MIO-PLIOCENE CRUSTACEANS FROM THE CANARY ISLANDS, SPAIN

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Abstract. There are few previous references to fossil crustaceans for the Neogene marine layers of the Canary Islands (Spain). The Mio-Pliocene marine sedimentary layers in the eastern islands (Gran Canaria, Fuerteventura and Lanzarote) were previously characterised by the presence of numerous fossil fauna, mainly anthozoans and molluscs, which correspond to an equatorial-type paleoclimate, warmer than the present climate. This Mio-Pliocene transition dated between 9.3 and 4.1 Ma. In this paper, 12 fossil crustacean taxa are identified and classified, including decapods and barnacles: Balanus cariosus Bronn, 1831, Balanus spongcola Brown, 1827, Balanus perforatus Bruguier, 1789, Chelonolobus testudinaria Linne, 1767, Tetraactis cf. murrayi Darwin, 1854, Callianassa matsoni Rathbun, 1935, Callianassa sp., Upogebia sp., Erphia aff. verrucosa (Forsskal, 1775), Maja sp., Scylla micheibi Milne-Edwards, 1861 and Oxyplectra sp. Some of these taxa mean new references for the Atlantic islands and the North African Atlantic and definitely enlarge the palaeographic distribution of Neogene crustaceans beyond the Mediterranean region, extending it to the North Atlantic. Particularly significant are the presence of Tetraactis cf. murrayi, this being the first reported fossil occurrence of this barnace outside the North America Pacific coasts, and Chelonolobus testudinaria, indicating for the first time the existence of marine turtles in these islands during the Neogene. These results are coherent with previous research hypothesising the existence of a flow of surface water between the Pacific and Atlantic in the Mio-Pliocene transition (Central American Seaway, CAS) which explains the arrival of organisms, in larval stage, from Central America to the Canary Islands.

Introduction

Fossil fauna from the Canary Islands of the Mio-Pliocene age plays an important role in understanding climate evolution in the North African Atlantic. The very few crustacean fossil records for the Canaries come from the XIX century (Rothpletz & Simonelli 1890) [PMM collection: Paläontologisches Museum München, Germany] and the ULPGC-Pal collection [Palaeontological Laboratory of the Universidad de Las Palmas de Gran Canaria, Spain]. However, other fossil fauna groups of Mio-Pliocene sedimentary layers in the Canaries have been studied by Buch (1825), Lyell (1865), Rothpletz & Simonelli (1890) and more recently by Meco (1975). These layers appear in the eastern Canary Islands (NE of Gran Canaria, S and W of Fuerteventura and S of Lanzarote) at varying elevations above more than 140 km of the present-day coastline (Fig. 1).

The chronostratigraphic position of the fossiliferous sedimentary layers corresponds to the Late Mio- Cene and Early Pliocene and was determined by Lietz & Schmincke (1975), Meco & Stearns (1981), and Meco et al. (2007) from K/Ar radiometric dating of lava flows and submarine pillow lavas.

Recently, a Mio-Pliocene fauna association was determined from a study of the ULPGC-Pal collection by Meco et al. (2005, 2007). They established a group of three main fossils and a group of three accompanying fossils (all anthozoans and molluscs) to characterise the Mio-Pliocene layers of the eastern Canary Islands from a chronostratigraphic perspective. In palaeoclimatic terms, these layers importantly indicate temperatures typical of tropical-type warm waters, which are higher than those of the present day are.

The new findings and systematic classification of fossil crustaceans in the sedimentary strata of the Neogene in the Canary Islands contribute to augmenting the palaeontological record and to a better understanding of

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palaeoecological conditions during this period in the North African Atlantic region.

There are very few previous references to fossil crustaceans for these marine layers in the Canaries. Rothpletz & Simonelli (1892) noted the presence of Balanus perforatus Bruguière, 1789 and defined the new species Chenolobia hemisphaerica.

As for accompanying fauna, Meco et al. (2005) defined a group of species of stratigraphic and palaeoecological interest, divided into an first triad that characterises these layers in the Canaries (Gryphaea virletii Deshayes, 1832, Nerita emilia Mayer, 1872 and Strombus coronatus Defrance, 1827) and a second triad of chronostratigraphic confirmation (Ancilla glandiformis Lamarck, 1822, Rothpletzia residua Simonelli, 1890 and Siderastra miocenica Osasco, 1897). This fauna not only provides stratigraphic contextual information corresponding to the Miocene-Pliocene transition, consistent with the different existing radiometric dating, but also additionally informs us of climate conditions different to those of the present day.

Geological and stratigraphic setting

The Canary Islands comprise seven main volcanic islands and several islets and are located in the Eastern Atlantic Ocean between N 27° and N 30° latitudes, forming a chain that extends latitudinally about 450 km; with the easternmost point just over 100 km off the north-western African coast (Fig. 1). The islands have a complex geological history, with volcanic formations over 20 million years old, but they also include extensive sedimentary deposits.

