American Journal of Bioscience and Bioengineering
2018; 6(2): 6-13
http://www.sciencepublishinggroup.com/j/bio
doi: 10.11648/j.bio.20180602.11
ISSN: 2328-5885 (Print); ISSN: 2328-5893 (Online)

Diversity and Distribution of the Genus *Platypeltoides* (Nileidae) in Morocco

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To cite this article:
Joan Corbacho, Francisco J. López-Soriano, Ulrich Lemke, Scott Morrison, Keith Hammond. Diversity and Distribution of the Genus *Platypeltoides* (Nileidae) in Morocco. *American Journal of Bioscience and Bioengineering*. Vol. 6, No. 2, 2018, pp. 6-13.
doi: 10.11648/j.bio.20180602.11

Received: August 13, 2018; **Accepted**: September 5, 2018; **Published**: October 13, 2018

Abstract: Recently two new species of the genus *Platypeltoides* (Nileidae, Trilobita) from the Anti-Atlas region of Morocco have been described. Because new material is still appearing in this area, we have considered to review this subject. The aim of this article is to describe all the species of the genus *Platypeltoides* appeared in the Lower Fezouata Formation (Tremadocian, Lower Ordovician) and distributed in three different locations of the Moroccan Anti-Atlas. Several specimens of this genus and kept in the Museo Geológico del Seminario (Barcelona, Spain), Museo Geominero (Madrid, Spain) and the Natural History Museum (London, UK) are here described and discussed. In this paper, all known species of the *Platypeltoides* genus of Morocco are presented. All them appear in the Zagora region and in the Guelmim area. Three species have already been described: *P. magrebiensis*?, *P. hammondi* and *P. carmenae*. We left two more in open nomenclature, *Platypeltoides* aff. *carmenae* and *Platypeltoides* sp. Finally, another species changes its genus: *Asaphellus cuervoae* = *Platypeltoides cuervoae*. Indeed, four species (but possibly two more) of the genus *Platypeltoides* are present in the Lower Ordovician of Morocco.

Keywords: Trilobita, *Platypeltoides*, Palaeozoic, Tremadocian, Morocco

1. Introduction

In the last two years, we have described two new species of *Platypeltoides* from the Lower Ordovician (Tremadocian) of the Fezouata Shale of Morocco: *P. hammondi* Corbacho & López-Soriano, 2016 [1] and *P. carmenae* Corbacho *et al*., 2017 [2]. After obtaining two new species, we have decided to write this article, which is a part of the project that, since 2005, we have been developing on the study of the trilobites of the Ordovician of Morocco, supported by the Museo Geológico del Seminario de Barcelona (Spain) and the Department of Paleontology of the Associació de Perits i Taxadors de Catalunya (Spain), founded by one of the autors (JC).

Historical Background

The first geological research done in Morocco was carried out by the French geologist Henri Coquand (1813-1881), who collected and described the first fossils [3]. The presence of Ordovician rocks in the Anti-Atlas zone was firstly mentioned by Neltner [4], specifically in the Tafilalt area. Similarly, it was established the existence of the Ordovician system both in the western (Jbel Tachilla, Tiznit area [5]) and central Anti-Atlas (Foum Zguid area; Bondon in [6]).

A long list of authors have studied the trilobite faunas from the Upper and Middle Ordovician of Morocco: Barthoux [7], Termier [6, 8], Neltner [4], Roch [9], Destombes [10-13], Destombes *et al.* [14] and Rábano [15], and more recently Vela and Corbacho [16], Corbacho [17], Corbacho and Kier [18], López-Soriano and Corbacho [19], Corbacho and López-Soriano [20], Corbacho and Calzada [21], Corbacho *et al.* [2, 22], and Fortey and Edgecombe [23]. On the other hand, the studies on the trilobites from the Lower Ordovician of Morocco have been carried out by Pruvost (in [24]), Termier and Termier [25], Hupé (in [26]), Destombes [12, 13,

27-35], Destombes *et al.* [14], Rábano [15], Vidal [36-38], Vela [39], Vela and Corbacho [40], Corbacho [41], Fortey [42-44], Corbacho and Vela [45-47], Corbacho and López-Soriano [1, 48], and Corbacho *et al.* [2]. See also Basse [49] and Lemke [50] for the described species.

The described species of the genus *Platypeltoides* in Morocco are: *Platypeltoides magrebiensis*? Rábano, 1990; *Platypeltoides cuervoae* (Corbacho & López-Soriano, 2012); *Platypeltoides hammondi* Corbacho & López-Soriano, 2016; and *Platypeltoides carmenae* Corbacho *et al.* 2017.

