BUCCINUM THERMOPHILUM (GASTROPODA: NEOGASTROPODA: BUCCINIDAE), A NEW SPECIES FROM THE ENDEAVOUR VENT FIELD OF THE JUAN DE FUCA RIDGE

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(Received 20 April 2001; accepted 9 August 2001)

ABSTRACT

Buccinum thermophilum new species, is described from abyssal depths of the Endeavour Vent Field, a portion of the Juan de Fuca Ridge in the northeastern Pacific. The new species is provisionally assigned to the subgenus *Viridibuccinum* Golikov and Sirenko, 1988, primarily on the basis of its conchological similarities with some of the species included in this subgenus, especially its type species *B. (V.) viridum* Dall, 1890. The anatomy of this new species is similar in most respects to that of the few species of Buccininae for which the anatomy is known. *Buccinum thermophilum* most closely resembles *B. viridum, B. rondinum* Dall, 1919, and, to a much lesser extent, *Buccinum diplodetum* Dall, 1907, which has a similar geographic and bathymetric range.

INTRODUCTION

Whelks of the family Buccinidae are the most geographically widespread and ecologically diverse neogastropods, ranging from the intertidal to the hadal zone, from the poles to the tropics, and have even invaded fresh water. It is therefore not surprising that buccinids are among the more conspicuous of the predatory and scavenging gastropods in hydrothermal vent communities. While their presence at hydrothermal vents has previously been noted (e.g. Warén & Bouchet, 1991; 2001), most publications dealing with the gastropod faunas of hydrothermal vents have thus far emphasized the novel, and often endemic, higher taxa (e.g., McLean, 1988; Warén & Ponder, 1991).

The taxonomy of the Buccinidae is not yet stable, and continues to be refined. Northern Pacific members of this family have been divided into six subfamilies (Habe & Sato, 1972). Golikov (1980) monographed the subfamily Buccininae, subdividing it into 3 genera, containing 3 subgenera and 88 species. This classification was updated by Golikov and Sirenko (1988) to include 5 genera, 23 subgenera and 108 species within Buccininae, all from the cold and temperate waters of the Northern Hemisphere. While most species of *Buccinum* inhabit sublittoral to bathyal depths, several have been reported from the abyssal zone (Clarke, 1962). Although several species of Buccinidae are known from oil and methane seeps (Warén & Bouchet, 2001: Appendix 2), only two species of the related genus *Eosipho* are confirmed to occur at hydrothermal vent sites in the Pacific (Okutani & Ohta, 1993; Warén & Bouchet, 2001).

The present paper is a taxonomic preamble to the publication by Martell, Tunnicliffe and McDonald (2001), which reports the results of a long-term study of the ecology of a *Buccinum* that occurs commonly along the Endeavour Vent Field of the Juan de Fuca Ridge, southwest of Vancouver Island, Canada. As these animals could not be assigned to any of the 108 species discussed by Golikov & Sirenko (1988) or described since (e.g. Kantor & Harasewych, 1998), they are here described as a new species. This new species is included in the subgenus *Buccinum (Viridibuccinum)* Golikov and Sirenko (1988), based on its conchological resemblance to the type species of the subgenus.

MATERIALS AND METHODS

Formalin fixed, alcohol preserved specimens collected on a series of research cruises to the Endeavour Segment of the Juan de Fuca Ridge were kindly provided by Dr. Verena Tunnicliffe, University of Victoria. For details of collection methods, habitat and ecology of this species, see Martell, Tunnicliffe and McDonald (this issue).

Abbreviations:

BM(NH)—The Natural History Museum, London
CMN—Canadian Museum of Nature, Ottawa
LACM—Natural History Museum of Los Angeles County, Los Angeles
MNHN—Museum national d'Histoire naturelle, Paris
ROM—Royal Ontario Museum, Toronto
USNM—National Museum of Natural History, Smithsonian Institution, Washington, DC
ZISP—Zoological Institute, Russian Academy of Sciences, St. Petersburg
ZMMU—Zoological Museum, University of Moscow.

SYSTEMATIC DESCRIPTION

Family BUCCINIDAE Rafinesque, 1815

Subfamily Buccininae Rafinesque, 1815

Genus ***Buccinum*** Linnaeus, 1758

Subgenus ***Viridibuccinum*** Golikov & Sirenko, 1988

Type species: *Buccinum viridum* Dall, 1890, by original designation.

