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First record of marine gastropods (wentletraps) from mid-Cretaceous Burmese amber

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Abstracts

Gastropod fossils are rarely preserved in amber with only a few records of terrestrial snails. Two new species, *Epitonium* (*Epitonium*) *zhuoi* n. sp. and *Epitonium* (*Papyriscala*) *lyui* n. sp. are described based on two well-preserved specimens from mid-Cretaceous amber from northern Myanmar. Highresolution three-dimensional images using X-ray micro-computed tomography (micro-CT) are provided. These species can be attributed to the family Epitoniidae (wentletraps) based on the shell characters such as the slender and conical shell-shape, numerous whorls, round aperture and regular, axial sculpture of high, sharply-ribbed costae. Our find is the first record of marine gastropods preserved in amber, and suggests that the Burmese amber forest probably existed close to the seashore.
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Keywords: Burmese amber; Caenogastropoda; Marine prosobranch gastropod; Epitoniidae; *Epitonium*; New species

1. Introduction

The Epitoniidae, commonly known as wentletraps ("spiral staircase" shells), is a large family of Caenogastropoda. It resembles Family Cerithiidae Fleming, 1822 in having elongate conical shells and an ornament of spiral and axial ribs, but the apertures of the latter usually have flared outer lips and a more or less long and curving siphonal canal (Bandel, 2006). Extant epitoniids occur in practically all seas from the lower intertidal zone to abyssal depths (Cox and Moore, 1960; Kilburn, 1985). Mesozoic epitoniids are widespread from tropical and warm-temperate seas, e.g., *Acirsa* Sohl, 1964 from the Upper Cretaceous of Mississippi, USA (Sohl, 1964); *Gibboscala* Kollmann, 2005 and *Confusiscala* de Boury, 1909a from the Lower Cretaceous of the Volga Region near Ulyanovsk, Russia (Blagovetshenskiy, 2015); and a possible epitoniid, *Claviscala* sp. from the Lower Cretaceous of southern Mazowsze, Poland (Kaim, 2004). Compared with the relatively abundant fossil record in the Western Hemisphere, records from eastern Asia are rare, comprising only species belonging to the genera *Acirsa* Mörch, 1857 and *Confusiscala* de Boury, 1909a from the Lower Cretaceous of Japan (Kase, 1984).

The type genus *Epitonium* Röding, 1798 is abundant in records documenting the Cenozoic, e.g., *Epitonium* (*Boreoscala*?) sp. from the Eocene of Tanga (Ladd, 1970); *Epitonium* (*Crisposcala*) *okinavensis* Macneil, 1960 and *Epitonium* (*Glabriscala*) *submaculosum* Macneil, 1960 from the Pliocene of Japan (Macneil, 1960). However, Mesozoic records of *Epitonium* are rather sparse: *Epitonium* cf. *faearium* Dockery, 1993 has been reported from the lower Maastrichtian of southern Mexico (Perrilliat et al., 2000); *Epitonium* sp. from the Creta-

