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# Affinity of *Aporia martineti* (Oberthür, 1884) and *Mesapia peloria* (Hewitson, 1853) inferred from morphological comparison and distribution

(Lepidoptera, Pieridae)

by

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**Abstract**: A comparison of the morphological features of the wing markings and ♂ genitalia of *Aporia martineti* (Oberthür, 1884) and *Mesapia peloria* (Hewitson, 1853) suggested that the two species are closely related. On the basis of the geographical cline, it was suggested that *M. peloria* (Hew.) speciated from *A. martineti* (Obth.); this supported the conjecture that *Mesapia* is a synonym of *Aporia*.

**Introduction**: Kanoh et al. (2017) showed hat the process of geographical diffusion remained as a continuous geographical cline in the genus *Aporia*, and Kanoh & Sakai (2017) and Kanoh (2017) obtained the same result for each species group in the genus *Aporia*. *Aporia martineti* (Obth.) is mainly distributed in the Hengduan Mountain regions in China. *Mesapia peloria* (Hew.) is mainly distributed from the central Himalayas to the high mountain ranges of northwest China. Using the geographical distribution and shape of the uncus in the ♂ genitalia, Kanoh et al. (2017) speculated that these two species were likely to be related. In this study, the processes of geographical diffusion and speciation were inferred from the features of the wing markings and continuity of the ♂ genitalia in the two species. In the light of the results, the relationship between the genera *Aporia* and *Mesapia* was inspected.

**Materials and methods**: The ♂ genitalia of four specimens of *A. martineti* (Obth.) and four specimens of *M. peloria* (Hew.) from different localities were analyzed. To observe the male genitalia, the abdomen of each specimen was excised, soaked in an aqueous solution of 10% potassium hydroxide at room temperature for one day, washed in water, and examined with a binocular stereomicroscope. The transverse plane of the uncus was observed from the apex, and the microscopic examination was focused on the area considered to capture the features of the middle portion. A distribution diagram was prepared based on the specimens owned by the Research Institute of Evolutionary Biology in Tokyo. The subspecies names of *A. martineti* (Obth.) were based on Della Bruna et al. (2013) and the subspecies names of *M. peloria* (Hew.) were based on Sakai (2018).

**Results**: The specimens used for observation of ♂ genitalia are shown in fig. 1. *A. m. martineti* (Obth.) (figs 1-A B) has a black line on the wing vein near the tip of the forewing. The specimen of *A. m. kreitneri* (Frivaldszky, 1886) shown in figs 1-C D has a reduced black line on the wing vein; however, it has prominent black discal spots on the upperside and underside of the forewing. The specimen shown in fig. 1-D from the Killen Mts. has prominent black discal spots on both the upperside and underside of the forewing and hindwing.

*Mesapia peloria* (Hew.) (Figs.1-E-H) is small and has rounded wings. *Mesapia p. grayi* Bang-Haas, 1934 from Caka (fig. 1-E) is the largest in the genus *Mesapia* and has prominent black discal spots on both sides of the forewing and hindwing. Common features of *A. martineti* (Obth.) and *M. peloria* (Hew.) are that the underside of the hindwing is deep yellow and the black line on the wing veins is thick.

The results of the observations of the ♂ genitalia are shown in fig. 2. Both, *A. martineti* (Obth.) and *M. peloria* (Hew.), have a cylindrical apex and rounded end of the uncus. In addition, the ventral side of the uncus was nearly flat or slightly inflated in the lateral view. This differed from the typical form in which the apex is flat and the ventral side swollen, as seen in the species group including *A. agathon* (Gray, 1831) (see Kanoh et al. 2017).

The transverse plane of the uncus in both, *A. martineti* (Obth.) and *M. peloria* (Hew.), displayed overlapping circular bulges upward and downward. One of the clear differences between the two species was in the position of a large circle. *Aporia martineti* (Obth.) had a large circle on the lower side, whereas in *M. peloria* (Hew.) it was on the upperside. *A. m. kreitneri* (Friv.) from the Killen Mts. had the least difference in the sizes of the upper and lower circles compared with the four specimens of *A. martineti* (Obth.).

