A new fossil silky lacewing genus (Neuroptera, Psychopsidae) from the Early Cretaceous Yixian Formation of China

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Abstract
A new genus and species, Undulopsychopsis alexi gen. et sp. n., is described from the Early Cretaceous Yixian Formation of western Liaoning Province, China. This genus is probably most closely related to the Asian Cretaceous genus Kagapsychops Fujiyama, 1978. The family affinity of Undulopsychopsis gen. n. is discussed. The genus is preliminarily assigned to Psychopsidae, although it shares some character states with Osmyllopsychopidae (e.g., crossveins are very scarce; Rs1 and 1A are multi-branched).

Keywords
Psychopsidae, Osmyllopsychopidae, fossil, Mesozoic, Huangbanjigou, China
Introduction

The extant Psychopsidae is a small family (five genera and 27 described species), currently restricted to disjunct regions in southern Africa, southeastern Asia and Australia (New 1988; Oswald 1993a; Wang and Bao 2006). Adult psychopsids are recognized by their broad wing shape, dense venation, the presence of *vena triplica*, spectacularly patterned and hairy wings, which gives psychopsids the common name of silky lace-wings (New 1989; Oswald 1993a, 1995).

Fossil psychopsids were much more widely distributed than the extant taxa. Since the early 20th century, fossil psychopsids have increasingly been found from all over the world, with species ranging in age from the Triassic to the Tertiary. The earliest fossil record of the Psychopsidae is *Triassopsychops* Tillyard, 1922 from the Late Triassic of Australia (Tillyard 1922), which possesses a true *vena triplica*, characteristic of this family. While many fossil psychopsids were recorded from the Mesozoic, few representatives have been described from the Tertiary. Hitherto, 35 fossil species (24 genera) have been referred to Psychopsidae (Table 1). The psychopsid affinity of many Jurassic and Cretaceous genera is debatable. For example, Jepson et al. (2009) believe that some genera (e.g., *Grammapsychops* Martynova, 1954, *Embaneura* G. Zalessky, 1953, *Pulchroptilonia* Martins-Neto, 1997, and *Kagapsychops* Fujiyama, 1978) may belong to another psychopsoid family, Osmylopschopidae. The position of these and some other fossil genera from the Mesozoic is questionable, due to certain differences in details of the wing venation between fossil and extant psychopsids (e.g., the pattern of Rs branches, the configuration of M and Cu in the forewing, the structure of *vena triplica*), although their general venational pattern is similar to that of extant representatives. Furthermore, the combination of a small number of known extant species and the often poor preservation of fossil representatives has greatly hindered the understanding of fossil psychopsids. The ambiguous diagnoses of many fossil psychopsids have resulted in potential confusion with other Mesozoic neuropterans (Andersen 2001; Makarkin and Archibald 2003). More evidence is needed to further the knowledge of fossil psychopsids. In recent years, many Mesozoic psychopsids described from Asia (particularly from Russia and China) have drawn increased attention to fossil psychopsids. In this paper, we describe a new genus and species of Psychopsidae from the Early Cretaceous Yixian Formation of Huangbanjigou Village, Liaoning Province, China.

Material and methods

The specimen described herein is from the Yixian Formation of Huangbanjigou Village, Shangyuan County, Beipiao City, western Liaoning Province, northeastern China. The principal fossil-bearing layers in Huangbanjigou locality are silty mudstone, yellowish to grayish, rich in insects, fish and plants (Chen et al. 2005). The age of these fossil-bearing strata in Sihetun area (including Huangbanjigou) is considered to be well supported by radiometric dating as Early Cretaceous (Middle/Late Barremian), from
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Table 1. Fossil species currently ascribed to the family Psychopsidae.