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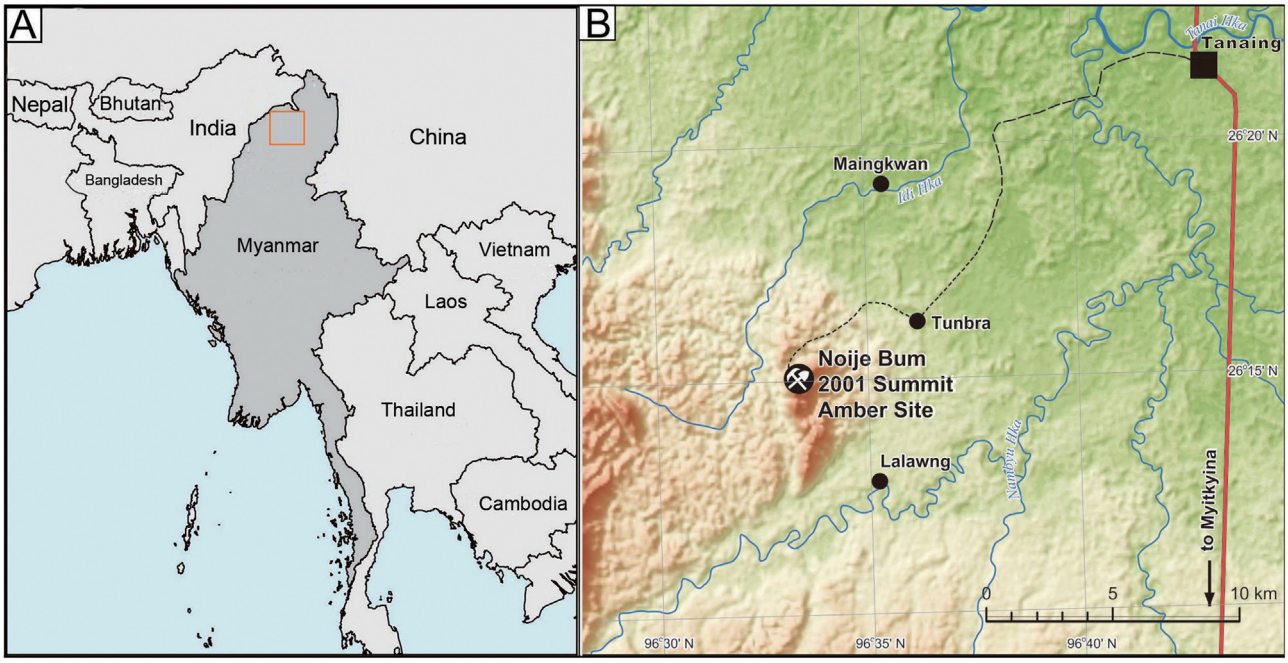

Fig. 1. Location of amber mining area near Noije Bum Village, Myitkyina District, Kachin State, Myanmar. Compiled from data provided by Cruikshank and Ko (2003) and Wandrey (2006). (A) Geographic location of Myanmar; (B) location of amber mining area, northern Myanmar.

ceous of Minnesota (Bergquist, 1944); and *Epitonium faearium* Dockery, 1993 from the Upper Cretaceous of Coffee Sand, Mississippi (Sohl, 1964; Dockery, 1993). In this work, we report the first record of Epitoniidae preserved in amber. Two new species, *Epitonium* (*Epitonium*) *zhuoi* n. sp. and *Epitonium* (*Papyriscala*) *lyui* n. sp., are described from Burmese amber dating from the mid-Cretaceous.

2. Geological setting

Amber has been recorded from the Shwebo, Thayetmyo, Pakokku, and Pegu districts in Myanmar. However, the only commercial source is the Hukawng Valley in Tanaing Township, Myitkyina District of Kachin State (Cruikshank and Ko, 2003; Ross et al., 2010). The amber pieces containing the entombed gastropods come from an amber mine located near Noije Bum Village, Tanaing Town (Kania et al., 2015; Fig. 1). The U-Pb dating of zircons from the volcanoclastic matrix of the amber gave a maximum age of about 99 million years (Shi et al., 2012).

3. Material and methods

The amber containing the gastropods is yellow and transparent. Photographs were taken using a Zeiss Stereo Discovery V16 microscope system at the State Key Laboratory of Palaeobiology and Stratigraphy, Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences. All images are digitally stacked photo micrographic composites of approximately 50 individual focal planes that were obtained using the software Helicon Focus 6 for better illustration of the 3D structures. All images and figures were prepared with the aid of CorelDraw X4 and Adobe Photoshop CS3 graphic design software. The specimens are housed in the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences (NIGPAS).

Some detailed structures of these amber gastropods (e.g., teleoconch ornamentation and aperture) are not visible under the light microscope; therefore, we scanned the holotypes (NIGP168832 and NIGP168833) in the micro-CT lab of NIGPAS using a 3D X-ray microscope (3D-XRM) Zeiss Xradia 520 versa for additional detail. Unlike conventional micro-CT, which relies on maximum geometric magnification and a flat panel detector to achieve high resolution, the 3D-XRM uses CCD-based objectives to get higher spatial resolution. A CCD-based 0.4× objective was used, providing isotropic voxel sizes from 0.5 mm with the help of geometric magnification. During the scan, the running voltage for the X-ray source was set at 60 kV (NIGP168832) and 50 kV (NIGP168833), and a thin filter (LE2) was used to avoid beam-hardening artefacts. To get a high signal-to-noise ratio, 2001 projections over 360° were collected and the exposure time for each projection was set at 1 s (for NIGP168832) and 4 s (for NIGP168833). Volume data processing was performed using the software Vgstudio Max (version 3.0, Volume Graphics, Heidelberg, Germany). All taxonomic acts established in the present work have been registered in ZooBank (see below), together with the electronic publication LSIC: urn:lsid:zoobank.org:pub: F24A8397-6C96-484C-BFD8-B03A38595440.