Fossil marine fauna of the Mio-Pliocene are found in coastal deposits on the eastern Canary Islands (NE of Gran Canaria, S and W of Fuerteventura and S of Lanzarote) at varying elevations above the present-day coastline (Fig. 1). They are always composed of layers of two materials: (1) reddish conglomerate (rubefacted conglomerates as a result of Fe oxidation), consisting of coarse gravel, cobble and medium to coarse size sand, and (2) grey to white sands, medium to fine in size, with bioturbation structures, which constitute reference layers (or strata) in the local stratigraphy of each island. The original conglomerates, comprised of cobbles and sands with a wide variety of fossils (anthozoans, brachiopods, molluscs, crustaceans, echinoderms, fishes, etc.), were deposited on wave-cut platforms tens of kilometres long. Subsequently, withdrawal of the sea saw oxidation of pebbles and fossil remains, because of contact with freshwaters. These reddish sandy conglomerates as a whole are considered regional key layers, in both a stratigraphic and palaeontological sense (Lamoschitz et al. 2011).

In order to establish a general time interval, the fossil specimens previously studied from these deposits dated to a Late Miocene and Early Pliocene age (Fig. 2). This agrees with K/Ar ages obtained from pillow lavas emplaced in the marine deposits (ca 4.1 Ma in Gran Canaria, ca 4.8 Ma in Fuerteventura) and from underlying (ca 9.3 Ma in Gran Canaria) or overlying (ca 8.9 Ma in Lanzarote) lava flows (Meco et al. 2007). Consequently, it is consistent to consider a time interval between 9.3 and 4.1 Ma for Neogene marine deposits in the eastern Canary Islands as a whole.

Another important aspect of the fossiliferous sedimentary layers is the varying height above present sea level (apsl) of the different outcrops in the Canaries. These range from 9 to 57 m apsl in Fuerteventura, from 21 to 69 m apsl in Lanzarote and from 50 to 120 m apsl in Gran Canaria. These variations in height have been
interpreted as being related to tectonic readjustments in the different island edifices (Meco et al. 2007). In addition, from a palaeoclimatic perspective these raised marine deposits in the eastern Canary Islands have been interpreted as warming episodes within Plio-Quaternary climate variations.

Stratigraphic sections

The fossil crustacean specimens were found in the sedimentary layers, consisting of old coastal and marine deposits which outcrop along more than a hundred kilometres, if all the different stretches are considered together. As these layers show many lateral variations along the outcrops, eight sections have been selected to be representative of the whole area: Janubio and Los Ajaches from S. Lanzarote Is., Aljibe de la Cueva and Ajui from W Fuerteventura Is. (Fig. 3), and Guiniguada, Barranco Seco, Arenales-Chil and Quintanilla from NE Gran Canaria Island (Fig. 4, Fig. 5A).

1 - Janubio section
Location: SW Lanzarote Is.
Latitude: 28°55'57.48", longitude: 13°49'17.72", height: 36 m (apd)
This section comprises three units, which are (top to bottom):
1) Basaltic lava flows (3 m). These are thin layers of rock with intercalations of pyroclasts, horizontally displayed and slightly weathered. They are of Early Pleistocene age according to IGME (2003) and Meco et al. (2007).
2) Reddish conglomerate with fossils (0.5 m). This is composed of sub-rounded basaltic pebbles and cobbles with a matrix of fine gravel and sand, partially cemented by calcite.
3) Basaltic lava flows (20-30 m). These are a succession of predominant lava flows and beds of scoria and buried tephra cones, which are densely crossed by dykes. All these materials are intensely weathered. They are of Middle to Late Miocene age, according to IGME (2005).

2 - Los Ajaches section
Location: SE Lanzarote Is.
This section comprises four units, which are (top to bottom):
4) Sandy gravel colluvium (0.5 m) of Holocene age.
3) White dune sand (3 m). Aeolianite composed of carbonate grains of medium to fine sand, with a characteristic cross-bedding internal structure.
2) Reddish conglomerate with fossils (1.5 m). This is composed of rounded to sub-angular basaltic pebbles, cobbles and some boulders with a matrix of fine gravel and sand, partially cemented by calcite.
1) Basaltic lava flows (35 m). These are massive and very thick layers of basalts, with columnar jointing. They are composed of dark basalt of aphanitic matrix, with weathered olivine (iddingsite) and pyroxene crystals. They are of Late Miocene age, according to IGME (2005).

3 - Aljibe de la Cueva section
Location: NW Fuerteventura Is.
This section comprises four units, which are (top to bottom):
4) White sand dunes (2 m). Aeolianite composed of carbonate grains of fine sand.
3) Basaltic lava flows and tephra (2 m). These are part of a succession of thin layers of olivine basalt, rather weathered, with some intercalated layers of pyroclasts. They are of Late Pliocene age, according to IGME (2006).
2) Reddish conglomerate with fossils (0.5-2 m). As a whole, it is composed of conglomerate and sand layers. The conglomerate layer has sub-rounded basaltic pebbles and cobbles with a matrix of gravel and sand, partially cemented by calcite. The sand layer is comprised of grey coarse sands with slightly defined planar lamination. They correspond to the Pliocene coast platform described in IGME (2006).
1) Basaltic lava flows and dykes (5 m). These are highly weathered rocks with olivine and pyroxene crystals and secondary filling of calcite and zeolite. Basaltic and trachytic dykes also densely cross them. This formation is of Early Miocene age, according to IGME (2006).

