and major part of the inner bay (20-30%). The lowest concentrations (10-20%) are given in the rest of external bay bottoms (Fig. 8).

The calcite is the predominant mineral in the carbonated fraction, being also the second mineral more abundant in the Cádiz bay sediments after the quartz. Displays average contents of 20 %, being constant his distribution in the sediments. Others carbonated mineral are the dolomite with very low contents (6%) and the aragonite (<5%). The molluscs are the majority components of the biogenic fraction, with great difference on the rest of organisms, followed by the echinoids foraminifera and bryozoans. Others rest of organisms present in the sand fraction are sponge spicules and ostracods. They present average contents of 15% (Table I) and correlate positively with the gravel fraction (0.77) and rock fragments (0.61). They are accumulated most frequently in the coarser and very coarser sand fraction, diminishing its content in the finest sub-fractions where they are replaced by the quartz (Fig. 7).

Two groups of foraminifera are present in Cádiz bay bottoms, the planktonics and the benthic ones. Both groups present negative correlation (-0.39). The planktonic foraminifera present average contents of 1 %. The maximum concentrations, (4%) are given in deep zones of the western external bay, located to more than 20 m and in front of the Guadalete River mouth (Fig. 9). The lowest contents (< 2%) occur in the rest of the bay bottoms, especially in the inner bay and near to Rota city, with concentrations inferior to 0, 5%. The benthic group appear with average contents of 2 % and present heterogeneous distribution. The maximum contents (5%) occur in the Eastern sector of the external bay, especially to the north of Cádiz, being able to reach 7% (Fig. 10). Also they appear in the internal bay, occupying the Eastern sector. The smaller concentrations (< 2%) occur in the western sector of the external bay bottoms and to NW of the inner bay, near the coastal barrier separating the bay to the ocean. The variation of the average contents of benthics and planktonics foraminifera with the grain size in the sand

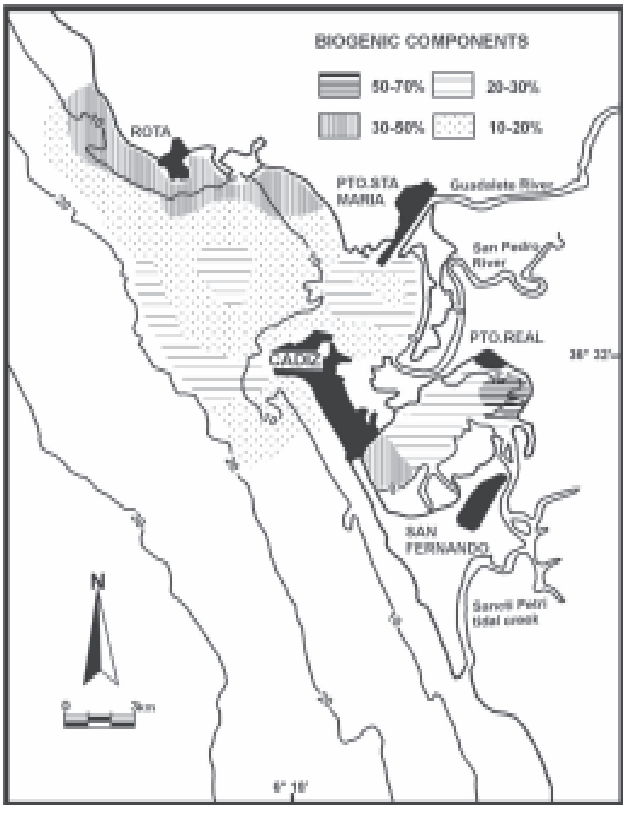

Figure 8.- Distribution of biogenic components in the sand fraction.

