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Agalope oshikirii n. sp., the first chalcosiine fossil (Lepidoptera, Zygaenidae) from Akita Prefecture, Japan

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Abstract

Agalope oshikirii n. sp. (Zygaenidae, Chalcosiinae) is described from the uppermost Miocene–Pliocene Sanzugawa Formation in Akita Prefecture, northern Japan. Because we found a single fossil forewing in this study, we give a table of the forewing characters of various groups of the genus *Agalope* and related genera and compared them with this new species, confirming that it does not match any of the species. This is the first discovery of chalcosiine fossils in Japan and provides evidence of a historically broader distribution of the genus.

http://zoobank.org/999828b5-4f91-470f-bc15-6b6fe7a8ec61

Non-technical Summary

Agalope oshikirii n. sp. (Zygaenidae, Chalcosiinae) is described from the uppermost Miocene–Pliocene Sanzugawa Formation in Akita Prefecture, northern Japan. This is the first discovery of chalcosiine fossils and provides evidence of a historically broader distribution of the genus.

Introduction

The subfamily Chalcosiinae (Lepidoptera, Zygaenidae) is distinguished by its high morphological and ecological diversity. The group comprises ~70 genera and 370–400 species (e.g., Bryk, 1936; Tremewan, 1973; Fletcher and Nye, 1982; Yen et al., 2005) and is distributed from Palaearctic eastern Asia, through subtropical southeastern Asia, to the Melanesian and Micronesian archipelagos (with the exception of the western Palaearctic genus *Aglaope* Latreille, 1809). To date, no fossil record of the subfamily has been identified (Sohn et al., 2012) largely due to the lepidopterans' low preservation potential, even in lacustrine deposits, as suggested by taphonomic simulations with existant species (Duncan, 1997).

The genus *Agalope* Walker, 1854, consists of small to medium-sized chalcosiine moths known for their translucent and thinly-scaled broad wings with a colored forewing base and various blackish patterns on the forewing upperside. Adults are active from spring to late summer and are typically observed flying slowly during the day (Huang et al., 2022). The genus currently includes 15 species, divided into four species groups—*hyalina*, *eronioides*, *livida*, and *geoffi*—distributed in the eastern Palaearctic and Oriental regions, including Kashmir, India, Nepal, Bhutan, northern Myanmar, various provinces in southwestern, central, and southern mainland China, Taiwan Island, and northern Vietnam (Huang et al., 2023).

Previously, six species groups—*hyalina*, *eronioides*, *bieti*, *pica*, *glacialis*, and *immaculata*—were recorded within *Agalope* (Yen et al., 2005). Huang et al. (2023) recently reviewed and modified the generic concept; they transferred the *pica* and *glacialis* species groups to a newly established genus *Paragalope* Huang and Horie in Huang et al., 2023 and the *immaculata* species group to another new genus, *Rotundagalope* Huang and Horie in Huang et al., 2023. Yen et al. (2005) highlighted that *Agalope* is not monophyletic, recommending the exclusion of *Agalope glacialis* (Moore, 1872) and *Agalope immaculata* Leech, 1898, supporting their transfer to other genera. Huang et al. (2023) further excluded all species of the *pica* and *bieti* species groups (sensu Yen et al., 2005) from *Agalope*, combining them with *Agalope glacialis* under a new genus based on similar genitalia structures. Thus, the concept of the genus *Agalope* is complex. Here, we report the first fossil specimen belonging to the genus *Agalope* (sensu Huang et al., 2023), which is also the first fossil representative within the subfamily Chalcosiinae.

Geological setting

The Sanzugawa caldera is located in the southern part of Akita Prefecture, northern Japan. It is filled by the Torageyama Formation, Sanzugawa Formation, and post-caldera volcanics (Takeno, 1988; Fig. 1.1, 1.2). The Torageyama Formation primarily consists of felsic pumice lapilli tuff formed by deisitic pyroclastic flows. The Sanzugawa Formation, made up of lake deposits, includes tuffaceous siltstone, mudstone, and sandstone with fossiliferous layers. The postcaldera Quaternary volcanics are distributed in the central part of the caldera (Takeno, 1988). Takeno (1988), Ito et al. (1989), and Ito (2023) discussed the history of the Sanzugawa caldera. According to these studies, the first stage of a caldera-forming eruption occurred ~6–5 million years ago (Ma) at the Sanzugawa caldera, resulting in the deposition of the Torageyama Formation. Approximately 4–3 Ma, another major caldera-forming eruption happened in the eastern part of the Sanzugawa Caldera, leading to thick lacustrine sedimentation of the Sanzugawa Formation, with continuous deposition of the Torageyama Formation. The former is represented by lake deposits found in Minase-dam, Sanzugawa, and Oyasu areas in the southern part of Yuzawa. The formation mainly comprises alternating layers of tuffaceous sandstone and siltstone (Takeno, 1988). Well-preserved fossils, e.g., plants and insects, are found in the main part of the formation.

