A new genus and species of Cataegidae (Gastropoda: Seguenzioidea) from eastern Pacific Ocean methane seeps

Anders WARÉN
Swedish Museum of Natural History
Box 50007
SE-10405 Stockholm
Sweden
anders.waren@nrm.se

Greg W. ROUSE
Scripps Institution of Oceanography
University of California, San Diego
La Jolla, CA, 92093
USA
grouse@ucsd.edu

KEYWORDS. Seguenzioidea, Cataegidae, methane seep, Costa Rica, new genus, new species, deep-sea

ABSTRACT. A new genus, *Kanoia*, n. gen., is erected for an unnamed seguenzioid gastropod species, now known from several methane seeps off California, in Gulf of California and off Costa Rica, and named *Kanoia myronfeinbergi* n. sp. It differs from *K. meroglypta* (n. comb.) a Caribbean species, mainly in having fewer spiral ridges on the shell, a lower spire and more distinct crenulation on the apical spiral cords.

INTRODUCTION

During the last few decades there has been an explosive development in two fields which are of concern for this paper. One is the interest in the fauna in various kinds of springs in the deep-sea with water containing energy-rich compounds (hydrothermal vents and methane seeps) and "food-falls" of all kinds, from whales to squid jaws and *Casuarina* cones. Sasaki et al. (2010) reviewed the gastropods in hot vents and cold seeps; the food-fall gastropod information is more dispersed, but Marshall (1986, 1988) and Warén (2011) give some introduction to the gastropods associated with food-falls. The second field is the application of molecular methods to gastropod, especially vetigastropod classification, which as a consequence has changed drastically. Information on this can be found in Aktipis & Giribet (2012), Bouchet et al (2005), Kano (2008), Kano et al. (2009) and Williams (2012). Of special interest for this paper is that a large number of genera now are considered to belong to Seguenzioidea, not only among the skeneimorph species, but also among more normal-looking "trochoids".

MATERIAL and METHODS

The specimens used for this paper have been collected in connection with different projects for the exploration of deep-sea methane cold seeps off the Central and North American west coasts, with the aid of manned submersibles or remotely controlled vehicles (ROVs). All specimens used for this paper are listed in Table 1. Some material used for comparison has been collected during the last decades of French exploration of the bathyal fauna in the South Pacific, led by Bertrand Richer de Forges (then at IRD, New Caledonia) and Philippe Bouchet (MNHN) (Bouchet et al. 2008). The origin of each sample is mentioned in the list of specimens. The specimens were fixed in formalin and transferred to 80% ethanol or directly preserved in 95% ethanol for genetic work. Radular preparations and critical point drying were performed as outlined by Geiger et al. (2007). The specimens are deposited in SMNH, MNHN, MNCR and SIO.

Abbreviations

IRD: Institut de recherche pour le developpement, Noumea, New Caledonia
MNCR: Museo Nacional de Costa Rica, San Jose
MNHN: Muséum national d'Histoire naturelle, Paris
ROV: remotely operated vehicle
SIO-BIC: Scripps Institution of Oceanography, Benthic Invertebrate Collection, La Jolla, CA
SMNH: Swedish Museum of Natural History, Stockholm

SYSTEMATICS

Family **CATAEGIDAE** McLean & Quinn, 1987

Remarks. This little known family was introduced as Cataeginae, a subfamily of Trochidae, by McLean & Quinn (1987). Hickman & McLean (1990) recognized the affinities of Chilidontini and Calliotropini to Cataeginae but all were at that time considered trochids. Bouchet et al. (2005) classified the Cataeginae in Chilodontidae (Seguenzioidea). Kano (2008), Kano et. al (2009) and Aktipis & Giribet (2012) supported a position within the Seguenzioidea on molecular evidence, Kano et al. (2009) as a family and one of the six main groups of the Seguenzioidea. When introduced, the subfamily Cataeginae consisted of one genus with three species:
-*Cataegis toreuta* McLean & Quinn, 1987 (September) = *Homalopoma finkli* Petuch, 1987 (April) off Pensacola, FL to Colombia, 337 – 1283 m depth. On sunken turtle grass.
- *Cataegis celebesensis* McLean & Quinn, 1987, Celebes, Makassar Strait, 1080 m.
- *Cataegis meroglypta* McLean & Quinn, 1987, south of Mississppi River delta, Louisiana, and off Colombia, 421-858 m depth; recorded from seeps by Warén & Bouchet (1993, 2001).
A fourth species, *C. leucogranulatus* (Fu & Sun, 2006) (South China Sea), was described as *Hybochelus leucogranulatus* in Trochidae and transferred to *Cataegis* by Warén (2011), who found it regularly on sunken drift-wood. It differs from *C. celebesensis* by having more distinct spines on the spiral ribs.
Warén & Bouchet (1993) described the radula of *C. meroglypta*, which was found to differ profoundly from the type species, *Cataegis toreuta,* and suggested that that could be a result of a life in a seep environment and presumably a different diet compared to *C. toreuta* which had been found to feed on dead and sunken turtle grass (*Thalassia testudinum*). The finding of a second species on the western side of the isthmus, living in seep environments, morphologically similar to *C. meroglyta* and with the same radular morphology, motivates a separation of this group from seeps, as a new genus, *Kanoia*, n.gen.