Translation of original description: 'The subgenus *Viridibuccinum* is characterized by a relatively thin shell with convex whorls that have the tendency to form an angulated or rounded shoulder, and are separated by a deep suture. The periostracum is well developed, usually with hairs or lamellae. Spiral sculpture predominates and consists of numerous cords that are similar in size, narrow and slightly wavy. In addition to the type species, this variable subgenus includes: *B. takagawai, B. striatellum, B.*

osagawai, B. rossicum, B. fukureum, B. kinukatsugai, B. rondinum, B. aleuticum, B. elatior, B. shiritokoensis, and the fossil species *B. paramushiriense* and *B. bogachielii*.'

Remarks: The partition of the genus *Buccinum* into 23 subgenera (Golikov & Sirenko, 1988) was based on the scheme of inferred evolutionary relationships within the genus proposed by Golikov (1980: Fig. 206) and represents the intuitive views of the authors, founded mostly on conchological similarities. Penis morphology is similar among those species of *Viridibuccinum* for which it is known [*B. rossicum* Dall, 1907; *B. kinukatsugai* Habe & Ito, 1965; *B. osagawai* Habe & Ito, 1965; *B. rondinum* Dall, 1919; *B. elatior* (Middendorff, 1849)—Golikov, 1980: Figs. 170–174] and is characterized by the presence of a medium-sized, broadly conical seminal papilla surrounded by a circular fold. However, very similar penis morphology is also found in species that are thought to be more distantly related, e.g. *Buccinum* (*Sulcatibuccinum*) *tenuisulcatum* Golikov & Gulbin, 1977 and *B.* (*Sigmoidibuccinum*) *polium* Dall, 1907.

Viridibuccinum appears to be a rather heterogeneous taxon that, in addition to species conchologically similar to the type species, includes *B. elatior,* characterized by strong axial ribs and very fine spiral cords. As the shell of *B. thermophilum* is similar in general outline and shell sculpture to that of *B. viridum* and *B. rossicum*, we provisionally include it in subgenus *Viridibuccinum*.

Buccinum thermophilum new species

Figures 1–3, 5–17.

Shell morphology: Shell (Figs. 1, 3) height to 38 mm, extremely thin, ovate-conic, with regular, roundly inflated whorls, very short, broad siphonal canal. Protoconch unknown, eroded in all available specimens (Fig. 6). Teloconch of up to 5 evenly rounded to very weakly shouldered whorls. Suture abutted to slightly impressed well anterior to periphery of previous whorl. Axial sculpture (Fig. 5) limited to fine, occasionally irregular, weakly recurved, opisthocyrt growth lines. Spiral sculpture (Figs. 3, 5, 6) of numerous tightly spaced, low cords of varying prominence between suture and shoulder. Cords become widely spaced below shoulder and may be interspersed with thin spiral threads. Along the siphonal canal, the cords become tightly spaced again, with spaces between adjacent cords appearing as narrow, incised furrows. Aperture large, ovate, nearly elliptical, roughly half the length of the shell, deflected from the coiling axis by 24–27°. Outer lip evenly rounded, thin, not reflected. Columella weakly concave, roughly coincident with shell axis, forming an angle of 48–52° with parietal lip. Siphonal fasciole absent, siphonal fold sharp, winding tightly around shell axis. Periostracum and outer shell layer resorbed from inductural area, exposing white, translucent shell. Siphonal canal very short, broad, open. Shell uniformly white in color. Periostracum (Figs. 9–10) extremely thin (~ 12 μm), olive brown in colour, finely lamellose, shrinks and cracks upon drying. Shell strongly pitted in areas were periostracum is damaged or absent. Operculum (Figs. 2, 3) of moderate size (~ 2/3 aperture length), ovate, corneous, concentric, with subcentral nucleus, thin adaxial edge.

Shell microstructure: Shell (Fig. 7) extremely thin (135 μm), consists of three crystalline layers. Outermost layer (Fig. 7, ca) 37 μm thick, composed of columnar calcitic crystals. Middle layer (Fig. 7, ccl) thickest (63 μm), composed of collabrally oriented, aragonitic, crossed-lamellar units. Inner layer (Fig. 7, rcl) thinnest (35 μm), composed of aragonitic,crossed-lamellar units oriented perpendicular to growing edge of shell. In some specimens, innermost layer is absent near shell edge, first appearing about 1/16 whorl within the aperture.

