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THORACIC CIRRIPIEDIA OF THE SAN DIEGO FORMATION,  
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# THORACIC CIRRIPIEDIA OF THE SAN DIEGO FORMATION, SAN DIEGO COUNTY, CALIFORNIA

By VICTOR A. ZULLO<sup>1</sup>

**ABSTRACT:** The cirriped fauna of the Pliocene San Diego Formation, San Diego County, California, includes six species of *Balanus* Da Costa and one each of *Cetolepas* gen. nov., *Coronula* Lamarck, and *Lepas* Linnaeus. Three species, *Balanus* (*Balanus*) *kanakoffi*, *B.* (*Megabalanus*) *wilsoni*, and *Cetolepas* *hertleini* are new and known only from the San Diego Formation. The single lepadid scutum represents the first fossil record of Lepadomorpha from the margins of the eastern Pacific Basin. The *Coronula* appears to be *C. barbara* Darwin, known previously from the Pliocene and Early Pleistocene of Europe. *Cetolepas* *hertleini* affords a clue to the derivation of *Tubicinella* Lamarck from *Coronula*.

This warm temperate to subtropical fauna is composed of a mixture of extinct and living species and is transitional between California Miocene faunas characterized by extinct species and Pleistocene faunas dominated by living species.

## INTRODUCTION

This paper is part of a series (Hertlein and Grant, 1944, 1960) dealing with the geology and paleontology of the San Diego Formation of San Diego County, California, that is being developed under the aegis of Dr. Leo G. Hertlein, California Academy of Sciences. The bulk of the material used in this study was collected by Mr. George P. Kanakoff, former Curator of Invertebrate Paleontology, Los Angeles County Museum of Natural History, and the present Curator, Dr. Edward C. Wilson, and is supplemented by specimens from the collection of the California Academy of Sciences.

Altogether, nine species, of which three are new, representing four genera, of which one is new, are recognized. However, this account does not include all of the species that were evidently present during the deposition of the sediments of the San Diego Formation, for a few isolated opercular valves and disarticulated compartmental plates could not be identified with recognized taxa.

It is difficult to characterize the cirriped fauna of the San Diego Formation, either geographically or historically, primarily because of the present lack of data on fossil barnacle faunas of the Pacific Coast. Of the nine species indicated by the collection, three, including one of a new genus, are new and not known from other deposits. Two, *Balanus* *gregarius* (Conrad) and *B.*

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*proinus* Woodring, are extinct species that were apparently widespread in shallow Pliocene seas of southern California and endemic to the Pacific Coast of North America. A third extinct species, tentatively identified with the whale barnacle *Coronula barbara* Darwin, is otherwise known only from the Pliocene and Early Pleistocene of Europe. Two of the remaining species appear to represent the extant Pacific Coast barnacles *Balanus nubilus* Darwin and *B. pacificus* Pilsbry. The *Lepas* sp. is similar to an extant cosmopolitan species usually found attached to floating seaweed and debris.

Comparison of this fauna with one of similar size and age from the San Joaquin Basin to the north (unpublished data based on UCMP collections) indicates little similarity between them. Two species, *Balanus gregarius* and *B. proinus*, are common to both faunas, but the remaining San Joaquin species appear to be endemic to the basin. The Pliocene barnacles of the geographically closer Santa Maria District are poorly known, and the two species reported (the *B. aquila* Pilsby and *B. hesperius proinus* of Woodring, in Woodring and Bramlette, 1950) are the same species that tenuously link the San Diego fauna to that of the San Joaquin Basin.

In a broad sense, the barnacle fauna of the San Diego Formation suggests warm temperate to tropical conditions, and is compositionally transitional between that of the Pacific Coast Miocene, whose species are largely extinct, and that of the Pleistocene, which is composed primarily of extant species. On the other hand, surprisingly little information is afforded by the fauna, with the possible exception of the new whale barnacle, regarding the evolution of extant Pacific Coast species.

In order to facilitate identification of the species reported herein, keys to scuta, terga, and shells have been prepared, and are to be found immediately following the section on systematic descriptions. Caution must be exercised in the use of these keys, for they are applicable only to the barnacles of the San Diego Formation, and although the common barnacles of the formation can be recognized from the keys, note must be made of the fact that other species are evidently present and may be better represented in future collections.

