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Apriacma acoronata sp. nov., a new cupedid beetle (Coleoptera: Archostemata) from the Lower Cretaceous Jiufotang Formation of North China

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Abstract

Cupedidae is the most species-rich family within the extinct beetle suborder Archostemata, noted for its abundance, diversity, and broad geographic distribution in the Mesozoic. Although archostematans are relatively common in the Jehol Biota of northeastern China, most records to date have been recovered from the Yixian Formation. In this study, we report a new cupedid beetle fossil from the Jiufotang Formation. The new species, *Apriacma acoronata* **sp. nov.**, is characterized by an elongate body; long antennae with the pedicel distinctly shorter than the other antennomeres; large, flattened mandibles; a subrectangular prothorax slightly wider than the head, with gently curved lateral margins and lacking anterior corners; and distinctly stout profemora. This discovery constitutes the first record of Archostemata from the Jiufotang Formation, extending the stratigraphic and geographic distribution of cupedid beetles within the Jehol Biota, and contributes to our understanding of archostematan persistence and diversity in Early Cretaceous lacustrine ecosystems.

Key words: Insect fossil, Beetle, Jehol Biota, Xilongtou Basin, XRF

Introduction

Coleoptera (beetles) is not only the most species-rich extant insect order but also has an exceptionally abundant fossil record (Carpenter 1992; Eggleton 2020; Cai *et al*. 2022; Gui *et al*. 2024). Archostemata, one of the four extant beetle suborders, comprises only about 15 genera and roughly 50 extant species (Hörnschemeyer 2016; Li *et al.* 2019). Archostematan beetles first appeared in the Early Permian (Crowson 1962; Atkins 1963) and are often regarded as “living fossils” (Cai & Huang 2017; Jarzembowski *et al.* 2020). The group was remarkably diverse during the Mesozoic and experienced a rapid decline in both diversity and abundance by the Cretaceous (Soriano & Delclòs 2006; Friedrich *et al.* 2009; Li *et al.* 2023).

Archostemata fossils are relatively common in the Early Cretaceous Jehol Biota, but most come from the Yixian Formation (10 genera and 28 species recorded), with no prior records from the Jiufotang Formation (Ren *et al.* 2024). Here we describe a new fossil, *Apriacma acoronata*, as the first known Archostemata taxa from the Jiufotang Formation of Xilongtou basin, shedding new light on the Archostemata biodiversity evolution in the Jehol Biota.

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Material and methods

The study area is situated within the Lower Cretaceous Xilongtou Basin in Weichang County, Hebei Province, China (Fig. 1A). The Lower Cretaceous of the area, from bottom to top, comprises the Zhangjiakou Formation, Yixian Formation, and Jiufotang Formation (Regional Geological Survey Institute of Hebei Province 2024). The Zhangjiakou Formation is dominated by rhyolitic–quartz latitic pyroclastic rocks and lava flows. The Zhangjiakou Formation is fault-bounded against the overlying fourth member of the Yixian Formation, the massive grey to dark-grey andesite and latite with minor andesitic breccia and agglomerate, in the west, while the eastern contact is uncertain (Regional Geological and Mineral Survey Institute of Hebei Province 1996). The Jiufotang Formation conformably overlies the Yixian Formation and is subdivided into three members: Member I is composed of yellow-brown, grey-yellow, and grey-green polymictic conglomerate, tuffaceous conglomerate, and pebbly sandstone, intercalated with conglomeratic sandstone, siltstone, and shale. Member II consists of grey-yellow, grey-green, and grey-black (carbonaceous) shale, oil shale, siltstone, silty mudstone, and feldspathic sandstone, with lenses of conglomerate and pebbly sandstone. Member III comprises grey-white, yellowish-brown, and purplish-grey polymictic conglomerate interbedded with conglomeratic sandstone and sandstone (Regional Geological and Mineral Survey Institute of Hebei Province1996). The studied material was collected from the north of Dayuan Village, Xilongtou Township, where the section exhibits moderately continuous bedrock exposure (Fig. 1B). The base of the section is covered by upper Pleistocene loess and is not exposed, whereas the top reaches the yellowish conglomerate of Member III of the Jiufotang Formation. The fossil-bearing interval corresponds to Member II of the Jiufotang Formation (K_1j^2), where the strata form a gentle monocline dipping 6°–15° to the northwest with no significant deformation. The section comprises 14 beds, and the specimen was collected from the 11th bed, a yellow-grey argillaceous siltstone (Fig. 1C).