Anatomy: Preserved animal (Figs. 11–12) spans 2½ whorls, mantle cavity ¾ whorl, kidney ¼ whorl, digestive gland and gonad 1¼ whorl. Mantle edge broadly thickened, with narrow, reddish band along its margin. Ctenidium (Fig. 12, ct) 1½ times as wide, twice as long as osphradium (Fig. 12, os). Siphon broad, thick, forms groove that enfolds anteriormost portions of ctenidium and osphradium. Hypobranchial gland (Fig. 12, hg), as broad as ctenidium, strongly transversely pleated, right side overlaying pallial gonoduct. Head large, tentacles contracted (Fig. 11, cep.t), broad, with large black eyes at their bases. Foot short, wide (L/W ≈ 1.5), tapering posteriorly, with broad propodium. Body uniform brick red in color.

Alimentary system: Proboscis (Fig. 13–15, pr) long (≈ 0.75–0.85 aperture length), broad (≈ 0.25 retracted proboscis length), thickly muscular, same brick red color as body. Proboscis retractor muscles thick, attached along both sides of rhynchodeum at mid-length or posterior part of rhynchodeum (Fig. 13–14, prr). Mouth broadly oval. Radula (Fig. 8) short (0.6 aperture length), with 71 triserial rows of teeth. Rachidian teeth with four cusps. Outer cusps slightly longer, broader, more elevated from basal plate than inner cusps. Basal plate roughly rectangular, slightly concave along thinner anterior edge. Lateral teeth wider than rachidian teeth, with three prominent cusps. Outer cusp largest, most strongly elevated. Inner cusp shorter, broader. Middle cusp smallest, adjacent to, seemingly bifurcated from inner cusp. Anterior proboscis wide, thick-walled, dorso-ventrally flattened, leading to large, pyriform valve of Leiblein (Fig. 13, 15 vL) situated anterior to nerve ring. Nerve ring covered with dense connective tissue. Salivary glands large, pink, covering the nervous ring laterally. Left salivary gland (Fig. 14, 15, lsg) smaller than right salivary gland (Fig. 13, 15, rsg), situated more posteriorly. Salivary ducts thick, highly coiled, attached to rhynchodeum by thin layer of connective tissue. Mid-oesophagus (Fig. 14, mo) narrow. Gland of Leiblein (Fig. 13–15, gL) compact, yellowish, adjacent to left salivary gland. Duct of Gland of Leiblein rather broad, opening into oesophagus laterally on right side (Fig. 13, 15, dgL). Posterior oesophagus expanded to form large, muscular crop lined with transverse epithelium folds, at rear of cephalic haemocoel (Fig. 13–15, cr). Stomach (Fig. 16) large, with long, broad caecum. Ducts of digestive gland enter stomach ventrally, one near the entrance of the oesophagus, the other near the entrance to the intestine. Stomach morphology is similar to that of other Buccininae. Intestine is narrow before expanding into broad rectum that overlays pallial gonoduct. Rectum free at distal end, its anterior margin even with anterior edge of bursa copulatrix of females. Anus with small ventral papilla. Rectum of Paratype 2 full of large alvinellid polychaete setae, tentatively identified by V. Tunnicliffe as belonging to *Paralvinella palmiformis*.

