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AUTOCHTHONOUS BIOFACIES IN THE PLIOCENE LORETO BASIN, BAJA CALIFORNIA SUR, MEXICO

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Riassunto. In questo lavoro vengono esaminate le associazioni di molluschi e/o echinoidi rinvenute in due unità litostratigrafiche (Piedras Rodadas Sandstone e Arroyo de Arce Norte Sandstone) presenti nel bacino pliocenico di Loreto (Baja California Sur, Messico). Sono state individuate dieci biofacies: Biofacies a *Trachycardium procerum-Trachycardium senticosum*, Biofacies a *Chione compta-Transennella modesta*, Biofacies a *Laevicardium elenense-Chione kelletii*, Biofacies a *Xenophora* sp. 1-*Strombus subgracilior*, Biofacies a *Crassostrea californica osunai*, Biofacies a *Myrakeena angelica*, Biofacies a Vermetidi-*Nodipecten*, Biofacies a *Argopecten abietis abietis*, Biofacies a *Aequipecten dallasi*, Biofacies a *Encope*. Le prime quattro sono state definite sulla base di analisi statistiche (cluster analysis, MDS), mentre le restanti sei, monospecifiche o a diversità molto bassa, sono state individuate direttamente durante il lavoro di campagna. Il significato ambientale delle biofacies è stato dedotto in larga parte dal confronto con gli analoghi attuali più affidabili. Sulla base delle informazioni ottenute, si è elaborata l'interpretazione paleoambientale inquadrandola nel contesto deposizionale delineato dalle evidenze sedimentologiche e confrontandola con il quadro tettono-sedimentario recentemente proposto da ricercatori americani. Le diverse biofacies suggeriscono ambienti fra loro differenziati in termini di granulometria del substrato, presenza di copertura vegetale e livello energetico, variamente distribuiti tra il livello di bassa marea e circa 40 m di profondità.

Abstract. The present paper examines the molluscan and/or echinoid assemblages recovered from two lithostratigraphic units (Piedras Rodadas Sandstone and Arroyo de Arce Norte Sandstone) outcropping in the Pliocene Loreto Basin, Baja California Sur, Mexico. Ten biofacies have been identified, i.e. *Trachycardium procerum-Trachycardium senticosum* Biofacies, *Chione compta-Transennella modesta* Biofacies, *Laevicardium elenense-Chione kelletii* Biofacies, *Xenophora* sp. 1-*Strombus subgracilior* Biofacies, *Crassostrea californica osunai* Biofacies, *Myrakeena angelica* Biofacies, Vermetid-*Nodipecten* Biofacies, *Argopecten abietis abietis* Biofacies, *Aequipecten dallasi* Biofacies and *Encope* Biofacies. The first four biofacies have been defined on the basis of statistical analyses (cluster analysis, MDS). The other six, which are monospecific or definitely low-diversity, were already identified during field work. The deduced paleoecological bearing of biofacies, largely relying upon the comparison to their closest modern counterparts, provides the basis for the paleoenvironmental reconstruction. The latter also considers sedimentological evidence and is framed within the tectonic and sedimentary context recently proposed by American workers. Biofacies point toward environments differing in terms of substrate texture, presence/absence of vegetal cover, energy level, variously distributed within the low tide mark-40 m bathymetric range.

Introduction.

The present paper examines molluscan and echinoid assemblages recovered from two lithostratigraphic units in the Pliocene Loreto Basin, Baja California Sur, Mexico. Field work was carried out in January 1988 and the fossil material was obtained primarily from stratigraphic sections, but some spot localities were also considered (Fig. 1). The study aims to distinguish, describe and discuss the autochthonous biofacies on the basis of 1) the statistical treatment of data pertaining to taxa, 2) the analysis of species autoecology focusing on life-habit, feeding type, substrate preference, depth range and ecological meaning within biofacies and 3) the taxonomic structure.

The fossil faunas are extremely rich and occur throughout the basin predominantly as shell concentrations. Molluscs constitute the largely dominant element, but corals, bryozoans, echinoids, barnacles and crabs are also found and may be locally abundant. These faunas have so far received little attention, a few authors having dealt with them only occasionally. Reference is made to Hanna & Hertlein (1927), Durham (1950), Smith (1991 a, b) and Piazza & Robba (1994). Relevant information on Pliocene molluscs of other areas of Baja California Sur was provided by Arnold (1906), Jordan & Hertlein (1926a, b), Durham (1950), Hertlein & Emerson (1959), Hertlein (1966), Moore (1984, 1987), Smith (1984, 1991 a, b) and Quiroz-Barroso & Perrilliat (1989). Meldahl (1993) investigated the taphonomic processes that have formed the fossil concentrations (mostly allochthonous) in Plio-Pleistocene deposits of coastal areas in the Gulf of California and will referred to in the following.

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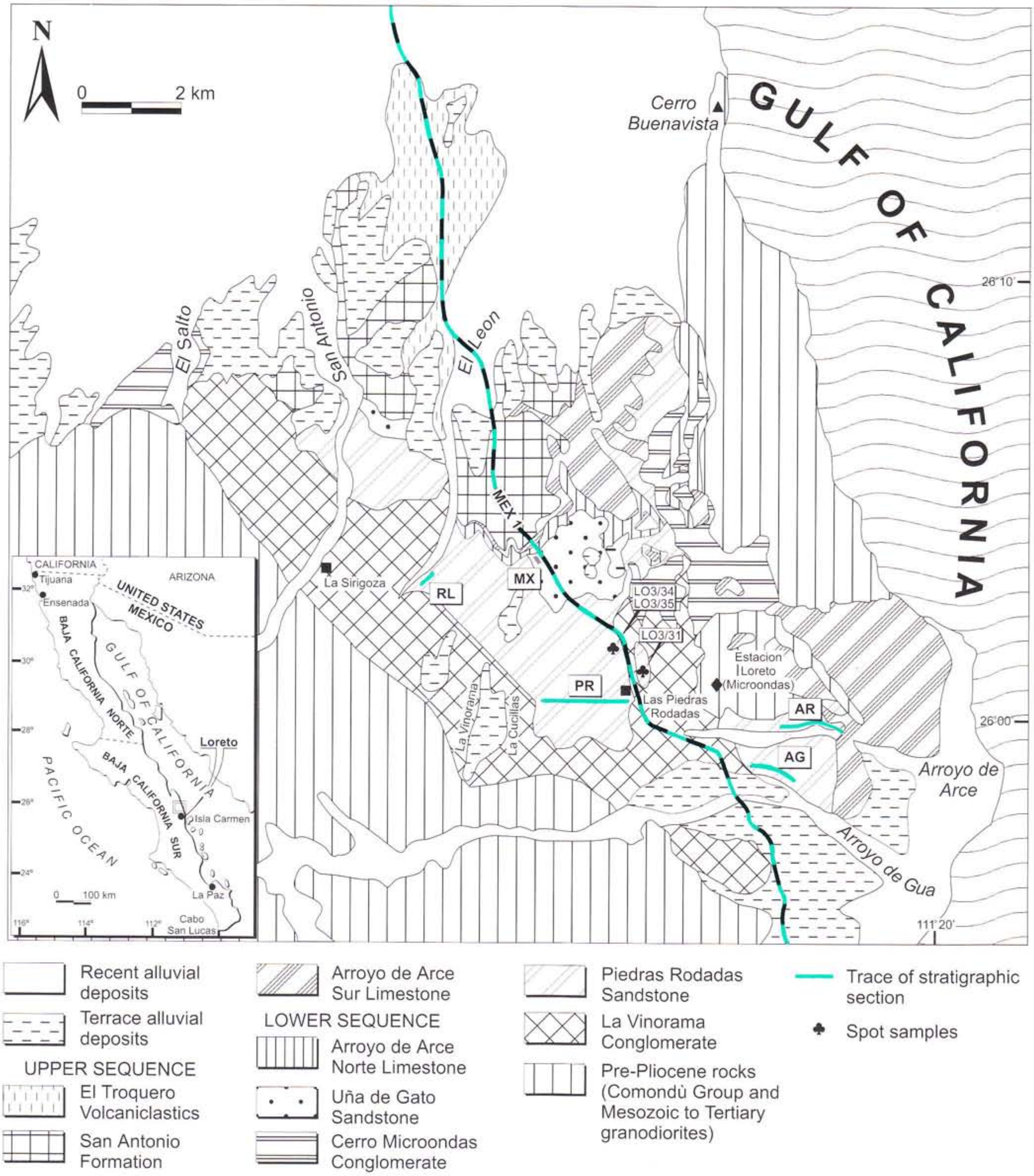

Fig. 1 - Geological sketch map of the study area (based on Zanchi et al., 1993, unpublished report) showing location of stratigraphic sections and spot samples. RL) Rancho El Leon Section; MX) Highway (Mexico 1) Section; PR) Rancho Piedras Rodadas Section; AG) Arroyo de Gua Section; AR) Arroyo de Arce Section.

Except for short comments provided by Piazza & Robba (1994), no attempt was made so far to interpret the depositional environments of the Loreto Basin on the basis of autochthonous benthic biofacies. This study investigates biofacies, identifies their closest modern counterparts, discusses their paleoenvironmental meaning as inferred from autoecology of species and modern analogs, and compares the obtained results with those based on sedimentological analyses (Dorsey et al., 1995; Dorsey et al., in press).

Geologic framework.

The Loreto Basin is located in the southern part of Baja California, just north of the town of Loreto, and

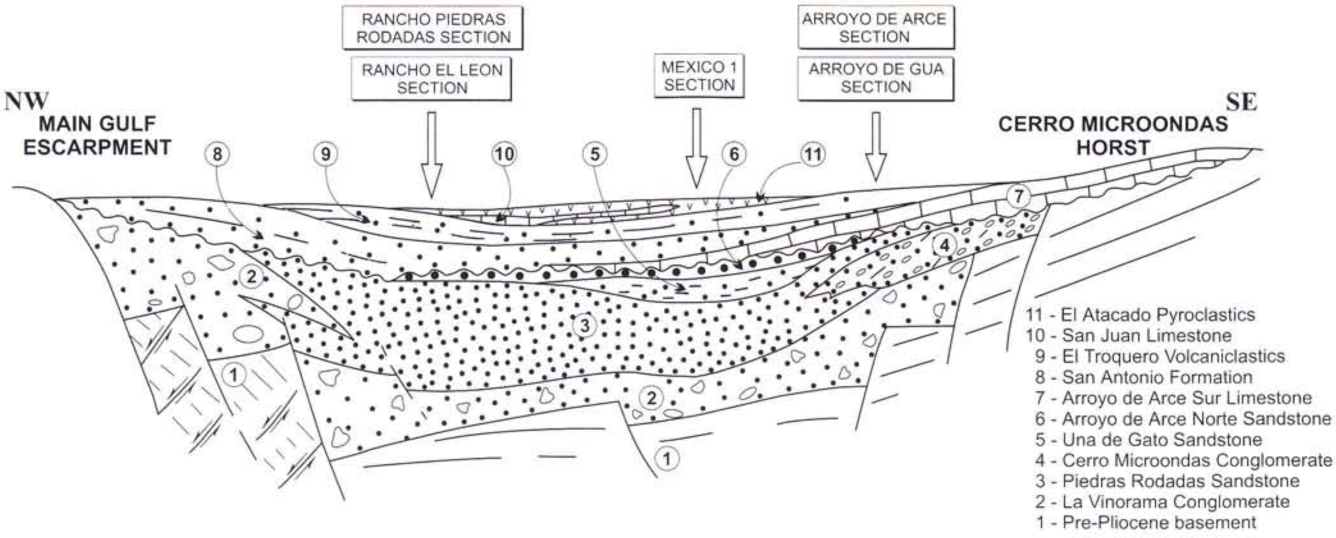

Fig. 2 - Generalized cross-section of the Loreto Basin showing the relationships among lithostratigraphic units (based on Zanchi et al., 1993, unpublished report).

stretches along the western escarpment of the Gulf formed by the Sierra de La Giganta (Fig. 1). The Cretaceous granitic basement, exposed northwest of Loreto, is overlain by the late Oligocene to middle Miocene volcaniclastic deposits and lava flows currently referred to the Comondù Group (Gastil et al., 1979; McLean, 1988; Piazza & Robba, 1994). During the transtensional event starting at about 4-5 Ma (Zanchi, 1989b, 1993; Dorsey et al., 1995), a marine basin developed north of Loreto between the Sierra de La Giganta and the strongly tilted blocks of the Comondù Formation (McLean, 1988; Zanchi, 1989b; Dorsey et al., 1995). The basin was filled with almost 1200 m of mainly marine sediments. These unconformably overlie the tilted blocks of the Comondù Formation and form two distinct sequences separated by an unconformity (Zanchi, 1989a, b, 1993; Zanchi et al., 1988; Zanchi et al., 1993, unpublished report; Piazza & Robba, 1994). Sedimentation in the basin was coeval with the intensive volcanic activity of the Mencenares Volcanic Complex (Bigioggero, 1993, written communication) as indicated by reworked pyroclastics in both sequences and manifest interfingering between volcanics and marine deposits of the upper sequence (Zanchi, 1989b, 1993). For additional information on tectonic and geologic setting reference can be made to Umhoefer et al. (1994), Dorsey et al. (1995) and Dorsey et al. (in press).

The most up-to-date studies focusing on the stratigraphy of the Loreto Basin were provided by Zanchi et al. (1993, unpublished report), Piazza & Robba (1994), Dorsey et al. (1995) and Dorsey et al. (in press). In the last two papers, different areas of the basin are dealt with and several lithofacies associations are described and interpreted in terms of depositional environment and tectonic control. Piazza & Robba (1994) discussed the formational names available in previous literature and concluded that they hardly serve for the lithostratigraphic units noted in the Loreto Basin.

The detailed lithostratigraphic framework presented by Zanchi et al. (1993, unpublished report) is followed herein. Two sequences separated by a regional unconformity have been distinguished within the basin (Fig. 1). The lower sedimentary sequence rests directly on the Comondù Formation with a strong angular unconformity. It consists of debris-flow dominated fan-delta deposits evolving laterally and upward into thick shallow marine, fossiliferous sediments. The upper sequence contains bioclastic and terrigenous units, and is clearly transgressive along the margin of the basin. A total of 10 lithostratigraphic units have been proposed (Fig. 2), i.e. Cerro Microondas Conglomerate, La Vinorama Conglomerate, Piedras Rodadas Sandstone, Uña de Gato Sandstone and Arroyo de Arce Norte Sandstone included in the lower sequence, Arroyo de Arce Sur Limestone, San Antonio Formation, El Troquero Volcaniclastics, San Juan Limestone and El Atacado Pyroclastics forming the upper sequence. The last unit, linked to the activity of the Mencenares Volcanic Complex, interfingers with the San Juan Limestone and also forms the top of the sedimentary succession in the Loreto Basin (Fig. 2). For further details reference can be made to Piazza & Robba (1994). However, since the autochthonous biofacies described in the following were recovered from the Piedras Rodadas Sandstone and the Arroyo de Arce Norte Sandstone, information on these units is provided herein. The pertinent stratigraphic sections are depicted in Fig. 3 through 7.

Piedras Rodadas Sandstone. The unit is dominated by irregularly alternating, grey to yellowish-grey, massive to roughly bedded, bioturbated, poorly to moderately sorted shelly sand and sandstone. The size of sedimentary particles ranges widely, from silt to pebbles,

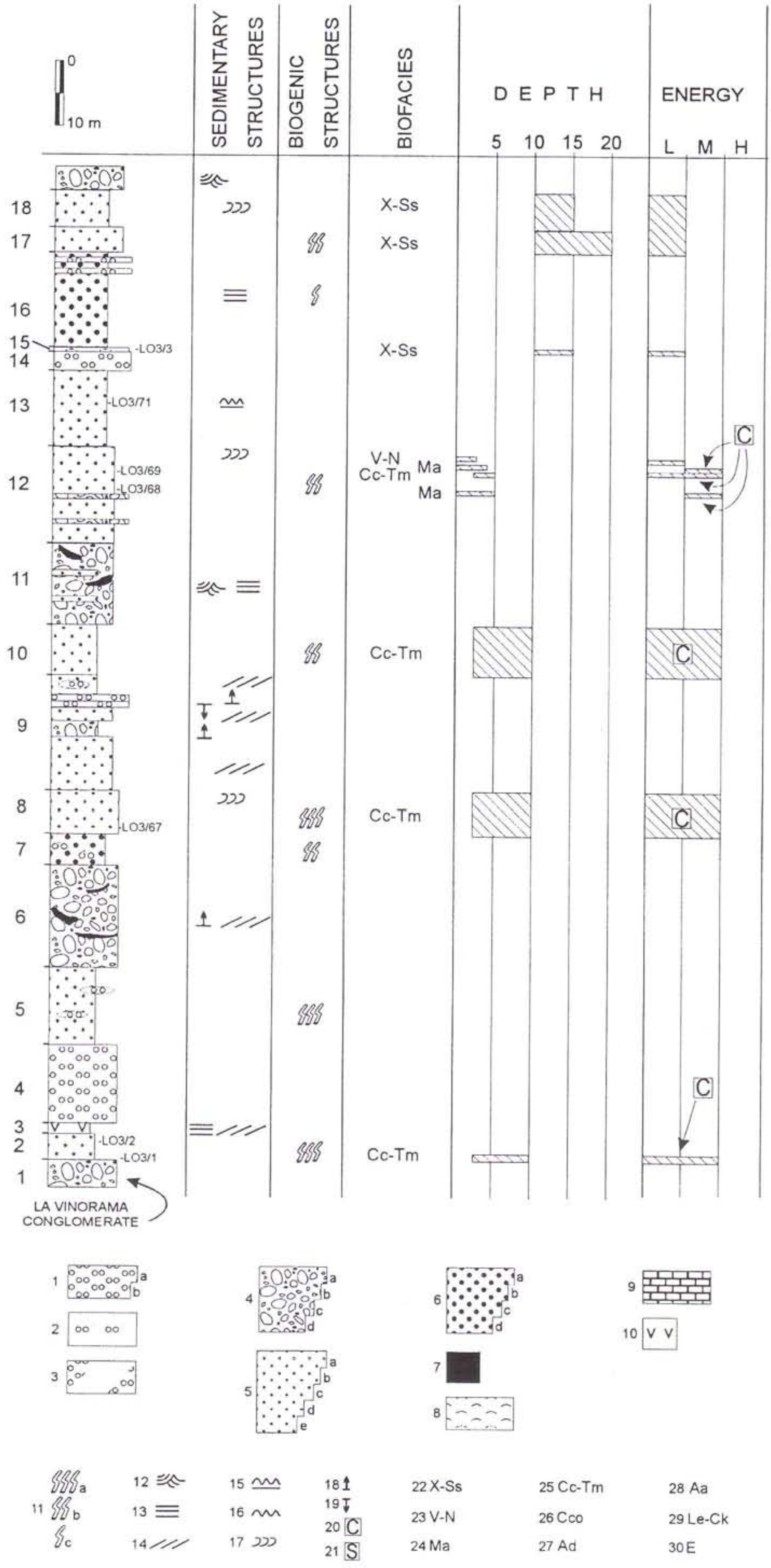

Fig. 3 - Rancho Piedras Rodadas Section. 1) Gravel (a: clean, b: sandy); 2) pebble layer; 3) scattered pebbles; 4) conglomerate (a: coarse orthoconglomerate, b: coarse paraconglomerate, c: medium, d: fine); 5) sand (a: medium to coarse, b: medium, c: fine to medium, d: fine, e: grain size undetermined); 6) sandstone (a: conglomeratic, b: coarse, c: medium, d: grain size undetermined); 7) silty mudstone/mudstone; 8) shell layer; 9) bioclastic limestone; 10) cineritic tuffite; 11) burrows (a: abundant, b: common, c: present); 12) festoon; 13) parallel lamination; 14) low angle lamination; 15) ripples; 16) erosional surface; 17) shell concentrations; 18) normal grading; 19) inverse grading; 20) current; 21) surf; 22) *Xenophora* sp. 1-*Strombus subgracilior* Biofacies; 23) Vermetid-*Nodipecten* Biofacies; 24) *Myrakeena angelica* Biofacies; 25) *Chione compta-Transennella modesta* Biofacies; 26) *Crassostrea californica osunai* Biofacies; 27) *Aequipecten dallasi* Biofacies; 28) *Argopecten abietis abietis* Biofacies; 29) *Laevicardium elenense-Chione kelletii* Biofacies; 30) *Encope* Biofacies.

and some proportion of clay may be occasionally present. Grading, parallel and cross lamination are present. Lenticular-bedded, unsorted to sorted shelly conglomerate is frequently intercalated. Conglomerate beds, 0.10 to about 1.5 m thick, commonly have an erosional base, may be internally structureless, but often display normal or inverse grading along with large-scale festoon and/or cross stratification. Massive mudstone, siltstone, pebbly shell concentrations and tuff are minor components of the unit. The total thickness is about 400 m.

Arroyo de Arce Norte Sandstone. Grey to yellowish-grey, medium- to thick-bedded, moderately sorted, predominantly fine shelly sand. Bioturbation is rare throughout. Intercalated sandstone beds, 10-50 cm thick, exhibit lamination and sometimes wedge-shape geometries. Pebbles, sparse or forming small lenticular bodies occur in the middle part of the unit. Conglomeratic sandstone and shelly conglomerate with lenticular or wedging geometries are intercalated in the upper part. The exposed thickness, measured along Mexican Highway 1, is about 60 m.

