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Discovery of *Hemeroscopus baissicus* (Odonata, Anisoptera, Hemeroscopidae) from the Lower Cretaceous Naijiahe Formation (Ningxia, NW China) and its stratigraphic significance

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Abstract

Several newly collected dragonfly wings from the Lower Cretaceous Naijiahe Formation (Kangjiawan locality, Tongxin County, Ningxia Hui Autonomous Region, NW China) have been identified as belonging to the widely distributed species *Hemeroscopus baissicus*, found in North China and South Korea at similar palaeolatitudes. This species shows potential for stratigraphic correlation. The findings suggest that the Shahai-Fuxin Formation (western Liaoning), Lushangfen-Xiazhuang Formation (western Beijing), Madongshan-Naijiahe Formation (Ningxia), and Zhonggou Formation (Jiuquan Basin) are likely of comparable ages.

Key words: Anisoptera, biostratigraphy, late Early Cretaceous, Aptian–Albian, North China

Introduction

Compression fossils of Odonata are relatively common in Chinese continental Mesozoic deposits, particularly from the Middle Jurassic to the Early Cretaceous. Certain groups, such as Campterophlebiidae, Isophlebiidae, Aeschnidiidae, and Aeshnoptera, are especially diverse and abundant. However, there have been few attempts to use Mesozoic Odonata for stratigraphic correlation, likely due to their rapid evolutionary rates associated with high group diversity. Other representative insect taxa, such as *Ephemeropsis trisetalis* and *Coptoclava longipoda*, have been used for biostratigraphic analyses. However, these taxa may represent multiple species, complicating their utility for precise stratigraphic correlations (e.g., Zhang 1997; Huang & Ren 2008).

Recently, new insect fossils were collected from the Lower Cretaceous Naijiahe Formation near Kangjiawan Village, Naijiahe County, Ningxia, NW China (Fig. 1). The palaeoentomofauna is rich but displays low diversity, with only a few insect orders represented, including Hemiptera (true bugs), Coleoptera (mainly isolated elytra), Diptera, Thysanoptera, and abundant Odonata fragments. Another dragonfly species, *Guyuanaeschnidia eximia*, was previously described from this area, though its horizon within the Liupanshan Group remains uncertain (Lin *et al*. 2022). The newly collected dragonfly specimens primarily consist of wing fragments, along with some isolated heads, legs, and abdominal segments. In this study, we describe these new dragonfly remains from the Lower Cretaceous Naijiahe Formation, assigning them to *Hemeroscopus baissicus* Pritykina, 1977, a widespread taxon in the Early Cretaceous of Asia. Additionally, we discuss the significance of this species for stratigraphic purposes.

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Material and methods

Fragments of adult dragonflies, including hind wings, heads, legs, and nymph remains, were collected from the yellow shale and marlite of the Lower Cretaceous Naijiahe Formation near Kangjiawan Village, Tongxin County, Wuzhong City, Ningxia Hui Autonomous Region, NW China (Fig. 1). Based on sporopollen analysis, the Naijiahe Formation has been dated to the Albian stage (Wang & Lu 2012). Correlative strata, such as the Pukou Formation in Nanjing, were recently dated using U-Pb zircon analysis, yielding an age of 106.5 Ma from its basal layer (Gao *et al.* 2024).

Some specimens were carefully prepared using a sharp knife. The fossils were photographed using a Zeiss AXIO Zoom V16 stereomicroscope. All specimens were deposited at Nanjing Institute of Geology and Palaeontology, CAS, Nanjing.

The higher classification of fossil and extant Odonatoptera, as well as familial and generic characters follow the phylogenetic system proposed by Bechly (1996). Wing venation terminology follows Riek & Kukalová-Peck (1984), as amended by Nel *et al.* (1993) and Bechly (1996).

Abbreviation of venation: Ax1 and Ax2 primary antenodal crossveins; C costa; CuA cubitus anterior; CuP cubitus posterior; IRxx supplementary longitudinal veins between branches of RP; MAa anterior branch of media anterior; MAb posterior branch of media anterior; MP media posterior; Mspl supplementary vein in postdiscoidal area; 'O' oblique crossvein between IR2 and RP2; RA radius anterior; RP radius posterior, Rspl supplementary vein in area between IR2 and RP3/4; PsA anterior branch of AA; ScP subcostal posterior.