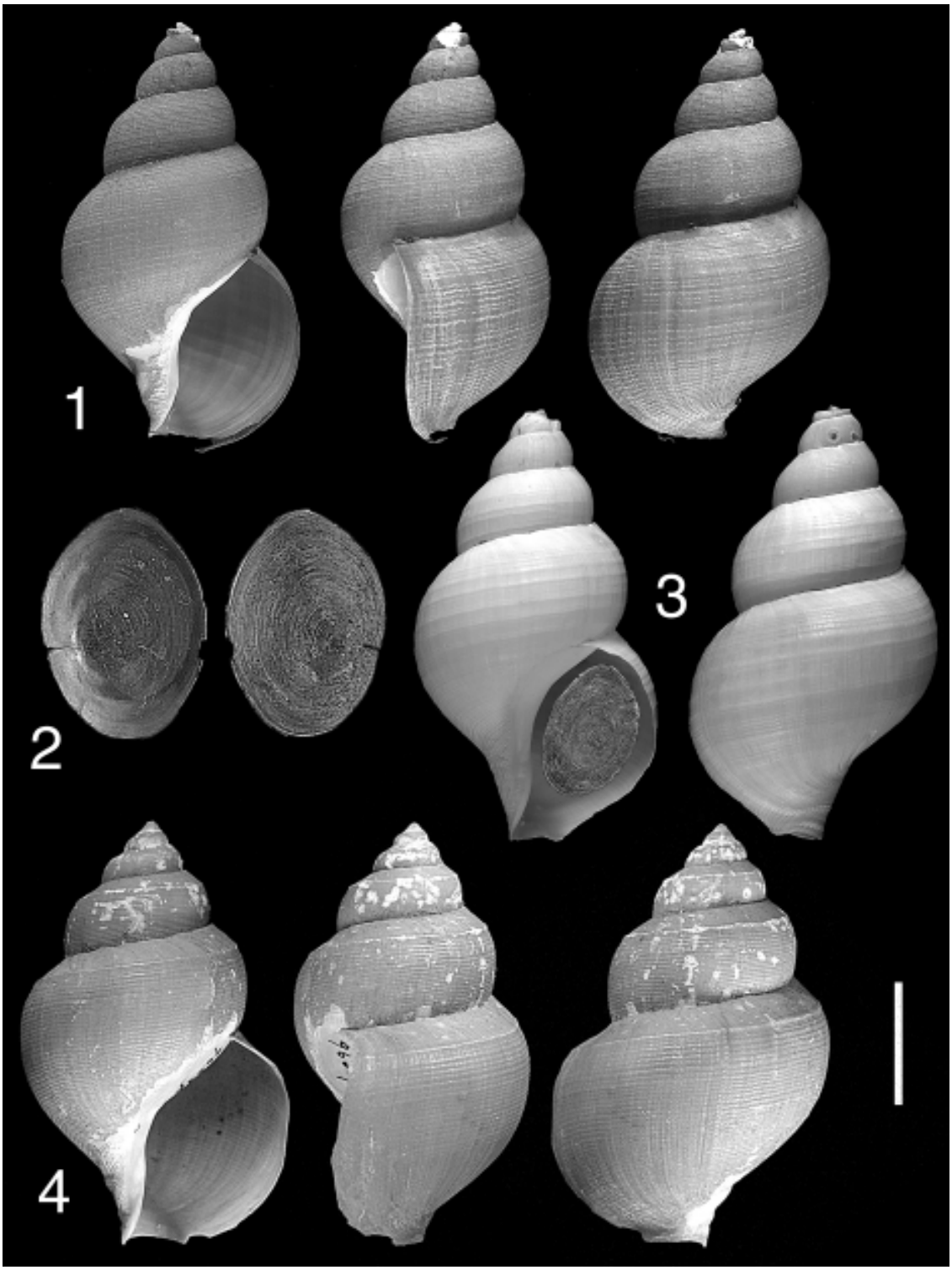
Male reproductive system: Testis, reddish orange in color, overlaying inner surface of digestive gland. Testicular duct thin, enters posterior margin of mantle cavity, runs along lateral wall before descending to floor of mantle cavity at mid-length, were it forms thick-walled duct that leads to base of penis. Penis (Fig. 17) long, broad, dorso-ventrally compressed. Distal end appears obliquely truncated, with broad, low conical papilla surrounded by thickened ring along its outer edge.

Female reproductive system: Ovary yellowish white, granular, lining adaxial side of digestive gland from apex to posterior limit of stomach. Oviduct passes anteriorly along pericardium to open into albumen gland adjacent to kidney. Capsule gland long, thickly glandular, broadly oval in transverse section, running along right wall of mantle cavity for ¾ of its length, leads into small rounded bursa copulatrix situated below and anterior to

capsule gland. Egg capsules and contents are described and illustrated in Martell *et al.* (2002: Fig. 6, Table 2).

Type Locality: 'Smoke and Mirrors' site, Endeavour Segment, Juan de Fuca Ridge, 47°56.89′N, 129°05.91′W, in 2194 m.