The chronological constraints of the Jiufotang Formation in the study area have not been well studied previously due to the lack of volcanic tuff beds. The K–Ar age of the andesite from the Yixian Formation in the Xilongtou area is 124.5 ± 2.8 Ma (Regional Geological and Mineral Survey Institute of Hebei Province 1996). The zircon dating from the adjacent Jianchang Basin in western Liaoning and northern Hebei indicates that the sedimentary strata of the Jiufotang Formation date to 122.0–118.9 Ma, corresponding to the latest Barremian–Aptian of the Early Cretaceous (Yu *et al*. 2021). The Jiufotang Formation of the Xilongtou Basin is likely of approximately the same age. However, the stratigraphic history of the Jiufotang Formation in Hebei Province is rather complicated, with numerous homonymous lithostratigraphic units referring to different lithologic intervals (Li, 1996). Many studies still employ divergent stratigraphic subdivision schemes (Pan *et al.* 2013; Qin *et al.* 2023; Regional Geological Survey Institute of Hebei Province 2024), and its correlations with the strata of western Liaoning remain to be further clarified.

Photographs were taken with the Axio Zoom.V16 microscope (Figs. 2, 3). Images were stacked in Helicon Focus 7.0.2 to extend the depth of field and further processed in Adobe Photoshop CC to enhance contrast. X-ray fluorescence (µXRF; Bruker M4 TORNADO) was also used to observe fine morphological structures and to map the elemental distribution of the fossil in situ (Fig. 4). The parameters of µXRF were configured as follows: the mapping parameters included a width of 318 pixels (12.659 mm), a height of 930 pixels (37.184 mm), a pixel size of 40 µm, and a total pixel count of 295740 pixels; the acquisition parameters covered a frame count of 1 and a pixel time of 10 ms per pixel; the detector parameter was a max. pulse throughput of 275000 cps. The holotype (HQDY2025023) is permanently deposited in the Regional Geological Survey Institute of Hebei Province, Langfang, China.

Systematic palaeontology

Order Coleoptera Linnaeus, 1758
Suborder Archostemata Kolbe, 1908
Family Cupedidae Laporte, 1836 sensu stricto
Genus *Apriacma* (Tan, Ren & Shin, 2006)

Type species. *Apriacma tuberculosa* (Tan, Ren & Shin, 2006)

Diagnosis. Body elongate, of medium size. Integument with moderately coarse sculpture and punctation; elytra with large subquadrangular (transverse) to polygonal cells arranged in nine long longitudinal rows and a short prescutellar row, interspaced by weak secondary and more prominent primary veins. Head with two pairs of subacute tubercles. Mandibles rather strong, arcuately curved along the outer edge, terminating in a stout bidentate apex. Antennae subfiliform and moderately long, less than half the total body length. Pronotum subtrapezoid, widening rectilinearly anteriad, with widely explanate sides. Prosternum anterior to procoxae markedly longer than procoxae. Elytra 2.2–2.5 times as long as wide combined, with subrectilinear lateral edges, subrounded to subacute apices, and apparently steeply (subvertically) sloping sides. Abdominal ventrites articulated without clear overlap; ventrite 1 subequal to or clearly longer than each of ventrites 2–4, and hypopygidium about as long as or longer than ventrite 1, with a rounded apex. Legs moderately slender, often comparatively long; protibia straight, tarsi narrow (Tan *et al*. 2006; Kirejtshuk *et al*. 2016).

