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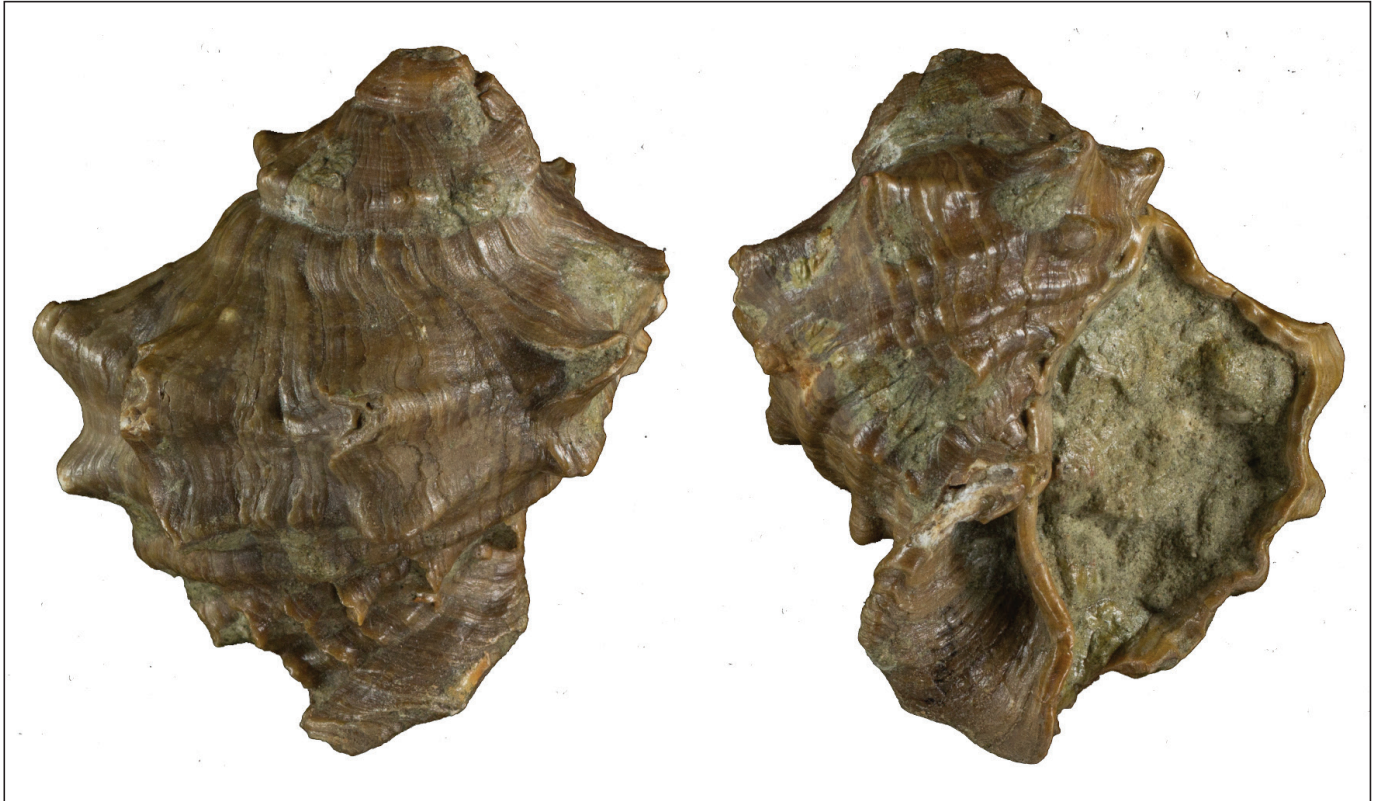
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CHARLES L. POWELL, II & ROLAND HOUART (2021). *Califrapana*: a new genus of California and Baja California late Oligocene to early Miocene muricids previously attributed to the genus *Rapana* (Mollusca: Gastropoda: Muricidae).

Cover: *Califrapana vaquerosensis* (Arnold, 1907) n. comb. collected from the “Vaqueros” Formation at Plano Trabuco, Santa Ana Mountains, Orange County, California, UCMP 31627 in adapertural (left) and apertural (right) view. See Figure 3 for more details. Cover image courtesy of Ashley Dineen.

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***Califrapana*: a new genus of California and Baja California late Oligocene to early Miocene muricids previously attributed to the genus *Rapana* (Mollusca: Gastropoda: Muricidae)**

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Califrapana n. gen., is proposed for California late Oligocene to early Miocene muricids attributed previously to the possibly Paleocene to modern western Pacific and Indian oceans genus *Rapana*. Four fossil species have been assigned to *Rapana* in the eastern Pacific. One of these species, *R. perrini* Clark and Arnold (1923), should be placed in another genus, the other species *Purpura vaquerosensis* Arnold (1907), *R. imperialis* Hertlein and Jordan (1927), and *R. serrai* Wiedey (1928) are synonymized here with the morphologically variable species *Califrapana vaquerosensis* n. comb. We confirm *C. vaquerosensis* is an index fossil for the lower and middle "Vaqueros" California provincial molluscan stage of late Oligocene to early Miocene age in southern California and Baja California, México, although the lack of numerical dating and the misuse of lithostratigraphic and biostratigraphic names had made that difficult to determine. *Califrapana* is distinguishable from similar genera by 1) its heavier shell, 2) an aperture that is pointed at its anterior and posterior ends, 3) more numerous fine to coarse spiral cords on the ultimate whorl, 4) less numerous nodes at the top of the ultimate whorl, which are commonly larger and more pronounced, and 5) the siphonal fasciole, which is large and broad, with a large, open channel.

Keywords: *Califrapana vaquerosensis*, new combination, fossil gastropod, shallow-marine, "Vaqueros" molluscan stage, eastern Pacific, western Pacific

INTRODUCTION

Over many years of working with California fossil mollusks the senior author (CLP) has noted several genera and species names used in California that are out of place biogeographically. That is a scientific name used for a fossil genus and (or) species in California literature, which has its modern geographic range, and other fossil occurrences far from California. An example is the calyptraid gastropod *Trochita trochiformis* (Gmelin, 1791) reported by Grant and Gale (1931) from the Miocene to Pliocene of southern California has a modern occurrence from Ecuador to Chile (Keen 1971, Pastorino and Urteaga 2012) and a fossil record from the Paleocene of Virginia (Lerich 1942), Oligocene of Costa Rica (Aguilar

1999) and Panama (Woodring 1957), Miocene of Panama (Woodring 1957), Pliocene of Chile (Walsh and Hume 2001, Nielsen 2013), and Quaternary of Chile (Rivadeneira and Carmona 2008), Morocco (Lecointre 1952), and Peru (Ortleib et al. 1996, 1999) far from California. Even if a couple of these occurrences are likely due to misidentifications (Lerich 1942, Lecointre 1952) its occurrences in California is still incongruent.

One of these temporal anomalies is the use of the name *Rapana* Schumacher (1817) (Mollusca: Gastropoda: Muricidae) for a group of fossil muricids from central and southern California, USA, and Baja California, México. The genus *Rapana* includes three modern species (Houart 2008; Fig. 1), *R. bezoar* (Linnaeus, 1767), type species by subsequent designation (Gray 1847:135), *R. rapiformis* (Born, 1778), and *R. venosa* (Valenciennes,

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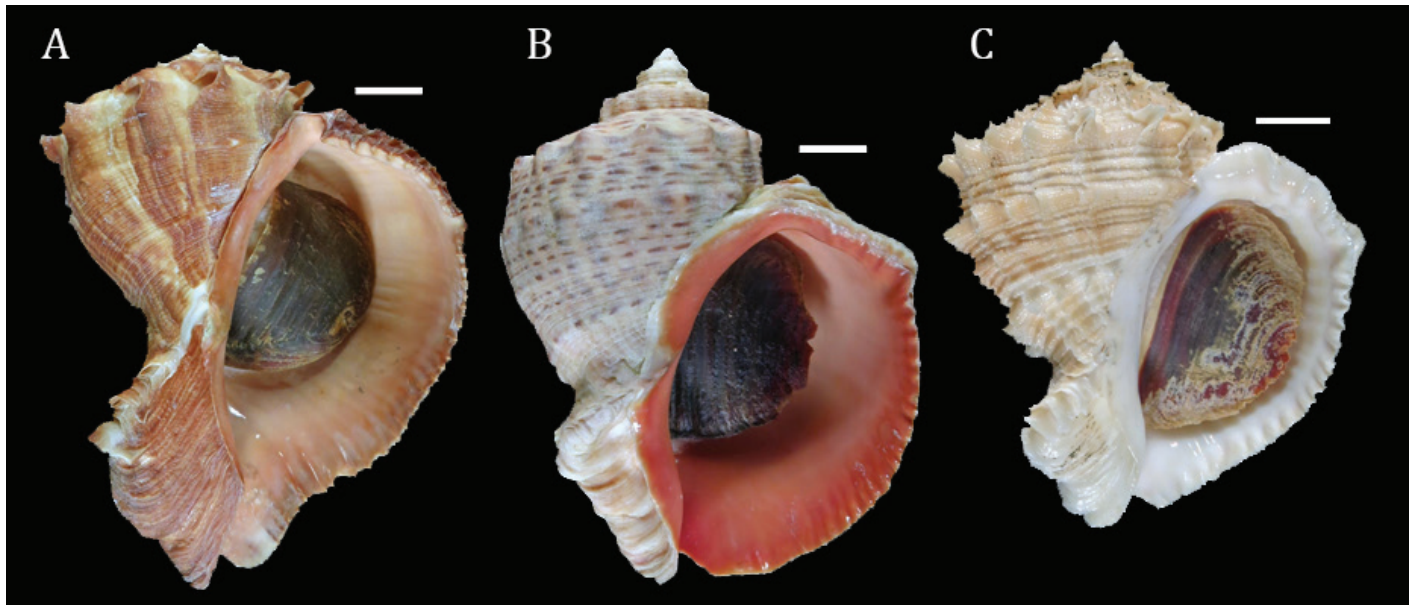


Figure 1. Extant species of the west Pacific and Indian Ocean genus *Rapana*. Scale bars=1 cm. **A.** *Rapana rapiformis* (Born, 1778), RH-Rapn-01. Negros Island, Philippines. **B.** *Rapana venosa* (Valenciennes, 1846). Black Sea, Strait of Bosphorus, Turkey (invasive), RH-Rapn-02. **C.** *Rapana bezoar* (Linnaeus, 1758). Anori, Shima, Mie Prefecture, Japan, RH-Rapn-03.