Genus ***Kanoia*** n. gen.

Type species: *Kanoia myronfeinbergi* n. sp.

Etymology. Named after Professor Yasunori Kano, University of Tokyo, who has meant so much for our understanding of vetigastropod phylogeny during the last decade and a half.

Diagnosis. Shell large, helicoid, depressed globular with a few prominent spiral ridges. No umbilicus. Periostracum well developed, greenish brownish. Operculum corneous, multispiral with central nucleus, slightly concave, with short incremental zone. Radula n – 4 - 1 – 4 - n, long and slender with small and plesiomorphic teeth. Jaws sturdy, almost round with well-developed prismatic elements. Soft parts, see species description.

Remarks. Species of Cataegidae may resemble a *Homalopoma* (Colloniidae) or *Hybochelus* (Chilodontidae). *Homalopoma* can easily be separated by having a calcareous operculum and lacking the distinctly spiny spiral ridges of most Cataeginae. *Hybochelus* has distinct axial riblets between the spiral cords and lives in shallow water.
It seems that no specimen of *Kanoia* has been found as fossil from the West American Cenozoic seep sediments that have been pretty well explored by Kiel and co-workers (Kiel 2010; Kiel & Little 2006), in spite of being a large and conspicuous shell.

Kanoia myronfeinbergi n. sp.
Figs 1C-E, G, 2B-K

Type material. Holotype (Figure 1C-E, G) in SIO-BIC M14400 (ex SMNH 109257); 3 specimens MNCR (numbers not available) (ex SMNH 108742); 5 specimens SMNH type collection #8824, 8825 (from SMNH 109261 & 109257, see table 1).

Type locality. Off Costa Rica, off Puntarenas, Methane seep Mound 12 methane seep, 08°55.84'N, 084°18.74'W, 1000-1018 m depth, Alvin dive # 4587, on a wooden test panel, deployed for colonization experiments.

Distribution. Known living from hydrocarbon seeps at the American west coast in 745 to 1800 m depth, from San Diego CA, to Costa Rica.

Material examined. See Table 1.

Etymology. Named in honor of Myron Feinberg (1918 - 2009, Cleveland, Ohio, U.S.A.) in recognition of the support by Joyce Feinberg and David K. Foot for the SIO-BIC.

Diagnosis and Description. Shell (Figure 1 C-E, G) large, helicoid, depressed globular with a few prominent spiral ridges. No umbilicus. Protoconch (Figure 2C) with ¾ of a whorl, diameter ca 280 µm, with an almost smooth surface and an unusually loosely or openly coiled initial part. Teleconch whorls, ca 4.5 in number, slightly convex; initial 1.5 whorl (Figure 2 B), micro-sculptured with short spiral and tangential riblets (similar to many species in most vetigastropod families) on a more or less smooth background. After 1.0 whorl also smooth axial riblets appear, at the same time as the irregular microsculpture becomes less distinct. After ca 1.5 whorls the micro sculpture is completely replaced by

fine and regular incremental wrinkles and a single strong spiral keel appears which becomes the peripheral keel in adult specimens. The two apical keels start later as a series of knobs. Adult specimens have one additional sutural keel and six to eight additional spirals on the quite flat basal area. Umbilical chink small and narrow, mostly concealed by the nacreous parietal glaze. Peristome strongly indented by the interspace between the spiral ribs. Periostracum greenish, often damaged, usually resulting in strong damage of the underlying strongly nacreous layer. Maximum diameter ca 16 mm (25 mm, smoother form).

