Cretaceous Research 100 (2019) 46–50

Contents lists available at ScienceDirect

Cretaceous Research

journal homepage: www.elsevier.com/locate/CretRes

Short communication

The first corydalid larva (Megaloptera: Corydalidae) with gut-contents from the Early Cretaceous Jehol biota of northeastern China

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ARTICLE INFO

Article history:
Received 5 December 2018
Received in revised form
11 February 2019
Accepted in revised form 15 March 2019
Available online 21 March 2019

Keywords:
Gut contents
Corydalid
Megaloptera
Cretaceous
Jehol biota

ABSTRACT

The fossil record of the family Corydalidae (Megaloptera) is rare with only six reported species and several undescribed larvae from the Middle Jurassic to Eocene. Little is known about the food habits and digestive system of ancient insects. We report the first corydalid larva preserved with gut contents from the Lower Cretaceous Yixian Formation of northeast China, examining the contents using a scanning electron microscope with energy dispersive X-ray analysis. The results show that the main component of the gut contents is quartz gastroliths ('stomach stones'), providing the first fossil evidence of a gastric mill promoting digestion in a megalopteran larva, extending the record of this behaviour to the Early Cretaceous.

1. Introduction

Megaloptera is a small insect order containing more than 300 living species (Cover and Resh, 2008). They are generally considered to be among the most primitive of the neuropterid holometabolous insects, but their systematic relationships with Raphidioptera and Neuroptera remain unclear (New and Theischinger, 1993; Beutel and Friedrich, 2008). Their larvae are powerful, active predators (Neunzig and Baker, 1991), mostly restricted to lentic habitats with minimal water movement (Cuyler, 1958) and with well-developed chewing mouthparts and lateral gills. The order contains two extant families, the Sialidae (alderflies) and Corydalidae; the latter is subdivided into the subfamilies Corydalinae (dobsonflies) and Chauliodinae (fishfllies).

The earliest megalopteran fossils were reported from the upper Permian of Russia and Mongolia and attributed to an extinct family, Parasialidae (Ponomarenko, 1977, 2000). Corydalidae are very rare in the fossil record, with only two reported species (*Jurochauliodes ponomarenkoi* Wang & Zhang, 2010 and *Eochauliodes striolatus* Liu, Wang, Shih, Ren & Yang, 2012) from the Middle Jurassic of China; two species (*Cretochaulus lacustris* Ponomarenko, 1976, *Chauliosialis sukatshevae* Ponomarenko, 1976) from the Early and Late Cretaceous respectively of Russia; and two species (*Chauliodes prisca* Pictet and Haǵen, 1856, *Chauliodes carsteni* Wichard, 2003) from Eocene Baltic amber. In addition, several

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https://doi.org/10.1016/j.cretres.2019.03.015
0195-6671/

undescribed larvae were mentioned in Ponomarenko (2002). Though carnivorous, little is known about the alimentary system and food habits of Corydalidae from the fossil record. We report the first corydalid larva preserved with gut contents from the Lower Cretaceous Yixian Formation of China, revealing a hundred and twenty million year old dependence on gastroliths as in some crustaceans and reptiles.

2. Material and methods

The specimen was collected from the Lower Cretaceous Yixian Formation of Yangshuwanzi Village in Inner Mongolia (Fig. 1). The sedimentary strata of the Yixian Formation are grey (less weathered) or yellow (weathered) mudstones (Ohta et al., 2011). The age of the Yixian Formation is radiometrically dated to ca. 129.7–122.1 Ma (Barremian to early Aptian), and the mean annual palaeotemperature is commonly interpreted as ca. 10 ± 4 °C., i.e., a temperate climate (Chang et al., 2003; Chang et al., 2009; Zhang et al., 2010; Amiot et al., 2011). The specimen is pyritized and incomplete, being preserved in lateral aspect with deformed head and waterlogged abdominal segments, but nevertheless with entrails intact.

The specimen was examined using an optical microscope and the photographs were taken using a ZEISS Stereo Discovery V16 microscope system. The specimen was further examined uncoated using a scanning electron microscope (LEO1530VP SEM) with energy dispersive X-ray analysis at variable voltages; microsurface information was obtained in the low vacuum mode (100 pa in sample chamber) with an accelerating voltage of 5–20 KV (Orr et al., 2009). The SEM analyses were performed in the State Key Laboratory of Palaeobiology and Stratigraphy, Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences (NIGPAS). Line drawings were adjusted with image editing software (CorelDraw X7). The specimen (NIGP154958) is deposited in the Nanjing Institute of Geology and Palaeontology (NIGP), Chinese Academy of Sciences.