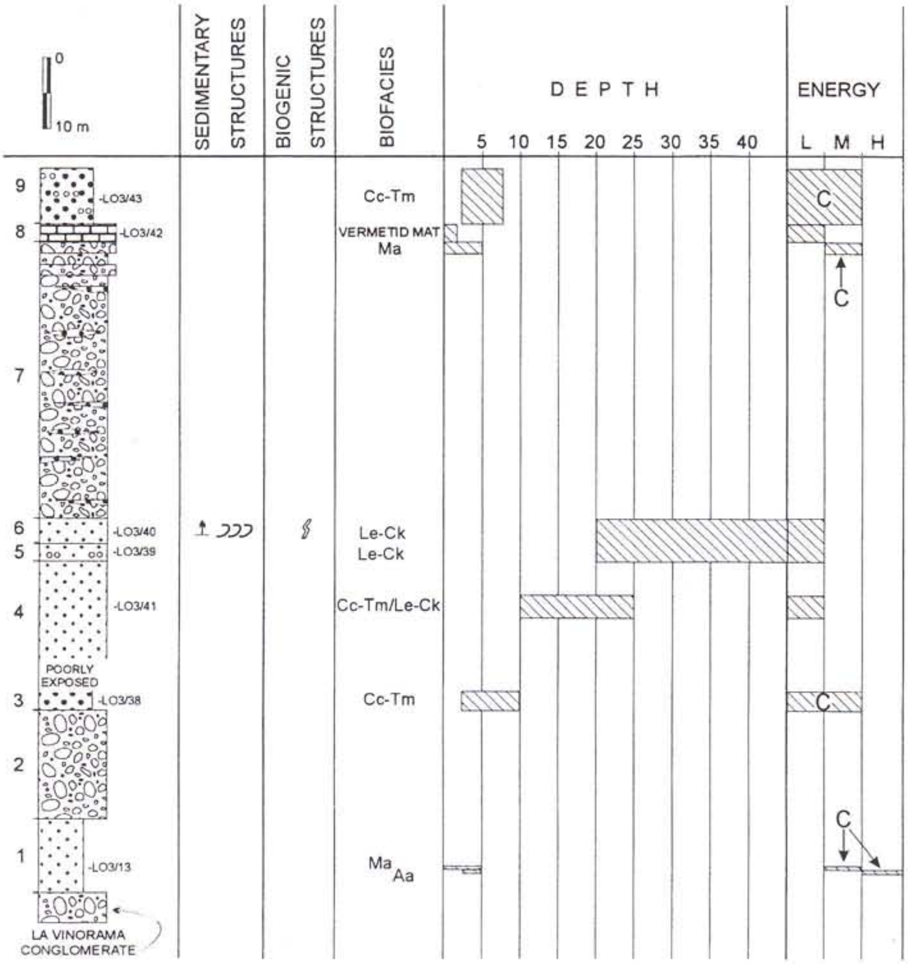

Fig. 4 - Rancho El Leon Section. For legend see Fig. 3.

It is to be noted that the Cerro Microondas Conglomerate and La Vinorama Conglomerate basically correspond to the alluvial-fan conglomerate and sandstone facies association of Dorsey et al. (1995) and to sequence 1 of Dorsey et al. (in press). The rest of the lower sequence seems to be equivalent to the shelf-type fan deltas and shallow marine to marginal-marine shelly sandstone and conglomerate linked to Gilbert-type fan deltas dealt with by the same authors.

On the basis of $^{40}Ar/^{39}Ar$ dating of the interbedded tuffs (Umhoefer et al., 1994; Dorsey et al., 1995) and of foraminiferal assemblages (Piazza & Robba, 1994), the stratigraphic succession of the Loreto Basin is concluded to have been deposited during the Late Pliocene.

Methodology.

Seventeen community beds, i.e. autochthonous mollusc assemblages (cf. Norris, 1986; Meldahl & Cutler, 1992; Meldahl, 1993), were bulk-sampled in the Piedras Rodadas Sandstone and Arroyo de Arce Norte Sandstone in order to obtain quantitative data. Megafossils from other shell beds, which appeared to contain assemblages akin to the bulk-sampled ones, were cursorily collected and faunal interpretation basically rests on field observations. A total of 29 beds were considered which yielded moderate to high-diversity assemblages. In addition to these, some monospecific or nearly monospecific assemblages, characterized respectively by ostreids, pectinids or echinoids were noted and are incorporated in this study. Conversely, those layers that appeared to contain clearly allochthonous assemblages (storm beds, tidal channel beds, beach berm beds, current/wave-winnowed beds in the sense of Meldahl, 1993) are not considered in the present paper.

The grain size distribution, a relevant factor controlling presence/absence and dominance of marine benthic animals (Parker, 1956; Picard, 1965; Driscoll & Brandon, 1973; Franz, 1976; Di Geronimo, 1985; Aberhan & Fürsich, 1991; Robba, 1996) was determined for those community beds whose assemblages have a total abundance great enough to permit the statistical elaboration described below and discussed in the following. The textural data are arranged in the standard size classes (Wentworth, 1922; Friedman & Sanders, 1978), i.e. pebbles (>2.0 mm), very coarse sand (2.0-1.0 mm), coarse sand (1.0-0.5 mm), medium sand (0.5-0.25 mm), fine sand (0.25-0.125 mm), very fine sand (0.125-0.063 mm), coarse silt (0.063-0.008 mm), fine silt (0.008-0.002 mm) and clay (<0.002 mm). The proportion of mud (silt + clay) is also reported. The compilation of these data is presented in Tab. 1. The sediment of the analyzed samples is moderately sorted sand, slightly silty or silty, occasionally clayey or pebbly. Only bulk-sample LO3/31 consists of silty, slightly sandy clay. It is to be noted that the adjectives pebbly, sandy or silty are added if the proportion of the secondary constituent exceeds 5%; the modifier slightly is added if the minor constituents range from 5 to 15%, and very if it constitutes 30 to 49% (Stanley, 1970).

Faunal components were picked through the sediment with great caution in order to minimize bias from differential preservation and extractibility of specimens. These latter were identified to the species level using the most extensive accounts on Pliocene to Recent West

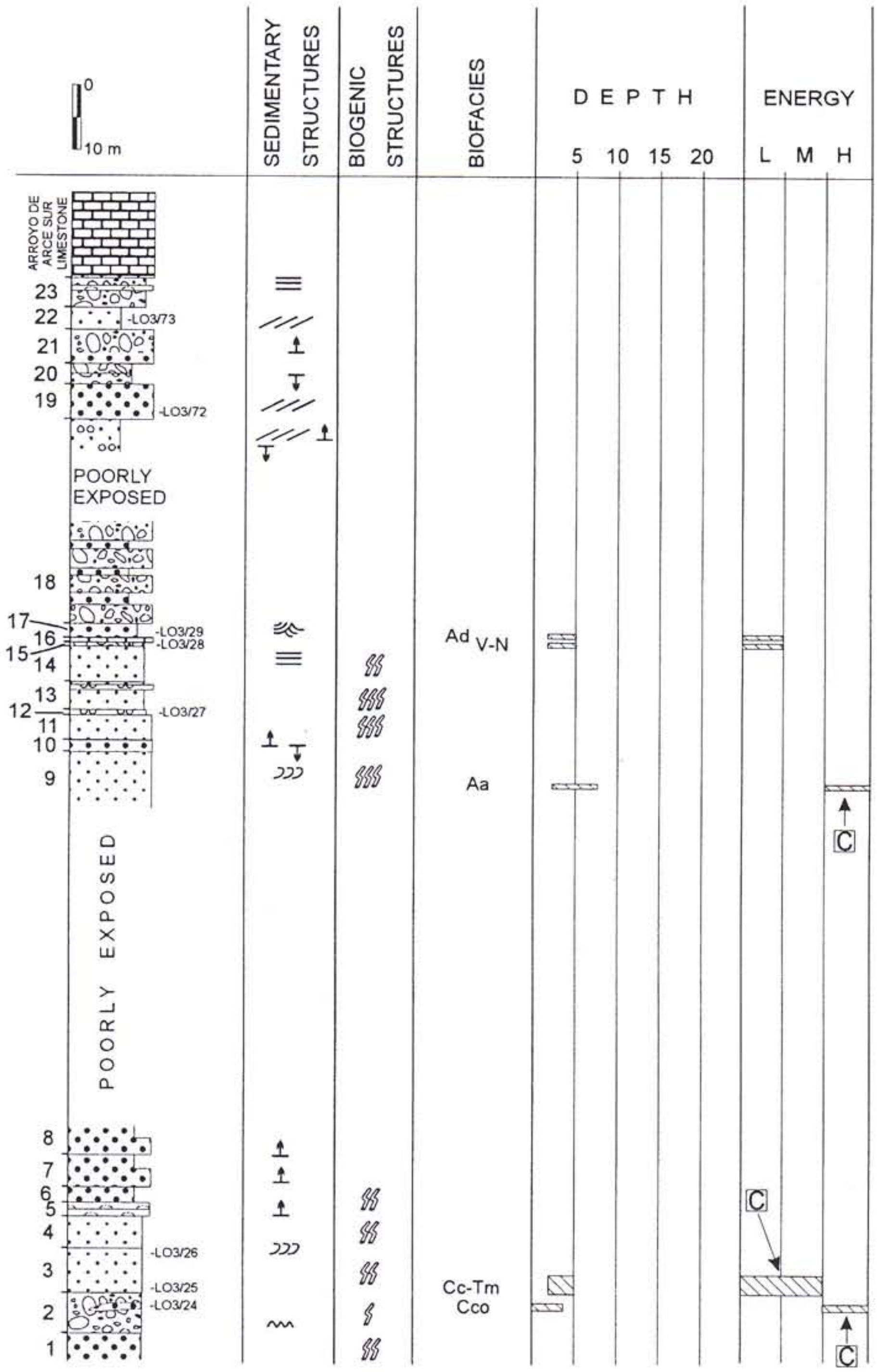

Fig. 5 - Arroyo de Arce Section. For legend see Fig. 3.

American megafaunas, and the abundance of species (number of specimens per species in a given sample) was determined following the method suggested by Di Geronimo & Robba (1976). The faunal composition recorded in each bulk-sampled bed is shown in the appendix. Taxa are listed in systematic order with respective abundance values.

Information on species autoecology was obtained from literature as regards extant taxa, or deduced mainly on the basis of recurrent associations with other species and sedimentological evidence as regards extinct taxa. In the latter case, information on closely related modern species and genera was also considered. Reference was made to Hanna (1927), Pilsbry & Lowe (1932) Pilsbry & Olsson (1935), Bruff (1946), Hertlein & Strong (1946a, b, 1947, 1948, 1950, 1955), Demond (1952), Abbott (1954), Rost (1955), Soot-Ryen (1955), Bandy (1958), Grau (1959), Olsson (1961), Valentine (1961), Weisbord (1962), Parker (1964), DuShane & Poorman (1967), DuShane & Brennan (1969), Waller (1969), Stanley (1970), Coan (1971, 1988, 1990), Keen (1971), Stenzel (1971), Warme (1971), Dowlen & Minch (1972), Hertlein & Grant (1972), Kern (1973), Humfrey (1975), Kay (1979), Moore (1979, 1983, 1984, 1987, 1988, 1992), Emerson et al. (1981), Petuch (1981), Abbott & Dance (1982), Al Barash & Zenziper (1985), Harry (1985), Bratcher & Cernohorsky (1987), Laborel (1987), Aberhan & Fürsich (1991), Fürsich & Schödlbauer (1991), Fürsich et al. (1991), Smith (1991a), Meldahl & Cutler (1992), Meldahl (1993), Piazza & Robba (1994). The behavioral attributes and some habitat preferences of the considererd molluscs and echinoids are summarized in Tab. 2. It is to be noted that some ecological requirements of a moderate number of taxa remain undetermined.

The faunal lists pertaining to each bulk-sample were considered for statistical treatment. In order to base the analysis on significant data, uncommon taxa and less representative samples were removed using, with slight adjustment, the procedure recently suggested by Bernasconi & Stanley (1997). A data matrix including 17 samples as variables and 209 mollusc and echinoid species as observations (abundance values in rows) was composed. The 2.5% of highest cumulative abundance (1997 in sample LO3/59) was calculated, and those samples with a cumulative abundance of less than the calculated value (50) were eliminated. A similar procedure was applied to species, using 2 % of highest abundance (1129 pertaining to *Laevicardium elenense* in

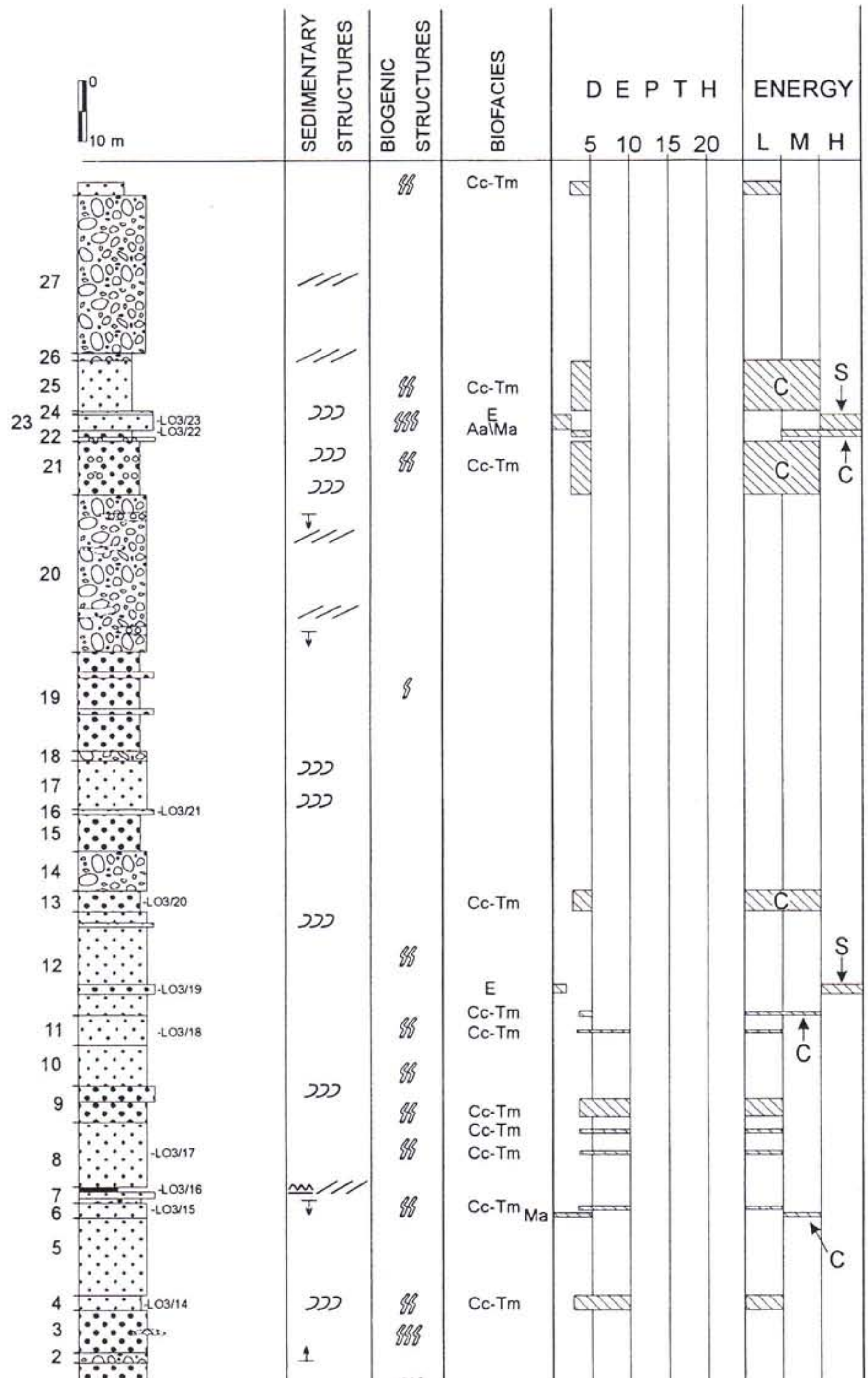

Fig. 6 - Arroyo de Gua Section. For legend see Fig. 3.

sample LO3/59). The final number of samples was 13, and 22 molluscan species with a minimum abundance of 23 in at least one sample entered the statistical analysis. Thus, a data matrix containing 13 variables and 22 observations (Tab. 3) provides the basis for Q-mode cluster analysis and non-metric Multi-dimensional Scaling Ordination (MDS) on a Bray-Curtis similarity matrix of transformed species abundance data. An R-mode factor analysis was also performed, based on ten variables, i.e. the dominance (proportion pertaining to each species in a given assemblage) of 1) *Trachycardium procerum*, 2) *Trachycardium senticosum*, 3) *Laevicardium clarionense*, 4) *Laevicardium elenense*, 5) *Transennella modesta*, 6) *Chione compta*, 7) *Chione kelletii*, 8) *Strombus subgracilior*, 9) *Xenophora* sp. 1 and 10) the percentage of clay in the 13 bulk-samples involved in the cluster analysis. The first three factors were considered, accounting for 78.0% of the total variability. As shown later, the nine species cited above characterize the biofacies. Data were processed using the PC software *Statgraphics* and *PRIMER*.

The obtained dendrogram (Fig. 8) shows sample affinities, based on the double square-root transformed abundance of the 22 species, using the Bray-Curtis measure of similarity. A line drawn arbitrarily at the similarity level of 30% delineates two groups of samples, whereas samples LO3/31 and LO3/3 remain unclustered. Cluster 1 includes samples LO3/14, LO3/15, LO3/17, LO3/20, LO3/34, LO3/35 and LO3/67 which are from the Piedras Rodadas Sandstone. Cluster 2 comprises samples LO3/39, LO3/58, LO3/59 and LO3/61 mainly from the Arroyo de Arce Norte Sandstone. The MDS ordination (Fig. 9), based on the same similarity matrix, basically shows the same result of the dendrogram and conforms to it. The stress for this two dimensional plot is 0.1043 and implies a fairly good representation. We consider the assemblages yielded by samples in the two clusters along with those of samples LO3/31 and LO3/3 as representative of 4 discrete biofacies which will be described in the following section.

The factor analysis aims to explain the relationships in a relatively large group of assemblages. The data set contains, besides the dominant species in assemblages or groups of assemblages delineated by cluster analysis and MDS, also one environmental variable (clay) in

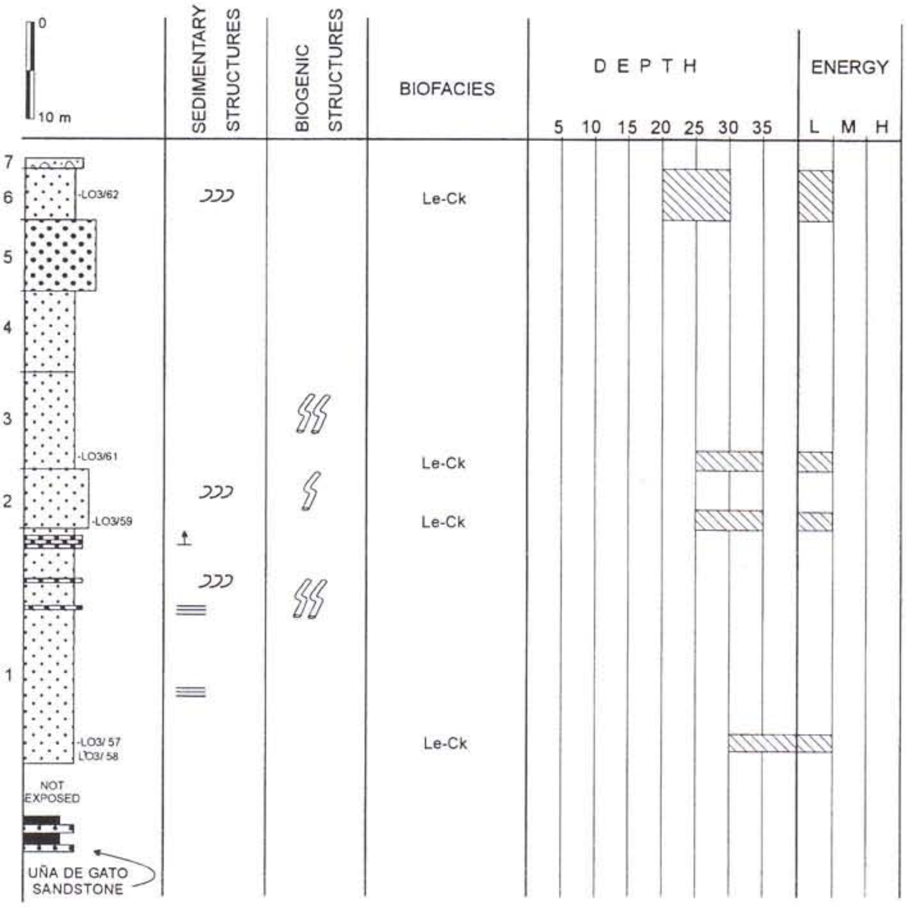

Fig. 7 - Highway (Mexico 1) Section. For legend see Fig. 3.

order to deduce more easily the meaning of the factors. The F1/F2 plot (Fig. 10 A) shows that F1 loads significantly on clay, *Trachycardium procerum* and *Trachycardium senticosum* (loadings 0.89253, 0.94095 and 0.88063 respectively) and does seem to reflect the sediment grain size. It is notable that *Trachycardium procerum* and *Trachycardium senticosum* are in the positive field of F1 as is clay, and are correlated with it. F1 loads insignificantly on the other species (loadings <0.33). *Chione kelletii* and *Laevicardium clarionense* are clearly separated from *Chione compta* and *Transennella modesta* in the space of F2 (loadings 0.71687, 0.71681, -- 0.69913, -- 0.86855 respectively). Since *Chione kelletii* and *Laevicardium clarionense* are reported to dwell in relatively deeper settings in respect to *Chione compta* and *Transennella modesta*, F2 is deduced to reflect bathymetry. *Xenophora* sp. 1, *Strombus subgracilior*, *Trachycardium senticosum*, *Trachycardium procerum* and *Laevicardium elenense* appear to be unrelated to depth (loadings <0.4). The F1/F3 plot (Fig. 10 B) shows a significant load of F3 on *Xenophora* sp. 1 and *Strombus subgracilior* (loadings 0.90403 and 0.91066 respectively). Strombids are known to prefer grassy sand flats where they graze on macroalgae, epiphytes or algal detritus (Abbott, 1960; Pérès, 1982; Geary & Allmon, 1990). Accordingly, F3 is believed to discriminate between presence and absence of seagrass cover of the sea-bottom.

