

Rediscovery of the Mathieu collection of Carboniferous (Pennsylvanian)–Permian (Cisuralian) arthropods from the Kaiping Coalfield (northeastern China)

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ABSTRACT

Numerous arthropods (e.g. branchiopods, insects) collected during the first half of the 20th century by F.-F. Mathieu within the Pennsylvanian–Cisuralian (Moscovian–Asselian) succession of the Zhaogezhuang colliery (Hebei Province, China), romanised notably as Chao Ko Chwang, or Chaokochuang, in the literature, have been recently located in the palaeontological collections of the Royal Belgian Institute of Natural Sciences (Brussels). This historical material from one of the classic localities of the Kaiping Coalfield includes a large number of wings of stem-Dictyoptera, mainly from the Tangshan Formation and to a lesser extent from the Kaiping and Zhaogezhuang formations. The exceptional richness in insects of a particular horizon developed within the Moscovian part of the Tangshan Formation was already pointed out at the end of the 1920s by the French palaeoentomologist P. Pruvost, who provided the first account on the arthropods of Mathieu’s collection from the Kaiping Coalfield. This singular Dictyoptera material was later studied by D. Laurentiaux in his unpublished Ph.D. thesis. In order to promote the revision of Mathieu’s collection by specialists, we provide here a detailed scientific background and re-illustrate the arachnids (and formerly alleged ones: (*Poliochera* vel *Curculioides*) [sic] *pustulatus* Laurentiaux-Vieira & Laurentiaux), branchiopods (*Lioestheria? mathieui* (Pruvost)), and insects from the Zhaogezhuang colliery, notably using the Reflectance Transformation Imaging methodology.

KEYWORDS

Moscovian–Kasimovian,
Gzhelian–Asselian,
Arachnida,
Branchiopoda,
Insecta,
Hebei Province

Article history

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1. Introduction

The Kaiping Coalfield, where the industrial mining of the Pennsylvanian and Cisuralian coals started during the last quarter of the 19th century (Carlson, 1971), is situated in Eastern Hebei Province (northeastern China), E-SE of Beijing (Han et al., 2016) (Fig. 1A–C). In this area, the onset of palaeontological research dates back to Schenck (1883), who described the plants collected by the German geologist Friederich von Richthofen. This is also in this coalfield that the first occurrence of eurypterid (*Adelophthalmus chinensis* (Early Permian); e.g. Tetlie et al., 2007) was reported in China (Andersson in Grabau, 1920a; Grabau, 1920b).

Carboniferous and Permian arthropods from the Kaiping Coalfield were briefly documented by Pruvost (1928) on the basis of specimens gathered by Fernand-François Mathieu (1886–1958), who was employed as a geologist and consulting engineer by the Kailin Mining Administration—the consortium

exploiting the mines at Kaiping along the Beijing–Shenyang railway (Carlson, 1971)—between 1920–1926 and 1946–1949 (Sluys, 1959). The latter contributed largely to the knowledge of the geology of the Kaiping Coalfield as reflected by the numerous papers he dedicated to this subject (Mathieu, 1921, 1922, 1923a, 1923b, 1923c, 1927, 1928a, 1928b, 1939, 1955; Mathieu in Grabau, 1920b; Stockmans & Mathieu, 1939, 1957).

Although several authors pointed out the importance of the discovery of many insects in the Kaiping Coalfield (Mathieu, 1927, 1928a, 1939; Pruvost, 1928; Laurentiaux, 1947a, 1958), the historical material collected by Mathieu has never been properly documented, except in the unpublished Ph.D. thesis of Laurentiaux (1958); therefore, it remains largely unknown to specialists, most likely because the whole material was borrowed for almost 40 years by the latter in three separate loans (1946, 1947, and 1951), preventing investigations by other experts. According to a letter written by P. Sartenaer to

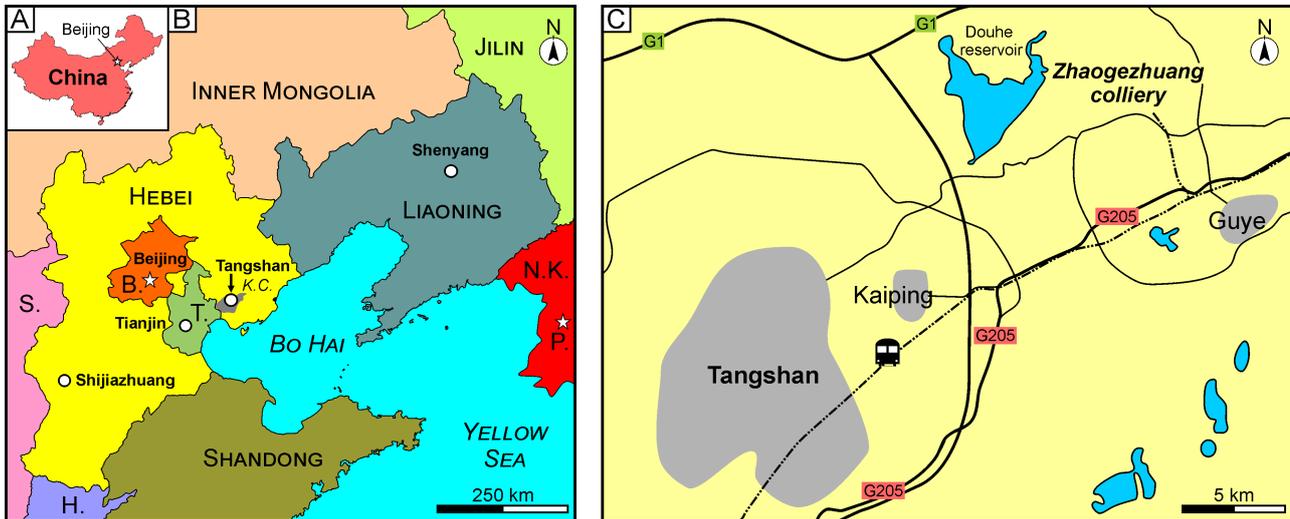


Figure 1. A. Map of China. B. Map of northeastern Chinese municipalities and provinces with location of the town of Tangshan in the Hebei Province; the location of the Kaiping Coalfield is adapted from Han et al. (2016). C. Location of the Zhaogezhuang (Chaokouchung; 赵各庄) colliery. Abbreviations: B., Beijing Municipality; H., Henan; K.C., Kaiping Coalfield; N.K., North Korea; P., Pyongyang; S., Shanxi, T., Tianjin Municipality.

D. Laurentiaux in July 1972, it appears that the latter submitted a manuscript to V. Van Straelen for review in the late 1950s or early 1960s but, as the circumstances of the time were not very favourable, the manuscript, which was not found in the archives of the Royal Belgian Institute of Natural Sciences, remained in abeyance and was never published.

A search for the type material of the insects of the Belgian Coal Measure Group (Bashkirian–Moscovian; Namurian–Westphalian of the traditional subdivision) deposited at the Royal Belgian Institute of Natural Sciences allowed us to rediscover the forgotten Mathieu collection of Chinese Carboniferous and Permian arthropods. As discoveries of abundant insects were reported recently by Liao et al. (2019) and Wang et al. (2022) from the Kaiping Coalfield, it seemed relevant to shed new light on Mathieu’s collection. Therefore, this contribution aims at (1) documenting the types and illustrated specimens included in the collection, and (2) highlighting the historical and scientific importance of this collection, especially for the knowledge of the Carboniferous of China. We provide Reflectance Transformation Imaging (RTI) of some well-preserved or enigmatic specimens, that we think may be of immediate interest for research (see online Supplementary material).

2. Previous studies on Mathieu’s palaeontological collection of the Kaiping Coalfield

So far, the Mathieu collection is especially known for its palaeobotanical content thanks to the exquisitely illustrated monographs by Stockmans & Mathieu (1939, 1957), complemented by a study by Piérart (1961) on megaspores. Marine invertebrates were identified by Delépine (1928), whereas the continental fauna was discussed by Pruvost (1928). However, only the branchiopods (‘conchostracans’) were illustrated by the latter and by Defrise-Gusshoven & Pastiels (1957). Among the continental fauna, the presence of insects (stem-Dictyoptera) is remarkable (Pruvost, 1928; Mathieu, 1939; Laurentiaux, 1947a, 1958). Scorpions were cited by Pruvost (1928) and described by Laurentiaux-Vieira & Laurentiaux (1963), who also described an alleged ricinuleid (see section 5.2.4). Unfortunately, the eurypterids reported by Pruvost (1928) and Mathieu (1939) have not yet been located, nor any of the trilobites referred to by Delépine (1928) (see section 3).

3. Geological setting

The Kaiping Coalfield (Fig. 1B) corresponds to a large northeast-trending coal-bearing syncline structure, which includes four coal-bearing synclines according to Han et al. (2016, figs 1–2). The material was collected by F.-F. Mathieu at the Zhaogezhuang (Chaokouchung; 赵各庄) colliery either in the mine itself or on the spoil heap (Fig. 1C). Note that the romanisation of the geographic name Chaokouchung has led to different transcriptions for this locality (Zhang, 2009), e.g. Chaokouchuang (Grabau, 1920a), Chao-Ko-Chwang (Mathieu, 1928a), Chao Ko Chwang (Mathieu, 1939), Chao-ko-chuang (Carlson, 1971), and Chaokochuang (Li & Zhang, 1983). Mathieu (in Grabau, 1920b) and Mathieu (1927, 1928a, 1939) subdivided the lithological succession observed in the coal mine into three ‘assises’, from base to top: ‘assise de Tongshan (ou Tangshan)’, ‘assise des 14^{es} couches’, and ‘assise de Chao Ko Chwang’ (Figs 2A, 3). Nowadays, there is no consensus on the lithostratigraphic terminology to be adopted because several formation names are applied to the same units (e.g. Liao et al., 2019; Shen et al., 2022). We adopted that proposed by Gao et al. (1983) and Li & Zhang (1983) (see Shen et al., 2022, fig. 9) (Fig. 3).

