ISSN 0738-9388

Some cone shells with nodules that persist at least into the middle whorls (subfamilies Conilithinae and Coninae) from the East Pacific region

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INTRODUCTION

In the first installment of this series, five species of spotted cone shells were considered. In this paper eleven other species are detailed. These include those species that have nodules along the shoulder angle and where the nodules reach the middle spire whorls. Most of these species actually retain nodules along the shoulder angle throughout growth. All of these species were considered in detail in the comprehensive volume on all of the East Pacific cone shell species (*i.e.,* Tenorio *et al*., 2012) use of this book will help establish species identities for all of these species.

Even though the taxonomy of East Pacific cone shells is relatively stable, some problem areas seem to remain. The figure captions are designed to point out the difficulties along with useful key-characters for species identifications. Complete species descriptions are available along with comprehensive illustrations in Tenorio *et al*. (2012). Those interested in the East Pacific cone shells should consult that book.

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ISSN 0738-9388

Descriptive figure captions: Figures 1 to 3 illustrate images of the East Pacific cone shells that have nodulose shoulder angles with images from Tucker & Tenorio, 2013. Figures 1 to 5 represent the species of *Virroconus* from the East Pacific (Tucker & Tenorio, 2009).

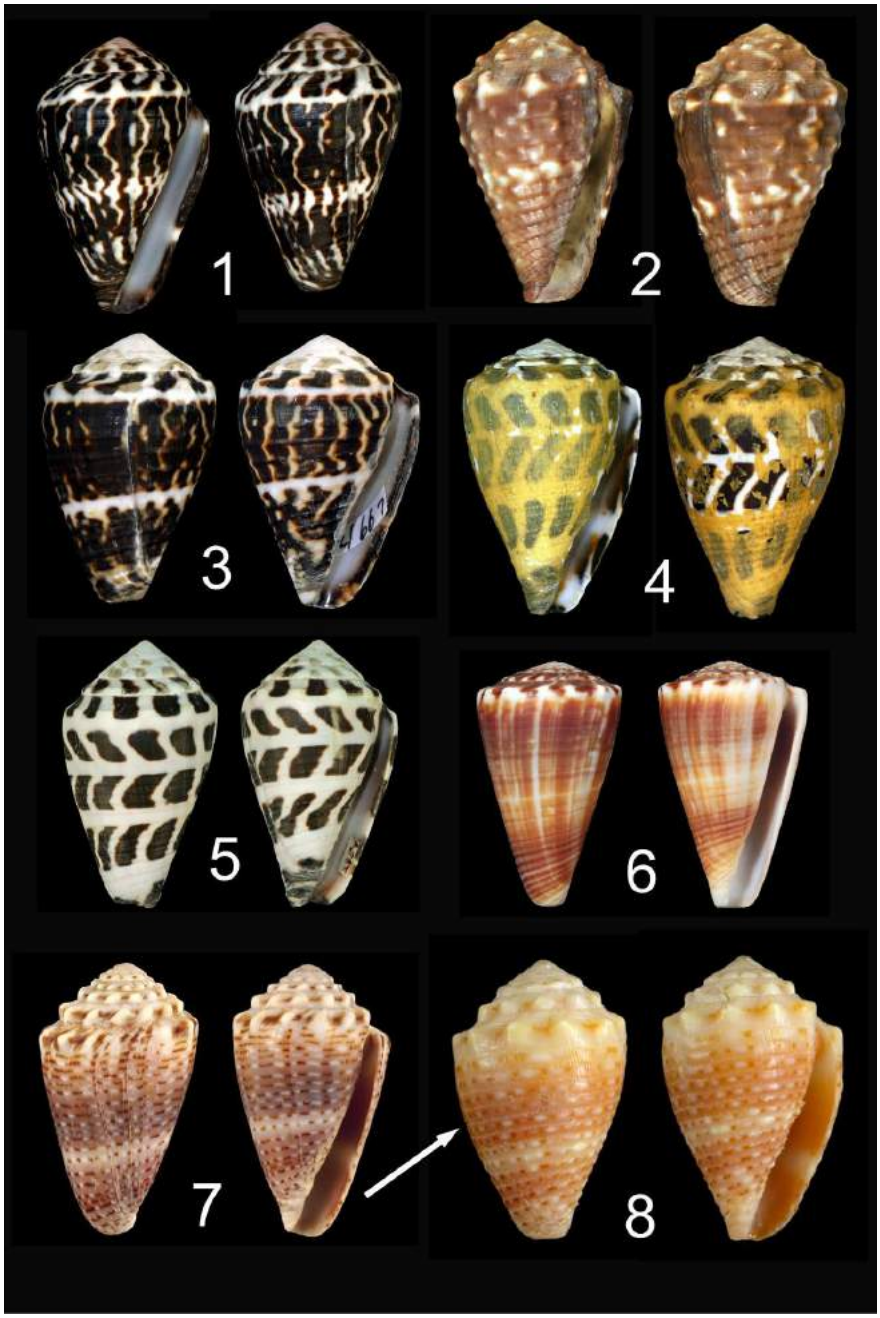
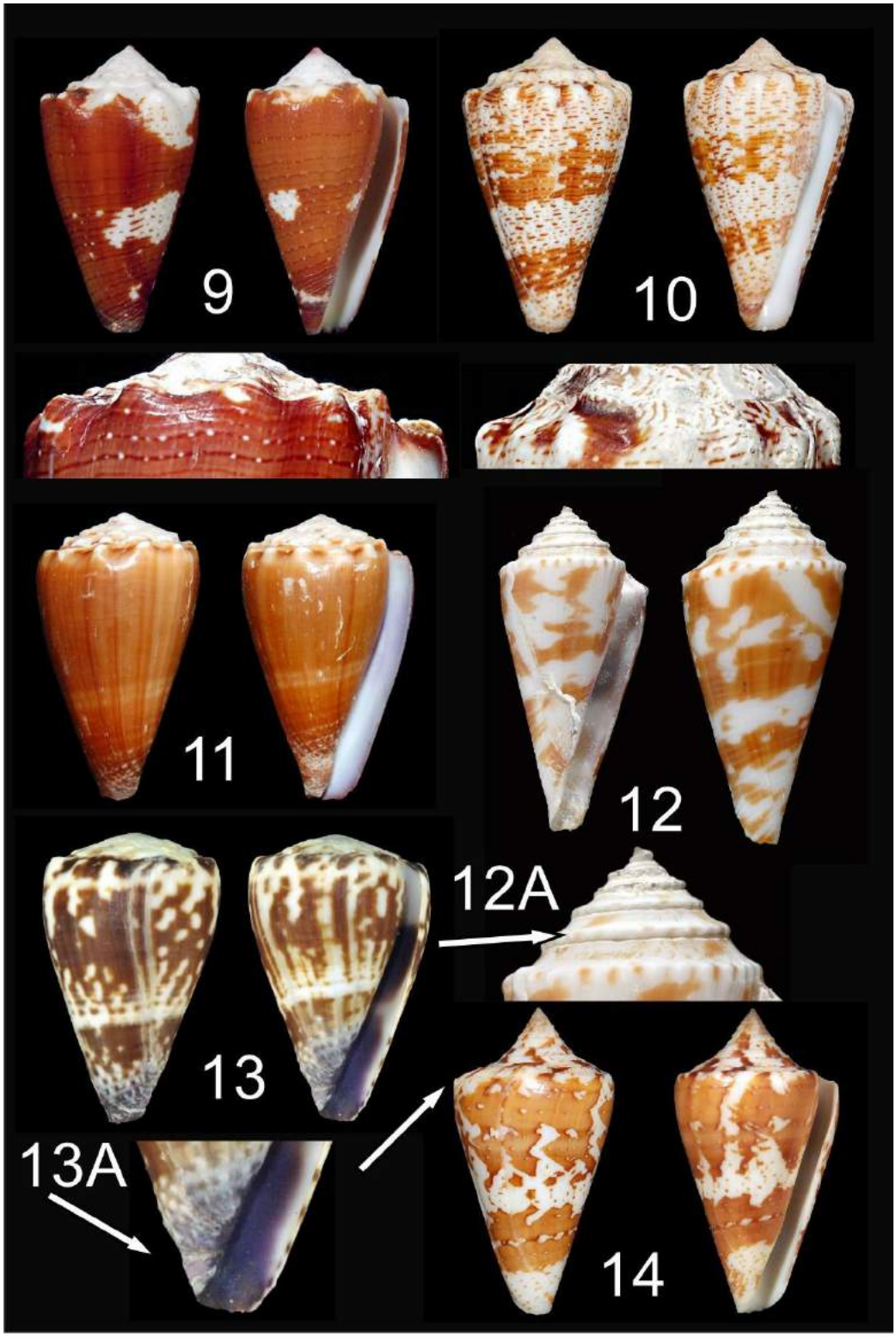