Biofacies interpretation.

The following pertains to the description and paleoenvironmental interpretation of the four biofacies delineated by the statistical treatment of faunal lists (see methodology), and of the other six represented by monospecific or definitely low-diversity assemblages. Biofacies are named using the most abundant, dominant taxa, and discussed in terms of respective organization, bathymetric meaning and assignment to major faunal units. The taxonomic structure was investigated following the approach proposed by Robba (1990). Within each biofacies, only those species having a Dm value greater than or equal to 1 were considered and Dm values attributed to families. In order to base the discussion on the best represented families, only those present in at least 2 biofacies were retained along with those attaining a cumulative Dm greater than or equal to 2. The results of this elaboration are shown in Tab. 4. Tables 5-8 show the composition of the first four biofacies. The species obtained from the various bulk-samples are listed with respective abundance (A) and dominance (D) figures, and ranked according to the decreasing values of the dominance or mean dominance (Dm). The proportions (cumulative D or Dm) of the ecological categories considered are also indicated in the right or bottom part of tables. Table 9 summarizes the basic characters of each biofacies.

Trachycardium procerum-Trachycardium senticosum Biofacies (Tab. 5). This biofacies is recorded only in sample LO3/31 from the basal Piedras Rodadas Sandstone, and occurs in silty, slightly sandy clay (Table 1). It is relatively low-diversity, largely composed (Fig. 11 A) of infaunal molluscs (89.54%) among which the free-lying shallow infaunal element is prevalent (73.26%). Most taxa are mud-related (65.13%), whereas species linked to sandy substrates slightly exceed the total proportion of 6% (Fig. 11 B). Nearly all the biofacies members are suspension-feeders, toghether attaining 98.84% of the total D. *Nuculana* sp. and *Ficus* sp. are the only representatives of respectively detritus-feeding and carnivore

	pebbles	v. coarse sand	coarse sand	medium sand	fine sand	v. fine sand	coarse silt	fine silt	clay	mud
SAMPLE	%	%	%	%	%	%	%	%	%	%
LO3/3	3.411	7.492	14.919	21.292	18.140	16.312	14.023	2.360	2.051	18.434
LO3/14	3.516	1.532	9.802	31.101	37.611	9.167	7.282			7.282
LO3/15	17.720	14.660	10.490	11.750	13.940	16.290	12.290	2.870		15.160
LO3/17	1.164	0.424	1.181	14.442	39.296	23.861	11.964	2.591	5.077	19.632
LO3/18	0.716	0.989	2.342	8.083	24.995	23.100	15.915	5.054	18.807	39.776
LO3/20		0.241	3.608	28.662	34.118	14.962	17.884		0.526	18.410
LO3/22	14.930	10.230	11.840	16.040	15.960	17.110	13.890			13.890
LO3/28	0.503	0.839	4.406	20.096	14.814	17.946	11.198	15.423	14.777	41.397
LO3/29		20.170	20.220	19.030	15.590	8.630	16.360			16.360
LO3/31	0.169	0.250	0.211	0.620	0.533	10.795	13.581	8.649	65.194	87.424
LO3/34	1.339	4.159	8.551	15.883	27.335	24.069	12.507	3.971	2.187	18.664
LO3/35	16.256	1.592	3.519	16.319	28.166	14.241	9.640	3.127	7.140	19.908
LO3/39	2.929	1.263	7.576	19.744	20.528	27.239	10.505	10.134	0.082	20.722
LO3/41	3.941	6.505	15.549	17.427	16.667	19.496	13.912	2.083	4.420	20.416
LO3/42			1.422	9.858	4.146	5.760	15.594	27.452	35.768	78.814
LO3/58			1.005	4.749	18.433	39.404	18.058	1.687	16.665	36.410
LO3/59	2.308	9.033	14.489	26.114	23.181	11.039	5.790	4.233	3.813	13.835
LO3/61	1.126	7.642	10.699	21.652	32.000	16.527	3.894	3.008	3.453	10.354
LO3/67	18.356	4.721	10.634	18.951	26.081	12.028	9.229			9.229

Tab. 1 - Grain size distribution of the studied samples.

trophic practice (Fig. 11 C). In terms of taxonomic structure (Tab. 4), bivalves make up over 96% of the total dominance. The considerable cumulative proportion (39.54%) of cardiids stands as the most distinctive character. The venerids are the second well-represented family (28.49%), followed by psammobiids (11.04%) and arcids (10.46%). Other taxa bear a negligible significance within the biofacies.

On the basis of depth ranges of species (Fig. 11 D), a very shallow inner sublittoral setting can be inferred. In particular, the presence of abundant (16.86%) autochthonous bivalve shells of *Pitar unicolor* firmly points toward a depth of 0-10 m (Keen, 1971; Abbott & Dance, 1982). The other species may range deeper, but also occur in the 0-10 bathymetric interval. The intertidal *Tagelus subteres*, represented by a few poorly preserved valves, is likely to be the unique allochthonous element. According to the interpretation of the F1/F2 plot (Fig. 10 A), *Trachycardium procerum* and *Trachycardium senticosum* are correlated with clay and unrelated to depth. This implies that this biofacies could have also dwelt in deeper infralittoral settings, possibly down to 30 m depth, provided that muddy substrates were available. If so, the replacement of the shallowest elements with more widely ranging species is to be expected. It is of note that both the muddy substrate and the abundant presence of *Trachycardium procerum* provide evidence in favour of a protected environment. The almost exclusive presence of suspension-feeders does suggest rather high sedimentation rate and turbidity due to local terrigenous sources. It is not unlikely that the biofacies considered here might have graded upward to intertidal assemblages similar to the *Chione* association A of Aberhan & Fürsich (1991).

Cardiid-dominated biofacies of shallow, protected muddy bottoms seem to occur uncommonly in the fossil record, and no reliable example from North America is known to us. The *Loxocardium pallasianum* Community described from Oligocene silty deposits of Northern Italy (Lugaresi, 1995) may parallel the *Trachycardium procerum-Trachycardium senticosum* Biofacies in having a basically similar taxonomic structure, with Cardiidae and Veneridae as major components, and being largely dominated by infaunal suspension-feeders. The *Loxocardium pallasianum* Community was inferred to have dwelled shallow infralittoral muddy bottoms in a delta-influenced environment. The *Trachycardium procerum-Trachycardium senticosum* Biofacies exhibits only a superficial resemblance with the Pleistocene assemblages recovered from clayey intercalations in the Palos Verdes Sands of Newport Bay area (California), which were regarded as having occurred in shallow muddy bay bottoms (Bruff, 1946).

A possible modern counterpart is represented by the group of assemblages dominated by the cockle *Fulvia hungerfordi* which were recovered from muddy bottoms in protected inshore embayment conditions in Tolo Harbour, Hong Kong (Shin, 1985), at depth not exceeding 10 m (Morton, 1982). It is to be noted that the abundance *Fulvia hungerfordi* is related primarily to the high level of turbidity brought about by heavy rains (Reid & Shin, 1985). According to these authors, "turbidity is to some extent a necessary condition for the nutrition of the bivalve, since it is a suspension-feeder that acquires resuspended deposit material".

In terms of major faunal units, the *Trachycardium procerum-Trachycardium senticosum* Biofacies may be included in the Pliocene equivalent of the modern shallow-water *Macoma* assemblages (Thorson, 1957; Pérès, 1982). In this frame, the biofacies would represent a peculiar aspect linked to unstable, high-turbidity conditions due to tectonic or climatic events (see Di Geronimo & Robba, 1989).

Chione compta-Transennella modesta Biofacies (Tab. 6). The biofacies is recorded throughout the Piedras Rodadas Sandstone and occurs in slightly silty to silty, occasionally pebbly, moderately sorted sand (Tab. 1). Seven taxa, i.e. *Anadara reinharti*, *Transennella modesta*, *Argopecten circularis circularis*, *Dosinia ponderosa*, *Chione compta*, *Pitar unicolor* and *Pitar* sp., account for over 90% of the total similarity. The biofacies includes low to moderate-diversity individual assemblages, constantly dominated by infaunal taxa which attain 77.06% of the total Dm (Fig. 11 A). The free-lying shallow burrowing element is prominent (67.38%). Semi-infaunal and epifaunal species show balanced proportions and together slightly exceed 22% of the total Dm. The biofacies members exhibit different substrate requirements (Fig. 11 B): 51.17 % are sand-related, 9.72% are mud-related, whereas 15.27% can dwell on various kind of substrates. Suspension-feeders largely outnumber (94.49%) other feeding groups which bear a negligible weight in the biofacies (Fig. 11 C). Regarding the taxonomic structure (Tab. 4), bivalves contribute over 79% of the total Dm to the biofacies. Venerids are the dominant (50.79%) and most diverse family; as many as 8 species may occur in individual assemblages. Arcids, pectinids, cardiids, thraciids and the lucinid *Divalinga eburnea*, in descending order of importance, are other significant components.

The elaboration of depth ranges of species (Fig. 11 D) points toward a shallow inner sublittoral allocation, within a bathymetric interval of 0-10 m or somewhat deeper. This conclusion is consistent with the interpretation of the F1/F2 plot (Fig. 10 A) previously discussed. The abundant presence of *Anadara reinharti* and *Dosinia ponderosa* seems to exclude the shallowest part of the cited interval since these species were never reported in waters shallower than 2-3 m (Rost, 1955; Keen, 1971; Abbott & Dance, 1982). *Argopecten abietis abietis* and *Dosinia ponderosa* were regarded as indicative of bottom currents (Piazza & Robba, 1994). However, the textural features of the beds (Tab. 1) that have yielded the *Chione compta-Transennella modesta* Biofacies show that the original substrate contained a variable proportion of mud (7-20 %). From these two lines of evidence it seems that currents existed in the considered environmental context, but were not swift enough to fully remove silt and clay fractions. The high proportion of suspension-feeders and, conversely, the definitely low total Dm of deposit-feeders (2.60%) do suggest that the greatest part of clay-sized organic detritus was prevented from accumulating and/or resuspended. The composition of the *Chione compta-Transennella modesta* Biofacies reflects that of modern associations which develop in environmental settings protected from the effects of waves. The high percentage of articulated shells in life position (outstanding examples are offered by *Pinna rugosa*, *Dosinia ponderosa* and *Panopea generosa*) and/or the balanced proportion of right and left disarticulated valves indicate that most species were preserved in their original habitat, with little reworking and no transportation. Few intertidal species such as *Chione fluctifraga*, *Tagelus subteres* and *Mytella tumbezensis* along with *Petricola* sp., *Spondylus* sp., *Crucibulum personatum* and *Cardita affinis* which are linked to hard substrates are likely to constitute the allochthonous element.

Up-to-date information on Pliocene molluscan-dominated communities of Baja California is so far lacking. However, on the basis of scanty paleoecological information (Rowland, 1972) and faunal lists (cf. Durham, 1950; Smith, 1991b), the *Chione compta-Transennella modesta* Biofacies seems to have been widespread in the Pliocene shallow inner sublittoral environments of Baja California. The *Tellina bodegensis-Forreria*

Tab. 2 - Species autoecology; species are listed in systematic order. Abbreviations are: VAG INF = vagile infaunal; ATT INF = attached infaunal; FRL SINF = free-lying shallow infaunal; FRL DINF = free-lying deep infaunal; VAG SEMINF = vagile seminfaunal; ATT SEMINF = attached seminfaunal; FRL SEMINF = free-lying seminfaunal; VAG EPIF = vagile epifaunal; ATT EPIF = attached epifaunal; FRL EPIF = free-lying epifaunal; SUPRTD = supratidal; INTD = intertidal; VSISUBL = very shallow inner sublittoral; SISUBL = shallow inner sublittoral; ISUBL = inner sublittoral; SOSUBL = shallow outer sublittoral; DOSUBL = deep outer sublittoral; OSUBL = outer sublittoral; SUBL = sublittoral; LRE = wide ecological range; SSPR = no precise ecological meaning; BC = bottom current; EXP = exposed; PR = protected; UNDET = undetermined; TOL = tolerant, applying to species able to endure a small fraction of sediment other than that they are commonly related to.

Species	Life-habit	Substrate preference	Feeding type	Depth range	Ecological meaning
Nucula exigua	VAG INF	SAND	DEPOSIT	SUBL	TOL SAND-RELATED
Nuculana ornata	VAG INF	UNDET	DEPOSIT	UNDET	UNDET
Nuculana sp.	VAG INF	UNDET	DEPOSIT	UNDET	UNDET
Barbatia sp.	ATT EPIF	HARD	SUSPENSION	SISUBL	UNDET
Anadara concinna	FRL SEMINF	MUD	SUSPENSION	SUBL	TOL MUD-RELATED
Anadara cf. *marksi*	FRL SEMINF	UNDET	SUSPENSION	UNDET	UNDET
Anadara cf. *perlabiata*	FRL SEMINF	UNDET	SUSPENSION	UNDET	UNDET
Anadara reinharti	FRL SEMINF	VARIOUS	SUSPENSION	SUBL	LRE
Anadara sp. 1	FRL SEMINF	UNDET	SUSPENSION	UNDET	UNDET
Anadara sp. 2	FRL SEMINF	UNDET	SUSPENSION	UNDET	UNDET
Anadara sp. 3	FRL SEMINF	UNDET	SUSPENSION	UNDET	UNDET
Anadara sp. 4	FRL SEMINF	UNDET	SUSPENSION	UNDET	UNDET
Anadara sp. 5	FRL SEMINF	UNDET	SUSPENSION	UNDET	UNDET
Anadara sp. 6	FRL SEMINF	UNDET	SUSPENSION	UNDET	UNDET
Glycymeris maculata	FRL SINF	GRAVEL	SUSPENSION	SISUBL	BC
Glycymeris gigantea	FRL SINF	UNDET	SUSPENSION	VSISUBL	UNDET
Glycymeris subobsoleta	FRL SINF	SAND	SUSPENSION	SISUBL	SAND-RELATED, EXP
Glycymeris sp. 1	FRL SINF	UNDET	SUSPENSION	UNDET	UNDET
Glycymeris sp. 2	FRL SINF	UNDET	SUSPENSION	UNDET	UNDET
Glycymeris sp. 3	FRL SINF	UNDET	SUSPENSION	UNDET	UNDET
Mytella tumbezensis	ATT EPIF	MUD	SUSPENSION	INTD	MUD-RELATED
Crenella divaricata	FRL EPIF	GRAVEL	SUSPENSION	SUBL	UNDET
Lithophaga clarki	BORER	HARD	SUSPENSION	UNDET	SSPR
Lithophaga attenuata rogersi	BORER	HARD	SUSPENSION	SUBL	SSPR
Modiolus pseudotulipus	ATT EPIF	UNDET	SUSPENSION	VSISUBL	UNDET
Pinna rugosa	ATT SEMINF	VARIOUS	SUSPENSION	INTD-SISUBL	TOL MUD-RELATED
Atrina sp.	ATT SEMINF	MUD	SUSPENSION	ISUBL	TOL MUD-RELATED
Pteria sterna	ATT EPIF	HARD	SUSPENSION	INTD-ISUBL	LRE
Aequipecten dallasi	FRL EPIF	SAND	SUSPENSION	SISUBL	SAND-RELATED, PR
Argopecten abietis abietis	FRL EPIF	SAND	SUSPENSION	SISUBL	SAND-RELATED, BC
Argopecten circularis circularis	FRL EPIF	VARIOUS	SUSPENSION	INTD-DOSUBL	LRE
Argopecten circularis aequisulcatus	FRL EPIF	SAND	SUSPENSION	ISUBL	TOL SAND-RELATED
Nodipecten nodosus	ATT EPIF	VARIOUS	SUSPENSION	SISUBL	LRE
Flabellipecten stearnsii	VAG EPIF	UNDET	SUSPENSION	SUBL	UNDET
Flabellipecten diegensis	VAG EPIF	VARIOUS	SUSPENSION	SUBL	LRE
Patinopecten healeyi	VAG EPIF	SAND	SUSPENSION	ISUBL	SAND-RELATED
Spondylus princeps	ATT EPIF	HARD	SUSPENSION	ISUBL	SSPR
Spondylus sp.	ATT EPIF	HARD	SUSPENSION	UNDET	SSPR
Anomia peruviana	ATT EPIF	HARD	SUSPENSION	INTD-SOSUBL	PR
Placunanomia cumingii	FRL EPIF	GRAVEL	SUSPENSION	INTD-SOSUBL	UNDET
Pycnodonte hermanni	ATT EPIF	HARD	SUSPENSION	UNDET	UNDET
Pycnodonte erici	ATT EPIF	HARD	SUSPENSION	UNDET	UNDET
Undulostrea megodon	ATT EPIF	HARD	SUSPENSION	SISUBL	SSPR
Crassostrea californica osunai	ATT EPIF	HARD	SUSPENSION	INTD-VSISUBL	SSPR
Dendostrea weatchii	ATT EPIF	HARD	SUSPENSION	INTD-SISUBL	EXP
Myrakeena angelica	ATT EPIF	HARD	SUSPENSION	INTD-SISUBL	BC, PR
Lucina nuttalli nuttalli	FRL DINF	SAND	SUSPENSION	INTD-SOSUBL	TOL SAND-RELATED
Lucina cf. *fenestrata*	FRL DINF	UNDET	SUSPENSION	UNDET	UNDET
Ctena mexicana	FRL DINF	SAND	SUSPENSION	INTD-ISUBL	TOL SAND-RELATED
Linga cancellaris	FRL DINF	GRAVEL	SUSPENSION	SUBL	UNDET
Linga undatoides	FRL DINF	MUD	SUSPENSION	SISUBL	TOL MUD-RELATED
Parvilucina mazatlanica	FRL DINF	UNDET	SUSPENSION	INTD-SISUBL	UNDET
Miltha sp.	FRL DINF	UNDET	SUSPENSION	UNDET	UNDET
Pegophysema cf. *edentuloides*	FRL DINF	UNDET	SUSPENSION	UNDET	UNDET
Divalinga eburnea	FRL DINF	UNDET	SUSPENSION	INTD-DOSUBL	UNDET
Diplodonta inezensis	FRL SINF	GRAVEL	SUSPENSION	ISUBL	UNDET
Felaniella sericata	FRL DINF	MUD	SUSPENSION	INTD-ISUBL	TOL MUD-RELATED
Chama frondosa	ATT EPIF	HARD	SUSPENSION	INTD-VSISUBL	SSPR
Chama echinata	ATT EPIF	HARD	SUSPENSION	INTD-SISUBL	SSPR
Chama sp.	ATT EPIF	HARD	SUSPENSION	UNDET	SSPR
Pseudochama exogira	ATT EPIF	HARD	SUSPENSION	INTD	SSPR
Cardita affinis	ATT EPIF	HARD	SUSPENSION	INTD-SISUBL	SSPR
Cyclocardia megastropha	FRL SINF	SAND	SUSPENSION	SUBL	SAND-RELATED
Eucrassatella gibbosa	FRL SINF	MUD	SUSPENSION	SUBL	TOL MUD-RELATED
Eucrassatella digueti	FRL SINF	SAND	SUSPENSION	SUBL	TOL SAND-RELATED
Trachycardium senticosum	FRL SINF	MUD	SUSPENSION	INTD-SOSUBL	TOL MUD-RELATED
Trachycardium procerum	FRL SINF	MUD	SUSPENSION	SISUBL	TOL MUD-RELATED, PR
Trigonocardia biangulata	FRL SINF	GRAVEL	SUSPENSION	INTD-DOSUBL	UNDET
Trigonocardia cf. *obovalis*	FRL SINF	UNDET	SUSPENSION	UNDET	UNDET
Laevicardium elatum	FRL SINF	MUD	SUSPENSION	INTD-ISUBL	TOL MUD-RELATED
Laevicardium elenense	FRL SINF	SAND	SUSPENSION	INTD-DOSUBL	TOL SAND-RELATED
Laevicardium clarionense	FRL SINF	MUD	SUSPENSION	SUBL	TOL MUD-RELATED