The Sanzugawa Flora consists of 45 species and 30 genera, belonging to 20 families (Huzioka and Uemura, 1974). With seven species, Salicaceae is the largest family in the flora, followed by Betulaceae with five species, and Fagaceae and Sapindaceae with four species each. Prominent genera include *Salix* Linnaeus, 1753 with five species and *Acer* Linnaeus, 1753 with four species. Their probable habitats closely resemble the cool-temperate forest of northern Japan. Moreover, a majority of the Sanzugawa species are believed to have lived in forested valleys and on mixed slopes (Huzioka and Uemura, 1974), with the flora deposited in a freshwater lake basin. Oshikiri (2001) also reported plant fossils, e.g., winged seeds of Oleaceae and *Styrax protoobassia* Tanai and Onoe, 1961. Most Sanzugawa plants are identical or similar to late Miocene to earlier Pliocene species (Huzioka and Uemura, 1974).

Studies of insect fossils have been promoted by S. Oshikiri, a high school teacher, who described such species as *Bibio* sp. indet. (Bibionidae) and Tipulidae gen. indet. sp. indet., likely belonging to Ctenophorinae or Tipulinae (Oshikiri, 1979). Oshikiri (1982) reported 27 specimens belonging to 14 families with brief descriptions, and seven different Aphididae types based on additional specimens (Oshikiri, 1988). Fujiyama (1983) reviewed fossil localities in northern Japan, noting that Mycetophilidae and Bibionidae (Diptera), Ichneumonoidea and Formicidae (Hymenoptera), and Aphididae (Homoptera) are well represented among the insect fossils based on the occurrence list.

Material

The studied fossil is preserved in whitish tuffaceous siltstone and is part of Oshikiri's insect fossil collection. It was derived from an outcrop of the uppermost Miocene–Pliocene Sanzugawa Formation beside the old Kurotakibashi Bridge (39°1'21"N, 140°35'12"E; Fig. 1.3), which was lost due to a landslide in 2008. The studied specimen is deposited in Geosta Yuzawa, Yuzawa City, Akita Prefecture with a repository number OF-I74. In describing the characters of the specimens below, we follow Efetov and Tarmann's (2017) terminology of Zygaenidae.

Repository and institutional abbreviation. Type specimen examined in this study is deposited in Geosta Yuzawa—Oshikiri Fossil Insect Collections (OF-I).

Systematic paleontology

Order **Lepidoptera** Linnaeus, 1758
Superfamily **Zygaenoidea** Latreille, 1809
Family **Zygaenidae** Latreille, 1809
Subfamily **Chalcosiinae** Hampson, 1893
Genus ***Agalope*** Walker, 1854

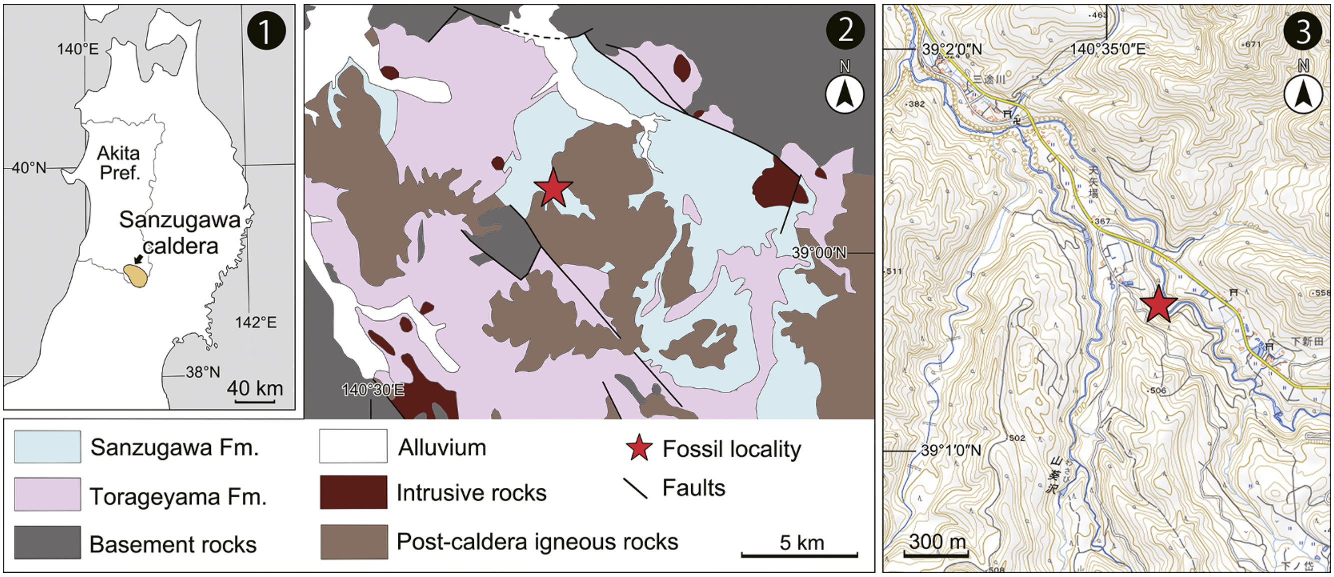

Figure 1. Locality of the studied fossil. (**1**) Location of the Sanzugawa caldera in Tohoku region, northern Japan; based on Ito (2023). (**2**) Simplified geological map of the Sanzugawa caldera; based on Ito et al. (1989). (**3**) The location map based on the digital topographic map published by the Geospatial Information Authority of Japan (GSI).