The bulk of the arthropods is from the former ‘assise de Tongshan’ that corresponds to the Penchi Formation (Lee & Chao, 1926) (see Gao et al., 1983) or to the Tangshan Formation (e.g. Li & Zhang, 1983; Shen et al., 2022) (Figs 2A, 3). According to Mathieu (1939), this c. 70 m-thick unit essentially comprises shales and siltstones with three marine limestone beds and a few thin coal seams. Its base is characterised by the presence of an oolitic ironstone horizon (Mathieu, 1928b). The age of the Tangshan Formation is Moscovian to Gzhelian (Shen et al., 2022). All the insects collected *in situ* are from the roof of the 16th coal seam, exploited at the fourth floor of the mine, mostly in the western mining gallery, the rest in the eastern one (Fig. 2A–C) according to Mathieu (cited by Laurentiaux, 1958). They were complemented by *ex situ* findings made on the spoil heap (Laurentiaux, 1958). Their age is most likely Moscovian, although a Kasimovian age cannot be ruled out (Shen et al., 2022). Eurypterids were cited by Pruvost (1928) and Mathieu (1939), whereas Delépine (1928) reported the presence of trilobites in the first marine limestone horizon (ML 1 in Fig. 2B–C).

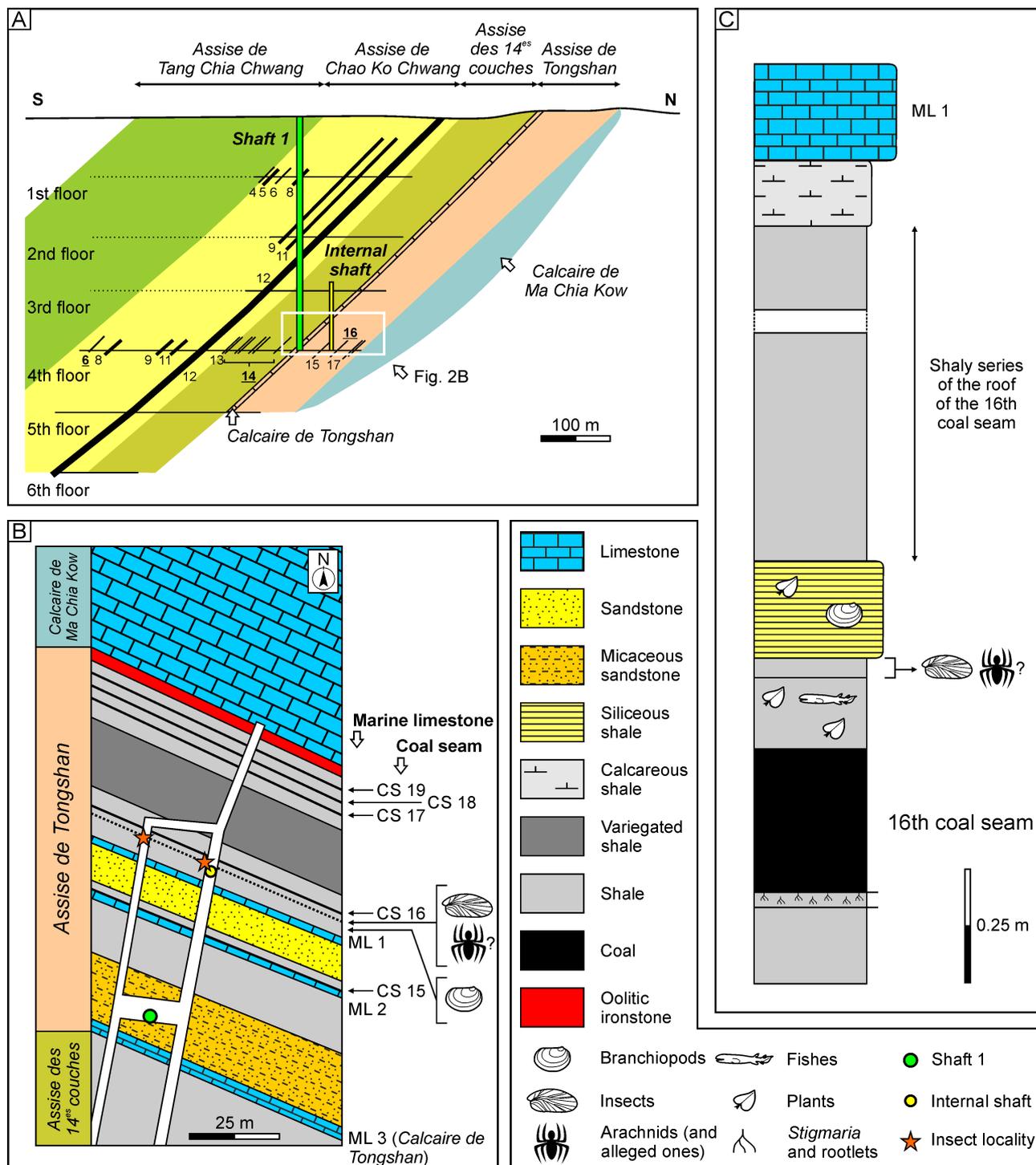


Figure 2. A. Cross-section of the Zhaogezhuang coal mine (simplified from Mathieu, 1939) (see Fig. 3 for current lithostratigraphic units). B. Geological scheme of the fourth floor of the Zhaogezhuang coal mine (modified from Mathieu, 1939 and Laurentiaux, 1958). C. Log of the succession observed above the 16th coal seam (Laurentiaux, 1958).

The ‘assise des 14^{es} couches’, which corresponds to the Gzhelian Kaiping Formation (Gao et al., 1983; Shen et al., 2022) (Fig. 2A, B), consists of sandstones, micaceous sandstones and shales, and attains c. 60 m in thickness. It includes four to five irregular and unexploitable thin coal seams. From it, only one poorly preserved insect wing was reported by Mathieu (1928a, 1939) and Pruvost (1928). Mathieu (1939) reported the presence of ‘*Eurypterus*’.

The ‘assise de Chao Ko Chwang’, i.e. the Zhaogezhuang Formation of Gzhelian–Asselian age (e.g. Li & Zhang, 1983; Shen et al., 2022), comprises sandstones, shales and exploitable

coal seams. As is the case for the previous lithostratigraphic unit, only a limited number of insect wings, one or two depending on the authors, was found in the roof of the 6th coal seam (Mathieu, 1928a, 1939; Pruvost, 1928). The eurypterid *Adelophthalmus chinensis* (Grabau, 1920a) was found one meter above the 13th coal seam (Andersson in Grabau, 1920a; Grabau, 1920b) (Fig. 2A).

Sy.	Su.	Series	Stage	Formation (Shen et al., 2022)	Mathieu's (1939) 'assise'	Mathieu's arthropod collection		
PER. CARBONIFEROUS	Pennsylvanian	Cisuralian	Asselian	Damiaozhuang	Tang Chia Chwang	(6th coal seam) ← 		
			Gzhelian	Zhaogezhuang	Chao Ko Chuang	←  (unspecified level)		
		Upper	Kasimovian	Kaiping	14 ^{es} couches	Tongshan (ou Tangshan)	?    ? (roof of the 16th coal seam)	
			Moscovian					
		Middle	Bashkirian	Fengfeng	Calcaire de Ma Chia Kow	Legend:  Branchiopods  Insects  Arachnids (and alleged ones)		
							Lower	
		ORDOVICIAN						

Figure 3. Comparison of the lithostratigraphical units used in Shen et al. (2022) and in Mathieu (1939) with approximative stratigraphic position of the arthropods of Mathieu's collection.

4. Material and methodology

All the illustrated specimens are part of the palaeontological collections of the Royal Belgian Institute of Natural Sciences (prefixed RBINS), Brussels. Except for the branchiopods (IG 14529), they are all registered under the general inventory number IG 11471 and were offered to the RBINS by F.-F. Mathieu in February 1938. As indicated above, several arthropods and the rest of the fauna described by Delépine (1928) and Pruvost (1928) from the Kaiping Coalfield have not yet been recovered from the RBINS collections but they may have been included in the c. 8000 uncatalogued drawers of the collection of the 'Centre national de Géologie houillère' (Pastiels, 1960) that are now deposited at Péronnes-lez-Binche (Belgium) (Mottequin et al., 2022).

Specimens were photographed using a Nikon D800E digital camera equipped alternately with Nikkor 50 mm F1.8 AF, Tamron SP 90 mm F2.8 Macro MF or Cosina 100 mm F3.5 Macro AF macro lens. Specimens selected for scanning electron microscopy were imaged with an ESEM FEI Quanta 200, under low vacuum; specimens were uncoated. To make the anatomy of some fossils available right away to the reader, RTI models were computed for five specimens (an arachnid, three insects and an undetermined arthropod; Supplementary material). The sets of photographs used to compute these RTI models were acquired using a light portable RTI FlyDome of 30 cm, equipped with 54 white LEDs sources successively enlightening the fossil in automated coordination with camera shooting (see

Béthoux et al., 2016 for details). Photographs were taken using an EOS 90D digital camera coupled to an EF 100 mm f/2.8L macro IS USM macro lens (Canon, Tokyo, Japan), both mounted on a vertical stand. Sets of 54 photographs were acquired and processed for each specimen. The size of the processed photographs ranges from c. 10 to 37 MB. Metallic reflecting hemispheres of 2 or 1 mm in diameter (necessary to infer the position of the light source during the computing process) were placed aside, and at equal depth of field, of the fossils. The resulting photographs were batch-labelled using Bridge, and processed with CameraRaw (Adobe Systems, San Jose, CA, USA). Photographs of each set were then cropped and compiled into an RTI file using RTIbuilder 2.0.2 (freely available under GNU license; using the HSH fitter). The five RTI files are accessible as Supplementary material, along with the corresponding photographs with scales and link to RTI viewer software (freely available under GNU license).

5. RBINS collections of the Kaiping Coalfield

5.1. Preliminary remarks

The species are presented herein class by class; the synonymy lists do not claim to be exhaustive.

In order to promote and facilitate future taxonomic studies by specialists, all the significant information regarding specimens is provided as well as a short discussion, except for

those described by Laurentiaux (1958) (see additional comments in section 5.2.3).

