A Study on the Male Genitalia of Some Asian Species of *Pheidole* (Hymenoptera, Formicidae, Myrmicinae)

by

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ABSTRACT

This study describes the male genitalia of 32 *Pheidole* species, and seven pheidoline species of other genera from Asia. An aedeagal plate with a ventral, apicoventral or apical concavity is found only in the genus *Pheidole* among the tribe Pheidolini. Aedeagal plates without such a concavities have so far been known in *Aphaenogaster*, *Goniomma* and *Messor*, but not in *Pheidole*. I also report the occurrence of the latter type of aedeagal plate also in the genus *Pheidole*, and discuss morphological characters of male genitalia as a contribution toward the infrageneric taxonomy of the genus.

INTRODUCTION

The morphology of the male genitalia of the order Hymenoptera was well reviewed by Birket-Smith (1981) based on his examination of *Dorylus* species ("Formicoidea, Dorylidae"). The increase in the number of studies concerning morphology of the male genitalia of ants has provided evidence for its great taxonomic value. Examinations of the male genitalia at the generic level were done by Krafchik (1959) for N. American Formicidae, Ogata (1987, 1991) for Japanese poneroid complex, Agosti (1994) for the tribe Formicini, and others. The importance of the male genitalia and adjacent abdominal segments for infrageneric taxonomy has been so far recognized in several taxa, e.g., in *Myrmecia* by Forbes (1967), in *Tetraponera* by Ward (2001), in *Formica* and *Lasius* by Clausen (1938), and in *Polyergus* by Forbes and Brassel (1962), in *Myrmica* by Weber (1947, 1948, 1950). Buren (1958) states that the differences in the genitalia are so slight as to be useless for species diagnosis in the genus *Crematogaster*.

The ant genus *Pheidole* Westwood belongs to the tribe Pheidolini in the subfamily Myrmicinae together with *Aphaenogaster*, *Chimaeridris*, *Goniomma*, *Huberia*, *Kartidris*, *Lophomyrmex*, *Messor*, *Ocymyrmex* and *Oxyopomyrmex* (and two fossil genera) (Bolton 1995). The genus is one of the most species-rich genera in the family Formicidae. Male genitalia

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of *Pheidole* have hitherto been insufficiently studied (Clausen 1938; Krafchik 1959 for N. American species; Ogata 1982 for Japanese species), and so their value for a quite difficult infrageneric taxonomy of this genus has not been well assessed yet. This paper aims to describe the male genitalia, especially volsella and aedeagal plate, of 32 Asian species of *Pheidole*, and those of seven pheidoline species, *Aphaenogaster famelica* Fr. Smith, *A. gracillima* Watanabe & Yamane, *A. luteipes* Watanabe & Yamane, *A.* sp. 7, 13 and 18 (K.-G. Kim's species code) and *Lophomyrmex bedoti* Emery. Furthermore, based on limited information, I present a provisional assessment of morphology of the male genitalia as a contribution toward infrageneric taxonomy of *Pheidole*.

MATERIALS AND METHODS

Male genitalia were cleared and mounted through the following procedure partly modified from Takagi (1970). Genitalia together with two or three apical segments of the gaster were removed, and then soaked in several kinds of solution in the following order: 10% potassium hydroxide for 12-24 hours at room temperature (or for 1-1.5h at 60-70 °C), lacto-phenol for 12h at room temperature (or for 1.5-2h at 60-70 °C), aceto-salicylate for 12h at room temperature (or for 1-1.5h at 60-70°C), and carbo-xylol for more than 10 minutes at room temperature. Takagi (1970) recommended dissection of cleared specimens in carbo-xylol where specimens do not become hard and friable, and then soaked finally in xylol for a few minutes at room temperature prior to mounting. But I swiftly dissected genitalia in xylol after soaking in carbo-xylol, and immediately mounted them on a slide or hole slide with Canada balsam. The composition of these solutions are as follows. Phenol should be liquefied in a bottle kept in hot water prior to mixing.

- Lacto-phenol consists of a 10:1:2 mixture of lactic-acid, phenol and acetic-acid.

- Aceto-salicylate consists of a 1:1 mixture of acetic-acid and methyl-salicylate.

- Carbo-xylol consists of a 1:3 mixture of phenol and xylene.

Less-sclerotized parts are somewhat deformed because they are pressed by cover-glass. Thus I chose well-conserved genital parts for photographing. Since the location of mounted genitalia on slides is capricious, their orientation on photographs is inconsistent.

Identification of examined *Pheidole* species and *Lophomyrmex bedoti* was done with my reference collection of Indo-Chinese and Indo-Malayan ants through examining workers from the same colony to which given males belong. Examined males of *Aphaenogaster gracillima* and *A. luteipes* were cited in Watanabe & Yamane (1999), and those of

A. famelica were determined by H. Watanabe. Examined males of *Aphaenogaster* sp. 7, 13 and 18 were determined by Kim Ki-Gyung based on the associated workers. Terminology mostly follows that in Ogata's table 2 (Olgata 1991: 67); for additional terms and measuring points and their abbreviations see Fig. 1. The colony-code is given in parentheses following the number of specimens examined, like "5 males (Eg96-BOR-266)".

Descriptions of male genitalia of *Pheidole*

Thirty two species of Asian *Pheidole* were examined, including representative members of several distinct species groups which were recognized based on worker morphology (Eguchi 2001b). These share the following characteristics (Fig. 1A-F).

Male genitalia composed of three pairs of valves, i.e., paramere, volsella and aedeagal plate, which are surrounded basally by basal ring. Retractile into a genital cavity at the posterior end of gaster, encompassed dorsally by annal segment with pygostyles (terga IX and X) and ventrally by subgenital plate (sternum IX) which is subtriangular to subpentagonal. Paired parameres narrowly fused basidorsally (arrow in Fig. 1E) and completely opened ventrally, almost encompassing volsella and aedeagus; each paramere in profile subtriangular with blunt apex which bears simple hairs on outer surface (arrows in Fig. 1F); gonocoxal arm (*ga* in Fig. 1A) projecting from ventrobasal part of each paramere. Volsella (*v* in Fig. 1 A, B) attached to basiventral part of each paramere, located between paramere and aedeagal plate, bearing several simple hairs ventrally. Apicoventral part of volsella often weakly produced as a lobe. Digitus curved or bent ventrad, covered with very short setulae on outer surface. Cuspis absent (see "Discussion" of the present paper). Aedeagus located medially in genitalia, consisting of paired aedeagal plates (*ap* in Fig. 1C); the plate well sclerotized, with a serrate ventral margin; or the plate subdivided by a concavity into apical (*al*) and ventral lobes with a serrate ventral margin (*sm*); aedeagal apodeme (*aa*) projecting from the basal portion of outer face of aedeagal plate, extending basidorsally, and connected with inner face of paramere.

Pheidole aglae Forel (Figs. 2)

Pheidole aglae Forel 1913: 32, major, minor and queen (MHNG). Type locality: Bogor, Java. Lectotype designation and redescription of type material: Eguchi 2001a. For synonymy see Eguchi 2001a, b.

Specimens examined - 5 males (Eg96-BOR-266), Poring (450-500 m alt.), Sabah, Borneo, 21/xi/1996, K. Eguchi leg.; 4 males (Eg98-BOR-805), Lambir N. P., Sarawak, Borneo, 20/vi/1998, K. Eguchi leg.

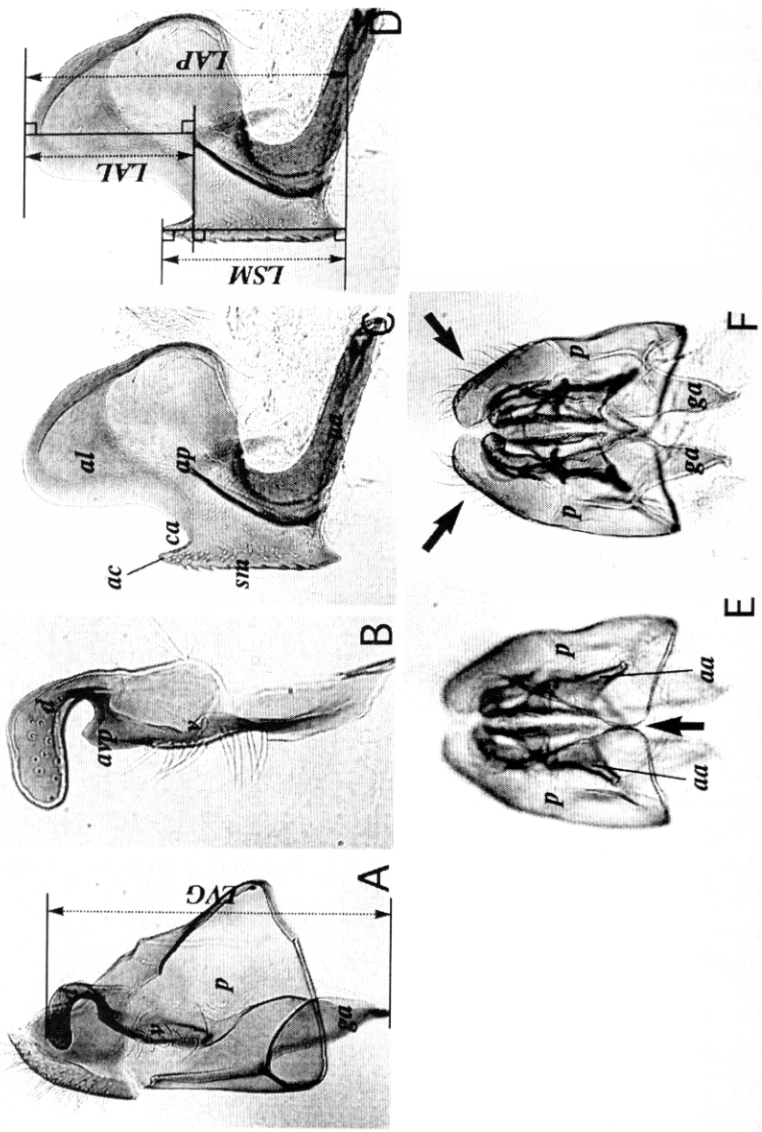

Fig. 1. Male genitalia of Pheidole spp. A, left paramere and volsella of P. sp. eg-75 (Eg01-TH-127); B, right volsella of P. sarawakana (Eg96-BOR-164) in lateral view; C and D, right aedeagal plate of P. lucioccipitalis (Eg96-BOR-042) in lateral view; E-F, whole genitalia of P. hortensis (Eg01-TH-037) in dorsal view. Abbreviations as follows: aa, aedeagal apodeme; ac, apical corner of serrate margin; al, apical lobe; ap, adeagal plate; avp, apicoventral part of volsella; ca, concavity of aedeagal plate; d, digitus; ga, gonocoxal arm; p, paramere; sm, serrate margin; LAL, length of apical lobe of aedeagal plate; LAP, length of aedeagal plate; LSM, length of serrate margin of aedeagal plate; LVG, length of volsella + gonocoxal arm. In A-F, top-bottom corresponds apical (posterior)-basal (anterior); in A-D, left-right corresponds ventral-dorsal.

Description - LVG 0.483-0.535 mm, LAP 0.254-0.295 mm, LAL 0.125-0.139 mm, LSM 0.140-0.174 mm. Volsella with 10-15 simple hairs ventrally; its apicoventral part not produced as a lobe. Digitus bent ventrad at a right or obtuse angle. Aedeagal plate with a broad concavity ventrally; apical lobe 0.77-0.90 times as long as serrate margin; serrate margin with 11-13 teeth; its apical corner well produced.

Pheidole aristotelis Forel (Figs. 3A, B)

Pheidole aristotelis Forel 1911a: 43, major, minor and male (MHNG). Type locality: Sarawak, Borneo. Lectotype designation and redescription of type material: Eguchi 2001a.

Specimens examined - 2 males (Eg96-BOR-191), 3 males (Eg96-BOR-205) and 4 males (Eg96-BOR-235), Danam Valley, Sabah, Borneo, 5, 6/xi/1996, K. Eguchi leg.; 4 males (Eg96-BOR-317), Gunong Rara, Sabah, 8/xii/1996, K. Eguchi leg.; 2 males (Eg97-BOR-511), Sepilok Forest, Sandakan, Sabah, 28/i/1997, K. Eguchi leg.

Description - LVG 0.452-0.574 mm, LAP 0.220-0.279 mm, LAL 0.118-0.144 mm, LSM 0.108-0.169 mm. Volsella with 11-17 simple hairs ventrally; its apicoventral part not produced as a lobe. Digitus massive, curved ventrad at an acute or right angle; dorsal corner occasionally produced dorsad. Aedeagal plate in profile with a distinct concavity ventrally; apical lobe 0.72-1.14 times as long as serrate margin; serrate margin with 11-13 teeth; its apical corner weakly or strongly produced.

Remarks - The worker morphology suggests a close relationship between this species and the members of *P. hortensis* group (Eguchi 2001b). Massive digitus with a well developed dorsal corner of this species is, however, not seen in at least *P. clypeocornis* and *P. hortensis* of *P. hortensis* group.