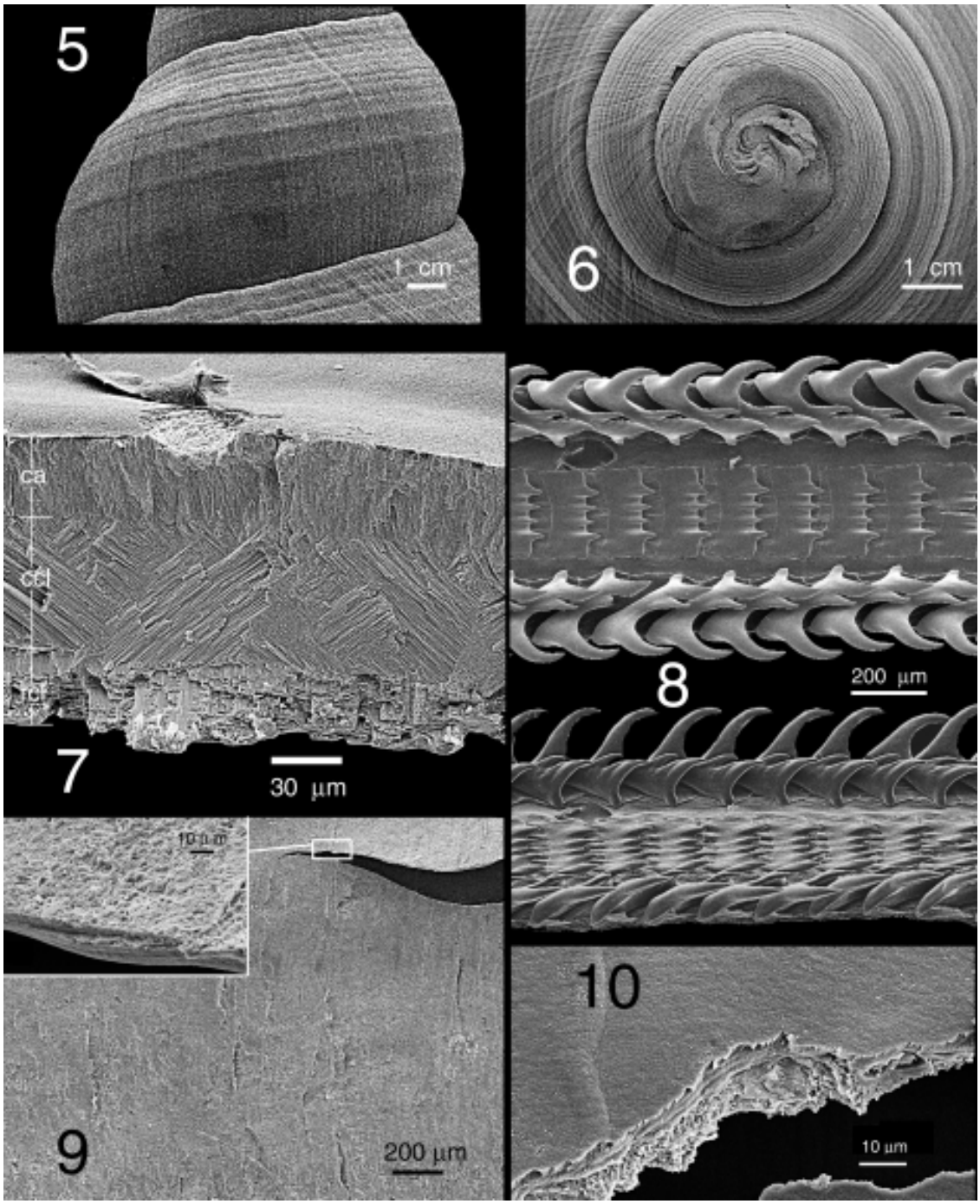
Type material: Holotype ♀ (Length = 32.9 mm), USNM 894801, Paratypes 1–25, USNM 905358; Paratypes 26–27, BM(NH) 20010204; Paratypes 28–29, CMN; Paratypes 30–31, CMNML 093360; LACM 2893; Paratypes 32–33, MNHN; Paratypes 34–35, ROM IZ M10427; Paratypes 36–37, ZISP 59678/1; Paratypes



Figures 1–4. *Buccinum thermophilum* n. sp. 'Smoke and Mirrors' Site, Endeavour Segment, Juan de Fuca Ridge. 47°56.89′N, 129°05.91′W, in 2194 m. **1.** Apertural, right lateral, and dorsal views of holotype (♀) (USNM 894801), and **2.** Outer and inner surfaces of the operculum of the holotype. **3.** Apertural and dorsal views of Paratype 1 (♀) (USNM 905358). The periostracum has been removed by soaking in bleach in order to expose details of shell sculpture. **4.** *Buccinum viridum* Dall, 1890. Apertural, right lateral, and dorsal views of holotype (USNM 96557), Off Santa Barbara Island, California. 33°08′N, 118°40′W, trawled in 757 m, on gray sand (5.2°C). Scale bar = 1 cm for figures 1 and 3, 7.5 mm for figure 4, 5 mm for figure 2.