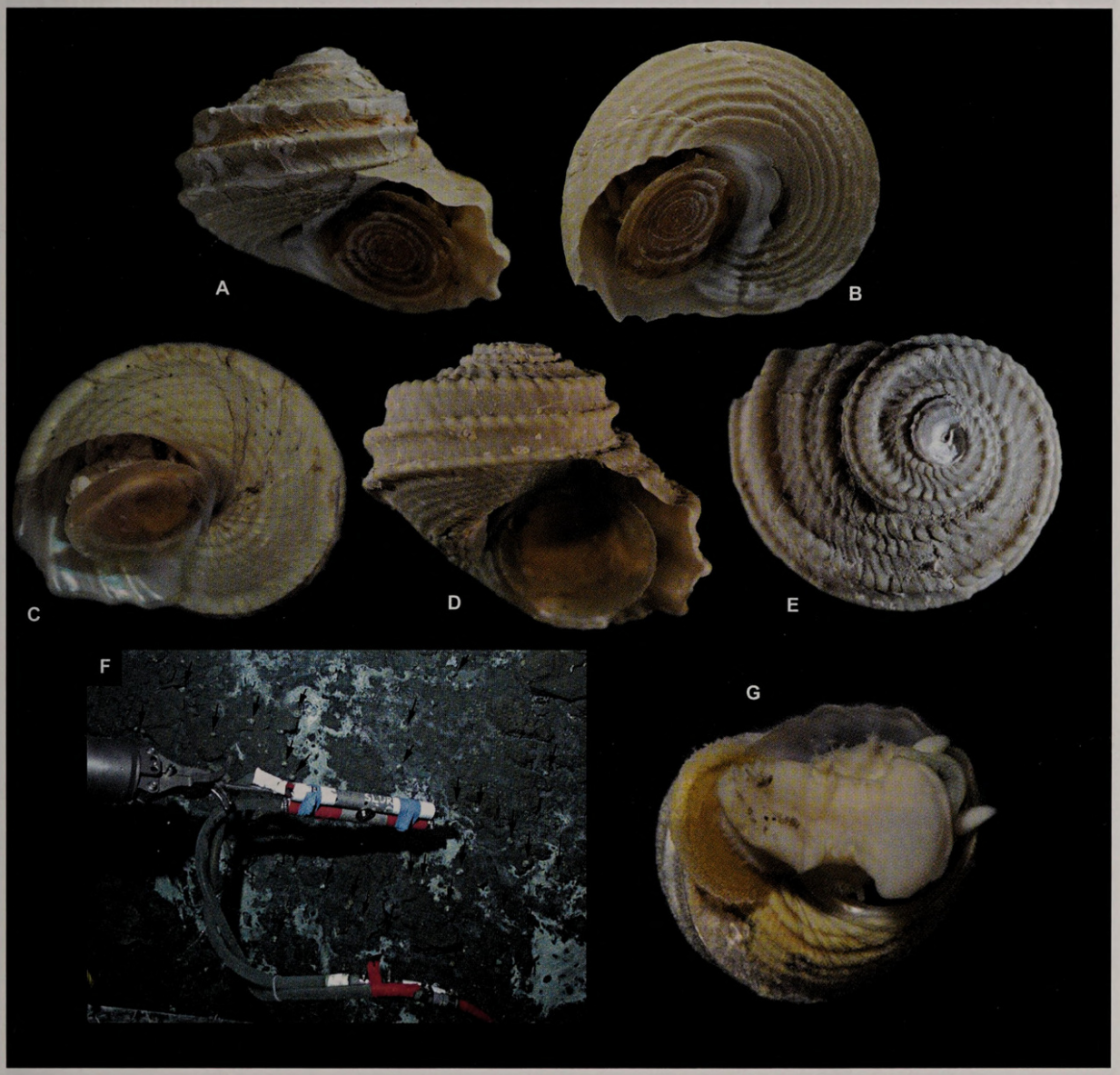


Figure 1

A-G. *Kanoia myronfeinbergi* n. sp.
A-B. *Kanoia* aff. *myronfeinbergi*, large, smooth specimen, Ø 22 mm, SMNH 108680; **C-E.** *K. myronfeinbergi* n. sp., holotype, diameter 15.5 mm. SIO-BIC M14400.
F. Numerous specimens of *K. myronfeinbergi* on a calcareous rock at the type locality methane seep (Mound 12) off Costa Rica. The surface is being suction sampled by the submersible *Alvin*; **G.** *K. myronfeinbergi* n. sp., SIO-BIC M13152, diameter ≈ 15 mm.

Operculum (Figure 2D), round, multispiral, brownish transparent, fragile, with central nucleus, almost filling the peristome.
Radula (Figures 2E-F), ∞ – 4 – 1 – 4 – ∞, 6 times as long as wide, 5 mm long in a normal adult specimen. Rachidian and three lateral teeth of similar shape and size, with interlocking bases and elongate, almost smooth apical cusp, fourth lateral tooth with distinctly oblique, laterally serrated apical cusp. Marginal teeth

