A Hot-Vent Gastropod with Iron Sulfide Dermal Sclerites

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A recently discovered gastropod (Fig. 1A) differs from all known mollusks by having its foot covered by scales of conchiolin, mineralized with pyrite (FeS_2) and greigite (Fe_3S_4). The animal lives a sedentary life at the base of black-smoker chimneys in the Kairei vent field in the Indian Ocean (*1*, *2*). Its scaly scleritome resembles those characteristic of numerous metazoans (halkieriids, tommotiids, and others) appearing in the Cambrian explosion (*3*), but gene sequences (mt16S DNA) and anatomy show that it belongs to the Neomphalina (SOM text), an order endemic to modern hydrothermal vents.

The sclerites [up to 8 mm long (fig. S2, E and F)] cover the sides of the foot in a roof-tile fashion (Fig. 1, A and B). Their outer, mineralized layer is black and ferrimagnetic. It begins at the base of the scales as a thin crust; more apically it may reach 0.2 mm in thickness (Fig. 1, C and D). The dominant crystalline mineral phase is pyrite, whereas greigite, the sulfide analog of magnetite, is present in lower proportions and accounts for the ferrimagnetism. The interior of the sclerites is penetrated by a pulp of pedal tissue that extends almost to the tip. Between the pulp and the outer mineralized layers there is a tough, laminated, organic layer, histologically indistinguishable from molluscan conchiolin. The conchiolin is studded with minute (typically about 1 μm in diameter) iron sulfide granules and finely dispersed iron sulfur compounds; these minerals are more common in the outer layers of the conchiolin. Where the sclerite surface is overlain by adjacent sclerites, the sclerites are covered by a coat of bacteria (Fig. 1C; fig. S2G).

Iron sulfide as a skeletal material is not known in metazoans (*4*), although accumulations of metal sulfides occur in animal tissues and may represent a detoxification process (*5*). Hydrothermal vent fluids are rich in dissolved sulfides and metals (*6*), and mixed deposits of minerals including sulfides frequently occur on animals living in vent environments (*7*). The purity of the iron sulfides (i.e., the absence of zinc or copper contamination) in the sclerites, the inclusion of sulfide granules in the conchiolin, and the regular depositional pattern of the sulfide-mineralized tissues suggest that the mineral fortification of the sclerites is directly controlled by the gastropod. At present it is not known what role, if any, the bacterial episymbionts and endosymbionts play in mediating sulfide deposition.

The phylogenetic position within a clade of vent gastropods (fig. S1) that have a conchiolin operculum suggests that the scaly scleritome is homologous to the gastropod operculum. Given the unusual fortifying minerals and the phylogenetic position of the snail, we suggest that the scleritome evolved recently, in the vent environment. The function of the sclerites remains speculative; they may form a protection against co-occurring predatory gastropods of the genus *Phymorhynchus*. Like the related cone snails, *Phymorhynchus* injects venom into its prey but its radular darts are too short to penetrate the scleritome (*8*). The scaly-footed gastropod demonstrates that a complex scleritome of the kind which evolved repeatedly in metazoans of the Cambrian explosion may appear in an evolutionary instant, and it reinforces the idea that fortifying biominerals may reflect the availability of minerals in the environment where the structures evolved.

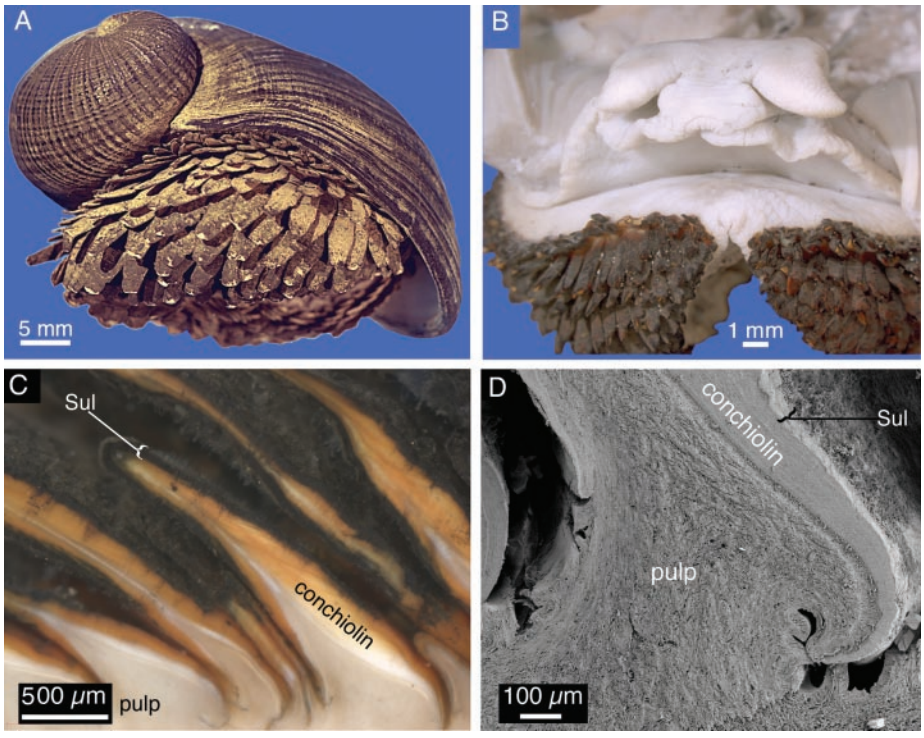

Fig. 1. The new gastropod. (**A**) Retracted in shell; scales and shell are rusty from storage in low grade ethanol. (**B**) Shell removed; front view of head-foot. Scales are in their normal, black color. (**C** and **D**) Longitudinal sections of scales, viewed with light microscopy (C) and scanning electron microscopy (D) photos. Sul, sulfide layers [black in (C), light in (D)].

References and Notes

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2. Materials and methods are available as supporting material on *Science* Online.
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Materials and Methods
SOM Text
Figs. S1 and S2

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