Figure 1. Specimen of *Virroconus chaldaeus* (SBMNH 99965). 35.7 mm shell length, from Clipperton Island. **Figure 2.** Holotype of *Conus brunneus pemphigus* Dall, 1910, (USNM 37449), 26 mm shell length, from Ilas Tres Marias, Nayarit, Mexico. Tenorio *et al*. (2012) pointed out that Dall's specimen is actually a specimen of *V. chaldaeus* and that *Conus brunneus pemphigus* is a synonym of *V. chaldaeus*. **Figure 3.** An Indo-Pacific specimen of *Virroconus chaldaeus* (INHS 45013), 26.2 mm in shell length, from Hundred Islands, Lingayen Gulf, Luzon, Philippines, which was illustrated by Tucker & Tenorio (2013); shown here for comparison with the East Pacific *V. chaldaeus* in Figure 1. The spires of East Pacific specimens are slightly but statistically significantly higher than are the spires of their Indo-Pacific counterparts. More interesting and possibly diagnostic are differences in the radular teeth of the East Pacific and Indo-Pacific specimens. The latter has slight but distinctly developed serrations on the tooth (see Figures 28 and 28A). The radulae from the East Pacific specimens do not have serrations (see Figures 29 and 29A). However, few samples of the Indo-Pacific *V. chaldaeus* have been examined and previous illustrations of radulae of Indo-Pacific specimens do not show the serrations that Tenorio *et al*., 2012, reported for *V. chaldaeus* from the Seychelles. This may be due to the small and indistinct nature of the serrations in the Indo-Pacific specimens leading to them being overlooked. **Figure 4.** An East Pacific specimen (LACM 72-68.9) of *Virroconus ebraeus*, 37 mm in shell length, from Isla del Cano, Costa Rica with a portion of the periostracum preserved. **Figure 5.** An Indo-Pacific specimen of *V. ebraeus* (INHS 44784), 38.1 mm shell length, from Cebu Island, Philippines shown for comparison with those from the East Pacific. **Figure 6.** A specimen of *Gladioconus gladiator* (MJT collection), 36.7 mm in shell length, from Playa Maculis, El Salvador. **Figures. 7 and 8**. Specimens of *Miliariconus tiaratus*. Figure 7 is the normal form of the species, shell length is 45.7 mm (SBMNH 90852) and came from Isla Bartolome, Galapagos; Figure 8 is the holotype (USNM) of the form *roosevelti*, shell length of 15.3 mm, from Clipperton Island. Specimens of this form are wider bodied than the nominate form (note arrow) and have pink interiors, whereas the nominate form has either white or purple interior coloration.

ISSN 0738-9388

Figures 9 to 14 illustrate a number of images of more nodulose species.