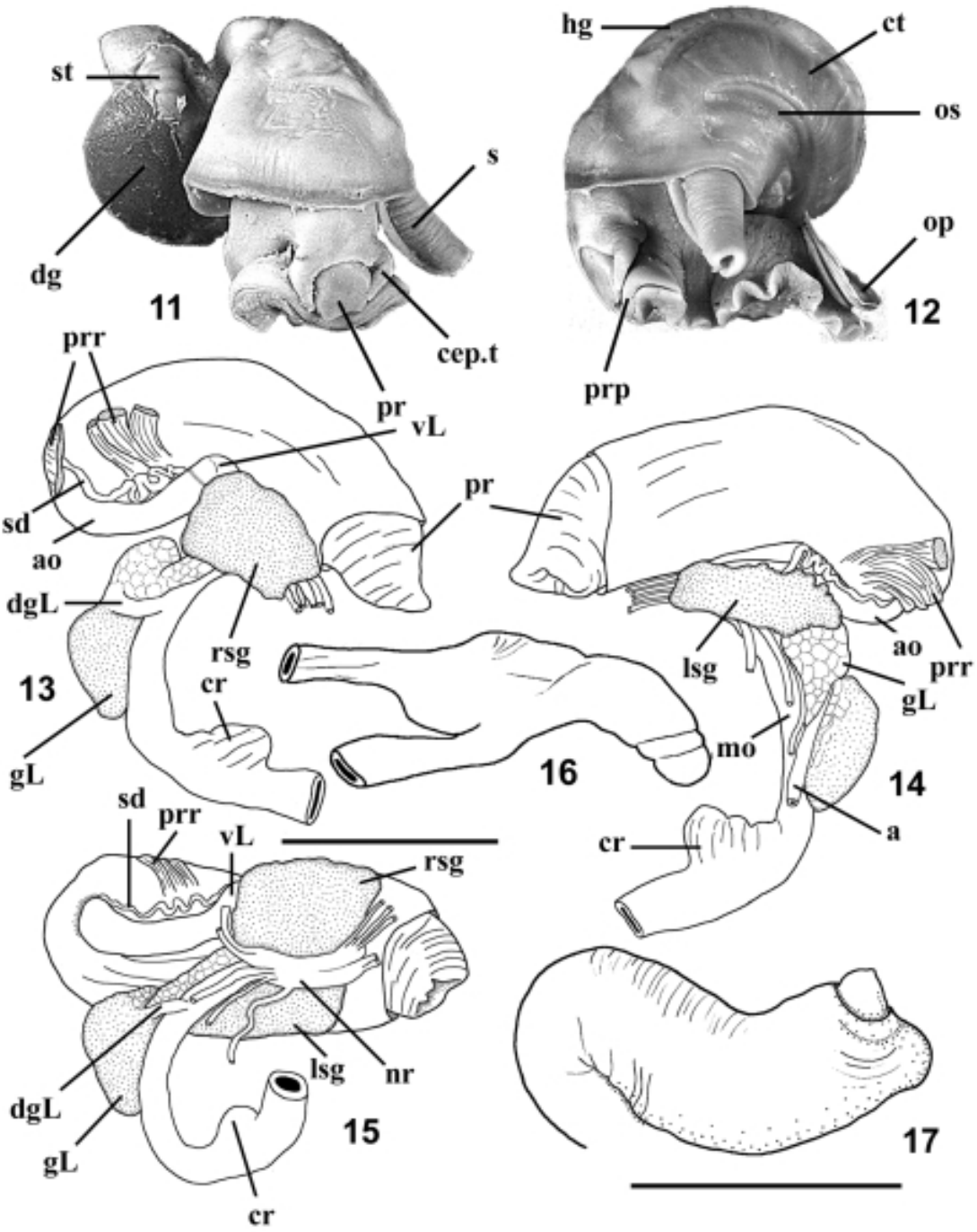
38–39, ZMMU Lc25329; all from the type locality, collected 22 August 1996 [University of Victoria coll. No. R359–365]. Paratypes 40–52, USNM 905359, from the type locality, collected 15 July 1995 [University of Victoria coll. No. R314–366].

