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The supposed giant spider *Mongolarachne chaoyangensis*, from the Cretaceous Yixian Formation of China, is a crayfish

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Abstract

A supposed giant spider, *Mongolarachne chaoyangensis* Cheng, Liu, Huang, Liu, Li & Li, 2019, from the Lower Cretaceous Yixian Formation of China, is here shown, with the aid of fluorescence microscopy, to be a faked fossil spider, with a fossil crayfish as its core. We tentatively place *M. chaoyangensis* in *Cricoidoscelosus aethus* Taylor, Schram & Shen, 1999 **n. syn.**.

Keywords: Arachnida, Araneae, Astacidea, Crustacea, Decapoda, faked fossil, fluorescence microscopy

Introduction

The Lower Cretaceous (Barremian) Yixian Formation of northeastern China is renowned for its excellent preservation of terrestrial and freshwater biota, including many feathered dinosaurs, and is known as the Jehol Biota (Chang *et al*., 2003; Ren *et al*., 2019). Few arachnids are known from this formation, and they are not as well preserved as other fauna in the Jehol Biota. Chang (2004), Cheng *et al*. (2008, 2009), and Selden *et al*. (2016) described some spiders from the formation, although not all of the identifications are accurate (Dunlop *et al*., 2019). In this contribution, we discuss a large specimen of supposed spider, *Mongolarachne chaoyangensis* Cheng, Liu, Huang, Liu, Li & Li, 2019, which was referred to the family Mongolarachnidae Selden, Shih & Ren, 2013 by Cheng *et al*. (2019).

The family Mongolarachnidae was erected to accommodate a genus and species, *Mongolarachne jurassica* Selden, Shih & Ren, 2013, of giant spider from the Middle Jurassic Jiulongshan Formation (= Haifanggou Formation) of Daohugou, Inner Mongolia (the Yanliao Biota). The female was first described as *Nephila jurassica* by Selden, Shih & Ren (2011) and referred to the ecribellate Araneidae: Nephilinae. However, when an adult male of the same species bearing a distinct calamistrum was discovered, the monotypic genus was placed in its own family, which lies within the UDOH grade of entelegyne spiders (referring to the Uloboridae, Deinopidae, and Oecobiidae + Hersiliidae spider families: Fernández *et al*., 2018).

The Yixian Formation is not without its share of fake fossils, the most famous case being *Archaeoraptor* (Rowe *et al*., 2001, 2016). Fossil collectors or dealers sometimes modify or enhance a fossil to make it look more appealing and more saleable. Here, we describe a fossil that was described as a giant spider but which is actually a forgery produced by adding morphology to a poorly preserved crayfish.

The first indications that the specimen was not a spider was when it was clear that the specimen had separate sternites, there were too many proximal podomeres on the legs, and a pair of what appeared to be enormous eyes. Discerning the distal morphology of the legs was difficult, because these features had been painted onto the rock. These clearly lack arachnid setae, both where cuticle is evident and where it is faked. One of us (CKS) suggested that the core fossil was actually a poorly preserved crayfish, of the kind that is not uncommon in these beds at this locality (Dawangzhangzi, Lingyuan City, Liaoning Province of China). The spiders described from here, *Cretaraneus liaoningensis* Cheng, Meng & Wang, 2008, *Cretadromus liaoningensis* Cheng, Shen & Gao, 2009, are considerably smaller.