thin, inner ones apically hand-like with lateral rake-like denticles; more laterally they are taller and form a transition to the very thin, oar-like outermost ones.
Jaw, sturdily built with prismatic elements.
Soft parts (Figures 1G, 2G-K) light beige to light blueish depending on illumination, more or less unpigmented; unpigmented pit eyes present in eye-lobe. Live animal slow and sluggish. Cephalic and epipodial tentacles covered by sensory papillae. Head large with well-defined oral disc, a pair of slowly tapering cephalic tentacles and almost smooth eye-lobe; cephalic lappets missing. Foot large and flat with well-developed propodium and smooth, demarcated margin. Epipodial membrane conspicuous; each side with at least a dozen epipodial tentacles, each with a dorsal-basal epipodial sense organ. Anterior left part of fold expanded and flattened, more densely set with epipodial tentacles. Anterior right part of fold almost hand-like with half a dozen epipodial tentacles, starting with a smooth tentacle of size comparable to the epipodial ones; function unknown. Pallial margin smooth, only wrinkled by contraction. Gill of normal size, bipectinate with sensory bursicles.

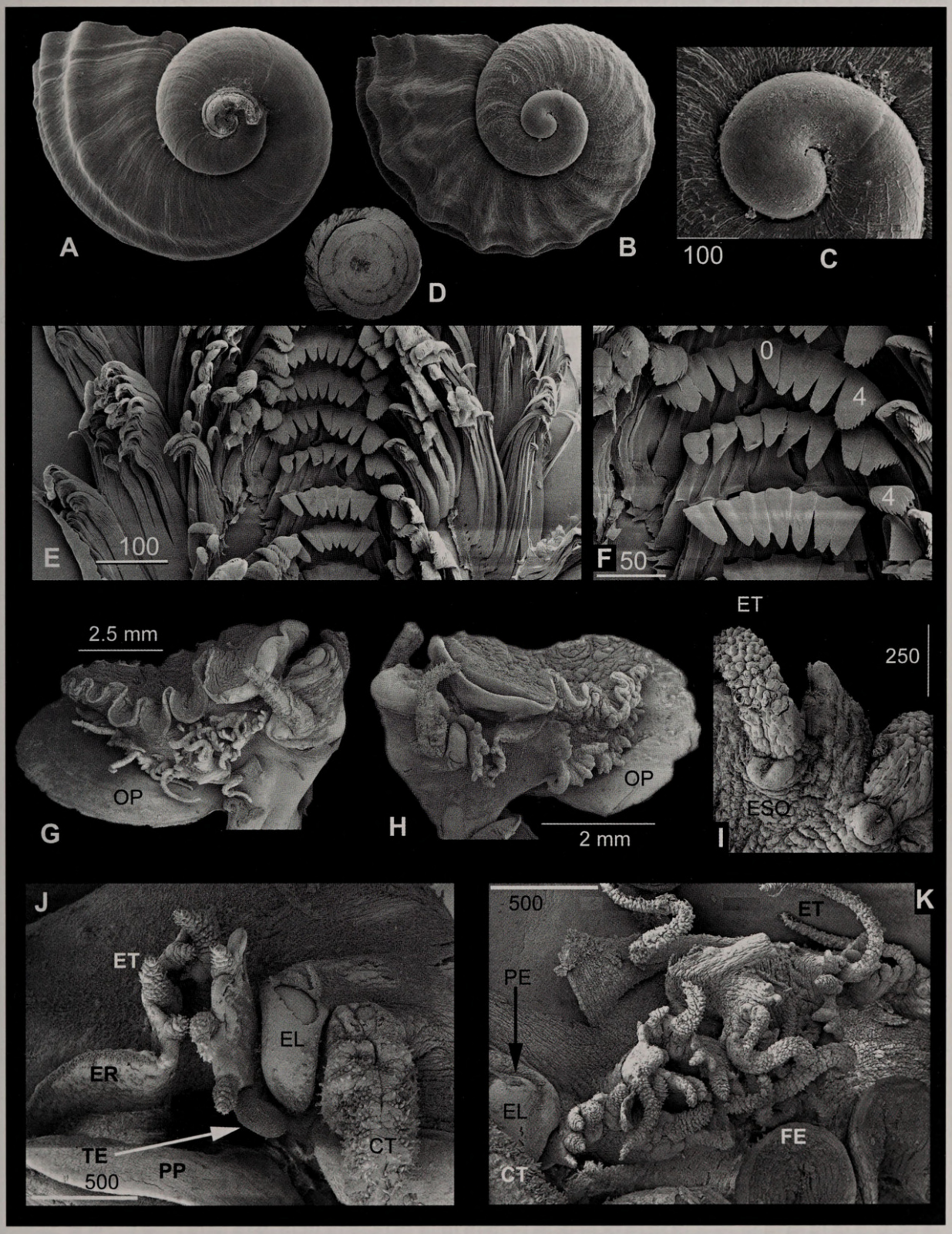
Remarks. The specimens were found on rocks, shell debris and wood, both natural sediments and test samples at sites with active hydrocarbon seeps. Direct observation showed that the species is capable of crawling on almost fluid mud also (SMNH 108680). The Costa Rica environment was described by Levin et al. (2015), that of the Del Mar seep (California, USA) in Grupe et al. (2015) and the Guaymas Basin (Mexico) sites in Portail et al. (2015) Some specimens have numerous specimens of *Eufolliculina* sp. (a heterotrich ciliate) attached to the shell (Pasulka et al. in review), a good indication of water rich in bacteria (Kouris et al. 2007).
It is possible that two species are involved. One (Figure 1A-B) with less distinct sculpture, more similar to *Kanoia meroglypta* from the Caribbean side and one with more pronounced and spiny spiral cords, but our material was insufficient for a detailed approach, due to the usually bad corrosion of apical whorls in specimens larger than a few mm. The name is based on the spiny type (Figure 1C-E). We found a single very young, almost smooth specimen (Figure 2A) which may be a young one of a second possible species, but that's uncertain.
This possibility is also supported by the molecular analysis of specimens in Rouse et al. (in prep.), though the molecular distance based on cytochrome oxidase subunit I is only ~4% and we consider further assessment to be needed.
The protoconch is large, Ø ≈280 µm, and supports the normal lecithotrophic development of vetigastropods, usually with a planktonic dispersal phase. Its morphology is unusual, with a very small initial part and "loose" coiling. It seems not to be caused by dissolution of the initial shell of the larva, since the larval peristome is quite sharp and well defined.
The gut contains sediment with many tests and fragments of radiolariae and scattered nematodes. The snail is evidently ingesting bacterial film and sediment deposited on the hard surfaces where it is usually found. We did not have material enough well preserved to check for sexual differences and look for a copulatory organ as described by Kano (2008).