Additional material examined: 15 specimens, USNM 905360, 'Easter Island' site, main field, Endeavour Segment, Juan de Fuca Ridge. 47°56.90′N, 129°05.93′W, in 2192 m, 11 July 1995 [University of Victoria coll. No. R309–367]; 4 specimens, USNM 905361, Endeavour Segment, Juan de Fuca Ridge. 47°57′N, 129°05′W, in 2192 m, 2 September 1984 [University of Victoria coll. No. A1446–3–356]; 3 shells, USNM 894802, Endeavour Segment, Juan de Fuca Ridge, September 1988 (J2F, A. Reysenbach coll.)[University of Victoria coll. No. A368]; Egg capsules, USNM 905362, main field, Endeavour Segment, Juan de Fuca Ridge. 47°57.1′N, 129°05.7′W, in 2225 m, 11 July 1991 [University of Victoria coll. No. A2404–8211].



Figures 5–9. *Buccinum thermophilum* n. sp. 'Smoke and Mirrors' Site, Endeavour Segment, Juan de Fuca Ridge. 47°56.89′N, 129°05.91′W, in 2194 m. **Figs. 5–7, 9, 10.** Paratype 3 (♂) (USNM 905358). **5.** Detail of surface sculpture on penultimate whorl (periostracum removed). **6.** Apical view of eroded early whorls. **7.** Shell ultrastructure, fracture surface parallel to and whorl behind the growing edge of the outer lip. **8.** Dorsal (above) and left lateral (below) views of the radula of the holotype. **9.** Outer surface of periostracum. Inset shows fine detail. **10.** Inner surface of periostracum.

Abbreviations: **ca**, calcitic, columnar crystals; **ccl**, collabrally oriented, crossed-lamellar aragonitic crystals; **rcl**, radial, crossed-lamellar aragonitic crystals.



Figures 11–17. *Buccinum thermophilum* n. sp. Anatomical features. **11.** Dorsal and **12.** Left lateral views of the animal of the holotype (♀). **13**. Right lateral, **14.** left lateral, and **15.** Ventral views of anterior alimentary system of paratype 37. **16.** Stomach of Paratype 3, outer view. **17.** Penis of Paratype 3. Scale bars = 0.5 mm for figs. 13–16, 1 cm for fig 17.

Abbreviations: **a**, anterior aorta; **ao**, anterior oesophagus; **cep.t**, cephalic tentacles; **cr**, crop of posterior oesophagus; **ct**, ctenidium; **dg**, digestive gland; **dgL**, duct of gland of Leiblein; **gL**, gland of Leiblein; **hg**, hypobranchial gland; **lsg**, left salivary gland; **mo**, mid-oesophagus; **nr**, nerve ring; **op**, operculum; **os**, osphradium; **pr**, proboscis; **prp**, propodium; **prr,** proboscis retractors; **rsg**, right salivary gland; **s**, siphon; **sd**, salivary duct; **st,** stomach; **vL**, valve of Leiblein.

DISCUSSION

This species can readily be assigned to the genus *Buccinum* on the basis of the morphology of its shell and operculum. The morphology of its radula is entirely consistent with that of other species of *Buccinum*, including its type species, *B. undatum* Linné, 1758 (see Friele, 1879; Golikov, 1980). It gross anatomy also agrees in all respects with that of the few species of *Buccinum* that have been studied to date (e.g. Dakin, 1912; Golikov, 1980; Medinskaya, 1993). It is precluded from the closely related genus *Bathybuccinum* because it lacks a triangular operculum with terminal nucleus or an osphradium that is roughly as large as the ctenidium (Kantor & Harasewych, 1998).

An interesting character of the foregut anatomy, found in *B. thermophilum*, and which seems to be an apomorphy within

Buccininae (since it is found in *Buccinum* and *Bathybuccinum*), is the presence of a muscular crop on the posterior oesophagus at the rear of the cephalic haemocoel. The function of this structure remains obscure.