Huge numbers of crustacean species have been

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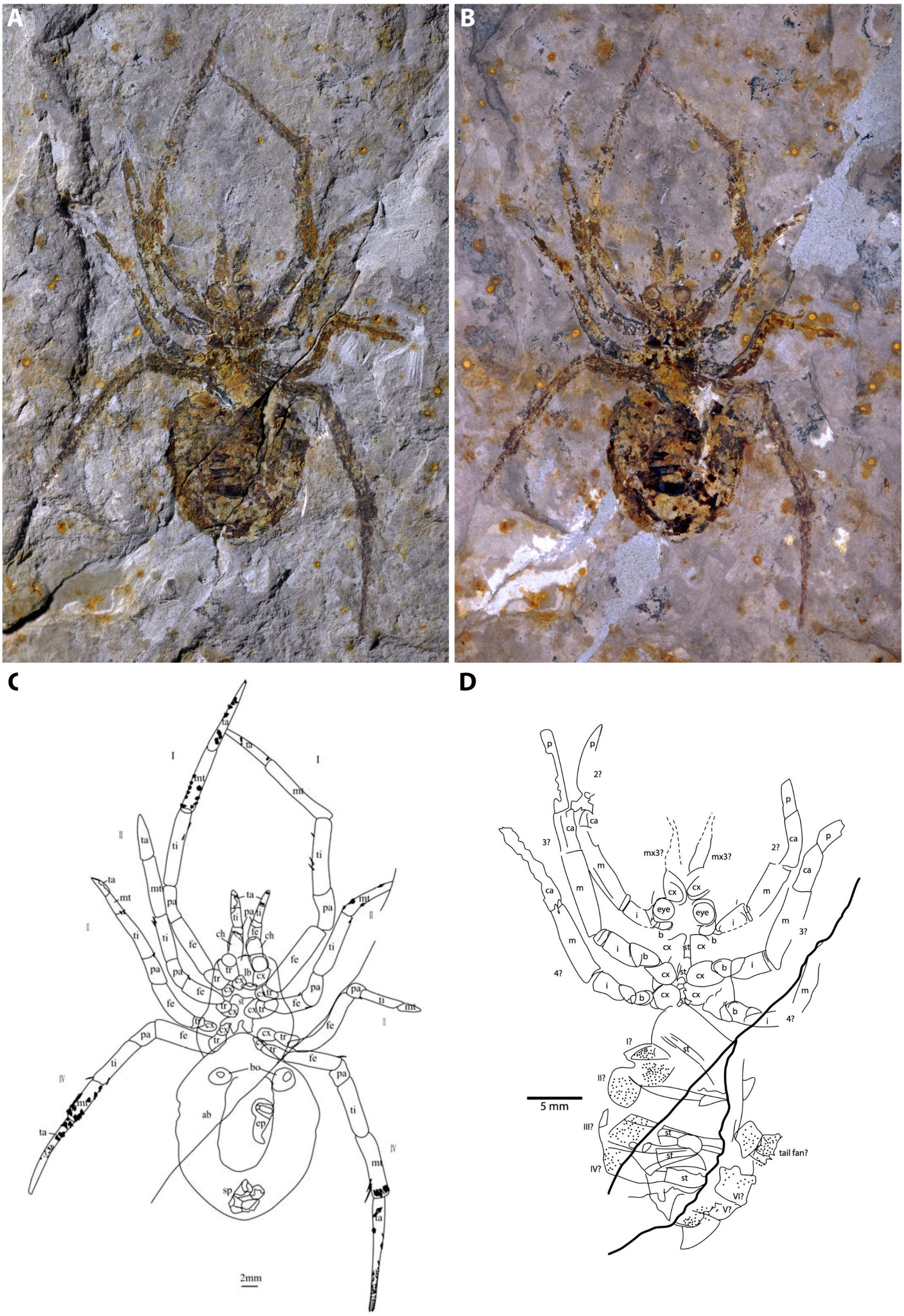

FIGURE 1. Holotype (D3088) of *Mongolarachne chaoyangensis* Cheng, Liu, Huang, Liu, Li & Li, 2019. **A**, Photograph of specimen dry. **B**, Photograph of specimen under ethanol. **C**, Interpretation of specimen as a spider (Fig. 1 in Cheng *et al*., 2019). **D**, Interpretation of specimen as a crayfish. Abbreviations: **C**: I–IV = walking legs, ab = abdomen, bo = book lung operculum, ch = chelicera, cx = coxa, ep = epigynum, lb = labium, fe = femur, mt = metatarsus, pa = patella, sp = spinnerets, st = sternum, ta = tarsus, ti = tibia, tr = trochanter; **D**: 1–5 = pereiopods, I–VI = abdominal segments, b = basis, ca = carpus, cx = coxa, i = ischium, m = merus, mx3 = maxilliped 3, p = propodus, st = sternite.