ACKNOWLEDGEMENTS

We thank the science parties, captains and crew members of the R/V *Atlantis*, and R/V *Western Flyer* as well as the pilots of *Alvin* and *Doc Ricketts*. We thank R. Vrijenhoek (MBARI) for inviting GWR to Guaymas, and to the Del Mar Seep. AW thanks H. Sahling (Marum) for specimens from R/V *Sonne* cruises 143 and 148 (1999); K. Olu (IFREMER) and E. Escobar (UNAM) and her students are thanked for specimens, records and pictures of specimens from the BIG cruise (IFREMER) in the Gulf of California in 2010. AW also thanks P. Bouchet (MNHN) for opportunities to study the gastropods on food-falls, during many cruises in the south Pacific. Support for this research was provided by grants OCE 0826254 and OCE 0939557 from the US National Science Foundation (NSF). Work aboard the R/V *Western Flyer* was partially supported by the David and Lucile Packard Foundation's funding of MBARI. We also thank Joyce Feinberg and David K. Foot for financial support to the Benthic Invertebrate collection at SIO.

Figure 2

A. *Kanoia* aff. *myronfeinbergi*, young specimen, SMNH 110565, diameter 1.7 mm.
B-K. *Kanoia myronfeinbergi* n. sp. Scale lines in µm unless indicated.
B-C. Young specimen and larval shell, SMNH 110565, diameter 1.7 mm and 0.28 mm; **D.** Operculum, SMNH 82450, Ø5.3 mm; **E-F.** Radula. Scale lines 100 and 50 µm. numbers indicate the order of the lateral teeth; rachidian counted as "0". SMNH 82021; **G-H.** Head-foot, left and right side SMNH 108356; I. Epipodial tentacle and sense organ, SMNH 108356; **J.** Detail of left side of neck with cephalic tentacle, eye lobe and anterios part of epipodium, SMNH 108356; **K.** Detail of right side of neck with cephalic tentacle, eye-lobe, and epipodium, SMNH 108356: CT – cephalic tentacle, EL – eye-lobe, ESO – epipodial sense organ, ET – epipodial tentacle, F – foot, FE – edge of foot, OP – operculum, PE – pit eye (unpigmented), PP – propodium, TE – epipodial appendage of unknown function.


A
B
C
100
D
E
100
F
0
4
4
50
2.5 mm
OP
G
OP
H
2 mm
ET
250
ESO
I
J
ET
EL
ER
TE
PP
CT
500
500
ET
K
PE
EL
FE
CT

REFERENCES

Abbott, R. T. 1987. [Review of] New Caribbean Mollusca Faunas by Edward J. Petuch, 1987. *American Conchologist* 15(4): 19.

Aktipis, S.W., & Giribet, G. 2012. Testing relationships among the vetigastropod taxa: a molecular approach. *Journal of Molluscan Studies* 78: 12–27.