Of the species included in *Viridibuccinum*, *B. shiritokoensis* Habe & Ito, 1957, *B. takagawai* Habe & Ito, 1972, *B. striatellum* Golikov, 1980, *B. osagawai* Habe & Ito, 1965, *B. fukureum* Habe & Ito, 1976, and *B. kinukatsugai* Habe & Ito, 1968, are large, thick-shelled species that inhabit upper bathyal depths (65–500 m) and are restricted to the Okhotsk Sea and adjacent areas. *Buccinum elatior* (Middendorff, 1849) is more widely distributed, occurring in the Okhotsk Sea, Bering Sea, and circum-Arctic Seas, in depths as great as 1267 m, but mostly in less than 300 m. While most records of *B. rossicum* Dall, 1907, are from the northwestern Pacific in depths more shallow than 400 m, a variety named *B. rossicum tsubai* Kuroda & Kikuchi, 1933 is known from the Bering Sea along the Central Aleutians, at depths up to 1000 m. Only *B. aleuticum* Dall, 1895, *B. rondinum* Dall, 1919, and *B. viridum* Dall, 1890, occur along the Pacific coast of North America, and only *B. viridum* is confined to depths greater than 700 m.

Among the species assigned to *Viridibuccinum*, *B. thermophilum* most resembles *B. viridum,* and *B. rondinum*. From *B. viridum*, *B. thermophilum* differs in having a smaller, narrower, more highly spired shell with a proportionally smaller and more ovate aperture. *Buccinum viridum* (Figure 4) has a strong spiral cord along the shoulder that separates a region with very fine spiral threads (between suture and spiral cord) from a region of extremely uniform, closely spaced cords (anterior to major cord). In contrast, *B. thermophilum* lacks this demarcating spiral cord, or a distinct shoulder. Its spiral sculpture consists of cords that vary markedly in prominence and spacing. The radula of *B. thermophilum* has a four-cusped rachidian, while that of *B. viridum* has a five-cusped rachidian (Golikov, 1980:279). It should be noted, however, that the number of cusps on the rachidian has been found to vary considerably (within a certain range) in every species of *Buccinum* for which larger numbers of specimens were available (Friele, 1879; Lebour, 1906). Warén and Bouchet (2001: 190) report the occurence of *Buccinum* sp. at nearby vent fields of the Endeavour Segment, and speculate that this may be conspecific with *Buccinum viridum*. They note that, like *B. viridum*, the specimens they examined have unpigmented eyes, which they report as 'rare for the genus.' In his description of *B. viridum*, Dall (1890: 320) noted that the eyes of this species are 'usually unpigmented, though a trace of the color seems to remain in some specimens,' indicating eye pigmentation may be a variable character in deep sea buccinids. As Warén and Bouchet (2001) neither described nor illustrated their material, detailed comparisons with *B. thermophilum* are not possible.

Buccinum rondinum more closely resembles *B. thermophilum* in general shape and proportions, as well as in lacking a spiral cord or discernible shoulder, but is a smaller species that may readily be distinguished by on the basis of its densely spaced and uniform spiral sculpture, and its more rounded anterior edge of the shell. Radular and penis morphology are similar to that of *B. thermophilum* (Golikov, 1980: 280, fig. 173), but *B. rondinum* has a minutely hirsute periostracum, while that of *B. thermophilum* is finely lamellar.

Buccinum (Japonibuccinum) diplodetum Dall, 1907, has an overlapping geographic and bathymetric distribution with *B. thermophilum*. While *B. diplodetum* resembles *B. thermophilum* in terms of shell shape and size, its two pronounced spiral bands, one at the shoulder, the other just above the suture, not only distinguish it from *B. thermophilum*, but also serve as the basis for its inclusion in the subgenus *Japonibuccinum* (Golikov & Sirenko, 1988). The rachidian teeth of *B. diplodetum* may have either three (Golikov, 1980: fig. 132) or four (Golikov, 1980: 335) cusps. Unlike *B. thermophilum*, the cephalic tentacles of *B. diplodetum* lack basal lobes and eyes, while its penis lacks a terminal papilla (Golikov, 1980: 335).

ACKNOWLEDGMENTS

We are grateful to Prof. Verena Tunnicliffe for making the material available for study, and for identifying polychaete spicules that were found in the rectum of Paratype 2. Thanks are due to Susann Braden for assistance with the Scanning Electron Microscopy. We acknowledge Drs. Boris Sirenko and Alexander Golikov for insightful discussions of *Buccinum* systematics.

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