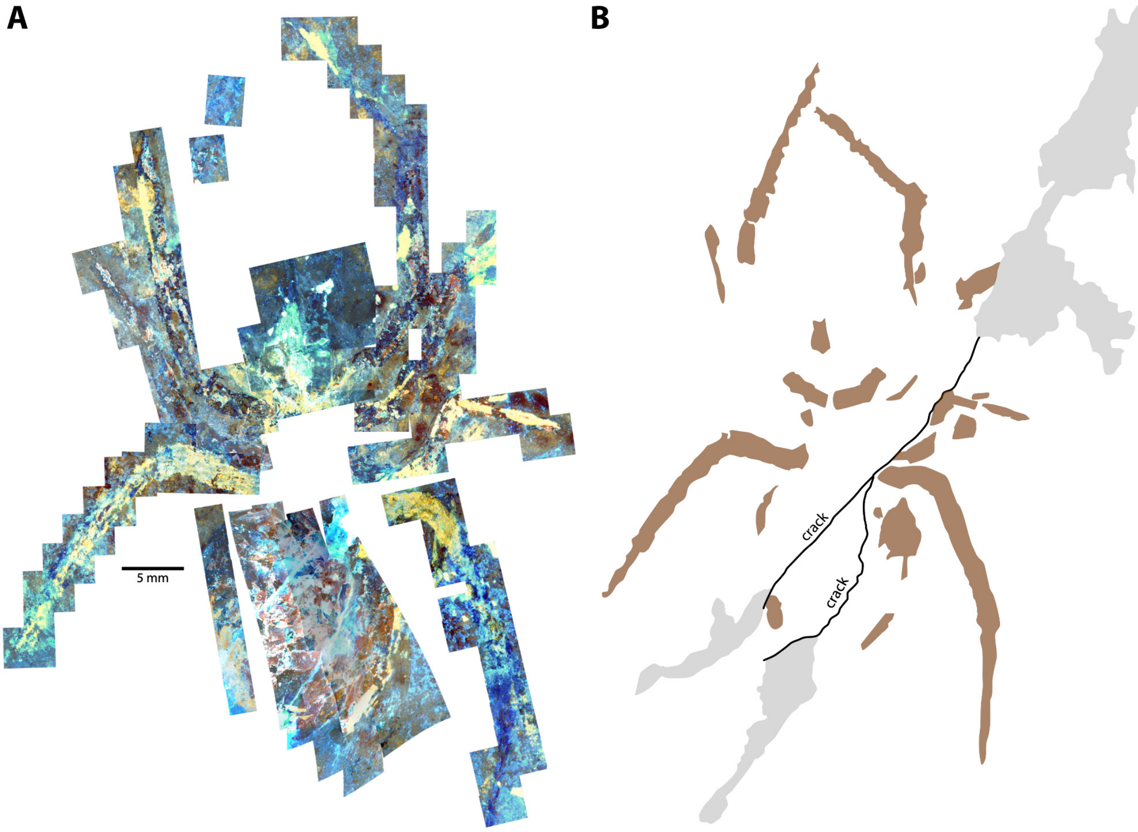

FIGURE 2. Holotype (D3088) of *Mongolarachne chaoyangensis* Cheng, Liu, Huang, Liu, Li & Li, 2019. **A**, Mosaic of parts of the specimen as seen under fluorescence microscopy: bright white shows areas of cement used to repair the specimen, bright blue shows the rock matrix, bright yellow marks areas painted with oil-based paint, and dull red is the fossil cuticle. **B**, Map of specimen showing cracks, cemented areas (grey), and painted parts (brown).

described from the Jehol biota, most of which are branchiopods and ostracods; among malacostracans apart from crayfish is the spelaeogriphacean *Liaoningogriphus quadripartitus* Shen, Taylor & Schram, 1998, (Chang, 2004). Only two monotypic species of decapods have been described, both from the locality near Dawangzhangzi Village: the crayfishes *Palaeocambarus licenti* (Van Straelen, 1928) and *Cricoidoscelosus aethus* Taylor, Schram & Shen, 1999. While the differences between them have become obscure following detailed examination of numerous new specimens (Shen *et al*., 2001), based on general similarities to fossil crayfish from the locality, we tentatively consider the faked fossil to belong to *Cricoidoscelosus aethus*.

