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A New Species of *Abyssochrysos* (Gastropoda: Loxonematoidea) from a Middle Eocene Cold-Seep Carbonate in the Humptulips Formation, Western Washington

by

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Abstract. A very small, localized, authigenic carbonate deposit within the lower part of the middle and early late Eocene Humptulips Formation in Grays Harbor County, Washington, preserves a molluscan fauna that is unique among recognized ancient chemosynthetic assemblages because the dominant faunal member is a large loxonematoidean gastropod, *Abyssochrysos* ***raui,*** sp. nov. The associated megafauna includes an unidentified neritiform gastropod, modiolid, thyasirid, and lucinid bivalves, numerous specimens of the bivalve *Vesicomya* sp., worm tubes, and crustacean fragments.

This is the first record of the genus *Abyssochrysos* from the northeastern Pacific Ocean, the oldest record for the genus, and the first report of *Abyssochrysos* from a chemosynthetic environment.

INTRODUCTION

The gastropod superfamily Loxonematoidea Koken, 1889, has a diverse pre-Cretaceous fossil record worldwide (Hoare & Sturgeon, 1985), but is almost unknown in Tertiary rocks. The Loxonematoidea contains only two surviving families; the Provannidae Warén & Ponder, 1991, and the Abyssochrysidae Tomlin, 1927. The Provannidae presently includes four genera (Warén & Bouchet, 1993), and almost all are exclusively from hydrothermal vents or cold seeps. The only fossil record for the Provannidae is *Provanna antiqua* Squires, 1995, from late Eocene and Oligocene cold-seep deposits in Washington State (Goedert & Campbell, 1995; Squires, 1995).

The Abyssochrysidae includes five living species, and all are rare: *Abyssochrysos bicinctum* Bouchet, 1991, from the Makassar Strait, Indonesia; *A. brasilianum* Bouchet, 1991, from the continental slope, southeastern Brazil; *A. eburneum* (Locard, 1897), from off of northwestern Africa; *A. melanioides* Tomlin, 1927, from bathyal depths off South Africa (Houbrick, 1979) and southeast Asia (Bouchet, 1991); and *A. melvilli* (Schepman, 1909) from bathyal depths in the Indo-West-Pacific (Figure 1). The only previous fossil record for the genus *Abyssochrysos* was from early Miocene strata at Suva, Fiji, where fossils of *A. melvilli* have been found (Ladd, 1977; Houbrick, 1979). Little is known about the ecology of *Abyssochrysos,* and *Abyssochrysos* has not been reported previously from chemosynthetic environments.

A fossil molluscan assemblage preserved in an authigenic carbonate deposit within the Humptulips Formation in western Washington was first described by Goedert & Squires (1990). We have discovered another previously unrecognized paleocommunity within a cold-seep carbonate (CSUN loc. 1583) in the lower part of the Humptulips Formation (Figure 2), and the purpose of this paper is to