The following abbreviations are employed herein to designate those institutions whose collections were examined: CAS, California Academy of Sciences, San Francisco; LACM, Los Angeles County Museum of Natural History, Los Angeles, Section of Invertebrate Paleontology; SDSNH, Natural History Museum, San Diego; UCMP, University of California Museum of Paleontology, Berkeley.

#### AGE OF THE SAN DIEGO FORMATION

The San Diego Formation has been considered of Middle Pliocene ("Etchegoin") age in terms of Pacific Coast marine chronology. However, in recent years the temporal extent of the Pliocene on the Pacific Coast has been significantly reduced with the establishment of the Pliocene-Pleistocene

boundary at the base of the Calabrian in Italy (circa 3.5 million years Before Present) and the recognition of the Hemphillian-Clarendonian Boundary as the boundary between Pliocene and Miocene (circa 10 m.y. B.P.). This time span reduction coupled with paleontological evidence presently being obtained from a review of the Late Cenozoic of the Pacific Coast suggests that a two- rather than threefold division of the Pliocene is more realistic. On this basis, the San Diego Formation would be regarded as Late Pliocene in age and is treated accordingly herein.

DESCRIPTION OF BARNACLE LOCALITIES  
IN THE SAN DIEGO FORMATION

Los Angeles County Museum of Natural History

107. Clay and gravel quarry at end of Arroyo Drive, City of San Diego, California. The 40 to 50-foot high cut contains oyster and pecten beds about 20 to 30 feet above road level and scattered large concretions throughout. G. P. Kanakoff, coll., May 12, 1947.
122. Shore bluff at the end of Loring Street, Pacific Beach, California. San Diego Formation exposed from 0 to 20 feet above sea level is overlain by fossiliferous, coarse grained, red sand of Late Pleistocene age. G. P. Kanakoff, coll.
180. On east side of 2200 block of La Jolla Boulevard at intersection with Tiras Street, ?Pacific Beach, California. G. P. Kanakoff, coll., January 28, 1950.
305. 2400 feet east and 1350 feet south of the northwest corner of Section 8, T. 19 S, R. 2 W, San Bernardino Base and Meridian, San Ysidro quadrangle, 1943 ed. (=CAS Loc. 34814). G. P. Kanakoff, coll.
- 305A. West side of next gulley east of LACM Loc. 305 at the same elevation. Fossils in float slump and consolidated boulders, silt, and sandstone, and silt in place (=CAS Loc. 36555). G. P. Kanakoff and W. K. Emerson, coll., December, 1957.
- 305C. Exposure at base of hill 100 feet west and 440 feet south of the northeast corner of Section 8, T. 19 S, R. 2 W, San Bernardino Base and Meridian, San Ysidro quadrangle, 1953 ed., G. P. Kanakoff, coll.
319. Exactly between U.S.-Mexico boundary fence and Mr. Ericson's (the manager) house; 27 feet above road level on shoulder of second hill. G. P. Kanakoff, coll.
323. Under bridge between Fifth Street and the Radio Station, about 160 feet from fence and about 350 feet from Radio Station. J. Arndt, coll., February, 1961.

485. Marine invertebrates and shark teeth collected from an estimated 20-foot thickness of mostly unconsolidated, yellow, medium to coarse grained sand on 30° bulldozed slope north of Market Street and east of Euclid Avenue, City of San Diego. Intersection of projection of arrows on edges of northwest quarter of map marked "2.6 mi. to U.S. 101" and "0.6 mi. to U.S. 80" on 7.5' National California quadrangle, 1953 ed. E. C. Wilson, coll., December 10 and 24, 1967.
492. Southwest corner of intersection of Home and Fairmont Avenues, City of San Diego. J. Arndt, coll., June, 1957.
493. East side of Wabash Canyon, below Juniper Street, City of San Diego. C. Anderson and E. P. Chace, coll., 1961.

California Academy of Sciences

1405. Street cut 0.2 miles southwest of Alamo Drive and Center Street, City of San Diego.
33218. Near intersection of Maple and Haller Streets, City of San Diego. L. L. Mills, coll., January, 1951.

San Diego Museum of Natural History

- L-2451. Same locality as LACM 485, E. C. Wilson, coll., July 31, 1967.