4 - Ajui section
Location: W Fuerteventura Is.
This section comprises five units, which are (top to bottom):
5) Sandy gravel colluvium (1 m) of Holocene age.
4) White sand dunes (2 m). Aeolianite composed of carbonate grains of medium to fine sand, with a characteristic cross-bedding internal structure.

3) Basaltic pillow lavas and hyaloclastites (3 m). These come from olivine basaltic lava flows that erupted about 9 km inland. This formation is of Early Pliocene age, according to IGME (2006) and Meco et al. (2007).

2) Reddish conglomerate with fossils (1.5 m). This is mainly composed of basaltic sub-rounded pebbles, gravels and cobbles with sandy matrix. It is part of the Pliocene marine platform described in IGME (2006).

1) Basaltic lava flows and dykes (8 m). These are badly defined layers of basaltic materials: lava flows, breccias, tuffs and hyaloclastites. They are highly weathered rocks and densely crossed by dykes. As a whole, they are part of the "basal complex" of Fuerteventura that is of Oligocene age, according to IGME (2006).

**Fig. 3** Stratigraphical sections on Lanzarote and Fuerteventura islands where the fossil crustaceans have been found. K/Ar dating ages (*) from (+) Custo et al. (1992) and (++) Meco et al. (2007).

**Fig. 4** Stratigraphical sections on NE Gran Canaria where the fossil crustaceans have been found. Modified from Galdón et al. (1989) and Meco et al. (2005). K/Ar dating ages (*) from (+) Guillou et al. (2004) and (++) Meco et al. (2007).

This section comprises five units, which are (top to bottom):

5) Heterogeneous sandy conglomerate of phonolitic and basaltic pebbles (>15 m). This is a mixture of coarse gravel with sand, cobbles and boulders, angular to sub-rounded in shape and slightly horizontally layered. It is an alluvial fan deposit of Pliocene age.

4) Reddish conglomerate with fossils (1.5 m). This is composed of sub-rounded phonolitic pebbles and cobbles with a matrix of fine gravel and sand, partially cemented by calcite. It is a Lower Pliocene deposit and was formed in a tidal environment of a coastal platform.

3) Reddish phonolitic lava flow (1-12 m). The variable outcropping thickness of this layer is due to coastal erosion that occurred on an old phonolite cliff. A later exposure to fresh water caused the red colour, which is common in weathering processes.

2) Heterogeneous sandy conglomerate of phonolitic pebbles (3-10 m). This is a mixture of coarse gravel, pebbles and cobbles with a matrix of coarse sand and fine gravel. Their clasts are sub-angular to sub-rounded in shape. It corresponds to a Miocene alluvial fan.

1) Phonolitic non-welded ignimbrite (>15 m). This has a homogeneous appearance and is composed of thick layers of yellow to white rocks. It corresponds to the Miocene of Gran Canaria.
6 - Barranco Seco section (Las Palmas)
Location: NE Gran Canaria Is.
This section comprises six units, which are (top to bottom):
6) Heterogeneous sandy conglomerate of phonolitic and basaltic pebbles (20-25 m). It is similar to unit 5 of the Guiniguada section, described above.
5) White sand dunes (5-10 m). Aeolianite composed of carbonate grains of fine to medium sand, with a characteristic cross-bedding internal structure.
4) Grey sand with bioturbation structures (3-8 m). This is a deposit of medium to fine sand, which originated in a foreshore environment.
3) Reddish conglomerate with fossils (2 m). It is similar to unit 3 of the Guiniguada section, described above.
2) Heterogeneous sandy conglomerate of phonolitic pebbles (20-25 m). It is similar to unit 2 of the Guiniguada section, described above.
1) Phonolitic non-welded ignimbrite (>15 m). It is similar to unit 1 of the Guiniguada section, described above.

7 - Arenales-Chil section (Las Palmas)
Location: NE Gran Canaria Is.
This section comprises five units, which are (top to bottom):
5) Heterogeneous sandy conglomerate of phonolitic and basaltic pebbles (20-25 m). It is similar to unit 5 of the Guiniguada section and unit 6 of the Barranco Seco section, described above.
4) Grey sand with bioturbation structures (5 m). This is a deposit of medium to fine sand, which originated in a foreshore environment.
3) Reddish conglomerate with fossils (2-3 m). It is similar to unit 3 of the Guiniguada and Barranco Seco sections, described above.
2) Heterogeneous sandy conglomerate of phonolitic pebbles (20-25 m). It is similar to units 2 of the Guiniguada and Barranco Seco sections, described above.
1) Phonolitic lava flow (>12 m). This is composed of a hard rock, dark green in color and with homogenous appearance. It corresponds to the Miocene of Gran Canaria, which are of Late Miocene age.