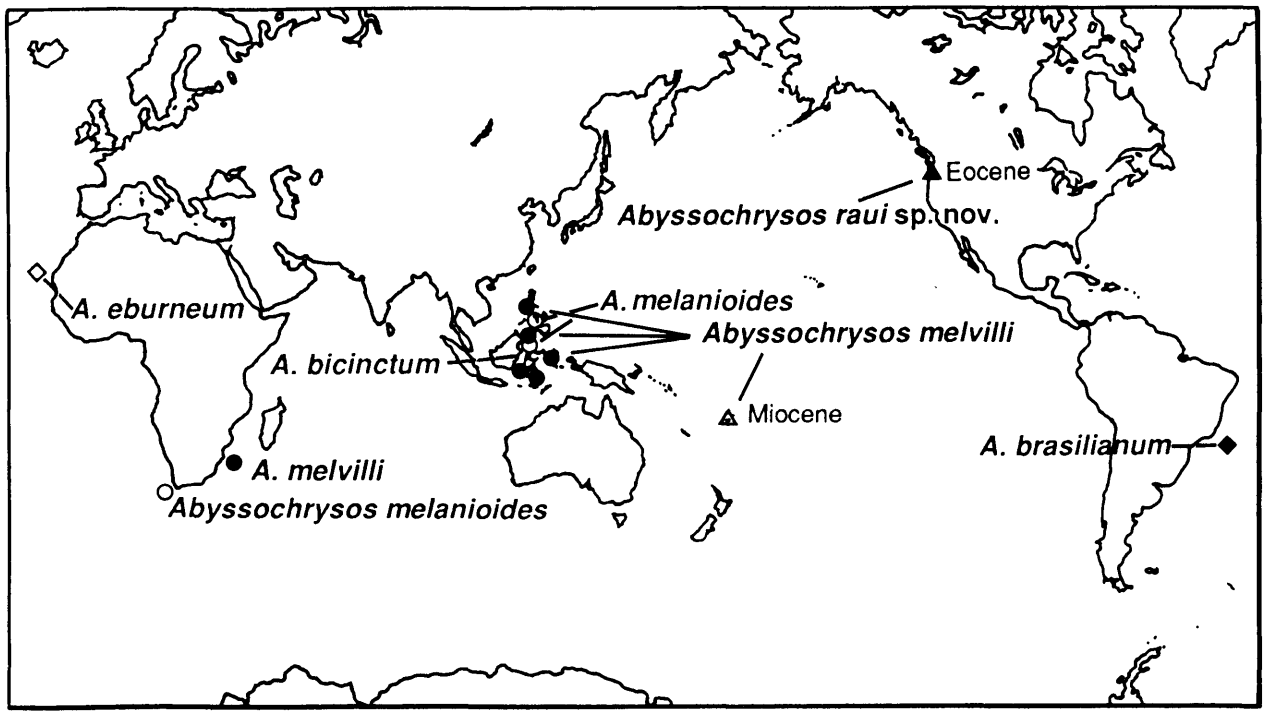


Figure 1

World map showing distribution of living and fossil *Abyssochrysos* species.

describe a new species of the gastropod *Abyssochrysos* from this assemblage.

Acronyms used for locality and specimen numbers are: CSUN, California State University, Northridge, California; and LACMIP, Natural History Museum of Los Angeles County, Invertebrate Paleontology Section, Los Angeles, California.

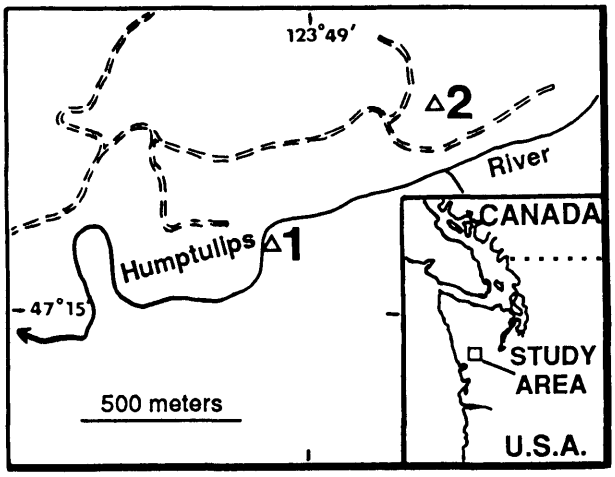


Figure 2

Maps showing location of study area and location of cold-seep carbonate deposits (*1* = CSUN loc. 1583; *2* = LACMIP 12385) along the east fork of the Humptulips River, Grays Harbor County, Washington (base maps: Burnt Hill & Railroad Camp, USGS 7.5 minute quadrangles, Prov. Editions 1990).

Geology

Exposures of siltstone, mudstone, and sandstone along the east fork of the Humptulips River in the study area were selected by Rau (1984, 1986) as the type section for the Humptulips Formation. The contact between the Humptulips Formation and the underlying early to middle Eocene Crescent Formation is a thrust fault (Rau, 1986), and in the study area, the formation is unconformably overlain by Pleistocene? gravels and younger fluvial deposits. The stratigraphy of this part of the Humptulips Formation is complicated by faults and limited exposures (Rau, 1984, 1986), and because of the nearly vertical attitude of the rocks, there is uncertainty regarding the superpositional relationships of some beds (W. W. Rau, written communication).

