Aesthete Canals in the Chiton *Euleptochiton spatulatus* (Polyplacophora, Mollusca) from the Pennsylvanian of Ohio

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Abstract. Thin sections of the plates of the Pennsylvanian chiton *Euleptochiton spatulatus* (Hoare, Sturgeon and Hoare 1972) show the pattern and sizes of the aesthete canals. In general the canals are slightly curved extending from the dorsal surface to the ventral surface. Canals close to the articulamentum layer curve upward around the layer and run longitudinally parallel to the dorsal surface before curving to the dorsal surface or extending to the anterior margin. Canals near the lateral and anterior margins curve laterally to the margins. The canals average .05 mm in diameter and are spaced .01 mm apart. Micraesthete and megalaesthete structures were not seen in the sections. One section shows only longitudinal canals probably representing a new taxon.

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INTRODUCTION

Chitons normally have eight plates on the dorsal surface: a head plate, six intermediate plates and a tail plate (Fig. 1). Plate growth proceeds anteriorly and laterally from the posterior apex of the head and intermediate plates and anteriorly, laterally, and posteriorly from the area of the mucro in the tail plate. The plates are composed of calcium carbonate and are composed of three layers, outer or dorsal tegmentum, articulamentum, and ventral hypostracum. In *Euleptochiton spatulatus* the articulamentum layer is restricted to narrow triangular areas extending from the apex on the posterior margin of the intermediate plates and the mucro on the tail plate to the anterior margin forming prong-like extensions called sutural laminae (Fig. 1). The aesthete canals do not penetrate the articulamentum.

Among the many studies of aesthete canals in modern chitons, those of Fernandez and others (2007) and Vendrasco and others (2008) are most instructive to the present study. By casting the canal system with epoxy in a vacuum in a desiccating chamber they were able to illustrate the complete canal system including the micraesthete and megalaesthete chambers. These reports show the usefulness of determining the canal systems in chitons for taxonomic and phylogenetic studies.

Relatively few reports have been made concerning the aesthete canals in fossil specimens (see summary by Vendrasco and Runnegar 2004, p. 679). In addition to those listed, Hoare and others (1972, p. 676, figs. 1.2, 1.3) described the preserved "pore" fillings of *Glapurochiton carbonarius* (Stevens 1858) from the Pennsylvanian of Ohio, Kues (1978, p. 305) described the pits on the dorsal surface of *Gryphochiton parvus* (Stevens 1858) from the Mississippian of Indiana, and Hoare and Karasawa (2008, p. 322) mentioned the canal openings on the surface of the new species *Glaphurochiton asamiae* from the Permian of Japan.

A large number of plates were found at a locality of the shale over the Desmoinesian Vanport Limestone exposed near the mouth of an abandoned drift mine on the north side of the road along Bufer Run, SW1/4SE1/4 sec. 24 in Milton Township, Jackson County, Ohio, Mulga 7 1/2' quadrangle. Besides several hundred plates of *E. spatulatus,* the collections also contained numerous specimens of four other chiton species.

Atwater (1979) in his study of the microstructure of *Gryphochiton simplex* (Raymond 1910), by cutting serial sections, was able to discern traces of aesthete canals in the plates. Most of his specimens came from the locality described above. In addition to these two species, thin sections had been cut near the lateral dorsal surface of intermediate plates of *Glaphurochiton carbonarius* (Stevens 1858), *Acutichiton pyrmidalus* (Hoare, Sturgeon and Hoare 1972), and *Elachychiton juxtaterminus* (Hoare and Mapes 1985), to show the differences in cross section size and spacing of the canals (Hoare 2000).

MATERIALS AND METHODS

The shale samples were boiled in water and Quaternary O to remove the clay portion. After drying, the residue was screened and then sorted under a microscope, picking out the chiton plates. The plates of *E. spatulatus* were separated into head, intermediate, and tail plates. The large number of plates made this species convenient for this type of study.

A plate or fragment was mounted on a glass slide using a small piece of Lakeside Brand thermoplastic (quartz) cement, setting it in the desired orientation. Grinding was done by hand on narrow strips of wet 400 and 600 grit carborundum paper laid on a glass plate. When the desired section in the plate was reached, the slide was reheated and the specimen turned upside down. Further grinding reduced the specimen to the final thickness and a cover slip was then placed on the slide. Several of the sections were left a little thick to provide a better opportunity to study the arrangement of the canals. Grinding too thin may cause the structures to become indistinct due to the recrystallization of the shell material or may cause the section to break apart when applying pressure on the cover slip to get rid of bubbles on the section. In the early stages of grinding some specimens were found to be coarsely preserved or the canals extensively filled with matrix or iron sulfide which prevented study and were discarded.

