The first liupanshaniid hawker dragonfly from the ‘African’ Cretaceous Paleocontinent

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Abstract. Xxxx

Key words. Insecta; Odonata; Aeshnoptera, gen. et sp. nov.; Cenomanian; Lebanon.

1. Introduction

Xxxx

2. Outcrop, material and methods

2.1. Outcrop

Xxxx

2.2. Materials and methods

The fossil was examined and measured using an incident light stereomicroscope under normal and ultraviolet lights (xxxx). Photographs were taken using a xxxx. Optical instruments were equipped by camera lucida and digital cameras. The raw digital images were processed with focus stacking software, and figure plates prepared with Adobe Photoshop™.

The nomenclature of the odonatan wing venation used in this paper is based on the interpretations of Riek & Kukalova-Peck (1984), as modified by Nel et al. (1993) and Bechly (1996). The higher classification of fossil and extant Aeshnoptera follows Bechly et al.

(2001). Wing abbreviations are as follows: CuA, cubitus anterior; IR1, intercalary radial veins; MA, median anterior; MP, median posterior; N, nodus; Pt, pterostigma; RA, radius anterior; RP, radius posterior; Sn, subnodal crossvein. All measurements are given in mm.

3. Systematic palaeontology

Odonata Fabricius, 1793

Anisoptera Selys in Selys and Hagen, 1954

Aeshnoptera Bechly, 1996

Liupanshaniidae Bechly et al., 2001

Type genus. *Liupanshania* Hong, 1982 (China, Aptian to mid Albian, 125.45 to 112.6 Ma, after Fossilworks, Paleobiology Database)

Other genera. *Protoliupanshania* Huang and Nel, 2010 (China, Aptian, 125 Ma), *Guyuanaeschnidia* Lin, 1982 (China, Aptian to mid Albian), *Araripeliupanshania* Bechly et al. 2001 (Brazil, Aptian to mid Albian, 122 to 112 Ma), *Paramesuropetala* Bechly et al., 2001 (Brazil, Aptian to mid Albian), *Lebanoliupanshania* gen. nov. (Lebanon, Cenomanian), *Galloliupanshania* Nel et al., 2015 (France, Cenomanian), and *Paraliupanshania* Bechly et al., 2001 (Southern Kazakhstan, Turonian).

New genus *Lebanoliupanshania* gen. nov.

Type species: *Lebanoliupanshania magnifica* sp. nov.

Etymology. Named after Lebanon and *Liupanshania*.

Diagnosis. Wing characters only. Rspl and Mspl present but zigzagged; only two rows of cells between Rspl and IR2; a strong secondary longitudinal vein branching posteriorly from IR2; submedian space of forewing with several crossveins, while that of hindwing is free; a strong trigonal planate in hindwing; pterostigmata covering only four cells; anterior side of hindwing discoidal triangle ending at triangle apical angle; Mab strongly angled and curved; presence of a supplementary posterior branch of AA between anal triangle and anal loop in hindwing; anal loop posteriorly closed.

Lebanoliupanshania magnifica sp. nov.

(Figs. Xxxx)

Material. Holotype specimen xxxx, stored in xxxx (a nearly complete fossil, with only legs, apical part of a forewing, and apical part of abdomen missing.

Age and outcrop. Cenomanian, Xxxx, Lebanon.

Description. Head poorly preserved, probably visible from below, mm long, mm wide.

Thorax large, but apparently narrower than head (possible deformation due to compression), mm long, mm wide.