Species	Life-habit	Substrate preference	Feeding type	Depth range	Ecological meaning
Mactra sp.	FRL SINF	SAND	SUSPENSION	SISUBL	SAND-RELATED
Tellina meropsis	FRL DINF	SAND	DEPOSIT	INTD-ISUBL	SAND-RELATED, PR
Tellina simulans	FRL DINF	UNDET	DEPOSIT	INTD-SISUBL	UNDET
Tellina sp. 1	FRL DINF	UNDET	DEPOSIT	UNDET	UNDET
Tellina sp. 2	FRL DINF	UNDET	DEPOSIT	UNDET	UNDET
Macoma cf. *indentata*	FRL DINF	UNDET	DEPOSIT	UNDET	UNDET
Leporimetis cognata	FRL DINF	UNDET	DEPOSIT	INTD-SISUBL	UNDET
Gari cf. *maxima*	FRL DINF	UNDET	SUSPENSION	UNDET	UNDET
Gari helenae	FRL DINF	UNDET	SUSPENSION	UNDET	UNDET
Asaphis sp.	FRL DINF	SAND	SUSPENSION	INTD-SISUBL	TOL SAND-RELATED
Sanguinolaria tellinoides	FRL DINF	SAND	SUSPENSION	INTD-SISUBL	BC
Semele pulchra	FRL DINF	MUD	SUSPENSION	INTD-SISUBL	TOL MUD-RELATED
Semele verrucosa pacifica	FRL DINF	SAND	SUSPENSION	INTD-ISUBL	TOL SAND-RELATED
Tagelus californianus	FRL DINF	SAND	SUSPENSION	INTD-VSISUBL	TOL SAND-RELATED, PR
Tagelus subteres	FRL DINF	MUD	SUSPENSION	INTD	TOL MUD-RELATED, PR
Ventricolaria isocardia	FRL SINF	UNDET	SUSPENSION	SUBL	UNDET
Ventricolaria magdalenae	FRL SINF	UNDET	SUSPENSION	SUBL	UNDET
Transennella modesta	FRL SINF	SAND	SUSPENSION	ISUBL	TOL SAND-RELATED
Pitar unicolor	FRL SINF	MUD	SUSPENSION	INTD-VSISUBL	TOL MUD-RELATED
Pitar cf. *catharius*	FRL SINF	UNDET	SUSPENSION	UNDET	UNDET
Pitar sp.	FRL SINF	UNDET	SUSPENSION	UNDET	UNDET
Megapitaria squalida	FRL SINF	SAND	SUSPENSION	ISUBL	TOL SAND-RELATED
Dosinia ponderosa	FRL SINF	SAND	SUSPENSION	ISUBL	TOL SAND-RELATED
Cyclinella cf. *ulloana*	FRL SINF	UNDET	SUSPENSION	UNDET	UNDET
Chione californiensis	FRL SINF	SAND	SUSPENSION	INTD-VSISUBL	TOL SAND-RELATED, PR
Chione cf. *californiensis*	FRL SINF	UNDET	SUSPENSION	UNDET	UNDET
Chione compta	FRL SINF	SAND	SUSPENSION	SISUBL	TOL SAND-RELATED
Chione fluctifraga	FRL SINF	SAND	SUSPENSION	INTD	TOL SAND-RELATED, PR
Chione cf. *fluctifraga*	FRL SINF	UNDET	SUSPENSION	UNDET	UNDET
Chione gnidia	FRL SINF	SAND	SUSPENSION	INTD-SISUBL	TOL SAND-RELATED
Chione jamaniana	FRL SINF	SAND	SUSPENSION	SISUBL	SAND-RELATED
Chione cf. *purpurissata*	FRL SINF	UNDET	SUSPENSION	UNDET	UNDET
Chione cf. *discrepans*	FRL SINF	UNDET	SUSPENSION	UNDET	UNDET
Chione kellettii	FRL SINF	VARIOUS	SUSPENSION	SUBL	LRE
Chione sp. 1	FRL SINF	UNDET	SUSPENSION	UNDET	UNDET
Chione sp. 2	FRL SINF	UNDET	SUSPENSION	UNDET	UNDET
Chione sp. 3	FRL SINF	UNDET	SUSPENSION	UNDET	UNDET
Protothaca coronadosensis	FRL SINF	UNDET	SUSPENSION	UNDET	UNDET
Petricola sp.	BORER	HARD	SUSPENSION	INTD-SISUBL	SSPR
Corbula nuciformis	ATT INF	MUD	SUSPENSION	SUBL	MUD-RELATED
Corbula sp.	ATT INF	UNDET	SUSPENSION	UNDET	UNDET
Hiatella solida	NESTLER	HARD	SUSPENSION	UNDET	UNDET
Panopea generosa	FRL DINF	SAND	SUSPENSION	INTD-ISUBL	TOL SAND-RELATED
Teredo sp.	BORER	WOOD	SUSPENSION	UNDET	UNDET
Pholadomya cf. *candida*	FRL SINF	UNDET	SUSPENSION	UNDET	UNDET
Periploma planiusculum	FRL SINF	SAND	SUSPENSION	SISUBL	SAND-RELATED
Thracia sp.	FRL SINF	UNDET	SUSPENSION	UNDET	UNDET
Cyatodonta undulata	FRL SINF	SAND	SUSPENSION	INTD-DOSUBL	SAND-RELATED
Cardiomya sp.	FRL SINF	UNDET	CARNIVORE	SUBL	UNDET
Theodoxus luteofasciatus	VAG EPIF	VARIOUS	HERBIVORE	INTD	LRE
Diodora cf. *saturnalis*	VAG EPIF	HARD	HERBIVORE	UNDET	UNDET
Hemitoma natlandi	VAG EPIF	HARD	DEPOSIT	ISUBL	SSPR
Calliostoma annulatum	VAG EPIF	UNDET	DEPOSIT	SISUBL	UNDET
Calliostoma eximium	VAG EPIF	VARIOUS	DEPOSIT	ISUBL	LRE
Calliostoma sp. 1	VAG EPIF	UNDET	DEPOSIT	UNDET	UNDET
Calliostoma sp. 2	VAG EPIF	UNDET	DEPOSIT	UNDET	UNDET
Parviturbo erici	VAG EPIF	UNDET	HERBIVORE	ISUBL	SSPR
Parviturbo sp.	VAG EPIF	UNDET	HERBIVORE	UNDET	UNDET
Macrarene sp.	VAG EPIF	UNDET	HERBIVORE	UNDET	UNDET
Teinostoma sp.	VAG EPIF	UNDET	DEPOSIT	UNDET	UNDET
Collonia sp.	VAG EPIF	UNDET	HERBIVORE	UNDET	UNDET
Tricolia sp. 1	VAG EPIF	SEAGRASS	HERBIVORE	SISUBL	SSPR
Tricolia sp. 2	VAG EPIF	SEAGRASS	HERBIVORE	SISUBL	SSPR
Alabina sp.	VAG EPIF	SEAGRASS	HERBIVORE	SISUBL	SSPR
Bittium sp.	VAG EPIF	UNDET	DEPOSIT	UNDET	UNDET
Cerithium ocellatum	VAG EPIF	SAND	DEPOSIT	SISUBL	UNDET
Cerithium sp. 1	VAG EPIF	UNDET	DEPOSIT	UNDET	UNDET
Cerithium sp. 2	VAG EPIF	UNDET	DEPOSIT	UNDET	UNDET
Cerithium sp. 3	VAG EPIF	UNDET	DEPOSIT	UNDET	UNDET
Cerithium sp. 4	VAG EPIF	UNDET	DEPOSIT	UNDET	UNDET
Turritella marcosensis	VAG SEMINF	SAND	SUSPENSION	UNDET	UNDET
Vermicularia pellucida	ATT EPIF	HARD	SUSPENSION	INTD	SSPR

Species	Life-habit	Substrate preference	Feeding type	Depth range	Ecological meaning
Serpulorbis sp.	ATT EPIF	HARD	SUSPENSION	INTD-VSISUBL	PR
Rissoa sp. 1	VAG EPIF	SEAGRASS	DEPOSIT	SISUBL	SSPR
Rissoa sp. 2	VAG EPIF	SEAGRASS	DEPOSIT	SISUBL	SSPR
Rissoina cf. *stricta*	VAG EPIF	SEAGRASS	DEPOSIT	SISUBL	SSPR
Schwartziella sp.	VAG EPIF	SEAGRASS	DEPOSIT	SISUBL	SSPR
Pusillina sp.	VAG EPIF	SEAGRASS	DEPOSIT	SISUBL	SSPR
Micranellum sp.	VAG EPIF	SAND	DEPOSIT	UNDET	UNDET
Elephantanellum sp.	VAG EPIF	SAND	DEPOSIT	UNDET	UNDET
Strombus subgracilior	VAG EPIF	SAND	HERBIVORE	ISUBL	SSPR
Strombus granulatus cortezianus	VAG EPIF	SAND	HERBIVORE	ISUBL	SAND-RELATED
Strombus sp.	VAG EPIF	UNDET	HERBIVORE	UNDET	UNDET
Crucibulum spinosum	VAG EPIF	VARIOUS	SUSPENSION	INTD-ISUBL	LRE
Crucibulum umbrella	VAG EPIF	HARD	SUSPENSION	INTD	SSPR
Crucibulum personatum	VAG EPIF	HARD	SUSPENSION	SISUBL	SSPR
Crucibulum subacutum	VAG EPIF	UNDET	SUSPENSION	SUBL	UNDET
Xenophora sp. 1	VAG EPIF	UNDET	DEPOSIT	UNDET	UNDET
Xenophora sp. 2	VAG EPIF	UNDET	DEPOSIT	UNDET	UNDET
Dendropoma sp.	ATT EPIF	HARD	SUSPENSION	INTD-VSISUBL	SSPR
Cypraea sp.	VAG EPIF	HARD	HERBIVORE	SISUBL	SSPR
Polinices otis	VAG INF	MUD	CARNIVORE	SUBL	MUD-RELATED
Polinices bifasciatus	VAG INF	SAND	CARNIVORE	INTD-ISUBL	TOL SAND-RELATED
Polinices cf. *bifasciatus*	VAG INF	UNDET	CARNIVORE	UNDET	UNDET
Polinices sp.	VAG INF	UNDET	CARNIVORE	UNDET	UNDET
Cassis sp.	VAG INF	SAND	CARNIVORE	UNDET	UNDET
Galeodea sp.	VAG INF	UNDET	CARNIVORE	UNDET	UNDET
Casmaria cf. vibexmexicana	VAG INF	SAND	CARNIVORE	UNDET	UNDET
Ficus sp.	VAG INF	UNDET	CARNIVORE	UNDET	UNDET
Malea ringens	VAG INF	SAND	CARNIVORE	SISUBL	SAND-RELATED
Triphora sp.	VAG EPIF	HARD	CARNIVORE	UNDET	UNDET
Epitonium sp.	VAG EPIF	UNDET	CARNIVORE	UNDET	UNDET
Hexaplex princeps	VAG EPIF	VARIOUS	CARNIVORE	SISUBL	LRE
Thais sp.	VAG EPIF	HARD	CARNIVORE	INTD-SISUBL	LRE
Melongena patula	VAG EPIF	MUD	CARNIVORE	INTD	TOL MUD-RELATED
Nassarius corpulentus	VAG EPIF	SAND	CARNIVORE	SUBL	SAND-RELATED
Nassarius cf. *versicolor*	VAG EPIF	UNDET	CARNIVORE	UNDET	UNDET
Nassarius tiarula	VAG EPIF	MUD	CARNIVORE	INTD	TOL MUD-RELATED
Nassarius cf. *californianus*	VAG EPIF	UNDET	CARNIVORE	UNDET	UNDET
Nassarius sp. 1	VAG EPIF	UNDET	CARNIVORE	UNDET	UNDET
Nassarius sp. 2	VAG EPIF	UNDET	CARNIVORE	UNDET	UNDET
Nassarius sp. 3	VAG EPIF	UNDET	CARNIVORE	UNDET	UNDET
Colubraria sp. 1	VAG EPIF	UNDET	CARNIVORE	UNDET	UNDET
Colubraria sp. 2	VAG EPIF	UNDET	CARNIVORE	UNDET	UNDET
Agaronia sp.	VAG INF	SAND	CARNIVORE	SISUBL	UNDET
Polystira oxytropis	VAF INF	SAND	CARNIVORE	SUBL	TOL SAND-RELATED
Kylix sp.	VAG INF	UNDET	CARNIVORE	UNDET	UNDET
Crassispira sp.	VAG INF	UNDET	CARNIVORE	UNDET	UNDET
Hindsiclava militaris	VAG INF	SAND	CARNIVORE	SUBL	TOL SAND-RELATED
Conus scalaris	VAG EPIF	SAND	CARNIVORE	SUBL	SAND-RELATED
Conus arcuatus	VAG EPIF	VARIOUS	CARNIVORE	SUBL	UNDET
Conus sp. 1	VAG EPIF	UNDET	CARNIVORE	UNDET	UNDET
Conus sp. 2	VAG EPIF	UNDET	CARNIVORE	UNDET	UNDET
Terebra petiveriana	VAG INF	SAND	CARNIVORE	INTD-ISUBL	SAND-RELATED
Architectonica nobilis	VAG EPIF	SAND	CARNIVORE	INTD-DOSUBL	TOL SAND-RELATED
Turbonilla lamna	VAG EPIF	UNDET	PARASITIC	UNDET	UNDET
Turbonilla cf. *ulloa*	VAG EPIF	UNDET	PARASITIC	UNDET	UNDET
Turbonilla sp.	VAG EPIF	UNDET	PARASITIC	UNDET	UNDET
Acteocina carinata	VAG INF	SAND	CARNIVORE	ISUBL	TOL SAND-RELATED
Ringicula sp.	VAG INF	UNDET	CARNIVORE	SUBL	UNDET
Bulla aspersa	VAG EPIF	SAND	HERBIVORE	UNDET	UNDET
Volvulella cylindrica	VAG INF	MUD	CARNIVORE	SUBL	TOL MUD-RELATED
Pedipes angulatus	VAG EPIF	RUBBLE	HERBIVORE	SUPRTD	UNDET
Dentalium oerstedi	FRL SEMINF	SAND	DEPOSIT	SUBL	TOL SAND-RELATED
Dentalium cf. *divulgatum*	FRL SEMINF	UNDET	DEPOSIT	UNDET	UNDET
Dentalium sp.	FRL SEMINF	UNDET	DEPOSIT	UNDET	UNDET
Tesseracme quadrangulare	FRL SEMINF	SAND	DEPOSIT	ISUBL	SAND-RELATED
Cadulus perpusillus	FRL SEMINF	UNDET	DEPOSIT	SUBL	UNDET
Cadulus sp.	FRL SEMINF	UNDET	DEPOSIT	UNDET	UNDET
Clypeaster marquerensis	VAG INF	SAND	DEPOSIT	INTD-SUBL	SAND-RELATED
Encope grandis	VAG INF	SAND	DEPOSIT	INTD-SISUBL	SAND-RELATED
Encope cf. *grandis*	VAG INF	SAND	DEPOSIT	UNDET	UNDET
Encope angelensis	VAG INF	SAND	DEPOSIT	SISUBL	SAND-RELATED
Encope arcensis	VAG INF	SAND	DEPOSIT	SISUBL	SAND-RELATED
Encope sp.	VAG INF	SAND	DEPOSIT	UNDET	SAND-RELATED

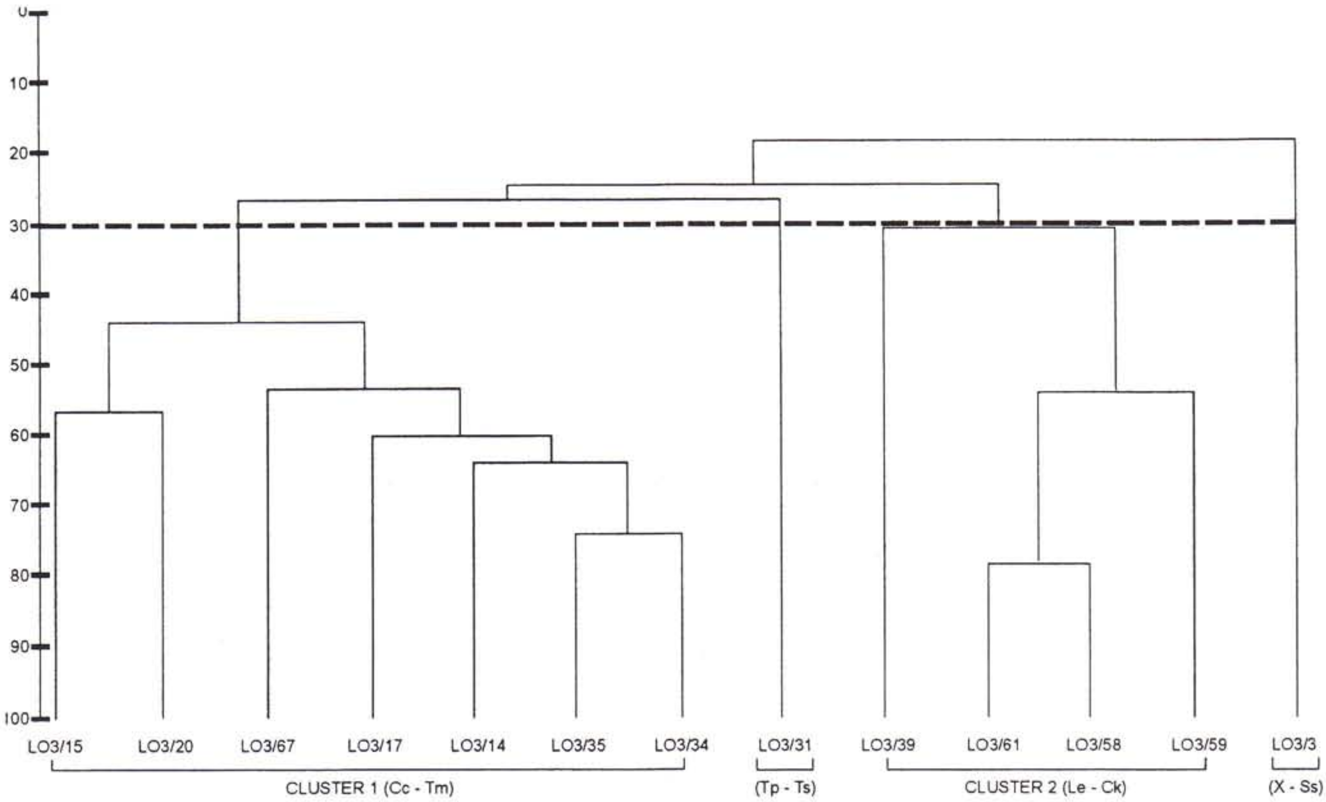

Fig. 8 - Dendrogram obtained from the abundance data matrix of Tab. 3 using the Bray-Curtis measure of similarity. Cc-Tm) *Chione compta-Transennella modesta* Biofacies; Tp-Ts) *Trachycardium procerum-Trachycardium senticosum* Biofacies; Le-Ck) *Laevicardium elenense-Chione kelletii* Biofacies; X-Ss) *Xenophora* sp. 1-*Strombus subgracilior* Biofacies.

belcheri Community described from Southern and Baja California (Valentine, 1961; Valentine & Mellory, 1965) appears to be a reliable Pleistocene analog in having a relatively similar species composition, primarily in terms of *Dosinia ponderosa* element. It is of note that the *Tellina bodegensis-Forreria belcheri* Community was inferred to have dwelt in shallow inner sublittoral (0-30 m) sandy bottoms, in moderately quiet waters (Valentine, 1961; Valentine & Mellory, 1965; Valentine & Rowland, 1969). As regards the Plio-Pleistocene community beds dealt with by Meldahl (1993) in the coastal area of the Gulf of California, any comparison is difficult because of the lack of faunal lists. Some resemblance can be only supposed with Meldahl's community bed type 2 (p. 10).

The benthic megainvertebrate assemblages described in the Gulf of California from intertidal sand beaches and sand-flats to 10 m (Parker, 1964) appear to be the most confident modern analog. In fact, these assemblages seem to have a basically similar taxonomic structure and share several species with the Pliocene biofacies here discussed. In particular, *Pinna rugosa*, *Dosinia ponderosa*, *Chione compta* and a transennellid clam are prominent members in both the modern and fossil assemblages. The presence of the sand dollar *Encope* is further evidence of similarity. The Baja California *Prionospio* Community described by Barnard (1970) in the San Quintin Bay, may be related in being characterized by the clam *Transennella tantilla*. This community develops on sand-flats at depths of from 4 to 10 m. The *Chione compta-Transennella modesta* Biofacies may also parallel the modern assemblages of the shallow continental shelf of the Gulf of Mexico facing the Mississippi delta reported on by Parker (1956). The predominantly sandy bottom stretches from 0 to about 25 m depth off barrier islands, and houses a mollusc-fauna again having a rather similar taxonomic structure: significant components, among the others, are species of *Nuculana*, *Anadara*, *Dosinia*, *Chione* and the Atlantic geoduck *Panopea bitruncata* which is currently regarded as a close relative of *Panopea generosa*. According to Parker (1956), the Atlantic environment is affected by wave action. Thus, assemblages in the Mississippi delta area are to be considered a more exposed modern counterpart. From information on modern analogs, it may be assumed that the *Chione compta-Transennella modesta* Biofacies was typical of the 3-10 m subtidal interval. It graded downward, to approximately 25 m, into the *Laevicardium elenense-Chione kelletii* Biofacies (see below). Assemblages of mixed composition in this range (cf. LO3/41 for example) are similar to those occurring in the Gulf of California between 11 and 26 m (Parker, 1964).

The present biofacies can be assigned to a major faunal unit whose modern analog is represented by the sandy bottom *Venus* Communities dealt with by Thor-

Species	LO3/31	LO3/34	LO3/35	LO3/14	LO3/17	LO3/20	LO3/58	LO3/59	LO3/61	LO3/67	LO3/3	LO3/39	LO3/15
Nuculana exigua					1		3	54	7				
Nuculana ornata							2	32	2				
Anadara concinna	12							34	2				
Anadara reinharti		27	32	8	12	7	2	57	12	2		1	3
Argopecten circularis circularis		1	2	7	24	5	4	35	8	1	2		2
Ctena mexicana							5	112	5				
Parvilucina mazatlanica							1	61	5				
Trachycardium senticosum	29			1	7					10		1	
Trachycardium procerum	34	5			1		1			1			
Laevicardium elenense		3	4	11			59	1129	30			2	
Transennella modesta	2	14	12	9	19	31		8					16
Pitar unicolor	29	1	3		19					8		1	
Pitar sp.				6	35	4							1
Dosinia ponderosa		17	4	5	6					23	1		
Chione compta			27		60	96							13
Chione fluctifraga						24							
Chione cf. *purpurissata*						54							
Chione cf. *discrepans*			1		211								
Chione kelletii							12	29	3			11	
Rissoa sp.2								23					
Polinices bifasciatus								43	2				
Ringicula sp.								90					

Tab. 3 - Data matrix based on 13 samples (variables) and 22 molluscan species (observations). Numerical data in the matrix denote abundance values.

son (1957). According to Pérès (1982), the greatest part of Thorson's *Venus* Communities fits in with the Fine Well-Sorted Sand Assemblages (SFBC) of French bionomists. It is of note that SFBC currently occurs within the bathymetric interval of 3-40 m and exhibits very similar features all over the world. Taking into account the moderate sorting of sand beds that yielded the *Chione compta-Transennella modesta* Biofacies, this latter is likely to represent a less typical aspect of Pliocene SFBC, linked to more protected environmental conditions.