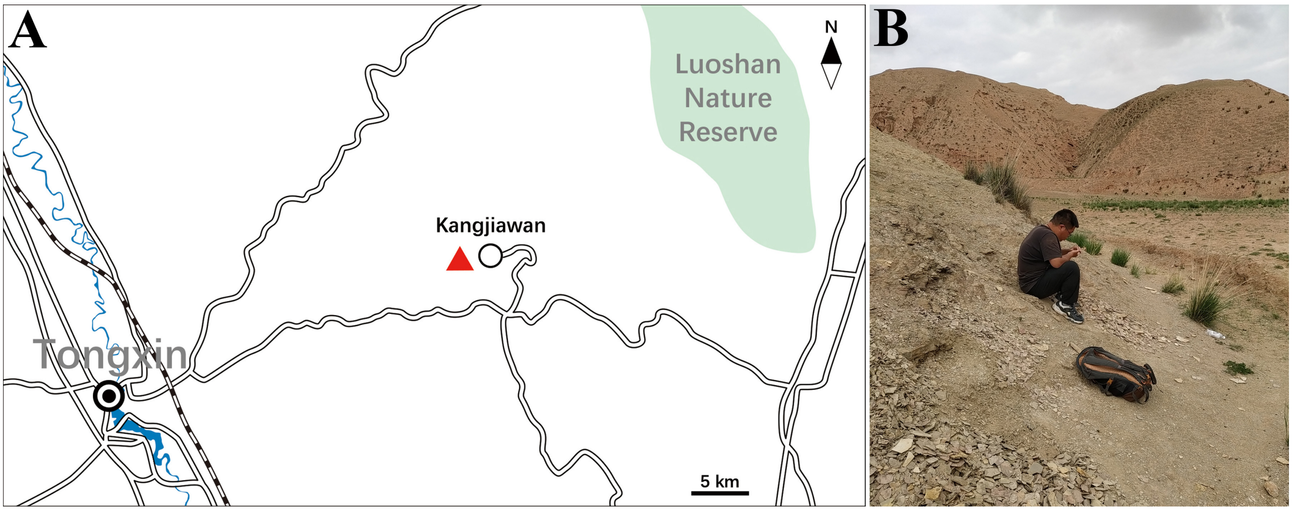

Figure 1. Fossil locality. **A,** map of fossil locality (red triangle); **B,** outcrop with new dragonfly fossils collected.

Results

Order Odonata Fabricius, 1793
Suborder Anisoptera Selys-Longchamps (*in* Selys-Longchamps & Hagen, 1854)
Family Hemeroscopidae Pritykina, 1977
Genus *Hemeroscopus* Pritykina, 1977

***Hemeroscopus baissicus* Pritykina, 1977**
(Figs 2–4)

Material. Specimen NIGP206076a (part), NIGP206076b (counterpart) (a nearly complete hind wing). Several fragments of wings, a head and a leg illustrated (NIGP206346–206353).

Age and outcrop. Yellow shale and marlite, Lower Cretaceous Naijiahe Formation near Kangjiawan Village, Tongxin County, Wuzhong City, Ningxia Hui Autonomous Region, NW China.