Type species. *Agalope basalis* Walker, 1854, by monotypy (currently a junior synonym of *Chalcosia hyalina* Kollar in Kollar and Redtenbacher, 1844).

Agalope oshikirii new species
[Japanese name: Oshikiri-usuba-hotaruga]
Figure 2

Holotype. OF-I74, a separated forewing (Fig. 2.1), Geosta Yuzawa, Yuzawa City, Akita Prefecture, Japan.

Diagnosis. *Agalope oshikirii* n. sp. is distinguished by the following combination of characteristics: medium-sized forewing (approximately 25 mm long) lacking blackish patterns; M_2 and M_3 veins are quite shortly stalked; R_4, R_5, M_1, and M_2 veins are parallel to each other; M_3 vein is parallel to CuA_1.

Occurrence. This species was discovered in the Sanzugawa Formation (latest Miocene–Pliocene) located in Sanzugawa Caldera, Yuzawa City, Akita Prefecture, Japan.

Description. Forewing 25.3 mm long, 12.2 mm wide, transparent, semitriangular. Forewing costa arched just before apex forming rounded wing tip. Termen almost straight, slightly concave between CuA_1 and CuP. Deeper colored small patch occupying basal one-eighth of wing, bordered with thin black arcuate band. Discal and terminal blackish maculations absent. Wing venation including full complement of veins. Sc vein ending near two-thirds of costa. Cross veins between costa and Sc absent. Discal cell slender, 17.2 mm long, 3.7 mm wide, spanning two-thirds of wing length. Discal cell closed with rudimentary medial stem vein in its distal part. R_1 and R_2 separated and arising independently from anterior part of cell. R_1 separated from Sc. R_2 and $R_{3–5}$ separated. R_3 and R_4 stalked. R_3 + R_4 shortly stalked with R_5. R_5 not strongly sinuate basally. Discocellular