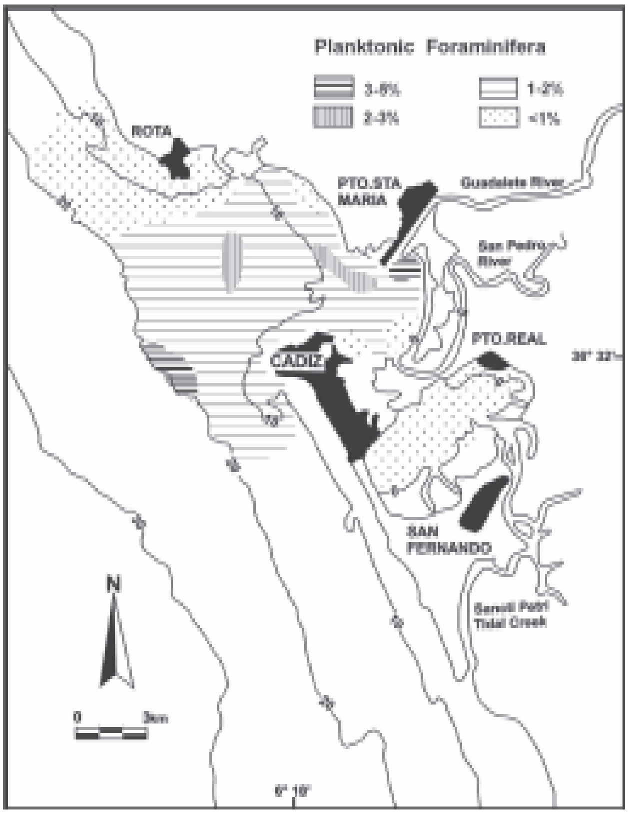

Figure 9.- Distribution of planktonic foraminifara in the sand fraction.

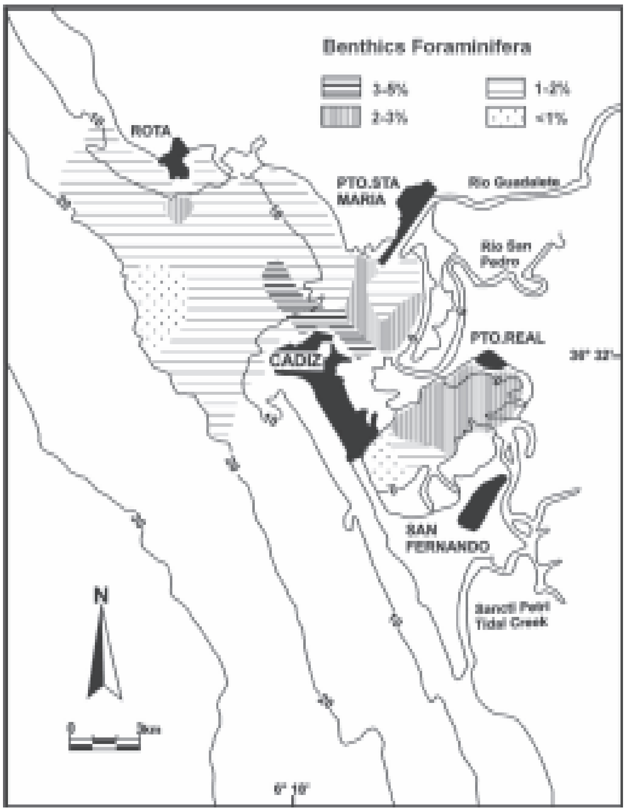

Figure 10.- Distribution of benthic foraminifera in the sand fraction.

fraction is represented in the figure 7, being observed that these appear most frequently in medium and fine sand, diminishing lightly their presence in the very fine sand. In the coarser and very coarser sand, the foraminifera tend to disappear totally, specially the planktonic groups.