Bouchet, P., Rocroi, J.-P., Fryda, J., Hausdorf, B., Ponder, W.F., Valdes, A. & Warén, A. 2005. Classification and nomenclator of Gastropod families. Malacologia 47: 1-397.

Bouchet, P., Héros, V., Lozouet, P. & Maestrati, P. 2008. A quater-century of deep-sea malacological exploration in the South and West Pacific: Where do we stand? How far to go? in Héros, V., Cowie, R.H. & Bouchet, P. (eds), *Tropical Deep-Sea Benthos* 25. *Mémoires du Muséum national d'Histoire naturelle* 196: 9-40. Paris ISBN: 978-2-85653-614-8.

Fu, I-F. & Sun, C.-L. 2006. A new bathyal trochid from South China Sea. *Bulletin of Malacology, Taiwan*, 30: 17-20 (*Hybochelus leucogranulatus*).

Geiger, F.L., Marshall, B.A., Ponder, W.F., Sasaki, T. & Warén, A. 2007. Techniques for collecting, handling, preparing, storing and examining small molluscan specimens. *Molluscan Research* 27: 1-50.

Grupe, B.M., Krach, M.L., Pasulka, A.L., Maloney, J.M., Levin, L.A., Frieder, C.A.. 2015. Methane seep ecosystem functions and services from a recently discovered southern California seep. *Marine Ecology*. 36(S1):91-108.

Hickman, C.S. & McLean, J.H. 1990. Systematic revision and suprageneric classification of trochacean gastropods. *Natural History Museum Los Angeles County Science Series* 35: 1-169.

Kano, Y., 2008. Vetigastropod phylogeny and a new concept of Seguenzioidea: Independent evolution of copulatory organs in the deep-sea habitats. *Zoologica Scripta* 37, 1-21.

Kano, Y., Chikiu, Y. & Warén, A. 2009. Morphological, ecological and molecular characterization of the enigmatic planispiral snail *Adeuomphalus* (Vetigastropoda: Seguenzioidea). *Journal of Molluscan Studies* 75: 397-418. (doi:10.1093/mollus/eyp037)

Kiel, S. 2010. *The fossil record of vent and seep mollusks.* In: Kiel, S., (Ed.), The Vent and Seep Biota. Springer Science + Business Media B.V., Heidelberg, pp. 255-277.

Kiel, S. & Little, C.T.S. 2006. Cold seep molluscs are older than the general marine fauna. *Science* 313: 1429-1431 (incl. Supporting Online Material). (doi: 10.1126/science.1126286)

Kouris, A., Juniper, K.S., Frébourg, G. & Gaill, F. 2007. Protozoan–bacterial symbiosis in a deep-sea hydrothermal vent folliculinid ciliate (*Folliculinopsis* sp.) from the Juan de Fuca Ridge. *Marine Ecology* 28: 63-71. (doi:10.1111/j.1439-0485.2006.00118.x)

Levin, L.A., Mendoza, G.F., Grupe, B.M., Gonzalez, J.F., Jellison, B., Rouse, G.W., Thurber, A.R. & Warén, A. 2015. Biodiversity on the Rocks: Macrofauna Inhabiting Authigenic Carbonate at Costa Rica Methane Seeps. *PLoS one* 10(7): e0131080. (doi:10.1371/journal. pone.0131080)

Marshall B.A. 1986. Recent and Tertiary Cocculinidae and Pseudococculinidae (Mollusca: Gastropoda) from New Zealand and New South Wales. *New Zealand Journal of Zoology* 12: 505-546.

Marshall, B.A., 1988. Skeneidae, Vitrinellidae, and Orbitestellidae (Mollusca: Gastropoda) associated with biogenic substrata from bathyal depths off New Zealand and New South Wales. *Journal of Natural History* 22, 949-1004.

McLean, J.H, & Quinn, J.F. 1987. *Cataegis*, new genus of three new species from the continental slope (Trochidae: Cataeginae new subfamily). *The Nautilus* 101: 111-116 (September).

Petuch, E. 1987. *New Caribbean molluscan faunas.* The Coastal Education & Research Foundation (CERF), Virginia. 154 pp. (published April 1987 when it was sent out with the "Journal of Coastal Research" according to E. Petuch, pers. comm.) (see also Abbott 1987.)