| Species                      | Age                        | Locality                        |
|------------------------------|----------------------------|----------------------------------|
| 1 Triassopsychops superbus   | Late Triassic (Carnian)     | Denmark Hill, Queensland, Australia |
| 2 Archaeopsychops triassicus | Late Triassic (Carnian)     | Denmark Hill, Queensland, Australia |
| 3 Apeirophlebia grandis      | Early Jurassic (Early Toarcian) | Dobbertin, Germany |
| 4 Cretapsychops decipiens    | Middle Jurassic (Aalenian/Bajocian) | Daohugou, Inner Mongolia, China |
| 5 Beipiaopsychops triangulatus | Middle Jurassic (Aalenian/Bajocian) | Haifanggou, Liaoning, China |
| 6 Sinapsychops chengdeensis  | Middle Jurassic (Aalenian/Bajocian) | Chengde, Hebei, China |
| 7 Calopsychops extinctus     | Late Jurassic (Oxfordian/Kimmeridgian) | Karatau, Kazakhstan |
| 8 Propсыpsychops karatavicus | Late Jurassic (Oxfordian/Kimmeridgian) | Karatau, Kazakhstan |
| 9 Angaropsychops sinicus     | ?Early Cretaceous           | Heishangou, Liaoning, China |
| 10 Kagapsychops aranea       | Early Cretaceous (Valanginian/Barremian) | Kuwajima, Japan |
| 11 Angaropsychops turgensis  | Early Cretaceous (Hauterivian) | Turga, Transbaikalia, Russia |
| 12 Psychopsites rolandi      | Early Cretaceous (Hauterivian) | Lower Weald Clay, Wealden, England |
| 13 Valdipsychops minimus     | Early Cretaceous (Hauterivian) | Lower Weald Clay, Wealden, England |
| 14 Baisopsychops lambkini    | Early Cretaceous (pre-Barremian) | Baissa, Transbaikalia, Russia |
| 15 Epipsychopsis fusca       | Early Cretaceous (pre-Barremian) | Baissa, Transbaikalia, Russia |
| 16 Epipsychopsis variegata   | Early Cretaceous (pre-Barremian) | Baissa, Transbaikalia, Russia |
| 17 Undulopsychopsis alexi gen. et sp. n. | Early Cretaceous (Barremian) | Huangbanjigou, Liaoning, China |
| 18 Cretapsychops corami      | Early Cretaceous (Barremian) | Upper Weald Clay, Wealden, England |
| 19 Micropsychops parallellus | Early Cretaceous (Barremian) | Upper Weald Clay, Wealden, England |
| 20 Valdipsychops brigidae    | Early Cretaceous (Barremian) | Upper Weald Clay, Wealden, England |
| 21 Valdipsychops logunovi    | Early Cretaceous (Barremian) | Upper Weald Clay, Wealden, England |
| 22 Valdipsychops proudlovei   | Early Cretaceous (Barremian) | Upper Weald Clay, Wealden, England |
| 23 Valdipsychops maculosus   | Early Cretaceous (Barremian) | Upper Weald Clay, Wealden, England |
126.1 ± 1.7 to 124.6 ± 0.1 Ma (e.g., Swisher et al. 1999; Wang et al. 2001b; Chen et al. 2004; Yang et al. 2007), although the upper-most beds of Huangbanjigou locality have an Early Aptian age, 123.3 ± 0.5 – 122.8 ± 1.6 Ma (Wang et al. 2001a; Yang et al. 2007). The specimen is deposited in the Chaoyang Bird Fossil National Geopark, Chaoyang City, Liaoning Province, China.

The material was examined using a Leica MZ12.5 dissecting microscope. The photographs were taken using a Nikon D100 digital camera coupled to a Nikkor 105mm macro lens, and final photographs were adjusted by using Adobe Photoshop 4.0 image-editing software. All line drawings were drawn made directly using CorelDraw 12 graphic software.

We follow the traditional (sensu Wootton 2003) venational terminology of Comstock (1918) with the recent interpretation of Oswald (1993b) and Archibald and Makarkin (2006). The abbreviations used in the text are: C, costa; Sc, subcosta; hv, humeral veinlet; R, radius; R1, first branch of R; Rs, radial sector; Rs1, basal-most branch of Rs; M, media; MA, media anterior; MP, media posterior; Cu, cubitus; CuA, cubitus anterior; CuP, cubitus posterior; 1A–2A, first to second anal veins.
Systematic palaeontology

Order Neuroptera Linnaeus, 1758

Family Psychopsidae Handlirsch, 1906

Genus Undulopsychopsis gen. n.
urn:lsid:zoobank.org:act:B718D980-A2EB-4293-B2CD-EF6C58E8F53E
http://species-id.net/wiki/Undulopsychopsis

Type species. Undulopsychopsis alexi sp. n.