Material and methods

Geological setting

The specimen was collected near Dawangzhangzi Village, Liaoning Province, northeastern China (41°08′02″N 119°15′45″E) (Cheng *et al*., 2019). The stratigraphy at the site consists of the Dawangzhangzi Bed of the Yixian Formation, dated as mid-Early Cretaceous (late Barremian), *ca*. 125 Ma (Zhou *et al*., 2003). The Yixian Formation consists of cyclic volcanic deposits and associated lacustrine sediments. The nearly complete preservation of the fossils, particularly plants, arthropods, and vertebrates, suggests that the biota was not transported far from where it lived (Zhou *et al*., 2003).

Preservation

The specimen consists of single slab bearing two large cracks across it (Figs 1, 2). The cracks are mended and a filling cement has been used to enhance the repair. The fossil is preserved partly as external mould and partly as cuticle. It shows mainly ventral structures in the anterior part, with fragments of dorsal tergites appearing as pitted cuticle on the left side of the posterior part. The tail fan is unclear. Only parts of the appendages are preserved, mainly the coxa to propodus of three pereiopods (walking legs). The first pereiopod (major cheliped, thoracopod 4) is not preserved. Large, circular structures, interpreted as eyes, are prominent anteriorly, with the bases of possibly maxilliped 3 seen in front. Considering the lack

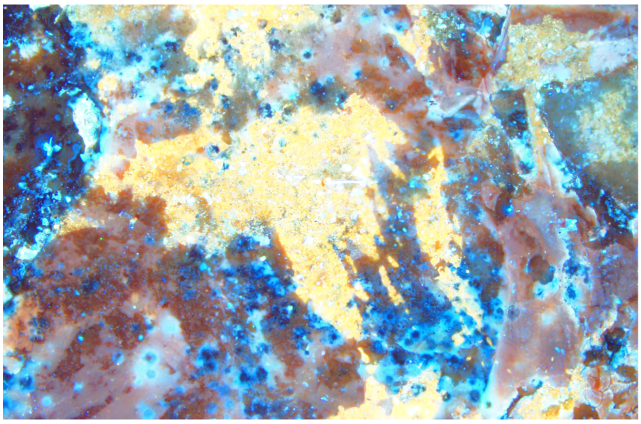

FIGURE 3. Holotype (D3088) of *Mongolarachne chaoyangensis* Cheng, Liu, Huang, Liu, Li & Li, 2019. Detail of an area near where the posterior (false) legs meet the body, showing bright yellow fluorescence (= paint) with brush strokes overlying dull red cuticle and blue matrix.

of a carapace (cephalothoracic shield), and the somewhat displaced nature of the appendages, the fossil could be preserved as a ventral view, or as a moult. Moulted crayfish showing similar characteristics to our fossil have been described from the same formation (Schram & Shen, 2000).

Methods

The specimen was studied, photographed and drawn using standard stereomicroscopy techniques (see Selden, 2014). In order to distinguish the real morphology from the features added by painting, the specimen was also studied under an Olympus BX51 petrographic microscope equipped with 4×, 10×, 20×, and 60× objectives, a mercury vapor arc-discharge lamp, and two exciter filters designed to transmit in the UV (330–385 nm wavelength) and violet-blue (400–440 nm wavelength) regions. The images were taken without a filter. Photographs were taken with an Olympus DP73 digital camera, and processed with Stream Image Analysis software, including using both the built-in manual Z-Axis stacking and Multiple Image Alignment options (olympus-lifescience.com). Note that the objective of this fluorescence study was to determine the areas of unnatural embellishment, not to study the taphonomy of the fossil in detail, which would require additional research.

Results

Fluorescence microscopy

Fluorescence is the emission of light by an object that has absorbed light. This emission occurs within nanoseconds of the absorption, and typically the emitted light is of a longer wavelength than the absorbed light (Lichtman & Conchello, 2005). The difference between these two wavelengths, called the Stokes Shift, is what makes fluorescent microscopy possible. In this technique, a sample is illuminated with short-wavelength light, typically UV (330–385 nm wavelength) or violet-blue (400–440 nm wavelength). If a sample absorbs the light and emits a different wavelength of light, the emitted light is observed thanks to filters on the microscope that only allow the longer-wavelength light through (Lichtman & Conchello, 2005). In biology, targets of interest are stained with fluorescent probes, allowing the illumination of selected features (Lichtman & Conchello, 2005). In contrast, geological samples are imaged through a sample's own autofluorescent properties. Not all samples autofluoresce; this phenomenon is caused by the presence of fluorophores, which are often organic compounds, but can also be rare earth elements, uranyl ions, or mineral lattice defects (Burruss, 1991). Given the number of different fluorophores possible in geology, the colour of fluorescence is not a definitive indicator of composition in and of itself, but when combined with the geological context of a sample, it can often be used to determine the likely chemical composition of a sample.