Other biogenic components of the sand fraction are the echinoids, with average contents inferior to 1% and maxima of 3%. They are observed as calcitc plates of white colour and spongy aspect, in which the places of insertion of spicules are appreciated. They are accumulated in the very coarser and coarser sand fractions, being reduced their content as the grain size decreases (Fig. 7). They present positive correlation with the planktonics foraminifera (0.54) and glauconite (0.4). The bryozoans appear in sediments of Cádiz bay with very low contents (0.68%). They are most abundant in areas of moderate to low depth, and present aragonitic or calcitic skeletons with high magnesium content (Gago-Duport, *et al.*, 1995). They appear in almost all the sizes of the sand fraction, decreasing in fine sands. They present positive correlation with the benthics foraminifera (0.66), calcite (0.36) and rock fragments (0.38). The ostracods appear in very small amounts (0.3%). They have calcitic test, and generally fragmented. Their existence is favored by the presence of muddy-sand bottoms (Mas and Alonso, 1989, Gutiérrez-Mas, 1992). They are concentrated exclusively in the finest sizes of sand and non-existing in the coarser fractions (Fig. 7). The sponge spicules appear in the sand fraction with radiated forms, mainly of silicic origin and with vitreous aspect. They are given in very low concentrations (0.2%) and they accumulate in the medium and fine sand sub-fractions, not being present in the coarser fractions (Fig. 7).

Authigenic components

The glauconite is considering the authigenic components more represented in the sand fraction. The importance of this mineral was found to be related with its genesis, restricted almost exclusively to the marine environment, and being indicating of certain environmental conditions (Odin and Lamboy, 1988).It seems that the organic matter in decomposition and the fragments of foraminifera constitute the ideal support of its genesis (Odin and Matter, 1981). In the Cádiz bay bottoms, the glauconite grains appear in dark green colour, which indicates an advanced evolutionary state in the glaunitization process. The form of the grains is of two types: internal molds of foraminiferal test, or simply granular forms, derived from the reworking of the previous forms. This mineral is presented more frequency in the fine and medium fractions (Fig. 7); with average contents inferior to 5% (Table I); reaching concentrations of to 10% in isolated points of the external bay (Fig. 11). The intermediate concentrations (1-3%) occur in front of the Guadalete River mouth and central parts the outer and inner bay.

Statistical analysis

With the objective to establish criteria of classification and differentiation of the Cadiz bay

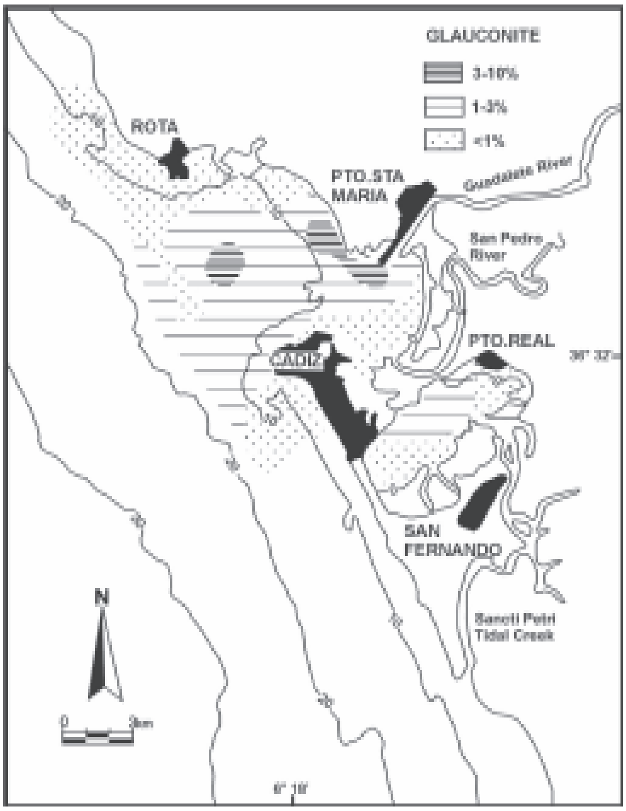

Figure 11.- Distribution of Glauconite in the sand fraction.