Pheidole bluntschlii Forel (Figs. 4A, B)

Pheidole (Ceratopheidole) bluntschlii Forel 1911b: 373, minor (MHNG). Type locality: Sumatra.

Specimens examined - 1 male (FI99-169), Ulu Gombak, S. Malay Pen., 28/v/1999, F. Ito leg.

Description - LVG 0.692-0.697 mm, LAP 0.386-0.394 mm, LAL 0.044-0.045 mm, LSM 0.341-0.350 mm. Volsella with 18-19 simple hairs ventrally; its apicoventral part weakly produced as a short lobe (arrow in Fig. 4A). Digitus slender, bent ventrad at a right angle. Aedeagal plate with a shallow emargination near the apex (arrow in Fig. 4B); apical lobe 0.13 times as long as serrate margin; serrate margin with 17-18 teeth; its apical corner blunt, not produced.

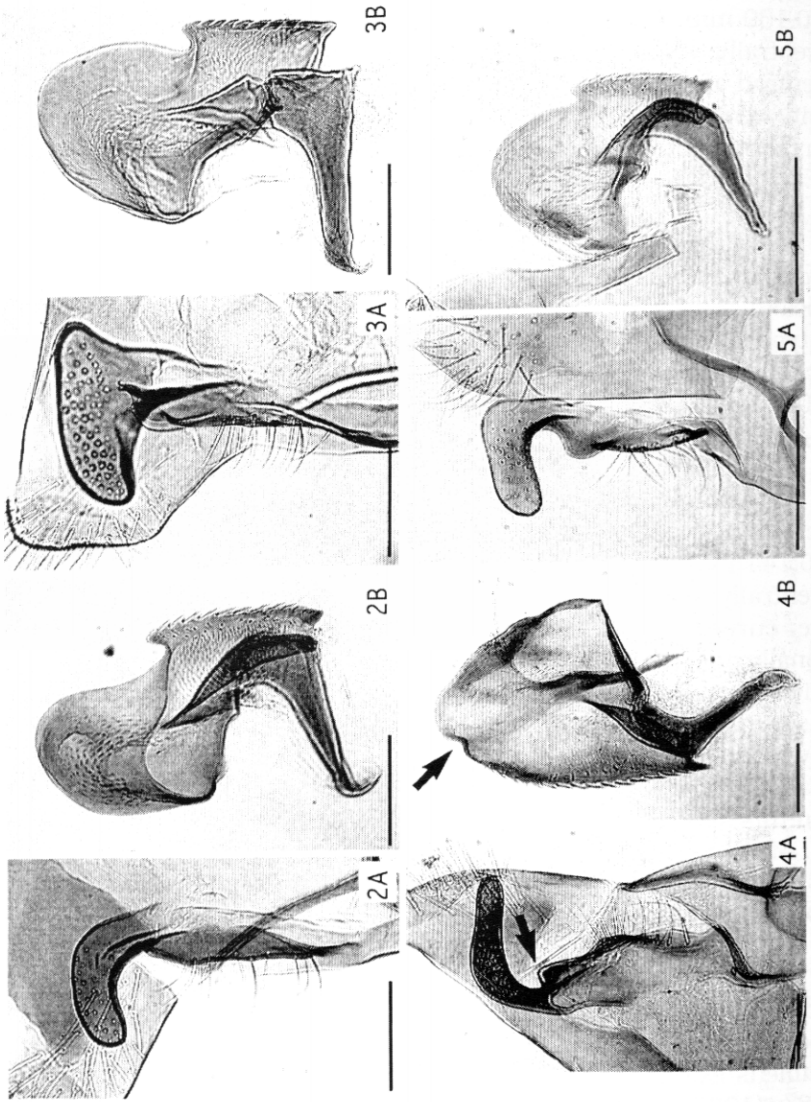

Fig. 2-5. Volsella and aedeagal plate of Pheidole spp. in lateral view. 2, Pheidole aglae Forel (Eg98-BOR-805), A, left volsella, B, right aedeagal plate; 3, Pheidole aristotelis Forel (Eg96-BOR-317), A, left volsella, B, right aedeagal plate; 4, Pheidole bluntschlii Forel (FI99-169), A, right volsella, B, left aedeagal plate; 5, Pheidole clypeocornis Eguchi (Eg99-BOR-124), A, left volsella, B, right aedeagal plate. Scale bars: 0.1 mm.

Remarks - A close relationship between this species and *P. quinata* group, e.g., *P. quinata* and *P. sabahna*, is suggested based on the worker morphology (Eguchi 2001b). In both *P. bluntschlii* and *P. sabahna*, the digitus is slender. Emargination of the aedeagal plate is more distinct in the former than in the latter.

Pheidole clypeocornis Eguchi (Figs. 5A, B)

Pheidole clypeocornis Eguchi 2001b:85-86, major, minor, queen and male (holotype in UMS). Type locality: Tawau Hills Park, Sabah, Borneo.

Specimens examined - 3 males (Eg96-BOR-035 to which the holotype and paratypes belong), Tawau Hills Park, Sabah, Borneo, 12/vii/1996, K. Eguchi leg.; 2 males (Eg96-BOR-168), Danum Valley, Sabah, 4/xi/1996, K. Eguchi leg.; 2 males (Eg96-BOR-347), Gunong Rara, Sabah, 12/xii/1996, K. Eguchi leg.; 1 male (Eg97-BOR-442), Sepilok Forest, Sabah, 23/i/1997, K. Eguchi leg.; 4 males (Eg99-BOR-124), Tasek Merimbun, Brunei, Borneo, 16/ii/1999, K. Eguchi leg.; 2 males (Eg98-LMB-1048), nr. Senaru, N. Lombok I., Lesser Sunda Is., 26/x/1998, K. Eguchi leg.

Description - LVG 0.313-0.375 mm; LAP 0.135-0.174 mm, LAL 0.051-0.071 mm, LSM 0.081-0.113 mm. Volsella with 8-14 simple hairs ventrally; its apicoventral part very weakly produced as a short lobe. Digitus bent ventrad at an acute or right angle. Aedeagal plate in profile with a small but distinct concavity ventrally; apical lobe 0.48-0.76 times as long as serrate margin; serrate margin with 8-11 teeth; its apical corner weakly produced.

Pheidole gatesi (Wheeler) (Figs. 6A, B)

Aphaenogaster (Attomyrma) gatesi Wheeler 1927: 44, minor (MCZ). Type locality: Rangoon (currently Yangon), Myanmar.

Specimens examined - 4 males (TH98-SKY-01), Doi Pui (1400 m alt.), Chiang Mai Prov., N. Thailand, 18/viii/1998, Sk. Yamane leg.

Description - LVG 0.589-0.628 mm, LAP 0.336-0.355 mm, LAL 0.010-0.040 mm, LSM 0.310-0.326 mm. Volsella with 16-19 simple hairs ventrally; its apicoventral part not produced as a lobe. Digitus relatively slender, bent ventrad at a right angle. Aedeagal plate only with an quite inconspicuous incision near the apex; apical lobe 0.03-0.13 times as long as serrate margin; with 19-21 teeth.

Remarks - A close relationship between this species and *P. smythiesii* is suggested based on the worker morphology (Eguchi 2001b), but the shape of aedeagal plate is rather different between the two. Apical lobe of aedeagal plate is much more distinct in *P. smythiesii* than in this species.

Pheidole havilandi Forel (Figs. 7A, B)

Pheidole havilandi Forel 1911a: 38, major, minor, queen and male (MHNG). Type locality: Sarawak, Borneo. For synonymy see Eguchi 2001a, b.

Specimens examined - 3 males (FI92-235), Bt. Sabalah, W. Sumatra, 8/i/1992, F. Ito leg.

Description - LVG 0.668-0.717 mm, LAP 0.321-0.349 mm, LAL 0.056-0.080 mm, LSM 0.265-0.275 mm. Volsella with 17-27 simple hairs ventrally; apical part of the area having a small projection with 1-2 simple short hairs (hardly recognizable this in Fig. 7A). Apicoventral part of volsella not produced as a lobe. Digitus bent ventrad at a right angle. Adeagal plate with a relatively small concavity apicoventrally; apical lobe small, 0.21-0.29 times as long as serrate margin; serrate margin with 14-16 teeth; its apical corner not produced.

Pheidole hortensis Forel (Figs. 8A-8C)

Pheidole hortensis Forel 1913: 31, major, minor, queen and male (MHNG). Type locality: Java.

Specimens examined - 4 males (Eg01-TH-037), Khao Soi Dao, Chanthaburi Prov., ME. Thailand, 3/vi/2001, K. Eguchi leg.; 1 male (15Q13B5), Kinabalu Park Headquarters area (ca. 1500 m alt.), Sabah, Borneo, 29/xii/1997, T. Kikuta leg.; 3 males (Eg96-BOR-283), 2 males (Eg96-BOR-305), Poring (450-500, 500-550 m alt.), Sabah, 22, 23/xi/1996, K. Eguchi leg.; 1 male (6X3006-12-6), 1 male (06Q45S5), Poring (ca. 600 m alt.), 30/x/1996, 8/i/1998, T. Kikuta leg.; 2 males (Eg97-BOR-444) 8 males (Eg97-BOR-448), Sepilok Forest, Sabah, 23/i/1997, K. Eguchi leg.; 5 males (Eg96-BOR-036), Tawau Hills Park, Sabah, 12/vii/1996, K. Eguchi leg.; 4 males (Eg99-BOR-604), Tasek Merimbun, Tutong, Brunei, Borneo, 20/viii/1999, K. Eguchi leg.; 1 male (FI95-392), Bogor, W. Java, 4/xii/1995, F. Ito leg.

Description - LVG 0.327-0.500 mm, LAP 0.162-0.239 mm, LAL 0.041-0.125 mm, LSM 0.101-0.133 mm. Volsella with 8-16 simple hairs ventrally; its apicoventral part not produced, or very weakly produced as a short lobe. Digitus bent ventrad at an acute or right angle. Aedeagal plate in profile with a small but distinct concavity ventrally; apical lobe 0.34-1.11 times as long as serrate margin; serrate margin slightly convex, with 9-13 teeth; its apical corner bluntly produced (not produced in the specimens from the colony 15Q13B5 collected at the altitude of ca. 1500 m in Kinabalu Park).

Remarks - LAL/LSM value is 0.34-0.35 in colony 15Q13B5, 0.43-0.63 in Eg96-BOR-283 (Fig. 8C), 0.53-0.57 in Eg96-BOR-305, 0.56 in 6X3006-12-6, 0.50-0.66 in Eg01-TH-037 (ME. Thailand), 0.59 in 06Q45S5, 0.69-0.91 in Eg99-BOR-604 (Fig. 8B), 0.73-0.77 in FI95-392 (Java: type locality), 0.91-1.11 in Eg97-BOR-448, 0.94-1.10 in Eg96-BOR-036, and 0.96-1.00 in Eg97-BOR-444. Thus in Kinabalu area (Poring and Kinabalu Park HQ) colonies show smaller LAL/LSM values

than in the other localities in Borneo. This suggests a certain possibility that local forms or even sibling species are involved in this wide-ranging species (in both geographical distribution and habitat preference). Further detailed morphological observation of worker and reproductives is required.

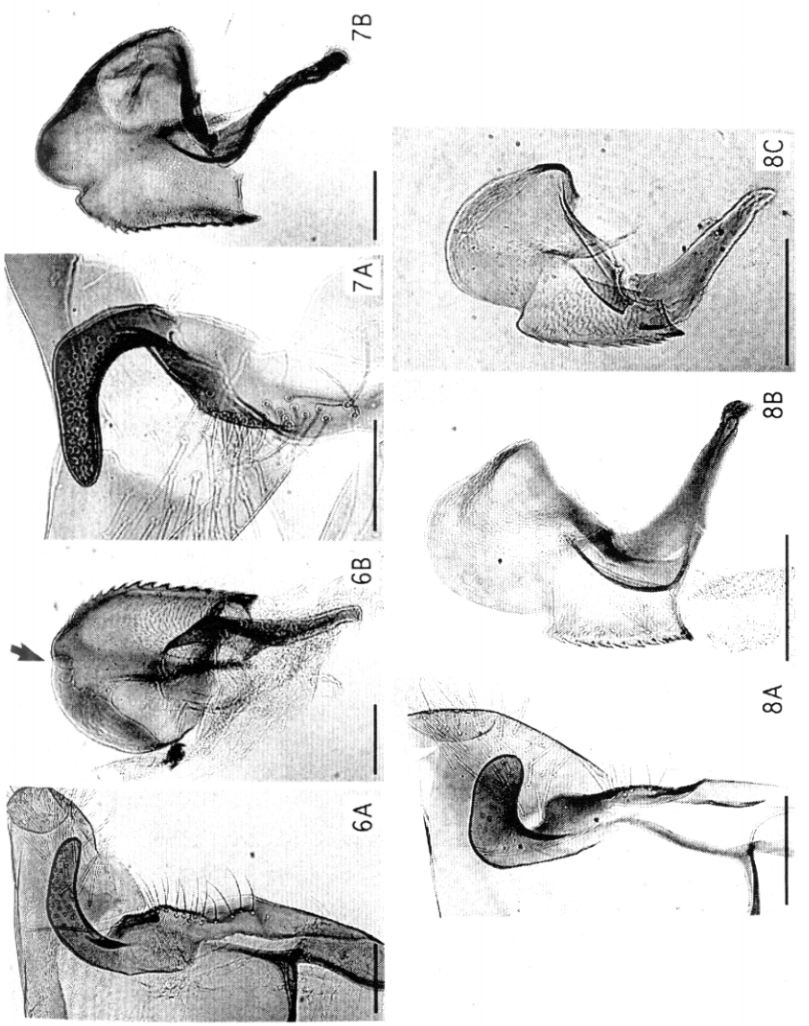

Fig. 6-8. Volsella and aedeagal plate of Pheidole spp. in lateral view. 6, Pheidole gatesi (Wheeler) (TH98-SKY-01), A, right volsella, B, right aedeagal plate; 7, Pheidole havilandi Forel (FI92-235), A, left volsella, B, left aedeagal plate; 8, Pheidole hortensis Forel, A, right volsella (Eg99-BOR-604), B, left aedeagal plate (Eg99-BOR-604), C, left aedeagal plate (Eg96-BOR-283). Scale bars: 0.1 mm.