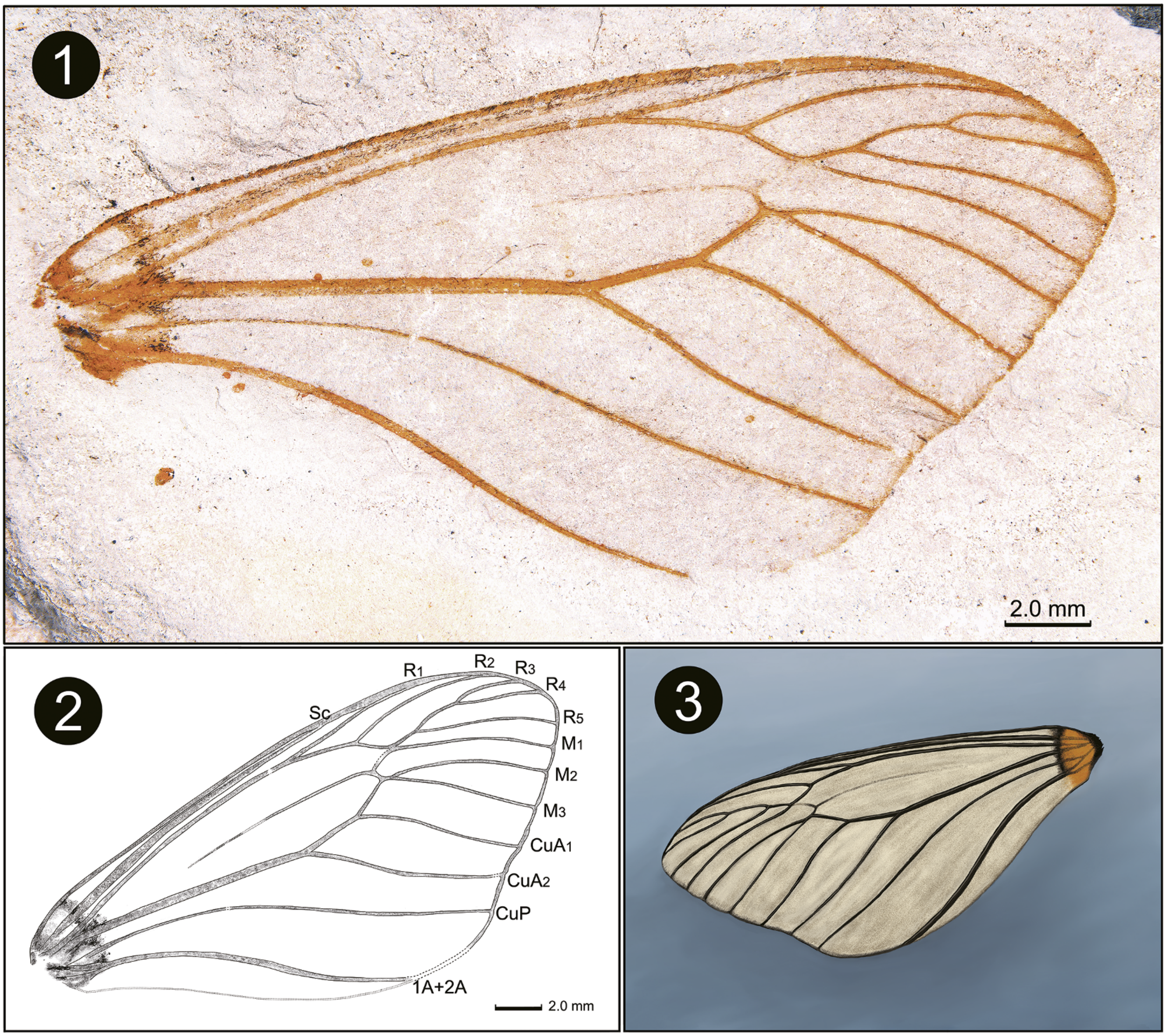

Figure 2 *Agalope oshikirii* n. sp. (**1**) Holotype, OF-I74, a separated forewing. (**2**) Drawing of OF-I74. We follow the terminology of Zygaenidae by Efetov and Tarmann (2017), with abbreviations for wing venation as follows: A = anal vein; CuA = cubital anterior; CuP = cubital posterior; M = median vein; R = radial vein; Sc = subcosta. (**3**) Color reconstruction of separated forewing of *Agalope oshikirii* n. sp. on the water surface in the lake. Art (**2**) and (**3**) are drawn by Kazuki Mera.

Table 1. Correlations of *Agalope oshikirii* n. sp. and relatives using the following ten elements: (1) forewing length; (2) forewing width; (3) L/W ratio; (4) discal cell length/forewing length ratio; (5) presence of colored patch in base; (6) length from base to basal black band/forewing length ratio; (7) presence of distinct maculations except for base; (8) presence of paralleled R$_4$, R$_5$, M$_1$, and M$_2$; (9) presence of quite shortly stalked M$_2$ and M$_3$; (10) presence of parallel M$_3$ and CuA$_1$. Cells in red font are elements shared with *Agalope oshikirii* n. sp. Measurements in mm.

		Character elements										
Taxon		1	2	3	4	5	6	7	8	9	10	Source
Agalope oshikirii n. sp.		24.9	11.8	2.11	0.70	+	0.11	–	+	+	+	This study
Genus *Agalope* Walker, 1854												
The *hyalina* species group												
Agalope hyalina (Kollar, 1844)	♂	20.6	11.5	1.79	0.71	+	N/A	+	±	+	–	Huang et al., 2023, p. 293, fig. 1
	♀	21.3	10.9	1.95	0.72	+	N/A	±	±	+	–	Huang et al., 2023, p. 293, fig. 2
Agalope glacialis (Moore, 1872)	♂	17.1–18.0	8.8–9.8	1.84–1.94	0.70–0.72	+	N/A	+	±	–	–	Huang et al., 2023, p. 293, figs. 4–6
	♀	17.1	9.4	1.82	0.73	+	N/A	+	–	–	–	Huang et al., 2023, p. 293, fig. 3
Agalope grandis Mell, 1922	♂	25.2	14.0	1.80	0.63	+	N/A	+	–	–	–	Owada and Horie, 2000, pl. 161, fig. 18
	♀	29.2	15.9	1.84	0.70	+	N/A	+	–	–	–	Owada and Horie, 2000, pl. 161, fig. 19
Agalope harutai Horie in Owada and Horie, 2000	♂	17.5–19.3	9.4–10.7	1.80–1.86	0.69–0.70	+	N/A	+	–	+	–	Owada and Horie, 2000, pl. 161, figs. 14, 15
Agalope jianqingi Huang in Huang et al., 2022	♂	20.0	11.2	1.79	0.68	+	N/A	±	–	–	–	Huang et al., 2022, p. 561, fig. 29
Agalope kishidograndis Owada and Horie, 2000	♂	22.0	12.1	1.82	0.68	+	N/A	+	–	–	–	Owada and Horie, 2000, pl. 161, fig. 20
	♀	21.2	11.3	1.88	0.68	+	N/A	+	–	–	–	Owada and Horie, 2000, pl. 161, fig. 21
Agalope mineti Owada in Owada and Horie, 2000	♂	18.8	10.4	1.81	0.68	+	N/A	+	–	–	+	Owada and Horie, 2000, pl. 161, fig. 17
Agalope primularis Butler, 1875	♂	17.5	9.7	1.80	0.66	+	N/A	+	–	–	–	Owada and Horie, 2000, pl. 161, fig. 16
Agalope suzukikojii Horie in Owada and Horie, 2000	♂	16.0	8.8	1.82	0.66	+	N/A	+	–	–	–	Owada and Horie, 2000, pl. 161, fig. 12
	♀	14.0	7.4	1.89	0.70	+	N/A	+	–	–	–	Owada and Horie, 2000, pl. 161, fig. 13
The *eronioides* species group												
Agalope eronioides Moore, 1879b	♂	27.4–31.3	12.8–14.8	2.11–2.14	0.72–0.74	+	0.06–0.08	+	–	–	–	Huang et al., 2023, p. 293, figs. 7, 9
	♀	28.7–33.3	14.0–16.0	2.05–2.08	0.72–0.74	+	0.06–0.07	+	–	–	–	Huang et al., 2023, p. 293, figs. 8, 10
The *livida* species group												
Agalope livida Moore, 1879a	♂	24.2	12.4	1.95	0.73	+	0.08	–	–	+	±	Huang et al., 2023, p. 293, fig. 11
	♀	27.6	14.2	1.94	0.74	+	0.08	–	–	±	±	Huang et al., 2023, p. 293, fig. 12
The *geoffi* species group												
Agalope geoffi Huang and Horie in Huang et al., 2023	♂	19.3	10.0	1.93	0.69	+	N/A	–	–	+	±	Huang et al., 2023, p. 293, fig. 13
Agalope liuzihaoi Huang and Horie in Huang et al., 2023	♂	21.1	11.9	1.77	0.72	+	N/A	–	–	–	–	Huang et al., 2023, p. 293, fig. 14