deposits, the most representative variables of sediments have been related, combining the properties of the sand fraction components and of the total fraction. The results of the Multivariate Factorial Analysis applied to the sand fraction components, granulometrics fractions, and the mineralogical data, provide three factors that explain almost the 100% of the model variance (Table III). The first Factor (F1) (95%) is the most significant, associates by decreasing values of factor scores the terrigenous components (2.24), the sand fraction (2.16) and the angular quartz (1.58) (Fig. 12). The second factor (F2) (3%) is less significant (Fig. 12), associates sub-rounded quartz (3.23), molluscs/shells (1.83), biogenic components (1.18) and sand fraction (1.65) among others. The factor (F3) explains only 2% of the total variance (Fig. 12), associates silt (3.67), carbonates (1.38), calcite (1.18) and terrigenous components (1.03).

Discussion

The sedimentary dynamics in Cadiz bay displays a specific behavior pattern, related with different environments of deposit, and the interaction of these with the hydrodynamic system dominant in the area. The analysis of sediments shows the existence of sedimentary facies with variable dsiposition and granulometric nature (Achab *et al.*, 1999b). These facies occupy differents sedimentary environments, sometimes in unbalance with the current hydrodynamic system. From the sedimentological characteristics, Cádiz bay constitutes an example of a siliciclastic sedimentary marine environment. Quarzitic sands fill up the external bay while in the lagoon the mud predominates. In the northern sector of the bay, the sedimentary contributions come from the Guadalete River and others smaller rivers, who, although dry almost all the year, constitute an important source of sediments in flooding periods. In the southern sector, the absence of rivers is supplied by the action of tidal current draining the inner zones and salt marshes system.

The sedimentary facies distribution reflect the action of hydrodynamic agents, fundamentally Ebb tidal currents and surge. In the external bay bottoms, the presence of muddy-sand and sandy mud facies

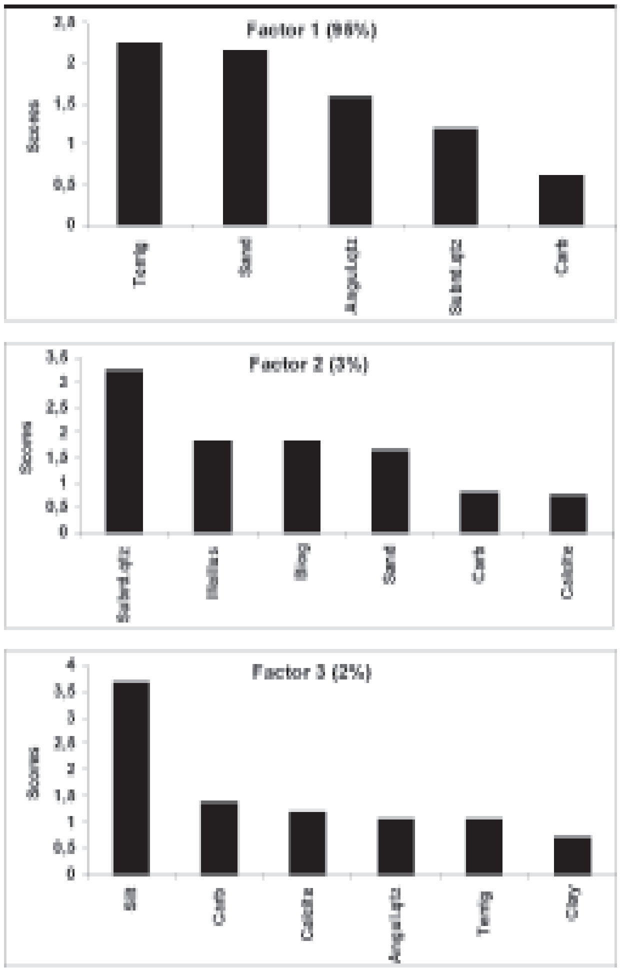

Figure 12.- Graphic representation of factor scores of F1, F2 and F3 obtained in Q-mode analysis. Terrig: terrigenous; Biog: biogenic; Carb: carbonate; Mollus: molluscs; Angul.qtz: angular quartz; Subrd.qtz: sub-rounded quartz.