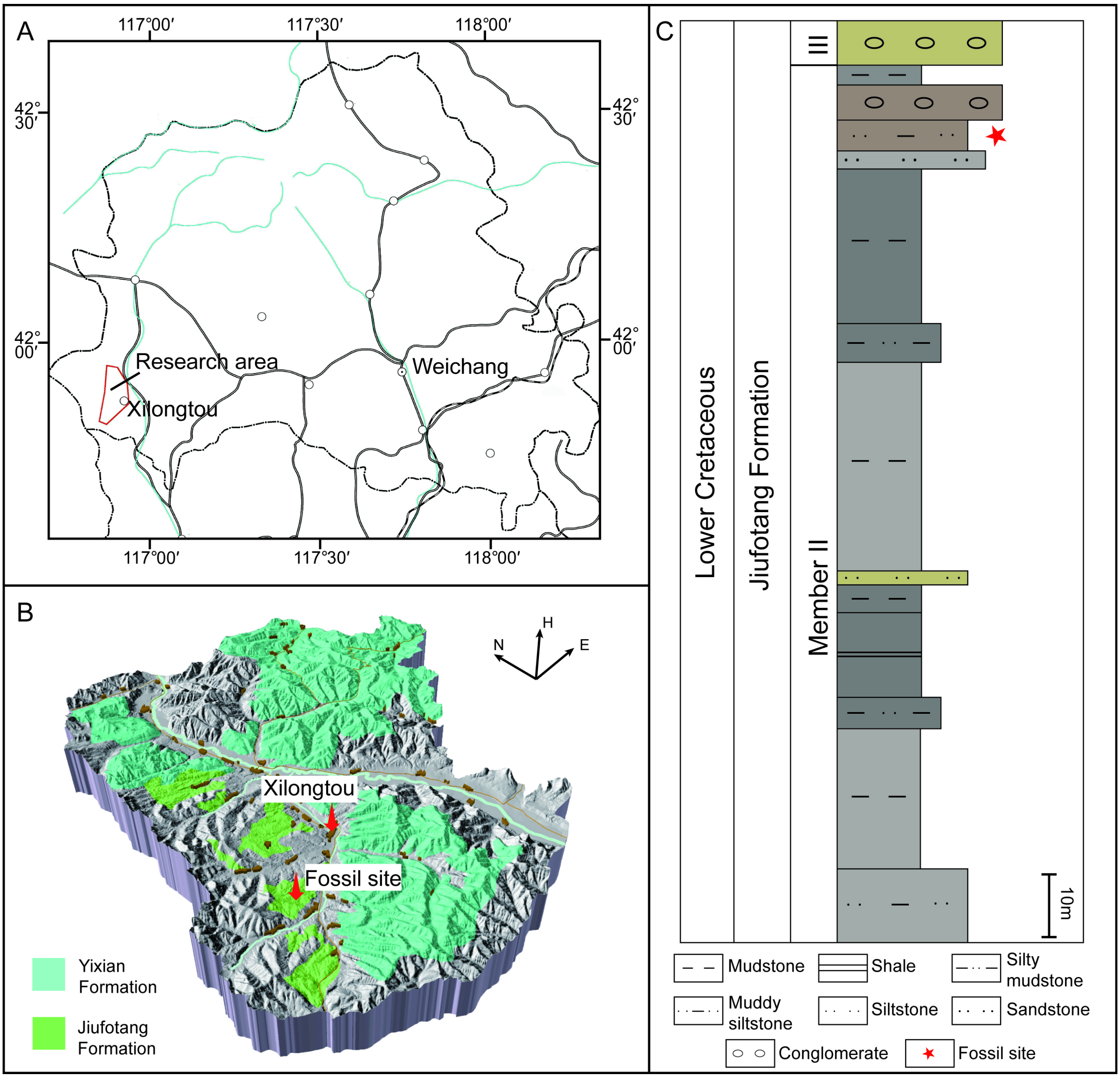

Figure 1. Location and stratigraphy of the study area. **A,** Map of the geographical location of the study area. **B,** 3D schematic diagram of the Xilongtou Basin. **C,** Stratigraphic column of the study section.

†*Apriacma acoronata* Gui & Cai sp. nov.
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(Figs. 2, 3)

Etymology. The species epithet *acoronata* is derived from the Latin prefix a- (without) and coronatus (crowned), referring to the pronotum of this species, which lacks anterior corners.

Material. Holotype, HQDY2025023. The fossil beetle is a well-preserved adult.

Locality and horizon. The fossil was collected near Dayuan Village, Xilongtou Township, Weichang County, Hebei Province, China; Jiufutang Formation, Lower Cretaceous.

Diagnosis. Body elongate. Antennae long, laterally inserted, and filiform, with 11 antennomeres; pedicel distinctly shorter than other antennomeres; flagellomeres subequal in length and apical antennomere rounded. Mandibles large and flattened. Prothorax subrectangular, slightly wider than the head, with lateral margins slightly curved and lacking anterior corners. Profemora distinctly stout.