5.2. Types and/or illustrated specimens

5.2.1. Class Branchiopoda

Lioestheria? *mathieui* (Pruvost, 1928)

(Fig. 4)

- p. 1928 *Estheria* (*Euestheria*) *mathieui* Pruvost, p. 171, 172, 173, fig. 1.
 1930 *E.* [*Estheria*] *mathieui*; Pruvost, p. 184.
 1931 *Estheria* (*Euestheria*) *mathieui*; Chi, p. 204, 217–218, 223, text-fig. 2 (copy of fig. 1 in Pruvost, 1928).
 non 1932 *Estheria mathieui*; Corsin, p. 25, pl. 39, figs 8–9.
 1939 *Estheria* (*Euestheria*) *mathieui*; Mathieu, p. 23.
 1946 *Lioestheria mathieui*; Raymond, p. 232, 298.
 1954 *Euestheria mathieui*; Kobayashi, p. 59, p. 160, fig. 15a (copy of fig. 1 in Pruvost, 1928).
 1957 *Lioestheria mathieui*; Defrise-Gussenhoven & PASTIELS, p. 12–19, pl. A, figs 1–14, pl. B, figs 1–12, pl. C, figs 1–7, pl. D, figs 11–12.
 1957 *Estheria mathieui*; Stockmans & Mathieu, p. 82.
 1958 *Lioestheria mathieui*; Laurentiaux, p. 741.
 1976 *Lioestheria?* *mathieui*; Zhang et al., p. 117, pl. 16, fig. 2 (copy of fig. 1 in Pruvost, 1928).
 2019 *Lioestheria?* *mathieui*; Liao et al., p. 381, 387.
 2020 *Lioestheria?* *mathieui*; Liao et al., p. 578.

Type material. Pruvost (1928) did not designate the holotype of his new species as already noted by Defrise-Gussenhoven & PASTIELS (1957), who also stressed the fact that none of the original specimens was designated as the type by an inscription or a label. Although it remains unverifiable, it is likely that Pruvost's (1928) original drawing was made based on a compilation of characters observed from several specimens. Defrise-Gussenhoven & PASTIELS (1957) indicated that D. Laurentiaux provided them with the material previously studied by Pruvost (1928) that was still housed at the geological laboratory of the University of Paris; according to the former authors, these specimens were numbered between 140 and 150 by themselves, but they have not yet been located at the RBINS. It must be noted that Defrise-Gussenhoven & PASTIELS (1957) wrongly considered all the specimens they studied as syntypes, even those that were not investigated by Pruvost (1928). Specimens illustrated in Figure 4 have to be considered as topotypes.

Type locality and horizon. Zhaogezhuang colliery, 4th floor, western mining gallery, 'Assise de Tongshan' (Tangshan Formation), 'toit de la 16^e couche' (roof of the 16th coal seam) (Fig. 2A–C) according to Pruvost (1928) and Defrise-Gussenhoven & PASTIELS (1957).

Description. See Pruvost (1928) and Defrise-Gussenhoven & PASTIELS (1957).

Remarks. Although the communication of Mathieu et al. (1928) was presented in April 1927, the date of publication of Pruvost's species is 1928 as the second fascicle of the volume 52 (pro 1927) of the *Annales de la Société géologique du Nord* was published in July of that year. Moreover, the five reprints available at the RBINS are dated 1928 (see the article 21.8 of the International Code of Zoological Nomenclature (International Commission on Zoological Nomenclature (ICZN), 1999). Pruvost's (1928) original description is particularly brief, but Defrise-Gussenhoven & PASTIELS (1957) extensively illustrated the species on the basis of the material

collected in the 1920s complemented by that gathered in the late 1940s. Stockmans & Mathieu (1957) seem to consider that several species are present within the roof of the 16th coal seam, as also reflected by a letter accompanying the specimens collected in the 1940s, contrary to the opinion of Defrise-Gussenhoven & PASTIELS (1957). From the generic viewpoint, Raymond (1946) transferred the species to the genus *Lioestheria* Depéret & Mazeran, 1912, while Zhang et al. (1976) and Liao et al. (2019, 2020) only questionably assigned it to this genus.

Besides the Kaiping Coalfield, Pruvost (1928) also recorded the new species in the Westphalian C of northern France (Onnaing, Courcelles-lès-Lens) (see also Corsin, 1932) and in the Coal Measure of the North Sydney cliff (Cape Breton Island, Canada). Defretin-Lefranc (1970) revised the French material and assigned it to a new species, *Pseudestheria hersinensis*.

5.2.2. Class Arachnida

Telyphonida incertae sedis

(Fig. 5A–D, RTI interactive file in Supplementary material)

- 1928 *Geralinura* cf. *britannica*; Pruvost, p. 170, 171.
 1939 *Geralinura* sp.; Mathieu, p. 24.
 1985 '*Geralinura* cf. *britannica*'; Brauckmann et al., p. 19.
 1991 '*Geralinura* cf. *britannica*'; Brauckmann, p. 36.
 1963 cf. *Prothelyphonus britannicus*; Laurentiaux-Vieira & Laurentiaux, p. 25, text-fig. 2, pl. 3, fig. 2.
 1996 *Telyphonida incertae sedis*; Dunlop & Horrocks, p. 302.
 2008 '*Geralinura* cf. *britannica*'; Tetlie & Dunlop, p. 310.

Material. RBINS a13852 (previously IG 11471/10).

Provenance and horizon. Spoil heap of the Zhaogezhuang colliery, Tangshan Formation, most probably from the roof of the 16th coal seam (Fig. 2A–C).

Description. See Laurentiaux-Vieira & Laurentiaux (1963).

Remarks. One single specimen was reported by Pruvost (1928) but not illustrated. According to Laurentiaux-Vieira & Laurentiaux (1963), it consists of a subcylindrical opisthosoma that cannot be identified with certainty, even if they noted that a comparison with the abdomen of Pocock's (1911) species from the Bashkirian (Westphalian B of the traditional subdivision; Duckmantian) of Coseley (Staffordshire, United Kingdom) (Dunlop & Horrocks, 1996) is the most satisfactory. It seems that Laurentiaux-Vieira & Laurentiaux's (1963) illustration of this single specimen from the Kaiping Coalfield was overlooked by some subsequent workers who discussed Pruvost's (1928) report (Brauckmann et al., 1985; Tetlie & Dunlop, 2008). However, Brauckmann (1991) considered the generic and specific identification of the Kaiping specimen to be uncertain due to its incompleteness, while Dunlop & Horrocks (1996) regarded it as *Telyphonida incertae sedis* for the same reasons.

5.2.3. Class Insecta

Mathieu (1928a), but more particularly Pruvost (1928) first mentioned the presence of insects in the Tangshan Formation, within the layers of the roof of the 16th coal seam (Fig. 2A–C, Table 1). Pruvost (1928), who examined about 30 wings, recognised the three following genera, in order of frequency: *Archimylacris*, *Phyloblatta*, and *Soomylacris*. Although he announced a monograph on this material, it was never published. In a note presented in June 1946, but published in September 1947, Laurentiaux (1947b) briefly announced his study on the specimens from the Kaiping Coalfield. Laurentiaux (1947a) reported four insect genera among the Mathieu collections from the Kaiping Coalfield: *Archimylacris*,