Age and Depositional Environment

Benthic Foraminifera are well represented in most samples from the Humptulips Formation, and they represent the Narizian Stage (middle and early late Eocene) and indicate bathyal depths, between 150 and 2500 meters

(Rau, 1984, 1986). Foraminifera in three samples (Rau, 1986:samples S-1011, S-1022, S-1021) from strata near CSUN loc. 1583 are characteristic of the middle Eocene part of the Narizian Stage as applied by Rau (1981) and clearly indicate bathyal conditions, perhaps within a lower middle bathyal range of 1500 to 2000 m (W. W. Rau, written communication).

Cold-Seep Carbonates

Rau (1984, 1986) reported that the type section of the Humptulips Formation included at least one thick "calcareous zone" (= LACMIP loc. 12385), and this limestone had earlier been described by Hodge (1938) and Danner (1966), but these authors did not recognize that it contained a diverse megainvertebrate assemblage. This calcareous zone was recently recognized as being an ancient cold-seep deposit (Goedert & Squires, 1990; Squires & Goedert, 1991), and the invertebrate assemblage was interpreted as having been supported by chemosynthesis via the bacterial oxidation of methane at a cold seep. This interpretation was later corroborated by Campbell & Bottjer (1993). Detailed petrographic and isotopic studies of these carbonates are not yet published, and are beyond the scope of this paper.

Lithologically, the carbonates at LACMIP loc. 12385 and CSUN loc. 1583 are broadly similar to each other, and they are similar to other recognized ancient cold-seep carbonates. At LACMIP loc. 12385, the carbonate is fossiliferous micrite in places; some parts of the outcrop are composed of fossiliferous carbonate breccia, and others are wavy, laminated, carbonate crusts. The entire outcrop at LACMIP loc. 12385 is more than 30 m thick (Danner, 1966; Rau, 1986).

At CSUN loc. 1583, the carbonate outcrop is only 2 m long and 1 m wide. The carbonate mound was about 1 m high, but the maximum thickness is unknown because the carbonate is completely surrounded by gravels in the riverbed. We excavated to a depth of 0.5 m (below water level) without finding the carbonate/siltstone contact, and therefore its stratigraphic location is uncertain. Most of the carbonate is highly indurated fossiliferous micrite, but it grades outward(?) into a breccia composed of small (≤3 cm) subrounded fragments of indurated micrite within a siltstone matrix. Wavy, laminated carbonate crusts, common at LACMIP loc. 12385, are only very weakly developed at CSUN loc. 1583. Gastropods and closed-valved bivalves are randomly oriented and are most common in the indurated carbonate; crustacean fragments are most abundant in the breccia. The gastropods are difficult to extract from the indurated carbonate, and preservation of the shell is generally poor; however, external molds do preserve surface sculptural detail. This carbonate preserves a fauna that is distinct from that in carbonate at LACMIP loc. 12385 (Table 1); therefore, it is not an allochthonous block derived from the carbonate deposit at LACMIP loc. 12385.