SYSTEMATIC DESCRIPTIONS

Suborder LEPADOMORPHA Pilsbry, 1916

Family LEPADIDAE Darwin, 1851

Genus **Lepas** Linnaeus, 1758

**Lepas** sp.

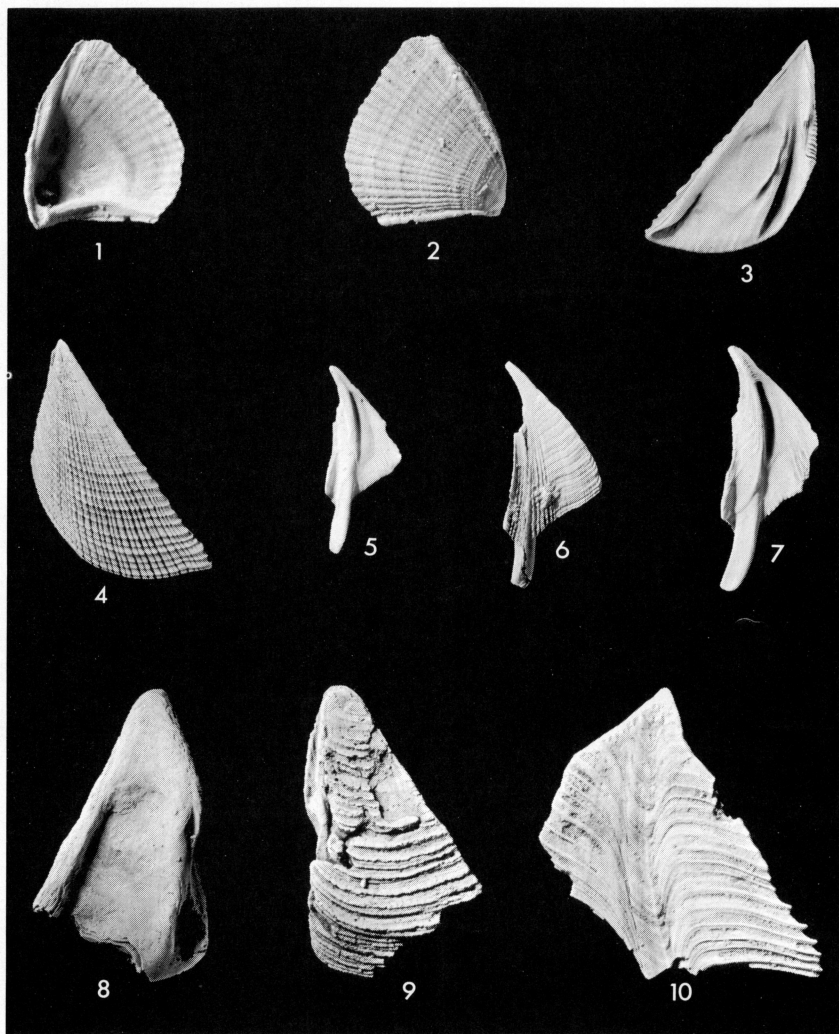
Figs. 1-2

*Occurrence*: LACM Loc. 305A.

*Range*: Late Pliocene, San Diego Formation.

*Remarks*: The single scutum available represents the only fossil lepadomorph to be recorded from the margins of the eastern Pacific Basin. As previously noted by Withers (1953, p. 354), the "*Lepas injudicata*" of Pilsbry (1919, p. 188, pl. 67, fig. 5) described from the Miocene of the Panama Canal Zone is in fact the broken half of a pelecypod shell, probably of the venerid *Chione* (*Lirophora*) *mactropsis* (Conrad).

Extant species of *Lepas* are difficult enough to identify from well preserved material, and at present are best differentiated by the number of filamentary appendages present at the base of the first cirrus. The fossil scutum is quite distinctive, but in itself does not provide sufficient criteria for specific



Figures 1-10. 1-2, opercular valves of *Lepas*, sp., (1-2), interior and exterior of scutum, Hypotype LACM 1196, LACM Locality 305A, height of valve 4 mm. 3-7, opercular valves of *Balanus gregarius* (Conrad), LACM Locality 485. (3) interior of scutum, Hypotype LACM 1197, height 22 mm; (4) exterior of scutum, Hypotype LACM 1198, height 22 mm; (5) interior of tergum showing purple color patch on carinal side, Hypotype LACM 1199, height 18 mm; (6) exterior of tergum, Hypotype LACM 1200, height 21 mm; (7) interior of tergum, Hypotype LACM 1201, height 23.5 mm. 8-10, opercular valves of *Balanus nubilus* Darwin, LACM Locality 305. (8-9) interior and exterior of scutum, Hypotype LACM 1203, height 27 mm; (10) exterior of tergum, Hypotype LACM 1204, height 14.5 mm.

identification. Among extant species that possess strong radial sculpture, it approaches the scutum of *L. pectinata* Spengler, especially in the narrowness of the margin on the occludent side of the ridge extending from umbo to apex.