(*Continued*)

Table 1. (*Continued*)

Taxon		Character elements										Source
		1	2	3	4	5	6	7	8	9	10	
Genus *Rotundagalope* Huang and Horie in Huang et al., 2023												
Rotundagalope immaculata (Leech, 1898)	♂	24.7–28.3	13.4–15.3	1.83–1.85	0.71–0.74	+	N/A	—	+	no stem	+	Huang et al., 2023, p. 298, figs. 15–17
	♀	24.5	12.7	1.93	0.71	+	N/A	—	+	no stem	+	Huang et al., 2023, p. 298, fig. 18
Genus *Paragalope* Huang and Horie in Huang et al., 2023												
Paragalope basiflava Huang and Horie in Huang et al., 2023	♂	29.8	12.5	2.38	0.70	+	0.17	+	—	—	—	Huang et al., 2023, p. 299, fig. 29
	♀	30.3	13.7	2.21	0.70	+	0.16	+	—	—	—	Huang et al., 2023, p. 299, fig. 30
Paragalope bieti (Oberthür, 1886)	♂	22.4–25.9	10.4–11.8	2.14–2.22	0.69–0.73	+	0.09–0.15	+	±	±	—	Huang et al., 2023, p. 299, figs. 33, 35–37
	♀	19.8–21.3	9.1–9.6	2.18–2.22	0.71–0.75	+	0.10–0.15	+	±	—	—	Huang et al., 2023, p. 299, figs. 34, 38
Paragalope dejeani (Oberthür, 1893)	♂	30.7	15.3	2.01	0.72	+	0.11	+	—	—	±	Huang et al., 2023, p. 298, fig. 19
	♀	21.9–28.8	10.8–13.3	2.03–2.17	0.67–0.70	+	0.09–0.11	+	—	—	—	Huang et al., 2023, p. 298, figs. 20, 21
Paragalope gracilis (Moore, 1872)	♂	21.4–26.8	10.7–13.1	1.96–2.05	0.69–0.74	+	0.14–0.17	+	±	±	+	Huang et al., 2023, p. 301, figs. 40, 41, 43
	♀	27.1–33.6	14.2–17.7	1.90–1.97	0.71–0.74	+	0.12–0.16	+	—	—	±	Huang et al., 2023, p. 301, figs. 39, 42, 44
Paragalope haoi (Huang in Huang et al., 2022)	♂	21.5	10.7	2.01	0.71	±	N/A	+	—	—	—	Huang et al., 2023, p. 299, fig. 31
	♀	17.4	7.9	2.20	0.69	±	N/A	+	—	—	—	Huang et al., 2023, p. 299, fig. 32
Paragalope lucia (Oberthür, 1923)	♂	24.9	12.3	2.02	0.69	—	N/A	+	—	—	—	Huang et al., 2023, p. 298, fig. 23
	♀	25.2–29.7	12.0–14.1	2.10–2.11	0.70–0.71	+	N/A	+	—	—	—	Huang et al., 2023, p. 298, figs. 22, 24
Paragalope pica (Wileman, 1910)	♂	19.8–23.6	10.8–12.5	1.83–1.89	0.68–0.73	±	0.13	+	—	—	—	Huang et al., 2023, p. 299, figs. 25, 26
	♀	21.6–22.1	10.7	2.01–2.07	0.71–0.73	±	0.08–0.10	+	—	—	—	Huang et al., 2023, p. 299, figs. 27, 28
Genus *Agacysma* Huang and Horie in Huang et al., 2023												
Agacysma sinica Huang and Horie in Huang et al., 2023	♂	22.8–26.3	11.0–13.6	1.93–2.10	0.70–0.72	±	N/A	—	+	no stem	+	Huang et al., 2023, p. 304, figs. 45–48
Genus *Elcysma* Butler, 1881												
Elcysma westwoodii (Vollenhoven, 1863)	♂	32.3	17.0	1.90	0.69	+	0.12	±	—	—	—	Huang et al., 2023, p. 304, fig. 49
	♀	32.3	16.8	1.92	0.70	+	0.12	±	—	—	—	Huang et al., 2023, p. 304, fig. 50

cross vein M_1-M_2 bent inward at medial stem. M_1 anterior, M_2 slightly posterior of medial stem vein in discal cell. M_1 close to R veins at base. R_4, R_5, M_1, and M_2 almost parallel to each other. M_2 and M_3 quite shortly stalked. M_2 not strongly curved anteriorly. M_3 not strongly curved posteriorly, parallel to CuA_1. CuA_1 and CuA_2 arising independently from discal cell. CuP distinctly present, complete. 1A+2A sinuate with basal fork. Cross vein between CuP and 1A+2A absent.