According to Della Bruna et al. (2013), the tegumen is "centrally domed" in *A. martineti* (Obth.), but none of the four individuals observed in this study had a domed tegumen; in both species, the back of the tegumen was almost flat. The valva was characterized by having scales from the top to the tip in *A. martineti* (Obth.); this was common to the four individuals observed in this study. The valva had a prominent distal apex in both *A. martineti* (Obth.) and *M. peloria* (Hew.), except for *M. peloria* (Hew.) from Rawok/Tibet. In addition, the fovea inside the valva was clearly present in *A. martineti* (Obth.), but no fovea was found in *M. peloria* (Hew.), except for *M. p. grayi* Bang-Haas. The fovea of *M. p. grayi* Bang-Haas was shallower than that of *A. martineti* (Obth.).

Moreover, features such as a narrow juxta, stout saccus, and loosely curved aedeagus are common in both species, and the ♂ genitalia of the two species were overall very similar.

**Discussion**: In both *A. martineti* (Obth.) and *M. peloria* (Hew.), the transverse plane of the uncus displayed a form in which circular bulges overlapped upward and downward, and there was only one species (*A. potanini* Alphéraky, 1892) showing a similar form in the genus *Aporia* (Kanoh et al., 2017). In addition, the basic structure of the ♂ genitalia was similar in the two species. This suggests that these two species are closely related.

Based on a comparison of closely related species, Kanoh et al. (2017) speculated that *A. martineti* (Obth.) had speciated in the centre of the Hengduan Mountains. The centre of the Hengduan Mountains was thought to be the origin of the diffusion of *A. martineti* (Obth.).

As shown in fig. 3, it is thought that *A. m. konbogyandaensis* Yoshino, 1998 speciated from the population that diffused to the west in the direction of Tibet, and *A. m. kreitneri* (Friv.) speciated from the population around Lake Qinghai that diffused to the north.

*Aporia m. kreitneri* (Friv.) has prominent black discal spots on the upperside and underside of the forewing, and as shown in fig. 1-D, some specimens have prominent discal spots on both, the forewing and hindwing. The wing markings of *M. p. grayi* Bang-Haas were similar to those of *A. m. kreitneri* (Friv.). In addition, *M. p. grayi* Bang-Haas had the largest size in the genus *Mesapia*. Furthermore, in *M. p. grayi* Bang-Haas , the fovea was inside the valva in the male genitalia as in *A. martineti* (Obth.). According to Della Bruna et al. (2014), the fovea is absent in the genus *Mesapia*. In this study, the fovea was absent in individuals from three sites (Datongshan, Mt. Rajishan-Pass, Rawok), but a clear fovea was observed in *M. p. grayi* Bang-Haas from Caka.

The smallest difference in the sizes of the upper and lower circular bulges seen in the transverse plane of the uncus was in *A. m. kreitneri* (Friv.) from the Killen Mts. These characteristics implied the relationship between *A. martineti* (Obth.) and *M. peloria* (Hew.). As shown in fig. 3, the distribution of *A. m. kreitneri* (Friv.) and *M. p. grayi* Bang-Haas overlapping near Lake Qinghai suggested that *M. peloria* (Hew.) speciated from *A. martineti* (Obth.) in this area.

After speciation, *M. peloria* (Hew.) was thought to have diffused to the Tibetan plateau, where the environmental conditions had improved because of global warming following a glacial period, and the species then spread further south to the Himalayas. The remarkable miniaturization of *M. peloria* (Hew.) would be an adaptation to alpine zones. The process of speciation due to geographic diffusion is shown by the arrow marks in fig. 3.

Of the specimens observed in this study, the prominent distal apex of the valva was a feature common to both *A. martineti* (Obth.) and *M. peloria* (Hew.). However, the apex of the valva of *M. peloria* (Hew.) from Rawok/Tibet was rounded and was not projected (fig. 2-H). This feature is common to *M. peloria epsteina* Tadokoro et al., 2014 in central Nepal as described by Tadokoro et al. (2014). Other features, in which the rear of the tegumen is somewhat rounded (fig. 2-H), are common in individuals from Rawok/Tibet and in *M. p. epsteina* Tadokoro et al., 2014. Both groups are thought to have common features as populations which spread in the Himalayas.