Photography was done with a Nikon Coolpix 5400 camera on a Lica DMLP microscope using a blue filter. The sections have been placed in the repository at the Orton Museum, The Ohio State University (OSU). All additional specimens have been placed in the repository at the National Museum of Natural History, Smithsonian Institution.

RESULTS

Over 120 plates and plate fragments of topotype specimens of *E. spatulatus* were sectioned including 12 head plates, 42 intermediate plates, and 31 tail plates. More than 30 attempted sections were discarded due to preservation. Several of the very thin sections were broken when too much pressure was applied on the cover slip to get rid of bubbles (Fig. 2.12). These could still be used for study.

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The aesthete canals in *E. spatulatus* are mainly vertically curved, extending from the dorsal surface to the ventral surface of the plate. In the intermediate and tail plates the presence of the articulamentum layer, which is not penetrated by the canals, causes changes in the canal shape and orientation as they curve around and extend over the articulamentum layer. Canals measured just below the dorsal surface on the lateral portion of an intermediate plate average .05 mm in diameter and are spaced about .01 mm apart.

In transverse sections of the head plate the canals appear straight in the central region and slightly curved toward midline in the lateral areas (Fig. 2.1). In longitudinal sections near the midline all of the canals appear curved anteriorly from the dorsal to ventral surface (Fig. 2.2).

In intermediate plates the transverse sections show canals that are slightly curved in the lateral portions of the plates and are more strongly curved beside the articulamentum layer (Fig. 2.9 arrow). They may appear vertically straight in the dorsal area when viewed from an anterior or posterior direction (Fig. 2.6). When sectioned near the midpoint in the anterior half of the shell some of the canals may appear as circular cross sections depending on the forward curvature of the canals (Fig. 2.9). Over the articulamentum layer, the area of coarse crystals in the sections, the canals are horizontal and run parallel to the dorsal surface and are seen as cross sections in the transverse sections (Fig. 2.7 arrow). Some of the horizontal canals curve over the edge of the articulamentum layer and extend vertically to the ventral surface of the hypostracum layer (Fig. 2.4 arrow). In longitudinal sections cut near the midline, all of the canals curve anteriorly from the dorsal to ventral surface of the hypostracum layer (Fig. 2.8). They do not penetrate the apical area on the posterior ventral surface. In horizontal sections cut over the articulamentum area, the horizontal canals form a fan-shape near the anterior margin of the plate (Fig. 2.3 arrow). In longitudinal sections the canals over the articulamentum layer curve down from the dorsal surface extending anteriorly (Fig. 2.5 arrow) or curve ventrally in the hypostracum layer over the side of the articulamentum layer.

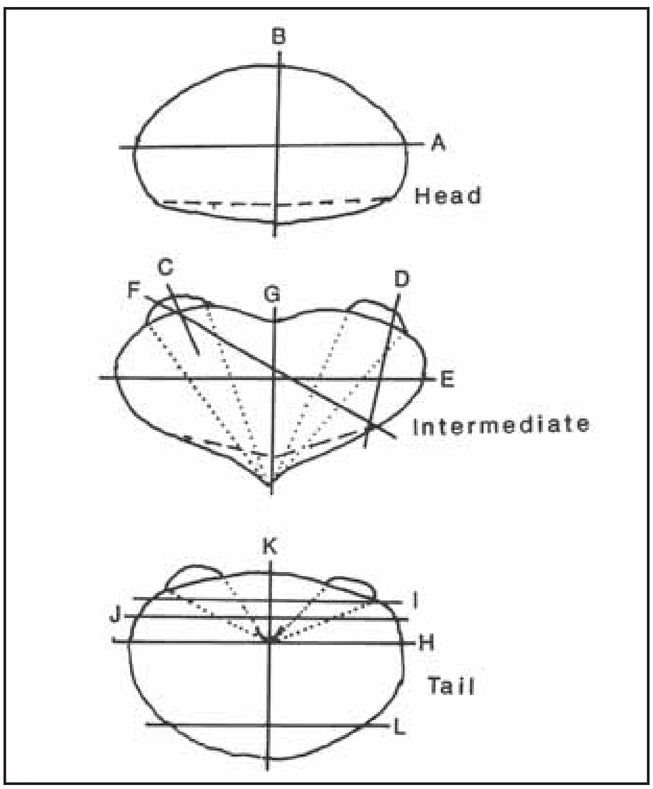

Figure 1. Diagrammatic sketch of the three types of chiton plates showing approximate positions of thin sections illustrated in Figure 2. Dashed lines represent the edge of the apical area on the ventral surface of the head and intermediate plates and the dotted lines which enclose the articulamentum layer in the intermediate and tail plates. Small V on the tail plate represents the position of the mucro. Line C indicates the position of both a vertical section and a horizontal section. Not to scale.