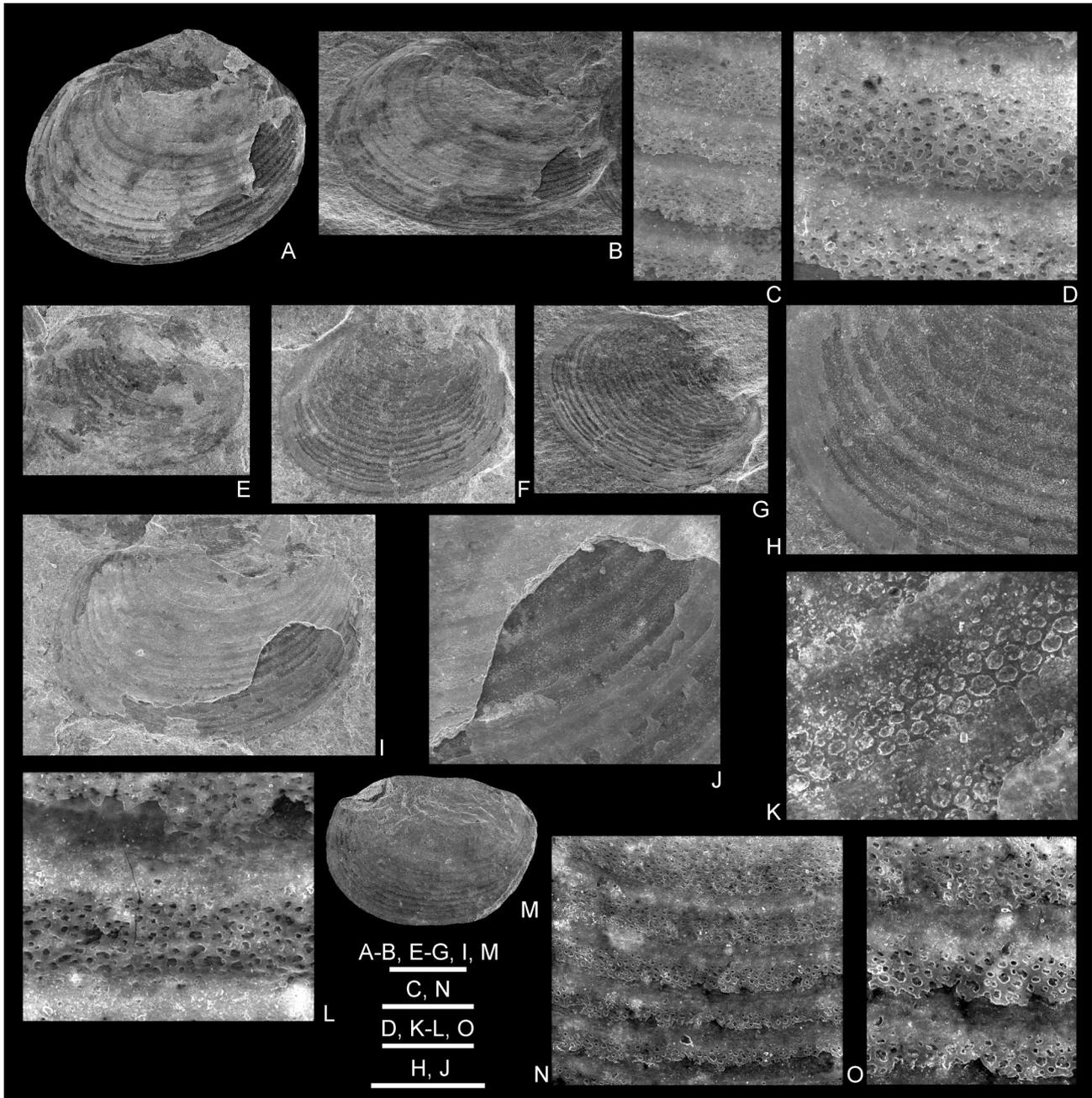


Figure 4. *Lioestheria? mathieui* (Pruvost, 1928); Zhaogezhuang colliery, 4th floor, western mining gallery, Tangshan Formation, roof of the 16th coal seam (Fig. 2). **A–D.** RBINS a9481b, right valve in normal and oblique lateral views and enlargements of the microstructure observed on the growth bands. **E.** RBINS a9481c, right valve. **F–H.** RBINS a9482b, right valve in normal and oblique lateral views, and close-up of the growth bands. **I–L.** RBINS a9477b, right valve and enlargements of the microstructures on the growth bands. **M–O.** RBINS a9477c, right valve and close-up of the microstructures on the growth bands. All SEM. Scale bars: A–B, E–G, I, M = 1 mm; C, N = 200 μm ; D, K–L, O = 100 μm ; H, J = 500 μm .

Phyloblatta, *Asemoblatta* and *Soomylacris*. He also identified the blattid species *Soomylacris burri* Bolton, 1912, *S. lievinensis* Pruvost, 1919 and *Phyloblatta cuvelettei* Pruvost, 1912, which were previously known from the Westphalian C of Western Europe. Eleven years later, in his Ph.D. thesis, Laurentiaux (1958) provided the first systematic description of the insects from the Tangshan Formation at the Zhaogezhuang colliery, all known from isolated wings, and commented on the fauna. He recognised 20 species and forms, out of which 18 were new ones belonging to seven genera among which three were regarded as new. Nevertheless, in regard to Article 8.6 of the International Code of Zoological Nomenclature (ICZN, 1999), all the new generic and specific names erected by Laurentiaux (1958) must be considered as nomina nuda; they are listed in

Table 2 following the Recommendation 51F of the Code (ICZN, 1999). Note that the taxa designated as ‘forma’ by Laurentiaux (1958) should have been considered as subspecies following the Article 45.6.4 of the Code if they were published. The three new genera based on the Kaiping Coalified material were the following: *Pseudaphtoromylacris* Laurentiaux, 1958 [nomen nudum] (RTI in supplementary material), *Spilarchimylacris* Laurentiaux, 1958 [nomen nudum], and *Spilarchiblatta* Laurentiaux, 1958 [nomen nudum] (RTI in supplementary material). Most of the specimens from the Tangshan Formation, which were figured by Laurentiaux (1958), were traced in the Mathieu collection and are re-illustrated here (Figs 6, 7, 8A–B) as well as the very limited and unidentified material from the Kaiping and Zhaogezhuang formations (Fig. 8C–F).

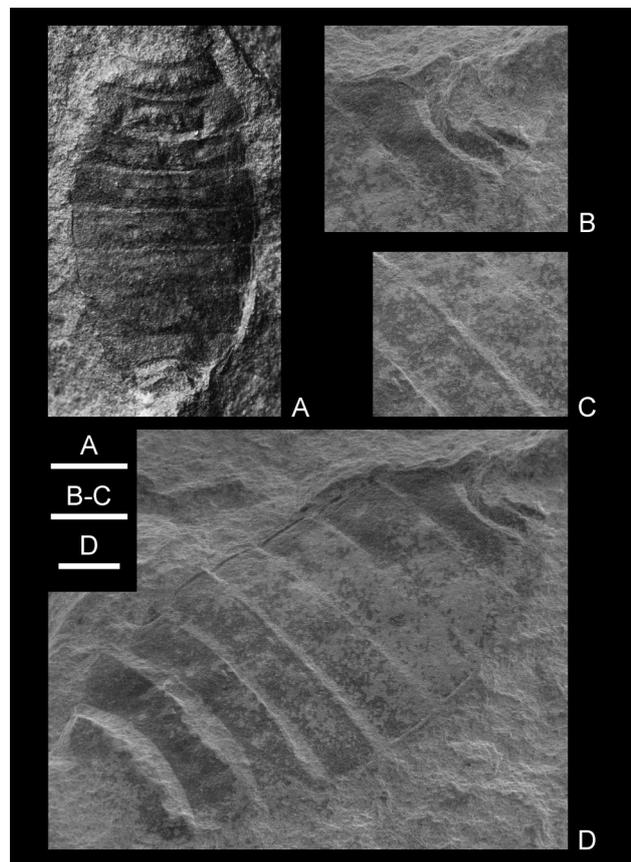


Figure 5. A–D. Telyphonida incertae sedis, RBINS a13852; spoil heap of the Zhaogezhuang colliery (Hebei Province, China), Tangshan Formation, most probably from the roof of the 16th coal seam (Fig. 2). A. Dorsalmost part of the opisthosoma. B. Close-up of the poorly preserved anterior segments of the pygidium (SEM). C. Close-up of opisthosomal segments (SEM). D. Lateral oblique view the opisthosoma with the pygidium on the upper right (SEM). Scale bars: A = 2 mm; B–C, D = 1 mm.

Liao et al. (2019) recently reported the discovery of numerous insects in the Kaiping Coalfield, within the Benxi Formation (= Penchi Formation), few meters below a layer that yielded the new branchiopod species *Pemphilimnadiopsis cheni*. They tentatively attributed an early Kasimovian age to the insects they collected. According to their log devoid of scale (Liao et al., 2019, fig. 2A), the three limestone beds may correspond to those recognised by Mathieu (1928a, 1939) (ML 1–3 in Fig. 2B). They locate the occurrence of the insect below the *Calcaire de Tongshan* (ML 3), whereas Mathieu's specimens were collected below the first limestone occurrence (Fig. 2B–C); therefore, the material collected by Mathieu is clearly older and most likely of Moscovian age (Fig. 3).

5.2.4. Class unknown

non Ricinulei

(Fig. 9, RTI interactive file in Supplementary material)

- 1963 (*Poliochera* vel *Curculioides*) [sic] *pustulatus* Laurentiaux-Vieira & Laurentiaux, p. 25–26, text-fig. 3; pl. 3, fig. 3.
 1987 '(*Poliochera* vel *Curculioides*)' [sic] *pustulatus*; Brauckmann, p. 99.
 1991 '(*Poliochera* vel *Curculioides*)' [sic] *pustulatus*; Brauckmann, p. 48.
 1992 '(*Poliochera* vel *Curculioides*)' [sic] *pustulatus*; Selden, p. 595, 598.
 1992 non Ricinulei; Selden, p. 632.
 2011 *Poliochera* [sic] *pustulatus*; Prendini, p. 122.
 2020 *Poliochera/Curculioides pustulatus*; Dunlop et al., p. 126.

Material. RBINS a13853 (previously IG 11471/51); holotype of (*Poliochera* vel *Curculioides*) [sic] *pustulatus* Laurentiaux-Vieira & Laurentiaux, 1963 (see below).

Type locality and horizon. Spoil heap of the Zhaogezhuang colliery, Tangshan Formation, most probably from the roof of the 16th coal seam.

Table 1. Origin of the specimens housed at RBINS from the Tangshan (16th coal seam), Kaiping (14^{es} couches) and Zhaogezhuang (6th coal seam) formations, per represented taxa. * most spoil heaps are referred linked to the exploitation of the roof of the 16th coal seam.

Taxa	Number of specimens	Number of pieces	Formation of origin	Age
Blattodea	45	66	16th coal seam and roof	Probably Moscovian
	1	1	'Assise des 14 ^{es} couches'	Late Gzhelian
	2	3	6th coal seam	Late Gzhelian–early Asselian
	17	20	Spoil heaps*	Probably Moscovian–mid-Gzhelian?
	5	5	Provenance unknown	
	70	95		
Arachnida and alleged arachnids	1	1	Spoil heaps*	Probably Moscovian
	1	1	Provenance unknown	
	2	2		
Branchiopoda	Unknown number	13	Roof of 16th coal seam	Probably Moscovian
Total	72 (excluding Branchiopoda)	110		

Table 2. Insect species described from the Tangshan Formation by Laurentiaux (1958) in his unpublished Ph.D. thesis. Abbreviations: H, 'holotype'; P, 'paratype'.