Diagnosis. Forewings: costal gradate series absent; branches of Rs dichotomously branched; Rs1 multi-branched, pectinate with branches directed anteriorly; M forked far distal to origin of Rs; CuP dichotomously branched. Hind and outer margins of both wings undulate.

Etymology. The generic name is derived from the Late Latin undula (meaning a small wave, refers to its undulate wing margins) and Psychopsis (the type genus of the family). The gender is feminine.

Remarks. This new genus differs from all other psychopsids by possessing undulate outer and hind margins of both wings. The combination of the following forewing character states is also characteristic: no costal gradate series; branches of Rs dichotomously branched; the basal-most branch of Rs multi-branched, and M forked far distal to the origin of Rs. The new genus has scarce costal crosveins, which are not arranged in gradate series, in contrast to the genera Grammapsychops, Miopsychopsis Makarkin, 1991, Baisopsychops Makarkin, 1997, Cretapsychops Jepson et al., 2009 and Epipsychopsis Makarkin, 2010. Undulopsychopsis gen. n. possesses the dichotomously branched branches of Rs; this condition is also present in the following psychopsid genera: Triasopsychops, Angaropsychops Martynova, 1949, Psychopsites Jepson et al., 2009, Valdispsychops Jepson et al., 2009, Epipsychops, Pulchroptilonia, Putzneura Martins-Neto et Rodrigues, 2010, Kagapsychops, Grammapsychops, and Embanuera. Among these the new genus is most similar to those genera which have the multi-branched Rs1 and M forked far distal to the origin of Rs. This combination is present only in the genus Kagapsychops. The type species of this genus (K. aranea Fujiyama, 1978) is fragmentary and poorly preserved, but K. continentalis Makarkin, 1994 is well-preserved (although incomplete). Undulopsychopsis gen. n. clearly differs from Kagapsychops by being a much smaller size (the forewing of the former is approximately twice shorter than that of the latter), and the absence of the gradate series of crosveins in the radial space. Other fossil psychopsids, for example Propsychops Krüger, 1923, Litopsychopsis Engel et Grimaldi, 2008 and Micropsychops Jepson et al., 2009 differ strongly from the new genus by having mostly unbranched veins of Rs before end-twigging and several long gradate series of crosveins in the radial space.
**Undulopsychopsis alexi sp. n.**
urn:lsid:zoobank.org:act:29E097D3-A80A-48B2-88D7-8240349F17D0
http://species-id.net/wiki/Undulopsychopsis_alexi
Figs 1–3

**Material.** Holotype CYNB044, a well-preserved specimen, with body partially preserved and four wings overlapping pairwise.

**Diagnosis.** As for the genus.

**Description.** Body: only partial thorax preserved. Pronotum sub-rectangular, 1.2 mm long, 2.8 mm wide, suffused with many long hairs. Mesonotum 3 mm long, 3.5 mm wide, with some long hairs laterally.

Forewing (Fig. 3) subtriangular, 21.5 mm long, 12.3 mm wide. Costal space broad throughout; subcostal veinlets forked; humeral veinlet slightly recurrent, branched. Subcostal space much broader than R1 space. R1 space narrow. Sc and R1 close distally but not fused. Rs with 10 primary branches, branches of Rs dichotomously branched; Rs1 pectinately branched with branches directed anteriorly. M appears originating from R, forked far from origins of Rs1. MA and MP probably simple (their terminal parts not preserved). Cu forked near wing base. CuA pectinately branched distal to fork of M. CuP multi-branched, dichotomous. Anal area well-developed. 1A long, dichotomously branched. 2A multi-branched (incompletely preserved). Only few crossveins detected: costal space basally with scarce crossveins, not forming gradate series; subcostal space with 4 crossveins preserved; R1 space with 5 crossveins preserved; medial space with 2 crossveins preserved. Veins covered with dense hairs, particularly long basally. Trichosors distinct. Wing membrane in general brownish; colour pattern consists mainly of two pale transverse zigzagged bands which are proximally darker than other portions of wing; indistinctly mottled basally and apically. Wing margin haired; hind and outer margins undulate.

Hind wings almost entirely hidden under forewing, about 16.5 mm long as preserved, 10 mm wide. Venation very poorly preserved; no details visible. Outer margin undulate.