Description. Hind wing 40.8 mm long, 12.4 mm wide at level of nodus; distance from base to nodus 17.1 mm, from nodus to pterostigma 12.4 mm; pterostigma 5.5 mm long, 0.7 mm wide; pterostigma not parallel sided with basal side somewhat less oblique than distal side, and covering three cells. IR1 short, originating on RP1 just below pterostigmal apex; area between IR1 and RP1 with two rows of cells, and between IR1 and RP2 with four rows; RP1 and RP2 with one row of cells between them only basally and becoming divergent; base of RP2 aligned with subnodus; one oblique crossvein ‘O’ between RP2 and IR2, three cells distal of subnodus; area between RP2 and IR2 distally widened with one row of cells basally and two-three rows distally; RP2 and IR2 gently curved, and reaching posterior margin obliquely; at least four antefurcal crossveins between RP and MAa basal of RP-midfork; Rspl present and weakly zigzagged, and one row of cells between IR2 and Rsp1; two long and convex secondary veins present between IR2 and RP3/4, both originating on Rspl; Mspl absent, but three long and convex secondary veins present in distal postdiscoidal area between MAa and MP; postdiscoidal area with two rows of cells basally; RP3/4 and MA running almost parallel, but slightly undulating at level of oblique crossvein ‘O’; area between RP3/4 and MA slightly widened sub-distally with one row of cells basal of oblique crossvein ‘O’ and two rows distally; discoidal triangle wide and not divided by crossveins; hypertriangle free; median space free of crossveins; subdiscoidal triangle unicellular; MP gently curved and extended to end nearly at level of subnodus; CuAa well defined, with posterior branches; area between CuA and MP basally distinctly widened with two rows of cells below discoidal triangle, and five cells near posterior wing margin; “gaff” straight and very elongated; CuAb (most basal posterior branch of CuA) strongly angular to “gaff”-portion of CuA basally; CuAb and a posterior branch of AA enclosing a relatively wide anal loop with at least 14 cells; arculus slightly angled, and bases of MA and RP distinctly separated at arculus. Ax1 and Ax2 present but poorly preserved.