Insect species and illustrated specimens from the Tangshan Formation (Mathieu's collection)	Laurentiaux (1958)	Original registration number	RBINS
<i>Pseudaphtoromylacris paucinervis</i> Laurentiaux, 1958 [nomen nudum]	p. 503, text-fig. 116, pl. 30, figs 4-5	IG 11471/0 (H)	a13854 (Fig. 6A-B)
<i>Spilarchimylacris kaipingensis</i> Laurentiaux, 1958 [nomen nudum]	p. 524bis, text-fig. 123bis (A), pl. 38, fig. 1	IG 11471/8 (H)	a13855 (Fig. 6C)
<i>Spilarchimylacris kaipingensis</i> Laurentiaux, 1958 [nomen nudum]	p. 524bis, text-fig. 123bis (B), pl. 38, fig. 2	IG 11471/13 (P)	a13856 (Fig. 6D)
<i>Phyloblatta nitida</i> Laurentiaux, 1958 [nomen nudum]	p. 541, text-fig. 130, pl. 38, fig. 6	IG 11471/1A-B (H)	a13857 (Fig. 6E-F)
<i>Phyloblatta subsimoni</i> Laurentiaux, 1958 [nomen nudum]	p. 546, text-fig. 132, pl. 35, fig. 2	IG 11471/2A-B (H)	a13858 (Fig. 6G-H)
<i>Phyloblatta</i> aff. <i>subsimoni</i> Laurentiaux, 1958 [nomen nudum]	p. 547, pl. 35, fig. 3	IG 11471/4 (H)	a13859 (Fig. 6I)
<i>Phyloblatta asiaticus</i> Laurentiaux, 1958 [nomen nudum]	p. 548, text-fig. 133, pl. 32, fig. 5	IG 11471/3 (H)	a13860 (Fig. 6J)
<i>Phyloblatta kailanensis</i> Laurentiaux, 1958 [nomen nudum]	p. 550, text-fig. 134, pl. 32, fig. 6	IG 11471/58 (H)	a13861 (Fig. 7A)
<i>Phyloblatta kailanensis</i> forma <i>orientalis</i> Laurentiaux, 1958 [nomen nudum]	p. 553, text-fig. 135, pl. 35, fig. 4	Untraced	a13862 (untraced)
<i>Phyloblatta tardimedialis</i> Laurentiaux, 1958 [nomen nudum]	p. 556, text-fig. 136, pl. 35, fig. 5	IG 11471/25 (H)	a13863 (Fig. 7B)
<i>Phyloblatta tardimedialis</i> forma A Laurentiaux, 1958 [nomen nudum]	p. 556, text-fig. 137, pl. 35, fig. 6	IG 11471/49	a13864 (Fig. 7C)
<i>Phyloblatta sublenta</i> Laurentiaux, 1958 [nomen nudum]	P. 560, text-fig. 139, pl. 36, fig. 1	IG 11471/15 (H)	a13865 (Fig. 7D)
<i>Phyloblatta circularis</i> Laurentiaux, 1958 [nomen nudum]	p. 563, text-fig. 140, pl. 37, fig. 3	IG 11471/36 (H)	a13866 (Fig. 7E-F)
<i>Phyloblatta</i> aff. <i>manca</i> von Schlechtendal in Handlirsch, 1906 in 1906-1908	p. 566, pl. 36, fig. 2	IG 11471/30 (H)	a13867 (Fig. 7G)
<i>Phyloblatta cuvettei</i> forma <i>sinensis</i> Laurentiaux, 1958 [nomen nudum]	p. 581, text-fig. 147, pl. 39, fig. 1	IG 11471/7 (H)	a13868 (Fig. 7H)
<i>Spilarchiblatta mathieui</i> Laurentiaux, 1958 [nomen nudum]	p. 587, text-fig. 148, pl. 38, fig. 4	IG 11471/11 (H)	a13869 (Fig. 7I)
<i>Spilarchiblatta chilhiensis</i> Laurentiaux, 1958 [nomen nudum]	p. 591, text-fig. 149, pl. 38, fig. 5	IG 11471/51 (H)	a13870 (Fig. 7J)
<i>Phylomylacris costalis</i> Laurentiaux, 1958 [nomen nudum]	p. 645, text-fig. 167, pl. 42, fig. 3	IG 11471/44 (incorrect number; untraced)	a13871 (untraced)
<i>Sooblattella ater</i> Laurentiaux, 1958 [nomen nudum]	p. 652, text-fig. 170, pl. 42, fig. 6	IG 11471/12 (H)	a13872 (Fig. 8A)
<i>Etomylacris straeleni</i> Laurentiaux, 1958 [nomen nudum]	p. 655, text-fig. 172, pl. 43, fig. 1	IG 11471/29 (H)	a13873 (Fig. 8B)
Hind wing of stem-Dictyoptera	pl. 25, fig. 2	IG 11471/43	a13874
Hind wing of stem-Dictyoptera	pl. 25, fig. 3	IG 11471/23	a13875
Hind wing of stem-Dictyoptera	pl. 25, fig. 4	IG 11471/17	a13876
Hind wing of stem-Dictyoptera	pl. 25, fig. 5	IG 11471/37	a13877

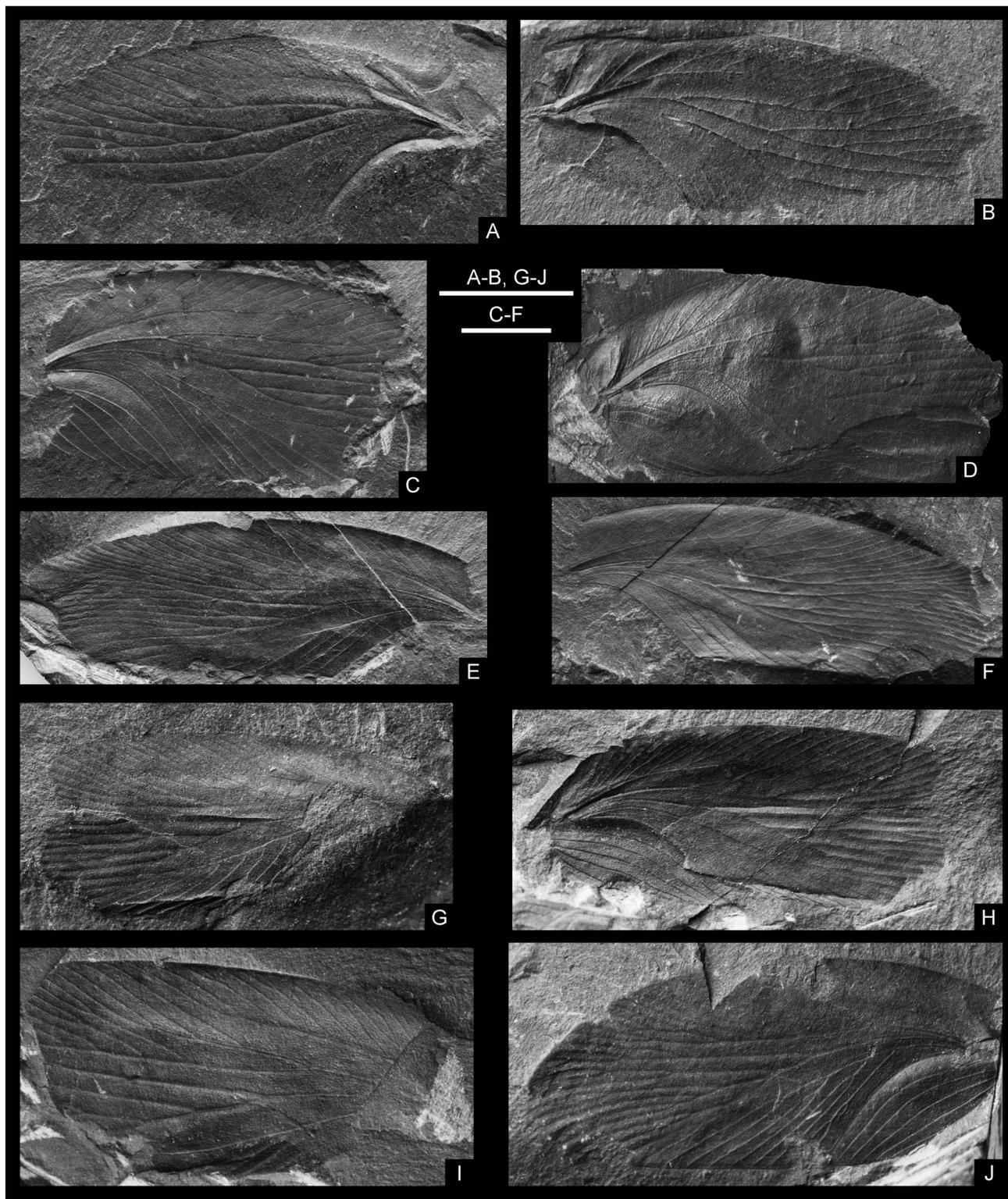


Figure 6. Insects, described in the unpublished Ph.D. thesis of Laurentiaux (1958), from the Zhaogezhuang coal mine (Kaiping Coalfield, Hebei Province, China), Tangshan Formation. All the specimens were collected from the roof of the 16th coal seam in the aforementioned mine (4th floor) (see Fig. 2), except otherwise stated. **A–B.** *Pseudaphthoromylacris paucinervis* Laurentiaux, 1958 [nomen nudum], RBINS a13854, type specimen ('holotype'); spoil heap (most probably from the roof of the 16th coal seam). **C–D.** *Spilarchimylocris kaipingensis* Laurentiaux, 1958 [nomen nudum], RBINS a13855 (C) and a13856 (D), type specimens ('holotype' and 'paratype'). **E–F.** *Phyloblatta nitida* Laurentiaux, 1958 [nomen nudum], RBINS a13857, type specimen ('holotype'). **G–H.** *Phyloblatta subsimoni* Laurentiaux, 1958 [nomen nudum], RBINS a13858, type specimen ('holotype'). **I.** *Phyloblatta* aff. *subsimoni* Laurentiaux, 1958 [nomen nudum], RBINS a13859; spoil heap (most probably from the roof of the 16th coal seam). **J.** *Phyloblatta asiaticus* Laurentiaux, 1958 [nomen nudum], RBINS a13860, type specimen ('holotype'). All scale bars are 5 mm.