Figures 9-11, and 14. Four brown cone species. **Figure 9.** *Stephanoconus brunneus* (MJT collection), 33.0 mm shell length, from Isla Gobernadora, Panama. This species has at least 5 cords on the spire whorl tops. The other three species (Figures 10, 11 and 14) have fewer (2 or 3 for *Lividoconus diadema*) or have the whorl tops that are smooth as for *S. bartschi* and *Tenorioconus archon*. Like *S. bartschi* (Figure 23) and *T. archon* (Figure 24), *S. brunneus* (Figure 22) has the typical short thick and spiny radular morphology associated with predation on amphinomid polychaetes (see Tenorio *et al*., 2012). In contrast, *L. diadema* has a thin elongated tooth that has no serrations but does have a terminating cusp (Figure 25; Tenorio *et al*., 2012). *Lividoconus diadema* feeds on a variety of other polychaetes (Nybakken, 1978 and 1979). **Figure 10.** *Stephanoconus bartschi* (MJT collection), 45.4 mm shell length, collected south of Acapulco, Copala region, Mexico. This species has the radula and general shell morphology similar to *S. brunneus*. In general, *S. bartschi* is lighter colored than the usually darker brown coloration of *S. brunneus*. However, shell color is not the identifying criteria for *S. bartschi*. Rather it is the lack of cords on the whorl tops of *S. bartschi*. In contrast, the whorl tops of *S. brunneus* have at least

5 well developed cords (Tucker, 1979). **Figure 11.** *Lividoconus diadema* (MJT collection), 38.7 mm shell length, Las Perlas, Panama. Specimens of *L. diadema* are most often confused with 'clean' specimens of *S. brunneus*. Besides differences in radular teeth (compare Figures 22 and 25), the structure of the whorl tops are completely different. *Stephanoconus brunneus* has at least five and often more cords on the spire whorl tops (Figure 9). The spire whorl tops of *L. diadema* have two to sometimes 3 grooves on the whorl tops. These grooves often fade in outer whorls. Besides this highly reliable difference in whorl top structure, these species also differ in the structure of the operculum and periostracum. In the *Stephanoconus* species (*S. brunneus* and *S. bartschi*) the operculum is relatively large and the periostracum is smooth. The operculum of *L. diadema* is small and the periostracum is tufted along the shoulder angle and often on the body whorl as well. **Figure 12.** *Profundiconus emersoni* (LACM 146906), 33.7 mm shell length, collected in 300 m off Isla Santa Maria (Charles), Galapagos Islands. This species is the only member of the Family Conilithidae included here; all of the other species belong in the family Conidae, subfamily Puncticulinae. It is included in this section because the small square shaped nodules (*see* arrow in Figure 12A) of *P. emersoni* that usually persist into the outer spire whorls. The nodules are arranged along a carina and are probably not homologous with the nodules in the Conidae included here. The nodules of the Conidae are arranged along the shoulder angle but they are not square shaped and are not associated with a carina; they are hemispherical in shape instead. The operculum of *P. emersoni* is unique among East Pacific cone shells. It is serrated along its inner margin and relatively large. Other Indo-Pacific species of *Profundiconus* (e.g., *P. teramachii*) also have large serrated opercula (Tucker & McLean, 1993; Tucker & Tenorio, 2013). These observations are summarized in Tucker & McLean (1993). **Figure 13.** *Harmoniconus nux* (INHS 45028), 22.5 mm in shell length, collected from Clipperton Island. Some associate this unique cone shell with *H. sponsalis* or *H. nanus*, both Indo-Pacific species of *Harmoniconus*. Tenorio *et al*. (2012) outlined differences in shell parameters between *H. nux* and *H. sponsalis*. Moreover, Duda *et al*. (2008) showed that *H. nux* represents a reproductively isolated evolutionarily significant unit, which supports its recognition as a separate species from Indo-Pacific species of *Harmoniconus*. **Figure 14.** *Tenorioconus archon* (MJT collection), 45.6 mm in shell length, from Isla Canal de Afeura, Panama. This species of *Tenorioconus* differs from the two species of *Stephanoconus* in the nature of the periostracum. It is smooth in *Tenorioconus* but tufted or ridged in *Stephanoconus*. These genera also differ in the persistence of the nodules. In the *Tenorioconus* the nodules fade out well before middle spire whorls. These are well developed in the early whorls and the spire tends to be convex in profile. Nodules of the *Stephanoconus* species persist. Finally the operculum of *T. archon* is relatively small compared to the larger one present in the East Pacific *Stephanoconus* species.