1846), with modern occurrences in the west Pacific and Indian oceans and fossil occurrences from Paleocene to Quaternary age rocks in Iran, Japan, Nigeria, Pakistan, and Taiwan (<http://fossilworks.org/bridge.pl?a=home>, retrieved 11/2020). Two other modern species *Rapana pellucida* Bozzetti (2008) and *R. bella* G. Nevill and H. Nevill (1869) found in MolluscaBase (2021) are young *Rapa rapa* (Linnaeus, 1758) in the first case and either *R. rapa* or *R. incurva* (Dunker, 1852) in the second (new synonymies), both in the family Coralliophilinae Chenu (1858). There is some doubt that all the species referred to fossil *Rapana* are actually *Rapana*, but delving into that problem is beyond the scope of this paper.

Here the new genus, *Califrapana*, is described to accommodate taxa previously referred to as the genus *Rapana* from the Oligocene and Miocene of California, U.S.A. and Baja California, México. *Califrapana* appears to be restricted to the “Vaqueros” California provincial molluscan stage (CPMS) of late Oligocene to early Miocene age. Three taxa are attributed to *Califrapana*: *Purpura vaquerosensis* Arnold (1907), *R. imperialis* Hertlein and Jordan (1927), and *R. serrai* Wiedey (1928). Petuch (2004:41) also noted the need for this new genus 16 years ago.

The shells of the west Pacific and Indian Ocean genus *Rapana* are generally voluminous, occasionally reaching more than 20 cm in length in *R. venosa*. Have numerous low axial lamellae or ribs, four primary spiral cords on the convex part of the teleconch whorl and additional

secondary cords and spiral threads. The aperture is wide, broadly ovate with a broad anal notch and crenelated outer edge, the columellar lip is adherent adapically and strongly erect abapically. The operculum is D-shaped with a lateral nucleus in lower right. The siphonal canal is broad, broadly open ventrally, short with three low primary spiral cords, few threads and an obvious umbilicus.

Califrapana differs from *Rapana* in having an obviously broader, concave, more strongly sloping subsutural ramp, a narrower, more ovate aperture, tapered at both ends and abapical ends and with a less crenelated, nearly smooth outer aperture edge. In addition, the siphonal fasciole is wide, with a shallow, open channel that points downward.

MATERIALS AND METHODS

Specimens of the large predatory muricid identified as *Rapana* from the Oligocene and Miocene of California and Baja California, México are easily recognized and are occasionally a common constituent of some late Paleogene/early Neogene shallow-marine fossil deposits. CLP has examined specimens in museum collections for over 40 years, including those at the California Academy of Sciences, the Natural History Museum of Los Angeles County, the San Diego Society of Natural History, and the Museum of Paleontology at Berkeley. Early on it became apparent that these specimens should not be referred to *Rapana* and a new genus was needed.

Institutional Abbreviations—CAS G, Department of

Geology, California Academy of Sciences, San Francisco, California; **LACMIP**, Invertebrate Paleontology Department, Natural History Museum of Los Angeles County, Los Angeles, California; **LSJU**, Leland Stanford Junior University (now Stanford University), Stanford, California (collections now housed at CAS; **J.T. Smith 1978**); **RH**, Roland Houart Research Collection, Brussels, Belgium; **SDSNH**, Paleontology Section, San Diego Society of Natural History, San Diego, California; **UCMP**, Museum of Paleontology, University of California at Berkeley, Berkeley, California; **USGS**, United States Geological Survey, Menlo Park/Moffett Federal Airfield, California (collections now housed at UCMP).

Measurements—Defined here as follows: **height**, greatest distance between the dorsal and ventral termini; **length**, greatest distance between the anterior and posterior termini; **width**, greatest distance between the left and right termini.

SYSTEMATIC PALEONTOLOGY

MOLLUSCA LINNAEUS, 1758

GASTROPODA CUVIER, 1795

MURICIDAE RAFINESQUE, 1815

RAPANINAE GRAY, 1853 (AS RAPANANINA)

CALIFRAPANA POWELL AND HOUART, N. GEN.

Califrapana vaquerosensis (Arnold, 1907) n. comb.

Purpura vaquerosensis Arnold, 1907:426, pl. 52, figs. 1a, b; Arnold and Anderson 1907, pl. 15, figs. 1a, b.

Rapana vaquerosensis. Wiedey 1928:115–116; Clark 1929, pl. 28, figs. 5, 6; Loel and Corey 1932:244–245, pl. 50, figs. 1–3a, b, pl. 51, figs. 2, 3; Bremner 1933, fig. 5; Squires and Fritsche 1978:15, pl. 1, figs. 2–6.

Rapana imperialis Hertlein and Jordan 1927:631–632, pl. 20, fig. 1.

Rapana serrai Wiedey, 1928:116–117, pl. 9, figs. 4–6.

Rapana vaquerosensis imperialis. Loel and Corey 1932:246, pl. 51, figs. 1a, b; pl. 52, figs. 1a, b; pl. 53, figs. 1a–c, 2, 3a–c, 4; pl. 54, figs. 1, 2a, b; pl. 55, figs. 1a, b. Bremner 1933, pl. 2, fig. 4. Hanna 1943:176, fig. 64–18. Avila and Weaver 1969:59, pl. 34, figs. 1a, b. Stadum 1973:25, pl. 3, fig. 10. Squires and Filewicz (eds.) 1983:172, unnumbered figure. Squires 1997:301, fig. 4a (refigure of Squires and Filewicz (eds.) 1983).

FIGS. 2–10

Generic Diagnosis—A large, heavy-shelled muricid variable in most of its sculptural features, but which can be distinguished from other similar looking genera by 1) its heavy shell, 2) an aperture that is bluntly pointed at both ends, and 3) the siphonal fasciole, which has a wide, shallow, ventrally open channel that points downward,

easily separating it from other genera.

Type species—*Purpura vaquerosensis* Arnold, 1907, by original designation.

Illustrated specimens—Nine specimens for the genus are illustrated here: five adult shells which show the range of sculptural variability and three juveniles showing ontogeny. The first is *Rapana imperialis*, Hertlein and Jordan (1927, pl. 20, fig. 1; also Loel and Corey 1932, pl. 54, fig. 1, pl. 55, figs. 1a, b), holotype CAS G 70611.00 from locality CAS G 70611 (=locality LSJU 57) (Fig. 2). Second is *Rapana vaquerosensis imperialis*, of Loel and Corey (1932; pl. 53, figs. 1a–c), hypotype (as plesiotype) UCMP 31627 from locality UCMP 6128 (Fig. 3). The third illustrated specimen is *R. v. imperialis*, of Loel and Corey (1932, pl. 52, figs. 1a, b), plesiotype UCMP 31625 from locality UCMP A311 (Fig. 4). Specimen four is the holotype of *Purpura vaquerosensis* Arnold (1907, pl. 52, figs. 1a, b) (also Loel and Corey [1932, pl. 50, fig. 2]), holotype CAS G 61932.01 (=holotype LSJU 208) from CAS locality 61932 (Fig. 5). The fifth is the holotype of *R. serrai* Wiedey (1928, pl. 9, figs. 4–6) SDSNH holotype 13 from locality SDSNH and LSJU 442 (Fig. 6). The sixth illustrated specimen is *R. vaquerosensis*, of Loel and Corey (1932, pl. 50, figs. 3a, b), hypotype (as plesiotype) UCMP 31621 from locality UCMP A543 (Fig. 7). Hypotype seven is a juvenile specimen of *R. v. imperialis* illustrated by Loel and Corey (1932, pl. 53, fig. 3a–c), hypotype (as plesiotype) UCMP 31628 from locality UCMP 6128 (Fig. 8). The specimen picked as hypotype eight is a juvenile specimen of *R. v. imperialis*, of Loel and Corey (1932, pl. 53, fig. 4), hypotype (as plesiotype) UCMP 31629 from locality UCMP 6128 (Fig. 9). Hypotype nine is also a juvenile specimen of *R. v. imperialis*, of Loel and Corey (1932, pl. 53, fig. 2), hypotype (as plesiotype) UCMP 31630 from locality UCMP 6128 (Fig. 10).

Type locality—The type locality is here changed from the Vaqueros Formation on Lynch Mountain (Tierra Redonda *vide* Keen and Bentson 1944) in Monterey County, California to the Vaqueros Formation at Tierra Redonda Mountain in San Luis Obispo County north of Lake Nacimiento, central California.