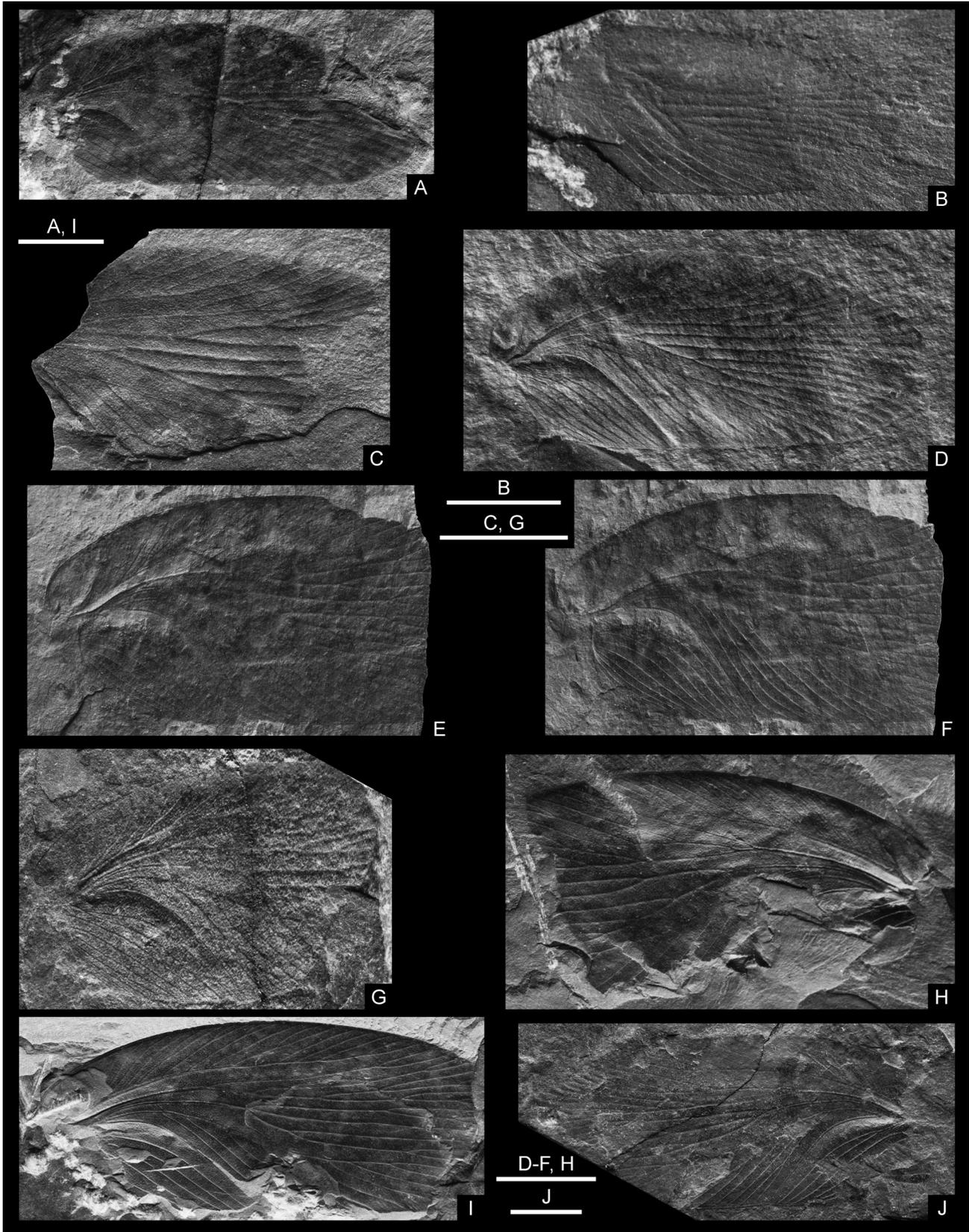


Figure 7. Insects, described in the unpublished Ph.D. thesis of Laurentiaux (1958), from the Zhaogezhuang coal mine (Kaiping Coalfield, Hebei Province, China), Tangshan Formation. All the specimens were collected from the roof of the 16th coal seam in the aforementioned mine (4th floor) (see Fig. 2), except otherwise stated. **A.** *Phyloblatta kailanensis* Laurentiaux, 1958 [nomen nudum], RBINS a13861, type specimen ('holotype'). **B.** *Phyloblatta tardimedialis* Laurentiaux, 1958 [nomen nudum], RBINS a13863, type specimen ('holotype'). **C.** *Phyloblatta tardimedialis* forma A Laurentiaux, 1958 [nomen nudum], RBINS a13864. **D.** *Phyloblatta sublenta* Laurentiaux, 1958 [nomen nudum], RBINS a13865, type specimen ('holotype'). **E–F.** *Phyloblatta circularis* Laurentiaux, 1958 [nomen nudum], RBINS a13866, lighting from left (E) and right (F), type specimen ('holotype'). **G.** *Phyloblatta* aff. *manca* von Schlechtendal in Handlirsch, 1906 in 1906–1908, RBINS a13867; spoil heap. **H.** *Phyloblatta cuvelettei* forma *sinensis* Laurentiaux, 1958 [nomen nudum], RBINS a13868, type specimen ('holotype'). **I.** *Spilarchiblatta mathieui* Laurentiaux, 1958 [nomen nudum], RBINS a13869, type specimen ('holotype'); spoil heap. **J.** *Spilarchiblatta chilhiensis* Laurentiaux, 1958 [nomen nudum], RBINS a13870, type specimen ('holotype'). All scale bars are 5 mm.

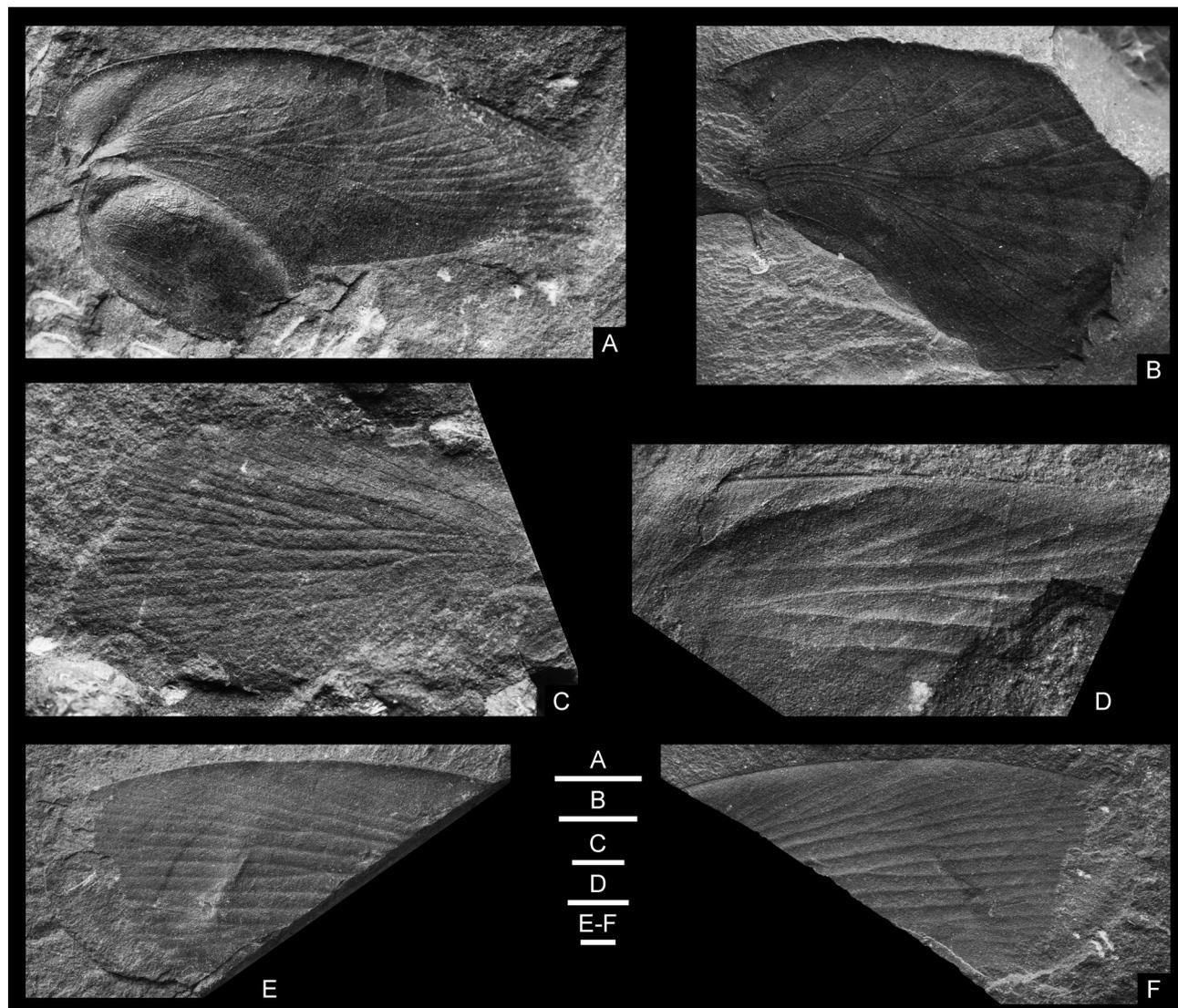


Figure 8. Insects, described in the unpublished Ph.D. thesis of Laurentiaux (1958), from the 4th floor of the Zhaogezhuang coal mine (Kaiping Coalfield, Hebei Province, China), unless otherwise stated (see Fig. 2). **A.** *Sooblattella ater* Laurentiaux, 1958 [nomen nudum], RBINS a13872, type specimen ('holotype'); Tangshan Formation, spoil heap (most likely from the roof of the 16th coal seam). **B.** *Etomylacris straeleni* Laurentiaux, 1958 [nomen nudum], RBINS a13873, type specimen ('holotype'); Tangshan Formation, roof of the 16th coal seam. **C.** Hind wing of a stem-Dictyoptera, RBINS a13878; Kaiping Formation. **D.** Unidentified insect, RBINS a13879; Zhaogezhuang Formation (6th coal seam). **E–F.** Unidentified insect, RBINS a13880; Zhaogezhuang Formation (6th coal seam). All scale bars are 2.5 mm.

Description. See Laurentiaux-Vieira & Laurentiaux (1963) and Selden (1992).

Remarks. Contrary to the Article 11.9.3 of the Code (ICZN, 1999), the species-group name, which was proposed by Laurentiaux-Vieira & Laurentiaux (1963) for the incomplete specimen RBINS a13853, namely (*Poliochera* vel *Curculioides*) [sic] *pustulatus*, is ambiguously combined with two generic names and their species is therefore regarded as invalid (see also articles 10 and 13.1 of the Code). As correctly noted by Brauckmann (1987), this incomplete specimen was originally described as a distinct species but without clear generic and familial assignment. According to Selden (1992), several features, such as the size and distribution of the tubercles, suggest that this specimen should be excluded from the Ricinulei and that the tuberculation is reminiscent of that observed in crustaceans and scorpions. It was considered as a nomen dubium by Dunlop et al. (2020).