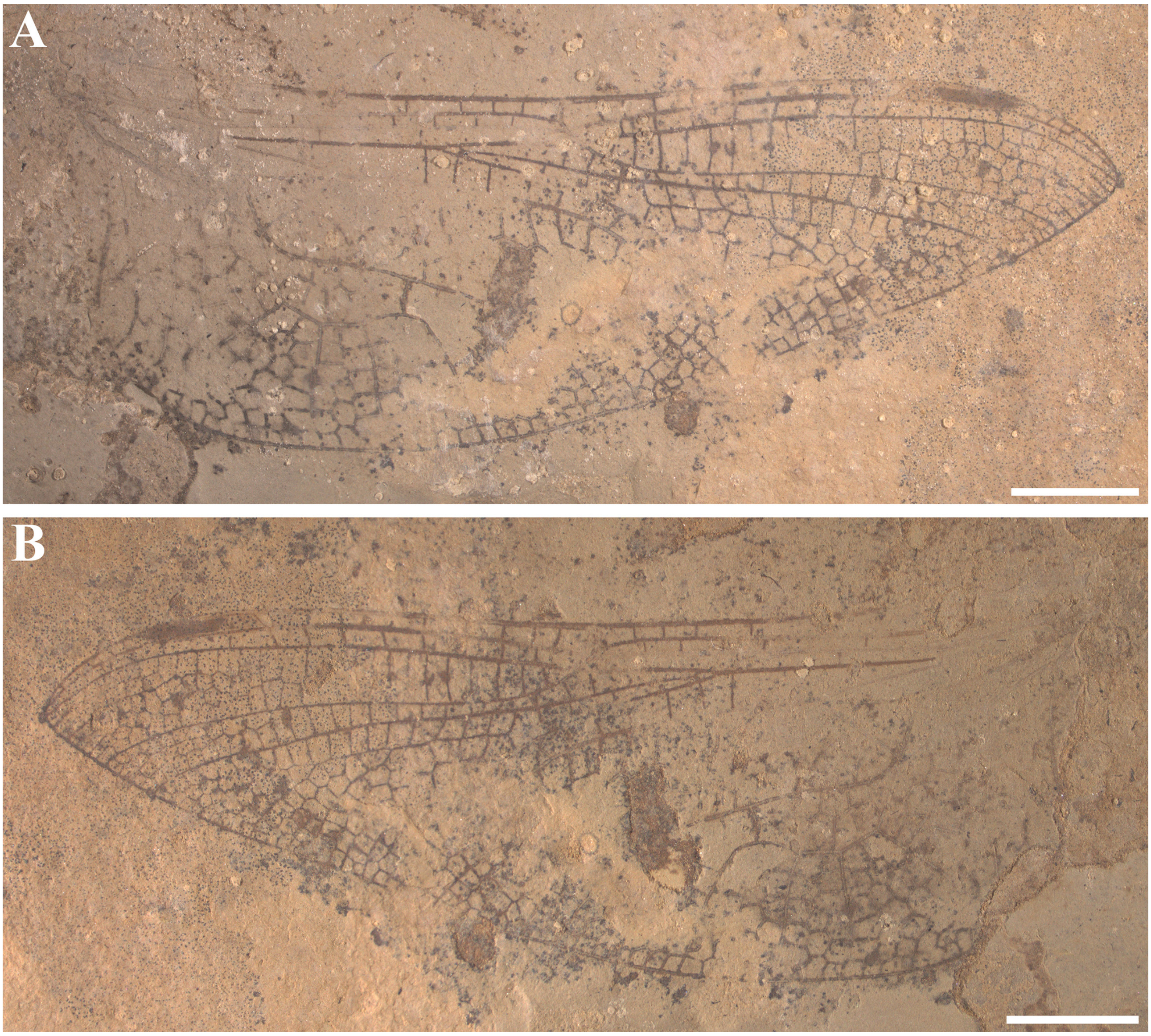

Figure 2. *Hemeroscopus baissicus*, from the Lower Cretaceous Naijiahe Formation, general habitus. **A,** part (NIGP206076a); **B,** counterpart (NIGP206076b). Scale bars = 5 mm.