Suborder **BALANOMORPHA** Pilsbry, 1916

Family **BALANIDAE** Leach, 1817

Genus **Balanus** Da Costa, 1778

Subgenus **Balanus**

**Balanus gregarius** (Conrad, 1856)

Figs. 3-7, 45

*Tamiosoma gregaria* Conrad, 1856, p. 315; 1857a, p. 72, pl. 4, fig. 18; Gabb, 1869, p. 61, pl. 18, figs. 22a-d; Dall, 1902, p. 5.

*Balanus estrellanus* Conrad, 1857b, p. 195, pl. 8, fig. 1; 1877, p. 156.

*Radiolites gregaria* Conrad, 1864, p. 214.

*Balanus H. estrellanus* Conrad, 1876, p. 273.

*Balanus gregarius* (Conrad). Pilsbry, 1916, p. 126, pl. 28, figs. 1-3, pl. 29; Zullo, 1964, p. 360; Durham and Addicott, 1965, p. 14, pl. 1, figs. 2, 3, 6, 8 (not pl. 2, figs. 4, 7).

*Balanus (Tamiosoma) cf. B. (T.) gregarius* (Conrad). Woodring, in Woodring, Stewart, and Richards, 1940, p. 96, pl. 36, figs. 2-5, 8, 9.

*Balanus concavus concavus* Bronn. Ross, 1962, p. 14, figs. 6, 7.

*Occurrence*: LACM Locs. 107, 305, 305C, 319, 323, 485, 492, 493; CAS Locs. 1405, 33218; SDSNH Loc. L-2451.

*Range*: Early Miocene through Late Pliocene, central and southern California; Pliocene, Baja California.

*Remarks*: *Balanus gregarius* is the most widespread and abundant barnacle in collections from the San Diego Formation. Opercular valves of this species, and especially scuta, are common at LACM Locs. 305 and 485, together with shells and isolated compartmental plates. Several complete specimens with opercular valves in life position were obtained from LACM Loc. 485. Scuta were also found at LACM Locs. 319 and 323 and CAS Loc. 1405. Large shells with the distinctive vesiculose basis of *B. gregarius* were collected at LACM Locs. 107, 492, and 493, and at CAS Loc. 33218.

*Balanus gregarius*, in the broad sense, is a common fossil encountered in Miocene and Pliocene deposits of the San Francisco Bay Area, Salinas Valley, and San Joaquin Valley in California, and in Pliocene rocks at Rosario in Baja California. As indicated by the preceding synonymy, there has been considerable confusion regarding its identification and affinities. Conrad



(1856, 1857a, 1864), who originally described *B. gregarius* from its distinctive vesiculose basis, considered it to be a rudistid pelecypod. Later, Conrad (1876) and Dall (1902) recognized its relationship to the genus *Balanus*, but did not have the opercular valves available to them. The valves were first described by Woodring, in Woodring et al. (1940), but because the delicate beaks of the terga were missing in the specimens examined, Woodring (*op. cit.*) was led to conclude that *B. gregarius* was closely related to *B. concavus* Bronn. The marked similarity of the scuta of *B. gregarius* to those of various subspecies of *B. concavus* was also responsible for Ross' (1962) record of *B. concavus concavus* on the basis of a scutum from the Pliocene of Rosario, Baja California. The reassignment of this scutum to *B. gregarius* is supported by the occurrence in the same deposit (UCMP Loc. 4300) of undoubted *B. gregarius* whose scuta are identical in form to that figured by Ross (*op. cit.*).