Laevicardium elenense-Chione kelletii Biofacies (Tab. 7). The biofacies occurs primarily in the Arroyo de Arce Norte Sandstone, occasionally in the Piedras Rodadas Sandstone (LO3/39), and was recovered from silty or silty-clayey, moderately to well sorted sand. *Laevicardium elenense*, *Chione kelletii*, *Anadara reinharti*, *Ctena mexicana*, *Argopecten circularis circularis*, *Nucula exigua* and *Nuculana ornata* account for 90% of total similarity. Except for sample LO3/59 that yielded over 70 species, the other individual assemblages are moderately diverse. The infaunal life habit is the most widespread (74.22%), with free-lying shallow burrowers attaining 57.89% of total Dm (Fig. 11 A). Epifaunal (13.90%) and semi-infaunal (11.78%) taxa are less important. As regards the substrate preference (Fig. 11 B), sand-related taxa are prevalent (58.38%), followed by eurytopic (16.90%) and mud-related (11.43%) species. Molluscs having other substrate requirements are also present, but with negligible Dm figures. Suspension-feeders (85.53%), carnivores (7.39%) and deposit-feeders (7.35%) are the significant contributors to the trophic structure (Fig. 11 C). Bivalves largely prevail, but the role of gastropods cannot be neglected (Table. 4). The cardiids *Laevicardium elenense* and *Laevicardium clarionense*, the venerids *Chione kelletii* and *Megapitaria squalida*, the lucinids *Ctena mexicana* and *Parvilucina mazatlanica* along with the gastropod *Turritella marcosensis* are prominent members of the biofacies.

The interpretation of the F1/F2 plot (Fig. 10 A) shows that the present biofacies is deeper than the *Chione compta-Transennella modesta* Biofacies. Constraints for the upper bathymetric limit are 1) the negligible weight of species restricted to the 0-10 m depth range (Fig. 11 D) and 2) the presence of dominant taxa such as *Chione kelletii* and *Laevicardium clarionense* which are never reported to occur shallower than 20 m (Hertlein & Strong, 1948, 1955; DuShane & Poorman, 1967). Some species, viz. *Ctena mexicana* and *Polinices bifasciatus* among the others, seem not to range deeper than 40 m (DuShane & Poorman, 1967). Thus, the *Laevicardium elenense-Chione kelletii* Biofacies is likely to have developed on sandy bottoms, from 20 m down to at least 40 m or slightly deeper. This inference is consistent with the great proportion (68.98% of total Dm) of eurybathyc molluscs (Fig. 11 D). As already noted, the *Laevicardium elenense-Chione kelletii* Biofacies and the *Chione compta-Transennella modesta* Biofacies may have overlapped in the bathymetric interval of between 10 and 25 m, grading into one another. Wave action can be

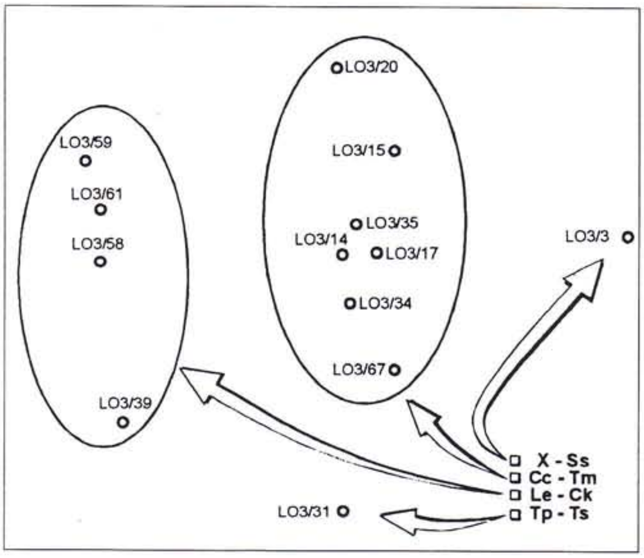

Fig. 9 - MDS ordination of samples based on the abundance data matrix of Tab. 3. Letter codes for biofacies are as in Fig. 8.

considered to have been negligible at the above cited depths. The proportion of mud (10-36 %) and of deposit-feeders (7.35% of total Dm) greater than that noted for the *Chione compta-Transennella modesta* Biofacies, points toward weaker current energy. This conclusion is also supported by the small number of allochthonous specimens which constitute 4 to nearly 7 percent of the individual assemblages. In fact, only shells of intertidal species along with those of species linked to hard substrates, pebbles and seagrass are regarded to have undergone significant transport.

No fossil communities or assemblages are known to the present authors which can explicitly parallel the *Laevicardium elenense-Chione kelletii* Biofacies. The *Lucinoma annulata-Turcica caffea* community of Southern and Baja California reported on by Valentine (1961) may be a Pleistocene equivalent of more muddy bottom within the same depth range.

The assemblages occurring in the Gulf of California, on sandy or muddy bottoms between 27 and 65 m (Parker, 1964), seem to be a modern counterpart because of similar taxonomic structure. It is notable that *Chione kelletii* is listed among the significant living species. The assemblages of the deeper continental shelf of the Gulf of Mexico in the Mississippi delta region (Parker, 1956) exhibit a close similarity too, and seem to represent the modern Atlantic analog. These assemblages were encountered on various fine-grained substrates, at depths greater than 25 m.

As regards the assignment of the present biofacies to major faunal units, the same conclusions already drawn concerning the *Chione compta-Transennella modesta* Biofacies are considered to be appropriate. The *Laevicardium elenense-Chione kelletii* Biofacies is likely to represent a deep, low-energy aspect of the Pliocene SFBC.

Xenophora sp. 1-Strombus subgracilior Biofacies (Tab. 8). It is recorded in sample LO3/3 from the upper Piedras Rodadas Sandstone and occurs in silty, moderately sorted sand (Tab. 1). The unique assemblage on which the biofacies is based is moderately low-diversity, dominated by epifaunal (79.99% of total D), mostly vagile taxa; the attached life-habit attains only 8.33% (Fig. 11 A). Species are primarily sand-related forms (33.34%) or eurytopic (Fig. 11 B) and adapted to a variety of substrates (18.33%). Each of the 4 trophic groups represented significantly contributes to the trophic structure (Fig. 11 C). In descending order of importance they are: suspension-feeders (31.67%), deposit-feeders (26.67%), carnivores (26.66%) and herbivores (15.00%). A marked difference in respect to the trophic organization of the 3 previously considered biofacies, largely dominated by suspension-feeders, is noticed. The dissimilarity further increases if taxonomic structure is considered (Tab. 4). In fact, gastropods are the prominent element and outnumber bivalves in terms of cumulative dominance attained by the most abundant species (71.65%). Relevant components are *Xenophora* sp. 1, *Strombus subgracilior*, conids, turritellids and, among bivalves, the family Pectinidae which is the most diverse.

Strombus gracilior, the modern counterpart of *Strombus subgracilior*, is reported to dwell on intertidal and subtidal sandy bottoms of the Gulf of California down to 45 m (Kerstitch, 1989). Known depth ranges of extant species belonging to the biofacies (Fig. 11 D) suggest a 0-30 m bathymetric interval, but the abundant occurrence of *Xenophora*, a moderately shallow to deep water element, leads us to propose a 10-30 m interval. It is not unlikely that the biofacies may have ranged also somewhat deeper in the infralittoral zone. According to the interpretation of the F1/F2 and F1/F3 plots (Fig. 10), the *Xenophora* sp. 1-*Strombus subgracilior* Biofacies was scarcely related to depth and primarily controlled by the presence of vegetal cover on the sea-floor. Strombids consumed algae associated with seagrass whereas deposit-feeders utilized more degraded organic matter. The *Xenophora* sp. 1-*Strombus subgracilior* Biofacies is supposed to have been a lateral equivalent of both the *Chione compta-Transennella modesta* and *Laevicardium elenense-Chione kelletii* biofacies which dwelt on unvegetated sandy bottoms. The trophic structure, primarily the significant total D attained by deposit-feeders, and the proportion of mud (18.43%) do suggest a low-energy environment. This inference is consistent with the negligible number of specimens (4% of total abundance) which are not in their original life environment as indicated by fragmentation and/or sorting of disarticulated valves.

The *Strombus floridanus* layer in the Pliocene "Pinecrest Beds" of Florida discussed by Geary & Allmon (1990) provides a suitable comparison. This layer ap-

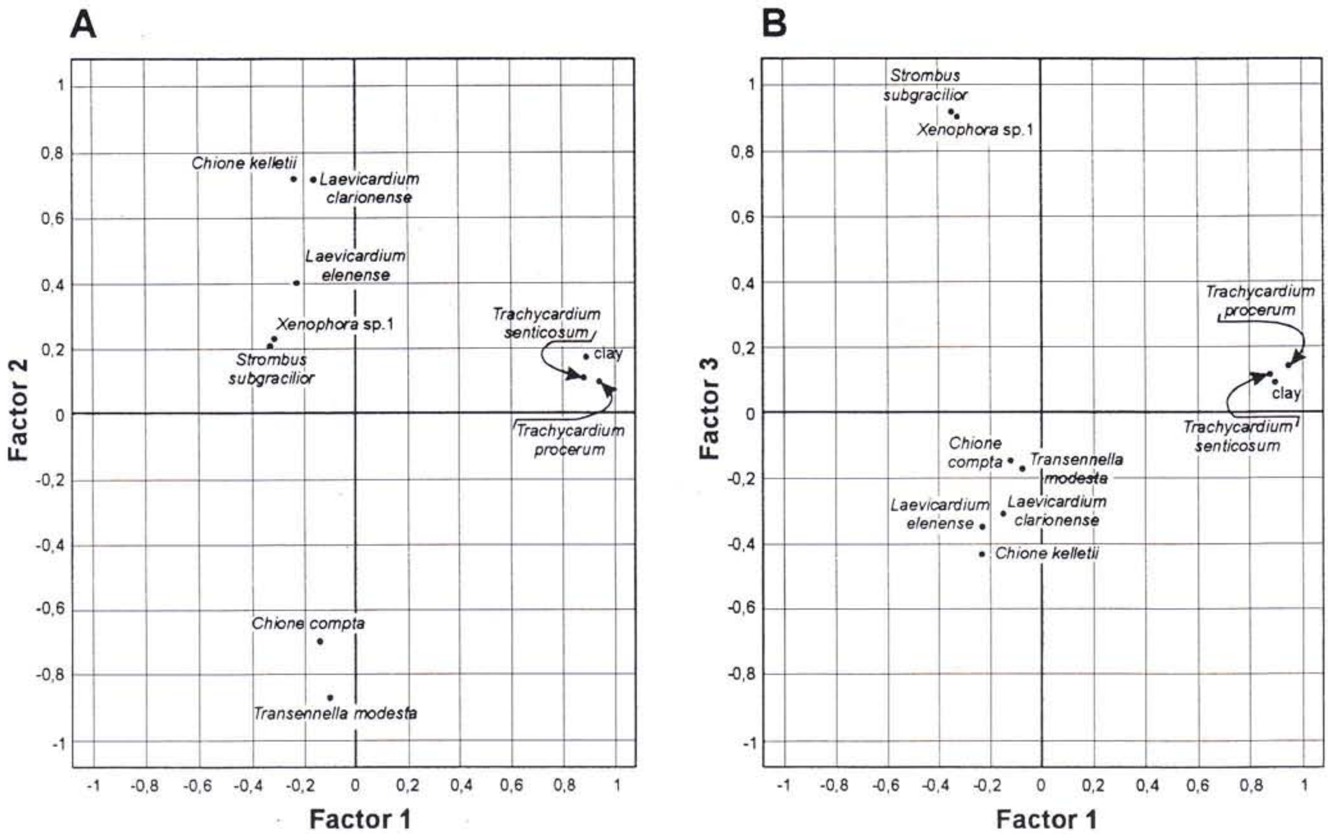

Fig. 10 - Plot of the first three factors (for variables see text) and their interpretation. F1, F2 and F3 denote respectively grain size, bathymetry and seagrass cover of the sea-bottom. A: F1/F2 plot; B: F1/F3 plot.

pears to have formed in a very different way in respect to the LO3/3 bed that yielded the *Xenophora* sp. 1-*Strombus subgracilior* Biofacies. In fact, according to the cited authors (p. 260), it "probably resulted from episodically high rates of sedimentation, followed by sediment winnowing by storms and condensation of shells". Apart from that, the parautochthonous shallow inner sublittoral assemblages which contributed to the formation of the *Strombus floridanus* layer seem to parallel the *Xenophora* sp. 1-*Strombus subgracilior* Biofacies in terms of taxonomic composition. It is of note that 12 out of 14 significant families represented in the Mexican biofacies are also present in the *Strombus floridanus* layer. This latter is taxonomically richer possibly because of the way it formed. The autochthonous and parautochthonous *Strombus* assemblages of the Mediterranean Basin are likely to be a Pleistocene (Tyrrhenian) counterpart. These assemblages, commonly dominated by *Strombus bubonius*, are composed by taxa related to a sandy seafloor with a vegetal cover of *Posidonia* and/or *Caulerpa*. A pertinent example from Lebanon was reported on by Fleisch et al. (1971) and inferred to have inhabited a sandy bottom 10-20 m deep.

The present biofacies may be confidently assigned to a Pliocene equivalent of the assemblages of modern Soft Bottoms with Metaphytes of the infralittoral zone, extensively dealt with by Pérès (1982). According to this author, the fauna is dominated by gastropods and, in tropical areas, comprises large-sized molluscs such as strombids, cypraeids and conids.

Crassostrea californica osunai Biofacies. Only one record from the mid-upper part of the Piedras Rodadas Sandstone (LO3/24) is available. There, large-sized *Crassostrea californica osunai* shells occur in living position to form the top of a coarse sand-layer in between two conglomeratic bodies. The oyster build up, some 20 cm-thick, is truncated by the upper conglomerate. The *Crassostrea* bed was interpreted as an incipient fringe reef killed by sudden pebble deposition (Piazza & Robba, 1994). Modern *Crassostrea*-reefs develop in a variety of environments such as delta shores, shallow bays and lagoons, banks of tidal streams, at depths hardly exceeding 6-7 m (Puffer & Emerson, 1953; Emery et al., 1957; Stenzel, 1971). Pertinent examples from western Atlantic and Pacific oceans are offered respectively by the extant species *Crassostrea virginica* and *Crassostrea gigas* (Johnson & Foster, 1951; Puffer & Emerson, 1953; Parker, 1956); *Crassostrea*-reefs were also reported to occur in the Gulf of California (Townsend, 1916). It is notable that *Crassostrea* species are chiefly estuarine elements, preferring low salinity (2-30‰) conditions (Parker, 1956; Harry, 1985). Thus, the *Crassostrea californica osunai* Biofacies seems to record definitely shallow, brac-

GROUPS	Cc-Tm	Tp-Ts	Le-Ck	X-Ss
NUCULIDAE			3.12	
ARCIDAE	9.88	10.46	4.68	
PECTINIDAE	6.45		4.96	20.00
LUCINIDAE	2.09	1.74	6.04	
CARDIIDAE	6.01	39.54	42.66	1.67
MACTRIDAE		5.23		
PSAMMOBIIDAE		11.04		
VENERIDAE	50.79	28.49	10.55	1.67
THRACIIDAE	4.07			
SUBTOTALS (%)	79.29	96.50	72.01	23.34
TURRITELLIDAE			5.28	6.67
STROMBIDAE				13.32
XENOPHORIDAE				26.67
NATICIDAE			1.07	1.67
CASSIDAE				3.34
TONNIDAE				3.33
NASSARIIDAE				3.33
CONIDAE			1.91	13.32
SUBTOTALS (%)			8.26	71.65
TOTALS (%)	79.29	96.50	80.27	94.99

Tab. 4 - Taxonomic structure of the four biofacies delineated by the statistical treatment (see text for the procedure followed). Letter codes for biofacies are as in Fig. 8.

kish waters in a delta environment. The textural features of the sediment suggest a high-energy context linked to current action.

The biofacies seems to have occurred elsewhere in Baja California Sur during Late Miocene-Early Pliocene times, as indicated by the abundant presence of *Crassostrea californica osunai* in some layers of the Trinidad Formation (Rodriguez Quintana & Segura Vernis, 1992).

Myrakeena angelica Biofacies. This common oyster occurs throughout the Piedras Rodadas Sandstone. Shells of *Myrakeena angelica* in living position, adhering to pebbles or to one another, were noted to form layers or clusters at the top of moderately sorted sandy beds that yielded the *Chione compta-Transennella modesta* Biofacies. *Myrakeena angelica* lives in water of marine oceanic salinity, on current-influenced bottoms sheltered from strong wave action, from very low tide level down to 5 m (Harry, 1985; Moore, 1987). On the basis of the available information, Piazza & Robba (1994) deduced that Pliocene oysters record the same environmental conditions in which *Myrakeena angelica* lives today. *Myrakeena angelica* has a totally different meaning in respect to *Crassostrea californica osunai* as regards salinity requirements, and is indicative of high-salinity marine waters. *Ostreola equestris*, reported to form small reefs in bays of the Texas coast (Puffer & Emerson, 1953; Parker, 1959), may be a modern Atlantic counterpart. It is notable that this species may completely replace the bay oyster *Crassostrea virginica* at stable high salinities (Parker, 1959).

Vermetid-*Nodipecten* Biofacies. The biofacies was noted at two locations in the Piedras Rodadas Sandstone: 1) level 8 (LO3/28) of the Arroyo de Arce Section and 2) uppermost part of level 12 of the Piedras Rodadas Section. It is characterized by tubes of an unidentified species of *Serpulorbis* whose maximum diameter attains 15 mm, and by many specimens of the thick-shelled scallop *Nodipecten nodosus*. Other common associates are the large venerid *Dosinia ponderosa* and *Chama* sp. Vermetids make up a few decimeters thick relatively loose aggregation, infilled with sand, on which the other molluscs rest or are partly embedded in living position. The scallops lie parallel to bedding with the right valve undermost; the upper left valve is often heavily encrusted by serpulid worms, barnacles and vermetids. The hard substrate required by vermetid snails consists of *Myrakeena angelica* shells and/or pebbles at both locations.

The genus *Serpulorbis* includes species having tubes which are the largest of the family (Keen, 1961). Some species, namely the extant Californian *Serpulorbis squamigerus*, are colonial and construct more or less crowded aggregates (Keen, 1961; Morton, 1965). It is of note that loose vermetid aggregations currently occur in calm waters (Al Barash & Zenziper, 1985) and that the mucous feeding *Serpulorbis* prefers "quieter and more sheltered situations" (Morton, 1965). Piazza & Robba (1994), dealing with this biofacies, interpreted the vermetid mat as formed at a depth of 2-5 m. Actually, 1) vermetids are mainly intertidal or occur slightly below low water mark (Kay, 1979; Al Barash & Zenziper, 1985; Laborel, 1987); 2) *Myrakeena angelica*, on which the considered vermetid mats often settle, is never found deeper than 5 m (Harry, 1985; Moore, 1987); 3) *Dosinia ponderosa* was never reported to occur in waters shallower than 2-3 m (Keen, 1971; Abbott & Dance, 1982). From these lines of evidence, the paleobathymetry inferred by Piazza & Robba (1994) seems reliable. This implies that, during the Pliocene, *Nodipecten nodosus* also dwelt in environments shallower than those currently inhabited by modern specimens. The Vermetid-*Nodipecten* Biofacies is regarded as indicative of sheltered conditions, protected from wave action.

Argopecten abietis abietis Biofacies. It occurs uncommonly in the Piedras Rodadas Sandstone, the most outstanding example being observable in level 22 (LO3/22) of the Arroyo de Gua Section. The biofacies consists of whole shells of *Argopecten abietis abietis* in living position, forming scattered clumps in pebbly sand, currently at the top of beds that yielded the *Chione compta-Transennella modesta* Biofacies. It is of note that these monospecific-dominated layers attain a thickness of approximately 10-15 cm, and specimens in each individual cluster hardly exceed ten in number. The *Ar-*

Species	LO3 /31			
	A	D	FRL SEMINF	10.46
Trachycardium procerum	34	19.77	FRL SINF	73.26
Trachycardium senticosum	29	16.86	FRL DINF	14.53
Pitar unicolor	29	16.86	VAG INF	1.75
Pitar cf. *catharius*	18	10.47		
Gari helenae	16	9.30	MUD	65.13
Anadara concinna	12	6.98	SAND	6.40
Mactra sp.	9	5.23	UNDET	28.47
Laevicardium clarionense	5	2.91		
Miltha sp.	3	1.74	SUSPENSION	98.84
Gari cf. *maxima*	3	1.74	DEPOSIT	0.58
Tagelus subteres	3	1.74	CARNIVORE	0.58
Anadara sp. 1	2	1.16		
Anadara sp. 2	2	1.16	INTD	1.74
Anadara sp. 4	2	1.16	INTD-VSISUBL	16.86
Transennella modesta	2	1.16	INTD-SOSUBL	16.87
Nuculana sp.	1	0.58	SISUBL	25.01
Atrina sp.	1	0.58	ISUBL	1.16
Ficus sp.	1	0.58	SUBL	9.89
TOTAL	172		UNDET	28.47

Tab. 5 - Composition of the *Trachycardium procerum-Trachycardium senticosum* Biofacies. Symbols are: A = abundance; D = dominance (%). Numbers in the right column are percentages. Abbreviations are as in Tab. 2.

gopecten abietis abietis Biofacies was inferred to have dwelt in current-influenced bottoms (Piazza & Robba, 1994).