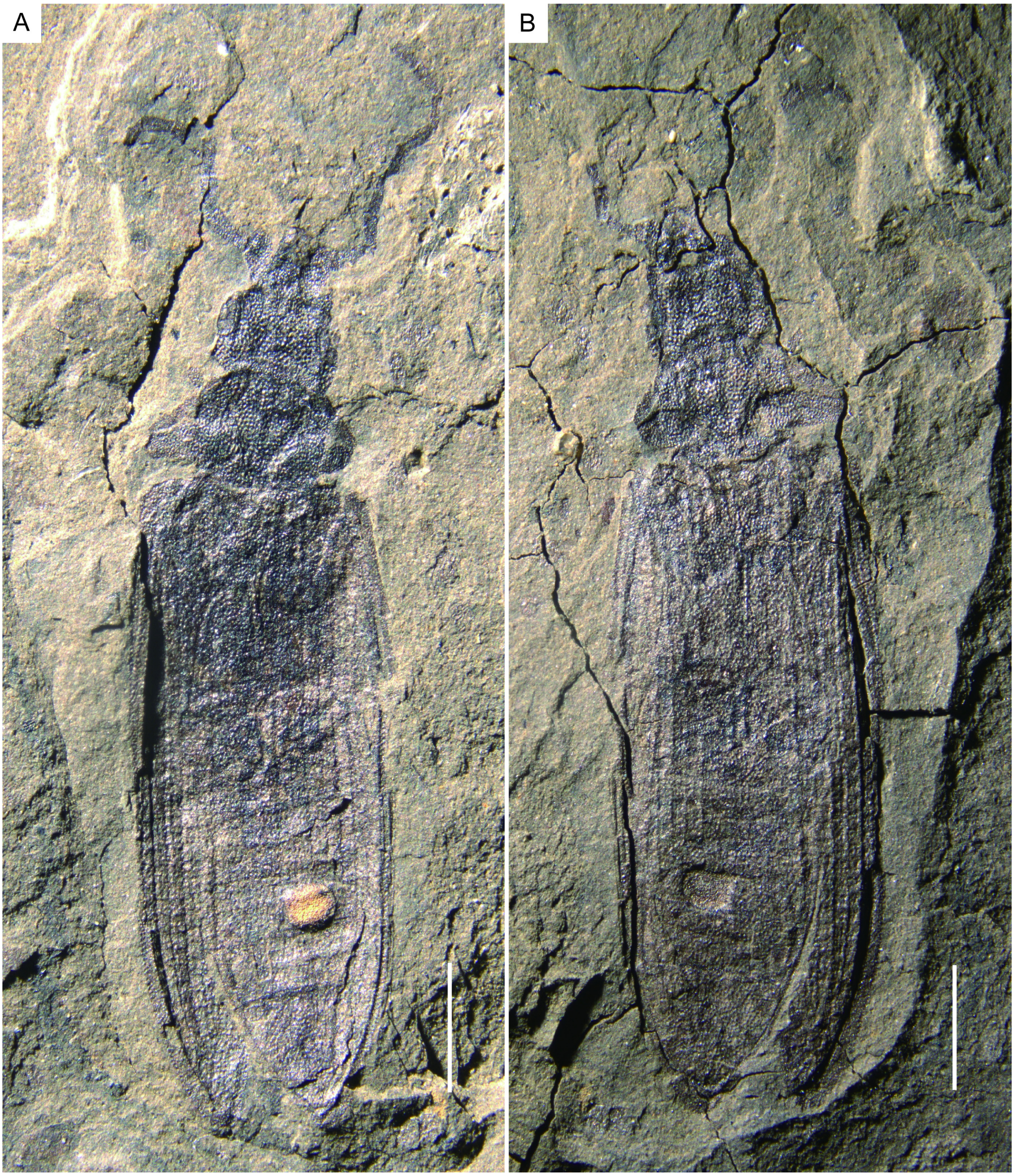

Figure 2. Photograph of *Apriacma* a*coronata* **sp. nov.**, holotype (HQDY2025023). Scale bars: 2 mm in **A**, **B**.