covering sediments of coarser nature (sand and gravel), indicates actual processes of transport and precipitation of fine sediments in suspension from the inner bay to be precipitated upon sands of the external zone (Fig. 5). The silt and clay are transported by tidal currents from internal bay to the external one especially in situation of strong East winds capable to remove the bottom. The silt; once leave the inner bay, is deposited in the external bay when transport energy of current decrease. The clay is of smaller size has a different hydrodynamic behaviour, tends to leave the bay being deposited in the

Measured variables	Factor 1 (95%)	Factor 2 (3%)	Factor 3 (2%)
Terrigenous	**2.24**	0.43	1.03
Biogenic	0.56	**1.18**	0.21
Carbonate	0.62	0.80	**1.38**
Mollusks	0.28	**1.83**	-0.09
Calcite	0.43	0.75	**1.18**
Sand	**2.16**	**1.65**	-3.12
Slit	0.49	0.07	**3.67**
Clay	0.1	0.02	0.67
Angular quartz	**1.58**	-1.51	1.04
Sub-rounded quartz	**1.19**	**3.23**	0.40

Table III.- Q-mode factor analysis showing the contribution of statistically dominant variables of grain size, mineralogy, and components of the sand fraction.

inner continental shelf (Gutiérrez Mas *et al.*, 1999 and Achab *et al.,* 1999a). This model of transport has been confirmed by means of studies of *bed forms* fields carried out in the study area (Parrado Roman *et al.*, 1999). These *bed forms* are generated by deep currents action on bottoms sediment and agree with the distribution of sedimentary facies.

The terrigenous components constitute the major part of the sand fraction of Cádiz bay sediments. These data indicate their predominance on the rest of others components (Achab *et al.*, 1999b). The predominance of the quartz indicates the importance of siliciclastic components in Cadiz bay bottoms and its origin from sources area rich in this mineral. The possible source areas and supplies of different terrigenous components and quartz morphology to the Cádiz bay correspond to sedimentary unites present in the Guadalete basin, such as the Aljibe Sandstone (Oligocene-Lower Miocene) and the calcarenites of the Upper Miocene. Both of them can provide materials of variable maturity and degree of reworking to the Cádiz bay through the Guadalete River (Achab and Gutiérrez-Mas, 2002). Another source of terrigenous grains is related to the erosion of plio-quaternary coastal cliffs and coastal dunes in storm events. These data generally coincide with the results of studies realised by diverse authors in the plio-quaternary detrital deposits (Torcal, 1989), in the Guadalete River basin (Moral Cardona *et al.*, 1997a and 1997b), and in the continental shelf of Cadiz Bay (Gutiérrez-Mas *et al.*, 2003).

The biogenic components constitute the fundamental part of the carbonates, with which they present positive correlation (0.6) due to his composition essentially calcitic (Gago-Duport *et al.*, 1995). The calcite has an origin clearly biogenic, although recrystallizations and cements have also been detected. They can correspond to older bioclastic remains. The aragonite is not very abundant in the biogenic fraction, due to his low stability, although he is also present in the skeletal remains of bivalves and gastropods. Its positive correlation with the calcite probably indicates very recent sediments in which the transformation aragonite-calcite has still not taken place, or the presence of organisms containing both minerals. The most frequent mollusks, were found to be represented by the rest of bivalves and gastropods. They show a high state of fragmentation, what indicates their clastic behaviour and a high degree of hydrodynamism. Their several supply sources was found to be related to the erosion of rocky shoals and plio-quaternary coastal cliffs bordering the Cádiz littoral. Both of them are rich in bioclasts (Achab, 2000). Other source of bioclasts is related to the growth rate of marine organisms, especially in the inner bay and the adjacent salt marshes.