Argopecten abietis abietis, like other members of the genus *Argopecten* (Waller, 1969), presumably lived unattached when fully grown. The wide umbonal angle (111°-118°) along with the relatively low auricle asymmetry ratio (less than 1.4) suggest that this scallop was able to swim (Stanley, 1970). However, swimming in *Argopecten abietis abietis* likely was an escape response to disturbance of any kind, and the animals spent most of their time reclining on the substrate, resting on the convex right valve. Waller (1969) reported that *Pecten maximus*, *Placopecten magellanicus*, *Argopecten irradians irradians* and species of *Notovola*, *Equichlamys* and *Mimachlamys* tend to lie "recessed in the bottom in a self-formed depression". The author stated that "the capacity to recess may indeed be widespread among unattached pectinids" and regarded it as a possible strategy "to stabilize the position of the scallop in areas of strong current". The current-related *Argopecten abietis abietis* quite possibly behaved like the above cited taxa, and this is consistent with the overgrowth of encrusters, primarily barnacles, noted in some instances upon the upper left valve. The nearly equiconvex shell may suggest that the scallop was adapted to both open-marine and inshore conditions (Waller, 1969).

Several pectinids are gregarious. Good examples among the others are offered by *Pecten maximus*, *Notovola meridionalis*, *Placopecten magellanicus*, *Argopecten gibbus*, *Argopecten irradians amplicostatus* (Fleming, 1957; Waller, 1969; Smith, 1991a), *Aequipecten opercularis* (Tebble, 1976; Seneš & Ondrejcíková, 1991) and by the Hawaiian *Haumea juddi* (Kay, 1979). *Argopecten abietis abietis* should have congregated in extensive beds with great density as suggested by the occurrence of thick shell beds entirely formed by an enormous number of allochthonous concave-down valves of this scallop. However, large autochthonous beds were never encountered during field work and, quite possibly, were not preserved. The considered biofacies is here interpreted as an incipient *Argopecten abietis abietis* bed which did not grow because of 1) sudden decrease of the current speed, 2) increase of the sedimentation rate and 3) consequent re-settlement of the *Chione compta-Transennella modesta* Biofacies.

The frequent presence of the *Myrakeena angelica* Biofacies immediately overlying clumps of *Argopecten abietis abietis* firmly points toward a water depth of approximately 5 m. The autochthonous occurrence within different sandy-bottom biofacies suggests that *Argopecten abietis abietis* likely ranged in the 5-30 m bathymetric interval. However, dense populations forming beds seem to have preferentially settled at around 5 m depth, i.e. close to the lower limit of *Myrakeena angelica*. In summary, scallop clumps denote relatively strong bottom current in definitely shallow water environment.

Several quotations of pectinid-rich beds are found in the paleontological literature, but none of these explicitly refer to autochthonous monospecific scallop assemblages that may parallel the *Argopecten abietis abietis* Biofacies. One record, concerning the New Zealand Castlecliffian *Pecten modestus kupei*, is worthy of note. Fleming (1957), with reference to the type collection of this taxon from the top of the Kupe Formation, reported that "abundant *Pecten*, lying with their right valves downward, are concentrated along the bedding in a zone about 3 in. thick". This occurrence of *Pecten modestus kupei* possibly represents a New Zealand analog of the *Argopecten abietis abietis* biofacies.

Tab. 6 - Composition of the *Chione compta-Transennella modesta* Biofacies. Symbols are: A = abundance; Am = mean abundance; D = dominance (%); Dm = mean dominance (%). Numbers in the bottom part are percentages. Abbreviations are as in Tab. 2.

Species	LO3 /14		LO3 /17		LO3 /67		LO3 /35		LO3 /34		LO3 /15		LO3 /20			
	A	D	A	D	A	D	A	D	A	D	A	D	A	D	Am	Dm
Chione compta			60	23.81			27	21.26			13	24.07	96	21.43	28.00	12.94
Transennella modesta	9	8.74	19	7.54			12	9.45	14	11.20	16	29.63	31	6.92	14.43	10.50
Anadara reinharti	8	7.77	12	4.76	2	2.74	32	25.20	27	21.60	3	5.56	7	1.56	13.00	9.88
Dosinia ponderosa	5	4.85	6	2.38	23	31.51	4	3.15	17	13.60					7.86	7.93
Chione cf. *discrepans*							1	0.79					211	47.10	30.29	6.84
Chione gnidia	1	0.97	13	5.16	1	1.37			12	9.60	8	14.81			5.00	4.56
Cyatodonta undulata	6	5.83	6	2.38	6	8.22	13	10.24	2	1.60			1	0.22	4.86	4.07
Argopecten circularis circularis	7	6.80	24	9.52	1	1.37	2	1.57	1	0.80	2	3.70	5	1.12	6.00	3.55
Pitar sp.	6	5.83	35	13.89							1	1.85	4	0.89	6.57	3.21
Pitar unicolor			19	7.54	8	10.96	3	2.36	1	0.80					4.43	3.09
Argopecten abietis abietis	17	16.50	3	1.19			3	2.36					1	0.22	3.43	2.90
Trachycardium senticosum	1	0.97	7	2.78	10	13.70									2.57	2.49
Laevicardium elenense	11	10.68					4	3.15	3	2.40					2.57	2.32
Divalinga eburnea	7	6.80	15	5.95							1	1.85			3.29	2.09
Chione cf. *purpurissata*													54	12.05	7.71	1.72
Felaniella sericata									11	8.80					1.57	1.26
Pinna rugosa	7	6.80					1	0.79	1	0.80					1.29	1.20
Trigonocardia cf. *obovalis*	4	3.88	2	0.79							2	3.70			1.14	1.20
Bulla aspersa			4	1.59	3	4.11	2	1.57							1.29	1.04
Tellina simulans							1	0.79	7	5.60					1.14	0.91
Trachycardium procerum			1	0.40	1	1.37			5	4.00					1.00	0.82
Panopea generosa			1	0.40	1	1.37			5	4.00					1.00	0.82
Chione cf. *californiensis*			12	4.76					1	0.80					1.86	0.79
Petricola sp.											3	5.56			0.43	0.79
Chione fluctifraga													24	5.36	3.43	0.77
Tagelus californianus	5	4.85	1	0.40											0.86	0.75
Corbula sp.	1	0.97			3	4.11									0.57	0.73
Laevicardium clarionense							2	1.57			1	1.85	5	1.12	1.14	0.65
Pholadomya cf. *candida*					2	2.74			2	1.60					0.57	0.62
Megapitaria squalida							4	3.15	1	0.80					0.71	0.56
Leporimetis cognata			1	0.40	2	2.74			1	0.80					0.57	0.56
Turritella marcosensis					1	1.37			3	2.40					0.57	0.54
Tagelus subteres					1	1.37					1	1.85			0.29	0.46
Pitar cf. *catharius*			6	2.38											0.86	0.34
Macoma cf. *indentata*							3	2.36							0.43	0.34
Nassarius sp. 1							3	2.36							0.43	0.34
Conus arcuatus											1	1.85	2	0.45	0.43	0.33
Polinices cf. *bifasciatus*							2	1.57					3	0.67	0.71	0.32
Eucrassatella gibbosa					1	1.37			1	0.80					0.29	0.31
Laevicardium elatum					1	1.37			1	0.80					0.29	0.31
Encope sp.	2	1.94													0.29	0.28
Spondylus sp.											1	1.85			0.14	0.26
Chione cf. *fluctifraga*											1	1.85			0.14	0.26
Crucibulum personatum	1	0.97					1	0.79							0.29	0.25
Ventricolaria magdalenae					1	1.37							1	0.22	0.29	0.23
Polinices sp.							1	0.79	1	0.80					0.29	0.23
Flabellipecten diegensis					1	1.37									0.14	0.20
Tellina sp. 2					1	1.37									0.14	0.20
Sanguinolaria tellinoides					1	1.37									0.14	0.20
Nassarius sp. 2					1	1.37									0.14	0.20
Colubraria sp. 2					1	1.37									0.14	0.20
Periploma planiusculum			1	0.40					1	0.80					0.29	0.17
Anadara cf. *marksi*	1	0.97													0.14	0.14
Anadara sp. 5	1	0.97													0.14	0.14
Trigonocardia biangulata	1	0.97													0.14	0.14
Chione sp. 3	1	0.97													0.14	0.14
Encope arcensis	1	0.97													0.14	0.14
Anadara cf. *perlabiata*			1	0.40									2	0.45	0.43	0.12
Semele pulchra									1	0.80					0.14	0.11
Mytella tumbezensis									1	0.80					0.14	0.11
Atrina sp.									1	0.80					0.14	0.11
Cardita megastropha									1	0.80					0.14	0.11
Eucrassatella digueti									1	0.80					0.14	0.11
Cyclinella cf. *ulloana*									1	0.80					0.14	0.11
Strombus subgracilior									1	0.80					0.14	0.11
Cardita affinis							1	0.79							0.14	0.11
Asaphis sp.							1	0.79							0.14	0.11
Semele verrucosa pacifica							1	0.79							0.14	0.11
Calliostoma sp. 2							1	0.79							0.14	0.11
Crucibulum spinosum							1	0.79							0.14	0.11

Species	LO3 /14		LO3 /17		LO3 /67		LO3 /35		LO3 /34		LO3 /15		LO3 /20			
	A	D	A	D	A	D	A	D	A	D	A	D	A	D	Am	Dm
Conus sp. 1							1	0.79							0.14	0.11
Nucula exigua			1	0.40											0.14	0.06
Mactra sp.			1	0.40											0.14	0.06
Crucibulum subacutum			1	0.40											0.14	0.06
Colubraria sp. 1													1	0.22	0.14	0.03
TOTAL	103		252		73		127		125		54		448			

ATT EPIF	0.48	MUD	9.72	SUSPENSION	94.49	INTD	1.34
FRL EPIF	6.45	SAND	51.17	DEPOSIT	2.60	INTD-VSISUBL	3.84
VAG EPIF	3.09	GRAVEL	0.14	HERBIVORE	1.15	INTD-SISUBL	8.56
ATT SEMINF	1.31	VARIOUS	15.27	CARNIVORE	1.76	INTD-ISUBL	2.61
FRL SEMINF	10.28	HARD	1.41			INTD-SOSUBL	2.49
VAG SEMINF	0.54	UNDET	22.29			INTD-DOSUBL	12.17
ATT INF	0.73					SISUBL	17.28
FRL SINF	67.38					ISUBL	19.21
FRL DINF	7.92					SUBL	11.94
VAG INF	1.03					UNDET	20.56
BORER	0.79						

Tab. 7 - Composition of the *Laevicardium elenense-Chione kelletii* Biofacies. Symbols are: A = abundance; Am = mean abundance; D = dominance (%); Dm = mean dominance (%). Numbers in the bottom part are percentages. Abbreviations are as in Tab. 2.

Aequipecten dallasi Biofacies. This biofacies was noted in sandy beds of the mid-upper Piedras Rodadas Sandstone. The most significant occurrence is in the basal level 9 (LO3/29) of the Arroyo de Arce Section. The biofacies consists of monospecific autochthonous assemblages characterized by the scallop *Aequipecten dallasi* with whole shells in living position. The upper, left valve is occasionally encrusted by the foraminifer *Cibicides* and exhibits rare *Polydora* borings.

The life habit of *Aequipecten dallasi* would have been similar to that of the Recent Atlantic-Mediterranean *Aequipecten opercularis*, i.e. attached by byssus in early life becoming free, able to swim when mature (Tebble, 1976). Values of umbonal angle (105°-110°) and of auricle asymmetry ratio (1.3-1.6) are transitional between ranges of respectively byssally-attached and free-swimming pectinids (Stanley, 1970; fig. 11). According to Piazza & Robba (1994), this sand-related scallop preferred relatively sheltered, low energy conditions, being replaced by *Argopecten abietis abietis* in current-influenced bottoms. The authors suggested that *Aequipecten dallasi* may have the same paleobathymetric meaning as *Argopecten abietis abietis* (5-30 m) and no evidence stands against this inference. However, on account of its location immediately at the top of the Vermetid-*Nodipecten* Biofacies, the *Aequipecten dallasi* assemblage here considered seems to have settled in very shallow water, at a depth hardly exceeding 5 m. It is not unlikely that the *Aequipecten dallasi* Biofacies might have occurred at greater depths, but no data were obtained in this respect.

The *Aequipecten dallasi* Biofacies may be a shallower analog of the *Aequipecten opercularis*-dominated assemblages cited by Seneš (1988) and Seneš & Ondrejcíková (1991) as regards the Mediterranean Sea. These authors reported on mass-occurrences of this scallop on sandy bottoms at depths of from 25 to 40 m. It is of note that the shallowest occurrences of *Aequipecten opercularis* are at extreme low tide (Poppe & Goto, 1993). Seneš & Ondrejcíková (1991) listed a number of Central European Miocene localities where similar fossil assemblages were recovered.

Encope Biofacies. The biofacies was noted in the mid-upper Piedras Rodadas sandstone and is characterized by monospecific assemblages of either *Encope grandis* (LO3/23, sand) or *Encope angelensis* (LO3/19, pebbly sand). These sand dollars are found in large numbers, occurring in life position parallel to bedding.

The Pliocene to Recent *Encope grandis* is widespread in the Gulf of California and ranges from low-intertidal zone down to 46 m (Kerstitch, 1989). The species is reported to be a conspicuous element on sand flats, often forming large beds (Mortensen, 1948; McLean, 1961; Kerstitch, 1989; Fürsich et al., 1991). According to Durham (1950), the strictly Pliocene *Encope angelensis* and the living *Encope stokesii* "may belong to the same stock". The latter taxon is strictly littoral (Mortensen, 1948). On the basis of the available information, the *Encope* Biofacies can be considered indicative of a bathymetric allocation at or just below the low tide mark, and of turbulent water related to surf.

Autochthonous, monospecific sand dollar assemblages that perfectly compare to the one here considered

Species	LO3 /58		LO3 /61		LO3 /59		LO3 /39			
	A	D	A	D	A	D	A	D	Am	Dm
Laevicardium elenense	59	47.58	30	31.25	1129	58.08	2	3.39	305.00	35.07
Chione kelletii	12	9.68	3	3.13	29	1.49	11	18.64	13.75	8.23
Laevicardium clarionense	4	3.23	9	9.38	16	0.82	10	16.95	9.75	7.59
Turritella marcosensis	9	7.26			6	0.31	8	13.56	5.75	5.28
Anadara reinharti	2	1.61	12	12.50	57	2.93	1	1.69	18.00	4.68
Ctena mexicana	5	4.03	5	5.21	112	5.76			30.50	3.75
Argopecten circularis circularis	4	3.23	8	8.33	35	1.80			11.75	3.34
Nucula exigua	3	2.42	7	7.29	54	2.78			16.00	3.12
Megapitaria squalida	1	0.81					5	8.47	1.50	2.32
Parvilucina mazatlanica	1	0.81	5	5.21	61	3.14			16.75	2.29
Conus scalaris	1	0.81			1	0.05	4	6.78	1.50	1.91
Argopecten abietis abietis	4	3.23	1	1.04	10	0.51	1	1.69	4.00	1.62
Nuculana ornata	2	1.61	2	2.08	32	1.65			9.00	1.34
Ringicula sp.					90	4.63			22.50	1.16
Polinices bifasciatus			2	2.08	43	2.21			11.25	1.07
Anadara concinna			2	2.08	34	1.75			9.00	0.96
Trigonocardia biangulata	3	2.42	1	1.04	4	0.21			2.00	0.92
Pegophysema cf. *edentuloides*							2	3.39	0.50	0.85
Chione sp. 1							2	3.39	0.50	0.85
Melongena patula							2	3.39	0.50	0.85
Patinopecten healey	3	2.42							0.75	0.60
Strombus subgracilior			2	2.08					0.50	0.52
Nassarius tiarula			2	2.08					0.50	0.52
Flabellipecten stearnsii	1	0.81	1	1.04	3	0.15			1.25	0.50
Bulla aspersa					2	0.10	1	1.69	0.75	0.45
Glycymeris sp. 2							1	1.69	0.25	0.42
Glycymeris sp. 3							1	1.69	0.25	0.42
Lucina cf. *fenestrata*							1	1.69	0.25	0.42
Trachycardium senticosum							1	1.69	0.25	0.42
Pitar unicolor							1	1.69	0.25	0.42
Chione cf. *fluctifraga*							1	1.69	0.25	0.42
Strombus sp.							1	1.69	0.25	0.42
Xenophora sp. 1							1	1.69	0.25	0.42
Polinices sp.							1	1.69	0.25	0.42
Dentalium sp.							1	1.69	0.25	0.42
Calliostoma eximium	2	1.61			1	0.05			0.75	0.42
Lucina nuttallii nuttallii	1	0.81			9	0.46			2.50	0.32
Rissoa sp. 2					23	1.18			5.75	0.30
Cerithium ocellatum	1	0.81			7	0.36			2.00	0.29
Aequipecten dallasi			1	1.04					0.25	0.26
Linga undatoides			1	1.04					0.25	0.26
Hindsiclava militaris			1	1.04					0.25	0.26
Terebra petiveriana			1	1.04					0.25	0.26
Glycymeris maculata	1	0.81			4	0.21			1.25	0.25
Acteocina carinata					18	0.93			4.50	0.23
Polystira oxytropis	1	0.81			2	0.10			0.75	0.23
Cadulus sp.					17	0.87			4.25	0.22
Placunanomia cumingii	1	0.81							0.25	0.20
Eucrassatella digueti	1	0.81							0.25	0.20
Trachycardium procerum	1	0.81							0.25	0.20
Architectonica nobilis	1	0.81							0.25	0.20
Cerithium sp. 4					12	0.62			3.00	0.15
Tesseracme quadrangulare					9	0.46			2.25	0.12
Transennella modesta					8	0.41			2.00	0.10
Corbula nuciformis					8	0.41			2.00	0.10
Rissoina cf. *stricta*					8	0.41			2.00	0.10
Polinices otis					8	0.41			2.00	0.10
Crenella divaricata					6	0.31			1.50	0.08
Pusillina sp.					6	0.31			1.50	0.08
Linga cancellaris					5	0.26			1.25	0.06

Species	LO3 /58		LO3 /61		LO3 /59		LO3 /39			
	A	D	A	D	A	D	A	D	Am	Dm
Nassarius corpulentus					5	0.26			1.25	0.06
Cerithium sp. 1					4	0.21			1.00	0.05
Rissoa sp. 1					4	0.21			1.00	0.05
Divalinga eburnea					3	0.15			0.75	0.04
Chione gnidia					3	0.15			0.75	0.04
Tricolia sp. 2					3	0.15			0.75	0.04
Cerithium sp. 3					3	0.15			0.75	0.04
Micranellum sp.					3	0.15			0.75	0.04
Turbonilla lamna					3	0.15			0.75	0.04
Parviturbo sp.					2	0.10			0.50	0.03
Tricolia sp. 1					2	0.10			0.50	0.03
Alabina sp.					2	0.10			0.50	0.03
Cerithium sp. 2					2	0.10			0.50	0.03
Elephantanellum sp.					2	0.10			0.50	0.03
Nassarius cf. *versicolor*					2	0.10			0.50	0.03
Nassarius sp. 3					2	0.10			0.50	0.03
Turbonilla cf. *ulloa*					2	0.10			0.50	0.03
Turbonilla sp.					2	0.10			0.50	0.03
Dentalium cf. *divulgatum*					2	0.10			0.50	0.03
Cadulus perpusillus					2	0.10			0.50	0.03
Barbatia sp.					1	0.05			0.25	0.01
Anadara sp. 6					1	0.05			0.25	0.01
Flabellipecten diegensis					1	0.05			0.25	0.01
Diplodonta inezensis					1	0.05			0.25	0.01
Calliostoma annulatum					1	0.05			0.25	0.01
Calliostoma sp. 1					1	0.05			0.25	0.01
Parviturbo erici					1	0.05			0.25	0.01
Macrarene sp.					1	0.05			0.25	0.01
Teinostoma sp.					1	0.05			0.25	0.01
Collonia sp.					1	0.05			0.25	0.01
Bittium sp.					1	0.05			0.25	0.01
Schwarziella sp.					1	0.05			0.25	0.01
Strombus granulatus cortezianus					1	0.05			0.25	0.01
Crucibulum subacutum					1	0.05			0.25	0.01
Xenophora sp. 2					1	0.05			0.25	0.01
Triphora sp.					1	0.05			0.25	0.01
Agaronia sp.					1	0.05			0.25	0.01
Kylix sp.					1	0.05			0.25	0.01
Crassispira sp.					1	0.05			0.25	0.01
Conus arcuatus					1	0.05			0.25	0.01
Volvulella cylindrica					1	0.05			0.25	0.01
Dentalium oerstedii					1	0.05			0.25	0.01
TOTAL	124		96		1944		59			

ATT EPIF	0.02	MUD	11.43	SUSPENSION	83.53	INTD	1.37
FRL EPIF	5.51	SAND	58.38	DEPOSIT	7.35	INTD-VSISUBL	0.42
VAG EPIF	8.47	GRAVEL	1.52	HERBIVORE	1.56	INTD-SISUBL	2.33
FRL SEMINF	6.49	VARIOUS	16.90	CARNIVORE	7.39	INTD-ISUBL	5.12
VAG SEMINF	5.29	SEAGRASS	0.64	PARASITIC	0.07	INTD-SOSUBL	0.94
ATT INF	0.10	HARD	0.02			INTD-DOSUBL	39.57
FRL SINF	57.89	UNDET	11.11			SISUBL	3.55
FRL DINF	7.99					ISUBL	4.44
VAG INF	8.24					SUBL	29.21
						UNDET	13.05

Species	LO3 /3			
	A	D		
Xenophora sp. 1	16	26.67	FRL EPIF	8.33
Strombus subgracilior	8	13.32	VAG EPIF	71.66
Conus arcuatus	8	13.32	VAG SEMINF	6.66
Flabellipecten stearnsii	6	10.00	FRL SINF	5.01
Turritella marcosensis	4	6.67	VAG INF	8.34
Argopecten abietis abietis	3	5.00		
Argopecten circularis circularis	2	3.33	MUD	1.66
Malea ringens	2	3.33	SAND	33.34
Nassarius cf. *californianus*	2	3.33	VARIOUS	18.33
Glycymeris gigantea	1	1.67	HARD	3.34
Flabellipecten diegensis	1	1.67	UNDET	43.33
Laevicardium clarionense	1	1.67		
Dosinia ponderosa	1	1.67	SUSPENSION	31.67
Cypraea sp.	1	1.67	DEPOSIT	26.67
Polinices cf. *bifasciatus*	1	1.67	HERBIVORE	15.00
Cassis sp.	1	1.67	CARNIVORE	26.66
Casmaria cf. *vibexmexicana*	1	1.67		
Thais sp.	1	1.67	INTD-SISUBL	1.67
TOTAL	60		INTD-DOSUBL	3.32
			VSISUBL	1.67
			SISUBL	10.00
			ISUBL	15.01
			SUBL	26.66
			UNDET	41.67

Tab. 8 - Composition of the *Xenophora* sp. 1-*Strombus subgracilior* Biofacies. Symbols are: A = abundance; D = dominance (%). Numbers in the right column are percentages. Abbreviations are as in Tab. 2.

were noticed in Oligocene sandy beds of northwestern Italy (Zaliani 1996, personal communication) linked to delta environment.