Pheidole huberi Forel (Figs. 9A, B)

Pheidole huberi Forel 1911b: 374 major and minor (MHNG). Type locality: Sumatra. Lectotype designation and redescription of type material: Eguchi 2001a.

Specimens examined - 4 males (SB01-SKY-01), Danum Valley, Sabah, Borneo, 17/ii/2001, Sk. Yamane leg.

Description - LVG 0.638-0.722 mm, LAP 0.326-0.365 mm, LAL 0.085-0.095 mm, LSM 0.238-0.275 mm. Volsella with 18-24 simple hairs ventrally; its apicoventral part very weakly produced as a short lobe. Digitus bent ventrad at a right angle; its basal part relatively thick. Aedeagal plate with a relatively shallow concavity apicoventrally; apical lobe 0.32-0.37 times as long as serrate margin; serrate margin with 15-17 teeth; its apical corner not produced.

Pheidole inornata Eguchi (Figs. 10A, B)

Pheidole inornata Eguchi 2001b: 66-67, major, minor and male (holotype in UMS). Type locality: Sayap Kinabalu, Sabah, Borneo.

Specimens examined - 4 males (Eg01-TH-018), Khao Soi Dao, Chanthaburi Prov., ME. Thailand, 3/vi/2001, K. Eguchi leg.; 3 males (TH00-SKY-17), Khao Yai N. P., M. Thailand, 30/v/2000, Sk. Yamane leg.; 6 paratype males (Eg96-BOR-064) and 9 males (Eg96-BOR-052), Sayap Kinabalu, Sabah, Borneo, 16/vii/1996, K. Eguchi leg.

Description - LVG 0.476-0.555 mm, LAP 0.243-0.289 mm, LAL 0.103-0.144 mm, LSM 0.145-0.175 mm. Volsella with 13-18 simple hairs ventrally; its apicoventral part not produced, or very weakly produced as a short lobe. Digitus curved ventrad at a right or obtuse angle. Aedeagal plate in profile broadly concave ventrally; apical lobe 0.61-0.95 times as long as serrate margin; serrate margin weakly and evenly convex, with 10-14 teeth; its apical corner strongly produced apically.

Pheidole lokitae Forel (Figs. 11A, B)

Pheidole (Pheidolacanthinus) lokitae Forel 1913: 46, major, minor, queen and male (MHNG). Type locality: Sumatra.

Specimens examined - 1 male (FI96-180), Sukarami, Padang, W. Sumatra, 21/viii/1996, F. Ito leg.

Description - LVG 0.658 mm, LAP 0.376 mm, LAL 0.170 mm, LSM 0.224 mm. Volsella with 12 simple hairs ventrally; its apicoventral part produced as a lobe. Digitus curved ventrad at a right angle. Aedeagal plate in profile with a relatively deep concavity ventromedially; apical lobe 0.76 times as long as serrate margin; serrate margin with 15-16 teeth; its apical corner well produced.

Pheidole longipes (Fr. Smith) (Figs. 12A, B)

Myrmica longipes Fr. Smith 1857: 70, minor (BMNH). Type locality: Singapore. Redescription: Eguchi 1999, 2001b.

Specimens examined - 1 male (FI92-5), Padang, W. Sumatra, i/1992, F. Ito leg.

Description - LVG 0.706, LAP 0.388-0.397 mm, LAL 0.104-0.105 mm, LSM 0.320-0.327 mm. Volsella with 15-17 simple hairs ventrally; its apicoventral part not produced as a lobe. Digitus slender, bent ventrad at an almost right angle. Aedeagal plate in profile with a narrow and deep concavity which is located apicoventrally; apical lobe 0.32-

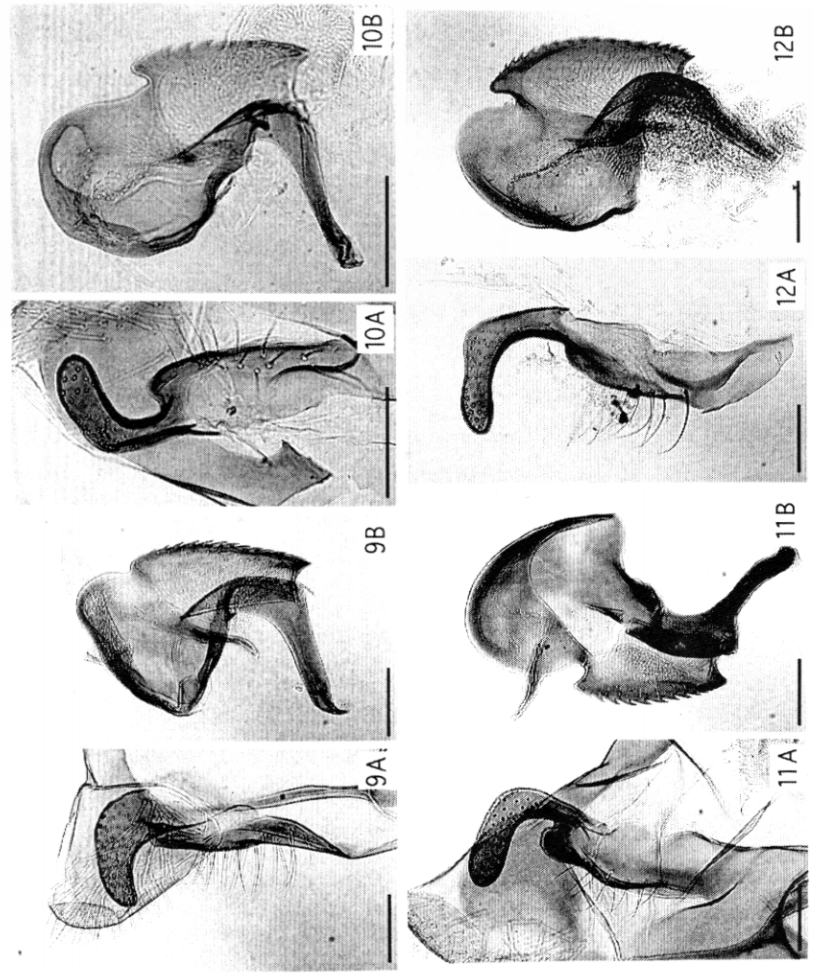

Fig. 9-12. Volsella and aedeagal plate of Pheidole spp. in lateral view. Pheidole huberi Forel (SB01-SKY-01), A, left volsella, B, right aedeagal plate; 10, Pheidole inornata Eguchi (Eg96-BOR-052), A, right volsella, B, left aedeagal plate; 11, Pheidole lokitae Forel (FI96-180), A, left volsella, B, left aedeagal plate; 12, Pheidole longipes Fr. Smith (FI92-5), A, left volsella, B, right aedeagal plate. Scale bars: 0.1 mm.

0.33 times as long as serrate margin; serrate margin weakly convex, with approximately 19 teeth; its apical corner well produced.

Remarks - My observation well agrees with Crawley's (1924) description of male genitalia of "*Ischnomyrmex longipes*" (= *Pheidole longipes*) from Sumatra. *P. longipes* and *P. montana* Eguchi is very similar to each other in morphology of the worker caste (Eguchi 1999, 2001b). Based on very limited information from only one male for each species, the following differences in male genitalia were found between them: apicoventral part of volsella produced as a short lobe in *P. montana*; digitus bent at an almost right angle in *P. longipes* but at an obtuse angle in *P. montana*; aedeagal plate with a concavity apicoventrally in *P. longipes* but apically in *P. montana*. These differences in male genitalia seem to strengthen my conclusion (Eguchi 1999, 2001b) that these two forms are biologically good species.

Pheidole lucioccipitalis Eguchi (Figs. 13A, B)

Pheidole lucioccipitalis Eguchi 2001b:73-75, major, minor and male (holotype in UMS). Type locality: Poring (500-550 m alt.), Sabah, Borneo.

Specimens examined - 6 males (Eg96-BOR-124), Danam Valley, Sabah, Borneo, 2/xi/1996, K. Eguchi leg.; 4 paratype males (Eg96-BOR-292), Poring (500-550 m alt.), Sabah, 23/xi/1996, K. Eguchi leg; 1 male (Eg96-BOR-042), Tawau Hills P., Sabah, 12/vii/1996, K. Eguchi leg.; 2 males (FI97-453), Ulu Gaduk, Padang, W. Sumatra, 27/iii/1997, F. Ito, leg.

Description - LVG 0.511-0.567 mm, LAP 0.256-0.285 mm, LAL 0.138-0.161 mm, LSM 0.135-0.152 mm. Volsella with 10-16 simple hairs ventrally; its apicoventral part very weakly or weakly produced as a short lobe. Digitus massive, bent ventrad at a right angle; its anterodorsal corner roundly angulate. Aedeagal plate broadly and largely concave ventrally; apical lobe large, gently expanding apicoventrally, 0 95-1.14 times as long as serrate margin; serrate margin with 10-13 teeth; its apical corner strongly and sharply produced.

Pheidole montana Eguchi (Figs. 14A, B)

Pheidole montana Eguchi 1999: 100-102, major, minor and queen (UMS, MNHA). Type locality: Mt. Kinabalu (nr. Park Headquarter, ca. 1500 m alt.), Sabah, Borneo.

Specimens examined - 1 male (Eg97-BOR-597), Kinabalu Park HQ, Sabah, Borneo, 2/xii/1997, T. Kikuta leg.

Description - LVG 0.739-0.766, LAP 0.396-0.406 mm, LAL 0.051-0.055 mm, LSM 0.371-0.381 mm. Volsella with 15 simple hairs ventrally; its apicoventral part produced as a short lobe. Digitus slender, rather gently bent ventrad at an obtuse angle. Aedeagal plate in profile with a narrow and deep concavity which is located almost apically; apical lobe 0.14-0.15 times as long as serrate margin; serrate margin with approximately 20 teeth.

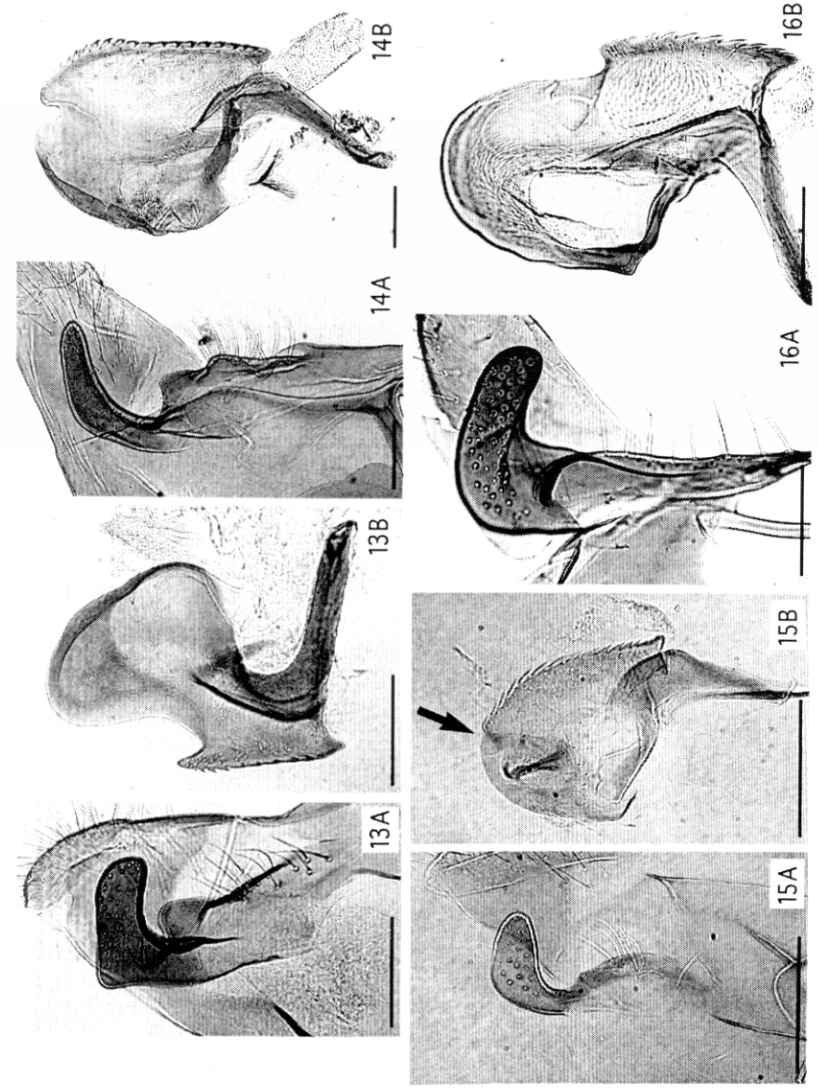

Fig. 13-16. Volsella and aedeagal plate of Pheidole spp. in lateral view. 13, Pheidole lucioccipitalis Eguchi (Eg96-BOR-042), A, right volsella, B, right aedeagal plate; 14, Pheidole montana Eguchi (Eg97-BOR-597), A, left volsella, B, left aedeagal plate; 15, Pheidole nodgii Forel (FI97-551), A, left volsella, B, right aedeagal plate; 16, Pheidole nodifera Fr. Smith (Eg99-HK-22), A, right volsella, B, right aedeagal plate. Scale bars: 0.1 mm.