Etymology. The specific name is derived from Oshikiri S., a high school teacher who studied insect fossils from the Sazugawa Formation.

Remarks. The specimen is characterized by its semitriangular forewing, presence of a medial stem vein, a closed discal cell spanning two-thirds of wing length, and a complete CuP vein, as well as 1A+2A veins with a basal fork. These characteristics clearly indicate the association of this specimen with the subfamily Chalcosiinae.

The translucent broad forewing with a colored wing base in this specimen is consistent with the genus *Agalope* and closely related genera among members of the subfamily. Huang et al. (2023) revised the concept of *Agalope*, diagnosed the genus by a forewing base bearing an orange patch extending from the costa to the base of cell 1A+2A, forewing veins M_2 and M_3 stalked, and the forewing bearing only one transverse band, which is sometimes vestigial or absent. The studied specimen shares these diagnostic characters of *Agalope*. It can be distinguished from members of the genera *Rotundagalope* and *Agacysma* Huang and Horie in Huang et al., 2023, because these genera have forewing veins M_2 and M_3 arising independently from the discal cell. Although the wing venations of *Agalope* and *Paragalope* are similar, they can be differentiated by the blackish bands on the forewing: *Paragalope* typically has two clear transverse bands extending from the base to the basal half of forewing or one thick, distinct black band occupying the basal third to half, whereas *Agalope* has only one narrow and blurry band present or lacks such black bands. Therefore, the specimen clearly belongs to the genus *Agalope*.

The genus *Agalope* is currently composed of four species groups: *hyalina*, *eronioides*, *livida* and *geoffi* (Huang et al., 2023). The studied specimen is different from the *hyalina* and *geoffi* species groups, which are characterized by relatively smaller forewings and the lack of a black band surrounding the basal patch. Although *Agalope grandis* Mell, 1922, belonging to the *hyalina* species group has a medium-sized forewing, it also lacks basal black band. Additionally, members of the *geoffi* species group have a more rounded forewing termen. The new species is also distinct from the *eronioides* species group because species in this group have darker wings. The forewing of the *livida* species group, represented solely by *Agalope livida* Moore, 1879a, is most similar in appearance to the studied specimen. The forewing of *Agalope livida* is medium-sized with an almost straight termen and lacks a dark transverse band on forewing. However, the wing venation of the specimen differs from *Agalope livida* due to the presence of a rudimentary medial stem vein. Additionally, the forewing veins R_4, R_5, M_1, and M_2 are parallel to each other, and M_3 is parallel to CuA_1. This vein configuration is distinctive within the genus. Therefore, the studied fossil is identified as *Agalope oshikirii* n. sp.

Discussion

Recent members of *Agalope* are distributed across a range that includes Kashmir, India, Nepal, Bhutan, northern Myanmar, and several provinces in southwestern, central, and southern mainland China, Taiwan Island, and northern Vietnam (Huang et al., 2023). The discovered fossil offers direct evidence of the presence of the species of *Agalope* related to the *livida* species group in the latest Miocene–Pliocene of Japan, suggesting a broader historical distribution for the genus.

Interestingly, the forewing of *Agalope oshikirii* n. sp. has characteristics more commonly found in other genera, e.g., *Rotundagalope*, *Paragalope*, and *Agacysma*, rather than most congeners of *Agalope* (Table 1). We compared the following ten character elements: (1) forewing length, (2) forewing width, (3) length-to-width (L/W) ratio, (4) discal cell length-to-forewing-length ratio, (5) presence of a colored patch in the base, (6) length from base to basal black band-to-forewing-length ratio, (7) presence of distinct maculations aside for base, (8) presence of paralleled R_4, R_5, M_1, and M_2 veins, (9) presence of quite shortly stalked M_2 and M_3 veins, and (10) presence of paralleled M_3 and CuA_1 veins. *Agalope oshikii* sp. n. is most similar to *Agalope livida*, sharing eight elements. It also shares six to eight elements with *Rotundagalope immaculata* (Leech, 1898), *Paragalope gracilis* (Moore, 1872), and *Agacysma sinica* Huang and Horie in Huang et al., 2023. In contrast, other species groups within *Agalope*—the *hyalina* species group (with two to five elements), the *eronioides* species groups (with four or six elements), and *geoffi* species group (with three or five elements)—display notable different from *Agalope oshikirii* n. sp. These distinctions offer insights into the evolution of *Agalope* and its related genera.

One hypothesis is that these *Agalope*-related genera were derived from the ancestral groups closely related to *Agalope oshikirii* n. sp. This hypothesis is supported by two main arguments. First, the overlapping of distributions of these genera suggests a broader historical range. Modern *Agalope*'s wide distribution implies that fossil congeners like *Agalope oshikirii* n. sp. could have extended farther into northern Japan. According to Huang et al. (2023), *Rotundagalope* is endemic to mainland China (Sichuan and Gansu provinces). *Agacysma* is also endemic to mainland China (Shaanxi, Hubei Province, and Chongqing), and *Paragalope* has wider distribution in northeastern India, southwestern mainland China, Taiwan Island, Thailand, Vietnam, and the Greater Sunda Islands (Java). These wide distributions indicate that unknown *Agalope* groups could have branched out in various regions.