Paleoenvironmental reconstruction.

Up-to-date studies on depositional environments of Baja California Pliocene sediments were recently offered by Meldahl (1993) and Dorsey et al. (1995). The first author considered several shell beds throughout the peninsula, focusing on taphonomic processes, and interpreted them to represent five types of beds, i.e. community beds, storm beds, beach berm beds, tidal channel beds, current/wave-winnowed beds. Meldahl concluded that Pliocene sediments were deposited in littoral or sublittoral environments, at depths not exceeding 10-15 m. Dorsey et al. (1995) dealt with the sedimentological features of the Loreto Basin. They described and interpreted a number of facies associations, mainly linked to stacked Gilbert-type fan deltas, and regarded the recurrent shell beds capping topset strata as "condensed intervals that record sediment starvation during abandonment of the fan-delta plain". The estimated water depths are of from 15 to 40 m.

In the following, the depositional environments of the sampled portions of the Piedras Rodadas Sandstone and Arroyo the Arce Norte Sandstone are interpreted on the basis of the identified autochthonous biofacies, mainly in terms of paleobathymetry and energy level. Paleodepth and energy variations are summarized in the right part of Figs. 3-7. Figure 12 shows both occupied and unoccupied environments in the 0-40 m bathymetric range.

As regards the Piedras Rodadas Sandstone, the recurrent presence of the *Chione compta-Transennella modesta* Biofacies throughout this unit points toward a water depth mostly of 3-10 m, in settings swept by weak to moderate currents, but protected from wave action. The uncommon occurrence of mudstone (LO3/31) that yielded the *Trachycardium procerum-Trachycardium senticosum* Biofacies does suggest local fully protected shallow bottoms where silt and clay carried in suspension by freshwater plumes were depositing. As previously said, the *Trachycardium procerum-Trachycardium senticosum* Biofacies was unrelated to depth, settling in the shallow inner sublittoral zone provided that muddy bottoms were available. However, since the biofacies was noted slightly above the alluvial fan deposits of La Vinorama Conglomerate, a 0-10 m depth may be inferred.

Besides the current paleobathymetry just cited, evidence does exist of definitely shallow and somewhat deeper end conditions. The *Encope* Biofacies records a turbulent environment at or immediately below low water mark. A depth hardly exceeding 5 m is suggested by the *Argopecten abietis abietis* and *Crassostrea californica osunai* biofacies which denote relatively strong to strong bottom currents. In the same depth range, the *Aequipecten dallasi*, *Myrakeena angelica* and Vermetid-*Nodipecten* biofacies are indicative of low to moderate currents. The deepest settings are evidenced in the uppermost Piedras Rodadas Section and in the middle part of Rancho El Leon Section. In the first location, the *Xenophora* sp. 1-*Strombus subgracilior* Biofacies records a 10-20 m depth range in low energy conditions. This biofacies may have ranged also somewhat deeper (i.e. to 30 m, see discussion above). However, a maximum depth of about 20 m may be reliable because of 1) the presence of the Vermetid-*Nodipecten* Biofacies some 15 m below and 2) the overlying festoon cross bedded conglomerate (Fig. 3). In the Rancho El Leon Section (Fig. 4), a transition from *Chione compta-Transennella modesta* Biofacies to *Laevicardium elenense-Chione kelletii* Biofacies through an ecotone (LO3/41) is observable, which testifies a dee-

Biofacies	Samples LO3/	Life habit	Substrate preference	Feeding type	Depth range (m)	Ecological meaning
Tp-Ts	31	FRL SINF	MUD	SUSPENSION	0-10→30	sheltered conditions high turbidity
Cc-Tm	1, 14, 15, 17, 18, 20, 25, 34, 35, 38, 43, 67, 69	FRL SINF	SAND	SUSPENSION	3-10⇒25	low/moderate-energy aspect of SFBC
Le-Ck	39, 40, 57, 58, 59, 61, 62	FRL SINF	SAND	SUSPENSION	10⇐20-40	deep, low-energy aspect of SFBC
X-Ss	3	VAG EPIF	SAND/VARIOUS	SUSPENSION DEPOSIT HERBIVORE CARNIVORE	10-30	vegetated seafloor
Cco	24	ATT EPIF	COARSE SAND	SUSPENSION	0-5	strong bottom current brackish water
Ma	13, 22, 68	ATT EPIF	HARD	SUSPENSION	0-5	moderate bottom current weak wave action marine salinity
V-N	28	ATT EPIF	HARD	SUSPENSION	2-5	weak wave action
Aaa	13, 22	FRL EPIF	SAND	SUSPENSION	3-7	strong bottom current
Ad	29	FRL EPIF	SAND	SUSPENSION	2-5	sheltered conditions
E	19,23	VAG INF	SAND	DEPOSIT	0-2	surf

Tab. 9 - Summary chart of the recognized biofacies: only the dominant ecological categories are reported for each of them. SFBC = Biocoenosis of Fine Well Sorted Sands; other abbreviations are as in Tab. 2.

pening phase in that area of the basin. As already pointed out, the *Laevicardium elenense-Chione kelletii* Biofacies dwelt on low-energy sandy bottoms at depths of from 20 to 40 m.

In summary, the Piedras Rodadas Sandstone results to have deposited within a bathymetric interval of from the very low tide mark to a depth of about 40 m. It is notable that the deepest recorded bathymetries (Piedras Rodadas Section, Rancho El Leon Section) occur near the western margin of the basin (Fig. 2), where the depocenter was located. Conversely, shallower depths, never exceeding 10 m, are persistently recorded in layers that crop out in the eastern part of the basin (Arroyo de Gua and Arroyo de Arce sections), toward the present day coastal area of the Gulf of California. According to Dorsey et al. (1995), this area worked as an active structural high during basin development. It is also worthy of note that in the Arroyo de Gua and Arroyo de Arce sections, which combined expose the overall thickness of the Piedras Rodadas Sandstone, a shallowing trend is recorded. In fact, the inferred depositional depth gradually reduces and, in the uppermost part, definitely shallow conditions (0-5 m) are indicated by the *Argopecten abietis abietis*, Vermetid-*Nodipecten* and *Aequipecten dallasi* biofacies. This is consistent with the subaerial conditions that followed the deposition of the Piedras Rodadas Sandstone in the eastern area (Zanchi & Gelati, 1996, personal communication). Evidence in this respect is provided by the erosional truncation at the top of the unit and by the unconformable contact with the overlying Arroyo de Arce Sur Limestone (Fig. 2).

The Arroyo de Arce Norte Sandstone was deposited in a somewhat deeper setting in respect to the Piedras Rodadas Sandstone. In fact, only the *Laevicardium elenense-Chione kelletii* Biofacies was recovered and occurs at various levels throughout the unit (Fig. 7), thus suggesting a water depth of from 20 to 40 m, in low energy conditions. A shallowing trend can be supposed taking into account that the Arroyo de Arce Norte Sandstone is truncated by the same erosional surface mentioned above. The eastward shift of the basin depocenter through time due to block faulting of the eastern margin of the basin is to be noted (Fig. 2).

It is worth comparing the sedimentological interpretation (Dorsey et al., 1995; Dorsey et al., in press) with the paleobiological results documented in the present study, relative to the Piedras Rodadas Sandstone and Arroyo de Arce Norte Sandstone.

The *Trachycardium procerum-Trachycardium senticosum*, *Chione compta-Transennella modesta* and *Xenophora* sp. 1-*Strombus subgracilior* biofacies were recovered from lithotypes that Dorsey et al. (in press) included in the "Shelly Sandstone and Pebbly Sandstone" facies association. This latter was interpreted as deposited in a siliciclastic shallow marine shelf setting, with fluctuations in the energy of the bottom currents. The paleobiological interpretation shows that the autochthonous molluscan assemblages dwelt on sandy bottoms swept by low to moderate currents; the mud-related *Trachycardium procerum-Trachycardium senticosum* Biofacies is indicative of fully protected seafloor. Thus, biofacies point toward a very low to moderate energy range. However, high-energy conditions are proved by the frequently noted current/wave-winnowed beds with shell accumulations (not considered in this study). Each of the three mentioned biofacies suggests a definite bathymetric in-

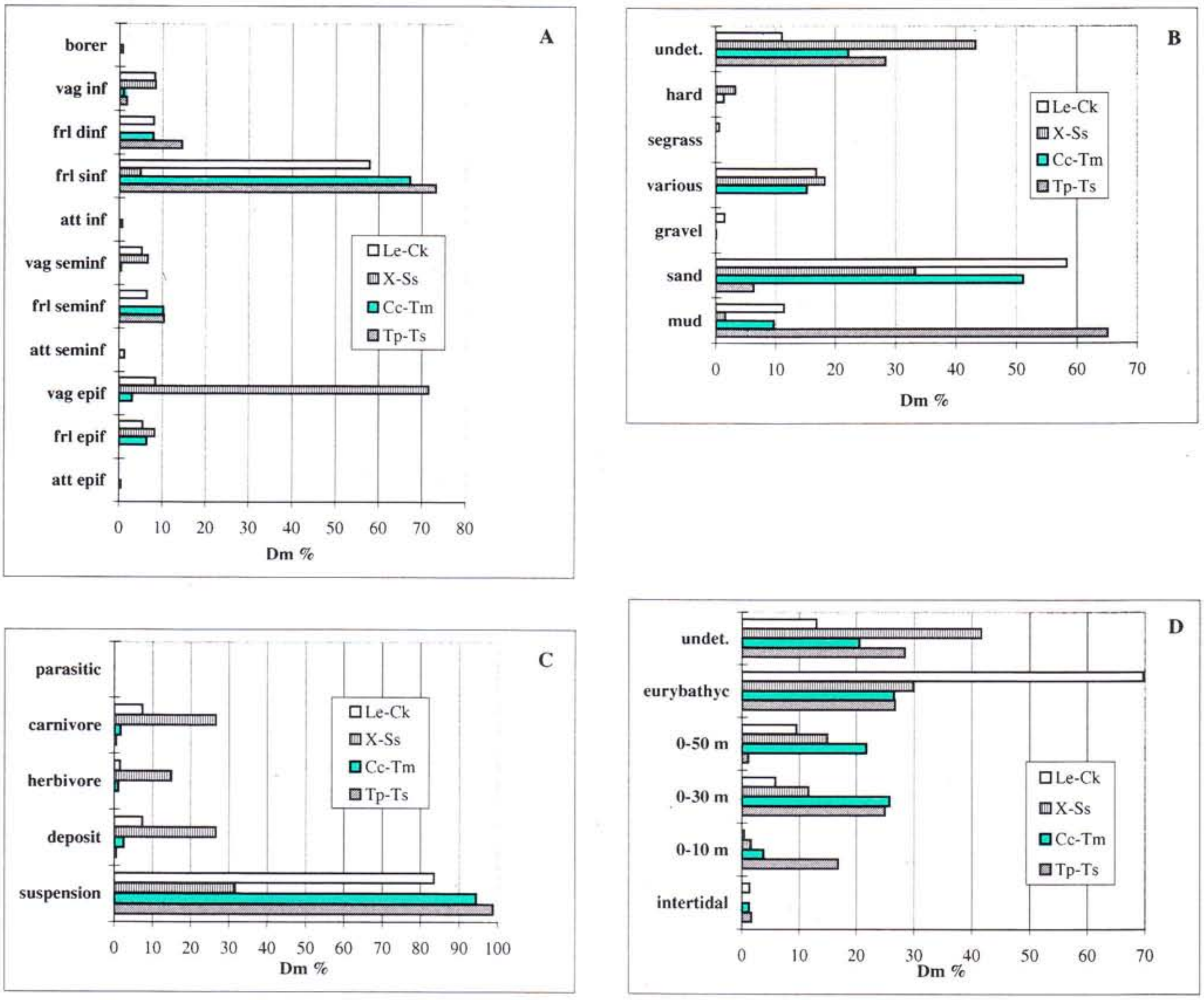

Fig. 11 - Histograms showing the composition in terms of ecological categories of the four biofacies delineated by the statistical treatment. A: life-habit; B: substrate preference; C: feeding type; D: bathymetric range. Letter codes for biofacies are as in Fig. 8.

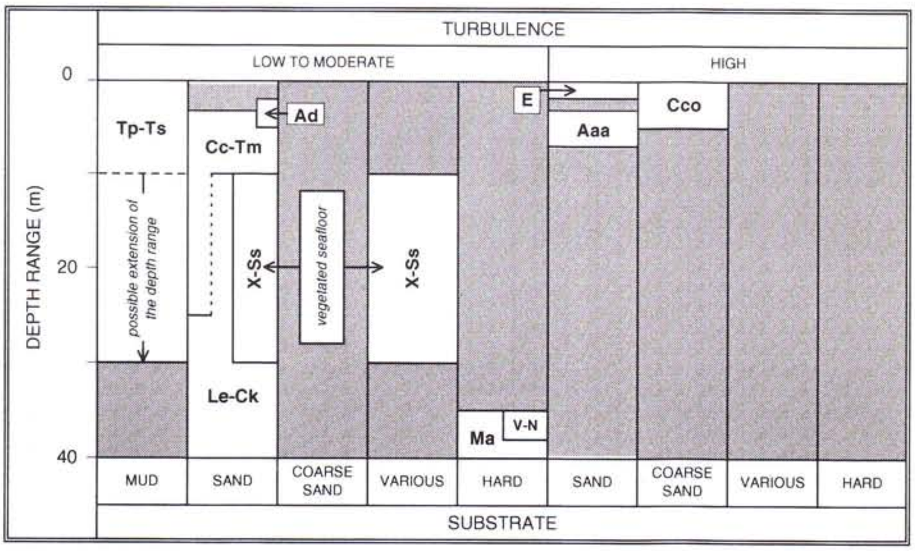

Fig. 12 - Diagram showing both occupied and unoccupied environments in the 0-40 m bathymetric range. Letter codes for biofacies are as in Fig. 8.

terval within a general 0-20 m depth range which is consistent with the sedimentological interpretation.

The *Laevicardium elenense-Chione kelletii* Biofacies mostly occurs in the Arroyo de Arce Norte Sandstone which directly overlies the Uña de Gato Sandstone. The latter unit displays the same charachters of the Distal Bottomsets lithofacies of Dorsey et al. (in press) and corresponds to it. According to the description of the Foreset Facies provided by Dorsey et al. (1995) and Dorsey et al. (in press), the Arroyo de Arce Norte Sandstone likely represents the deepest part of the foreset deposits grading into shelf sediments. The autochthonous assemblages belonging to the *Laevicardium elenense-Chione kelletii* Biofacies are from the interfingering shelf deposits and suggest a water depth of 20-40 m in a low-energy environment. It is notable that an identical paleodepth was inferred by Dorsey et al. (1995).

Summary and conclusions.

This study represents the first attempt to use autochthonous biofacies in reconstructing the depositional environment of portions of the succession exposed in the Pliocene Loreto Basin. The paleobiocoenotic approach, which has proved to be helpful as regards Miocene to Pleistocene fossil assemblages of the Mediterranean Basin (Di Geronimo, 1985; Bernasconi et al., 1991; Bernasconi & Robba, 1993; Bernasconi & Stanley, 1997), could not be used in the lack of a well established biocoenotic framework for the Gulf of California and adjoining seas. The thorough examination of the available literature, in order to obtain or infer reliable information on species autoecology, along with the application of cluster, MDS and factor analyses have led to the definition of four more or less diverse biofacies and to delineate their ecological meaning. In addition, six low-diversity or monospecific biofacies, which do not need any statistical treatment to be denoted, are also considered.

The investigation records 210 mollusc and 6 echinoid species. The 10 identified biofacies include: *Trachycardium procerum-Trachycardium senticosum* Biofacies, *Chione compta-Transennella modesta* Biofacies, *Laevicardium elenense-Chione kelletii* Biofacies, *Xenophora* sp. 1-*Strombus subgracilior* Biofacies, *Crassostrea californica osunai* Biofacies, *Myrakeena angelica* Biofacies, Vermetid-*Nodipecten* Biofacies, *Argopecten abietis abietis* Biofacies, *Aequipecten dallasi* Biofacies and *Encope* Biofacies.

The various biofacies record different environmental conditions in terms of kind of substrate, water depth and energy level. The seafloor was predominantly sandy, with or without vegetal cover, but muddy bottoms existed where silt and clay carried in suspension by freshwater plumes were depositing. Depth appears to have ranged widely in the infralittoral zone, from very low tide mark (*Encope* Biofacies) to 40 m or slightly deeper (*Laevicardium elenense-Chione kelletii* Biofacies). Biofacies indicate that energy was generally low to moderate because of weak currents and/or protection from the effect of waves. Nevertheless, local scouring and turbulent water due to surf are suggested respectively by *Crassostrea californica osunai* Biofacies and *Encope* Biofacies.

Precise information on paleodepth and energy level are likely to be the most relevant achievements since biofacies resulted to serve as useful indicators to evaluate the bathymetric changes in time and space as well as the kinds and strenght of water movements (Fig. 3-7) in a geological context which Dorsey et al. (1995) and Dorsey et al. (in press) interpreted as shelf-type to Gilbert-type delta influenced. Once more it appears that paleobiological and sedimentological methods integrate efficiently in refining paleoecologic and paleogeographic interpretations.

Locality data.

(Loreto quadrangle, 1:50,000, G12A88)

LO3/31. Mouth of unnamed cañada opposite of Rancho Las Piedras Rodadas, 250 m east of Mexico Highway 1. Grey sandy marl overlying matrix-supported conglomerate, lowermost Piedras Rodadas Sandstone.

LO3/34. Road cut on west side of big bend in Mexican Highway 1, 1.1 km north of Rancho Las Piedras Rodadas. Grey sandy marl forming a 3 m thick bed with abundant bivalves in living position, basal Piedras Rodadas Sandstone.

LO3/35. Same location as LO3/34. Conglomeratic bed 0.30 m thick that overlies the sandy marl, basal Piedras Rodadas Sandstone.

Rancho El Leon Section (RL). East side of Arroyo El Leon, at Rancho El Leon. Basal Piedras Rodadas Sandstone.

Highway Section (MX). Road cut on Mexican Highway 1, 3.8 km north of Rancho Piedras Rodadas and 1 km southwest of Rancho Uña de Gato (abandoned), between 160 m and 180 m contour. Arroyo de Arce Norte Sandstone.

Piedras Rodadas Section (PR). Eastern slope of Las Cuchillas between south side of Rancho Piedras Rodadas and elevation 230 m. Piedras Rodadas Sandstone.

Arroyo de Gua Section (AG). North side of Arroyo de Gua between point 200 m east of Vado on Mexican Highway 1 and cliff at 100 m contour about 1250 m downstream. Lower Piedras Rodadas Sandstone.

Arroyo de Arce Section (AR). North side of arroyo de Arce between point (elevation 70 m) 1.5 km east of junction of the arroyo with road to Estacion Loreto Microondas and the cliffs constricting the arroyo before the coastal plain. Upper Piedras Rodadas Sandstone.

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APPENDIX (Faunal composition in each bulk-sample. Numbers in the right part are abundance values.)