8 - Quemada section
Location: NE Gran Canaria Is.
Latitude: 28°07'12.84", longitude: 15°23'30.75", height: 97 m (apd).
This section comprises six units, which are (top to bottom):
6) Basaltic lava flows (25 m). These are horizontally displayed layers, with scoiactine larvae at their top. They are of Early Pleistocene age according to ITGE (1990).
5) Basaltic lava flows and pillow lavas (40 m). These form a monotonous layer, about 25 m thick, that is only disturbed at their bottom, where lava flows (orally serial) turn to pillow lavas and hyaloclastites (submarine) with an average thickness of 15 m. They are of Early Pleistocene age according to ITGE (1992) and Meco et al. (2007).
4) White alk and sand (0.5-1.5 m). This is an easily distinguishable layer because of its light colour. In detail, it is composed of 2-3 thin layers, which correspond to specific sedimentary facies: white alk with planar laminating; grey coarse sand with undulated laminating and grey coarse to fine sand with planar lamination. It most probably originated in a quiet and shallow foreshore environment, e.g. a small bay.
3) Reddish conglomerate with fossils (0.5-2 m). This is similar to unit 3 of the other Las Palmas sections, described above.

2) Heterogeneous sandy conglomerate of phonolitic pebbles (12-15 m). This is similar to unit 2 of the other Las Palmas sections, described above.
1) Phonolitic non-welded ignimbrite (15-20 m). This is similar to unit 1 of the Guiniguada and Barranco Seco sections, described above.

Canary Island Neogene Crustaceans

Twelve taxa have been identified in the different outcrops of the deposits in the islands, corresponding to both decapod and cirriped crustaceans. These Neogene fossil crustaceans are shown in the following list:
1. Balanus concavus Bronn, 1831
2. Balanus spongicola Brown, 1827
3. Balanus perforatus Bruguère, 1789
4. Chelonolobus testudinaria Linné, 1767
5. Terebralia cf. rubescens Darwin, 1854
6. Callianassa matsoni Rathbun, 1935
7. Callianassa sp.
8. Upogebia sp.
9. Erpibea aff. verrucosa (Forskal, 1775)
10. Maja sp.
11. Scylla michelini Milne-Edwards, 1861
12. Ocypode sp.

Systematic Palaeontology

Phylum Arthropoda Latreille, 1829
Subphylum Crustacea Pennat, 1777
Class Maxillopoda Dahl, 1956
Infraclass Cirripedia Burmeister, 1834
Superorder Thoracica Darwin, 1854
Order Sessilia Lamarck, 1818
Suborder Balanomorpha Pilsgby, 1916
Superfamily Balanoidea Leach, 1817
Family Balanidae Leach, 1817
Genus Balanus Da Costa, 1778

Balanus concavus Bronn, 1831
Pl. 1, figs A1, A2, A3
1856 Balanus concavus Darwin, p. 235, pl. 4, fig. 4a-e.
1906 Balanus concavus - Alessandri, p. 295, pl. XVI, figs 21-25.
1952 Balanus concavus - Davide, p. 17, pl. I, figs 1-2; pl. II, figs 1-2; pl. III, figs 1-2; pl. IV, figs 1-2; pl. V, figs 1-2.
1963 Balanus (Balanus) concavus - Davide, p. 52, pl. XXIV, figs 8-9.
Balanus concavus - Meens, p. 110, pl. IV, figs 2-6; pl. VI, figs 1-4; pl. X, figs 7-8; pl. XI, figs 1-2; pl. XVII, figs 3-8; pl. XIX, figs 1-3.
Balanus concavus - Cuerda and Sacares, p. 115, pl. II, fig. 1a-b; fig. 2.
1979 *Balanus concavus concavus* - D’Alessandro et al., p. 94, pl. 18, figs 4-5; pl. 19, figs 1-3.

**Material:** Many free *scutum* and a few shells attached to bivalves (*Chama sp.*).

**Locality:** Fuerteventura: Jandia (Costa Calma) (Fig. 1), Costa de Barlovento. Gran Canaria: Barranco de Mata, Las Rehoyas-El Polvorín, San José, Bañaderos.

**Remarks.** Reported for the Oligocene of Hungary and Algeria. Found at sites of Miocene age in Germany, Austria, France, Italy, Algeria, Portugal and even the Atlantic coasts of North America. During the Pliocene, it is very abundant in Italy, Algeria, Spain and England. Currently found in the Caribbean, Panama, Peru, the Philippine archipelago and Australia (Darwin 1854; Menesini 1964), but extinct in the Mediterranean (D’Alessandro et al. 1979). Displays a high degree of polymorphism, with a slender and angular *scutum*, the design of which has grooves, or vertical and horizontal lines, which criss-cross in a highly characteristic pattern.

*Balanus perforatus* Brugière, 1789
Pl. 1, fig. B1

1873 *Balanus perforatus* - Seguenza, p. 28, pl. I, figs 2-2a.
1926 *Balanus perforatus* - Alessandri, p. 294, pl. XVI, figs 17-20.
1952 *Balanus perforatus* - Davadie, p. 20, pl. III, fig. 3; pl. IV, fig. 1.
1963 *Balanus (Balanus)* perforatus - Davadie, p. 38, pl. XI, figs 5-8.
1964 *Balanus perforatus perforatus* - Menesini, p. 95, pl. I, figs 10, 12, 13; pl. II, figs 1-4; pl. VIII, figs 5-8; pl. XII, fig. 8; pl. XIV, figs 1-5.
1976 *Balanus (Balanus)* perforatus angustus - Pajaud, p. 483, fig. 1a-b, fig. 2.