In the tail plate the broad extent of the coarse crystalline articulamentum layer, in converging at or near the beginning of growth of the plate at the mucro, forms a large area where canals are not present (Figs. 2.10 arrow at contact of hypostracum and articulamentum layers). Transverse sections in the anterior portion of the plate contain vertical canals dorsally (Fig. 2.12 arrow), curving canals from the dorsal to ventral surface laterally, and circular cross sections of the canals over the articulamentum layer. Close to the anterior edge of the plate the circular cross sections of the canals may also be seen in the dorsal area (Fig. 2.11 arrow). Longitudinal sections near the midline contain either straight or slightly curved canals extending from the dorsal to ventral surface in the areas anterior and posterior to the mucro (Figs. 2.13, 2.14). In transverse sections cut near the posterior margin of the plate the canals are straight to slightly curved and some may appear in circular cross section (Fig. 2.15).

No distinction could be seen between the thin tegmentum and thicker hypostracum layers based upon the preserved shell microstructure. However, in numerous sections the deflection of the canals, forming a narrow dorsal band, may mark the contact between the two layers (Figs. 2.2, 2.13 arrows). The deflection is present in eight of the head sections, 18 of the tail sections, but only discernable in three of the intermediate sections.

An examination of the ventral surface of several well-preserved whole plates show canal openings. These were seen on the anterior and lateral edges of the head plates, the lateral areas of the intermediate plates, and the lateral and posterior areas of the tail plates.

One intermediate plate sectioned transversely near its mid-length has a significantly different canal arrangement (Fig. 2.16). All of the canals appear as circular transverse cross sections of longitudinal canals throughout the shell in the hypostracum layer of the plate. The general shape of the plate, the dorsal sculpture, and the sutural laminae are like *E. spatulatus*, the only difference being a slightly more broadly rounded dorsal profile. This plate appears to represent an unknown taxon at this time. It is the first reported occurrence of a Paleozoic specimen with a basic pattern of longitudinal canals throughout the plate. The silicified Permian *Ochmazochiton comptus* (Hoare and Smith 1984) from Texas, which has a longitudinal arrangement of the dorsal ornamentation and the oldest known insertion plates, may also possess a longitudinal canal system.

DISCUSSION

It is evident that thin sectioning of well-preserved fossil specimens of Paleozoic chitons will illustrate the aesthete canal system. Multiple sections cut at the same position in a plate may show differences in the preservation and attitude of the canal structure as well as variation in plate shape and thickness.

Initial sections cut in fragments of intermediate plates of *Acutichiton pyrmidalus* (Hoare, Sturgeon and Hoare 1972) and *Glaphurochiton carbonarius* (Stevens 1858) from the same locality as *E. spatulatus*, and from an undescribed species from the Permian of Texas show similar slightly curved canal structure. Atwater's (1979) study of the microstructure of *Gryphociton simplex*