Occurrences—*Califrapana* n. gen. has a limited geographic range from central California south to northern Baja California Sur, México (Fig. 11) with a distributional gap from northern San Diego County, California south to northern Baja California Sur. *Califrapana vaquerosensis* is reported in the “Vaqueros” Formation from San Luis Obispo County (Arnold 1907 [locality modified here], Wiedey 1928, as *R. serrai*, Loel and Corey 1932, the “Vaqueros” Formation in Ventura County (Loel and Corey 1932,

Cushman and Leroy 1938, Squires and Fritsche 1978) (common their lower unit and rare in the middle unit, absent in the upper unit), Haworth 1980, Moore 1987), “Vaqueros” Formation in the Santa Monica Mountains, Los Angeles County (Loel and Corey 1932, Osborne 1987), undifferentiated rocks attributed to the Sespe/“Vaqueros” formations in the Santa Ana Mountains of Orange County (Loel and Corey 1932, Yerkes 1957, Schoellhamer et al. 1981, CASG collections), and the San Joaquin Hills (Loel and Corey 1932). The species is also reported from the “Vaqueros” Formation on in the Southern California Bight on San Miguel (Loel and Corey 1932, Weaver and Doerner 1969, J.T. Smith 1991, CAS collections) and Santa Rosa (Loel and Corey 1932, Avila and Weaver 1969, J.T. Smith 1991, CAS collections) islands. Some rocks attributed to the “Vaqueros” Formation on the Channel Islands are considered middle Miocene in age (Powell and Geiger 2019) as are some from the Isidro Formation (=Ysidro Formation of Domning 1978 and Beal 1948) in central Baja California (J.T. Smith 1986), but not strata containing *C. vaquerosensis*. Elsewhere it occurs in the lower part of the Isidro Formation from between Arroyo San Ignacio to Arroyo la Purisima, Baja California Sur (J.T. Smith 1984).

Age Range—late Oligocene to early Miocene (see below).

Etymology—The name is a combination of “Calif” for

California and Bájá California where this new genus is found, and “rapana” for the genus *Rapana* with which it has been long confused. *Rapana* from Latin [rapa or rapum]=rave, turnip, edible vegetable with a globular root, and [-ana]=like, i.e. resembling turnip roots.

Description—The morphologically variable genus *Califrapana* has a large and heavy shell that shows considerable variability in shape, from ovate (Figs. 5, 7) to diamond shaped (Figs. 3, 4, 6, 8–10). The spire is broadly rounded, short to moderately high with little sculpture except for the spiral cords at the base of the spire whorls. The specimens illustrated herein are all previous holotypes, paratypes, and (or) hypotypes.

Sculpture is variable and consists of two styles. The first is only observable on well preserved specimens and consists of faint, widely and evenly spaced shallow, spiral cords (Figs. 6, 8–10). Some specimens show rows of larger to moderate spiral nodes of varying strength primarily at the base of the whorl on the ultimate whorls (Figs. 5, 6). In addition, all specimens have lines of nodes near the shell’s shoulder (Figs. 2–10), with a lesser and secondary line some distance below (Figs. 2–4, 6–10). The nodes higher on the ultimate whorl number between six and nine and may be closed bumps (Figs. 4–6, possibly 7) to spines that open in the direction of growth (Figs. 2, 3, 8–10) similar to those seen in the muricid genus

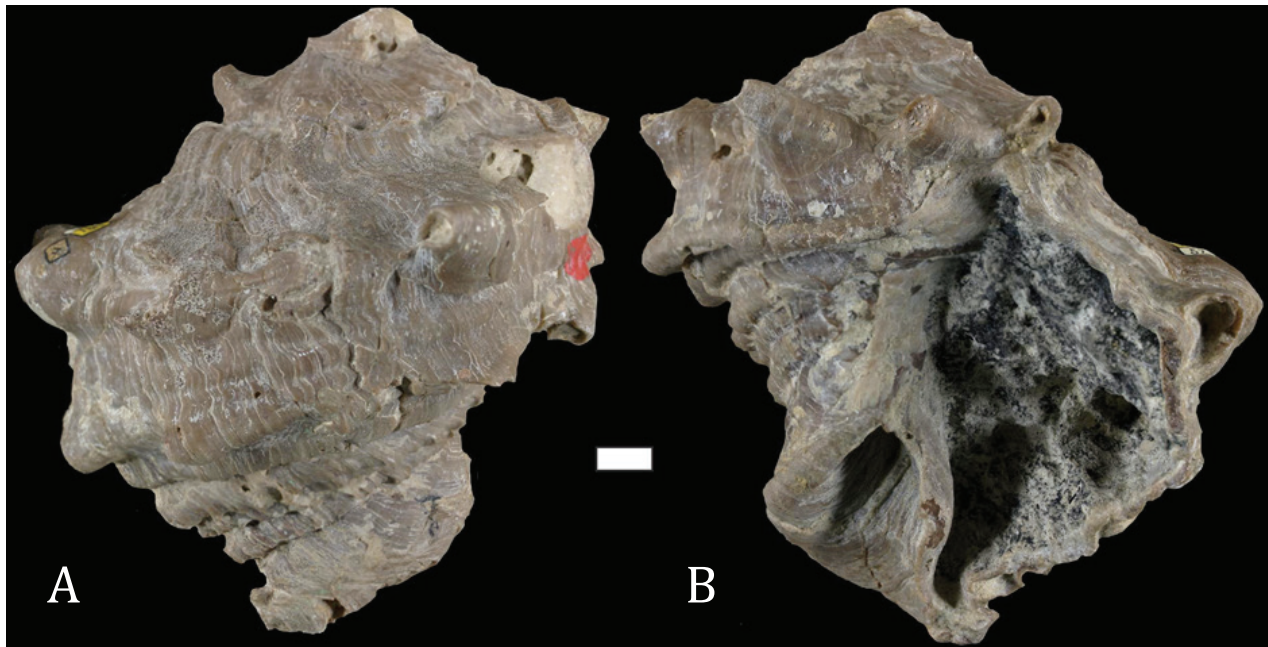


Figure 2. *Califrapana vaquerosensis* (Arnold, 1907) n. comb. Holotype CAS G 70611.00 from locality CAS G 70611 (=LSJU locality 57), La Purisima cliffs, Rio San Ramon, Bájá California Sur, México. Holotype of *Rapana imperialis* Hertlein and Jordan (1927) (pl. 20, fig. 1). A. Adapertural view. B. Apertural view. Scale bar=1 cm. Photograph courtesy of Christine Garcia, CAS.

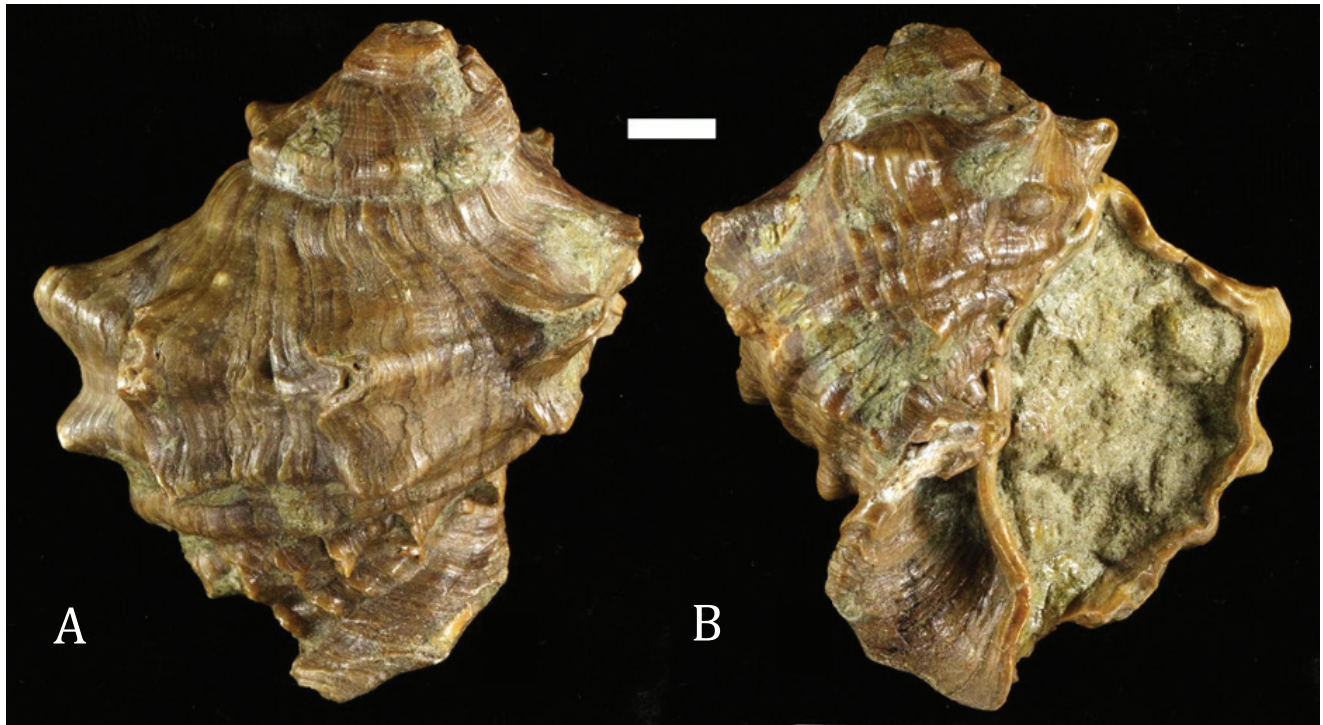


Figure 3. *Califrapana vaquerosensis* (Arnold, 1907) n. comb. Hypotype (as plesiotype) UCMP 31627 from locality UCMP 6128, Plano Trabuco, Santa Ana Mountains, Orange County, California. Hypotype (as plesiotype) of *Rapana vaquerosensis imperialis*, Loel and Corey (1932, pl. 53, figs. 1a-c). **A.** Adapertural view. **B.** Apertural view. Scale bar=1 cm. Photograph courtesy of Ashley Dineen, UCMP.