**Material:** Large number of specimens forming aggregates.

**Locality:** Fuerteventura: Coñute (Coñute, Risco del Moro).

**Remarks.** Reported in the Miocene and Pliocene levels of the Indian Ocean and Mediterranean Seas. Found today in the Mediterranean and Atlantic, along the French coast, England and west coast of Africa (Menesini 1964).

*Balanus spongicola* Brown, 1827
Pl. I, fig. C1, C2

1824 *Balanus spongicola* - Darwin, p. 225, pl. 4, fig. 1a-d.
1873 *Balanus spongicola var. pliocenica* Seguenza, pl. IX, fig. 9-17.
1926 *Balanus spongicola* - Alessandri, p. 290, pl. XVI, figs 6-13.
1963 *Balanus (Balanus)* spongicola - Davadie, p. 49, pl. XXIV, figs 1-7.
1965 *Balanus spongicola* - Menesini, p. 106, pl. III, figs 2-14; pl. IV, fig. 1-1a; pl. X, figs 1-6; pl. XVII, figs 1-2.

**Material:** Fragments of various large-sized *scuta*.

**Locality:** Fuerteventura: Costa de Barlovento (Barranco de la Cruz). Gran Canaria: Arenales (Fig. 1).

**Remarks.** Reported in the Miocene of England, Italy, Sardinia, France, Spain, Algeria, Tunisia, and Egypt. Very common during the Pliocene and Pleistocene of Italy, Portugal and Algeria. Currently found in the Mediterranean, Cape of Good Hope and south of England. It is characterised by its large-sized *scuta* with grooved or parallel line decoration.

**Genus Chelonibia (Chelonobia) Leach, 1817**

*Chelonibia testudinaria* Linné, 1758
Pl. 1, fig. D1, D2

1854 *Chelonibia testudinaria* - Darwin, pl. 14, fig. 1 a-d, fig. 5; pl. 15, fig. 1.
1966 *Chelonibia testudinaria* - Alessandri, p. 314, pl. XVIII, figs 6-7.
1982 *Chelonibia testudinaria* (Linnaeus, 1758). Morris et al., p. 516, fig. 149.

**Material:** A single fragment of *rostrum*.

**Locality:** Gran Canaria: Mata ravine.

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**PLATE 1**

Fossil crustaceans remains of the Mid-Pliocene transition in the eastern Canary Islands.


L - *Oxyode sp.* L1 Right chela, exterior view, L2) interior view, L3) meropodite fragments. Coñute, Fuerteventura.
Miocene-Pliocene crustaceans from the Canary Islands, Spain
Remarks. Reported in the Pliocene of the Mediterranean (Italy) and currently found in the Mediterranean and Pacific (Mexico and northern Australia), it is always associated with the presence of marine turtles. Epibiont barnacle on turtle shells. Reaches a maximum diameter of 8 cm (Morris et al. 1980), low height, smooth shell on the outside with only slight inclination. Rostrum consisting of three fused plates.

Superfamily Tetractitoidea Gruvel, 1903
Family Tetractitidae Gruvel, 1903
Subfamily Tetractitinae Gruvel, 1903
Genus Tetractita Schumacher, 1817

Tetractita aff. rubescens Darwin, 1854

1854 Tetractita porosa var. rubescens Darwin, p. 382, pl. 10, fig. 1b.
1916 Tetractita squamosa rubescens – Pilsbry, p. 250, pl. 61, fig. 1a-c.
1980 Tetractita rubescens – Morris et al., p. 157, pl. 150.

Material. Very abundant. Large-sized complete specimens and fragments of specimens found attached to bivalves (Gryphaea vireti Deshayes, 1832).

Locality: Lanzarote: Papagayo, Costa de Las Aijaches (Punta Gorda, La Colorada). Fuerteventura: Costa de Barlovento (between Los Molinos and Santa Inés), Jandía (Costa Calma – Costa Esmeralda). Alíbe de la Cueva. Gran Canaria: Ciudad Jardín, Guiniguada (Fig. 1).

Remarks. Limited in both its fossil (Pliocene and Pleistocene) and present-day form from Cape San Lucas, Baja California, Mexico, to San Francisco Bay (Pilsbry 1916). Exterior decorated with very marked grooves. The region of the orifice of these barnacles tends to be eroded and so is seen enlarged. They grow in intertidal habitats, in exposed and quite wave-beaten areas. They occasionally appear in the subtidal region, in this case attached to shells, mainly to Haliotis (Morris et al. 1980).

Subphylum Crustacea Brünich, 1772
Class Malacostraca Latreille, 1803
Subclass Eumalacostraca Grobben, 1892
Order Decapoda Latreille, 1803
Suborder Pleocyemata Burkenroad, 1963
Infraorder Thalassinidae Latreille, 1831
Superfamily Thalassinoidea Latreille, 1831
Family Callianassidae Dana, 1852
Genus Callianassa Leach, 1814

Callianassa cf. matsoni Rathbun, 1935
Pl. 1, fig. F1

Material. Two chelae without dactylopodites with different degree of preservation. One corresponds to a right pincer with a fragment of finger and the other to a left pincer with the two ends broken.