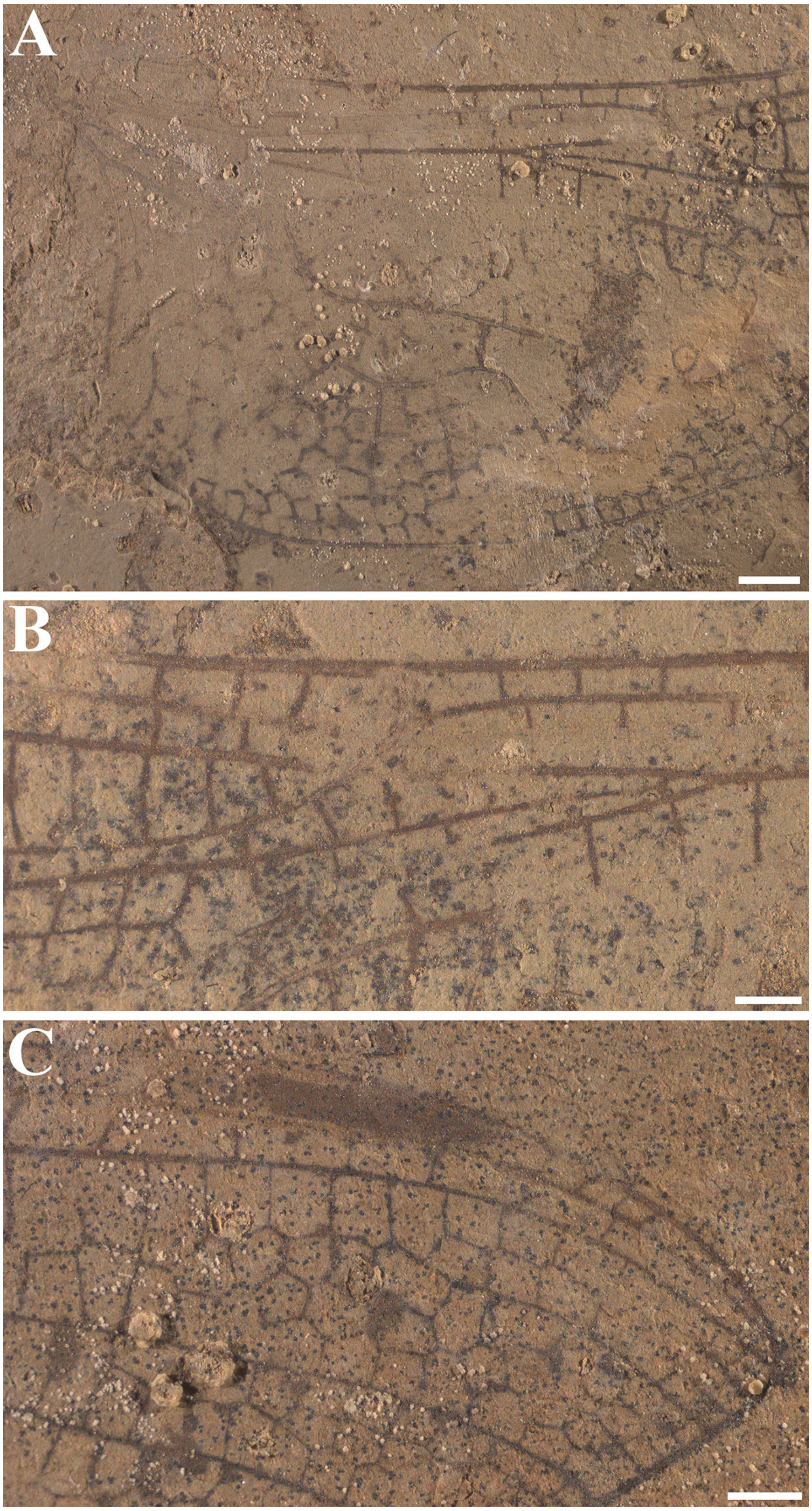

Figure 3. *Hemeroscopus baissicus*, from the Lower Cretaceous Naijiahe Formation, enlargements (NIGP206076). **A,** wing base; **B,** nodal area; **C,** wing apex. Scale bars = 2 mm.

Remarks. A well-preserved dragonfly leg is likely attributable to this species. The trochanter is developed and armed with spines on its inner section. The femur is robust, approximately 0.5 mm long, tapering toward the apex, with its inner edge bearing rows of spines. The tibia is equal in length to the femur, with the outer edge also armed with spine rows. A long, straight spine is present near the midsection, while the middle-posterior tibia features a row of nine long spines. The tibia is three-segmented: the first tarsomere is short and bears three long ventral spines; the second tarsomere is elongated, nearly twice the length of the first, and armed with three long ventral spines; the third tarsomere is longer than the combined length of the first and second tarsomeres and is armed with six long ventral spines.

Discussion

Morphological comparison of *Hemeroscopus baissicus* from different localities

The head (Fig. 4I) fits quite well the head attributed to *Hemeroscopus baissicus* by Pritykina (1977: text-fig. 8a), with the compound eyes meeting dorsally for a short distance. The new nearly complete hind wing fits quite well with that of *Hemeroscopus baissicus* as described by Pritykina (1977: text-fig. 7, pl. 3, fig. 2). The perceptible differences being as follows: hind wing 40.8 mm long vs 49 to 54 mm long in the latter; nine rows of cells in area between MP and CuAa (situated distad the third group of cells delimitated by the posterior branches of CuAa) along the posterior margin of wing vs seven; hind wing pterostigma covering three cells vs two; base of pseudo-IR1 situated 11 cells distad the base of RP2 vs situated five cells.

The hind wing from the Zhonggou Formation (Jiuquan Basin, Gansu Province, Northwest China) attributed to *H. baissicus* by Zheng *et al*. (2015) is 36.5 mm long. These last authors estimated the range of lengths of the hind wings in Jiuquan Basin between 30 and 42 mm, thus much smaller than the type material of the species but fitting well with the new specimen. The specimen figured by these authors has a pterostigma covering two cells, five rows of cells in area beween MP and CuAa along the posterior margin of wing, and the base of pseudo-IR1 situated four-five cells distad the base of RP2.

The hind wings from the Lushangfen Formation (western Beijing) attributed to *H. baissicus* by Ren *et al*. (1995) would be slightly longer than 50 mm, fitting well with the size of the type material of the species. The number of cells covered by their pterostigma, and the exact position of the base of the pseudo-IR1 are unknown, but they have five rows of cells in area between MP and CuAa along the posterior margin of wing.