Remarks - See under *P. longipes*.

Pheidole nodgii Forel (Figs. 15A, B)

Pheidole nodgii Forel 1905: 16, major, minor and queen. Type locality: Java. Lectotype designation and redescription of the type material: Eguchi 2001a.

Specimens examined - 1 male (FI97-551), Bogor, W. Java, 1997, F. Ito leg.

Description - LVG 0.317 mm, LAP 0.164-0.175 mm, LAL 0.015-0.022 mm, LSM 0.149-0.153 mm. Volsella with 9-11 simple hairs ventrally; its apicoventral part not produced as a lobe. Digitus bent ventrad at a right angle, relatively massive with a narrow peduncle. Aedeagal plate with only a quite small incision which is located near apex of aedeagal plate (arrow in Fig. 15B); apical lobe 0.10-0.14 times as long as serrate margin; serrate margin weakly convex, with 14 teeth.

Pheidole nodifera (Fr. Smith) (Figs. 16A, B)

Atta nodifera Fr. Smith 1858: 165, minor. Type locality: N. China.

Specimens examined - 3 males (Eg99-HK-22), Victoria Park, Hongkong I., 27/vi/1999, K. Eguchi leg.

Description - LVG 0.535-0.570 mm, LAP 0.281-0.316 mm, LAL 0.115-0.143 mm, LSM 0.170-0.180 mm. Volsella with 16-20 simple hairs ventrally; its apicoventral part not produced as a lobe. Digitus massive in particular at base, bent ventrad at a right angle. Aedeagal plate with a relatively small concavity ventrally; apical lobe 0.65-0.82 times as long as serrate margin; serrate margin with 10-13 teeth; its apical corner weakly produced; basidorsal margin of aedeagal plate strongly sclerotized.

Remarks - A close relationship between *P. nodifera* and *P.* sp. eg-142 is suggested by the morphology of male genitalia as well as the worker morphology (see under *P.* sp. eg-142).

Pheidole orophila Eguchi (Figs. 17A, B)

Pheidole orophila Eguchi 2001b: 85-86, major and minor (holotype in FRIM). Type locality: Cameron Highlands (ca. 1500 m alt.), Malay Pen.

Specimens examined - 2 males (211A), Mt. Kinabalu (ca. 1500 m alt.), Sabah, Borneo, 2/xii/1997, T. Kikuta leg.

Description - LVG 0.442-0.471 mm, LAP 0.244-0.249 mm, LAL 0.090-0.106 mm, LSM 0.185-0.214 mm. Volsella with 13-14 simple hairs ventrally; its apicoventral part not produced, or very weakly produced as a short lobe. Digitus gently bent ventrad at an obtuse angle. Aedeagal plate with a narrow and deep concavity apicoventrally; apical lobe 0.39-0.44 times as long as serrate margin; serrate margin with 13-15 teeth; its apical corner strongly produced.

Pheidole parvicorpus Eguchi (Figs. 18A, B)

Pheidole parvicorpus Eguchi 2001b: 86-88, major, minor and queen (holotype in UMS). Type locality: Gunong Rara, Sabah, Borneo.

Specimens examined - 3 males (from the same colony (Eg97-BOR-584) to which the type material belongs), 25/ii/1997, K. Eguchi leg.

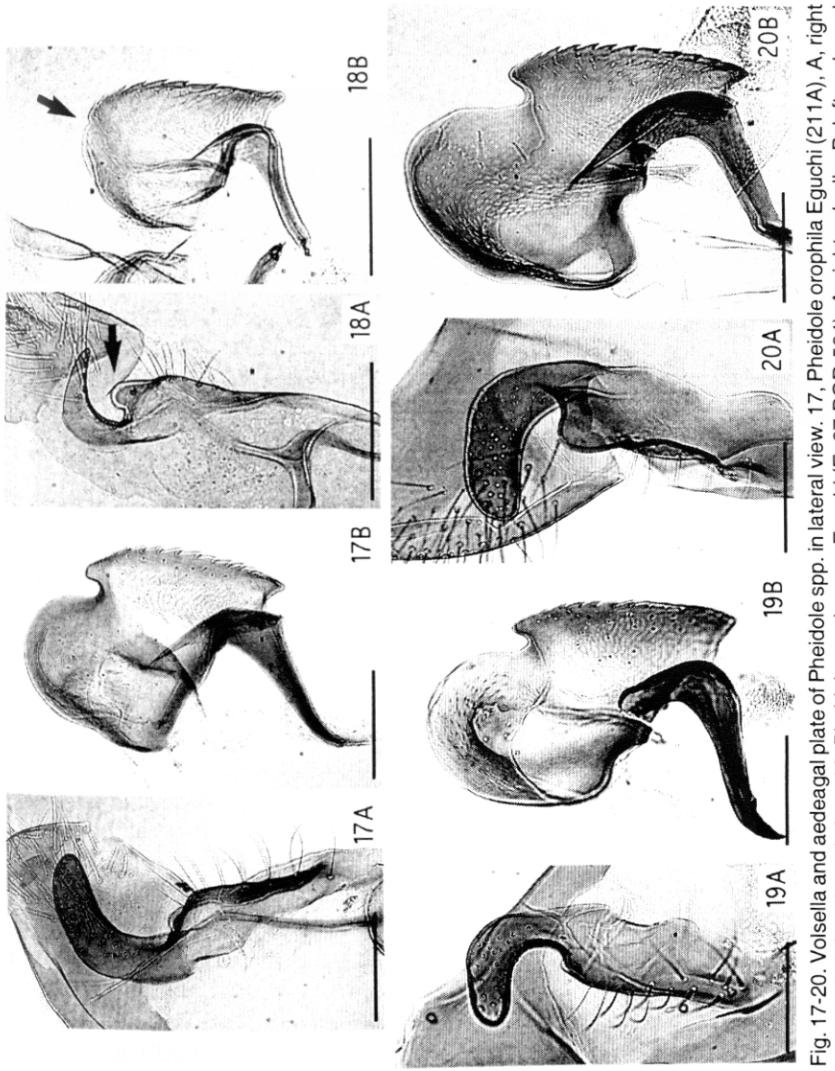

Fig. 17-20. Volsella and aedeagal plate of Pheidole spp. in lateral view. 17, Pheidole orophila Eguchi (211A), A, right volsella, B, left aedeagal plate; 18, Pheidole parvicorpus Eguchi (Eg97-BOR-584), A, right volsella, B, left aedeagal plate; 19, Pheidole plagiaria Fr. Smith (Eg98-BOR-819), A, left volsella, B, left aedeagal plate; 20, Pheidole quadrensis Forel (Eg00-BOR-129), A, right volsella, B, right aedeagal plate. Scale bars: 0.1 mm.

Description - LVG 0.270-0.290 mm, LAP 0.143-0.155 mm, LAL 0.008-0.010 mm, LSM 0.135-0.148 mm. Volsella with 10-12 simple hairs ventrally; its apicoventral part well produced as a lobe (arrow in Fig. 18A). Digitus bent ventrad at a right angle, tapering apically, sparsely covered by small setulae only ventrally on outer surface. Aedeagal plate only with a shallow and indistinct emargination or impression near apex (arrow in Fig. 18B); apical lobe 0.05-0.07 times as long as serrate margin; serrate margin weakly and evenly convex, with 10-13 teeth.

Pheidole plagiaria Fr. Smith (Figs. 19A, B)

Pheidole plagiaria Fr. Smith 1860: 112, major and minor. Type locality: Batjan, Indonesia.

Specimens examined - 4 males (Eg98-BOR-819), Lambir N. P., Miri, Sarawak, Borneo, 23/vi/1998, Eguchi leg.

Description - LVG 0.464-0.511 mm, LAP 0.255-0.283 mm, LAL 0.085-0.095 mm, LSM 0.181-0.206 mm. Volsella with 11-15 simple hairs ventrally; its apicoventral part not produced as a lobe. Digitus bent ventrad at a right angle. Aedeagal plate in profile with a distinct concavity apicoventrally; apical lobe approximately 0.43-0.48 times as long as serrate margin; serrate margin weakly convex, with 13-14 teeth; its apical corner well produced apicad.

Pheidole quadrensis Forel (Figs. 20A, B)

Pheidole quadrensis Forel 1900: 25, major (MHNG). Type locality: Kajactonam, Sumatra.

Specimens examined - 5 males (Eg96-BOR-034), Tawau Hills Park, Sabah, Borneo, 12/vii/1996, K. Eguchi leg.; 4 males (Eg00-BOR-129), Mahua Waterfall area, Crocker Range, Sabah, 5/xi/2000, K. Eguchi leg.

Description - LVG 0.481-0.579 mm, LAP 0.301-0.325 mm, LAL 0.103-0.128 mm, LSM 0.195-0.225 mm. Volsella with 12-17 simple hairs ventrally; its apicoventral part produced as a short lobe. Digitus bent ventrad at a right angle. Aedeagal plate with a concavity apicoventrally; apical lobe 0.46-0.62 times as long as serrate margin; serrate margin with 13-16 teeth; its apical corner well produced.

Pheidole quadricuspis Emery (Figs. 21A, B)

Pheidole quadricuspis Emery 1900: 683, major and minor (MCSN). Type locality: Sumatra.

Specimens examined - 6 males (Eg99-BOR-039) and 6 males (Eg99-BOR-111), Tasek Merimbun, Brunei, Borneo, 12, 15/ii/1999, K. Eguchi leg.

Description - LVG 0.496-0.545 mm, LAP 0.269-0.294 mm, LAL 0.090-0.106 mm, LSM 0.185-0.214 mm. Volsella with 10-21 simple hairs ventrally; its apicoventral part produced as a short lobe. Digitus bent ventrad at a right angle. Aedeagal plate in profile with a distinct concavity apicoventrally; apical lobe 0.44-0.55 times as long as serrate margin; serrate margin slightly convex, with 12-14 teeth; its apical corner well produced.

Pheidole retivertex Eguchi (Figs. 22A, B)

Pheidole retivertex Eguchi 2001b: 104-106, major, minor, queen and male (holotype in UMS). Type locality: Sepilok Forest, Sabah, Borneo.

Specimens examined - 3 males (Eg97-BOR-411) and 1 male (Eg97-BOR-496), Sepilok Forest, Sandakan, Sabah, Borneo, 22, 27/i/1997, K. Eguchi leg.

Description - LVG 0.315-0.335 mm, LAP 0.184-0.200 mm, LAL 0.010-0.015 mm, LSM 0.169-0.191 mm. Volsella with 7-10 simple hairs ventrally; its apicoventral part not produced as a lobe. Digitus bent ventrad at a right or acute angle. Aedeagal plate with only a quite small incision which is located near apex of aedeagal plate (arrow in Fig. 22B); apical lobe 0.05-0.09 times as long as serrate margin; serrate margin slightly convex, with 14-16 teeth.

Pheidole sabahna Eguchi (Figs. 23A, B)

Pheidole sabahna Eguchi 2000, major, minor and male (holotype in UMS). Type locality: Logging area nr. Kg. Yoshina, Ranau, Sabah, Borneo.

Specimens examined - 3 paratype males (Eg98-BOR-850), 30/vi/1998, K. Eguchi leg.

Description - LVG 0.678-0.722 mm, LAP 0.391-0.400 mm, LAL 0.029-0.043 mm, LSM 0.349-0.365 mm. Volsella with 14-20 simple hairs ventrally; its apicoventral part not produced as a lobe. Digitus slender, bent ventrad at a right angle. Aedeagal plate with an inconspicuous incision near the apex (arrow in Fig. 23B); apical lobe 0.08-0.12 times as long as serrate margin; serrate margin with 18-20 teeth.

Remarks - For the close relationship with *P. bluntschlii*, see under *P. bluntschlii*.