Locality: Fuerteventura: Alíbe de la Cueva (Fig. 1, Fig. 3). Gran Canaria: Chil (Fig. 1).

Remarks. Present in Florida Miocene deposits. Pincer of subrectangular form with smooth edges and convex appearance, which has a narrow fixed finger. The distal edge of the pincer where the dactylopodite is inserted is oblique or perpendicular. The outer surface is convex in a vertical direction. A deep, highly characteristic U-shaped sinus is observed at the base of the lower finger.

Callianassa sp.
Pl. 1, fig. G1, G2

Material. Two right chelae, one complete but with dactylopodite insertion point broken and eroded, the other in bad condition with complete fixed finger.

Locality: Costa de Barlovento (Barranco de Esquinces) and Jandía (Costa Calma), Fuerteventura (Fig. 1).

Remarks. Two chelae (manus and dactylus) with similar taxonomic features to those seen in the genus Callianassa Leach, 1814. These two chelae have the following characteristics: rectangular shaped, slender and narrow, slightly bulging. Concave interior and convex exterior. Long and inward-curving fingers. Very pronounced beak-like curvature of the fingertips. In the interior region of both the movable and fixed finger, a fine keel-like ridge (carina) extends over the finger from virtually the tip to the end giving it a blade-like appearance. This fine carina follows both the upper and lower edges of the chela and appears much more pronounced at the distal vertices, with a slight continuation noticeable towards the joint. A slight semi-circular depression is observed in the mid-interior region of the chela at the distal end where the joint is situated.

C. candida (Olivi, 1792), presently found in the Mediterranean, has the interior or cutting edges of the two fingers serrated, whereas they are smooth in Callianassa sp. The upper finger is notably more robust in the present day species and displays a series of tubercles on the interior edge which are absent in the Mio-Pliocene species.

Family Upogebiidae Borradaile, 1903
Genus Upogebia Leach, 1814

Family Callianassidae Dana, 1852
Genus Callianassa Leach, 1814
Upogebia sp.  
Pl. 1, fig. H1

Material: Partially broken left pincer.  
Locality: Gran Canaria: Las Rehojas - El Polvorín.

Remarks. Rectangular left chela, slightly concave interior and markedly convex exterior. Smooth external surface. Fine lower margin, finely and evenly serrated, with very small and flat, triangular shaped spines. Superior and anterior edge encrusted with sand. Superior or movable finger absent, as is its insertion. Fixed finger well preserved, small in size, very curved and interior edge with a carina that runs along its length.

Infraorder Brachyura Latreille, 1802  
Section Eubrachyura Saint Laurent, 1980  
Subsection Heterotremata Guinot, 1977  
Superfamily Eriphioidae MacLeay, 1838  
Family Eriphiidae MacLeay, 1838  
Genus Erphiia Latreille, 1817

Erphiia aff. verrucosa (Forskal, 1775)  
Pl. 1, fig. K1, K2

Material: Fragment of left pincer, broken at both joints and with encrustation of fine sands on both the interior and surface.  
Locality: Papagayo coast, Lanzarote (Fig. 1, Fig. 5C).

Remarks. Small squared chela with fixed finger and cusps. Smooth interior face, exterior face covered with rounded tubercles, moderately aligned longitudinally, that extend to the upper edge and slightly beyond to the interior face. They are of a larger size in the upper half. Fixed finger with a slight rectangular depression in the exterior surface.

There is a strong resemblance between this chela and that shown by Varola (1981) and classified as Erphiia verrucosa (Forskal, 1775) for the Neogene deposits (Miocene and Pliocene) of Sicily. Balanzá et al. (2013) quote this genus in the deposits of the lower Pleistocene of Siena Basin, Tuscany, Italy.

This crab is presently found in the Mediterranean Sea, West Africa and Canary Islands coasts (González Pérez, 1995).

Superfamily Majoidea Samouelle, 1819  
Family Majidae Samouelle, 1819  
Genus Maja Lamarck, 1801

Maja sp.  
Pl. 1, fig. J1

Material: Two dactylopodite fragments of different length and different states of preservation.

Locality: Fuerteventura: Añibe de la Cueva (Fig 1, Fig. 3).

Remarks. Reported for the levels of the Lower Pliocene of England, Upper Pliocene of Italy and the Pleistocene of Italy and Sicily (Varola 1981). Slender, curved cone-shaped dactylopodites with smooth surface. The fragments are very similar to the dactylopodite of Maja squamata (Herbst, 1788) of the Neogene of southern Italy (Varola 1981).

Superfamily Portunoidea Rafinesque, 1815  
Family Portunidae Rafinesque, 1815  
Subfamily Portuninae Rafinesque, 1815  
Genus Scylla de Hann, 1833

Scylla michelinii Milne-Edwards, 1861  
Pl. 1, fig. K1, K2

1861 Scylla michelinii Milne-Edwards, p. 262, pl. 3, fig. 3.

Material: Numerous pincer fragments (dactylopodites and propodites), varying in size from 0.9 to 3.83 cm.  
Locality: Fuerteventura: Añibe de la Cueva. Gran Canaria: Chil (Fig 1, Fig. 3).