Fluorescence microscopy on the fossil specimen reveals four distinct responses: regions that appear bright white, ones that are bright blue, ones that are bright yellow, and ones that are dull red. The bright white areas are found in association with a mended crack, and is likely the fluorescent response of the materials used to repair the crack (Petronella, 2006). The bright blue fluorescence is found throughout the matrix across the entire fossil slab. This could be due to the mineral composition of the host rock, especially as it is a response observed in other samples from the Jehol Biota (Hone *et al*., 2010), although it could also be the result of the unfiltered light used to observe the sample. The yellow and red fluorescence are found in association with the specimen itself. The material that fluoresces yellow is found mainly along the legs and along the back rim of the carapace. This fluorescent response is particularly strong along the two posterior legs. In contrast, a dull red fluorescent response is found across the carapace, along the front three legs, and on the anterior region. Where the posterior legs meet the body, the yellow material drapes across the red material in streaks (Fig. 3). Yellow fluorescence often indicates an aliphatic carbon (Pickel *et al*., 2017); it is likely that the paint used to alter the crayfish fossil was an oil-based pigment, consistent with the fluorescence response observed here (Carden, 1991). In contrast, the red fluorescence response is consistent both with the presence of calcite (Modreski & Aumente-

FIGURE 4. Specimen of *Cricoidoscelosus aethus* Taylor, Schram & Shen, 1999 (CNU-DEC-LB2019001p/c) from the Yixian Formation preserved in a similar manner to *Mongolarachne chaoyangensis*. **A**, Part. **B**, Counterpart. Note the translucent carapace showing detail of the thorax beneath, and abdomen curved round laterally almost into an oval shape, as seen in *M. chaoyangensis*.

Modreski, 1996) and with the presence of aromatic carbon (Pickel *et al*., 2017). This would indicate that the material that fluoresces red is likely the remnants of the original crayfish exoskeleton; studies have shown that chitinous crustacean cuticle begins to decay rather quickly upon death, leaving a compound composed mainly of calcite with some aromatic carbons (Stankiewicz *et al*., 1998).

Interpretation of the fossil

The specimen has clearly been reassembled from at least three pieces, with the cracks mended and cement used to fill the deeper areas; the cement shows up well under alcohol (Fig. 1B), and fluoresces white (Fig. 2). In addition, an oil-based paint (possibly mixed with clay) has been used to convert the poorly preserved crayfish specimen into a spectacular-looking spider. This was achieved by extending existing legs into long, thin, more spider-like walking legs, adding a fourth walking leg, and filling in between the pieces of abdomen to create a more oval, symmetrical, spider-like opisthosoma.

The specimen is shown photographed dry in Fig. 1A, and under ethanol in Fig. 1B; the latter reveals cemented areas used to repair the specimen. Interpretation of the fossil as a spider is given in Fig. 1C (Fig. 1 from Cheng *et al*., 2019), and as a crayfish in Fig. 1D. Fig. 3A shows the results of fluorescence microscopy as a map of the specimen; here, it can be seen that painted areas include distal parts of the anterior legs, both legs IV, and parts of the opisthosoma. In Fig. 3B, the painted and repaired areas are isolated to show the extent of the forgery.