The hind wings from the Jinju Formation (Gyeongsang Group, southern Korea) attributed to *H. baissicus* by Ueda *et al*. (2005) is 45 mm long; its pterostigma is covering two cells, base of pseudo-IR1 situated five cells distad the base of RP2; and it has eight rows of cells in area between MP and CuAa along the posterior margin of wing.

The hind wings from the Jinju Formation (Jinju area of Gyeongsangnam Province, Southern Korea) attributed to *H. baissicus* by Nam & Kim (2016: fig. 2a, b), is 46 mm long. Its pterostigma is covering two cells, the base of pseudo-IR1 situated four-five cells distad the base of RP2, and it has eight rows of cells in area between MP and CuAa along the posterior margin of wing. It is quite similar to the hind wing described by Ueda *et al.* (2005).

Another southern Korean specimen (Gi-Soo Nam, pers. comm.) has a hind wing 5.1 mm long, a pterostigma covering three cells, eight rows of cells between MP and CuAa, and the base of pseudo-IR1 situated seven cells distad the base of RP2.

As a result, the lengths of hind wings of these dragonflies greatly vary, ranging between 30(?) to 54 mm, with specimens having sizes in-between the extremes. Thus this character cannot be used to separate two species of *Hemeroscopus*. The number of rows of cells in area between MP and CuAa also varies, and, alone, cannot separate two species. The number of cells covered by the pterostigma is also not significant, it varies between two and three. But the forewing pterostigma in *H. baissicus* (type specimen) is also three, suggesting that the difference is not so crucial. The base of pseudo-IR1 is generally situated four-five cells distad the base of RP2, but if it is nine cells apart in the new fossil, one Korean fossil (Gi-Soo Nam pers. comm.) has it situated seven cells apart. Thus this character is also not sufficient to separate two species.

Thus, it seems that *Hemeroscopus baissicus* was a taxon with a very broad distribution, ranging from Transbaikalia, Mongolia, China in Gansu and Beijing, and southern Korea.

Analysis of stratigraphic correlation based on *Hemeroscopus baissicus*

Pritykina (1977) proposed a Barremian age for the type series of *Hemeroscopus baissicus* in Baissa (Transbaikalia), and an Aptian or early Albian age for the material from Bon-Tsagaan in Mongolia. According to the Palaeobiology Database, Baissa is dated from the Aptian (125.0 to 113.0 Ma). Huang *et al.* (2009) suggested that the Russian Zaza Formation, which yielded *H. baissicus*, correlates with the Lushangfen Formation based on similarities in fossil insect assemblages. Makarkin *et al*. (2012: 65) indicated that the age of Bon-Tsagaan 'is supposed to be Hauterivian/Barremian (Rasnitsyn *et al*. 1998; Vrsanský 2003) or Barremian/Aptian (Rasnitsyn & Zherikhin 2002)'. In the internet site mindat.org, (https://www.mindat.org/paleo_strat.php?id=20080), the age of Bon-Tsagaan would be between 125.0 and 113.0 Ma.