Although *M. peloria* (Hew.) has unique features, such as being compact and having rounded wings, Gray (1856), who first used the genus name "*Mesapia*", did not describe this species as an independent genus. Sakai (2018) stated "there is insufficient justification for using the genus name *Mesapia* to separate *peloria* from genus *Aporia*". Ding et al. (2017) suggested that *Mesapia* should be synonymized under *Aporia* by comparison of mitochondrial and nuclear DNA. The present study suggested that the two species *A. martineti* (Obth.) and *M. peloria* (Hew.) are very closely related based on the morphological observation of the ♂ genitalia and that *M. peloria* (Hew.) speciated from *A. martineti* (Obth.) through geographical diffusion. The results in this study thus support the theory of Sakai (2018) and Ding et al. (2017).

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Fig. 1: *Aporia* specimens of ♂♂ used genitalia dissection

(A, B) *Aporia martineti martineti* (Oberthür, 1884), (A) Deqen, Yunnan, China. FWL = 26.4 mm; (B) Miyaluo, Lizhan, Sichuan, China. FWL = 28.4 mm.

(C, D) *Aporia martineti kreitneri* (Frivaldszky, 1886), (C) Mt. Dabanshan-Pass, Tatungshan (Alexander Mts.), Kukunor, Qinghai, China. FWL = 26.4mm; (D) Killen, Killen Mts. Kukunor, Qinghai, China. FWL = 30.1 mm.

(E) *Mesapia peloria grayi* Bang-Haas, 1934, 25km N. of Caka, Qinghai, China. FWL = 24.3 mm.

(F, G) *Mesapia peloria lama* (Alphéraky, 1887), (F) Datong-shan, Qinghai, China. FWL = 21.7 mm; (G) Mt. Rajishan-Pass, Guide-Xian, Kukunor, Qinghai, China. FWL =20.1 mm.

(H) *Mesapia peloria leechi* O. Bang-Haas, 1934, Rawok, Nyingchi, Tibet, China. FWL = 22.0 mm