**Etymology.** The specific name is named in honor of the distinguished Russian paleontologist Prof. Alexandr (‘Alex’) Rasnitsyn.

**Type locality and horizon.** Yixian Formation, Huangbanjigou Village, Shangyu-an County, Beipiao City, Liaoning Province, China.

**Discussion**

Based on the configuration of the venation in the radial space of the forewing, fossil psychopsids can be divided into two groups. One group includes the taxa with simple branches of Rs, the majority of which are not branched before end-twigging. This group is represented by the genera *Propsychopsis, Baisopsychops, Cretapsychops, Micropsychops* and *Litopsychopsis*. The crossveins in these genera are usually arranged in one to two
Figure 1. *Undulopsychopsis alexi* gen. et sp. n. The holotype CYNB044. Photograph. Scale bar = 5 mm.

Figure 2. *Undulopsychopsis alexi* gen. et sp. n. The holotype CYNB044. Drawing. Scale bar = 5 mm.
gradate series in the costal space, and two to four long gradate series in the radial space. They occur in the Cretaceous and Eocene; all extant genera belong to this group as well.

Figure 3. *Undulopsychopsis alexi* gen. et sp. n. The forewing venation of the holotype CYNB044. A left forewing (converted to the right) B right forewing. Scale bar = 5 mm.
The other group includes the taxa which have the branches of Rs dichotomously branched, and often the basal-most branch of Rs multi-branched. Representative genera of this group are the earliest psychopsid Triassopsychops, and other Mesozoic psychopsids, e.g., Angaropsychops, Grammapsychops and Kagapsychops (see complete list above). They possess numerous radial crossveins, arranged in many short gradate series (often irregular), and usually no costal gradate series. Undulopsychopsis gen. n. belongs to the latter group. It is preliminarily assigned to Psychopsidae, as its Sc and R1 are not fused apically, and the costal space is broad, although it almost lacks crossveins. The latter feature, and the multi-branched Rs1 and 1A are shared by this genus with another Mesozoic psychopsoid family Osmlyopsychopidae (especially with its type genus) known from the Triassic of Australia and Central Asia (Lambkin 1992; Shcherbakov 2008). However, in the family Osmlyopsychopidae Sc and R1 are clearly fused apically. Some genera currently ascribed to Psychopsidae also have venation similar to that of Osmlyopsychopidae (e.g., Sinopsychops Hong, 1982; Grammapsychops). Unfortunately, the majority of these are either fragmentary or incompletely described and are in need of re-examination. Therefore, until the revision of psychopsoids has been completed, we consider all species enumerated in Table 1 as tentatively belonging to Psychopsidae.

Previously, only four species have been recorded from the Mesozoic of China, i.e., Angaropsychops sinicus Hong in Wang, 1980 (probably from the Early Cretaceous Yixian Formation), Sinopsychops chengdeensis Hong, 1982, Beipiaopsychops triangulatus Hong, 1983, and Cretapsychops decipiens Peng et al., 2010 (all from the Middle Jurassic Jiulongshan Formation). Undulopsychopsis gen. n. is the fifth representative of the Chinese psychopsids found from the different locality (Huangbanjigou). It is characterized by the undulate wing margin, a unique character state among known Psychopsidae, and the forewing venation that is not typical for this family compared with most other genera of Psychopsidae.

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References

Andersen S (2001) Silky lacewings (Neuroptera: Psychopsidae) from the Eocene-Paleocene transition of Denmark with a review of the fossil record and comments on phylogeny and zoogeography. Insect Systematics & Evolution 32: 419–438. doi: 10.1163/187631201X00290

Archibald SB, Makarkin VN (2006) Tertiary giant lacewings (Neuroptera: Polystoechotidae) revision and description of new taxa from western North America and Denmark. Journal of Systematic Palaeontology 4: 119–155, 307. doi: 10.1017/S1477201906001817

Chen PJ, Wang QF, Zhang HC, Cao MZ, Li WB, Wu SQ (2005) Jianshangou bed of the Yixian Formation in west Liaoning, China. Science in China, Series D (Earth Sciences) 48: 298–312.