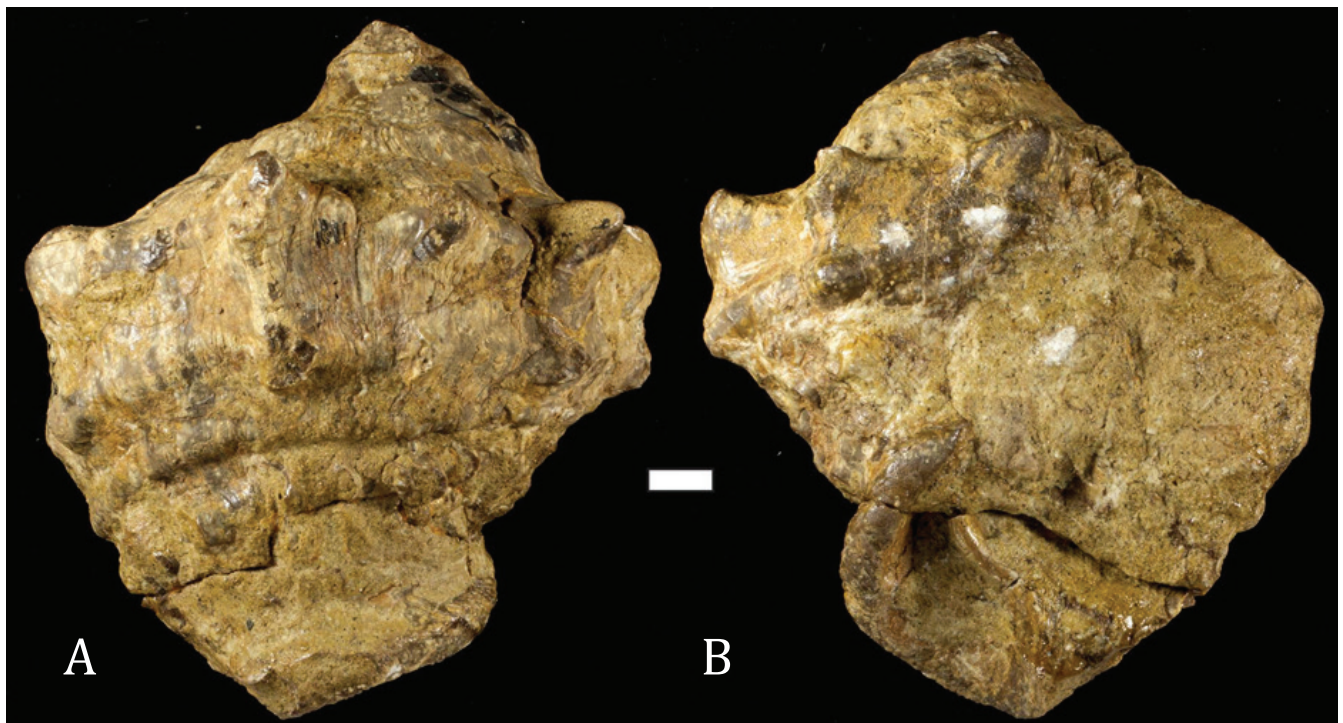


Figure 4. *Califrapana vaquerosensis* (Arnold, 1907) n. comb. Hypotype (as plesiotype) UCMP 31625 from locality UCMP A311, Santa Rosa Island, Santa Barbara County, California. Hypotype (as plesiotype) of *Rapana vaquerosensis imperialis*, Loel and Corey (1932, pl. 52, figs. a, b). **A.** Adapertural view. **B.** Apertural view. Scale bar=1 cm. Photograph courtesy of Ashley Dineen, UCMP.

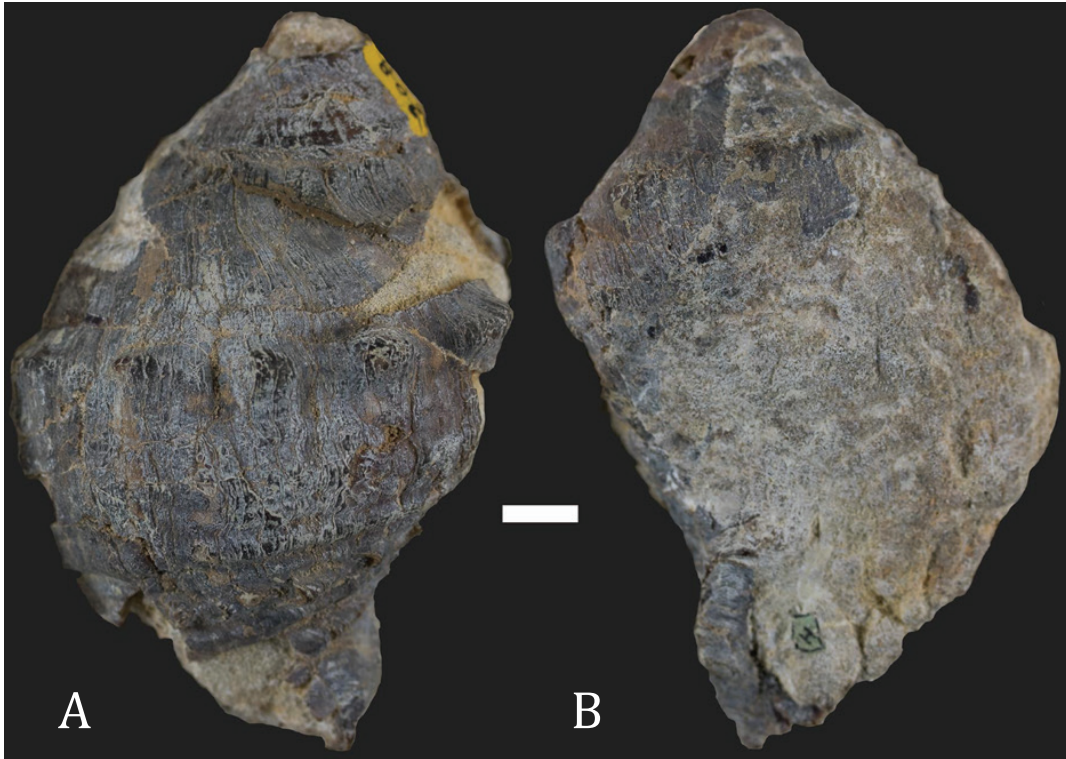


Figure 5. *Califrapana vaquerosensis* (Arnold, 1907) n. comb. Holotype CAS G 61932.01 from locality CAS 61932, “Lynch Mountain, Monterey County, California” (herein determined to be Terra Redonda Mountain, San Luis Obispo County). Holotype of *Purpura vaquerosensis* Arnold (1907, pl. 52, figs. 1a, 1b; Loel and Corey, (1932), pl. 50, fig. 2). **A.** Adapertural view. **B.** Apertural view. Scale bar=1 cm. Photograph courtesy of Christine Garcia, CAS.

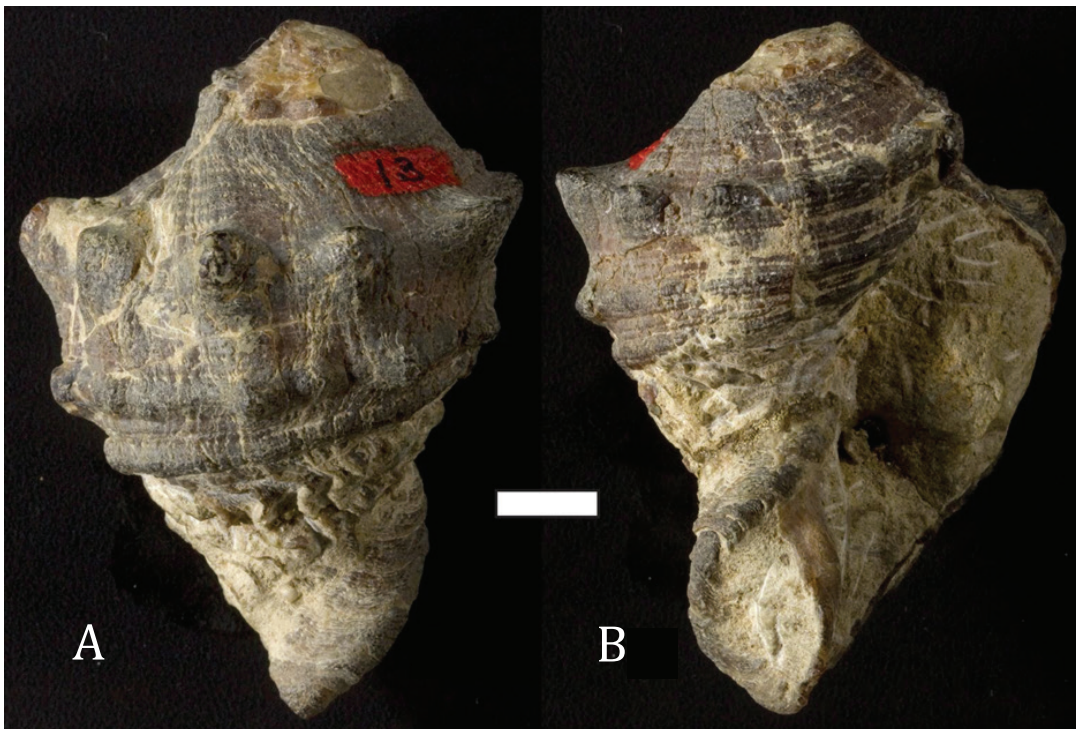


Figure 6. *Califrapana vaquerosensis* (Arnold, 1907) n. comb. Holotype SDSNH 13 from locality SDSNH and LSJU 442, near Nacimiento River, San Luis Obispo County, California. Holotype of *Rapana serrai* Wiedey (1928, pl. 9, figs. 4-6). **A.** Adapertural view. **B.** Apertural view. Scale bar=1 cm. Photographs courtesy of Kesler A. Randell, SDSNH.