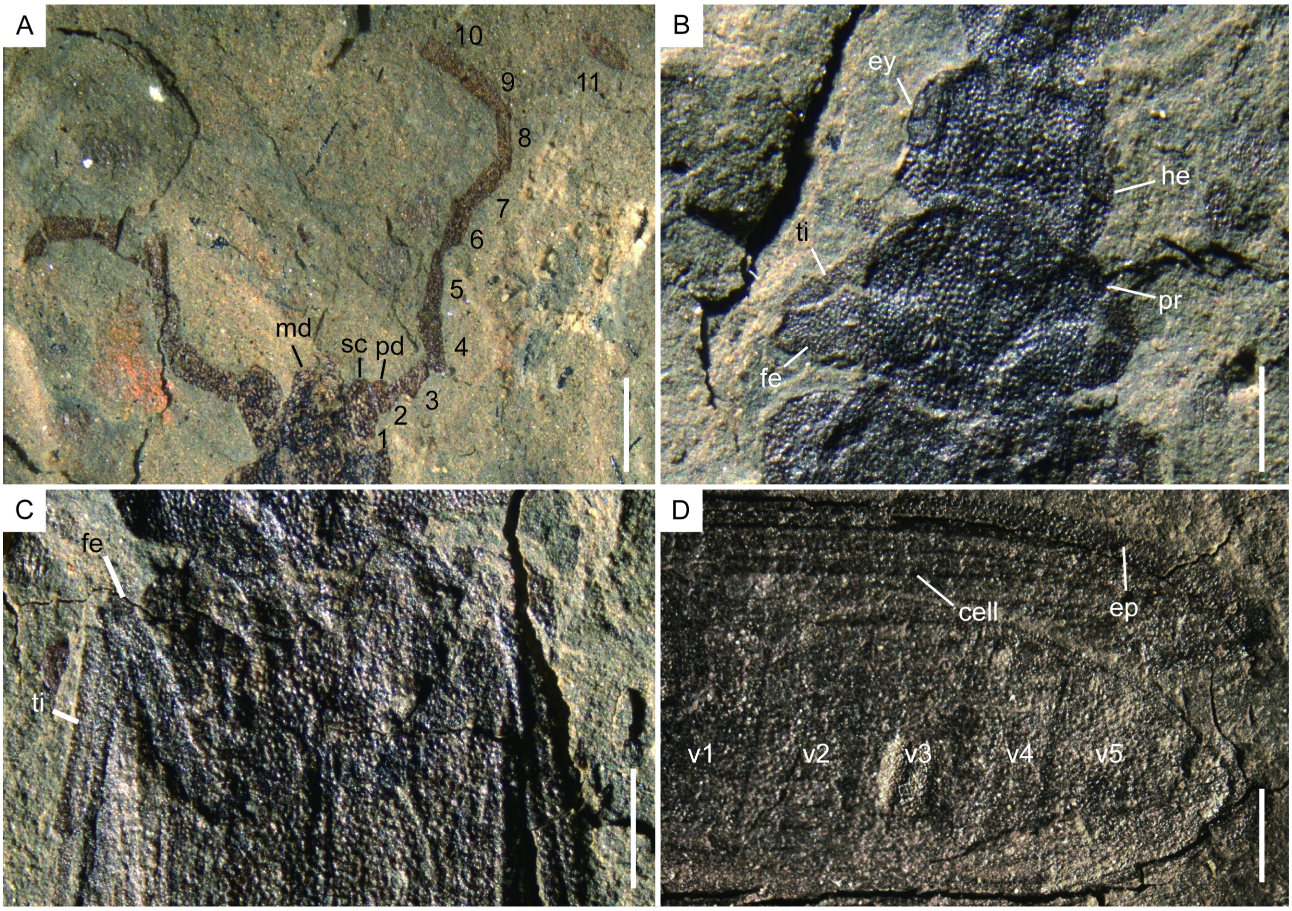

Figure 3. Detailed characteristics of *Apriacma acoronata* **sp. nov.**, holotype (HQDY2025023). Abbreviations: ep, epipleuron; ey, eye; fe, femur; he, head; md, mandible; pd, pedicel; pr, prosternum; sc, scape; ti, tibia; v, ventrite. Scale bars: 1 mm in **A**, **B**, **C**; 0.5 mm in **D**.