Table 1

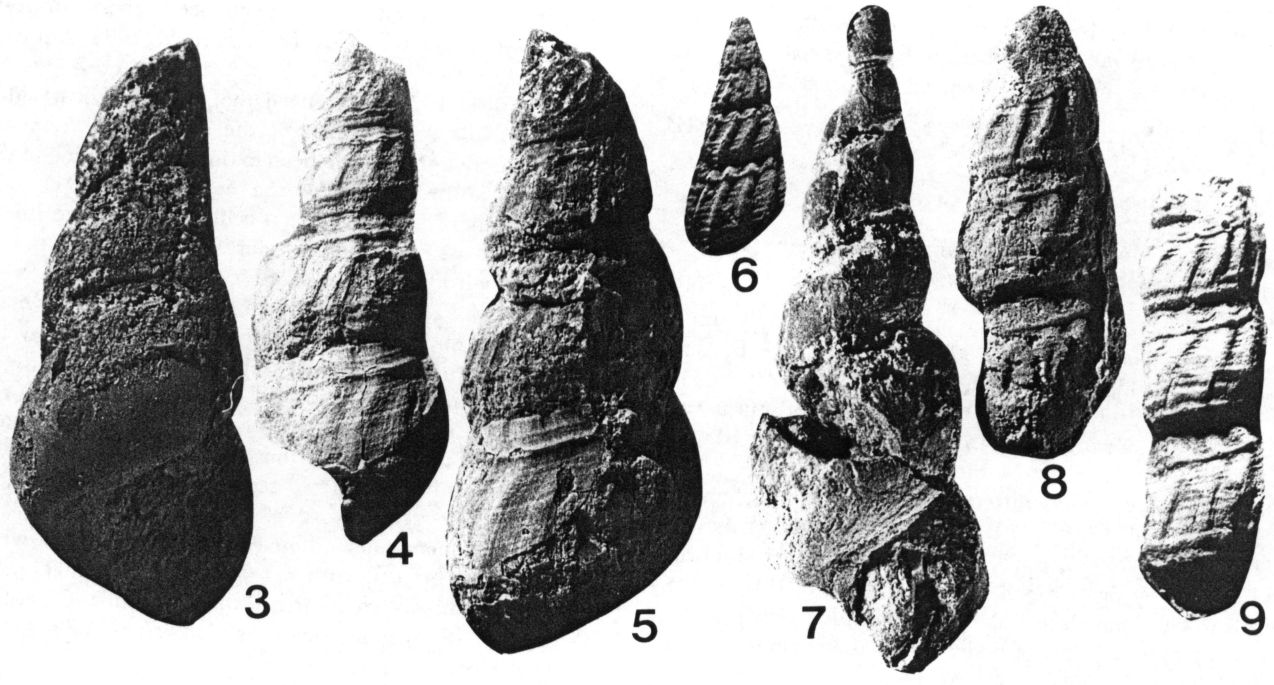
Faunal checklist for authigenic cold-seep carbonates within the lower part of the Humptulips Formation, east fork of the Humptulips River, Grays Harbor County, Washington. Data for LACMIP loc. 12385 is from Goedert & Squires (1990) and Squires & Goedert (1991, 1995).

Fauna	LACMIP loc. 12385	CSUN loc. 1583
Bivalvia:		
Acharax sp.	X	X
Calyptogena (*Calyptogena*) *chinookensis*, Squires & Goedert	X	—
Modiolus (*Modiolus*) *willapaensis*, Squires & Goedert	X	X
Thyasira (*Conchocele*) *folgeri*, Wagner & Schilling	X	X
Vesicomya sp.	—	X
lucinid (new genus?)	—	X
Gastropoda:		
Abyssochrysos ***raui***, sp. nov.	—	X
Homalopoma? sp.	X	—
limpets	X	—
naticid	X	—
neritiform gastropod	—	X
Other:		
Leptochiton (*Leptochiton*) *alveolus* (Lovén)	X	—
serpulid worm tubes	X	—
vestimentiferan? worm tubes	X	X
"*Callianassa*" sp. (crustacean)	X	X

Megapaleontology

Throughout this part of the Humptulips Formation, megafossils are extremely rare except in the authigenic cold-seep carbonates. The only megafossils found in the nearly barren strata were two unidentified shark teeth, some crinoid stem fragments, some poorly preserved specimens of a raninid crab, and a few wood fragments.