LO3/3 - Piedras Rodadas Sandstone

Glycymeris (Glycymeris) gigantea (Reeve, 1843)	1
Argopecten abietis abietis (Jordan & Hertlein, 1926)	3
Argopecten circularis circularis (Sowerby, 1835)	2
Flabellipecten stearnsii (Dall, 1878)	6
Flabellipecten diegensis (Dall, 1898)	1
Laevicardium clarionense (Hertlein & Strong, 1947)	1
Dosinia (Dosinia) ponderosa (Gray, 1838)	1
Turritella marcosensis Durham, 1950	4
Strombus (Lentigo) subgracilior Durham, 1950	8
Xenophora sp. 1	16
Cypraea sp.	1
Polinices (Polinices) cf. bifasciatus (Griffith & Pidgeon, 1834)	1
Cassis sp.	1
Casmaria cf. *vibexmexicana* (Stearns, 1894)	1
Malea ringens (Swainson, 1822)	2
Thais sp.	1
Nassarius (Demondia) cf. *californianus* (Conrad, 1856)	2
Conus (Asprella) arcuatus Broderip & Sowerby, 1829	8

LO3/14 – Piedras Rodadas Sandstone

Anadara (Anadara) cf. *marksi* Olsson, 1964	1	*Tagelus (Tagelus) californianus* (Conrad, 1837)	5
Anadara(Cunearca) reinharti (Lowe, 1935)	8	*Transennella modesta* (Sowerby, 1835)	9
Anadara sp. 5	1	*Pitar* sp.	6
Pinna rugosa Sowerby, 1835	7	*Dosinia (Dosinia) ponderosa* (Gray, 1838)	5
Argopecten abietis abietis (Jordan & Hertlein, 1926)	17	*Chione (Chionopsis) gnidia* (Broderip & Sowerby, 1829)	1
Argopecten circularis circularis (Sowerby, 1835)	7	*Chione* sp. 3	1
Divalinga (Divalinga) eburnea (Reeve, 1850)	7	*Corbula (Varicorbula)* sp.	1
Trachycardium (Dallocardia) senticosum (Sowerby, 1833)	1	*Cyatodonta undulata* Conrad, 1849	6
Trigonocardia (Americardia) biangulata (Broderip & Sowerby, 1829)	1	*Crucibulum (Crucibulum) personatum* Keen, 1958	1
Trigonocardia (Apiocardia) cf. *obovalis* (Sowerby, 1833)	4	*Encope arcensis* Durham, 1950	1
Laevicardium elenense (Sowerby, 1840)	11	*Encope* sp.	2

LO3/15 – Piedras Rodadas Sandstone

Anadara (Cunearca) reinharti (Lowe, 1935)	3	*Transennella modesta* (Sowerby, 1835)	16
Argopecten circularis circularis (Sowerby, 1835)	2	*Pitar* sp.	1
Spondylus sp.	1	*Chione (Chione) compta* (Broderip, 1835)	13
Divalinga (Divalinga) eburnea (Reeve, 1850)	1	*Chione (Chionista)* cf. *fluctifraga* (Sowerby, 1853)	1
Trigonocardia (Apiocardia) cf. *obovalis* (Sowerby, 1833)	2	*Chione (Chionopsis) gnidia* (Broderip & Sowerby, 1829)	8
Laevicardium clarionense (Hertlein & Strong, 1947)	1	*Petricola* sp.	3
Tagelus (Mesopleura) subteres (Conrad, 1837)	1	*Conus (Asprella) arcuatus* Broderip & Sowerby, 1829	1

LO3/17 – Piedras Rodadas Sandstone

Nucula (Lamellinucula) exigua Sowerby, 1833	1	*Pitar (Lamelliconcha) unicolor* (Sowerby, 1835)	19
Anadara(Cunearca) cf. *perlabiata* (Grant & Gale, 1931)	1	*Pitar (Pitarella)* cf. *catharius* (Dall, 1902)	6
Anadara (Cunearca) reinharti (Lowe, 1935)	12	*Pitar* sp.	35
Argopecten abietis abietis (Jordan & Hertlein, 1926)	3	*Dosinia (Dosinia) ponderosa* (Gray, 1838)	6
Argopecten circularis circularis (Sowerby, 1835)	24	*Chione (Chione)* cf. *californiensis* (Broderip, 1835)	12
Divalinga (Divalinga) eburnea (Reeve, 1850)	15	*Chione (Chione) compta* (Broderip, 1835)	60
Trachycardium (Dallocardia) senticosum (Sowerby, 1833)	7	*Chione (Chionopsis) gnidia* (Broderip & Sowerby, 1829)	13
Trachycardium (Mexicardia) procerum (Sowerby, 1833)	1	*Panopea generosa* (Gould, 1850)	1
Trigonocardia (Apiocardia) cf. *obovalis* (Sowerby, 1833)	2	*Periploma (Periploma) planiusculum* Sowerby, 1834	1
Mactra sp.	1	*Cyatodonta undulata* Conrad, 1849	6
Leporimetis cognata (Sowerby, 1835)	1	*Crucibulum (Dispotea) subacutum* Berry, 1963	1
Tagelus (Tagelus) californianus (Conrad, 1837)	1	*Bulla (Bulla) aspersa* A. Adams, 1850	4
Transennella modesta (Sowerby, 1835)	19		

LO3/18 – Piedras Rodadas Sandstone

Anadara (Cunearca) reinharti (Lowe, 1935)	1	*Chione* sp. 2	2
Argopecten abietis abietis (Jordan & Hertlein, 1926)	16	*Pholadomya (Pholadomya)* cf. *candida* Sowerby, 1823	1
Argopecten circularis circularis (Sowerby, 1835)	7	*Thracia* sp.	1
Argopecten circularis aequisulcatus (Carpenter, 1864)	1	*Cyatodonta undulata* Conrad, 1849	1
Tagelus (Tagelus) californianus (Conrad, 1837)	1	*Polinices* sp.	2
Transennella modesta (Sowerby, 1835)	3	*Bulla (Bulla) aspersa* A. Adams, 1850	3
Dosinia (Dosinia) ponderosa (Gray, 1838)	1		

LO3/20 – Piedras Rodadas Sandstone

Anadara (Cunearca) cf. *perlabiata* (Grant & Gale, 1931)	2	*Chione (Chione) compta* (Broderip, 1835)	96
Anadara (Cunearca) reinharti (Lowe, 1935)	7	*Chione (Chionista) fluctifraga* (Sowerby, 1853)	24
Argopecten abietis abietis (Jordan & Hertlein, 1926)	1	*Chione (Chionopsis)* cf. *purpurissata* Dall, 1902	54
Argopecten circularis circularis (Sowerby, 1835)	5	*Chione (Lirophora)* cf. *discrepans* (Sowerby, 1835)	211
Laevicardium clarionense (Hertlein & Strong, 1947)	5	*Cyatodonta undulata* Conrad, 1849	1
Ventricolaria magdalenae (Dall, 1902)	1	*Polinices (Polinices)* cf. *bifasciatus* (Griffith & Pidgeon, 1834)	3
Transennella modesta (Sowerby, 1835)	31	*Colubraria* sp. 1	1
Pitar sp.	4	*Conus (Asprella) arcuatus* Broderip & Sowerby, 1829	2

LO3/25 – Piedras Rodadas Sandstone

Modiolus pseudotulipus Olsson, 1961	1	*Transennella modesta* (Sowerby, 1835)	1
Pinna rugosa Sowerby, 1835	2	*Dosinia (Dosinia) ponderosa* (Gray, 1838)	10
Myrakeena angelica (Rochebrune, 1895)	1	*Epitonium* sp.	1
Trachycardium (Mexicardia) procerum (Sowerby, 1833)	4		

LO3/31 – Piedras Rodadas Sandstone

Nuculana sp.	1	*Laevicardium clarionense* (Hertlein & Strong, 1947)	5
Anadara (Anadara) concinna (Sowerby, 1833)	12	*Mactra* sp.	9
Anadara sp. 1	2	*Gari (Gobraeus)* cf. *maxima* (Deshayes, 1855)	3
Anadara sp. 2	2	*Gari (Gobraeus) helenae* Olsson, 1961	16
Anadara sp. 4	2	*Tagelus (Mesopleura) subteres* (Conrad, 1837)	3
Atrina sp.	1	*Transennella modesta* (Sowerby, 1835)	2
Miltha sp.	3	*Pitar (Lamelliconcha) unicolor* (Sowerby, 1835)	29
Trachycardium (Dallocardia) senticosum (Sowerby, 1833)	29	*Pitar (Pitarella)* cf. *catharius* (Dall, 1902)	18
Trachycardium (Mexicardia) procerum (Sowerby, 1833)	34	*Ficus* sp.	1

LO3/34 – Piedras Rodadas Sandstone

Anadara (Cunearca) reinharti (Lowe, 1935)	27	*Transennella modesta* (Sowerby, 1835)	14
Mytella tumbezensis (Pilsbry & Olsson, 1935)	1	*Pitar (Lamelliconcha) unicolor* (Sowerby, 1835)	1
Pinna rugosa Sowerby, 1835	1	*Megapitaria squalida* (Sowerby, 1835)	1
Atrina sp.	1	*Dosinia (Dosinia) ponderosa* (Gray, 1838)	17
Argopecten circularis circularis (Sowerby, 1835)	1	*Cyclinella* cf. *ulloana* Hertlein & Strong, 1948	1
Felaniella (Zemysia) sericata (Reeve, 1850)	11	*Chione (Chione) californiensis* (Broderip, 1835)	1
Cardita (Cyclocardia) megastropha (Gray, 1825)	1	*Chione (Chionopsis) gnidia* (Broderip & Sowerby, 1829)	12
Eucrassatella (Hybolophus) gibbosa (Sowerby, 1832)	1	*Panopea generosa* (Gould, 1850)	5
Eucrassatella (Hybolophus) digueti Lamy, 1917	1	*Pholadomya (Pholadomya)* cf. *candida* Sowerby, 1823	2
Trachycardium (Mexicardia) procerum (Sowerby, 1833)	5	*Periploma (Periploma) planiusculum* Sowerby, 1834	1
Laevicardium elatum (Sowerby, 1833)	1	*Cyatodonta undulata* Conrad, 1849	2
Laevicardium elenense (Sowerby, 1840)	3	*Turritella marcosensis* Durham, 1950	3
Tellina (Eurytellina) simulans C. B. Adams, 1852	7	*Strombus (Lentigo) subgracilior* Durham, 1950	1
Leporimetis cognata (Sowerby, 1835)	1	*Polinices* sp.	1
Semele pulchra (Sowerby, 1832)	1		

LO3/35 – Piedras Rodadas Sandstone

Anadara (Cunearca) reinharti (Lowe, 1935)	32	*Megapitaria squalida* (Sowerby, 1835)	4
Pinna rugosa Sowerby, 1835	1	*Dosinia (Dosinia) ponderosa* (Gray, 1838)	4
Argopecten abietis abietis (Jordan & Hertlein, 1926)	3	*Chione (Chionopsis) compta* (Broderip, 1835)	27
Argopecten circularis circularis (Sowerby, 1835)	2	*Chione (Lirophora)* cf. *discrepans* (Sowerby, 1835)	1
Cardita (Carditamera) affinis Sowerby, 1833	1	*Cyatodonta undulata* Conrad, 1849	13
Laevicardium elenense (Sowerby, 1840)	4	*Calliostoma* sp. 2	1
Laevicardium clarionense (Hertlein & Strong, 1947)	2	*Crucibulum (Crucibulum) spinosum* (Sowerby, 1824)	1
Tellina (Eurytellina) simulans C. B. Adams, 1852	1	*Crucibulum (Crucibulum) personatum* Keen, 1958	1
Macoma cf. indentata Carpenter, 1864	3	*Polinices (Polinices)* cf. *bifasciatus* (Griffith & Pidgeon, 1834)	2
Asaphis sp.	1	*Polinices* sp.	1
Semele verrucosa pacifica Dall, 1915	1	*Nassarius* sp. 1	3
Transennella modesta (Sowerby, 1835)	12	*Conus* sp. 1	1
Pitar (Lamelliconcha) unicolor (Sowerby, 1835)	3	*Bulla (Bulla) aspersa* A. Adams, 1850	2

LO3/39 – Piedras Rodadas Sandstone

Anadara (Cunearca) reinharti (Lowe, 1935)	1	*Chione (Chionista)* cf. *fluctifraga* (Sowerby, 1853)	1
Glycymerys sp. 2	1	*Chione (Lirophora) kelletii* (Hinds, 1845)	11
Glycymerys sp. 3	1	*Chione* sp. 1	2
Argopecten abietis abietis (Jordan & Hertlein, 1926)	1	*Turritella marcosensis* Durham, 1950	8
Lucina (Lucinisca) cf. *fenestrata* Hinds, 1845	1	*Strombus* sp.	1
Pegophysema cf. *edentuloides* (Verril, 1870)	2	*Xenophora* sp. 1	1
Trachycardium (Dallocardia) senticosum (Sowerby, 1833)	1	*Polinices* sp.	1
Laevicardium elenense (Sowerby, 1840)	2	*Melongena patula* (Broderip & Sowerby, 1829)	2
Laevicardium clarionense (Hertlein & Strong, 1947)	10	*Conus (Leptoconus) scalaris* Valenciennes, 1832	4
Pitar (Lamelliconcha) unicolor (Sowerby, 1835)	1	*Bulla (Bulla) aspersa* A. Adams, 1850	1
Megapitaria squalida (Sowerby, 1835)	5	*Dentalium* sp.	1

LO3/40 – Piedras Rodadas Sandstone

Argopecten abietis abietis (Jordan & Hertlein, 1926)	1	*Laevicardium clarionense* (Hertlein & Strong, 1947)	3
Argopecten circularis circularis (Sowerby, 1835)	2	*Chione (Lirophora) kellettii* (Hinds, 1845)	2
Lucina (Lucinisca) nuttallii nuttallii Conrad, 1837	2	*Cardiomya* sp.	1
Laevicardium elenense (Sowerby, 1840)	4	*Turritella marcosensis* Durham, 1950	2

LO3/41 – Piedras Rodadas Sandstone

Anadara (Cunearca) cf. *perlabiata* (Grant & Gale, 1931)	1
Glycymeris (Glycymeris) gigantea (Reeve, 1843)	1
Glycymerys sp. 1	1
Argopecten abietis abietis (Jordan & Hertlein, 1926)	1
Spondylus princeps (Broderip, 1833)	1
Chama (Chama) frondosa Broderip, 1835	3
Pseudochama (Pseudochama) exogira (Conrad, 1837)	2
Sanguinolaria (Sanguinolaria) tellinoides A. Adams, 1850	1
Megapitaria squalida (Sowerby, 1835)	1
Panopea generosa (Gould, 1850)	1
Pholadomya (Pholadomya) cf. *candida* Sowerby, 1823	1
Strombus (Lentigo) subgracilior Durham, 1950	1
Melongena patula (Broderip & Sowerby, 1829)	1

LO3/58 – Arroyo de Arce Norte Sandstone

Nucula (Lamellinucula) exigua Sowerby, 1833	3
Nuculana (Saccella) ornata (d'Orbigny, 1845)	2
Anadara (Cunearca) reinharti (Lowe, 1935)	2
Glycymerys (Glycymerys) maculata (Broderip, 1832)	1
Argopecten abietis abietis (Jordan & Hertlein, 1926)	4
Argopecten circularis circularis (Sowerby, 1835)	4
Flabellipecten stearnsii (Dall, 1878)	1
Patinopecten healeyi (Arnold, 1906)	3
Placunanomia cumingii Broderip, 1832	1
Lucina (Lucinisca) nuttallii nuttallii Conrad, 1837	1
Ctena (Ctena) mexicana (Dall, 1901)	5
Parvilucina (Parvilucina) mazatlanica Carpenter, 1855	1
Eucrassatella (Hybolophus) digueti Lamy, 1917	1
Trachycardium (Mexicardia) procerum (Sowerby, 1833)	1
Trigonocardia (Americardia) biangulata (Broderip & Sowerby, 1829)	3
Laevicardium elenense (Sowerby, 1840)	59
Laevicardium clarionense (Hertlein & Strong, 1947)	4
Megapitaria squalida (Sowerby, 1835)	1
Chione (Lirophora) kelletii (Hinds, 1845)	12
Calliostoma eximium (Reeve, 1843)	2
Cerithium ocellatum Bruguière, 1792	1
Turritella marcosensis Durham, 1950	9
Polystira oxytropis (Sowerby, 1834)	1
Conus (Leptoconus) scalaris Valenciennes, 1832	1
Architectonica (Architectonica) nobilis Röding, 1798	1

LO3/59 – Arroyo de Arce Norte Sandstone

Nucula (Lamellinucula) exigua Sowerby, 1833	54
Nuculana (Saccella) ornata (d'Orbigny, 1845)	32
Barbatia (Acar) sp.	1
Anadara (Anadara) concinna (Sowerby, 1833)	34
Anadara (Cunearca) reinharti (Lowe, 1935)	57
Anadara sp. 6	1
Glycymerys (Glycymerys) maculata (Broderip, 1832)	4
Crenella divaricata (d'Orbigny, 1846)	6
Argopecten abietis abietis (Jordan & Hertlein, 1926)	10
Argopecten circularis circularis (Sowerby, 1835)	35
Flabellipecten stearnsii (Dall, 1878)	3
Flabellipecten diegensis (Dall, 1898)	1
Lucina (Lucinisca) nuttallii nuttallii Conrad, 1837	9
Ctena (Ctena) mexicana (Dall, 1901)	112
Linga (Pleurolucina) cancellaris (Philippi, 1846)	5
Parvilucina (Parvilucina) mazatlanica Carpenter, 1855	61
Divalinga (Divalinga) eburnea (Reeve, 1850)	3
Diplodonta inezensis (Hertlein & Strong, 1947)	1
Trigonocardia (Americardia) biangulata (Broderip & Sowerby, 1829)	4
Laevicardium elenense (Sowerby, 1840)	1129
Laevicardium clarionense (Hertlein & Strong, 1947)	16
Transennella modesta (Sowerby, 1835)	8
Chione (Chionopsis) gnidia (Broderip & Sowerby, 1829)	3
Chione (Lirophora) kelletii (Hinds, 1845)	29
Corbula (Caryocorbula) nuciformis Sowerby, 1833	8
Calliostoma annulatum (Lightfoot, 1786)	1
Calliostoma eximium (Reeve, 1843)	1
Calliostoma sp. 1	1
Parviturbo erici (Strong & Hertlein, 1939)	1
Parviturbo sp.	2
Macrarene sp.	1
Teinostoma sp.	1
Collonia (Parvirota) sp.	1
Tricolia sp. 1	2
Tricolia sp. 2	3
Alabina sp.	2
Bittium sp.	1
Cerithium ocellatum Bruguière, 1792	7
Cerithium sp. 1	4
Cerithium sp. 2	2
Cerithium sp. 3	3
Cerithium sp. 4	12
Turritella marcosensis Durham, 1950	6
Rissoa sp. 1	4
Rissoa sp. 2	23
Rissoina (Rissoina) cf. *stricta* Manke, 1850	8
Schwartziella (Schwartziella) sp.	1
Pusillina (Pusillina) sp.	6
Micranellum sp.	3
Elephantanellum sp.	2
Strombus (Lentigo) granulatus cortezianus Durham, 1962	1
Crucibulum (Dispotea) subacutum Berry, 1963	1
Xenophora sp. 2	1
Polinices (Polinices) otis (Broderip & Sowerby,1829)	8
Polinices (Polinices) bifasciatus (Griffith & Pidgeon, 1834)	43
Triphora sp.	1
Nassarius corpulentus (C. B. Adams, 1852)	5
Nassarius (Nassarius) cf. *versicolor* (C. B. Adams, 1852)	2
Nassarius sp. 3	2
Agaronia sp.	1
Polystira oxytropis (Sowerby, 1834)	2
Kylix sp.	1
Crassispira sp.	1
Conus (Leptoconus) scalaris Valenciennes, 1832	1
Conus (Asprella) arcuatus Broderip & Sowerby, 1829	1
Turbonilla (Turbonilla) sp.	2
Turbonilla (Pyrgiscus) lamna Bartsch, 1917	3
Turbonilla (Pyrgiscus) cf. *ulloa* Bartsch, 1917	2
Turbonilla (Pyrgiscus) sp.	2
Acteocina carinata (Carpenter, 1857)	18
Ringicula sp.	90
Bulla (Bulla) aspersa A. Adams, 1850	2
Volvulella (Volvulella) cylindrica (Carpenter, 1864)	1
Dentalium (Dentalium) oerstedii Mörch, 1860	1
Dentalium (Dentalium) cf. *divulgatum* Jung, 1969	2
Tesseracme quadrangulare (Sowerby, 1832)	9
Cadulus (Gadila) perpusillus (Sowerby, 1832)	2
Cadulus (Platyschides) sp.	17

LO3/61 – Arroyo de Arce Norte Sandstone

Nucula (Lamellinucula) exigua Sowerby, 1833	7
Nuculana (Saccella) ornata (d'Orbigny, 1845)	2
Anadara (Anadara) concinna (Sowerby, 1833)	2
Anadara (Cunearca) reinharti (Lowe, 1935)	12
Aequipecten dallasi (Jordan & Hertlein, 1926)	1
Argopecten abietis abietis (Jordan & Hertlein, 1926)	1
Argopecten circularis circularis (Sowerby, 1835)	8
Flabellipecten stearnsii (Dall, 1878)	1
Ctena (Ctena) mexicana (Dall, 1901)	5
Linga (Pleurolucina) undatoides (Hertlein & Strong, 1945)	1
Parvilucina (Parvilucina) mazatlanica Carpenter, 1855	5
Trigonocardia (Americardia) biangulata (Broderip & Sowerby, 1829)	1
Laevicardium elenense (Sowerby, 1840)	30
Laevicardium clarionense (Hertlein & Strong, 1947)	9
Chione (Lirophora) kelletii (Hinds, 1845)	3
Strombus (Lentigo) subgracilior Durham, 1950	2
Polinices (Polinices) bifasciatus (Griffith & Pidgeon, 1834)	2
Nassarius (Phrontis) tiarula (Kiener, 1841)	2
Hindsiclavia militaris (Hinds, 1843)	1
Terebra petiveriana Deshayes, 1857	1

LO3/67 – Piedras Rodadas Sandstone

Anadara (Cunearca) reinharti (Lowe, 1935)	2
Argopecten circularis circularis (Sowerby, 1835)	1
Flabellipecten diegensis (Dall, 1898)	1
Eucrassatella (Hybolophus) gibbosa (Sowerby, 1832)	1
Trachycardium (Dallocardia) senticosum (Sowerby, 1833)	10
Trachycardium (Mexicardia) procerum (Sowerby, 1833)	1
Laevicardium elatum (Sowerby, 1833)	1
Tellina sp. 2	1
Leporimetis cognata (Sowerby, 1835)	2
Sanguinolaria (Sanguinolaria) tellinoides A. Adams, 1850	1
Tagelus (Mesopleura) subteres (Conrad, 1837)	1
Ventricolaria magdalenae (Dall, 1902)	1
Pitar (Lamelliconcha) unicolor (Sowerby, 1835)	8
Dosinia (Dosinia) ponderosa (Gray, 1838)	23
Chione (Chionopsis) gnidia (Broderip & Sowerby, 1829)	1
Corbula (Varicorbula) sp.	3
Panopea generosa (Gould, 1850)	1
Pholadomya (Pholadomya) cf. *candida* Sowerby, 1823	2
Cyatodonta undulata Conrad, 1849	6
Turritella marcosensis Durham, 1950	1
Nassarius sp. 2	1
Colubraria sp. 2	1
Bulla (Bulla) aspersa A. Adams, 1850	3