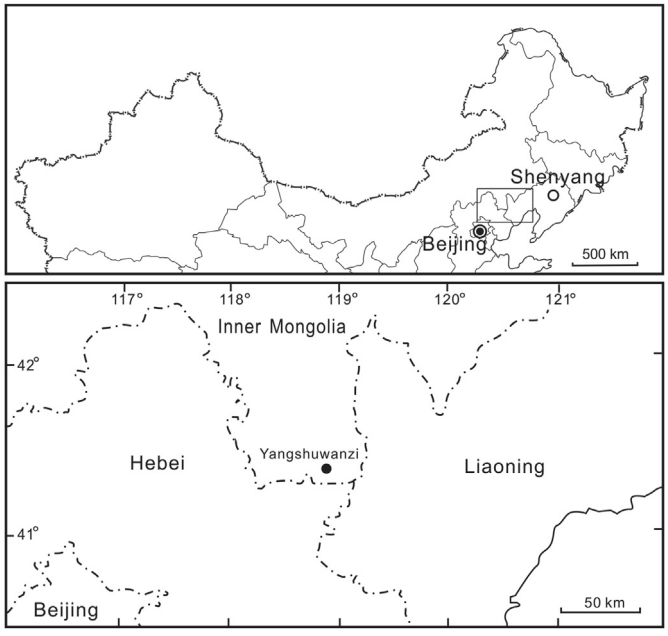

Fig. 1. Map showing the location of the fossil locality (Yangshuwanzi village in close-up).

3. Results and discussion

The body is large and elongate (Fig. 2), its length is 52.3 mm; head and thoracic terga are well sclerotized, other body parts slightly sclerotized. The pronotum, mesonotum and metanotum are gradually reduced in size; the length of the pronotum is 4.97 mm, mesonotum 2.56 mm, and metanotum 1.86 mm. The abdomen has 10 segments; the X abdominal segment is shortest and IV is largest; the X abdominal segment has two pairs of hooks, one pair of anal prolegs and each proleg bears two strong claws and a filament. The claws of the prolegs narrow apically and are slightly curved. The filament is about 1.45 mm and claws are about 0.9 mm long; the trachea and spiracles of abdominal segments II-VII are distinct. Small gastroliths are present in crop and alimentary tract (Fig. 2A).

The insect undoubtedly belong to Corydalidae as evidenced by the combination of the following characters: body large; long head; prothoracic segment long, ratio of mesonotum and metanotum to pronotum 0.49:1 and 0.36:1 respectively; last abdominal segment with two pairs of hooks and a pair of anal prolegs bearing claws (New and Theischinger, 1993). It can not be assigned to Chauliodinae or Corydalinae by the presence or absence of ventral gill tufts because we are not sure if they are truly absent or just not preserved (New and Theischinger, 1993).

This specimen retains some contents of the crop and gut opening a new window for studying the food habits of Corydalidae larvae. The contents, where preserved, can be identified based on comparison with the alimentary tract of living megalopteran larvae. There a mass of contents preserved in the crop and many scraps in the gut (Fig. 3), and this distribution is the same as that of the living larva *Neoneuromus ignobilis* Navás, in which gastrolithic sand grains are gathered in the crop with a few in the gut (Chen et al., 2011). Our energy dispersive X-ray analysis results show that the most abundant elements are oxygen and silicon (Fig. 3J–L), with the former more than double by weight, which indicates that the inclusions are most likely quartz (SiO_2).

Quartz is a stable mineral which would pass through the system, and it is difficult to visualise silicification of ingested food or faeces in a pyritic anaerobic setting (vide Wang et al., 2012 cited). Also, oxidation would generate gypsum which is absent in our analysis. Combining the evidence that the living species (*Neoneuromus ignobilis* Navás) feeds on sand, we believe that the inclusions of gut in our specimen are most likely to be left by the larvae feeding on the sand.

Gastroliths have typically been found in both living and fossil vertebrates, including birds, with trituration and mixing of foodstuff being their generally accepted function (Wings, 2007). However, little is known about gastroliths in fossil invertebrates so far. The fragmented quartz sand preserved as gut contents in our unique specimen was probably also used for assisting digestion.