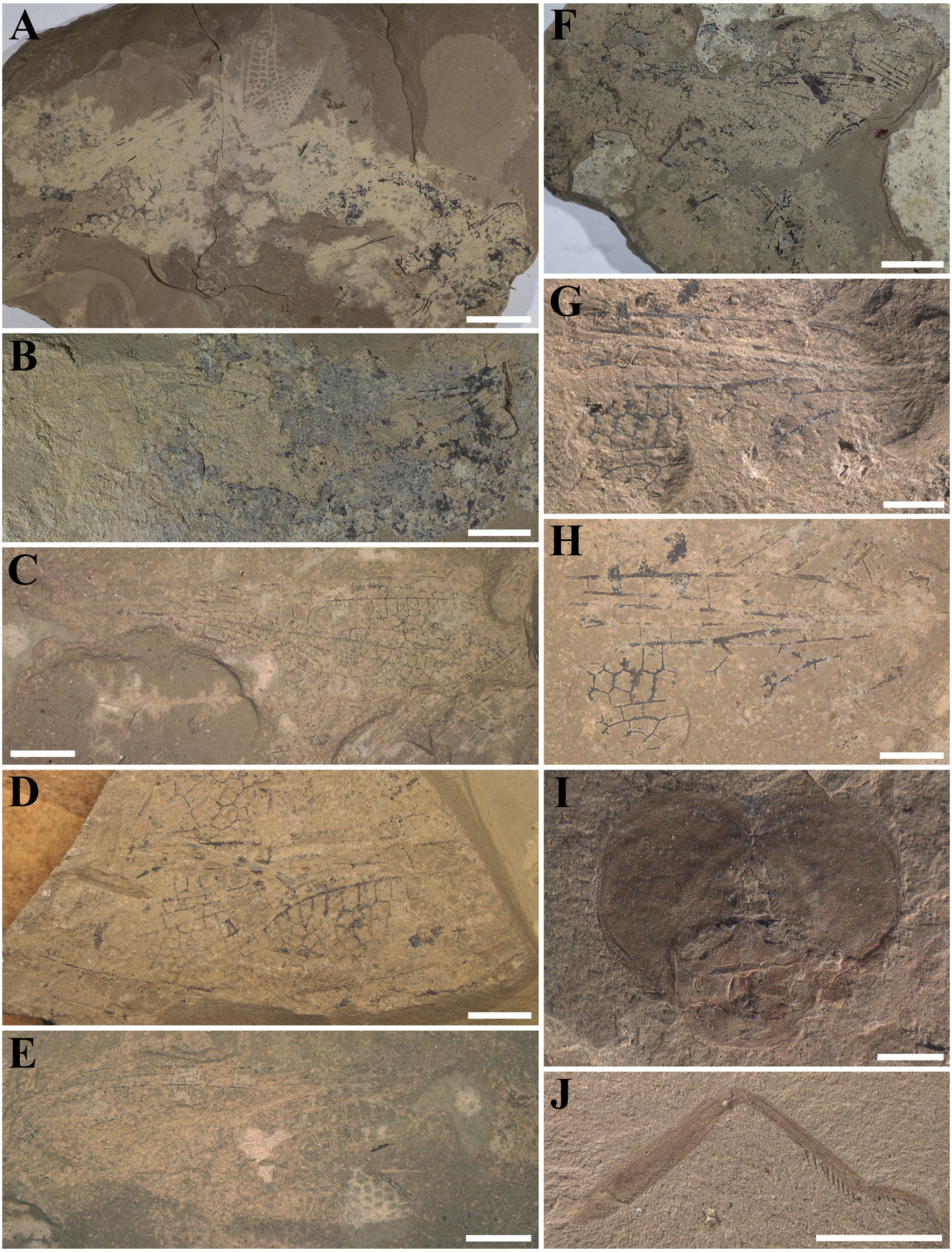

Figure 4. Dragonfly fragments attributable to *Hemeroscopus baissicus*, from the Lower Cretaceous Naijiahe Formation. **A–H,** wing fragments (NIGP206346–206353); **I,** head; **J,** leg. Scale bars = 5 mm in **A, B, F, D**; 2 mm in **C, E, G–J**.

Liao *et al*. (2014) proposed a late Aptian age for the Lushangfen Formation in Beijing. *H. baissicus* richly distributed in the upper sections of the Lushangfen Formation (Member 4; Huang & Lin 2001). Other *H. baissicus* from western Beijing were described by Ren *et al*. (1995) from the Chongqing Reservoir are in fact belonging to the overlying Xiazhuang Formation (Huang *et al*. 2009; Liao *et al*. 2014). Therefore, *H. baissicus* would range from late Apian to Albian in western Beijing. Xi *et al*. (2019) proposed an early Albian age of '113.7±1.8 Ma from the basalt was obtained in the base of the Zhonggou Formation'. Ueda *et al*. (2005) indicated that the Gyeongsang Group 'has been considered to be Early Cretaceous, the same age of the Kanmon Group, Kitakyushu' in Japan. Sur *et al.* (2002) indicated that 'the age of the Kammon group has been assigned to the late Valanginian to the early Albian'. Chae *et al*. (2020) proposed an age of ca. 106.5 Ma (middle Albian) for Jinju Formation. Considering all these data, *Hemeroscopus baissicus* appears to have had a relatively broad temporal range, likely spanning from the late Aptian to the middle Albian.