Description. Body elongate, 13.8 mm long, flattened. Head (Fig. 2) subtriangular, 2.2 mm long (including mandibles) and 2 mm wide; compound eyes approximately half the length of the head (excluding mandibles). Antennae (Fig. 3A) long, inserted laterally, approximately half the body length, with 11 antennomeres, filiform; scape broad and flattened; pedicel short; flagellomeres subequal in length, apical antennomere rounded. Mandibles (Fig. 3A) large and flattened. Prothorax (Fig. 3B) subrectangular, 1.6 mm long and 2.1 mm wide, slightly wider than head but narrower than elytra combined, without anterior corners; posterior tip blunt; lateral margins slightly curved. Prosternal process extending beyond the posterior margin of conical procoxae (Fig. 3B). Profemora stout. Elytra elongate, 9.8 mm long and 4 mm wide, with irregular and rounded window punctures (Fig. 3D). Abdomen elongate, apex acute and rounded, with five visible ventrites; ventrite 5 twice as long as ventrite 4; all ventrites except the first markedly depressed anteriorly and overlapping the successors from below.

Remarks. *Apriacma acoronata* **sp. nov.** shares many features with other species of the genus, but differs from *A. leconte* (Tan, Ren & Shin, 2006) by having larger compound eyes, a prothorax posteriorly not distinctly constricted with rounded anterior corners, and profemora markedly wider than tibiae; from *A. tuberculosa* by larger mandibles, a prothorax posteriorly not distinctly constricted with rounded anterior corners, and profemora markedly wider than tibiae; from *A. clavata* (Tan, Ren & Shin, 2006) by the shortest pedicel and a prothorax posteriorly not distinctly constricted with rounded anterior corners; and from *A. renaria* (Tan, Ren & Shin, 2006) by mandibles approximately as long as the head, the shortest pedicel, and a prothorax posteriorly not distinctly constricted with rounded anterior corners.

Elemental Enrichments. The distributions of S and Ca clearly delineate the body outline of *A. acoronata* **sp. nov.**, with the head, prothorax, antennae, and other regions appearing as distinct bright areas, and with overall elemental concentrations higher than those of the surrounding matrix (Fig. 4A, B). In contrast, Al and Si show markedly lower concentrations within the body than in the matrix, forming pronounced dark areas in the head and pronotal regions (Fig. 4C, D). The Fe signal in the head and prothorax is comparable to the background and thus difficult to distinguish; however, differences are observed in the elytra and abdomen, where Fe is enriched within the elytral cells, forming high-intensity (bright) areas (Fig. 4E). For other elements, such as Mn, Ti, Rb, Zn and K (Fig. 4F, G, H), *A. acoronata* exhibits no conspicuous contrast relative to the background.

Discussion

The generic name *Apriacma* is formed by combining the Greek privative prefix a**-** with the generic name *Priacma* (Kirejtshuk *et al*. 2016), indicating its connection with the extant genus *Priacma* LeConte, 1874. Four species were previously placed in *Apriacma*: *A. clavata*, *A. latidentata*, *A. renaria*, and *A. tuberculosa* (Ren *et al*. 2019), all originating from the Yixian Formation of Liaoning. They were initially assigned to *Priacma* because of the antennae being shorter than half of the body length, the interantennal distance being much greater than the eye diameter, the prosternal process only shallowly extending behind the coxae, and the pedicel being obviously shorter than the third antennomere as well as the anterior angles of the pronotum being sharp and projecting (Tan *et al*. 2006). Subsequent studies, however, revealed that these species differ markedly from *Priacma* in possessing apparently vertically sloping sides of the elytra, which show a simple edge (not thickened and not tuberculate), narrower tarsi, more or less open antennal insertions, and a Cupes-type aedeagus (Kirejtshuk *et al*. 2016; Li *et al*. 2019). Consequently, they were transferred to the new genus, *Apriacma* (Kirejtshuk *et al*. 2016). *A. acoronata* is likewise attributable to *Apriacma* owing to the simple lateral elytral margin and additional diagnostic features.