Figures 15 to 17 illustrate the *Ductoconus princeps* variants. This species is quite variable in the coloration of the longitudinal lines that may be or may not be present on the body. Besides these variants, the species is easily distinguished from other nodulose species by the constant orange to pink coloration of the body and spire. The narrow elongated radular tooth (Figure 28) is also diagnostic. Among the other nodulose cone shells, only *L. diadema* has an elongated radular tooth. However, that species does not have well developed serrations that extend for more than half the length of the tooth (compare Figures 25 and 28). The operculum of *D. princeps* is fairly large and the periostracum is thick and has rows of pronounced tufts on the body.

Figures 18 to 30 illustrate radulae of the nodulose East Pacific cone shells. See Tenorio *et al*. (2012) for details on scales and sources.

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ISSN 0738-9388

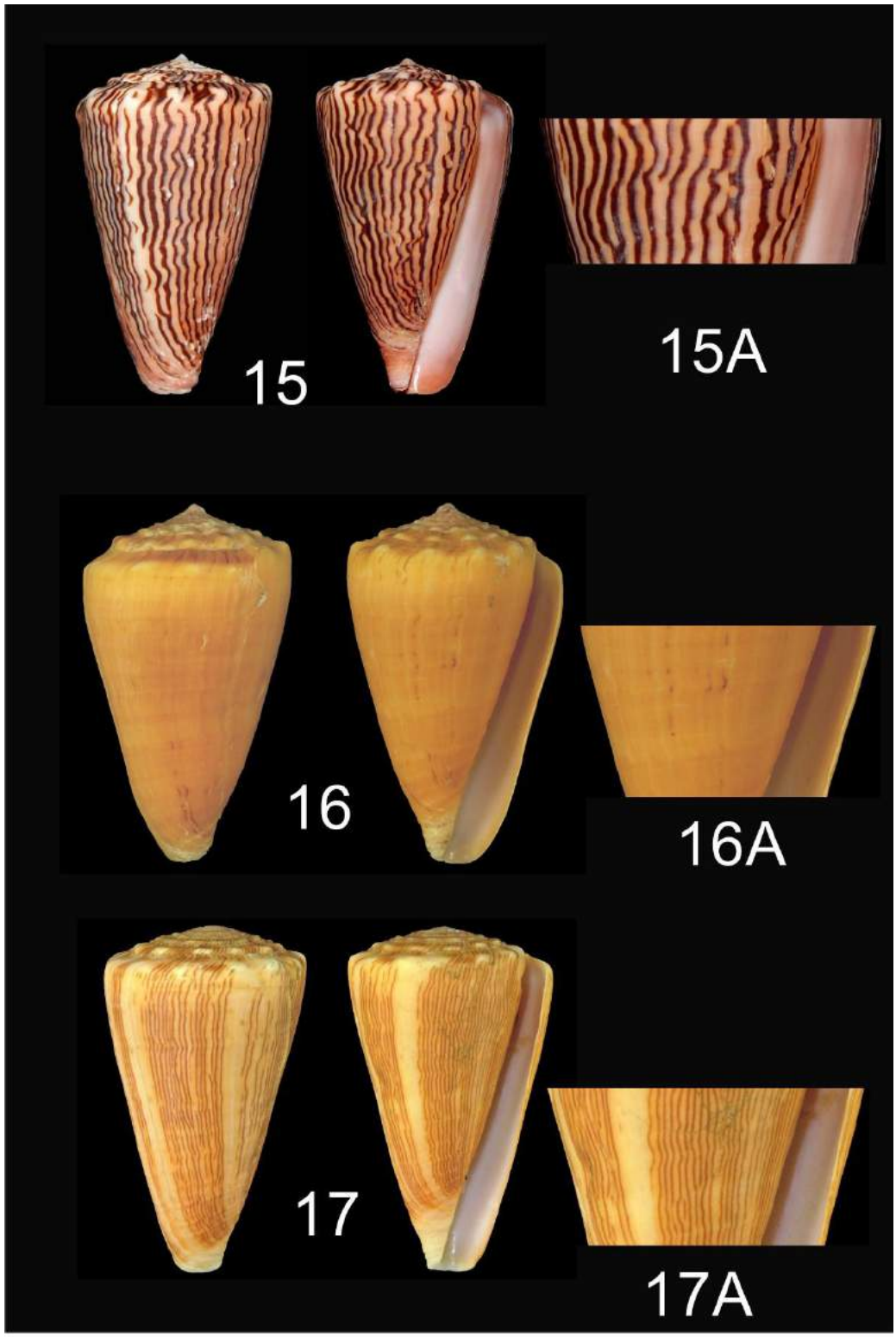

Figure 15. *Ductoconus princeps* variety *princeps* (MJT collection), shell length is 66.6 mm, collected from Guaymas, Sonora, Mexico. The nominate variety is characterized by the well-spaced fairly wide longitudinal lines (Figure 15A). **Figure 16.** *Ductoconus princeps* variety *apogrammatus* (INHS 45027), shell length is 52.0 mm, collected from Isla Gobernadora, Golfo de Montijo, Panama. This variety has little or no development of the longitudinal lines (Figure 16A). **Figure 17.** *Ductoconus princeps* variety *lineolatus* (INHS 45026), shell length 58.8 mm, trawled in 15 to 20 m, Panama Bay, Panama. This variety has the longitudinal lines closely spaced and they are quite narrow (Figure 17A). It often occurs with variety *apogrammatus* in Panama but any of the varieties can occur together.