The carbonate deposits in the Humptulips Formation contain fossil invertebrate assemblages (Table 1) with large numbers of individuals and low taxonomic diversity, characteristic of those found in other modern and ancient chemosynthetic environments. All of the bivalve genera reported herein are either present in other ancient cold-seep assemblages, or have species represented in modern seep and vent communities. The bivalve *Vesicomya* sp. has been reported from one other seep deposit of Oligocene age in Washington (Goedert & Campbell, 1995), and a species of *Vesicomya* was reported from a probable cold-seep deposit in late Eocene rocks of the Wagonwheel Mountain area in central California (Squires & Gring, in press). The lucinid (new genus?) is up to 90 mm long and may be conspecific with the unidentified lucinid reported by Goe-



Figures 3–9

Abyssochrysos ***raui*** Goedert & Kaler, sp. nov., from CSUN loc. 1583, lower part of the Humptulips Formation, Grays Harbor County, Washington. Figures 3–5, Holotype, LACMIP 12363; Figure 3, apertural view, ×1.6; Figure 4, latex peel of external mold, ×1.4; Figure 5, abapertural view, ×1.7. Figure 6, Paratype, LACMIP 12364 latex peel of external mold, ×2.9. Figure 7, Paratype LACMIP 12365, apertural view, ×1. Figure 8 & 9, Paratype LACMIP 12366, ×1.6. Figure 9, latex peel of external mold, ×1.6. All coated with ammonium chloride.

dert & Campbell (1995) from a cold-seep carbonate on the northwestern Olympic Peninsula, Washington.

The cold-seep carbonate at CSUN loc. 1583 is unique faunally in that it preserves the only known Paleogene chemosynthetic assemblage that is dominated by a single large gastropod species. This gastropod was up to 90 mm long, and they are randomly oriented, complete individuals representing a new species of *Abyssochrysos*. A chiton was reported from LACMIP loc. 12385 and several other cold-seep carbonates in Washington (Squires & Goedert, 1995), and chitons are associated with modern methane-derived authigenic carbonates on the continental shelf off the coast of Oregon (Kulm & Suess, 1990). None of the mollusks from the Humptulips Formation seep sites show evidence of predation by other mollusks.

Serpulid and vestimentiferan? worm tubes are common at LACMIP loc. 12385 (Goedert & Squires, 1990), and vestimentiferan? tubes were found at CSUN loc. 1583 (Table 1). Tubes of these worms are common in many modern and ancient chemosynthetic assemblages. The crustacean "*Callianassa*" sp. was found at both LACMIP loc. 12385 and CSUN loc. 1583, and callianassid fragments were reported from cold-seep carbonate on the north side of the Olympic Peninsula by Goedert & Campbell (1995).

SYSTEMATIC PALEONTOLOGY

Superfamily LOXONEMATOIDEA Koken, 1889

Family ABYSSOCHRYSIDAE Tomlin, 1927

Genus *Abyssochrysos* Tomlin, 1927

Type species: *Abyssochrysos melanioides* Tomlin, 1927, by monotypy, Recent, off Cape Point, South Africa.

Abyssochrysos ***raui***
Goedert & Kaler, sp. nov.

(Figures 3–9)

Diagnosis: An *Abyssochrysos,* much larger and less elongate than any other known species.

Description: Shell large, elongate, turriform, up to 90 mm long and 2.5 mm thick on inner lip, with up to nine whorls (as preserved). Whorls inflated, slightly overhanging at bases; suture impressed; sculpture variable, with both spiral cords and opisthocline axial ribs, prominent spiral cord intersecting axial ribs near top of each forming small nodes; two spiral cords cross bases of ribs; on very large specimens axial ribs less prominent so upper spiral cord is bold; on last whorls both spiral cords and/or axial ribs lacking or

faint. Spiral cords more numerous on smaller specimens; axial ribs can vary in number on the same specimen, most specimens having about 12 per whorl.

Types: Holotype, LACMIP 12363; Paratypes: LACMIP 12364, 12365, 12366.

Type locality: CSUN loc. 1583.

Material: More than 50 specimens were found; most are poorly preserved.