Compared with elemental distribution patterns documented for other fossils from the Jehol Biota, *A. acoronata* **sp. nov.** exhibits geochemical characteristics consistent with those of arthropod fossils, yet clearly distinct from vertebrate skeletal remains. Previous studies have demonstrated that in vertebrate fossils from the Jehol Biota, elements such as Ca, P, and Sr are closely associated with bioapatite in skeletal tissues, whereas metals including Fe, Mn, Ni, and Cu are commonly enriched in soft tissues or dark organic residues, reflecting elemental diffusion and retention during organic decay and subsequent diagenesis (Chen *et al.* 2023; Liu *et al*. 2024; Colombo *et al.* 2025). In contrast, arthropod fossils generally lack apatite-based skeletal tissues, and their elemental distributions are more commonly characterized by enrichments of S and K (Chen *et al.* 2023). In *A. acoronata*, enrichments of S and Ca clearly delineate the body and appendage outlines, whereas Al and Si are markedly depleted within the fossilized insect body, indicating that preservation was not achieved through simple siliceous or aluminosilicate infilling (Figs. 4C, D). This pattern is consistent with observations from other arthropod fossils in the Jehol Biota, in which S is closely associated with organic residues; however, unlike previously reported arthropod specimens, K does not show a pronounced enrichment in A. acoronata (Chen *et al.* 2023). Notably, Fe is not significantly enriched in the head or prothorax, but is instead concentrated within the elytra, particularly along the reticulate structures, suggesting a strong structural control on Fe distribution (Fig. 4E). Overall, the elemental distribution patterns of A. acoronata support a preservation mode dominated by organic residues with limited diagenetic replacement, and further highlight systematic differences in chemical preservation pathways between arthropods and vertebrates within the Jehol Biota.

It's worth noting that the Yixian and Jiufotang formations are the main strata of the Jehol Biota, which was initially characterized based on the *Eosestheria–Ephemeropsis–Lycoptera* assemblage at the end of the 20th century (Chen 1998; Pan *et al*. 2013). However, after several decades of continuous study, it has been recognized as a complex terrestrial biota distributed across northeastern Asia, comprising vertebrates, invertebrates, and plants (Zhou 2014; Shao *et al*. 2017). This biota includes feathered dinosaurs, birds, mammals, pterosaurs, lizards, turtles, choristoderes, amphibians, fishes, as well as abundant insects and flowering plants (Norell & Xu 2005; Meng 2014; Chiappe & Meng 2016; Zhou 2021). Consequently, the Jehol Biota has been acclaimed as a "world-class fossil treasure trove" and the "Pompeii of the Mesozoic" (Zhang *et al.* 2001). It is commonly subdivided into early, middle, and late stages (Qin *et al.* 2022), with more than 100 vertebrate species reported in total (Zhou & Wang 2017; Ren *et al.* 2019).

Among the various fossil groups, insects are undoubtedly the most significant in terms of both diversity and abundance and are collectively referred to as the Jehol Insect Fauna (Hong 1998; Zhang *et al.* 2010; Ren *et al.* 2024). Since 1995, insect fossils from the Yixian and Jiufotang formations were formally referred to the Jehol Biota (Ren *et al.* 1995, 1996, 2010). Since then, research on Jehol insects has expanded substantially, and by 2019 a total of 19 orders, 204 families, 573 genera, and approximately 862 species had been reported (Ren *et al.* 2019). Although numerous insects have been recorded from the Jehol Biota, most originate from the Yixian Formation, whereas insect fossils truly derived from the Jiufotang Formation remain exceedingly rare, with only 13 genera and 15 species reported (Ren *et al.* 2019, 2024; Zhang *et al.* 2024).