Portail, M., Olu, K., Escobar-Briones, E., Caprais, J.C., Menot, L., Waeles, M., Cruaud, P., Sarradin, , P.M., Godfroy, A. and J. Sarrazin 2015. Comparative study of vent and seep macrofaunal communities in the Guaymas Basin. *Biogeosciences*. 12(18):5455-79. (doi:10.5194/bg-12-5455-2015)

Sasaki, T, Warén, A., Kano, Y., Okutani, T., Fujikura, K. 2010. Gastropods from Recent hot vents and cold seeps: Systematics, Diversity and life Strategies. Topics in Geobiology 33: 170-254. (doi 10.1007/978-90-481-9572-5_7)

Warén, A. & Bouchet, P. 1993. New, records, species, genera, and a new family of gastropods from hydrothermal vents and hydrocarbon seeps. *Zoologica Scripta* 22:1-90.

Warén, A. & Bouchet, P. 2001. Gastropoda and Monoplacophora from hydrothermal vents and seeps; new taxa and records. *Veliger* 44: 116-231

Warén, A. 2011. Molluscs on biogenic substrates. pp 438-448 in: Bouchet, P., Le Guyader, H. & Pascal, O. Eds. *The natural history of Santo*. MNHN, Paris; IRD, Marseille, PNI, Paris, 572 pp.

Williams, S.T. 2012. Advances in molecular systematics of the vetigastropod superfamily Trochoidea. *Zoologica Scripta* 41: 571-595.

Table 1. Material examined of Cataegidae
More detailed information on substrate available for each register number on request to AW.
Register numbers SMNH unless stated; corr – corroded specimen, not safely identified to species; mf – *myronfeinbergi*;

Register number	species	n	Collecting effort	Latitude N (S)	Longitude W (E)	depth in m	Locality	
21178	*meroglypta*	35	SEALINK#3129	27° 46.91'	091° 30.34'	546	Gulf of Mexico, off Louisiana	80%
45408	*leucogranulatus*	1	Salomon#CP 1805	S 09° 35.0'	E 160° 47.2'	367-500	Solomon Islands, off southeastern Cristobal	95%
82021	mf	5 (7)	SONNE163TVG9	09° 01.96'	084° 37.2'	1408	Off Puntarenas	80%
82032	mf	2	SONNE163TVG5	08° 55.8'	084° 18.7'	1002	Off Puntarenas	dry
82036	mf	1	SONNE163TVG5	08° 55.8'	084° 18.7'	1002	Off Puntarenas	dry
82446	mf	1	SONNE#ROV 64	11° 12.2'	087 09.2'	1228	Off Nicaragua, Iguana Mound Site	80%
82449	corr	2	SONNE#ROV 74	09° 07.15'	084° 50.6'	1804	Off Puntarenas, Jaco Scarp	80%
82450	corr + mf	5	SONNE#ROV 78	08° 59.58'	084° 43.70'	1917	Off Puntarenas, "Mudpie Site"	95%
94092	*meroglypta*	15	Alvin#dive 4178	28° 07.64'	089° 08.47'	1075	Off Mississippi, Mississippi Canyon	80%
108342	mf	1	Alvin#dive 4586	08° 55.85'	084° 18.79'	1000	Off Puntarenas, Methane seep Mound 12	80%
108347	mf	4	Alvin#dive 4586	08° 55.85'	084° 18.79'	1000	Off Puntarenas, Methane seep Mound 12	80%
108356	mf	4	Alvin#dive 4586	08° 55.85'	084° 18.79'	1000	Off Puntarenas, Methane seep Mound 12	80%
108358	mf	1	Alvin#dive 4586	08° 55.85'	084° 18.79'	1000	Off Puntarenas, Methane seep Mound 12	80%
108441	mf	1	Alvin#dive 4589	08° 55.79'	084° 18.72'	998-1018	Off Puntarenas, Methane seep Mound 12	95%
108482	corr	1	Alvin#dive 4511	08° 55.83'	084° 18.74'	1001	Off Puntarenas, Methane seep, Mound 12	80%
108498	mf	1	Alvin#dive 4591	09° 07.09'	084° 50.35'	1800-1802	Off Puntarenas, Jaco Scarp, Methane seep	95%
108504	corr	3	Alvin#dive 4591	09° 07.09'	084° 50.35'	1800-1802	Off Puntarenas, Jaco Scarp, Methane seep	95%
108515	corr	1	Alvin#dive 4591	09° 07.09'	084° 50.35'	1800-1802	Off Puntarenas, Jaco Scarp, Methane seep	dry
108525	corr	9	Alvin#dive 4591	09° 07.09'	084° 50.35'	1800-1802	Off Puntarenas, Jaco Scarp, Methane seep	95%
108604	mf	1	Alvin#dive 4590	09° 07.05'	084° 50.37'	1800	Off Puntarenas, Jaco Scarp, Methane seep	95%
108626	corr	2	Alvin#dive 4590	09° 07.05'	084° 50.37'	1800	Off Puntarenas, Jaco Scarp, Methane seep	80%
108680	corr	1	Alvin#dive 4587	08° 55.84'	084° 18.74'	1000-1018	Off Puntarenas, Methane seep Mound 12	95%
108681	corr (Figure 1A-B)	1	Alvin#dive 4587	08° 55.84'	084° 18.74'	1000-1018	Off Puntarenas, Methane seep Mound 12	80%
108692	mf	5	Alvin#dive 4587	08° 55.84'	084° 18.74'	1000-1018	Off Puntarenas, Methane seep Mound 12	95%
108716	mf	6	Alvin#dive 4588	08° 55.85'	084° 18.75'	997-1018	Off Puntarenas, Methane seep Mound 12	95%
108721	mf	1	Alvin#dive 4588	08° 55.85'	084° 18.75'	997-1018	Off Puntarenas, Methane seep Mound 12	95%
108726	mf	3	Alvin#dive 4588	08° 55.85'	084° 18.75'	997-1018	Off Puntarenas, Methane seep Mound 12	dry
108737	mf	8	Alvin#dive 4588	08° 55.85'	084° 18.75'	997-1018	Off Puntarenas, Methane seep Mound 12	80%
108742	mf, 3 specimens to MNCR as paratypes.	14	Alvin#dive 4588	08° 55.85'	084° 18.75'	997-1018	Off Puntarenas, Methane seep Mound 12	95%
109248	mf	2	Alvin#dive 4587	08° 55.84'	084° 18.74'	1000-1018	Off Puntarenas, Methane seep Mound 12	95%