Remarks: *Abyssochrysos* ***raui*** sp. nov. is strikingly similar to *A. melanioides* (Tomlin, 1927:78–79, figs. 1–3; Barnard, 1963:141–143, fig. 27a–c; Houbrick, 1979:3–10, fig. 1a–i; Bouchet, 1991:311, figs. 8, 12–17) in sculptural variability, but *A.* ***raui*** differs in being less elongate and much larger, with whorls more inclined.

Abyssochrysos ***raui*** differs from *A. melvilli* (Schepman, 1909:170, pl. 12, fig. 1; Barnard, 1963:143–144, fig. 27f; Ladd, 1977:15–16, pl. 1, fig. 3, pl. 21, fig. 8; Houbrick, 1979:10–14, figs. 7a–j, 8, 9; Bouchet, 1991: 311, figs. 18–20) in being much less elongate and much larger, and by having only one row of nodes on axial ribs, more inflated whorls, whorls more inclined, with a more elongate aperture.

The shells of *Abyssochrysos bicinctum* Bouchet, 1991 (Bouchet, 1991:311–312, figs. 21, 22) differ from those of *A.* ***raui*** by being smaller, more elongate, with slightly concave whorls ornamented by two prominent noded spiral cords. Those of *A. brasilianum* Bouchet, 1991 (Bouchet, 1991:306–310, figs. 1–4, 9–11) are much smaller and more elongate that those of *A.* ***raui.*** *Abyssochrysos eberneum* (Locard, 1897:389–390, pl. 19, figs. 7, 8; Bouchet, 1991:310–311, figs. 5–7) differs from *A.* ***raui*** in having a smaller, more elongate shell, with large nodes only on the basal part of each whorl.

The smallest available specimen of *Abyssochrysos* ***raui*** (LACMIP 12364; Figure 6) is 14 mm long, and its upper spire appears to have a smooth protoconch of about 1.5 whorls. The upper spire of some large specimens of *Abyssochrysos* ***raui*** is flat-sided and smooth, possibly corroded during life. The shells of gastropods from chemosynthetic environments are commonly corroded (Warén & Bouchet, 1993:81).

Etymology: The species is named for Weldon W. Rau in recognition of his pioneering work on the Foraminiferal biostratigraphy of Tertiary marine rocks in the Pacific Northwest.

DISCUSSION

Abyssochrysos ***raui*** from the middle to early late Eocene Humptulips Formation in Washington is the oldest record for the genus, the first report of *Abyssochrysos* from the northeastern Pacific Ocean, and the first report of *Abyssochrysos* from a chemosynthetic environment. The earliest and first fossil records for the related genus *Provanna* are also from Eocene and Oligocene cold-seep deposits in western Washington (Goedert & Campbell, 1995; Squires, 1995).

Houbrick (1979) recognized that the Abyssochrysidae represented a relict family of the superfamily Loxonematoidea, thought to have been extinct since the end of the Jurassic. Subsequently, Warén & Ponder (1991) have classified the Provannidae as a relict family of the Loxonematoidea as well. Some other invertebrates found at modern hydrothermal vents and cold seeps are also relict taxa having Paleozoic and Mesozoic ancestors (Newman, 1985). These taxa may have survived mass extinction events by using deep-water vent and seep environments as refugia, functioning independent of global climatic changes (Yamaguchi & Newman, 1990; Tunnicliffe, 1992). This idea seems to be reinforced by the discovery of *Abyssochrysos* and *Provanna* in Eocene cold-seep deposits in Washington, the only Paleogene record of the once widespread and diverse Loxonematoidea. The convergent margin of western North America, with a record of deep-water, cold-seep environments from Jurassic to Recent time (Campbell & Bottjer, 1993), may have provided refuge for many of these ancient groups.

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LACMIP 12385. Small hill in abandoned meander of the east fork of the Humptulips River, northwest part of sec. 4, T. 20 N, R. 9 W, Burnt Hill USGS 7.5 minute quadrangle, Provisional Edition 1990, Grays Harbor County, Washington. Humptulips Formation. Age: Middle Eocene. Collectors: J. L. & G. H. Goedert, 1990.

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