Abbreviations: H = shell height; D = greatest width of shell; S = spire length (without aperture); h = aperture height; d = aperture width.

4. Systematic palaeontology

Superfamily Epitonioidea Berry, 1910

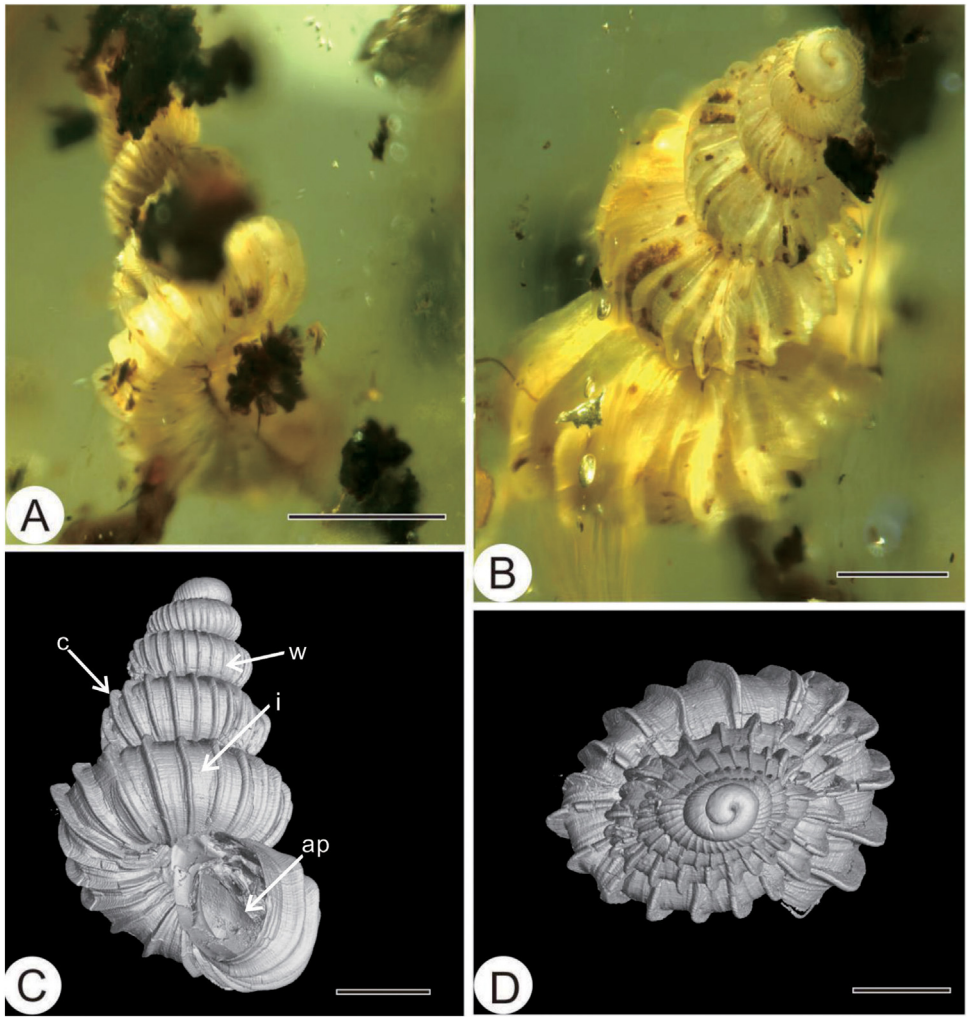

Fig. 2. *Epitonium* (*Epitonium*) *zhuoi* n. sp. (A, C) Apertural view; (B) lateral view; (D) apical view. (C, D) Micro-CT reconstruction. Scale bar = 0.5 mm. Abbreviations: ap – aperture (pertaining to the opening into the shell); c – costa (axial ridge); i – interspace (intermediate space between structural features on a shell surface); w – whorl (one complete 360° turn of a gastropod shell about the imaginary central axis).