Table 1 Continued

Register number	species	n	Collecting effort	Latitude N (S)	Longitude W (E)	depth in m	Locality	
109257	mf	3	Alvin#dive 4587	08° 55.84'	084° 18.74'	1000-1018	Off Puntarenas, Methane seep Mound 12	95%
109261	mf	11	Alvin#dive 4587	08° 55.84'	084° 18.74	1000-1018	Off Puntarenas, Methane seep Mound 12	95%
109272	mf	1	Alvin#dive 4587	08° 55.84'	084° 18.74'	1000-1018	Off Puntarenas, Methane seep Mound 12	95%
110565	mf	2	Alvin#dive 4588	08° 55.85'	084° 18.75'	997-1018	Off Puntarenas, Methane seep Mound 12	dry
110901	young	1	Alvin#dive 4587	08° 55.84'	084° 18.74'	1000-1018	Off Puntarenas, Methane seep Mound 12	dry
155221	corr	1	BIG#PL1762	27° 28.94	111°36.44	1550	Gulf of California, Sonora Margin	95%
SIO-BIC M14400	holotype mf, ex SMNH 109257	1	Alvin#dive 4587	08° 55.84'	084° 18.74'	1000-1018	Off Puntarenas, Methane seep Mound 12	95%
SIO-BIC M11975	mf	2	Alvin#dive 4501	08° 55.8'	084° 18.8'	1008	Off Puntarenas, Methane seep	95%
SIO-BIC M11976	mf	1	Alvin#dive 4501	08° 55.8'	084 °18.8'	1008	Off Puntarenas, Methane seep	95%
SIO-BIC M12052	mf	1	Alvin#dive 4510	09° 58.3'	084 °47.9'	745	Off Puntarenas, Methane seep	95%
SIO-BIC M12053	mf	1	Alvin#dive 4510	09° 58.3'	084° 47.9'	745	Off Puntarenas, Methane seep	95%
SIO-BIC M14303	mf	1	Alvin#dive 4590	09° 07.1'	084° 50.4'	1800	Off Puntarenas, Methane seep	95%
SIO-BIC M13149	mf	1	Doc Ricketts 380	27° 35.8'	111° 29.2'	1572	Gulf of California, methane seep	95%
SIO-BIC M13150	mf	1	Doc Ricketts 380	27° 35.8'	111° 29.2'	1572	Gulf of California, methane seep	95%
SIO-BIC M13151	mf	1	Doc Ricketts 380	27° 35.8'	111° 29.2'	1572	Gulf of California, methane seep	95%
SIO-BIC M13152	mf	2	Doc Ricketts 380	27° 35.8'	111° 29.2'	1572	Gulf of California, methane seep	95%
SIO-BIC M14395	mf	1	Doc Ricketts 472	32° 54.25'	117° 46.9'	1020	Del Mar Seep, California	95%
MNHN IM-2009-12199	*leucogranulatus*	1	Santo 2006/AT60	S 15° 33'	E 167° 22'	880-953	Vanuatu, NE of Tutuba Island	95%
MNHN IM-2009-12199a	*leucogranulatus*	(1)	Santo 2006/AT60	S 15° 33' S	E 167° 22'	880-953	Vanuatu, NE of Tutuba Island	shell of above