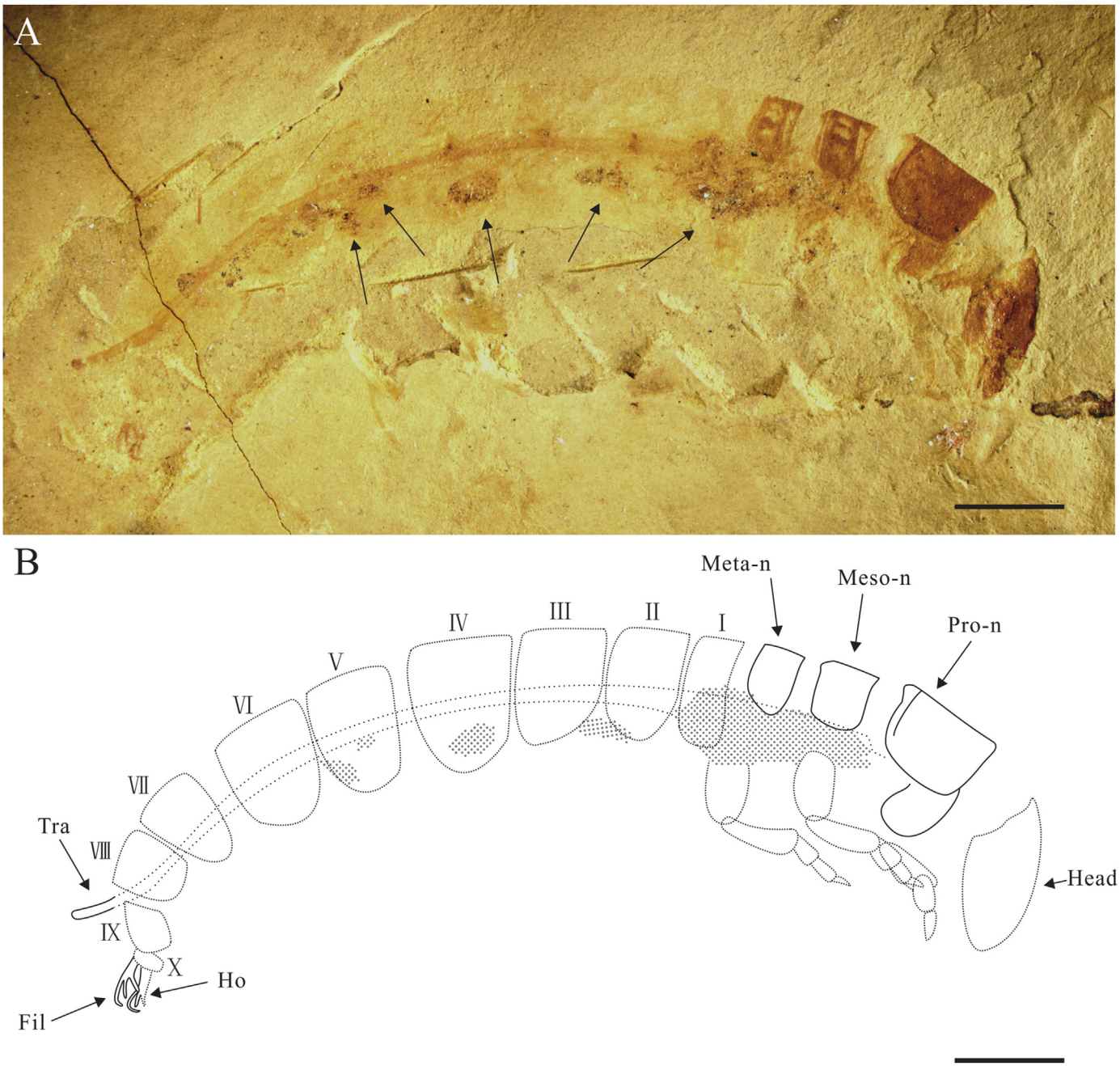

Fig. 2. Corydalid larva, NIGP154958. A, Body, gut inclusions indicated by arrows; B, Line drawing. Pro-n, pronotum; Meso-n, mesonotum; Meta-n, metanotum; Tra, trachea; Fil, filament; Ho, hook; gut inclusions indicated by grey hatching. Scale bars represent 5 mm.