ISSN 0738-9388

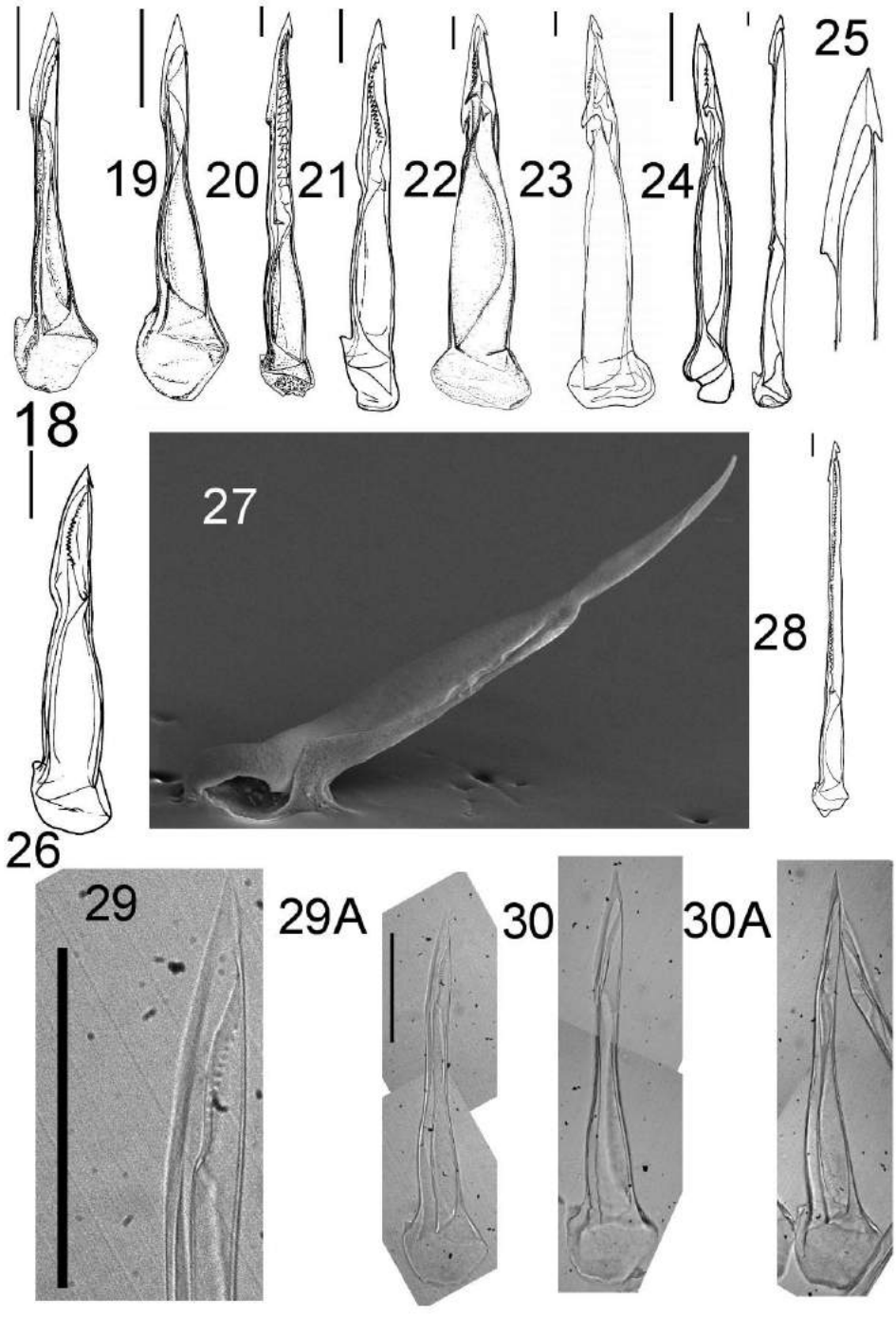

Figure 18. *Virroconus chaldaeus*, SBMNH 358607, Clipperton Island, Shell length ($S_{L)}$ = 38 mm, Tooth length ($T_{L)}$ = 0.37 mm. **Figure 19.** *Virroconus ebraeus*, SBMNH 358606, Clipperton Island, S_L = 44 mm, T_L = 0.39 mm. **Figure 20.** *Gladioconus gladiator*, Las Tunas, El Salvador, S_L = 38.4 mm, T_L = 1.36 mm. **Figure 21**. *Miliariconus tiaratus*, Golfo de Panama, S_L = 22.4 mm, T_L = 0.73 mm, from Nybakken , 1970. **Figure 22.** *Stephanoconus brunneus*, Golfo de Panama, S_L = 41.3 mm, T_L = 1.62 mm., from Nybakken, 1970. **Figure 23.** *Stephanoconus bartschi*, Golfo de Panama, S_L is unknown, T_L = 1.2 mm, from Nybakken, 1970. **Figure 24.** *Tenorioconus archon*, Golfo de Panama, S_L = 41.3 mm, T_L = 0.43 mm, from Nybakken, 1970. **Figure 25.** *Lividoconus diadema*, Islas Galapagos, S_L = 44.8 mm, T_L = 1.57 mm. **Figure 26.** *Harmoniconus nux*, Golfo de Panama, S_L = 20.8 mm, T_L = 0.54 mm, from Nybakken, 1970. **Figure 27**. *Profundiconus emersoni*, scanning electron micrograph, LACM 146906, Islas Galapagos, off Isla Santa Maria; S_L = 33.7 mm, T_L = 0.4 mm. **Figure 28.** *Ductoconus princeps*, Golfo de Panama, S_L = 37 mm, T_L = 1.6 mm, from Nybakken, 1970. **Figure 29.** *Virroconus chaldaeus* from Mahe, Seychelles (Y36-5251), light micrograph. Close up showing serrations and Figure 29A showing the entire tooth length also from Mahe, Seychelles; S_L = 30 mm, T_L = 0.35 mm. **Figure 30.** *Virroconus chaldaeus* from Clipperton Island (SBMNH 358607), light micrograph. Close up showing lack of serrations and Figure 30A showing the entire tooth length; S_L = 38 mm, T_L = 0.37 mm.