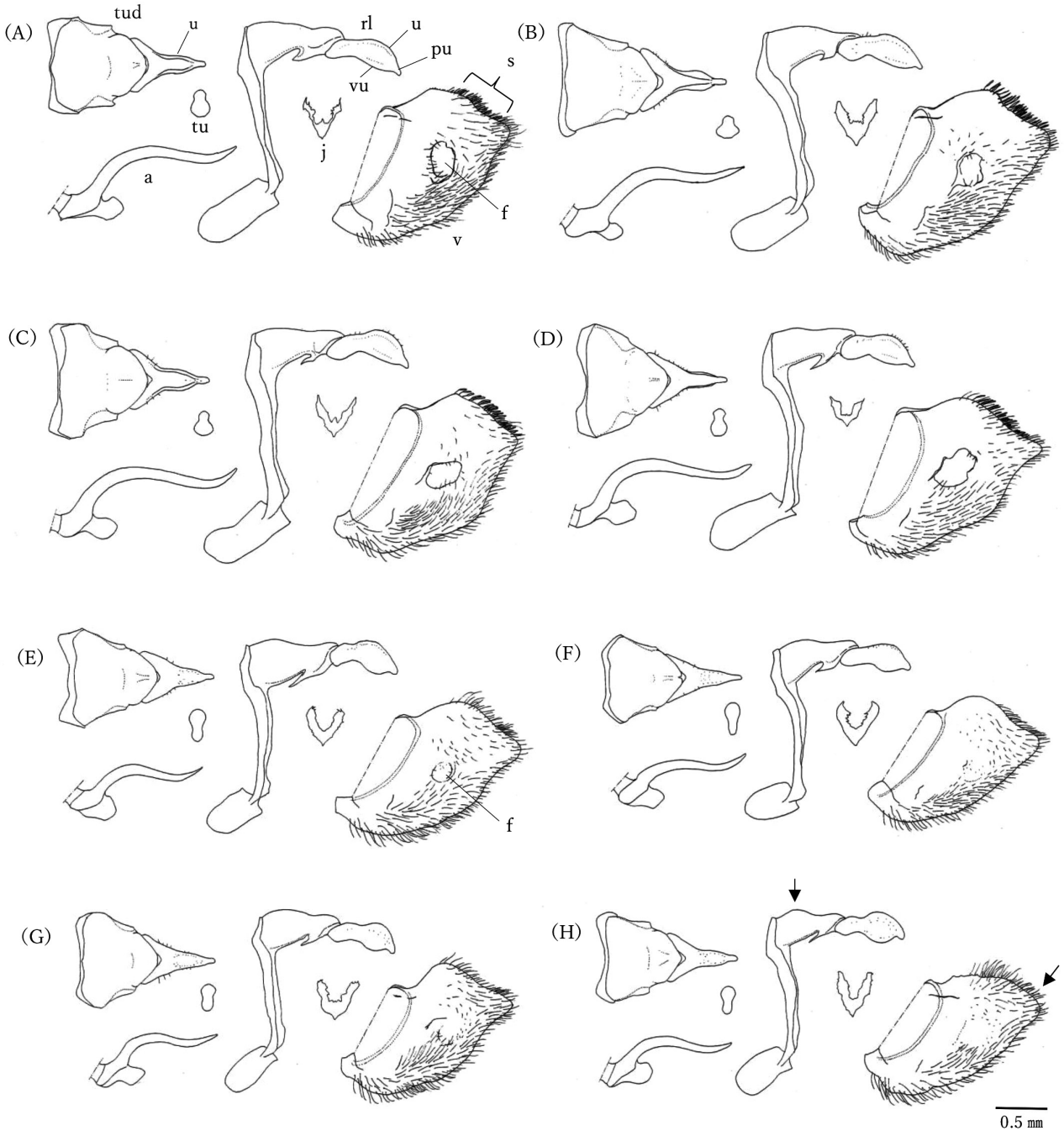


Fig. 2: ♂ genitalia of *Aporia martineti martineti* (Oberthür, 1884) and *Mesapia peloria* (Hewitson, 1853)
tud = Tegmen and uncus, dorsal view; rl = Ring, lateral view; u = Uncus. pu = protrusion of uncus; vu = Ventral side of uncus; tu = Transvers plane of uncus; a = Aedoeagus; j = Juxta. v = Right valva, inside view; s = Scales; f = Fovea. Arrow: Features similar to *Mesepia pelorioa epsteina* Tadokoro et al. (2014).
(A, B) *Aporia martineti martineti* (Oberthür, 1884), (A) Deqen, Yunnan, China; (B) Miyaluo, Lizhan, Sichuan,China.
(C, D) *Aporia martineti kreitneri* (Frivaldszky, 1886), (C) Mt. Dabanshan-Pass, Tatungshan (Alexander Mts.), Kukunor, Qinghai, China.; (D) Killen, Killen Mts. Kukunor, Qinghai, China.
(E) *Mesapia peloria grayi* Bang-Haas, 1934, 25km N. of Caka, Qinghai, China.
(F, G) *Mesapia peloria lama* (Alphéraky, 1887), (F) Datong-shan, Qinghai, China; (G) Mt. Rajishan-Pass, Guide-Xian, Kuku nor, Qinghai, China.
(H) *Mesapia peloria leechi* O. Bang-Haas, 1934, Rawok, Nyingchi, Tibet, China.