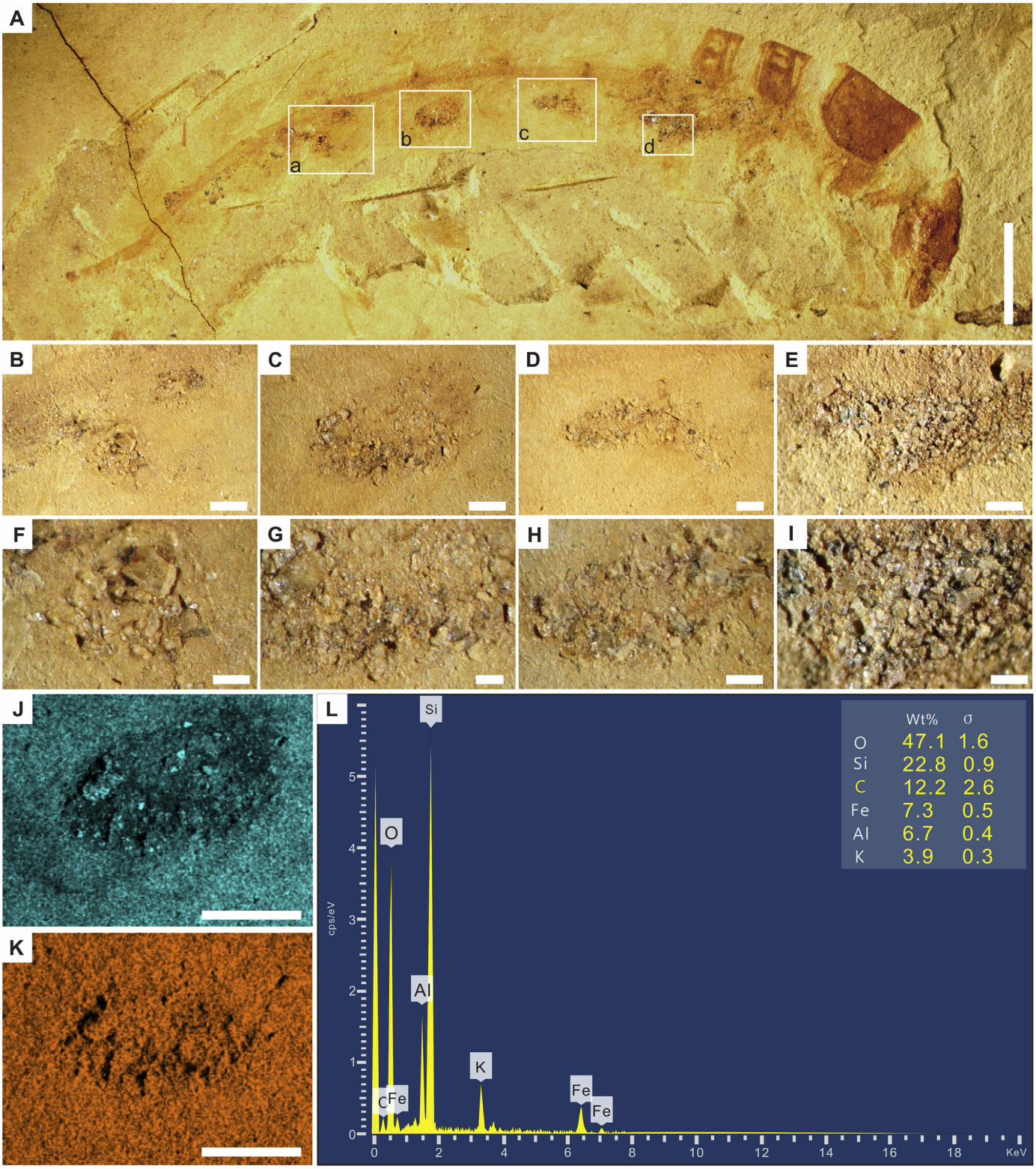

Fig. 3. Corydalid larva, NIGP154958. A, Light photomicrograph; B-E, magnifications of areas shown by white squares in A as follows: B–a; C–b; D–c; E–d; F–I; higher magnifications of B-E as follows: F–B; G–C; H–D; I–E; J–K and also, BSE image, Si and O maps of box a; L, elemental composition. Scale bars represent 5 mm in A; 1 mm in B-E and J-K; 0.5 mm in F.

4. Concluding remarks

The first fossil corydalid preserved with gut contents is described in this paper. The quartz grains distributed in the gut as in a recent relative were probably also used for assisting digestion and are sandy gastroliths. Our find extends the record of this ingesting behaviour in corydalid larva to the Early Cretaceous and reveals stasis in the feeding behaviour of megalopteran larvae dating back to the late Mesozoic.

Acknowledgements

We are grateful to two anonymous reviewers for useful suggestions to the manuscript. This research was supported by the Strategic Priority Research Program (B) of the Chinese Academy of Sciences (XDB26000000), the National Natural Science Foundation of China (41572010, 41622201, 41688103, 41502019), grants from the Key Laboratory of Zoological Systematics and Evolution of the Chinese Academy of Sciences (No. Y229YX5105), the State Key Laboratory of Palaeobiology and Stratigraphy (Nanjing Institute of Geology and Palaeontology, CAS) (No. 183101), the National Key Research and Development Program of China (2016YFC0601001) and SENS Research Foundation (2015RCJJ009, 2015YQJH102, 2015TDJH101). This is a Leverhulme Emeritus Fellowship contribution for EAJ.

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