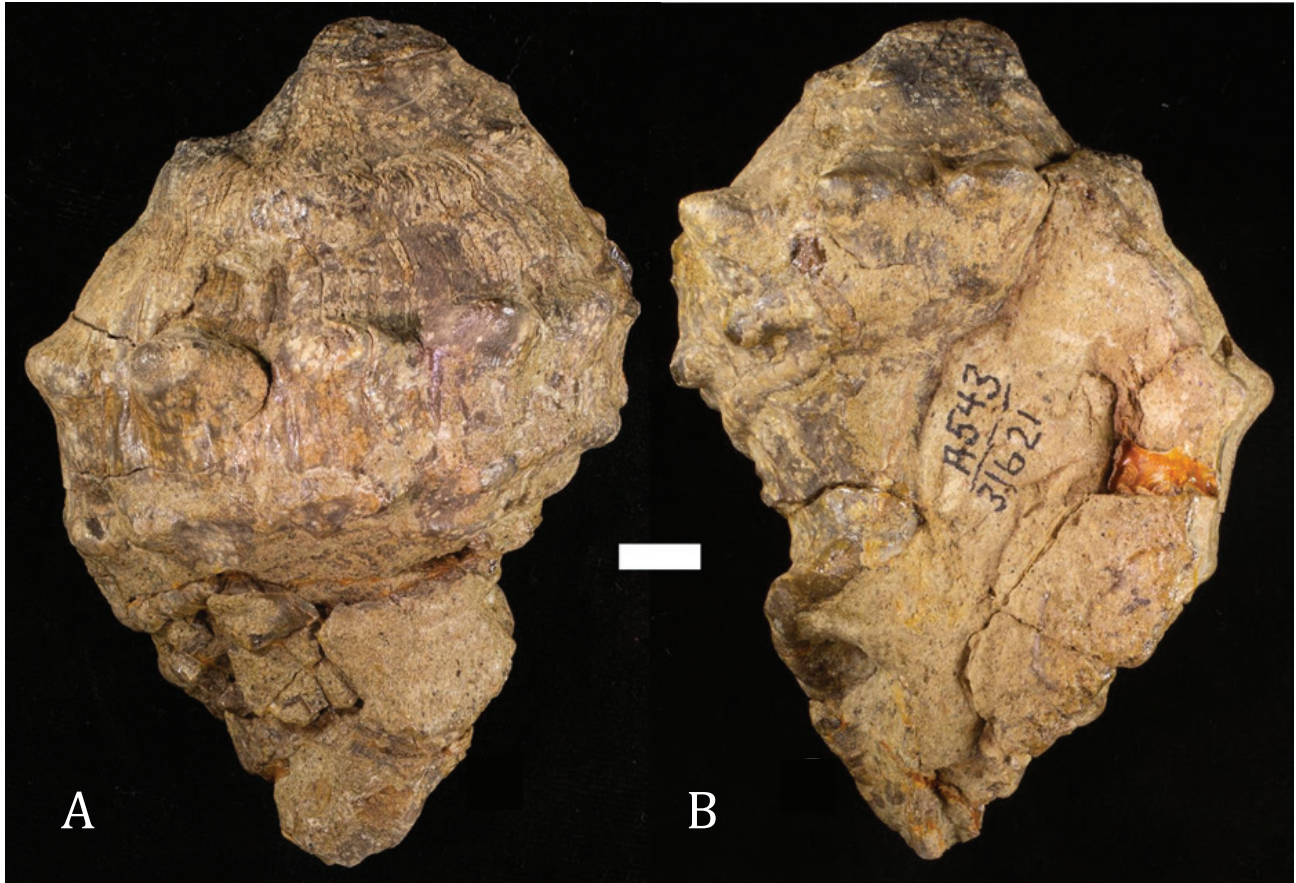


Figure 7. *Califrapana vaquerosensis* (Arnold, 1907) n. comb. Hypotype (as plesiotype) UCMP 31621 from locality UCMP A543, San Joaquin Hills, Orange County, California. Hypotype (as plesiotype of *Rapana vaquerosensis*, Loel and Corey (1932, pl. 50, figs. 3a, 3b). A. Adapertural view. B. Apertural view. Scale bar=1 cm. Photograph courtesy of Ashley Dineen, UCMP.

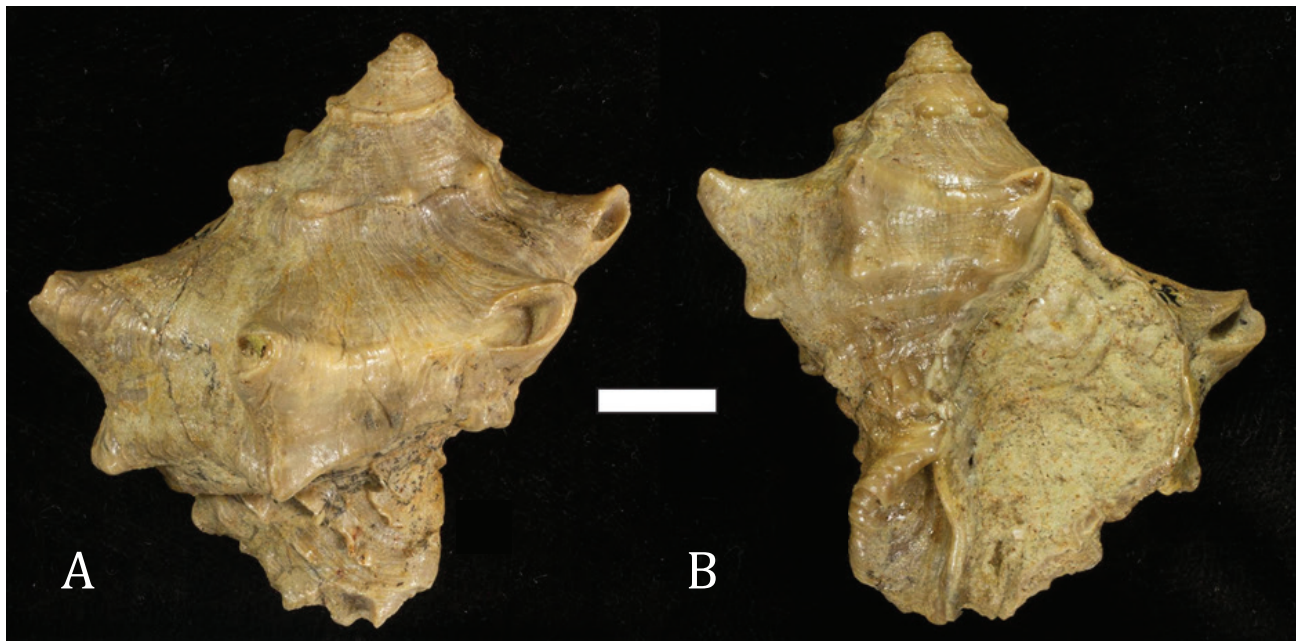


Figure 8. *Califrapana vaquerosensis* (Arnold, 1907) n. comb., juvenile. Hypotype (as plesiotype) UCMP 31628 from locality UCMP 6128, Plano Trabuco, Santa Ana Mountains, Orange County, California. Hypotype (as plesiotype of *Rapana vaquerosensis imperialis*, (Loel and Corey, 1932, pl. 53, figs. 3a-c). A. Adapertural view. B. Apertural view. Scale bar=1 cm. Photograph courtesy of Ashley Dineen, UCMP.