Wings hyaline; pterostigmata sclerotized, brown. Forewing. Length mm ; width at nodus mm; distance from base to arculus mm; distance from base to nodus mm; from nodus to pterostigma mm; pterostigma rather short (length mm; width mm) , covering four cells, and braced by a weakly oblique crossvein that is aligned with its basal side; pterostigma not in a basal position; 19 postnodal crossveins, not aliged with corresponding postsubnodal crossveins; 26 secondary antenodal crossveins between costal margin and ScP, well aligned with antenodal crossveins of second row; primary antenodal crossvein Ax1 stronger than secondry antenodals, but Ax2 not well distinct from these; Ax1 just basal of arculus; six secondary antenodals between Ax1 and Ax2; basal brace Ax0 visible; 18 antesubnodal crossveins between arculus and subnod s without any gap immediately basal of subnodus; RP and MA distinctly separated at angled arculus; three bridge-crossveins Bqs basal of subnodus; base of RP2 aligned with subnodus; nodus of normal anisopteran-type; only a single oblique vein ‘O’, one cell distal of subnodus; IR2 originating mm and RP3/4 (midfork) mm basal of subnodus; a concave, but zigzagged Rspl, not curved, with two rows of cells between it and IR2; a strong and convex secondary longitudinal vein looking like a posterior branch of IR2 three cells basal of base of Rspl; RP2 and IR2 parallel with only a single row of cells in-between, except two rows of cells near posterior wing margin; RP2 distinctly undulated on a level with pterostigma; pseudo-IR1 very weak; RP1 and RP2 closely parallel up to pterostigma (even converging near pterostigma) with only a single row of cells in-between, but below pterostigma they become strongly divergent with two or more rows of cells in-between. RP3/4 and MA parallel and weakly undulated with a single row of cells in-between (two rows near the posterior wing margin). A concave, but strongly zigzagged Mspl with one row of cells between it and MA. Postdiscoidal area distinctly widened distally (width near discoidal triangle mm; width at posterior wing margin mm) with three rows of cells immediately distal of discoidal triangle; hypertriangle free of crossveins (length mm ; max. width mm); discoidal triangle equilateral, large, and divided into four cells; length of anterior side mm; of basal side mm; of distal side MAb mm; MAb straight, without a distinct convex secondary vein (trigonal planate) originating on it; Mmedian space free of crossveins; submedian space traversed by several crossveins plus CuP-crossing; AA divided into a strong and oblique secondary anterior branch PsA and a posterior main branch AAa, delimiting a well-defined three-celled subdiscoidal triangle, max. mm long and basally mm wide (= length of PsA); PsA slightly curved and ends at basal angle of discoidal triangle; a single row of cells in area between MP and CuA; MP reaching posterior wing margin on a level with nodus; CuA reaching posterior wing margin somewhat basal of level of nodus; six weak posterior branches of CuA; max. width of cubito-anal area mm with max. five rows of cells between CuA and posterior wing margin; anal area ma x. mm wide (below PsA) with two rows of large cells between AA and posterior wing margin.

Hindwing. Length mm; width at nodus mm; distance from base to arculus mm; distance from base to nodus mm; from nodus to pterostigma mm; pterostigma elongated, covering four small cells (length mm; max. width mm); pterostigmal brace not oblique , aligned with basal side of pterostigma; 18 postnodal crossveins between nodus and pterostigma, not aligned with the 16 corresponding postsubnodal crossveins; 16 secondary antenodal crossveins between costal margin and ScP, not aligned with the second row of secondary antenodal crossveins between ScP and RA; primary antenodal crossveins aligned and distinctly stronger with about four or five secondary antenodal crossveins in-between; Ax1 slightly basal to arculus, and Ax2 two cells basal to distal angle of discoidal triangle; basal brace Ax0 visible; numerous antesubnodal crossveins in area between arculus and subnodus without any gap near subnodus; arculus weakly angled; bases of RP and MA shortly separated at arculus; three bridge-crossveins Bqs basal of subnodus; base of RP2 aligned with subnodus; only a single oblique vein 'O', one cell distal of subnodus; Rspl well-defined and straight with two rows of cells between it and IR2; a strong and convex secondary longitudinal vein looking like a posterior branch of IR2 three cells basal of base of Rspl; RP2 and IR2 more or less parallel with only a single row of cells in-between up to the level of pterostigma, but more distally three rows of small cells between these veins; IR2 and RP2 both strongly curved on a level with pterostigma, and RP2 even slightly undulated in this area; RP1 and RP2 are basally closely parallel (even converging near pterostigma) with only a single row of cells in-between up to pterostigmal brace vein, but more distally they become strongly divergent with two or more rows of cells in-between; pseudo-IRI weak; RP3/4 and MA are parallel and only weakly undulated with a single row of cells in-between, except between their strongly curved distal parts (two rows of cells); Mspl less well-defined than Rspl, zigzagged but with a general direction straight and parallel to MAa with one row of cells between it and MA; MA and MP strongly divergent; postdiscoidal area therefore distally widened, two rows of cells in basal part of postdiscoidal area, but with about 24 small cells along posterior wing margin; four convex secondary longitudinal veins (intercalaries) in distal part of postdiscoidal area; very strong convex secondary longitudinal vein (trigonal planate), originating at strongly pronounced angle of distal side MAb of discoidal triangle and distally becoming more indistinct and zigzagged, finally ending on MP; one row of cells between trigonal planate and MA, and one row of cells between it and MP; hypertriangle free of crossveins; discoidal triangle very long, narrow and divided into four cells by parallel crossveins; length of anterior side mm; of basal side mm; of distal side, mm; anterior side of discoidal triangle apically curved and ending at distal angle of discoidal triangle; MAb with a very peculiar structure, viz its basal part very concave, its distal angle very pronounced, and part distal of angle straight; median space free of crossveins; submedian space only traversed by CuP-crossing; PsA reduced to an oblique weak cubito-anal crossvein ending on basal side of discoidal triangle; subdiscoidal triangle indistinct, very small and unicellular. MP and CuA running parallel with a single row of cells in-between, except near posterior wing margin (two rows of cells); MP and CuA reaching posterior wing margin on a level with nodus; subdiscoidal veinlet reduced, and gaff very short; CuAa with five well-defined posterior branches; CuAb well-defined and basally curved towards wing base; cubito-anal area max. mm wide with up to six rows of cells between CuAa and posterior wing margin; anal area broad (max. width mm) with up to six rows of cells between AA and posterior wing margin; anal loop posteriorly closed, well-defined; AA with two posterior branches; anal margin angular with a rather weak anal angle but a clear anal triangle, thus, it is a male specimen.