Second, shared wing venation characteristics between *Agalope oshikirii* n. sp. and these related genera indicate a common primitive origin. For instance, a length-to-width (L/W) ratio of ~2.0, a discal cell length-to-forewing-length ratio ~0.7, paralleled R_4, R_5, M_1, and M_2 veins, paralleled M_3 and CuA_1 veins, presence of basal patch with surrounding black band extending to the wing's posterior margin could represent primitive features preserved in the fossil species *Agalope oshikirii* n. sp., with the long-stalked M_2 and M_3 veins being a derived trait. Therefore, it is plausible that unknown ancestral groups of *Agalope* related to *Agalope oshikirii* n. sp. branched into these *Agalope*-related genera. Primitive characteristics could be relatively well preserved in modern *Agalope livida*.

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References

Bryk, F., 1936, Zygaenidae 2, *in* Strands, E., ed., *Lepidopterorum Catalogus*, part 71: Berlin, W. Junk, p. 1–132.

Butler, A.G., 1875, Descriptions of several new species of Indian heterocerous Lepidoptera: *Proceedings of the Zoological Society of London*, **v. 1875**, p. 391–393.

Butler, A.G., 1881, Descriptions of new genera and species of heterocerous Lepidoptera from Japan: *Transactions of the Entomological Society of London*, **v. 1881**, p. 1–23, 171–200, 401–426, 579–600.

Duncan, I.J., 1997, *The taphonomy of insects* [Ph.D. thesis]: Bristol, UK, University of Bristol, Department of Geology, 328 p.

Efetov, K.A., and Tarmann, G.M., 2017, The hypothetical ground plan of the Zygaenidae, with a review of the possible autapomorphies of the Procridinae and the description of the Inouelinae subfam. nov.: *The Journal of the Lepidopterists' Society*, **v. 71**, p. 20–49, https://doi.org/10.18473/lepi.v71i1.a5

Fletcher, D.S., and Nye, I.W.B., 1982, Bombycoidea, Mimallonoidea, Castnioidea, Sesioidea, Cossoidea, Sphingoidea and Zygaenoidea, in Nye, I.W.B., ed., *The Generic Names of Moths of the World*, Volume **4**: London, Trustees of the British Museum, p. 1–192.

Fujiyama, I., 1983, Neogene termites from northeastern districts of Japan, with references to the occurrence of fossil insects in the districts: *Memoirs of the National Museum of Nature and Science*, **v. 16**, p. 83–98.

Hampson, G.F., 1893, *The Fauna of British India including Ceylon and Burma: Moths*, Volume **1**, Saturniidae to Hypsidae: London, Taylor & Francis, 627 p., 333 figs.

Huang, S.Y., **Horie, K.**, **Fan, X.L.**, **Wang, M. and Espeland, M.**, 2023, A review of the genus *Agalope* Walker (Lepidoptera, Zygaenidae, Chalcosiinae) with taxonomic notes and descriptions of three new genera and three new species: *Zootaxa*, **v. 5284**, p. 291–321, https://doi.org/10.11646/zootaxa.5284.2.4

Huang, S.Y., **Zhu, L.J.**, **Chen, E.Y.**, **Xu, Y.Q.**, **Wang, M.**, **Fan, X.L.**, **Pan, Z.H. and Espeland, M.**, 2022, Contribution to the knowledge of the genus *Agalope* Walker from mainland China, with descriptions of four new species (Lepidoptera, Zygaenidae, *Chalcosiinae): Zootaxa*, **v. 5165**, p. 557–574, https://doi.org/10.11646/zootaxa.5165.4.7

Huzioka, K., and Uemura, K., 1974, The late Miocene Sanzugawa flora of Akita Prefecture, northeast Honshu, *Japan: Bulletin of the National Science Museum*, **v. 17**, p. 325–366, 11 pls.

Ito, H., 2023, Quaternary caldera-forming eruptions at the Sanzugawa caldera, NE Japan, revealed by zircon U-Pb geochronology: *Frontiers in Earth Science*, **v. 10**, n. 964773, https://doi.org/10.3389/feart.2022.964773

Ito, T., **Utada, M., and Okuyama, T.**, 1989, Mio−Pliocene calderas in the backbone region in northeast Japan: *The Memoirs of the Geological Society of Japan*, **v. 32**, p. 409–429.

Kollar, V., and Redtenbacher, L., 1844, Aufzählung und Beschreibung der von Freiherr C. v. Hügel auf seiner Reise durch Kaschmir und das Himaleygebirge gesammelten Insekten, in Hügel, F.C., ed., *Kaschmir und das Reich der Siek*, Band 4: Stuttgart, Hallberger'sche Verlagshundlung, p. 393–564, pls. 1–28.

Latreille, P.A., 1809, *Genera Crustaceorum et Insectorum se Cun Dum Ordinem Naturalem in Familias Disposita, Iconibus Exemplisque Plurimis Explicita: Tomus Quartus et Ulti* Mus: Paris, Amand Koenig, 399 p.