Remarks. Reported for the Miocene of Ajou, France. According to Milne-Edwards (1861) the difference in pincers between the S. michelinii Milne-Edwards, 1861 and the Scylla serrata (Forskal, 1775) is minimal. Complete carapaces need to be examined for a full classification.

Section Thoracotremata Guinot, 1977  
Superfamily Ocypodoidea Rafinesque, 1815  
Family Ocypodidae Rafinesque, 1815  
Subfamily Ocypodinae Rafinesque, 1815  
Genus Ocypode Weber, 1795

Ocypode sp.  
Pl. 1, fig. L1, L2, L3

Material: Numerous stray fragments in compacted sands, fragments of legs, carapace and pincers, attributable to several individuals.  
Locality: Cofete, Fuerteventura (Fig 1, Fig. 5B).

Remarks. Robust and quadrangular-oval pincer with convex exterior and concave interior. Surface covered with granules, more pronounced in the distal region and the region near the fixed finger. In the interior side there is a rounded and prominent insertion point for the joint, with a well-defined sinus which tapers the chela to the insertion point in a highly characteristic form. Both upper and lower edges have a row of short
spines, more marked on the lower edge, which extend as far as the respective fingers. Triangular-shaped lower finger with dentate internal edge and 7-8 teeth, more pronounced in the central region. The tip of the pincer terminates in a hook-like tooth. The upper edge has a series of short spines. Both interior and exterior surfaces are adorned with two slightly raised lines comprising an alignment of granules which are more separated at the distal region of the fixed finger. The interior edge of the movable finger has 8-10 teeth of slight prominence. The exterior side has an alignment of well-defined spines in addition to a single ornamental line similar to that present in the fixed finger.

The remains found in the Canary islands and classified as *Ocydope* sp. do not allow a conclusive classification. The available remains display a certain resemblance to *Ocydope italica* Garassino, 2010 (Garassino et al. 2010) described for the Pliocene deposits of Tuscany, Italy. In terms of general appearance, there is a strong resemblance in the decoration of the *merus*, *carpus*, and *propodus* of the walking legs, in terms of overlapping grooves, and in the chelips, covered in fine granules. The main difference observed between *O. italica* and the *Ocydope* found in the Canary Mio-Pliocene lies in the shape of the chelips.

It also differs from other species of the genus *Ocydope*, both fossil and present day specimens, as for example *O. africana* De Man, 1881 in the general shape of the pincers and the decoration of the walking legs.

**Biogeography**

The species above have an extensive and variable bio-geographical distribution, both fossil and current (Tab. 1). They have been found in areas of the Atlantic, Pacific and Indian oceans and of the Mediterranean Sea. Three quarters of the Neogene species still exist now. However, in the Canary Islands, only half of the fossil species have been identified in present times. This is further evidence of the tropical-type climate which occurred in the Mio-Pliocene stage, different to today's subtropical-type climate.

**Conclusions**

This paper offers a review and systematic classification of the crustacean fossils of the Canary Neogene, a group of fossils which to date has not been the subject of a specific study.

These fossils were found in marine sedimentary deposits of the eastern Canary Islands (NE of Gran Canaria, S and W of Fuerteventura and S of Lanzarote) along more than 100 km of coast (if the different

Fig. 5 - Examples of outcrops where the fossil crustaceans have been collected: A) Barranco Seco (NE Gran Canaria): 1 - phonolite non-welded ignimbrite; 2 - reddish conglomerate with fossils; 3 - foreshore grey fine sand (2 and 3 correspond to the middle member of the Las Palmas Detritic Formation). B) Colote (SW Fuerteventura): 1 - basaltic lava flows and tephra cones; 2 - reddish conglomerate; 3 - white marine sandstone. 4 - Pleistocene dunes. C) Papagayo cliff (S Lanzarote): 1 - basaltic lava flows and pyroclasts; 2 - reddish conglomerate; 3 - Pleistocene aeolianite sandstone.
Tab. 1 - Global biogeography and chronostratigraphy of the crustaceans in the Mio-Pliocene marine deposits from the Canary Islands. Comparison between fossil and current species.