Chen SW, Jin CZ, Zhang YP, Zhang LD, Guo SZ (2004) Discussion on the structural-volcanic activities and biological events during the Early Cretaceous in the Sihetun Area, Liaoning Province, China. Tikhookeanskaya Geologiya 23(3): 52–59.

Comstock JH (1918) The wings of insects. Comstock Publishing Company, New York, 430 pp.

Engel MS, Grimaldi DA (2008) Diverse Neuropterida in Cretaceous amber, with particular reference to the paleofauna of Myanmar (Insecta). Nova Supplementa Entomologica 20: 1–86.

Fujiyama I (1978) Some fossil insects from the Tedi Group (Upper Jurassic-Lower Cretaceous), Japan. Bulletin of the National Science Museum. Series C (Geology & paleontology) 4: 181–194.

Handlirsch A (1906–1908) Die fossilen Insekten und die Phylogenie der rezenten Formen. Ein Handbuch für Paläontologen und Zoologen. Wilhelm Engelmann, Leipzig, ix+1430 pp. [Issued in 1906 (pp. 1–640); 1907 (pp. 641–1140); 1908 (pp. 1120–1430)].

Hong YC (1982) Mesozoic fossil insects of Jiuxian basin in Gansu Province. Geological Publishing House, Beijing, 187 pp.

Hong YC (1983) Middle Jurassic fossil insects in North China. Geological Publishing House, Beijing, 223 pp.

Jepson JE, Makarkin VN, Jarzembowski EA (2009) New lacewings (Insecta: Neuroptera) from the Lower Cretaceous Wealden supergroup of Southern England. Cretaceous Research 30: 1325–1338. doi: 10.1016/j.cretres.2009.07.012

Krüger L (1923) Neuroptera succincta baltica. Die im baltischen Bernstein eingeschlossenen Neuropteren des Westpreussischen Provinzial-Museums (heute Museum für Naturkunde und Vorgeschichte) in Danzig. Stettiner Entomologische Zeitung 84: 68–92.

Lambkin KJ (1992) Re-examination of the venation of Osmylopsychops spillerae Tillyard from the Triassic of Queensland. Memoirs of the Queensland Museum 32: 183–188.

MacLeod EG (1970) [1971] The Neuroptera of the Baltic amber. I. Ascalaphidae, Nymphidae, and Psychopsidae. Psyche 77: 147–180.

Makarkin VN (1991) Miocene Neuroptera from the northern Caucasus and the Sikhote-Alin. Paleontologicheskii Zhurnal, 1991(1): 57–68. [in Russian]

Makarkin VN (1994) Upper Cretaceous Neuroptera from Russia and Kazakhstan. Annales de la Société entomologique de France 30: 283–292.

Makarkin VN (1997) Fossil Neuroptera of the Lower Cretaceous of Baisa, East Siberia. Part 4: Psychopsidae. Beitrage zur Entomologie, Berlin 47: 489–492.
A new fossil silky lacewing genus (Neuroptera, Psychopsidae) ...

Makarkin VN (2010) New psychopsoid Neuroptera from the Early Cretaceous of Baissa, Transbaikalia. Annales de la Société entomologique de France 46: 254–261.

Makarkin VN, Archibald SB (2003) Family affinity of the genus Palaeopsychops Andersen with description of a new species from the Early Eocene of British Columbia, Canada (Neuroptera: Polystoechotidae). Annals of the Entomological Society of America 96: 171–180. doi: 10.1603/0013-8746(2003)096[0171:FAOTGP]2.0.CO;2

Martins-Neto RG (1997) Neurópteros (Insecta, Planipennia) da Formação Santana (Cretáceo Inferior), Bacia do Araripe, nordeste do Brasil. X - Descrição de novos táxons (Chrysopidae, Babinskaiidae, Myrmeleontidae, Ascalaphidae e Psychopsidae). Revista Universidade de Guarulhos, Série Ciências Exatas e Tecnológicas 2(4): 68–83.

Martins-Neto RG, Rodrigues VZ (2010) New neuropteran insects (Osmylidae, Palaeoleontidae, Araripeneuridae and Psychopsidae) from the Santana Formation, Early Cretaceous NE Brazil. Gaea – Journal of Geoscience 6: 1–8.