Pheidole sarawakana Forel (Figs. 24A, B)

Pheidole sauberi subsp. *sarawakana* Forel 1911a: 45, major and minor (MHNG). Type locality: Sarawak, Borneo. For status change to species see Eguchi 2001a, b.

Specimens examined - 8 males (Eg96-BOR-164) and 2 males (Eg96-BOR-231), Danum Valley, Sabah, Borneo, 4, 7/xi/1996, Eguchi leg.

Description - LVG 0.425-0.450 mm, LAP 0.210-0.234 mm, LAL 0.019-0.029 mm, LSM 0.189-0.207 mm. Volsella with 8-12 simple hairs ventrally; its apicoventral part produced as a short lobe. Digitus bent ventrad at a right angle. Aedeagal plate with only a quite small incision

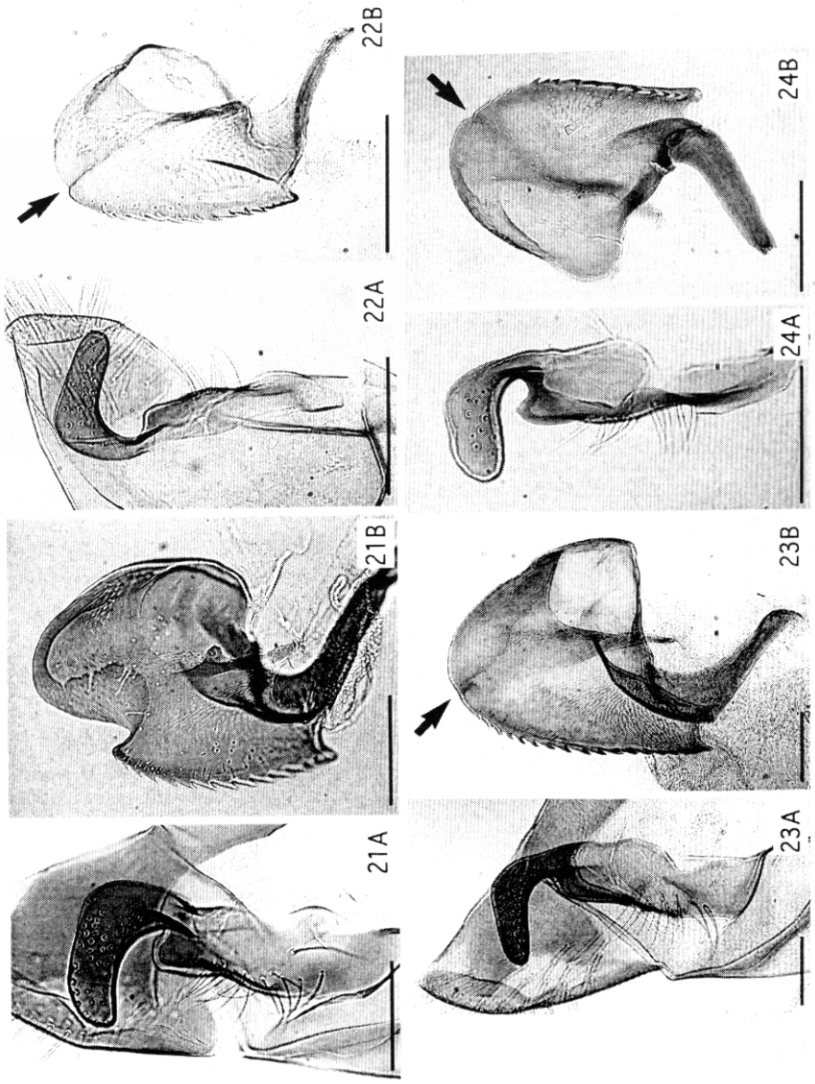

Fig. 21-24. Volsella and aedeagal plate of Pheidole spp. in lateral view. 21, Pheidole quadricuspis Emery (Eg99-BOR-039), A, left volsella, B, right aedeagal plate; 22, Pheidole retivertex Eguchi (Eg97-BOR-496), A, right volsella, B, right aedeagal plate; 23, Pheidole sabahna Eguchi (paratype), A, left volsella, B, left aedeagal plate; 24, Pheidole sarawakana Forel (Eg96-BOR-164), A, right volsella, B, right aedeagal plate. Scale bars: 0.1 mm.

which is located near the apex of aedeagal plate (arrow in Fig. 24B); apical lobe 0.09-0.14 times as long as serrate margin; serrate margin with 12-15 teeth.

Pheidole sauberi Forel (Figs. 25A, B)

Pheidole sauberi Forel 1905: 18, major and minor (MHNG). Type locality: Bogor, Java. Lectotype designation and redescription of type material: Eguchi 2001a.

Specimens examined - 4 males (Eg96-BOR-006) and 4 males (Eg96-BOR-020), Tawau Hills Park, Sabah, Borneo, 8, 9/vii/1996, K. Eguchi leg.; 4 males (Eg96-BOR-069), Sayap Kinabalu, Sabah, 15/vii/1996, K. Eguchi leg.

Description - LVG 0.370-0.470 mm, LAP 0.203-0.244 mm, LAL 0.026-0.048 mm, LSM 0.175-0.206 mm. Volsella with 8-11 simple hairs ventrally; its apicoventral part produced as a short lobe. Digitus bent ventrally at a right angle. Aedeagal plate with a quite small incision which is located near apex of aedeagal plate (arrow in Fig. 25B); apical lobe 0.15-0.25 times as long as serrate margin; serrate margin weakly and evenly convex, with 10-14 relatively large teeth.

Pheidole sayapensis Eguchi (Figs. 26A, B)

Pheidole sayapensis Eguchi 2001b: 114-115, major, minor, queen and male (holotype in UMS). Type locality: Sayap Kinabalu (1000 m alt.), Sabah, Borneo.

Specimens examined - 5 males (1 paratype and 4 males from the same colony (Eg96-BOR-051) to which the type material belongs), 16/vii/1996, K. Eguchi leg.

Description - LVG 0.288-0.335 mm, LAP 0.169-0.175 mm, LAL 0.020-0.026 mm, LSM 0.145-0.154 mm. Volsella with 6-9 simple hairs ventrally; its apicoventral part not produced as a lobe. Digitus bent ventrad at a right angle. Aedeagal plate with a shallow triangular emargination which is located near the apex of aedeagal plate (arrow in Fig. 26B); apical lobe 0.13-0.18 times as long as serrate margin; apical lobe small and subtruncate apically; serrate margin weakly convex, with 10-14 teeth.

Pheidole smythiesii Forel (Figs. 27A, B)

Pheidole smythiesii Forel 1902: 165, major, minor, queen and male (MHNG). Type loality: Assam, India.

Specimens examined - 1 male (Eg01-TH-075), Doi Suthep-Pui N. P. (ca. 800-900 m alt.), Chiang Mai Prov., N. Thailand, 7/vi/2001, K. Eguchi leg.

Description - LVG 0.863 mm, LAP 0.455-0.464 mm, LAL 0.081-0.093 mm, LSM 0.362-0.373 mm. Volsella with 20-24 simple hairs ventrally; its apicoventral part not produced as a lobe. Digitus relatively slender, bent ventrally at a right angle. Aedeagal plate with an inconspicuous emargination apicoventrally (arrow in Fig. 27B); apical lobe short, 0.24-0.26 times as long as serrate margin; serrate margin weakly and evenly convex, with 21 teeth.

Remarks - For the close relationship of this species with *P. gatesi*, see under *P. gatesi*.

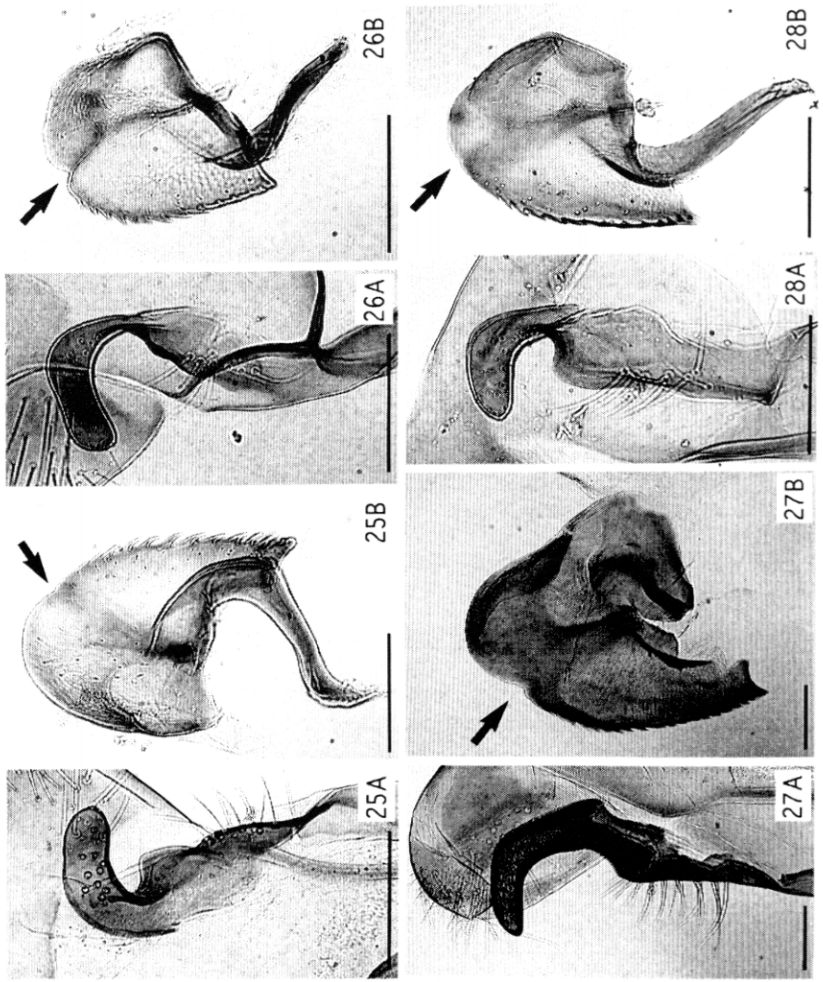

Fig. 25-28. Volsella and aedeagal plate of Pheidole spp. in lateral view. 25, Pheidole sauberi Forel (Eg96-BOR-069), A, right volsella, B, right aedeagal plate; 26, Pheidole sayapensis Eguchi (Eg96-BOR-051), A, right volsella, B, right aedeagal plate; 27, Pheidole smythiesii Forel (Eg01-TH-075), A, left volsella, B, left aedeagal plate; 28, Pheidole tandjongensis Forel (Eg01-TH-126), A, right volsella, B, right aedeagal plate. Scale bars: 0.1 mm.

Pheidole tandjongensis Forel (Figs. 28A, B)

Pheidole tandjongensis Forel 1913: 42, major and minor (MHNG). Type locality: Tandjong Slamat, Sumatra. Lectotype designation and redescription of type material: Eguchi 2001a.

Specimens examined - 4 males (Eg01-TH-126), Doi Chiang Dao, Chiang Mai Prov., N. Thailand, 9/vi/2001, K. Eguchi leg.

Description - LVG 0.409-0.428 mm, LAP 0.210-0.223 mm, LAL 0.018-0.022 mm, LSM 0.188-0.203 mm. Volsella with 7-10 simple hairs ventrally; its apicoventral part weakly produced as a short lobe. Digitus bent ventrally at a right angle, relatively thick. Aedeagal plate with a quite small incision which is located near apex of aedeagal plate (arrow in Fig. 28B); apical lobe 0.09-0.12 times as long as serrate margin; serrate margin weakly and evenly convex, with 12-15 teeth.

Pheidole sp. eg-59 (? *ocellata* Zhou) (Figs. 29A, B)

Specimens examined - 5 males (Eg01-TH-162), Campus of Chiang Mai Univ., Chiang Mai Prov., N. Thailand, 10/vi/2001, Eguchi leg.

Description - LVG 0.706-0.765 mm, LAP 0.391-0.412 mm, LAL 0.037-0.060 mm, LSM 0.332-0.370 mm. Volsella with 18-25 simple hairs ventrally; its apicoventral part well produced as a lobe. Digitus relatively slender, bent ventrally at a right angle; several relatively long setulae located ventrally near the apex. Aedeagal plate with a small emargination apicoventrally (arrow in Fig. 29B); apical lobe 0.10-0.18 times as long as serrate margin; serrate margin weakly convex, with 19-23 teeth.

Remarks - This species well agrees with *P. ocellata* Zhou in the worker caste (2001: 134, with an English description on p. 236-237), but as I have not yet examined the type of *P. ocellata* it is not certain that the present species is conspecific with the later. Both the subcastes of this extremely large-sized species are similar to those of *P. smythiesii* and *P. gatesi* in general habitus, but easily distinguished from the latter two by its 3-segmented antennal club. See also Discussion.

Pheidole sp. eg-75 (? *planifrons* Santsch) (Figs. 30A, B)

Specimens examined - 4 males (Eg01-TH-127), Doi Chiang Dao, Chiang Mai Prov., N. Thailand, 9/vi/2001, Eguchi leg.