Abdomen. Preserved part mm long; eight segments preserved; male secondary genital appendages visible on second segment; a strong constriction of segment 3.

Discussion. This fossil has all the synapomorphies of the aeshnopteran family Liupanshaniidae (Bechly et al., 2001), viz. unique shape of the very elongate and narrow hindwing discoidal triangle (anterior side of discoidal triangle distally curved and ending on the anterior side MA of hypertriangle; Mab strongly sigmoidally curved, with a very concave basal part and a strong angle in the distal part); hindwing discoidal triangle divided into several (at least three) cells by parallel crossveins; forewing discoidal triangle divided into three cells; both pairs of wings (but especially hindwing) with a strong convex secondary longitudinal vein (trigonal planate) in postdiscoidal area, originating at angle of MAb; distal accessory oblique vein between RP2 and IR2 secondarily absent.

The character 'presence of a strong, well-defined secondary vein looking like a posterior branch of IR2 basal of Rspl' is quite rare among liupanshaniids, only present in *Araripeliupanshania*, and absent in *Guyuanaeschnidia*, *Liupanshania*, *Paramesuropetala*, *Paraliupanshania*, *Galloliupanshania*, and *Protoliupanshania* (Lin, 1982; Hong, 1982; Bechly et al., 2001; Lin et al., 2002; Huang and Nel, 2010; Nel et al., 2015). Other differences with these genera are as follows: *Paramesuropetala* has a posteriorly opened anal loop and no supplementary crossvein in submedian area (Bechly, 2007); *Guyuanaeschnidia* has a weaker Rspl; *Protoliupanshania* and *Galloliupanshania* have a less distinctly curved and angled hindwing MAb; *Paraliupanshania* has a clearly more distinct Rspl with much more rows of cells between it and IR2, much more postnodal crossveins, a posteriorly opened anal loop, and a longer pterostigma; *Liupanshania* has a weaker Rspl, two rows of cells between trigonal planate and MAa close to discoidal triangle, and a longer pterostigma.

Difference between xxxx and *Araripeliupanshania annesusae* Bechly et al., 2001 are as follows: anterior margin of hindwing discoidal triangle ending at distal angle of triangle and not on MA; presence of a supplementary posterior branch of AA between anal triangle and anal loop in hindwing; forewing postdiscoidal areas much broader; presence of four crossveins (incl. CuP) in forewing submedian area. This last character is the main difference with this genus.Unfortunately, the submedian area is only known in *Araripeliupanshania* and

Paramesuropetala. Generally in extant Aeshnoptera, if there are numerous crossveins in the forewing submedian space, the situation is the same in the hindwing. Thus the special situation in xxxx is also quite rare.

This new Lebanese fossil can be considered as a new genus and species, probably sister group of *Araripeliupanshania* for the shared special vein that 'forks' from IR2.

The present discovery confirms that the Liupanshaniidae were present on the 'Eurasian' (including Europe), 'South American', but also 'African' Cretaceous paleo-continents. This family remains unknown in Antarctica, Australia, and North American paleo-continents. Together with the Rudiaeschnidae Bechly et al., 2001, Gomphaeschnidae Tillyard and Fraser, 1940, Burmaeshnidae Huang et al., 2017 and Enigmaeshnidae Nel et al., 2008 (Bechly et al., 2001; Nel et al., 2008; Huang et al., 2017a,b), it is one of the aeshnopteran families that diversified between the Earliest Cretaceous and the Turonian. Among them, only the Gomphaeschnidae went through the Late Cretaceous, while the oldest fossil record of the extant Aeshnidae is Cenozoic. These Odonata were probably affected by the mid-Cretaceous lacustrine revolution between the Albian and the Turonian (Buatois, 2016). It appears that the changes in the odonatan faunas were very progressive as many 'ancient' clades survived till the Turonian (Nel et al., 2015), while the 'modern' Libellulidae have their oldest record in the Lebanese Cenomanian.

Acknowledgements. xxxx

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Figures

Fig. 1. *Lebanoliupanshania magnifica* gen. et sp. nov., holotype xxxx. Photograph of general habitus (scale bar represents xxxx mm).

Fig. 2. *Lebanoliupanshania magnifica* gen. et sp. nov., holotype xxxx. Photograph under ultraviolet light (scale bar represents xxxx mm).

Fig. 3. *Lebanoliupanshania magnifica* gen. et sp. nov., holotype xxxx. Reconstruction of fore- and hindwing (scale bar represents xxxx mm).