<table>
<thead>
<tr>
<th>Taxa</th>
<th>Global biogeography</th>
<th>Global chronostratigraphy</th>
<th>Canary Islands</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fossil</td>
<td>Current</td>
<td>Mio-Pliocene</td>
</tr>
<tr>
<td>Balamus concaevus</td>
<td>Miocene Tethys coasts of Germany, France, Austria and Italy. Upper Neogene Atlantic and Mediterranean Basin (Italy, Algeria, Spain, England).</td>
<td>Caribbean Sea, Panama, Peru, Philippines, Australia</td>
<td>X</td>
</tr>
<tr>
<td>Brown, 1831</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balamus spongicola</td>
<td>England, Tethys and Mediterranean Basin (Italy, France, Spain, Algeria, Tunisia, Egypt).</td>
<td>Widespread along the Mediterranean and Atlantic coasts (from the south of England to Cape of Good Hope).</td>
<td>X</td>
</tr>
<tr>
<td>Brown, 1827</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Balamus perforatus</td>
<td>Miocene Tethys and Mediterranean Basin</td>
<td>Widespread along the Mediterranean and Atlantic coasts.</td>
<td>X</td>
</tr>
<tr>
<td>Bruguère, 1789</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Chelonibia testudinaria</td>
<td></td>
<td>Pliocene of Italy</td>
<td></td>
</tr>
<tr>
<td>Linné, 1767</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tetrasulcida cf. rubescens</td>
<td>Pacific coast of North America, from Cape San Lucas to San Francisco Bay</td>
<td>Pacific coast of North America, from Cape San Lucas to San Francisco Bay</td>
<td>X</td>
</tr>
<tr>
<td>Darwin, 1854</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Callianassa cf. matisoni</td>
<td>Miocene of Florida, east coast of North America</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rathbun, 1935</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Callianassa sp.</td>
<td>Widespread in the Miocene and Pliocene in the Tethys and Mediterranean Basin and Atlantic European Coast.</td>
<td>Widespread</td>
<td>X</td>
</tr>
<tr>
<td>Upogebia sp.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eriphia aff. verrucosus</td>
<td>Neogene Sicily, Pleistocene Sicily</td>
<td>Widespread along the Mediterranean, Atlantic coasts of Portugal, Morocco, Azores and Canary Islands</td>
<td>X</td>
</tr>
<tr>
<td>(Forskal, 1775)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maja sp.</td>
<td>Widespread in the Miocene and Pliocene in the Tethys and Mediterranean Basin and Atlantic European Coast.</td>
<td>Widespread</td>
<td>X</td>
</tr>
<tr>
<td>Scylla michelini</td>
<td>Miocene Of Tethys and Mediterranean</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milne-Edwards, 1861</td>
<td></td>
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<tr>
<td>Ocyopode sp.</td>
<td>Miocene and Pliocene in the Mediterranean Basin (Italy, Hungary, Spain, Morocco) and Atlantic (Florida and Argentina).</td>
<td>Widespread</td>
<td>X</td>
</tr>
</tbody>
</table>

stretches of coast are considered as a whole) and at varying elevations above the present-day coastline (Fig. 1).

Their assignment to the Mio-Pliocene transition has been possible by verifying their chronostratigraphic position with respect to lava flows for which there are previously published K/Ar datings (Meco et al. 2005, 2007). These allow establishing a range of ages for the marine deposits of between 8.9 and 4.1 Ma (Fig. 2).

Eight stratigraphic sections have been selected along the coasts of Gran Canaria, Fuerteventura and Lanzarote, representative of the marine sedimentary strata of this period in the Canary Islands (Figs 3-5).

The marine deposits are generally composed of two materials: 1) reddish conglomerate of gravel, cobble and sand, and 2) grey to white sands with bioturbation structures, which constitute a guide layer in the local geology of each island.

A total of 12 taxa have been identified and classified (Pl. 1): Balamus concaevus Brown, 1831, Balamus spongicola Brown, 1827, Balamus perforatus Bruguère, 1789, Chelonobia testudinaria Linné, 1767, Tetrasulcida cf. rubescens Darwin, 1854, Callianassa matisoni Rathbun, 1935, Callianassa sp., Upogebia sp., Eriphia aff. verrucosus (Forskal, 1775), Maja sp., Scylla michelini Milne-Edwards, 1861 and Ocyopode sp.

The studied fossil fauna, including cirripeds and decapods, provides new localities of their Neogene distribution and allow their presence to be extended beyond the Mediterranean region to the North Atlantic (Tab. 1).

It is notable that the observation of Tetrasulcida cf. rubescens Darwin, 1854 in the fossiliferous marine deposits of the Canary Neogene supposes the first fossil report of this barnacle outside the Pacific coasts of North America. This allows its palaeogeographical setting to be extended beyond the strictly defined region of the coasts of North America to the Canary Islands. Additionally, the appearance of Chelonobia testudinaria Linné, 1767 indicates the existence, sporadic or otherwise, of sea turtles in the Canary Islands during the Neogene.

The Mio-Pliocene fauna which accompany the Canary crustacean fossils indicate ecological and climatic conditions very different to those of today. The presence of fossil species belonging to the genera Strombus Linné, 1758 (Strombus coronatus Debrance, 1827), Ancilla Lamarck, 1799 (Ancilla glandiformis Lamarck, 1810) and others, as well as the presence of the coral Siderastrea miniacea Osasco, 1987, suggest climate conditions equivalent to those of present day tropical and sub-tropical regions, like the Caribbean Sea (West Atlantic) or the Gulf of Guinea (East Atlantic).

The results of this study are coherent with previous researches (e.g. Sumata et al. 2004) which hypothesise the existence of a flow of surface water between the Pacific and the Atlantic in the Mio-Pliocene transition (Central American Seaway, CAS). This Pacific-Atlantic connection explains how organisms arrived in larval stage from Central America to the Canary Islands in the Mio-Pliocene transition.
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