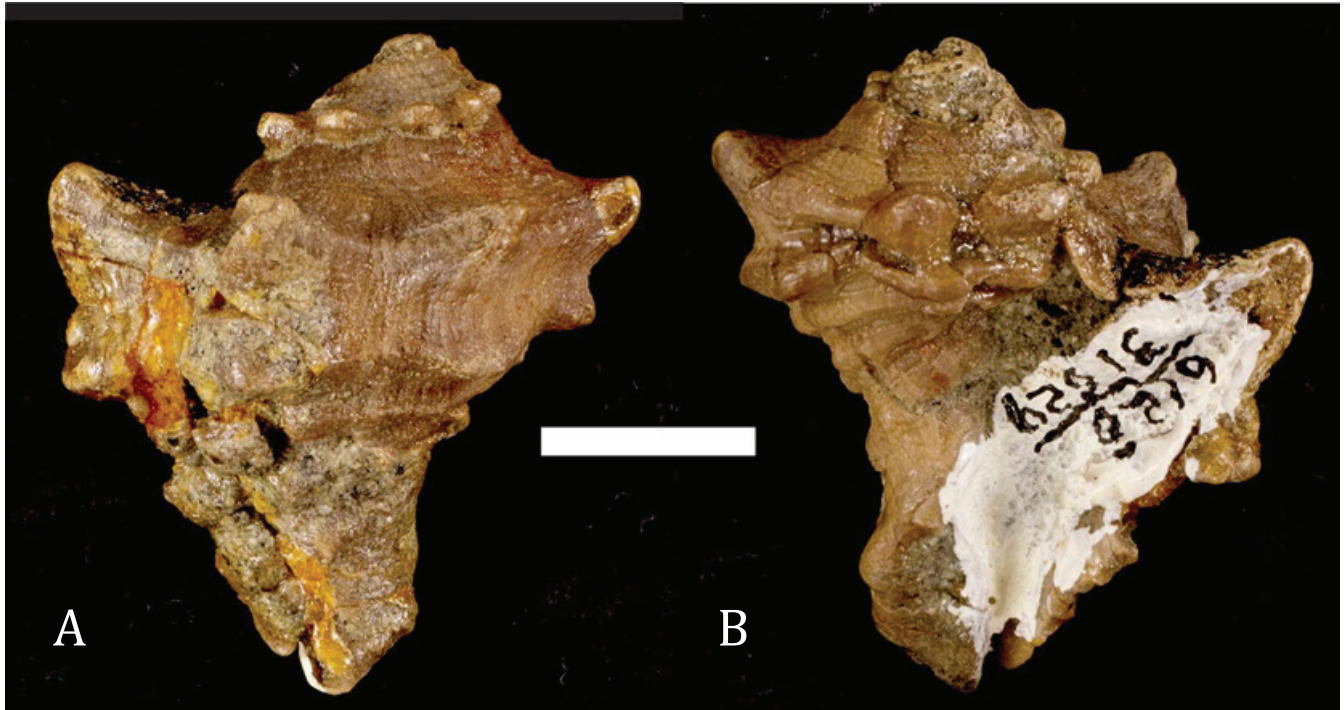


Figure 9. *Califrapana vaquerosensis* (Arnold, 1907) n. comb., juvenile. Hypotype (as plesiotype) UCMP 31629 from locality UCMP 6128, Plano Trabuco, Santa Ana Mountains, Orange County, California. Hypotype (as plesiotype) of *Rapana vaquerosensis imperialis* of Loel and Corey, (1932, pl. 53, fig. 4). **A.** Adapertural view. **B.** Apertural view. Scale bar=1 cm. Photograph courtesy of Ashley Dineen, UCMP.

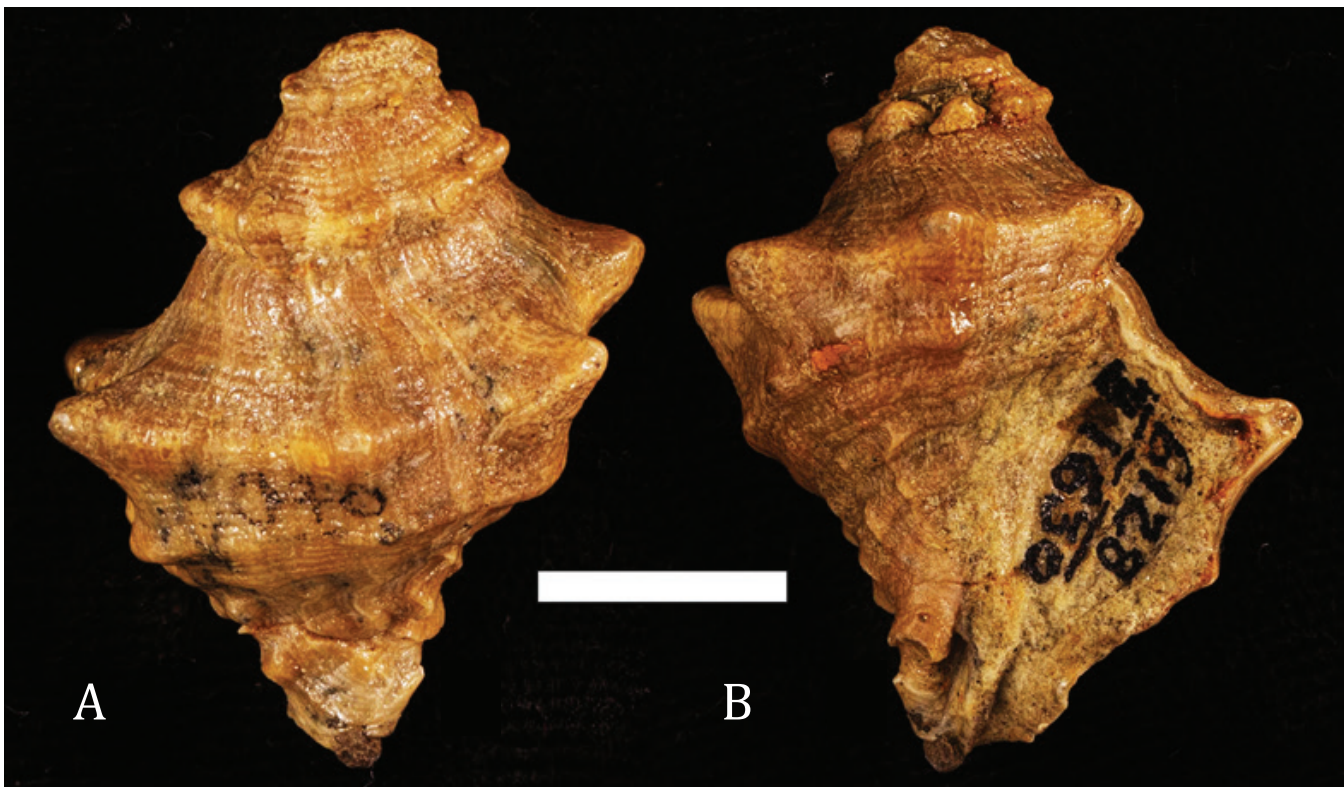


Figure 10. *Califrapana vaquerosensis* (Arnold, 1907) n. comb., juvenile. Hypotype (as plesiotype) UCMP 31630 from locality UCMP 6128, Plano Trabuco, Santa Ana Mountains, Orange County, California. Hypotype (as plesiotype) of *Rapana vaquerosensis imperialis*, Loel and Corey (1932, pl. 53, fig. 2). **A.** Adapertural view. **B.** Apertural view. Scale bar=1 cm. Photograph courtesy of Ashley Dineen, UCMP.



Figure 11. Occurrences of *Califrapana* n. gen. in California, U.S.A. and Baja California, México.

Forreria (Jousseume, 1880).

The aperture is difficult to see in most specimens but is well exposed in Figures 2, 3, and 8. It is pointed at both its anterior and posterior ends. Nearest the columella it is broadly and shallowly rounded meeting at the pointed anterior and posterior ends. The outer lip of the aperture is much more rounded and puckered by the expressions of the major spiral sculpture. The point of inflection correlates with the major row of nodes on the shoulder of the ultimate whorl.

Figures 8–10 illustrate a sequence of larger to smaller juvenile specimens collected from Plano Trabuco in the Santa Ana Mountains, Orange County, southern California. These specimens show a progression of the nearly

closed siphonal fasciole pointing downward (Fig. 10) to one that is more typical for the genus/species with a large open channel (Figs. 8, 9).

COMMENTS ON TAXONOMY, AGE, STRATIGRAPHY, AND BIOGEOGRAPHY

Taxonomy

Three taxa have been previously, originally or later referred to the genus *Rapana* in the California and Baja California, México: *R. imperialis* (Fig. 2, 3, 4, 8–10), *R. serrai* (Fig. 6), and *P. vaquerosensis* (Figs. 5, 7). *Rapana perrini* described from the Oligocene Sooke Formation on Vancouver Island, Canada should be attributed to another, yet to be determined genus. Vermeij (2001a) consider *C. imperialis* a spiny form of *C. vaquerosensis* with which the authors concur. Herein, *C. serrai* is also placed in synonymy with *C. vaquerosensis* as the two are very similar. The former is a slightly elongated form, but remarkably similar to the type of *R. vaquerosensis*. Intermediate forms between these three taxa can be found in California museum collections (CASG, LACMIP, SDSNH, and UCMP), and following Vermeij (2001a) the genus *Califrapana* is considered monotypical consisting of a single variable species *C. vaquerosensis*. The variation seen in this species is similar to that seen in the late Miocene to Holocene northeast Pacific muricid *Nucella lamellosa* (Gmelin, 1791) (see Kincaid 1957). Vermeij (1995, 2001b) suggested that *C. imperialis* (= *C. vaquerosensis*) may belong in the genus *Forreria*, but admits none of the specimens he examined had an intact outer lip or accompanying labral tooth which helps define the genus *Forreria*. In addition, Austin Hendy (personal communication, 12/2020) suggested that juvenile *C. vaquerosensis* resemble *F. carisaensis* (Anderson, 1905), but the latter are distinguished by their labral tooth and outward to posterior pointing shoulder spines as opposed to anterior pointing in *C. vaquerosensis*. In a review of California fossil *Austrotrophon* Dall (1902) and *Forreria*, Powell (2005) did not include any California Oligocene to Miocene *Califrapana* in the genus *Forreria* and examination of complete museum specimens at CAS G, LACMIP, and UCMP show no specimens with a labral tooth.

Squires and Fritsche (1978) compared *Solenosteira venturana* Loel and Corey (1932) (Mollusca: Gastropoda: Muricidae), the type of which can be found on CalPhoto (<https://calphotos.berkeley.edu>) with juvenile *C. vaquerosensis* noted their similarity and postulated they could be synonyms. The former species, *S. venturana*, only occurs in the Ventura County (Loel and Corey 1932)

where it co-occurs with *C. vaquerosensis*. It can be distinguished by the higher spire, subdued nodes connected by a concentric ridge (see https://calphotos.berkeley.edu/cgi/img_query?enlarge=0000+2222+6085+6020, retrieved 2/2021). In addition, the siphonal fasciole does not appear to be incised to any great extent.