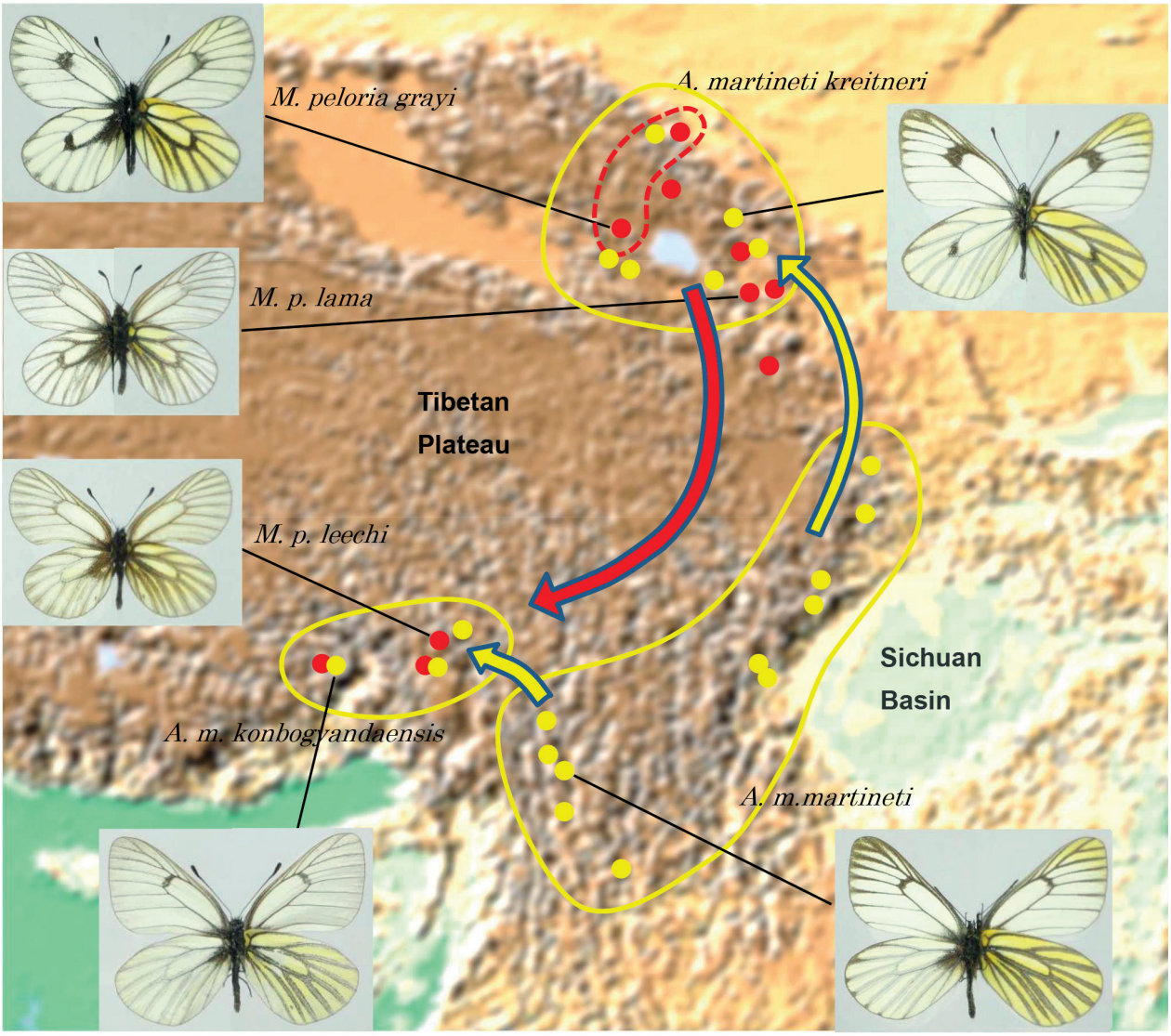


Fig. 3: Distribution map and diffusion route of *Aporia martineti* (Oberthür, 1884) and *Mesapia peloria* (Hewitson, 1853)

- *Aporia martineti* (Oberthür, 1884)
- *Mesapia peloria* (Hewitson, 1853)

The enclosure with the yellow line indicates the distribution area of each subspecies of *Aporia martineti* (Oberthür, 1884). The red dotted line indicates the distribution area of *Mesapia peloria grayi* Bang-Haas, 1934.