When well preserved, intact opercular valves of *B. gregarius* are available, the marked resemblance of this species to the extant Pacific Coast species *B. aquila* Pilsbry becomes immediately apparent. The resemblance is so great as to suggest that the two species are conspecific (Zullo, 1964), but a more detailed study of fossil populations, their variation, and their comparison with living *B. aquila* is needed before any conclusions can be drawn.

#### ***Balanus kanakoffi* sp. n.**

Figs. 11-22

*Diagnosis:* *Balanus* s.s. with conic, strongly ribbed or plicate shell and small, untoothed, subtriangular orifice; sutures between carinolaterals and carina linear and often obscured externally in older specimens; scutum with prominent growth ridges cut by deep longitudinal striae, giving a marked cancellate appearance to the exterior; beaked tergum with broad, basally truncate spur and open spur furrow.

*Description:* Shell conic, with small, subtriangular, untoothed orifice; parietes strongly and regularly ribbed or plicate, often preserving light, irregularly spaced, transverse color bands corresponding to growth increments against a darker background; parietal tubes large, rectangular, without transverse septa, but solidly filled in upper half; one or two secondary septa occasionally present on outer lamella between major parietal septa; radii narrow, solid, thick, with slightly oblique summits; sutural edges of radii coarsely denticulate; alae thin, with horizontal summits and sharp, non-denticulate sutural edges; sheath one-half height of shell, lower edge dependent; interior of parietes below sheath with conspicuous, square ribs corresponding to parietal septa; basis thick with large, radiating, non-septate tubes.

Scutum thick, slightly concave externally between apex and base; exterior ornamented by high, sharp, regularly spaced growth ridges crossed by broad, deeply incised radial striae, forming a lattice structure with nodes on the

growth ridges and thin vertical pillars in the inter-ridge areas between striae; tergal border reflexed 90°; adductor ridge absent, or at best defined as the raised lower lip of the large, deep, oval adductor muscle pit located in the upper half of the valve; articular ridge confined to upper half of tergal margin, reflexed over shallow articular furrow; depressor muscle pit lenticular, deep, extending from basal margin to base of articular ridge.

Tergum thin, narrow, beaked; width of basal margin equal to one-half height of valve; spur long, broad, situated close to basiscutal angle, and occupying about three-fifths the width of basal margin and one-fourth the total height of valve; juncture of spur with basal margin angular on scutal side, broadly curved on carinal side; articular ridge low, inconspicuous, erect; articular furrow broad, shallow; depressor muscle crests, numerous, conspicuous.

*Occurrence and Type Disposition:* LACM Locs. 305 (type locality), 305A, 305C; Holotype LACM 1209; Paratypes LACM 1205-1211; Paratypes CAS 13162-13165.

*Range:* Late Pliocene, San Diego Formation.

*Remarks:* *Balanus kanakoffi* differs most markedly from other species of the subgenus *Balanus* in the linear and often obscure nature of the suture between the carina and carinolaterals. It has its greatest affinities with the *B. calidus* Pilsbry—*B. spongicola* Brown—*B. trigonus* Darwin group. Although sharing certain characteristics with each of the above mentioned species, *B. kanakoffi* is readily distinguished from them in total aspect, which combines a strongly ribbed or plicate shell with a markedly cancellate scutum and a beaked tergum having a broad, basally truncate spur.

The scutum resembles that of *B. spongicola* in external sculpture, but differs in the shorter articular ridge and the larger depressor muscle pit. The tergum of *B. kanakoffi* is similar to that of *B. trigonus*, but can be recognized by the greater development of the beak and the longer, narrower spur whose juncture with the basal margin on the carinal side is not angular.

Although the shells are easily separated, the opercular valves of *B. kanakoffi* are somewhat similar to those of the extant Gulf of California species, *B. eyerdami* Henry. However, the latter differs in having a channel entering the base of the prominent beak on the inner surface, a more elongate and basally pointed tergal spur, and a larger, but less defined pit for the depressor muscle on the scutum.

This species is named in honor of Mr. George P. Kanakoff.

### ***Balanus nubilus* Darwin, 1854**

Figs. 8-10

*Balanus nubilus* Darwin, 1854a, p. 253, pl. 6, figs. 2a-c; Ross, 1962, p. 24.

*Balanus nubilus* (*sic*) Darwin. Pilsbry, 1916, p. 131, pl. 30, figs. 1-4, pl. 31, figs. 3, 3a, 4, 5.