Family Epitoniidae Berry, 1910

Genus *Epitonium* Röding, 1798

Subgenus *Epitonium* Röding, 1798

Diagnosis (after Dockery, 1993 and Kilburn, 1985): High-spired shell with a multispiral and usually smooth protoconch; teleoconch with convex whorls and with or without spiral sculpture in interspaces; axial ribs fine and filiform to strong and lamellate; spiral lirae relatively weak or absent; umbilicus present or absent; aperture circular, operculum usually lacking.

Type species: *Turbo scalaris* Linnaeus, 1758, subsequent designation by Suter (1913).

Epitonium (*Epitonium*) *zhuoi* n. sp.

urn:lsid:zoobank.org:act: D20E116D-FB1E-4D05-BF47-BEC955D56F8D

(Fig. 2)

Etymology: After De Zhuo, the collector of this specimen.

Holotype: Reg. no. NIGP168832.

Locality and horizon: Reportedly mined near Noije Bum Village, Tanaing Township, Myitkyina District, Kachin State, northern Myanmar (26°15′N, 96°33′E); unnamed horizon, mid-Cretaceous, upper Albian or lower Cenomanian.

Description: Shell minute, conical-turbinate in shape. Protoconch with about 1.5 smooth whorls; teleoconch highly spired with an apical angle of 78°. Whorls convex and regularly increasing in size. Teleoconch with about 4.5 whorls and sculptured with more than 20 strong and prominent axial ribs which connect at the suture; axial ribs thin, fairly low, straight, more or less continuous and consist of fine, intermittently raised glossy and opaque lamellae, with scratch-like spiral microstriae (visible under 3D X-ray microscope). Suture deeply impressed; umbilicus widely fenestrate, partly covered by labial expansion; aperture oblongovate; apertural margin thin and fragile.

Remarks: The specimen can be attributed to the genus *Epitonium* based on the shell characters of a conical shell, sculptured with prominent axial ribs and intervals glossy and smooth; it differs from all other species of this genus in having a thin and fragile apertural margin.