The foraminifera display generally a good state of conservation, without recrystalisation processes. The shells are of calcite and sometimes they appear fillers of glauconite (Boltouskoy, 1959). Their distribution varies according to the depth and the grains size of sediments, appearing most frequently in medium and fine sand and disappearing totally in the coarser sand fractions. With regard to the glauconite, the common factor of this mineral seems to be its greater concentration in well-communicated and opened water bottoms, able to maintain a certain foraminifer's population. Therefore, it is possible that a part of the glauconite has its origin en relation with the evolution undergone by these organisms, once died and buried in sediments. Later prediagenitic processes can transform them, break their test and incorporate the nodules to the sediment. In the continental shelf near to Cádiz bay, the glauconite presents a good correlation with the benthic and planktonic foraminifera, and with the depth (Gutiérrez-Mas, 1992). It may be concluded that part of the glauconite has an authigenic origin, directly related with the foraminifaral test filling. In the Cádiz bay, the areas of more glauconite concentration, present a perpendicular tendency to the coast and isobaths. It can indicate those zones more affected by the exchange of the water masses, and the effect of the ocean currents that receive greater amount of foraminifera. These last, once deads, are incorporated up to the marine sediments. Thus, it is possible to conclude that, the zones more affected by the currents are those that present a greater concentration of foraminifera and glauconite (Achab, 2000). In the littoral zones affected by the surge (waves) and currents action, the glauconite seems to have detritic origin, in relation with reworking and erosion processes of oldest sediments.

On the basis of the Factorial Analysis results, it has been possible to define several types of assemblages in correspondence with the three obtained factors. From the associated variables in each factor and of the values (scores) that take the factors in each one them, different associations have been defined. The principal one is representative of bottoms with clear predominance of siliciclastic terrigenous sediments, the second association represents bottoms where the biogenic components predominate slightly, while the last one is indicating bottoms of mixed sediment with predominance of the silt fraction of carbonated nature.

Conclusions

1) The superficial sediments present in the Cádiz bay are siliciclastic nature. The sandy bottoms predominate in the outer bay, while mud sediments constitute the inner bay fundamentally. In the sand fraction, the terrigenous components predominate; the most important mineral is the quartz. In spite of their siliciclastic character, the superficial sediments show very important carbonate concentrations. Their origin is fundamentally biogenic. Upon being constituted by skeletal remains of marine organisms, and represent the main components of the gravel and coarser fractions. The molluscs are the majority components, followed by the foraminifera, echinoids and bryozoans.

2) The glauconite grains appear in dark green colour, indicating an advanced glaunitization process. This mineral was found to be associated with the fine and medium sand fractions. A part of glauconite has an authigenic origin, directly related with the foraminiferal test filling, while in the littoral zones the glauconite seems to have detritic origin, in relation with reworking and erosion processes

3) The transport and distribution of sand fraction components is controlled mainly by the action of the hydrodynamic agents, especially tidal currents and surge, according to its size, forms and density. The nature of these components next to other properties reflects the petrographic nature and the characteristic of different continental and marine supplies to the bay. The possible sources of terrigenous supplies to the bay are related with the Aljibe Sandstone and the calcarenites present in the Guadalete River basin, as well as to the erosion of coastal dunes and cliffs in storm events. The several supply sources of biogenic components was found to be related to the erosion of rocky shoals and plio-quaternary coastal cliffs bordering the Cadiz littoral.

4) The Q-mode factor analysis of statistically dominant variables of grain size, mineralogy, and components of the sand fraction, has allowed to differentiate two types of associations: one principal and represents bottoms with a clear predominance of siliciclastic terrigenous sediments. The second association represents bottoms where the biogenic components especially molluscs and foraminifera predominate lightly.

Acknowledgements

This work/research has been financed under project Sea-98-0796 of the Comisión Interministerial de Ciencia y Tecnología (CICYT).

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Manuscrito recibido el xx de xxxxxxx de 2005
Aceptado el manuscrito revisado el xx de xxxxxxx de 2005