6. Perspectives

This short catalogue devoted to the arthropods of the Kaiping Coalfield in China (Pennsylvanian–Cisuralian), which are part of the Mathieu collection housed at the Royal Belgian Institute of Natural Sciences, constitutes an update of the available data, especially those regarding the numerous insect wings of most probably Moscovian age that were studied in the unpublished Ph.D. thesis of Laurentiaux (1958). After having been out of sight for several decades, the material is now available again for new studies.

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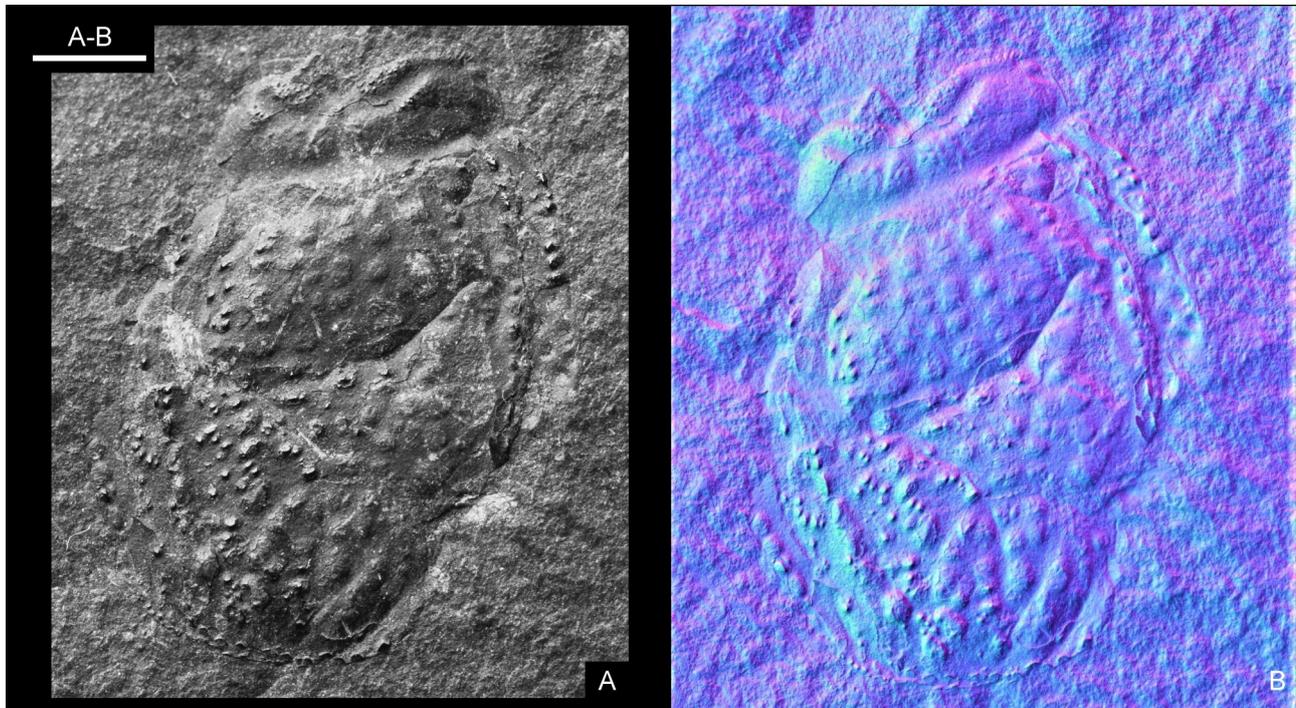


Figure 9. A–B. *non* Ricinulei, RBINS a13853 (holotype of (*Poliochera* vel *Curculioides*) [sic] *pustulatus* Laurentiaux-Vieira & Laurentiaux, 1963 [invalid species name]); spoil heap of the Zhaogezhuang colliery (Hebei Province, China), Tangshan Formation, most probably from the roof of the 16th coal seam (Fig. 2). A. Conventional photograph. B. RTI capture in normals visualization rendering mode. Scale bar: A–B = 2 mm.

loan of the camera lens used for the production of the RTI composing images. The manuscript benefited from the thorough reviews of Olivier Béthoux (Paris), Jörg Schneider (Freiberg), Frank Scholze (Schleusingen) and an anonymous reviewer.

Author contribution

B. Mottequin and N. Robin performed the data acquisition; the interpretation and the writing of this article was performed by B. Mottequin.

Data availability

All studied specimens are housed in an official repository ensuring their long-term safekeeping and availability to other researchers for future studies.

References

- Béthoux, O., Llamasi, A. & Toussaint, S., 2016. Reinvestigation of *Protelytron permianum* (Insecta; Early Permian; USA) as an example for applying reflectance transformation imaging to insect imprint fossils. *Fossil Record*, 20/1, 1–7. <https://doi.org/10.5194/fr-20-1-2016>
- Bolton, H., 1912. Insect-remains from the Midlands and South-Eastern Coal Measures. *Quarterly Journal of the Geological Society of London*, 68, 310–323. <https://doi.org/10.1144/gsl.jgs.1912.068.01-04.25>
- Brauckmann, C., 1987. Neue Arachniden (Ricinuleida, Trigonotarbida) aus dem Namurium B von Hagen-Vorhalle (Ober-Karbon; West-Deutschland). *Dortmunder Beiträge der Landeskunde, Naturwissenschaftliche Mitteilungen*, 21, 97–109.
- Brauckmann, C., 1991. Arachniden und Insekten aus dem Namurium von Hagen-Vorhalle (Ober-Karbon; West-Deutschland). *Veröffentlichungen aus dem Fuhlrott-Museum*, 1, 1–275.
- Brauckmann, C., Koch, L. & Kemper, M., 1985. Spinnentiere (Arachnida) und Insekten aus den Vorhalle-Schichten (Namurium B; Ober-Karbon) von Hagen-Vorhalle (West-Deutschland). *Geologie und Paläontologie in Westfalen*, 3, 1–131.
- Carlson, E.C., 1971. *The Kaiping mines, 1877–1912* (second edition). *Harvard East Asian Monographs*, 3, 1–235.
- Chi, Y.S., 1931. On the occurrence of fossil *Estheria* in China, and its geological significance. *Bulletin of the Geological Society of China*, 10, 189–227. <https://doi.org/10.1111/j.1755-6724.1931.mp10001010.x>
- Corsin, P., 1932. Guide paléontologique dans le terrain houiller du Nord de la France. *Travaux et Mémoires de l'Université de Lille, Albums : Fascicule n° 5, Institut de la Houille de l'Université de Lille (Musée houiller)*, 1–44.
- Defretin-Lefranc, S., 1970. Révision des Conchostracés westphaliens du bassin houiller du Nord-Pas-de-Calais. *Annales de la Société géologique du Nord*, 90/3, 121–136.
- Defrise-Gusshoven, E. & PASTIELS, A., 1957. Contribution à l'étude biométrique des Lioestheridae du Westphalien supérieur. *Publication de l'Association pour l'Étude de la Paléontologie et de la Stratigraphie houillères*, 31, 1–71.
- Delépine, G., 1928. Notes sur la faune des niveaux marins n° 1 et n° 3 (Calcaire de Tongshan) du Bassin Carbonifère de Kaïping (Chine). In Mathieu, F.-F., Delépine, G. & Pruvost, P., *Observations sur le terrain houiller de Kaïping (Chine)*. *Annales de la Société géologique du Nord*, 52/2 (pro 1927), 166–168.
- Depéret, Ch. & Mazeran, P., 1912. Les *Estheria* du Permien d'Autun. *Bulletin de la Société d'histoire naturelle d'Autun*, 25, 165–174.
- Dunlop, J.A. & Horrocks, C.A., 1996. A new Upper Carboniferous whip scorpion (Arachnida: Uropygi: Thelyphonida) with a revision of the British Carboniferous Uropygi. *Zoologischer Anzeiger*, 234/4, 293–306.
- Dunlop, J.A., Penney, D. & Jekel, D., 2020. A summary list of fossil spiders and their relatives. In *World Spider Catalog, version 20.5*. Natural History Museum Bern. <http://wsc.nmbe.ch>, accessed 02/01/2023.