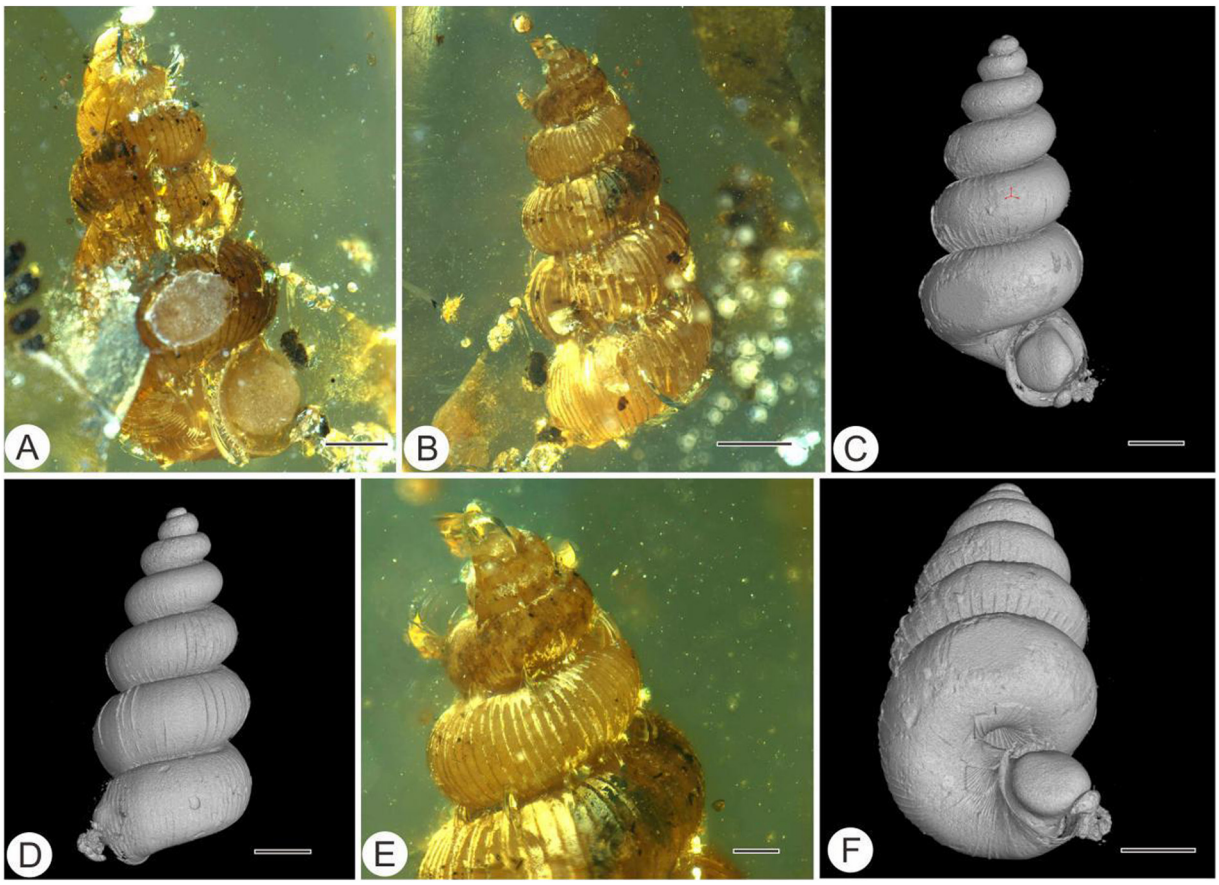

Fig. 3. *Epitonium* (*Papyriscala*) *lyui* n. sp. (A) Apertural view; (B) lateral view; (E) apical view showing embryonic shell. (C, D, F) Micro-CT reconstruction. Scale bar = 0.5 mm for (A–D, F); 0.2 mm for (E).

It resembles *Scala pallasii* Kiener, 1838 (Cernohorsky, 1978) from the Nansha Sea (Feng, 1996) in having the conical shell-shape, ornament of prominent spiral ribs and ovate aperture; it differs from the latter in having only two whorls in the protoconch, and a thin and fragile apertural margin.

E. (*Epitonium*) *zhuoi* n. sp. also resembles *E.* (*Periapta*) *pandion* (Clench and Turner, 1952) from Cobscook Bay in North Carolina (Clench and Turner, 1952) in having a slender, conical shell and a thin and fragile apertural margin, but it differs from the latter in having a smaller shell and thin, erect axial costae.

Measurements: Based on 5 or 6 whorls; H = 4.3 mm; D = 2.3 mm; S = 2.9 mm; h = 1.4 mm; d = 0.8 mm.

Subgenus *Papyriscala* de Boury, 1909b

Diagnosis: Shell moderately small, fragile, usually broadly pyramidal, whorls strongly convex, suture moderately deep, simple to narrowly fenestrate, umbilicus open, narrow; peristome thin, simple, not auriculate; axial ribs numerous, thin, low, non-cornate at shoulder; spiral sculpture absent or forming a few faint scratches (after Kilburn, 1985).

Epitonium (*Papyriscala*) *lyui* n. sp.

urn:lsid:zoobank.org:act: 68B9982C-ACE1-497A-AA01-01015F7EB74B

(Fig. 3)

Etymology: After Ming Lyu, the collector of the specimen.

Holotype: Reg. no. NIGP168833.

Locality and horizon: Reportedly mined near Noije Bum Village, Tanaing Township, Myitkyina District, Kachin State, northern Myanmar (26°15'N, 96°33'E); unnamed horizon, mid-Cretaceous, upper Albian or lower Cenomanian.

Description: Shell small, elongate with a high spire. Protoconch with about two smooth whorls. Teleoconch with four strongly convex whorls, sculptured with thin, low, straight and discontinuous axial ribs, more than 30 on body whorl (10–20 fewer on penultimate whorl), spiral sculpture absent; intervals smooth; suture deep but simple; umbilicus narrow and chinked. Aperture circular in shape, inner lip thin and slightly reflexed (visible under 3D X-ray microscope).

Remarks: The new species closely resembles *Epitonium* (*Papyriscala*) *emiliae* (Melvill and Standen, 1903), ranging from the Gulf of Arabia to Algoa Bay (South Africa), in its strongly convex whorls, numerous axial ribs, and lack of spiral sculpture. It differs from the latter in having much finer axial ribs (more than 36) on the body whorl; however, *E. emiliae* only has 21-36 axial ribs on the body whorl. Extant specimens of *E. emiliae* have been reported from inshore dredgings (Kilburn, 1985). *E. lyui* n. sp. probably lived in a similar shallow marine environment.

Measurements: 7 whorls; H = 3.4 mm; D = 1.5 mm; S = 2.5 mm; h = 0.9 mm; d = 0.7 mm.