Description - LVG 0.498-0.532 mm, LAP 0.259-0.277 mm, LAL 0.119-0.128 mm, LSM 0.153-0.177 mm. Volsella with 15-17 simple hairs ventrally; its apicoventral part weakly angulate. Digitus bent ventrad at a right angle. Aedeagal plate in profile with a distinct concavity ventrally; apical lobe approximately 0.67-0.84 times as long

as serrate margin; serrate margin weakly and evenly convex, with 10-13 teeth; its apical corner strongly produced apicad.

Pheidole sp. eg-119 (Figs. 31A, B)

Specimens examined - 3 males (Eg01-TH-128), Doi Chiang Dao, Chiang Mai Prov., N. Thailand, 9/vi/2001, K. Eguchi leg.

Description - LVG 0.412-0.444 mm, LAP 0.193-0.218 mm, LAL 0.089-0.099 mm, LSM 0.114-0.138 mm. Volsella with 9-12 simple hairs ventrally; its apicoventral part very weakly produced as an blunt angle. Digitus bent ventrally at a right angle, relatively thick. Aedeagal plate in profile with a conspicuous concavity ventrally; apical lobe 0.65-0.81 times as long as serrate margin; serrate margin weakly and evenly convex, with 11 teeth; its apical corner well produced apicad.

Remarks - This species and *P. rabo* Forel share the following characteristics and are very probably closely related to each other: hypostoma in the major with a pair of massive median processes; promesonotal dome in both the subcastes without a distinct prominence on its posterior declivity; head and alitrunk of the minor punctured over the surface. However, this species is distinguished from *P. rabo* by having spatulate propodeal spines in the major.

Pheidole sp. eg-141 (Figs. 32A, B)

Specimens examined - 2 males (Eg01-TH-052), Khao Soi Dao, Chanthaburi Prov., ME. Thailand, 4/vi/2001, K. Eguchi leg.

Description - LVG 0.332 mm, LAP 0.197-0.205 mm, LAL 0.050-0.060 mm, LSM 0.149-0.161 mm. Volsella with 6-10 simple hairs ventrally; its apicoventral part weakly produced as a short lobe. Digitus bent ventrally at a right angle. Aedeagal plate in profile with a conspicuous concavity apicoventrally; apical lobe 0.31-0.40 times as long as serrate margin, with an inconspicuous angle apicoventrally; serrate margin weakly and evenly convex, with 9-11 teeth; its apical corner moderately produced apicad.

Remarks - Both of the major and the minor workers of this species has a general habitus seen in those of *P. fervens* Fr. Smith.

Pheidole sp. eg-142 (Figs. 33A, B)

Specimens examined - 3 males (Eg01-TH-051), Khao Soi Dao, Chanthaburi Prov., ME. Thailand, 4/vi/2001, K. Eguchi leg.

Description - LVG 0.491-0.508 mm, LAP 0.273-0.303 mm, LAL 0.094-0.110 mm, LSM 0.190-0.204 mm. Volsella with 13-19 simple hairs ventrally; its apicoventral part not produced as a lobe. Digitus massive in particular at base, bent ventrad at a right angle. Aedeagal

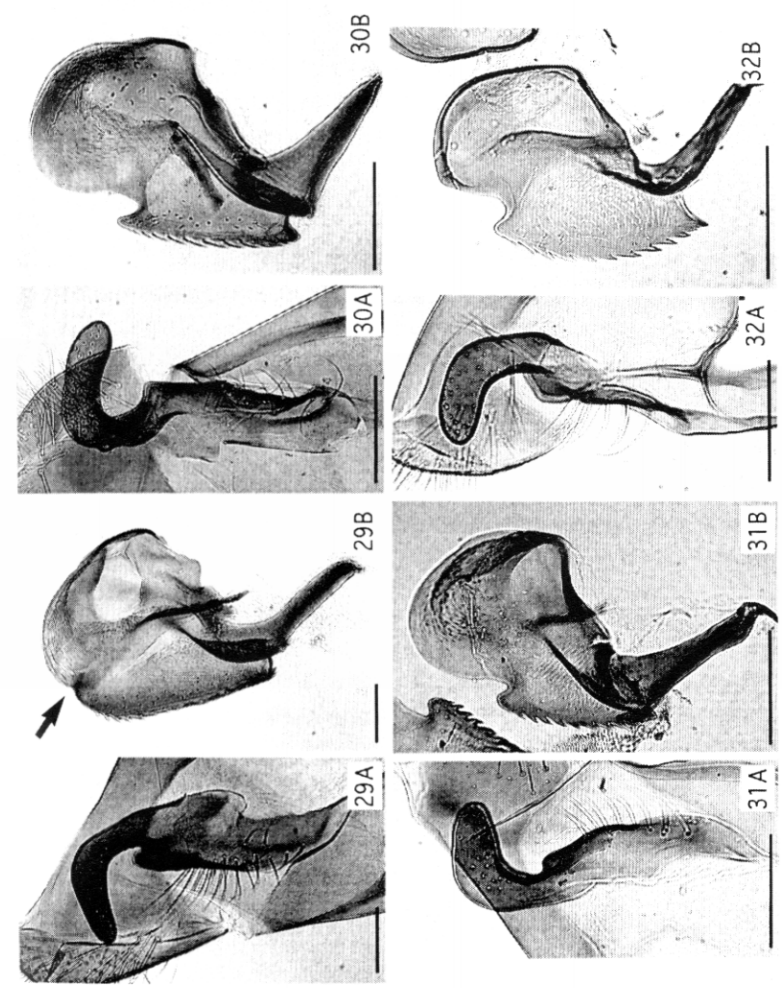

Fig. 29-32. Volsella and aedeagal plate of Pheidole spp. in lateral view. 29, Pheidole sp. eg-59 (?ocellata Zhou) (Eg01-TH-162), A, left volsella, B, right aedeagal plate; 30, Pheidole sp. eg-75 (?planifrons Santschi) (Eg01-TH-127), A, right volsella, B, right aedeagal plate; 31, Pheidole sp. eg-119 (Eg01-TH-128), A, left volsella, B, right aedeagal plate; 32, Pheidole sp. eg-141 (Eg01-TH-052), A, left volsella, B, right aedeagal plate, lateral view. Scale bars: 0.1 mm.

plate with a concavity ventrally; apical lobe 0.49-0.56 times as long as serrate margin; serrate margin weakly and evenly convex, with 11-13 teeth; its apical corner well produced; basidorsal margin of aedeagal plate relatively well sclerotized.

Remarks - This species belongs to the species group which is represented by *P. nodifera* Fr. Smith, *P. spathifera* Forel, etc. and is characterized by a large and lobate subpetiolar process of the major and massive postpetiole of both the subcastes. As far as my examination of my collection, this species is most similar to *P. nodifera*; the former is distinguished from the latter by the triangular subpetior process

(rectangular in the latter). There are also no significant differences between male genitalia of *P. nodifera* and *P.* sp. eg-142, while the peculiar shape of digitus is shared by the two species. Judging from the geographical range of *P.* sp. eg-142, at present limited to ME. and NE. Thailand and allopatric with *P. nodifera* (ranging from S. China to Malay Peninsula), there is a possibility that *P.* sp. eg-142 is a geographical race of *P. nodifera*.

Descriptions of male genitalia of related taxa

Aphaenogaster famelica (Fr. Smith) (Figs. 34A-C)

Ischnomyrmex famelicus Fr. Smith 1874: 405, worker. Type locality: Japan.

Specimens examined - 4 males (90050), Mt. Tsuma-dake (980 m alt.), Takamuma, Kagoshima pref., Japan, 8/viii/1990, H. Watanabe leg.

Description - LVG 0.495-0.530 mm, LAP 0.270-0.300 mm. Pygostyle relatively short, with a conspicuous apical process (arrows in Fig. 34A). Paramere in profile almost triangle, longer than broad, with well-developed gonocoxal arm; apical part of paramere bluntly produced, bearing simple hairs laterally. Volsella with approximately 15-18 simple hairs ventrally; its apicoventral part forming an acute angle which is weakly produced. Digitus gently bent ventrad, with scattered small setulae on outer surface of tapering apex. Cuspis projected apicad from outer face of apicolateral part of volsella near the base of digitus (arrow in Fig. 34B), short but distinct, bearing 1-2 hairs ventrally or basiventrally (the hairs hardly recognizable in Fig. 34B). Aedeagal plate oval in profile, gently tapering apicad in its apical 2/3, without any concavity on ventral and apicoventral margin; serrate margin extending very near to apex of aedeagal plate, with 20-22 teeth.

Aphaenogaster gracillima Watanabe & Yamane (Figs. 35A-C)

Aphaenogaster gracillima Watanabe & Yamane 1999: 735, worker. Type locality: Japan.

Specimens examined - 3 males (reared from the colony 91022), Mt. Omoto-dake (500 m alt., shade & wet habitat), Ishigaki-jima, Yaeyama Is., Ryukyus, Japan, H. Watanabe leg.

Description - LVG 0.412-0.456 mm, LAP 0.238-0.255 mm. Pygostyle relatively long, digitiform (arrows in Fig. 35A). Paramere in profile almost triangle, longer than broad, with a well-developed gonocoxal arm; apical part of paramere bluntly produced, bearing simple hairs laterally. Volsella with approximately 9-12 simple hairs ventrally; its apicoventral part forming an almost right angle. Digitus bent ventrad at a right angle, with scattered small setulae on outer surface of tapering apex; several relatively long setulae located ventrally. Cuspis projected apicad from outer surface of apicolateral part of volsella near the base of digitus (arrow in Fig. 35B), relatively large, bearing 0-1 hair near the apex, and sometimes with a hair near the base (hardly visible in Fig. 35B). Aedeagal plate oval in profile, gently tapering apicad in its apical 2/3, without any concavity on ventral and apicoventral margin; serrate margin extending very near to apex of aedeagal plate, with 17-20 teeth.

Aphaenogaster luteipes Watanabe & Yamane (Figs. 36A-C)

Aphaenogaster luteipes Watanabe & Yamane 1999: 733, worker. Type locality: Japan.

Specimens examined - 4 males (reared from the colony 91069), Mt. Inokawa-dake (370 m alt., shade & mesic habitat), Tokunoshima, Amami Is., Ryukyus, Japan, H. Watanabe leg.

Description - LVG 0.407-0.432 mm, LAP 0.213-0.233 mm. Pygostyle oviform (arrows in Fig. 36A). Paramere in profile almost triangle, longer than broad, with a well-developed gonocoxal arm; apical part of paramere bluntly produced, bearing simple hairs laterally. Volsella with approximately 10-14 simple hairs ventrally; its apicoventral part forming an almost right angle. Digitus bent ventrad at a right angle, with scattered small setulae on outer surface of tapering apex, and sometimes with several relatively long setulae apicoventrally. Cuspis projected apicad from outer surface of apicolateral part of volsella near the base of digitus (arrow in Fig. 36B), relatively large, bearing 0-3 hairs near the apex (hardly visible in Fig. 36B). Aedeagal plate oval in profile, tapering in its apical 2/3, without any concavity on ventral and apicoventral margin; serrate margin extending very near to apex of aedeagal plate, with 16-20 teeth.

Remarks - There are relatively minor differences in male genitalia and adjacent segments among *A. famelica*, *A. gracillima* and *A. luteipes* as follows: cuspis of *A. famelica* is relatively small; relative length of pygostyle is much greater in *A. gracillima* than in *A. famelica* and *A. luteipes*. Male genitalia of these species are well distinguishable from those of the three species belonging to "the subgenus *Deromyrma*" of *Aphaenogaster* described below (see under *Aphaenogaster* sp. 7 of Kim).

Aphaenogaster sp. 7 of Kim (Figs. 37A ,B)

Specimens examined - 2 males (Eg99-VN-116), Ba Vi N. P. (400-800 m alt.), Ha Tai Prov., N. Vietnam, K. Eguchi leg.

Description - LVG 0.399-0.429 mm, LAP 0.230-0.243 mm. Paramere in profile almost triangle, with well-developed gonocoxal arm; apical part of paramere bluntly produced, bearing simple hairs laterally.