The large, circular structures at the anterior end of the body are interpreted as eyes. Crayfish eyes are prominent structures, and can be well preserved (Audo *et al*., 2016). They are positioned rather more posteriorly in relation to the appendages than in living crayfish examined, but that may be the morphology of the fossil species. In front of the eyes, a pair of coxae and associated telopods may be remains of the third maxilliped (Fig. 1D). There is no sign of the first pereiopod, the large cheliped. In all, coxae of four pereiopods are preserved, together with the basis-propodus of legs interpreted as 2–4. The large gap between the last pair of pereiopods and the first abdominal tergite suggests that pereiopod 5 is missing. The powerful claws of the first pereiopod are missing. Between coxae of pereiopods 2–4 (and providing evidence for the numbering of these appendages) are three, narrow, λ-shaped sternites. Note that, in a spider, a large sternum would be present in this position; moreover, the walking leg podomeres would be less numerous and of a different morphology. The thoracic region shows ventral structures. Abdominal tergites are evidenced by their pitted cuticle; ventral sternites appear as shorter, brown cuticle, slightly narrowed medially. The preservation appears similar to that seen in the specimen CNU-DEC-LB2019001p/c (Fig. 4), with the abdomen curved laterally to give a somewhat oval outline. The tail fan is not discernible among the mess on the right side of the crack. Hence, the segment numbering is imprecise.

Systematic palaeontology

Subphylum Crustacea Brünnich, 1772
Class Malacostraca Latreille, 1802
Order Decapoda Latreille, 1802
Infraorder Astacidea Latreille, 1802
Superfamily Astacoidea Latreille, 1802
***Cricoidoscelosus aethus* Taylor, Schram & Shen, 1999**

Remarks. It is difficult to identify to which of the two species of crayfish known from the Yixian Formation, *Palaeocambarus licenti* (Van Straelen, 1928) and *Cricoidoscelosus aethus* Taylor, Schram & Shen, 1999, the present specimen belongs, because the identifying characters, the shape of the pleopods, are not preserved. Moreover, as pointed out by Shen *et al*. (2001) who studied many more specimens from the Yixian Formation, considerable variation in the shape of the pleopods suggests that this character is unreliable for discriminating the two species, and hence also distinguishing the family Cricoidoscelosidae Taylor, Schram & Shen, 1999. We tentatively place our specimen in *Cricoidoscelosus aethus* because this is marginally the commoner of the two crayfish recorded from the Yixian Formation (Shen *et al*., 2001), and our specimen resembles that identified as *C. aethus* and figured by Chang *et al*. (2003: fig. 62). It is possible that further work on Chinese fossil crayfish (Audo & Kawai, 2019) will synonymize these closely related genera (as *Palaeocambarus* in the family Cambaridae) in the future.

Mongolarachne chaoyangensis Cheng, Liu, Huang, Liu, Li & Li, 2019: p. 227; fig. 1. **new synonymy.**

Material. Single specimen (part only), number D3088, deposited in the Dalian Natural History Museum, Dalian 116023, Liaoning, China.

Discussion

Whilst it is quite obvious from a cursory look at the specimen under the stereomicroscope that it is not a spider, the fakery of the appendages is sufficiently accomplished that it is not entirely clear where real fossil ends and paint begins (in some areas the two are intermingled). However, using the technique of fluorescence microscopy, we were able to distinguish the painted areas, true cuticle remains, rock matrix, and cement used to repair the broken slab fairly easily.

Fluorescence microscopy is becoming increasingly useful in palaeontology, for identifying vertebrate bones, teeth, and feathers (*e.g*., Hone *et al*., 2010; Kaye *et al*., 2015; Delpueyo *et al*., 2016; Frese *et al*., 2017), to determine morphology in fossil arthropods (*e.g*., Haug *et al*., 2008; Charbonnier *et al*., 2017), and has been used previously to determine fake vertebrate fossils (*e.g*., Rowe *et al*., 2001). Here, we have used the technique to distinguish anthropogenic repair and alteration of an invertebrate fossil from the Lower Cretaceous Yixian Formation of China; specifically, an attempt to pass off a poorly preserved crayfish fossil as a giant spider by adding morphology with an oil-based paint, in addition to repairing the broken slab bearing the specimen.

Fakery of fossils to increase their value is widespread within particular Fossil-Lagerstätten. Usually, this involves fossils with a high value to start with, such as vertebrates (*e.g*., Stone, 2010), but can extend to those less desirable, *e.g*., the false spider described here. Within the Yixian Formation, forgeries are commonplace among vertebrates (*e.g*., Rowe *et al*., 2001); but other Lagerstätten are not immune. The only other described fake fossil spider of which we are aware is *Cretadiplura ceara* Selden in Selden *et al*., 2006, from the Cretaceous Crato Formation of Brazil, in which additional portions of the right walking legs were added using wax crayon (Selden *et al*., 2006).

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