The modern genus that appears most similar to *Califrapana* is the eastern Pacific muricid *Vasula* (Mörch, 1860) type species *V. melones* (Duclos, 1832). *Vasula* has a fossil record from the Miocene/Pliocene of Panama (Woodring 1959, as *Thais* (*Vasula*) aff. *T. melones*). The modern species *V. speciosa* (Valenciennes, 1832) found from Bahía Magdalena, Baja California, south throughout the Golfo de California, México, and south along Central America to Peru (Keen, 1971), is very similar in shape to *Califrapana*, but much smaller. *Vasula* can be separated by its differently shaped aperture. Specifically, in *Vasula* the upper part of the aperture is commonly rounded with a small outlet, as opposed to it being pointed in *Califrapana*. In addition, the siphonal fasciole is shorter and solid in *Vasula* and large and open in *Califrapana*. Lastly, *Vasula* does not have an umbilicus, while *Califrapana* has a pseudoumbilicus, that is a depression or cavity in the base of the shell, involving only the body whorl, so it is not a true umbilicus (<http://naturemappingfoundation.org/natmap/mollusks/glossary.html#P>, retrieved 3/2021).

Also similar to *Califrapana* is the muricid genus *Cymia* (Mörch, 1860), a genus that originated in the Miocene Caribbean faunal province of Woodring (1974). Today *Cymia* is considered a paciphile genus with a modern range from Costa Rica to Ecuador in the eastern Pacific (as *Cy. tecta* [Wood, 1828], Keen 1971) and extinct in the Caribbean, although with an extensive fossil record in the latter from the Miocene of Colombia (Gibson-Smith and Gibson-Smith 2012), the Dominican Republic (Saunders et al. 1986, Vokes 1989, Hendy et al. 2008), Haiti (Vokes and Vokes 1968), Panama (Woodring 1959, Aguilera and de Aguilera 1999), and Venezuela (Jung 1989) and the Pliocene of Trinidad (Jung 1969). *Cymia* can be separated from *Califrapana* by its small size with a higher spire, a strong fold midway of the columellar lip, and denticles on the inside of the outer lip. The nodes on the ultimate whorl also point outward and (or) posterior and not anteriorly as in *Califrapana*. In addition, *Cymia* has an umbilicus, while *Califrapana* has a pseudoumbilicus.

Molecular techniques have been used to distinguish various genera in the Rapaninae (Vermeij and Carlson 2000, Claremont et al. 2013), however *Califrapana* is strictly a fossil taxon and so cannot be evaluated using that technique. Still the comparable eastern Pacific

genera *Vasula* and *Cymia* cluster together far removed from the western Pacific and Indian Ocean genus *Rapana* (Claremont et al. 2013).

Age and Stratigraphy

The earliest report of *Rapana* in California is J.P. Smith (1919) who reported it as a diagnostic genus from west coast Miocene ("Vaqueros" CPMS) faunas and of western Pacific origin. Loel and Corey (1932:134) indicate a stratigraphic succession for *Califrapana* species with *C. vaquerosensis* s.s. occurring in the lowest part of the "Vaqueros" Formation s.s. and *C. v. imperialis* occurring higher in the section. However, no sections of the "Vaqueros" Formation (s.s. or s.l.) are well dated and biostratigraphic age determinations are not precise, therefore correlation of these sections is speculation and the validity of Loel and Corey's (1932) supposition is not supported, but also cannot be discounted. Given that form previously attributed to *C. vaquerosensis* s.s. only occurs in central California and southern California and forms identified as *C. v. imperialis* occur in southern California, the California Channel Islands and Baja California Sur, these distributions could be the result of temperature differences. Unfortunately, there is no direct evidence for differences in age or environment.

A precise stratigraphic age range *C. vaquerosensis* is difficult to determine, but all evidence indicates that it is restricted to the "Vaqueros" CPMS (circa. 32.6 to 19.5 Ma [middle early Oligocene to middle early Miocene], J.T. Smith 1991) and likely to lower and middle "Vaqueros" CPMS. The difficulty in determining a precise age arises from the misuse of lithostratigraphic names in California over the last two centuries and confusion with use of lithostratigraphic names as biostratigraphic units and thereby their assumed correlation. The Vaqueros Formation (of Hamlin 1904) with its type area in Reliz Canyon 7.5' quadrangle in Monterey County was studied by Durham (1963) who believed the type Vaqueros Formation to represent part, if not all, of Oligocene time. This age determination is at odds with the late Oligocene to early Miocene age determined for the "Vaqueros" CPMS (J.T. Smith 1991). Along those same lines the type Temblor Formation (of Anderson 1905) in the Temblor Range of southern San Luis Obispo County has an age range of late Oligocene to early Miocene (Addicott 1973) or equivalent to the "Vaqueros" CPMS, differing significantly from the "Temblor" CPMS (19.5 to 12 Ma [middle early to late middle Miocene; J.T. Smith 1991] on which the stage name is based.

In regards to misuse of biostratigraphic and

lithostratigraphic names specifically to *Califrapana*. J.T. Smith (1991) refers to both the “Vaqueros” and “Temblor” formations on San Miguel and Santa Rosa islands as early (lower) Miocene. Assuming as J.T. Smith (1991) did that both formations are early Miocene on the island then both formations fall into the “Vaqueros” CPMS, although exact age dating have not been determined. Also Powell and Geiger (2019) recently found rocks attributed to the “Vaqueros” Formation (name used in quotes to signify its difference from the type Vaqueros Formation) on Santa Miguel Island are middle Miocene in age and are, at least in part, correlative with the middle Miocene Topanga Canyon Formation (“Temblor” CPMS) in the Santa Monica Mountains, Los Angeles County. However, examination of collections by the senior author from San Miguel Island collected by geologists at the the Santa Barbara Museum of Natural History and USGS and assigned to the “Vaqueros” Formation by field geologists are assigned to the “Temblor” CPMS and do not contain *Califrapana* n. gen. Given these data care should be taken when dealing with these and many other lithostratigraphic units in California.

The occurrence of *Califrapana* with the bivalve *Gigantopecten magnolia* (Conrad, 1857) at locality LACMIP 7663 in the Los Angeles County and locality LACMIP 20608 in Ventura County supports a late Oligocene age, at least in part, for occurrences of *Califrapana*. In addition, Squires and Fritsche (1978) report the bivalve *Vertipecten kernensis* (Hertlein, 1925) as *V. nevadensis* (Conrad, 1855) of authors (*vide* J.T. Smith 1991) occurring with *Califrapana* near the Sespe Creek area also in Ventura County. J.T. Smith (1991) reports *G. magnolia* s.s. occurring in the lower “Vaqueros” CPMS of Addicott (1972, 1973) interpolated as 32 to 26 Ma (J.T. Smith 1991, fig. 11). Judy T. Smith (1991) reports the geologic age range of *Vertipecten kernensis* auct. as late Oligocene to early, early Miocene and an index fossil of the middle “Vaqueros” CPMS. Using J.T. Smith (1991, fig. 12) then a numeric age range of about 26 Ma to 22 Ma is indicated for the middle “Vaqueros” CPMS and *V. kernensis* auct. These ranges do not overlap, but are adjacent and together indicate a possible late early Oligocene to early Miocene (32–22 Ma) tielzone for *Califrapana*.

This age determination is supported by *Turritella* Lamarck (1799) associated with *Califrapana*. *Turritella* biostratigraphy is well developed in California (Loel and Corey 1932, Merriam 1941, Weaver 1943, Givens 1974, Saul 1983a, b, Squires 1987) and determining which species of *Turritella* are found associated with *Califrapana* may aid in determining the age of outcrops where

it is found. Along these lines Austin Hendy (personal communication, 12/2020) noted *T. ineziana* Conrad, 1857 s.l. and *T. ocoyana* Conrad (1855) found in proximity with *Califrapana* in collections at LACMIP. Three LACMIP collections (localities LACMIP 20605, 20608 and 22742) containing *Califrapana* also contain abundant *T. ineziana* s.s., while *T. ocoyana* is represented in few collections and not necessarily directly associated with *Califrapana*. Loel and Corey (1932) and Addicott (1970) consider *T. ocoyana* s.l. to range in age from lower to middle Miocene (upper “Vaqueros” CPMS) and it is considered representative of the “Temblor” CPMS, however its rarity and lack of detailed provenance of specimens associated with *Califrapana* indicates that it should be excluded from consideration here. *Turritella ineziana* s.l. is reported by Loel and Corey (1932) restricted to the early Miocene, although Addicott (1970) indicates it may get into the middle Miocene. However, overall it is considered restricted to the “Vaqueros” CPMS. *Turritella ineziana santana* Loel and Corey (1932) was described from near the top of the “Vaqueros” Formation in Plano Trabuco, Santa Ana Mountains, Orange County commonly associated with *Califrapana*, including those specimens illustrated in Figures 3, 8–10. Loel and Corey (1932) considered outcrops in Plano Trabuco to be early Miocene in age.

Given the data above *Califrapana* appears to ranges in age from the Oligocene, possibly late Oligocene, to early Miocene in age, or from the Rupelian to early Aquitanian stages of the International Stratigraphic Chart. This age determination is in general agreement with formational age range compiled from occurrences cited in Fossilworks (http://fossilworks.org/bridge.pl?a=taxonInfo&taxon_no=394735, retrieved 2/2021).