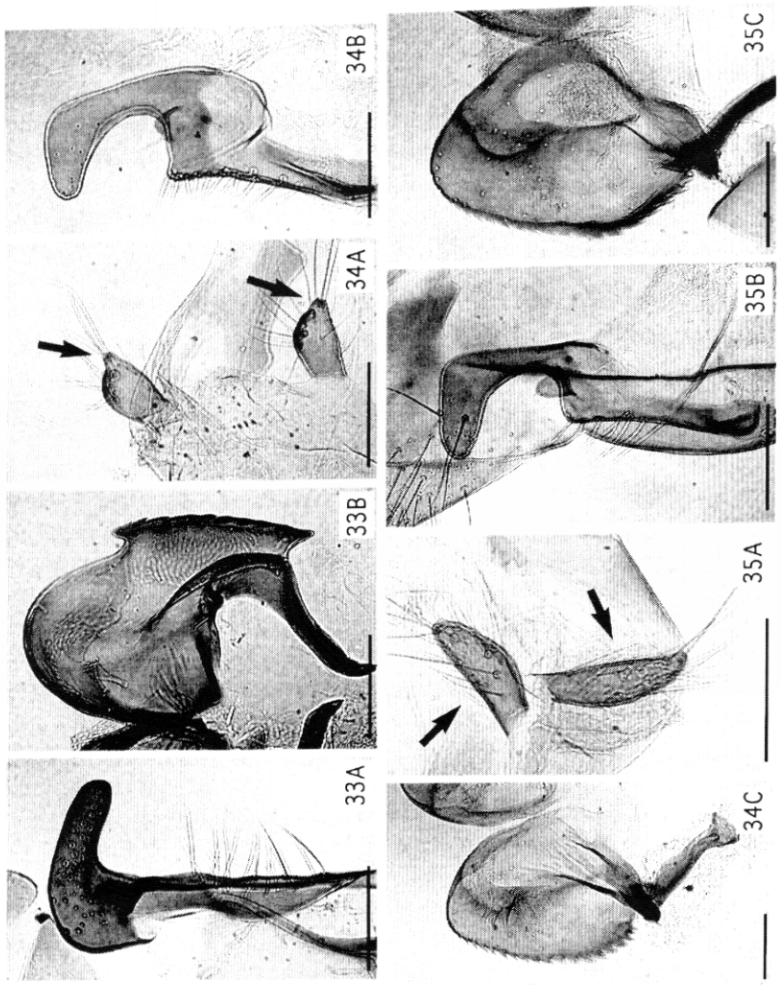

Fig. 33-35. Volsella and aedeagal plate of Pheidolini species in lateral view. 33, Pheidole sp. eg-142 (Eg01-TH-051), A, right volsella, B, left aedeagal plate; 34, Aphaenogaster famelica Fr. Smith (90050), A, pygostyles; B, right volsella; 35, Aphaenogaster gracillima Watanabe et Yamane (91022), A, pygostyles, B, right volsella, C, right aedeagal plate. Scale bars: 0.1 mm.

Volsella with approximately 9-11 simple hairs ventrally; its apicoventral part not forming an angle. Digitus gently bent ventrad, with a few small setulae on outer surface of the apex. Cuspis ill developed, with a relatively long and thick hair at the apex (arrow in Fig. 37A). Aedeagal plate longer than broad, broadest around its midlength, without any concavity on ventral and apicoventral margin; serrate margin extending very near to apex of aedeagal plate, with 15-16 teeth.

Remarks - This species together with A. sp. 13 and 18 of Kim can be arranged in the subgenus *Deromyrma* which is defined by the head with an elongate neck and body sparsely bearing paired stout hairs. Bolton (1982), however, relegated all the subgenera of *Aphaenogaster* including *Deromyrma* to synonyms. In male genitalia A. sp. 7, 13 and 18 of Kim are quite different from *A. famelica*, *A. gracillima* and *A. luteipes* in that digitus are gently curved, and cuspis is absent or ill-developed, never forming a distinct lobe. This fact seemingly supports the validity to recognize a natural group which is at least partly equivalent to "*Deromyrma*". This species has an ill-developed cuspis with a thick hair, by which it is distinguishable from the two "*Deromyrma*" species described below.

Aphaenogaster sp. 13 of Kim (Figs. 38A, B)

Specimens examined - 1 male (Eg96-BOR-181), Danum Valley, Sabah, Borneo, 1996 K. Eguchi leg.

Description - LVG 0.410 mm, LAP 0.285 mm. Paramere in profile almost triangle, longer than broad, with well-developed gonocoxal arm; apical part of paramere bluntly produced, bearing simple hairs laterally. Volsella with 11-12 simple hairs ventrally; its apicoventral part forming an acute angle. Digitus gently bent ventrad, with scattered small setulae on outer surface of tapering apex; a hair present ventrally near the base of digitus. Cuspis completely absent. Aedeagal plate much longer than broad, tapering in its apical 1/3, without any concavity on ventral and apicoventral margin; serrate margin extending very near to apex of aedeagal plate, with 19 teeth.

Aphaenogaster sp. 18 of Kim (Figs. 39A, B)

Specimens examined - 2 males (KT-98-017), W. Bali, 10/xi/1998, Ida Ketut Ginarsa leg.

Description - LVG 0.392-0.424 mm, LAP 0.243-0.265 mm. Paramere in profile almost triangle, with well-developed gonocoxal arm; apical part of paramere bluntly produced, bearing simple hairs laterally. Volsella with approximately 12-15 simple hairs ventrally; its apicoventral part forming an blunt corner. Digitus very weakly bent ventrad, with scattered small setulae on outer surface at the apex; a short hair sometimes present ventrally near the base of digitus. Cuspis unrecognizable. Aedeagal plate much longer than broad, tapering in its apical 1/3, without any concavity on ventral and apicoventral margin; serrate margin extending very near to apex of aedeagal plate, with 18-20 teeth.

Remarks - Male genitalia of this species are distinguished from those of *A.* sp. 13 of Kim by its blunt apicoventral corner of volsella.

Lophomyrmex bedoti Emery (Figs. 40A, B)

Lophomyrmex bedoti Emery 1893: 192, worker and queen. Type locality: Sumatra.

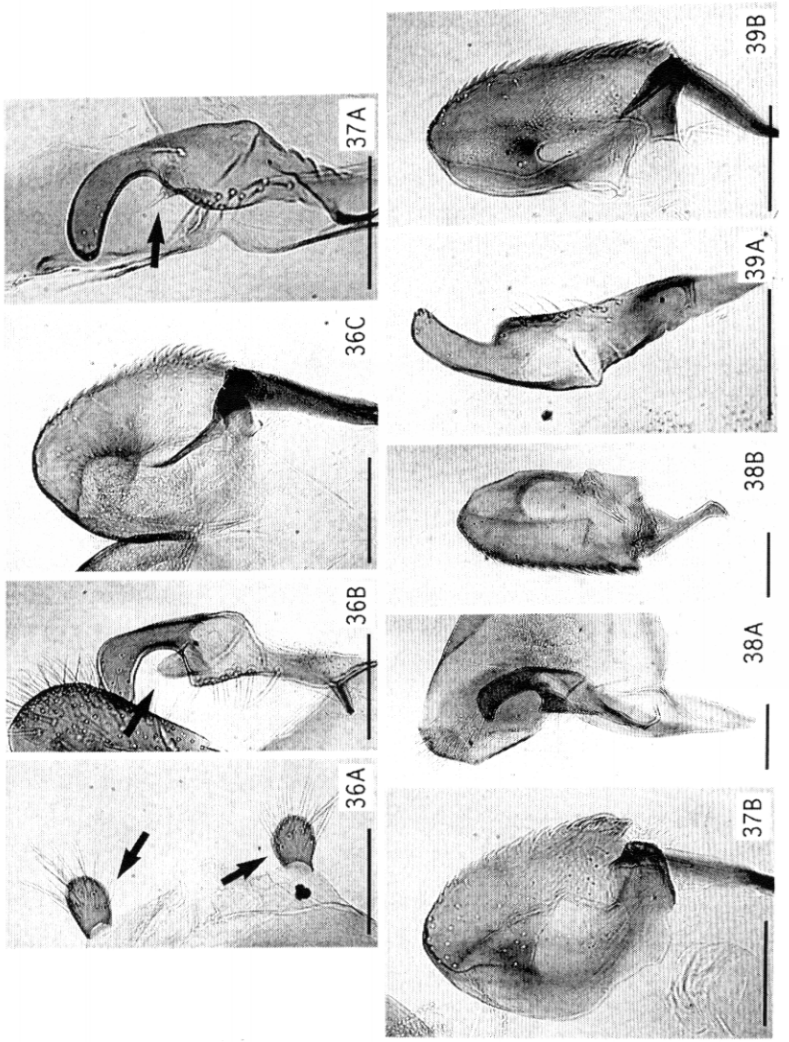

Fig. 36-39. Volsella and aedeagal plate of Aphaenogaster spp. in lateral view. 36, Aphaenogaster luteipes Watanabe et Yamane (91069), A, pygostyles; B, right volsella, C, left aedeagal plate; 37, Aphaenogaster (Deromyrma) sp. 7 of Kim (Eg99-VN-116), A, left volsella, B, left aedeagal plate; 38, Aphaenogaster (Deromyrma) sp. 13 of Kim (Eg96-BOR-181), A, leftvolsella, B, left aedeagal plate; 39, Aphaenogaster (Deromyrma) sp. 18 of Kim (KT-98-017), A, right volsella, B, left aedeagal plate. Scale bars: 0.1 mm.

Specimens examined - 3 males (Eg97-BOR-481), Sepilok Forest, Sabah, Borneo, 1997 K. Eguchi leg.

Description - LVG 0.958-1.005 mm, LAP 0.495-0.553 mm. Paramere in profile almost triangle, longer than broad; its apical part bluntly produced, bearing simple hairs on the outer surface. Volsella with 9-13 simple hairs ventrally; its apicoventral part produced as a lobe. Digitus gently bent, with small setulae scattering over at least ventral face of apical half, and with several relatively long and simple setulae apicoventrally. Cuspis absent. Aedeagal plate subtruncate apically,

without any concavity on the margin; ventral margin serrate almost for the whole length, with 20-23 teeth.

Remarks - The genus *Lophomyrmex* was placed in the tribe Pheidolini by Rigato (1994).

DISCUSSION

The male genitalia of species of *Pheidole* and other pheidoline genera examined here have the basic structure of those of the typical formicid shown by Ogata (1991). Number of hairs on ventral margin of volsella is variable within a species and sometimes even between the left and right of a single individual, and so it cannot be used as a species diagnosis. In the species listed below apicoventral part of volsella is developed as a lobe, but this part is probably not homologous to cuspis, because, according to the definition by Birket-Smith, cuspis is a lobe produced from apicolateral corner of volsella, laterally of the digitus (as seen in *Aphaenogaster famelica*, *A. gracillima* and *A. luteipes* (Figs. 34-36), and also in Cagniant's figures of Mediterranean *Aphaenogaster* (examples are cited in Fig. 41)): *Pheidole bluntschlii*, *P. montana*, *P. parvicorpus*, the members of *P. quadricuspis* group examined in this study (see Eguchi 2001b), i.e., *P. lokitae*, *P. quadrensis* and *P.*

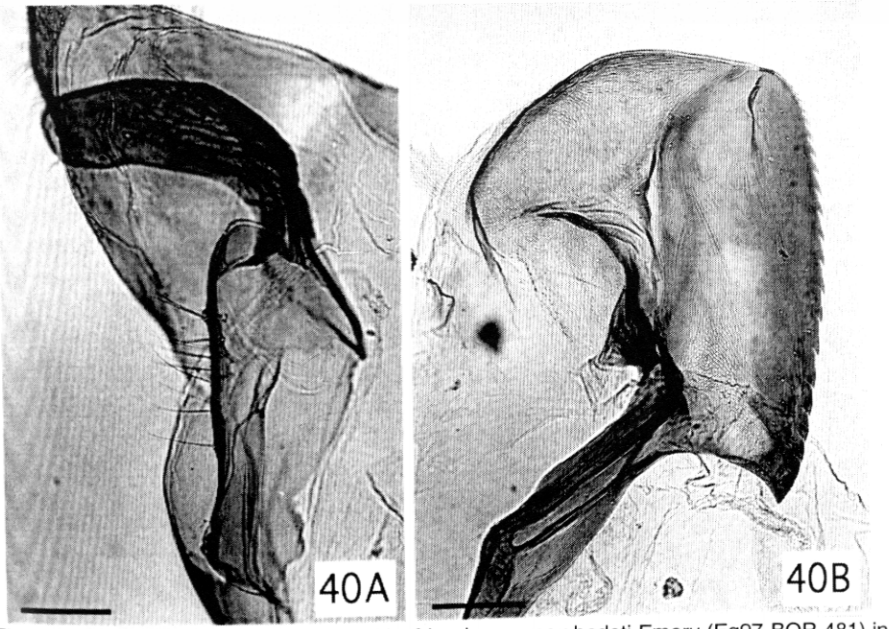

Fig. 40. Volsella (A) and aedeagal plate (B) of Lophomyrmex bedoti Emery (Eg97-BOR-481) in lateral view, A, left volsella, B, left aedeagal plate. Scale bars: 0.1 mm.

quadricuspis; and of *P. sauberi* group examined in this study (see Eguchi 2001b), i.e., *P. sarawakana*, *P. sauberi*, and *P. tandjongensis*. In *P. parvicorpus* the lobe is exceptionally large. Other than this lobate apicoventral part of volsella, there are no significant characteristics which support a close relationship among these species/species groups, and so this characteristics probably has appeared in different assemblages within *Pheidole* independently. Ventrally bent digitus, which is shared by all the *Pheidole* species examined in this study, is also common in other myrmicine genera (Table 1 of the present paper; Karfchick 1959; Ogata 1991). *P. aristotelis* and *P. lucioccipitalis* have an extremely massive digitus with a blunt apicodorsal angle, but worker morphology does not suggest their close relationship (see descriptions of their workers in Eguchi 2001b). Digitus has a thick basal part in *Pheidole huberi*, *P. nodifera* and *P.* sp. eg-142. Not only the shape of aedeagal plate but also the worker morphology, however, does not suggest their relationship between the former and the latter two; the worker of *P. nodifera* and P. sp. eg-142 has the following characteristics that are not observed in *P. huberi*: petiole of the major in dorsal view rectangular, margined laterally with a distinct flange; subpetiolar process well developed in the major, postpetiole of both the subcastes massive. Cuspis is absent in the genus *Pheidole* as mentioned above.