Martynova OM (1949) Mesozoic lacewings (Neuroptera) and their bearing on concepts of phylogeny and systematics of the order. Trudy Paleontologicheskogo Instituta 20: 150–170. [in Russian]

Martynova OM (1954) Neuropterous insects from the Cretaceous deposits of Siberia. Doklady Akademii Nauk SSSR 94: 1167–1169 (in Russian).

New TR (1988) The Psychopsidae (Insecta: Neuroptera) of Australia and the Oriental Region. Invertebrate Systematics 2: 841–883. doi: 10.1071/IT9880841

New TR (1989) Planipennia, Lacewings. In: Fischer M (Ed) Handbuch der Zoologie. Band IV. Arthropoda: Insecta. Part 30. Walter de Gruyter, Berlin, 132 pp.

Oswald JD (1993a) Phylogeny, taxonomy, and biogeography of extant silky lacewings (Insecta: Neuroptera: Psychopsidae). Memoirs of the American Entomological Society 40: 1–65.

Oswald JD (1993b) Revision and cladistic analysis of the world genera of the family Hemerobiidae (Insecta: Neuroptera). Journal of the New York Entomological Society 101: 143–299.

Oswald JD (1995) Revision of the southeast Asian silky lacewing genus Balmes (Neuroptera: Psychopsidae). Tijdschrift voor Entomologie 138: 89–102.

Panfilov DV (1980) New representatives of Neuroptera from the Jurassic of Karatau. In: Dolin VG, Panfilov DV, Ponomarenko AG, Pritykina LN. Iskopaemye nasekomye mezozoic [Fossil Insects of Mesozoic]. Naukova Dumka, Kiev, 82–111. [in Russian]

Peng YY, Makarkin VN, Yang Q, Ren D (2010) A new silky lacewing (Neuroptera: Psychopsidae) from the Middle Jurassic of Inner Mongolia, China. Zootaxa 2663: 59–67.

Shcherbakov DE (2008) Madygen, Triassic Lagerstätte number one, before and after Sharov. Alavesia 2: 113–124.

Swisher CCIII, Wang YQ, Wang XL, Xu X, Wang Y (1999) Cretaceous age for the feathered dinosaurs of Liaoning, China. Nature 400: 58–61. doi: 10.1038/21872

Tillyard RJ (1919) Mesozoic insects of Queensland. No. 5. Mecoptera, the new order Paratrichoptera, and additions to Planipennia. Proceedings of the Linnean Society of New South Wales 44: 194–212.

Tillyard RJ (1922) Mesozoic insects of Queensland. No. 9. Orthoptera, and additions to the Protorthoptera, Odonata, Hemiptera and Planipennia. Proceedings of the Linnean Society of New South Wales 47: 447–470.
Wang SS, Hu HG, Li PX, Wang YQ (2001a) Further discussion on geologic age of Sihetun vertebrate assemblage in western Liaoning, China: Evidence from Ar-Ar dating. Acta Petrologica Sinica 17: 663–668 [in Chinese, English abstract]

Wang SS, Wang YQ, Hu HG, Li HM (2001b) The existing time of Sihetun vertebrate in western Liaoning, China: evidence from U-Pb dating of zircon. Chinese Science Bulletin 46: 779–782. doi: 10.1007/BF03187222

Wang WL (1980) Phylum Arthropoda. In: Paleontological atlas of northeast China. Vol. 2. Mesozoic and Caenozoic. Geological publishing House, Peking, i-xiv, 1–403. [in Chinese]

Wang XL, Bao R (2006) A taxonomic study on the genus Balmes Navás from China (Neuroptera, Psychopsidae). Acta Zootaxonomica Sinica 31: 846–850.

Wootton RJ (2003) Wings. In: Resh VH, Carde RT (Eds) Encyclopedia of Insects. Academic Press, London, 1186–1192.

Yang W, Li SG, Jiang BY (2007) New evidence for Cretaceous age of the feathered dinosaurs of Liaoning: zircon U-Pb SHRIMP dating of the Yixian Formation in Sihetun, northeast China. Cretaceous Research 28: 177–182. doi: 10.1016/j.cretres.2006.05.011

Zalesky GM (1953) New localities of Cretaceous insects in the Volga region, Kazakhstan and Transbaikalia. Doklady Akademii Nauk SSSR 89: 163–166. [in Russian]