5. Discussion

The Epitoniidae is a large family with an estimated number of species exceeding 600 (Cox and Moore, 1960; Kilburn, 1985). It occurs in practically all seas and is easily distinguished by a long spire, very deep sutures, and characteristically strong axial varices that run across all of the whorls from the tip of the spire to the aperture. Most species have a slender, conical shell with joined whorls, a rounded aperture and a small umbilicus (Keen, 1971; Bouchet and Waren, 1986). Our new specimens can be attributed to Epitoniidae based on their slender and conical shells with a rounded aperture, and tallspired, numerous whorls. Furthermore, they belong to the genus *Epitonium* in having the lamellar axial sculpture consisting of thin raised lamellae, and regular axial costae and interspaces weakly sculptured (Bouchet and Waren, 1986).

Gastropod fossils are usually very rare in amber, but they are abundant in mid-Cretaceous Burmese amber. Although several gastropods have been mentioned or described from Burmese amber, none are marine gastropods (e.g., Grimaldi et al., 2002; Naggs and Raheem, 2005; Poinar and Poinar, 2007; Poinar, 2011; Yu et al., 2018). Our find is the first record of marine gastropods from this fossil resin. The palaeoenvironment is considered to have been coastal deltaic or estuarine from several lines of palaeontological evidence: the occurrence of a rare ammonite (*Mortoniceras* sp.), bedding of the enclosing siliciclastic sediment, and presence of bivalve body fossils and bivalve (pholadid) borings in the amber (Cruikshank and Ko, 2003; Smith and Ross, 2018). Our gastropod inclusions provide further evidence that the Burmese amber forest probably grew close to the seashore.

According to Bouchet and Waren (1986), there are three types of protoconch morphology in the family Epitoniidae: type 1, protoconch paucispiral, composed of 1 or 1.5 smooth whorls; type 2, protoconch multipiral, composed of 3 or 4 whorls with strong axial ribs; type 3, protoconch multipiral, composed of 3 or 4 whorls that appear smooth under the microscope, although a microsculpture is often present. Bouchet and Waren (1986) pointed out that the type 1 corresponds to species without planktotrophic larval development and could arise independently in different lineages. In *Epitonium*, this character appears at species level only and is probably a consequence of life in a high latitude environment. Types 2 and 3 correspond to species with planktotrophic larval development (Bouchet and Waren, 1986). *E. lyui* n. sp. and *E. zhuoi* n. sp. clearly conform to type 1, suggesting that these two species did not undergo planktotrophic larval development and probably lived in a high latitude environment. However, the palaeogeographical location of *E. lyui* n. sp. and *E. zhuoi* n. sp. from Burmese amber is in a low latitude area. This anomaly needs further research, because the multiple geologic events and dynamics of West Burma (source of Burmese amber) have a multi-facetted tectonic history (Hall, 2012; Sevastjanova et al., 2016).

The epitoniid family includes numerous species from all parts of the world, but its diversity is especially high in tropical and subtropical areas (Kilburn and Rippey, 1982). Extant epitoniids are parasitic on coelenterates and most are associated with sea-anemones (Kilburn and Rippey, 1982) or may be free-living micropredators feeding on invertebrates, such as annelid worms and nemerteans (Lima et al., 2012). Many extant species of this family live with or forage for the coelenterate hosts on which they feed, but some shallow-water species are reported to live with corals (Robertson, 1970). All the coral-associated Epitoniidae are likely to feed on the soft tissues of their hosts in the same way as the species that feed on sea anemones (Robertson, 1970). Like their extant counterparts, *E. lyui* n. sp. and *E. zhuoi* n. sp. from mid-Cretaceous Burmese amber are most likely tropical or subtropical and were part of the warm-water fauna in a normal shallow marine environment; they were also probably feeding on coelenterates although these are yet to be discovered in Burmese amber.

6. Conclusions

Two new species, *Epitonium* (*Epitonium*) *zhuoi* n. sp. and *Epitonium* (*Papyriscala*) *lyui* n. sp. are described from mid-Cretaceous Burmese amber. Our find is the first record of marine gastropods preserved in amber, and suggests that the Burmese amber forest probably grew close to the seashore. This is supported by the occurrence of pholadid bivalve borings in the amber whilst still resinous (Smith and Ross, 2018).

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