Conclusion

Stratigraphic correlation analyses for terrestrial basins in Mesozoic China remain challenging. Here, we propose that dragonfly assemblages could serve as valuable tools for comparing Early Cretaceous terrestrial strata. For example, the aeschnidiid genus *Sinaeschnidia* Hong, 1965 has been associated with the middle Early Cretaceous (Fleck *et al*. 2003), while *Hemeroscopus* is indicative of a late Early Cretaceous age in North China (Fig. 5). Notably, *Sinaeschnidia* can be traced to at least the middle parts of the Jiufotang Formation in western Liaoning, based on DYH's collections. The earliest representatives of Hemeroscopidae, such as *Abrohemeroscopus mengi*, were recorded in the Jiufotang Formation of western Liaoning (Ren *et al*. 2023). *Hemeroscopus baissicus* has been documented in the Lushangfen-Xiazhuang, Naijiahe, and Zhonggou formations of North China, as well as the Dongmyeong Formation of Korea, corresponding to a late Aptian to Albian age (Fig. 4). Furthermore, *Hemeroscopus* may also correlate these strata with those from Transbaikalia and Mongolia.

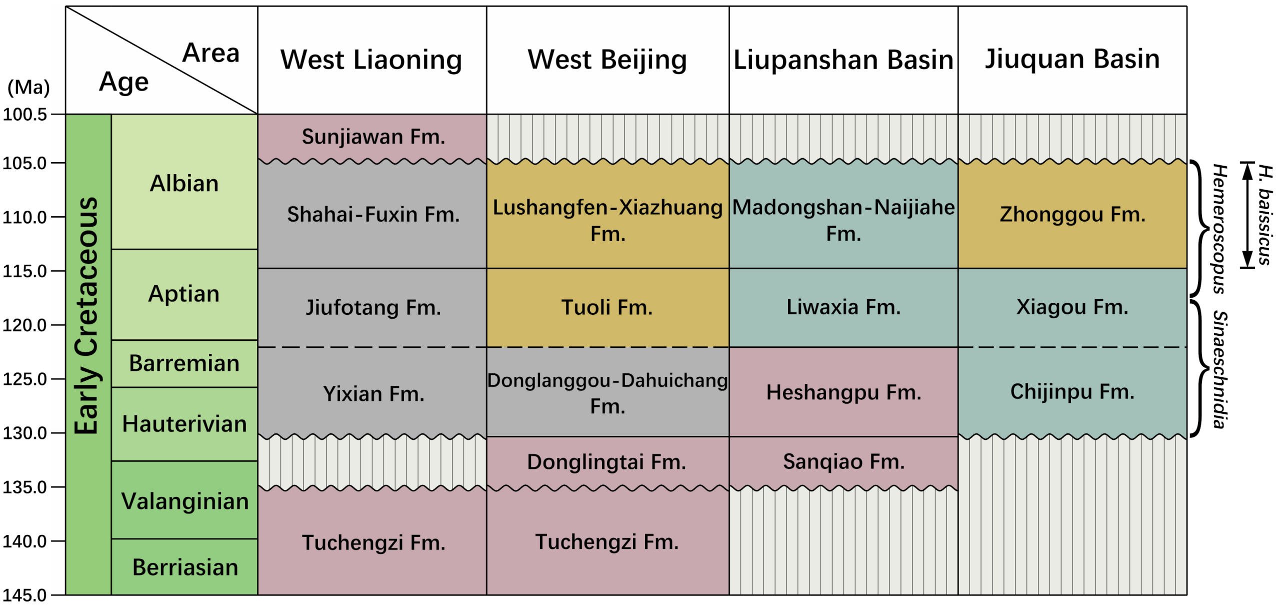

Figure 5. Biostratigraphic correlation based on the occurrence of *Hemeroscopus baissicus*.

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