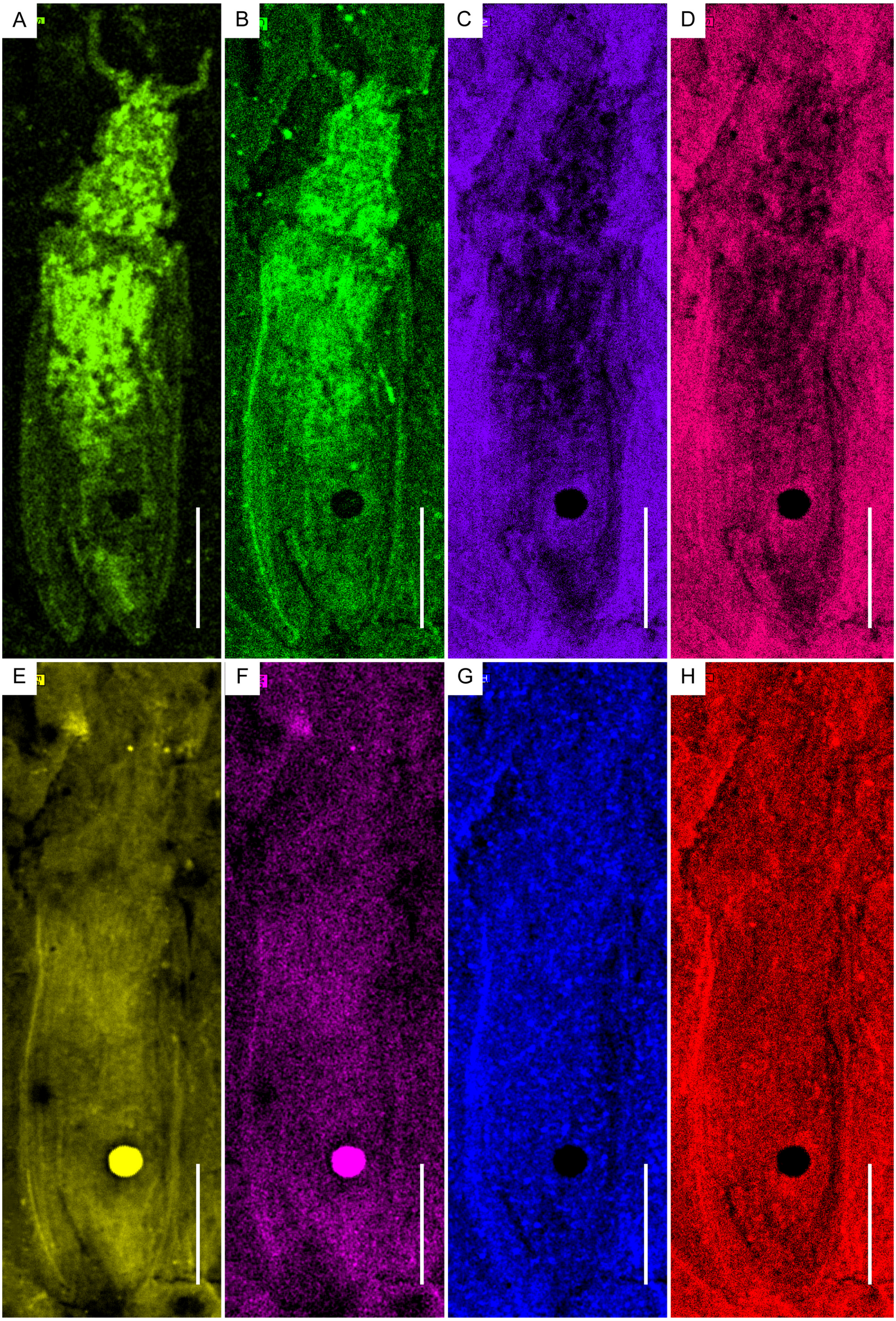

Figure 4. In situ elemental mapping images of *Apriacma acoronata* **sp. nov.** under μ-XRF. **A**–**H,** represent the elemental distribution maps of S, Ca, Al, Si, Fe, Mn, Ti and K, respectively, with higher brightness indicating higher element concentrations. Scale bar: 3 mm.

Archostemata fossils are relatively common in the Early Cretaceous, but most come from the Yixian Formation, with 10 genera and 28 species recorded, and no prior records from the Jiufotang Formation (Ren *et al.* 2024) until our discovery of *A. acoronata* **sp. nov.** from the Jiufotang Formation of the Xilongtou Basin. Thus, this discovery of our study represents the first record of Archostemata from the Jiufotang Formation, extending their known Mesozoic distribution. The same section and adjacent strata also yielded Neuroptera, Orthoptera, and Ephemeroptera, along with fishes, gastropods, bivalves, leafhoppers, various plant macrofossils, and abundant plant debris. Together, these finds indicate that the Jiufotang Formation also has high biodiversity, though further research is needed to clarify its ecological and environmental context.

Conclusion

We report a new species of Cupedidae from the Lower Cretaceous, representing the first record of the suborder Archostemata from the Lower Cretaceous Jiufotang Formation. *Apriacma acoronata* **sp. nov.** is assigned to *Apriacma* based on the following diagnostic characters: elongate body; long antennae with the pedicel distinctly shorter than other antennomeres; mandibles large and flattened; prothorax subrectangular, slightly wider than the head, with slightly curved lateral margins and lacking anterior corners; and distinctly stout profemora. This discovery not only enriches the known diversity of insects in the Jehol Biota but also extends the geographic and stratigraphic distribution of archostematous beetles.

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