- Gao, L., Wang, Z. & Wu, X., 1983. The middle Carboniferous of China. In Martínez Diaz, C. (ed.), *The Carboniferous of the World*, Volume 1: China, Korea, Japan & S.E. Asia. IUGS Publication, 16, 56–86.
- Grabau, A.W., 1920a. A new species of *Eurypterus* from the Permian of China. With a note on the occurrence of the specimen by Dr. J.G. Andersson. *Bulletin of the Geological Survey of China*, 2, 61–67.
- Grabau, A.W., 1920b. A Lower Permian fauna from the Kaiping coal Basin. With a note on the section in the Kaiping basin by F.F. Mathieu. *Bulletin of the Geological Survey of China*, 2, 69–79.
- Han, J., Zhang, H., Liang, B., Rong, H., Lan, T. & Liu, Y., 2016. Influence of large syncline on in situ stress field: a case study of the Kaiping Coalfield, China. *Rock Mechanics and Rock Engineering*, 49, 4423–4440. <https://doi.org/10.1007/s00603-016-1039-4>
- Handlirsch, A., 1906–1908. *Die fossilen Insekten und die Phylogenie der rezenten Formen. Ein Handbuch für Paläontologen und Zoologen*. Wilhelm Engelmann, Leipzig, 1430 p.
- International Commission on Zoological Nomenclature, 1999. *International Code of Zoological Nomenclature*. 4th ed. International Trust for Zoological Nomenclature, London, 306 p.
- Kobayashi, T., 1954. Fossil estherians and allied fossils. *Journal of the Faculty of Science (University of Tokyo)*, section 2 (Geology, Mineralogy, Geography, Geophysics), 9/1, 1–192.
- Laurentiaux, D., 1947a. Note préliminaire sur une faune d’Insectes de l’Assise de Tongshan (Bassin houiller de Kaïping, Chine). *Compte rendu sommaire des séances de la Société géologique de France*, 1947/5–6, 92–94.
- Laurentiaux, D., 1947b. La faune continentale des marnes de Tchakras (Asie Mineure). *Annales de la Société géologique du Nord*, 66/2 (pro 1946), 213–235.
- Laurentiaux, D., 1958. *Contributions à l’étude des Insectes carbonifères*. Unpublished Ph.D. thesis, Université de Paris, Paris, 758 p.
- Laurentiaux-Vieira, F. & Laurentiaux, D., 1963. Sur quelques restes nouveaux d’Arachnides du terrain houiller. *Annales de la Société géologique du Nord*, 83, 23–29.
- Lee, J.S. & Chao, Y.T., 1926. Classification and correlation of Palaeozoic coal-bearing formations in North China. *Bulletin of the Geological Society of China*, 5/1–2, 107–134. <https://doi.org/10.1111/j.1755-6724.1926.mp51-2015.x>
- Li, X. & Zhang, L., 1983. The upper Carboniferous of China. In Martínez Diaz, C. (ed.), *The Carboniferous of the World*, Volume 1: China, Korea, Japan & S.E. Asia. IUGS Publication, 16, 87–121.
- Liao, H.-Y., Shen, Y.-B., Gao, J. & Huang, D.-Y., 2019. *Pemphilmnadiopsis cheni* sp. nov. (Branchiopoda: Diplostraca: Spinicaudata) from the Upper Carboniferous of East Hebei, China and its biostratigraphic significance. *Palaeoentomology*, 2/4, 381–389. <https://doi.org/10.11646/palaeoentomology.2.4.12>
- Liao, H.-Y., Lian, X.-N., Gao, J., Cai, C.-Y., Feng, Z. & Huang, D.-Y., 2020. Discovery of *Pemphilmnadiopsis cheni* (Branchiopoda: Diplostraca: Spinicaudata) from the Benxi Formation in Taiyuan, North China and its stratigraphic significance. *Palaeoentomology*, 3/6, 578–581. <https://doi.org/10.11646/palaeoentomology.3.6.9>
- Mathieu, F.-F., 1921. Flore fossile du bassin houiller de Kaïping (Chine). (Note préliminaire). *Annales de la Société géologique de Belgique*, 44/1, B84–B90.
- Mathieu, F.-F., 1922. L’âge géologique des charbons de la Chine. (Note préliminaire). *Annales de la Société géologique de Belgique*, 45/2, B209–B215.
- Mathieu, F.-F., 1923a. La géologie et les richesses de minières de la Chine. *Publications de l’Association des Ingénieurs de l’École des Mines de Mons*, 1923/3, 281–529.
- Mathieu, F.-F., 1923b. Les dykes intrusifs du bassin de Kaïping. *Annales de la Société géologique de Belgique*, 45/3, B229–B244.
- Mathieu, F.-F., 1923c. Les minéraux du Bassin de Kaïping (Chine). *Annales de la Société géologique de Belgique*, 46/3, B141–B146.
- Mathieu, F.-F., 1927. Les cycles orogéniques dans la partie orientale de la province de Chihli (Chine). *Bulletin de la Société belge de Géologie, de Paléontologie et d’Hydrologie*, 36/2 (pro 1926), Procès-verbaux, 155–172.
- Mathieu, F.-F., 1928a. Note préliminaire sur la stratigraphie du Bassin Houiller de Kaïping (Chine). In Mathieu, F.-F., Delépine, G. & Pruvost, P., *Observations sur le terrain houiller de Kaïping (Chine)*. *Annales de la Société géologique du Nord*, 52/2 (pro 1927), 159–166.
- Mathieu, F.-F., 1928b. Note sur l’horizon ferrugineux inférieur des couches de Kaïping (Chine). *Annales de la Société géologique de Belgique*, 51/4, B109–B112.
- Mathieu, F.-F., 1939. La stratigraphie du bassin houiller de Kaiping (Chine). *Patrimoine du Musée royal d’Histoire naturelle de Belgique*, Bruxelles, 1–48.
- Mathieu, F.-F., 1955. Les dykes basaltiques du bassin houiller de Kaiping et leur influence sur les roches encaissantes. *Publication de l’Association pour l’Étude de la Paléontologie et de la Stratigraphie houillères*, 21 (hors-série), 21–45.
- Mathieu, F.-F., Delépine, G. & Pruvost, P., 1928. *Observations sur le terrain houiller de Kaïping (Chine)*. *Annales de la Société géologique du Nord*, 52/2 (pro 1927), 159–173.
- Mottequin, B., Fischer, J., Goolaerts, S. & Olive, S., 2022. Revisiting the chondrichthyan egg capsules inventory from the Pennsylvanian (Carboniferous) of Belgium: new data and perspectives. *The Science of Nature*, 109/39, 1–16. <https://doi.org/10.1007/s00114-022-01809-6>
- Pastiels, A., 1960. Le Centre national de Géologie houillère et ses antécédents. In *Le Mouvement scientifique en Belgique*, fascicule 2. Fédération belge des Sociétés scientifiques, Bruxelles, 138–148.
- Piérart, P., 1961. Les mégaspores du houiller de Kaiping (Chine). *Mededelingen van de Geologische Stichting in Nederland*, Nieuwe Serie, 13, 39–44.
- Pocock, R.I., 1911. A monograph of the terrestrial Carboniferous Arachnida of Great Britain. *Monographs of the Palaeontographical Society*, 64, 315, 1–84. <https://doi.org/10.1080/02693445.1911.12035553>
- Prendini, L., 2011. Order Ricinulei Thorell, 1876. In Zhang, Z.-Q. (ed.), *Animal biodiversity: An outline of higher-level classification and survey of taxonomic richness biodiversity*. *Zootaxa*, 3148, 122. <https://doi.org/10.11646/zootaxa.3148.1.22>
- Pruvost, P., 1912. Les insectes houillers du Nord de la France. *Annales de la Société géologique du Nord*, 41, 323–380.
- Pruvost, P., 1919. Introduction à l’étude du terrain houiller du Nord et du Pas-de-Calais. La faune continentale du terrain houiller du Nord de la France. *Mémoires pour servir à l’explication de la Carte géologique détaillée de la France*. Imprimerie Nationale, Paris, 1–584.
- Pruvost, P., 1928. La faune du terrain houiller de Bruay dans le Bassin de Kaïping (Chine). In Mathieu, F.-F., Delépine, G. & Pruvost, P., *Observations sur le terrain houiller de Kaïping (Chine)*. *Annales de la Société géologique du Nord*, 52/2 (pro 1927), 168–173.
- Pruvost, P., 1930. La faune continentale du terrain houiller de la Belgique. *Mémoires du Musée royal d’Histoire naturelle de Belgique*, 44, 103–280.
- Raymond, P.E., 1946. The genera of fossil Conchostraca — an order of bivalve Crustacea. *Bulletin of the Museum of Comparative Zoology at Harvard College*, 96/3, 215–308.
- Schenck, A., 1883. Pflanzen aus der Steinkohlenformation. In von Richthofen, F., *China. Ergebnisse eigener reisen und darauf gegründeter Studien*. Volume 4. D. Reimer, Berlin, 211–244.
- Selden, P., 1992. Revision of the fossil ricinuleids. *Earth and Environmental Science Transactions of The Royal Society of Edinburgh*, 83/4, 595–634. <https://doi.org/10.1017/S0263593300003333>
- Shen, B., Shen, S., Wu, Q., Zhang, S., Zhang, B., Wang, X., Hou, Z., Yuan, D., Zhang, Y., Liu, F., Liu, J., Zhang, H., Shi, Y., Wang, J. & Feng, Z., 2022. Carboniferous and Permian integrative stratigraphy and timescale of North China Block. *Science China Earth Sciences*, 65/6, 983–1011. <https://doi.org/10.1007/s11430-021-9909-9>

- Sluys, M., 1959. Fernand-François Mathieu. Académie royale des Sciences coloniales, Bulletin des séances, nouvelle série, 5/1, 183–200.
- Stockmans, F. & Mathieu, F.-F., 1939. La flore paléozoïque du bassin houiller de Kaiping (Chine). Patrimoine du Musée royal d’Histoire naturelle de Belgique, Bruxelles, 49–164.
- Stockmans, F. & Mathieu, F.-F., 1957. La flore paléozoïque du bassin houiller de Kaiping (Chine). (Deuxième partie). Publication de l’Association pour l’Étude de la Paléontologie et de la Stratigraphie houillères, 32, 1–89.
- Tetlie, O.E. & Dunlop, J.A., 2008. *Geralinura carbonaria* (Arachnida; Uropygi) from Mazon Creek, Illinois, USA, and the origin of subchelate pedipalps in whip scorpions. *Journal of Paleontology*, 82/2, 299–312. <https://doi.org/10.1666/06-138.1>
- Tetlie, E., Selden, P.A. & Ren, D., 2007. A new Silurian eurypterid (Arthropoda: Chelicerata) from China. *Palaeontology*, 50/3, 619–625. <https://doi.org/10.1111/j.1475-4983.2007.00651.x>
- Wang, Y.-H., Wan, M.-L., Zhang, H., Cai, C.-Y. & Huang, D.-Y., 2022. Palaeozoic insects from China with discussion on their ages. *Palaeoentomology*, 5/4, 362–377. <https://doi.org/10.11646/palaeoentomology.5.4.9>
- Zhang, S. (ed.), 2009. Geological Formation Names of China (1866–2000). Higher Education Press, Beijing and Springer-Verlag, Berlin, 1650 p. <https://doi.org/10.1007/978-3-540-93824-8>
- Zhang, W.T., Chen, P.J. & Shen, Y.B., 1976. Fossil conchostracans of China. Science Press, Beijing, 325 p. [In Chinese].

Supplementary material

Dryad dataset <https://doi.org/10.5061/dryad.sxksn0378>.