Biogeography

There is no direct evidence that *Califrapana* is related to *Rapana*. While dispersal of processors across the Pacific Ocean from east to west by equatorial countered currents during veliger stage cannot be discounted it seems more likely with the submergence of southern North America (Panamanian Seaway) currents crossed from the Atlantic to the Pacific and headed west as suggested by the dispersal of the planktonic gastropod *Janthina* Röding (1798) (Meco et al. 2016) during the Pliocene, but before the closure of the Panamanian Seaway. However, this also does not prevent the eastward dispersal by a northern Pacific counter current, but there is no direct evidence for this either. The seaway across Panama did not close until the late Pliocene (Keigwin 1978, Schmittner et al.

2004, Coates and Stallard 2013) so interchanges between these two oceans was open.

Califrapana has a disjunct distribution with specimens occurring in central and southern California and much further south in the middle of the Baja California peninsula. Using data from Addicott (1967) on the occurrence of *Turritella ineziana* s.l. (Fig. 12) an offset of about 315 km for the San Andreas fault can be determined since the late Oligocene/early Miocene. This determination compares favorably with that by Graham et al. (1989) for offset of the “Vaqueros” Sandstone in the Santa Cruz Mountain (320–315 km). The type locality for *Califrapana vaquerosensis* is located in Monterey County east side of the San Andreas fault on the relatively stable North American Plate. All other occurrences are on the west side of the San Andreas fault on the Pacific Plate and have moved north circa 315 km since deposition. Removing this displacement results in occurrences west of the San Andreas fault moving north so those now found in southern California would have been deposited around what is now San Luis Obispo/Monterey counties, California. This does not correct the large disjunct distribution between southern California and central Baja California, but does move the southern-most occurrences closer to what is now the US-México border. We feel this disjunct distribution is due to the lack of Oligocene and lower Miocene marine rocks on the Pacific slope of Baja California (Beal 1948, Dorsey and Burns 1994).

ECOLOGIC IMPLICATIONS

Califrapana vaquerosensis shows considerable sculptural variability, remarkably similar to that seen in the mostly intertidal Miocene to Holocene muricid *Nucella lamellosa*. The ornamentation in this latter species is attributed to wave exposure and population genetics (Kincaid 1957). Frilly forms with open spines such as *N. l. bormica* Dall (1915, pl. 74, fig. 8) and *N. l. lamellosa* s.s. of Dall (1915, pl. 74, fig. 7) are found in quiet water, whereas specimens that are smooth, with no or little closed spines on the shoulder, e.g., *N. l. cymica* Dall (1915, pl. 74, fig. 5) and *N. l. francisana* Dall (1915, pl. 74, fig. 6), are commonly found along the open coast and occasionally in quieter waters (Kincaid 1957, R. Clark, personal communication, 10/17/2020). In contrast, the most frilly and sculptured specimens of the California subtidal muricid *Ceratostoma foliatum* (Gmelin, 1791) occur around the California Channel Islands, which offer few protected environments (CAS and LACM Malacology collections). In addition, the most sculptured (“frillyist”) specimens of *Pteropurpura trialata* (Sowerby, 1834), a southern California muricid,

can be collected on the outer Los Angeles Harbor breakwater (R. Clark, personal communication 10/17/2020) where local wave action is high.

If it is assumed that *C. vaquerosensis* is mostly an intertidal to shallow subtidal species ecologically similar to *N. lamellosa* then similar environmental factors may also influence its sculpture. This line of thought indicates that most smooth-shelled forms previously identified as *C. serrai* and *C. vaquerosensis* s.s. are presumed to have lived in exposed, probably rocky shores, whereas the forms previously identified as *C. vaquerosensis imperialis* would most likely be found in quiet water environments with little wave exposure. However, the spiny form of *C. vaquerosensis* (*imperialis* form) are the only form found on the California Channel Islands, which implies wave exposure is not the major factor influencing ornamentation in this species. However, the Channel Islands were likely not islands where *Califrapana* was living or would be found in sediments deposited farther south (Kamerling and Luyendyk 1985).

Using the work of Squires and Fritsche (1978) for occurrences of *Califrapana* near Sespe Creek in Ventura County taxa associated with *Califrapana* (n=34) in the lower member are the arthropod *Balanus* da Costa (1778) (n=21), the bivalve mollusk *Anomia* Linnaeus (1758) (n=21), the gastropod *Turritella* (n=14) and the echinoid *Kewia* Nisiyama (1935) (n=12). Other identifiable taxa associated with *Califrapana* in the lower member are the bivalves *Mytilus* Linnaeus (1758) (n=3), *Macoma* Leach (1819) (n=2), the gastropod *Potamides* Brongniart (1810) (n=2), and represented at only a single locality associated with *Califrapana* the bivalves *Clementia* Gray (1842), *Saxidomus* Conrad (1837), and *Vertipecten kernensis* as *V. nevadensis* (Conrad, 1855) of authors (fide J.T. Smith 1991). In the middle member of the “Vaqueros” Formation along Sespe Creek they report *Califrapana* occurs in four collections associated with *Pycnodonte? howelli* Wiedey (1928) (syn. *Ostrea loeli* Hertlein (1928); *O. wiedeyi* Hertlein (1928); Wiedey published in March and Hertlein in October, so Wiedey’s name has priority) at three sites, and the bivalve *Chione* Megerle von Mühlfeld (1811) and gastropod *Turritella* at a single site each. They do not report *Califrapana* from the upper member or the overlying “Santa Margarita” Formation along Sespe Creek. Reid (1978) in the same volume attributes the lower member exposed near Sespe Creek to a bay environment separating out muddy beach, bay margin, open bay center, shallow grassy bay, inlet influence bay environments, and attributed the middle member, where *Califrapana* is much rarer, to either deep



Figure 12. Index map showing generalized paleogeography during the “Vaqueros” California provincial molluscan stage and the occurrence of *Turritella inezana* s.l. (after Addicott, 1967).

hypersaline bay or shallow inner shelf. Given the abundance of *Califrapana* in the lower member compared with the middle member of the “Vaqueros” Formation along Sespe Creek a bay environment seems most probably environmental setting for this new genus.

Austin Hendy (personal communication, 12/2020) also provided associated invertebrate taxa found with *C. vaquerosensis* (n=80) from the Natural History Museum of Los Angeles County fossil collections. The most common associated taxa are the gastropod genus *Turritella* (n=30), the barnacle *Balanus s.l.* (n=27), along with the bivalves *Anomia* (n=14), oysters (n=14) and various pectinids (n=13). All other taxa were present in less than five collections (<6.25%) and many in only a single collection so are deemed insignificant to our ecologic speculation. While the common associated taxa, above, may not have been collected in the exact same bed, still two substrates are indicated by taxa found in larger numbers with *Califrapana*, *Turritella* and pectinids are usually found on a sand and (or) silt, and *Balanus s.l.*, *Anomia*, and oysters are commonly found on rocky substrates. Sediments associated with all these collections are mostly sandstone and siltstone. So a sandy environment with associated rocks at shallow water depths, possibly in a bay, seems likely for *Califrapana* based on these collections.

Califrapana vaquerosensis (as *Rapana imperialis*) has been reported from the Isidro Formation (=yellow beds of Darton 1921, Ysidro Formation of Hertlein and Jordan (1927), Beal (1948), Monterrey and San Raymundo formations of Mina (1957), *vide* Squires and Demetron 1993; Mina (1957) has been modified by Lozano-Romen (1975), and Alatorre (1982) to not include the Monterrey Formation) (not to be confused with the Permian San Ysidro Formation in New Mexico or the Ordovician San Isidro Formation in Argentina) in Baja California Sur (J.T. Smith 1984), which was named by Heim (1922). It is believed to range from lower to middle Miocene based on stratigraphic position (Beal 1948, McLean et al. 1984), biostratigraphy (J.T. Smith 1984, 1986), and radiometric age-dating constraints (Gastil et al. 1979, Sawlan and Smith 1984, McLean and Hausbeck 1984, J.T. Smith 1984, McLean et al. 1987). The subtropical to tropical fauna of this formation has faunal connects with California (*C. vaquerosensis* [as *Rapana imperialis*], *Trochita* n. sp. [as *T. spirata* (Forbes, 1852)], cited in J.T. Smith 1984), but also Panama, the Dominican Republic, Peru, and northern Columbia (J.T. Smith 1984).

In addition, Austin Hendy (personal communication 12/2020) noted evidence of hermit crab occupation (i.e., peeled apertures, *Polydora* Bosc (1802), borings, and

barnacle encrustation traces) in *Califrapana* indicating these shells were common post-mortem hosts for barnacles and hermit crabs. This isn't surprising given their heavy shell, which would be resistant to environmental breakdown. Hendy (op. cit.) also noted the lack of bore holes in associated taxa so it does not appear that they bored bivalves to obtain food like some other California muricids. *Califrapana* also lacks a labral tooth, a structure that is commonly used to pry apart bivalve shells. Given these observations the mode of feeding remains unknown.

The presence of the abundant large *Turritella*, the gastropod genus *Trochita* Schumacher (1817), and the bivalve genera *Anadara* Gray (1847), *Antigona* Schumacher (1817), *Isognomon* Lightfoot (1786), *Pteria* Scopoli (1777), and *Spondylus* Linnaeus (1758), associated with *Califrapana* in LACMIP collections indicate warmer water temperatures than in the southern California Bight today, probably subtropical to tropical water temperatures. Part of this temperature increase is likely due to deposition south of where they occur today although later the middle Miocene was a period of warmer globe temperatures with the tropical bivalve genera *Anadara* and *Dosinia* Scopoli (1777), which occur today off Baja California, México and south, found as far north as Kodiak Island, Alaska (USGS collections, Narrow Cape Formation) and the warmer temperatures indicated here could of been a leadup to that time.

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