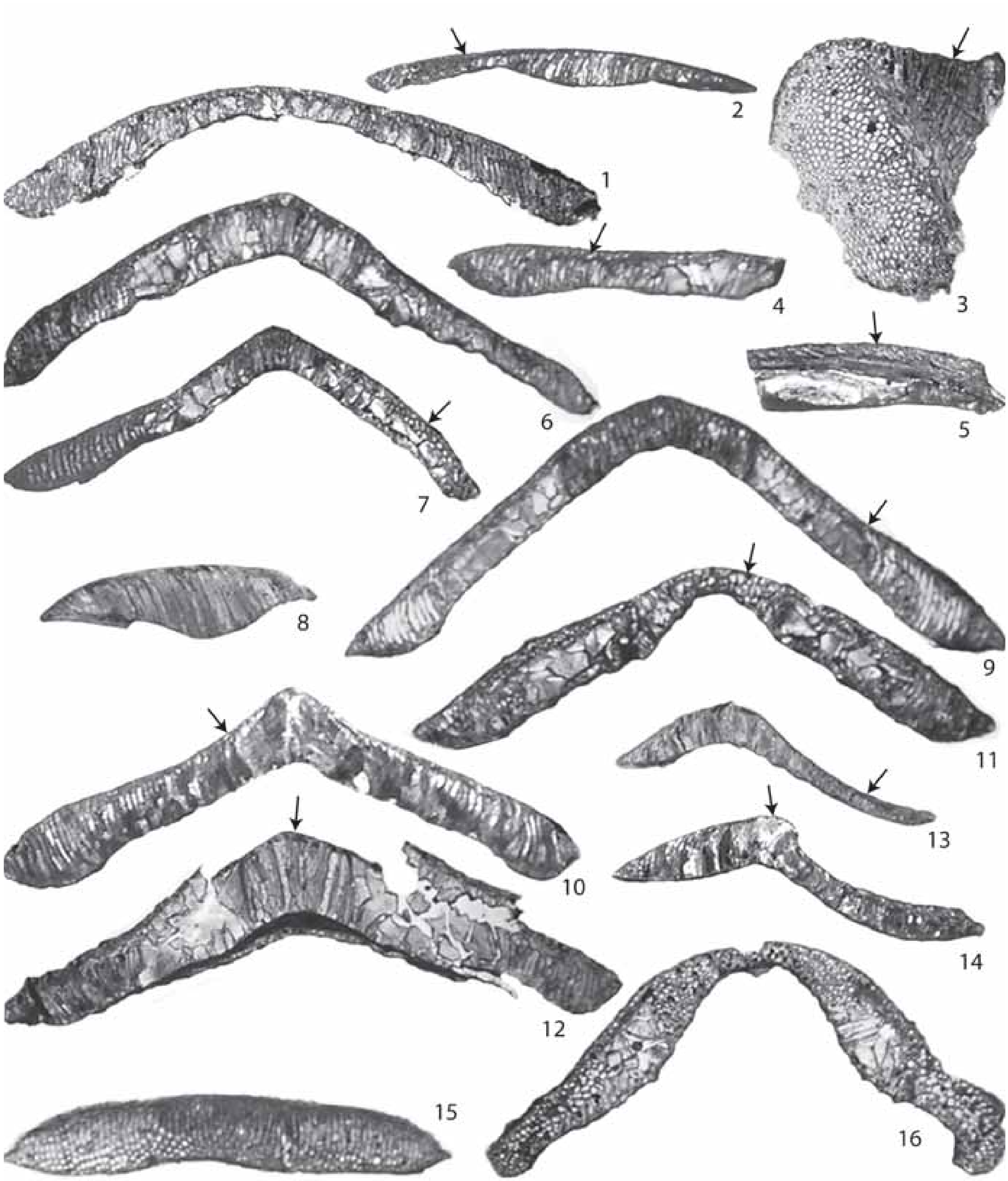

FIGURE 2. 1-15, thin sections of *Euleptochiton spatulatus*. 1(A), transverse section at mid-length of head plate, OSU 53471; 2(B), left lateral view near midline of head plate, OSU 53472; 3(C), horizontal section over left sutural lamina and portion of lateral area of intermediate plate, OSU 53474; 4(D), oblique section through portions of articulamentum layer and right lateral area of intermediate plate, OSU 53475; 5(C), right lateral view through left articulamentum layer and overlying hypostracum layer of intermediate plate, OSU 53476; 6,9(E), transverse sections near mid-point in the anterior half of intermediate plate, OSU 53477, 53478; 7(F), oblique section through intermediate plate, OSU 53479; 8(G), left lateral view near midline of intermediate plate, incomplete anteriorly, OSU 53490; 10(H), transverse section through mucro of tail plate, OSU 53481; 11(I), transverse section near anterior margin of tail plate, OSU 53483; 12(J), transverse section anterior to mucro of tail plate, OSU 53484; 13,14(K), left lateral views through mucro of tail plate, OSU 53486, 53485; 15(L), transverse section through posterior portion of tail plate, OSU 53488. 16, Unknown taxon, transverse section near mid-length of intermediate plate, OSU 53490. All figures x25.

(Raymond 1910), from the same Vanport locality, illustrates canals which are basically vertical and slightly curved. The spacing of the canals, as illustrated, appear wider than in *E. spatulatus*, which may be related to preservation of the specimens studied. The canals in these species are similar to those described by Bergenhayn (1930, p. 14, pl. 2), at least in the head plate, for modern lepidopleurid chitons. Sirenko (2006, p.44) places *Euleptochiton* in the suborder Lepidopleurina (Thiell 1910).

The canal system described above, except for the one specimen showing only longitudinal canals (Fig. 2.16), is significantly different from the dominantly horizontal arrangement in modern chitons as illustrated by Fernandez and others (2007) and Vendrasco and others (2008). No evidence for micraesthetes and megalaesthetes, present in the modern specimens, was seen in the Pennsylvanian specimens such as is illustrated by Sturrock and Baxter (1993) in the modern *Leptochiton asellus* which is classified in the same suborder as *E. spatulatus*. Whether this is due to preservation or non development is unknown.

Pojeta and others (in press) have described preserved aesthete canals in the Upper Cambrian chiton *Hemithecella eminensis* (Stinchcomb and Darrough 1995), from Missouri. These canals are horizontal extending laterally across the plates, not longitudinal lengthwise or vertical, so are much different than all other known orientations.

The canal system in sclerites of the Lower Cambrian *Sinosachites* recently described by Vinther (2009) is thought to be molluscan but not a chiton. This system, as illustrated, consists of a large central canal with numerous smaller canals branching laterally from both sides which then branch into several finer tubules near the lateral plate margins. This arrangement is somewhat similar to the canal system in the Multiplacophora (Hoare and Mapes 1995) which has been assigned to the chitons (Vendrasco and others 2004, Vinther 2009).

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