Leech, J.H., 1898, Lepidoptera Heterocera from northern China, Japan and Corea: *Transactions of the Entomological Society of London*, **v. 1898**, no. 3, p. 261–379.

Linnaeus, C., 1753, Species Plantarum, Exhibentes Plantas Rite Cognitas, ad Genera Relatas, cum Diferentiis Specificis, Nominibus Ttrivialibus, Synonymis Selectis, Locis Natalibus, Secundum Systema Sexuale Digestas, Volume 2: Stockholm, Laurentius Salvius, 1200 p.

Linnaeus, C., 1758, *Systema Naturae per Regna Tria Naturae* (tenth edition), Volume **1**, Regnum Animale: Stockholm, Laurentii Salvii, 824 p.

Mell, R., 1922, Neue südchinesische Lepidoptera: *Deutsche Entomologische Zeitschrift*, **v. 1922**, p. 113–129.

Moore, F., 1872, Descriptions of new Indian Lepidoptera: *Proceedings of the Zoological Society of London*, **v. 1872**, no. 2, p. 555–583, pls. 32–34.

Moore, F., 1879a, Description of new genera and species of Asiatic Lepidoptera Heterocera: *Proceedings of the Zoological Society of London*, **v. 1879**, p. 387–417, pls. 32–34.

Moore, F., 1879b, Descriptions of Indian Lepidoptera Heterocera from the collection of the late Mr. *W.S. Atkinson,* in *Descriptions of new Indian Lepidopterous Insects from the Collection of the Late Mr. W.S. Atkinson*, Volume **1**: Calcutta, Asiatic Society of Bengal, p. 5–88, pls. 1–3.

Oberthür, C., 1886, Nouveaux Lépidoptères du Thibet: *Études d'Entomologie*, **v. 11**, p. 13–38, pls. 1–7.

Oberthür, C., 1893, Lépidoptères d'Asie: *Études d'Entomologie*, **v. 18**, p. 11–45, pls. 2–6.

Oberthür, C., 1923, Lépidoptères de la Région Sino-Thibétaine: *Études de Lépidopterologie Comparée*, **v. 20**, p. 199–211.

Oshikiri, S., 1979, [Insect fossils discovered from the Sanzugawa Formation, Yuzawa City, Akita Prefecture]: *Koukou Rika Kenkyu*, **v. 15**, p. 50–54. [in Japanese; original title translated]

Oshikiri, S., 1982, [Neogene insect fossils from the Sanzugawa Formation in southern part of Akita Prefecture]: Akita, Japan, Akita Prefectural Yuzawa High School, 26 p. [in Japanese; original title translated]

Oshikiri, S., 1988, [Fossil aphidids from the Sanzugawa Formation, southern part of Akita Prefecture]: *Akita Chigaku*, **v. 37**, p. 1–4. [in Japanese; original title translated]

Oshikiri, S., 2001, [Plant fossils from the Akita Chigaku]: Akita Chigaku, **v. 49**, p. 7–9. [in Japanese; original title translated]

Owada, M., and Horie, K., 2000, The genus *Agalope* (s. str.) (Zygaenidae, Chalcosiinae) from the Himalayas and the Indo-Chinese Peninsula, *in* Haruta, T., ed., Moths of Nepal, Part 6: Tokyo, Japan Heterocerist's Society, p. 1–8, pl. 161.

Sohn, J.C., **Labandeira, C.C.**, **Davis, D.R., and Mitter, C.**, 2012, An annotated catalog of fossil and subfossil Lepidoptera (Insecta: Holometabola) of the world: *Zootaxa*, **v. 3286**, p. 1–132, https://doi.org/10.11646/zootaxa.3286.1.1

Takeno, N., 1988, Geology of the North Kurikoma geothermal area, Akita Prefecture, northeast Japan: Reports, *Geological Survey of Japan*, **v. 268**, p. 191–210.

Tanai, T., and Onoe, T., 1961, Mio–Pliocene flora from the Ningyo-toge area on the border between Tottori and Okayama prefectures, Japan: Reports, *Geological Survey of Japan*, **v. 187**, p. 1–62.

Tremewan, W.G., 1973, A catalogue of the genus-group names of the Zygaenidae (Lepidoptera): Bulletin of the British Museum (Natural History), *Entomology*, **v. 28**, p. 111–151.

Vollenhoven, S.C.S., 1863, Description de quelques nouvelles espéces de Lépidoptéres des Indes Orientales: *Tijdschrift voor Entomologie*, **v. 6**, p. 129–144, pls. 8–10.

Walker, F., 1854, Catalogue of the Lepidoptera Heterocera, *in* Gray, J. E., ed., List of the Specimens of Lepidopterous Insects in the Collection of the British Museum, Part 2, Lepidoptera, Heterocera: London, Trustees of the British Museum, p. 279–581.

Wileman, A.E., 1910, Some new Lepidoptera-Heterocera from Formosa: *Entomologist*, **v. 43**, p. 189–193.

Yen, S.H., Robinson, G.S., and Quicke, D.L., 2005, The phylogenetic relationships of Chalcosiinae (Lepidoptera, Zygaenoidea, Zygaenidae): *Zoological Journal of the Linnean Society*, **v. 143**, p. 161–341, https://doi.org/10.1111/j.1096-3642.2005.00139.x