Two generalized types of aedeagal plate are recognized among 32 *Pheidole* species examined. One of them is characterized by the presence of a distinct concavity which is located on ventral, apicoventral or apical margin of the plate. This type is hereafter referred to as "concavity-type". Ogata (1982) reported the concavity-type aedeagal plate ("the concave ventrodistal margin of aedeagus" in his descriptions) in six Japanese species: *P. fervida* Fr. Smith, *P. pieli* Santschi, *P. indica* Mayr, *P. noda* Fr. Smith, *P. fervens* Fr. Smith, and *P. megacephala* (Fabricius), and mentioned a possibility that this type is one of the synapo-morphic characteristics of the genus *Pheidole*. Krafchick (1959) reported the concavity-type aedeagal plate in *Pheidole anastasii* Emery and *P. dentata* Mayr, both from North America (Krafchick 1959, pl. 4, fig. 28 & 29), and also treated it ("the margin interrupted by a rounded notch") as one of the diagnostic characteristics of *Pheidole* in his key. I found this condition in *P. aglae*, *P. aristotelis*, *P. clypeo-cornis*, *P. havilandi*, *P. hortensis*, *P. huberi*, *P. inornata*, *P. lokitae*, *P. longipes*, *P. lucioccipitalis*, *P. montana*, *P. nodifera*, *P. orophila*, *P. plagiaria*, *P. quadrensis*, *P. quadricuspis*, *P.* sp. eg-75 (? *planifrons*), *P. quadrensis*, *P. quadri-cuspis*, *P.* sp. eg-119, *P.* sp. eg-141 and *P.* sp. eg-142. Concavity-type aedeagal plate has so far not been reported in the other genera in the tribe Pheidolini (Table 1). With the present material I have not found

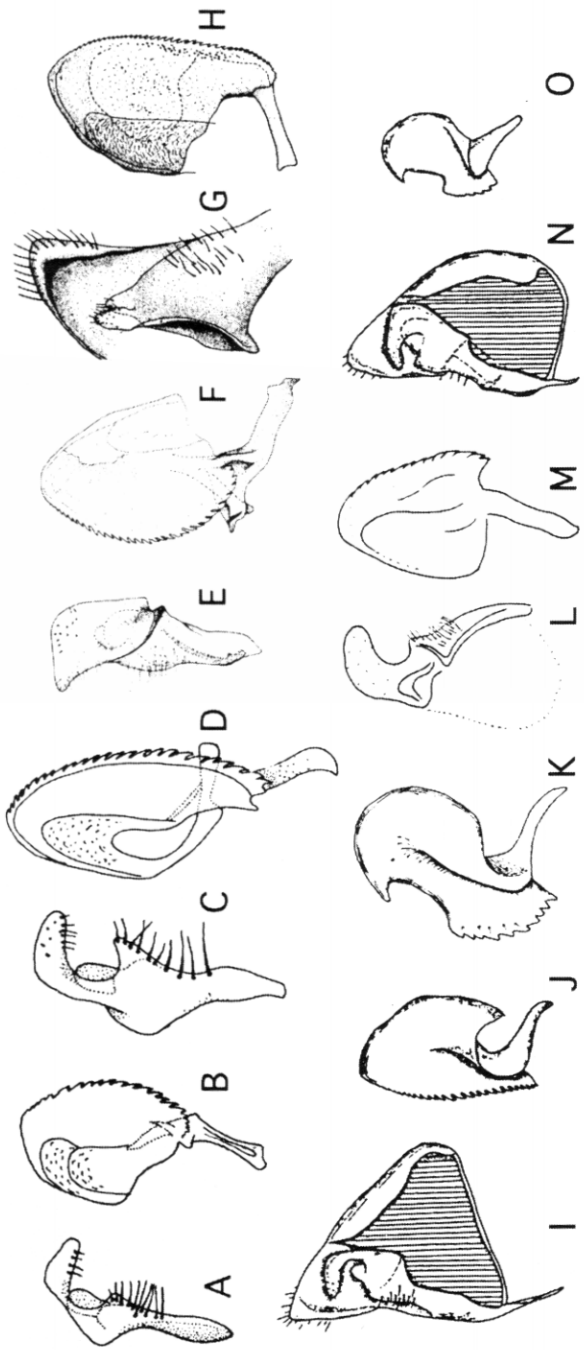

Fig. 41. Male genital parts (in lateral view) of myrmicine species reported in previous papers. A, volsella, Aphaenogaster depilis; B, aedeagal plate, same; C, volsella, A. testaceopilosa; D, aedeagal plate, same; E, volsella, A. fallax; F, aedeagal plate, same; G, paramere+volsella, Messor capitata; H, aedeagal plate, same; I, paramere+volsella, M. aciculatus; J, aedeagal plate, same; K, aedeagal plate, P. pieli; L, volsella, Goniomma blanci; M, aedeagal plate, same; N, paramere+volsella, Leptothorax congruus; O, aedeagal plate, same. A-D, I-J cited from Cagniant (1966); E-H from Cagniant (1992a); I-J, N-O from Ogata (1991); K from Ogata (1982); L-M from Espadaler (1984).

Table 1. A list of major publications concerning male genitalia of pheidoline ants (? = no information).

Species	Aedeagal plate	Digitus	Cuspis	References
Aphaenogaster albisetosa	no concavity	gently bent ventrad	?	Krafchick, 1959
A. atlantis	no concavity	bent at 90°	lobate	Cagniant 1990
A. baronii	no concavity	short, bent at 90°	lobate	Cagniant 1988b
A. crocea	no concavity	bent ventrad	lobate	Cagniant 1969a
A. depilis	no concavity	falciform, bent at 90°	lobate	Cagniant 1966
A. fallax	no concavity	extremely massive, bent ventrad	as a fold, or absent	Cagniant 1992b
A. fulva	no concavity	bent ventrad	lobate	Krafchick 1959
A. gamella	?	bent ventrad	lobate	Cagniant 1994
A. minita	?	bent at 90°	lobate	Cagniant 1990c
A. praedo	no concavity	spatulate	very small or absent	Cagniant 1969b
A. rifensis	?	bent at 90°	lobate	Cagniant 1994
A. rupestris	no concavity	spatulated, slightly curved	round	Cagniant 1969b
A. sicardi	?	bent ventrad	lobate	Cagniant 1990b
A. theryi	no concavity	bent at 90°	very small	Cagniant 1986
A. tinauti	no concavity	massive, bent at 90°	lobate	Cagniant 1992a
A. testaceopilosa	no concavity	falciform, bent at 90°	lobate	Cagniant 1966
A. torossiani	no concavity	clubbed, weakly bent ventrad	oval	Cagniant 1988a
Japanese *Aphaenogaster*	no concavity	slender, curved ventrad	small, lamelliform	Ogata 1982, 1991
Messor aciculatus	no concavity	slender, curved ventrad	small	Ogata 1982, 1991
M. capitata	no concavity	spoon like	lobate	Cagniant 1966
M. mediorubra	no concavity	slightly clubbed	lobate	Cagniant 1966
M. pergandei	no concavity	falciform	?	Krafchick 1959
Goniomma baeticum	no concavity	falciform, bent at 90°	?	Reyes, *et al.*, 1987
G. blancino	concavity	curved	very short	Espadaler, 1984
G. kugleri	no concavity	curved	very short	Espalader 1985

the concavity with the acute apical corner which Ogata (1982) observed in *P. pieli, P. fervens* and *P. megacephala*. The condition of the apical corner of the concavity at least has an important taxonomic value for species diagnosis.

The other type of aedeagal plate is characterized by the absence of the concavity, or presence of only an inconspicuous emargination/incision near apex of the plate. This type is hereafter referred to as "round-type". I found round-type in *P. gatesi, P. nodgii, P. parvicorpus, P. retivertex, P. sabahna, P. sarawakana, P. sauberi*, and *P. tandjongensis*. Among the genera of the tribe Pheidolini, aedeagal plate without any concavity has been reported by previous authors in *Aphaenogaster albisetosa* Mayr, *A. atlantis* Santschi, *A. baronii* Cagniant, *A. crocea* André, *A. depilis* Santschi, *A. fallax* Cagniant, *A. famelica* (Fr. Smith), *A. fulva* Roger, *A. praedo* Emery, *A. rifensis* Cagniant, *A. rupestris* Forel, *A. testaceopilosa* (Lucas), *A. theryi* Santschi, *A. tinauti* Cagniant, *A. torossiani* Cagniant, Japanese species of *Aphaenogaster*, *Messor aciculatus* Forel, *Messor capitata* (Latreille), *M. mediorubra* Santschi ("*M. instabilis mediorubra* (Forel)"), *M. pergandei* (Mayr), *Goniomma baeticum* Reyes, Espadaler & Rodriguez, *G. blanci* (André), and *G. kugleri* Espadaler (Table 1, Fig. 41). I also found similar conditions in *Aphaenogaster famelica, A. gracillima, A. luteipes, A.* sp. 7, 13 and 18 and *Lophomyrmex bedoti* (see also under "Description of male genitalia of related taxa"). Round-type aedeagal plate in *Pheidole* species is generally broadest basally and narrowing apicad. This general condition has not been observed in two "subgenera" of *Aphaenogaster* species and *Lophomyrmex bedoti*, and is most similar to that of *G. blanci* and *G. kugleri* among pheidoline species for which aedeagal plate has been observed (see Fig. 41).

P. bluntschlii, P. sayapensis, P. smythiesii and *P.* sp. eg-59 has aedeagal plates with a shallow triangular emargination, which may represent an intermediate condition between round-type and concavity-type. Thus the distinction of concavity-type from round-type still involves a certain obscurity. *P. nodgii, P. retivertex* and *P. sayapensis* belong to the same species group (Eguchi 2001b), but aedeagal plate of *P. sayapensis* clearly differs from that of the other two in having a relatively conspicuous emargination. *P. gatesi* and *P. smythiesii* are probably closely related to each other judging from the worker morphology (Eguchi 2001b), but the shape of aedeagal plate is rather different between the two. Aedeagal plate and digitus of *P.* sp. eg-59 is morphologically very similar to those of *P. smythiesii* and *P. bluntschlii*. *P.* sp. eg-59 should be more carefully compared with the members of *P. smythiesii* group and of *P. bluntschlii+quinata* group for other morphological characters. At species/species group level potential diagnostic charac-

ters in aedeagal plate are: relative size of apical lobe (e.g., small and narrow in *P. havilandi*), position of concavity (e.g., almost apically in *P. montana*), shape of apicoventral corner of apical lobe (e.g., sharply produced in *P. pieli*), presence/absence of concavity (e.g., absence in *P. sauberi* group), relative size of concavity (e.g., very large in *P. lucioccipitalis*), apical corner of serrate margin (e.g., strongly produced apicad in *P. lucioccipitalis*). Number of teeth on serrate margin is variable within a species and sometimes between the left and right side of a single individual, suggesting invalidity of this character for species diagnosis.

Based on previous (Krafchick 1959; Ogata 1982) and present studies, it can be said that round-type is widely spread within the subfamily Myrmicinae in spite of its minority status within the genus *Pheidole*. However, under the present situation where information concerning the genitalia of *Pheidole* and its allied genera is still insufficient, and where phylogeny within the tribe Pheidolini has been poorly resolved, it is difficult to state whether round-type aedeagal plate is plesiomorphic within *Pheidole*. On the other hand, aedeagal plates of *Leptothorax nadigi* Kutter (Espadaler 1984; see Fig. 41 of the present paper), *L. sallei* (Guérin-Méneville) (Krafchick 1959) and *L. longispinosus* Roger of the tribe Formicoxenini (Krafchick 1959) recalls that of *Pheidole pieli* shown by Ogata (1982; see Fig. 41 of the present paper), suggesting the possibility that concavity-type has arisen independently in several tribes within the subfamily Myrmicinae. Furthermore, if concavity-type is apomorphic, it should have independently arisen several times within *Pheidole*, because the condition is shared by quite heterogenous species/species groups, e.g., *P.* sp. eg-119, *P. quadricuspis* group, *P. longipes* group, *P. nodifera* group (see remarks of P. sp. eg-142) and *P. hortensis+aristotelis* group. Round-type is also shared among quite heterogeneous species / species groups, e.g., *P. gatesi*, *P. nodgii*, *P. parvicorpus*, *P. retivertex*, *P. sauberi* group and *P. quinata* group (definition of these species groups based on the worker morphology is given in Eguchi 2001b).

Phylogenetical implications of characters of male genitalia and adjacent segments should be discussed in combination with further detailed examinations and analyses of total morphology of the worker as well as the male. On the other hand several characters mentioned above are in some cases diagnostic at species level or species-group level within the genus *Pheidole*. Further accumulation of information on male morphology will make it possible to sort male specimens collected by light traps, which are currently employed in biodiversity studies worldwide.

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