2. Materials and Methods

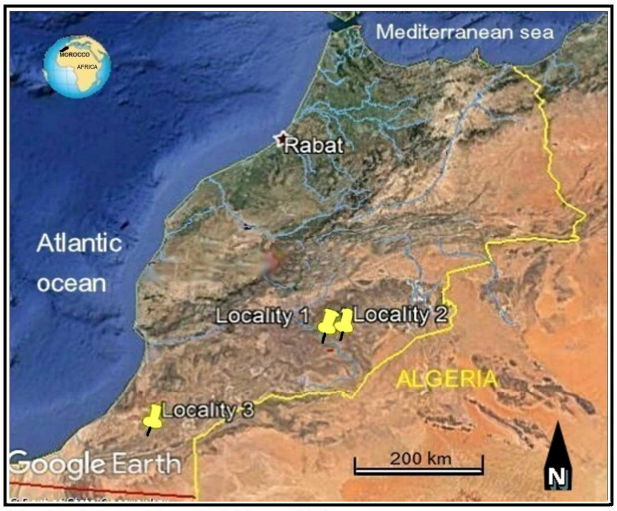
2.1. Origin of the Specimens

The specimens examined in this study originate from Anti-Atlas, Morocco and belong to the Lower Ordovician (Tremadocian), Lower Fezouata Formation. All the sites mentioned in this study have been visited by the first author (JC). The images of the holotypes of the different species from the cited publications are presented. *Platypeltoides magrebiensis*? is also represented by the paratype (MGM902X) conserved in the Museo Geominero of Madrid (Spain) and an authentic specimen (MGSB-JC224) conserved in the Museo Geológico del Seminario of Barcelona (Spain) and *P. cuervoae* two paratypes are also presented (MGSB-JC76 and MGSB-JC77) conserved in the Museo Geológico del Seminario of Barcelona (Spain) and one (NHMUK-it28945) conserved in the Natural History Museum of London (UK).

2.2. Preparation and Treatment of Specimens

All the specimens presented in this study, except the holotype and paratype of *P. magrebiensis*, have been obtained and worked by Moroccan specialists for the first author (JC).

All specimens, except *P. magrebiensis*?, have been treated with ammonium chloride to highlight their details (the quality of the figures of *P. magrebiensis*? has been improved through the PhotoScape software). A Canon digital camera, model EOS 1100 D, has been used to take the pictures. For the coordinates, a Garmin GPS Foretrex 401 model has been used.



System	Series	Stages	Groups	Formations
Ordovician	Middle	Darriwilian	Outer Feijas	Tachilla
	Lower	Floian		Zini / Upper Fezouata
		Tremado-cian		Lower Fezouata *

Figure 1. *Map of Morocco and Stratigraphy of Lower Ordovician from the Anti-Atlas. The number on white circles indicate the localities: (1)* Platypeltoides magrebiensis?*,* P. hammondi*; (2)* Platypeltoides *sp. and* Platypeltoides *aff. carmenae; (3)* P. carmenae *and* P. cuervoae*.*

Table 1. *Measurements (mm) of the different species of* Platypeltoides *from Morocco.*

Platypeltoides magrebiensis?

Specimen number	TL	EL	CL	DEC	CW	CW1	GW	FWG	PW	RW	RL	PL
MGM901X	53	8	20	6	33	24	13	18	27	9	14	17
MGM902X	277	24	98	27	152	122	41	52	130	44	64	88
MGSB-JC224	235	21	78	17	120	90	50	70	130	34	60	70

Platypeltoides hammondi

Specimen number	TL	EL	CL	DEC	CW	CW1	GW	FWG	PW	RW	RL	PL
MGSB-82122	165	17	50	20	129	80	37	50	74	24	42	54

Platypeltoides carmenae

Specimen number	TL	EL	CL	DEC	CW	CW1	GW	FGW	PW	RW	RL	PL
NHMUK-it29220	220	25	94	22	180	112	50	76	124	33	50	66

Platypeltoides cuervoae

Specimen number	TL	EL	CL	DEC	CW	CW1	GW	FWG	PW	RW	RL	PL
NHMUK-it28944	125	16	44	16	210	68	30	44	76	24	X	X
NHMUK-it28945	115	13	37	15	210	62	28	42	69	17	32	39

Platypeltoides aff. carmenae

Specimen number	TL	EL	CL	DEC	CW	CW1	GW	FWG	PW	RW	RL	PL
MGSB-KH2b	155	15	57	19	138	84	34	50	88	23	40	50

Platypeltoides sp.

Specimen number	TL	EL	CL	DEC	CW	CW1	GW	FWG	PW	RW	RL	PL
MGSB-JC561	56	7	21	6	40	26	12	20	30	10	12	18

TL = total exoskeleton length; EL = total eye lenght; CL = total cephalon length; DEC = distance between the posterior eye side and the posterior cephalon side; CW = total cephalon width; CW1 = maximun cranidium width (in posterior margin); GW = basal glabela width; FWG = frontal glabela width in the widest part; PW = máximum pygidium width; RW = anterior width of the pygidial rachis; RL = total length of pygidial rachis; PL = total pygidium length.

3. Systematic Paleontology

The specimens indicated under the entries MGSB are housed in the collections of the Museo Geológico del Seminario de Barcelona (Spain), those indicated under the entries NHMUK are housed in the Natural History Museum of London (UK), and those indicated under the entries MGM are housed in the Museo Geominero de Madrid (Spain).

Order ASAPHIDA Salter, 1864

Suborder ASAPHINA Salter, 1864 emend.

Fortey & Chatterton, 1988

Superfamily CYCLOPYGOIDEA Raymond, 1925

Family NILEIDAE Angelin, 1854

Genus *Platypeltoides* Pribyl in Prantl & Pribyl, 1949

Type species - *Platypeltis croftii* Callaway, 1877 from the Tremadocian of Shropshire (England, UK).

Geographical and stratigraphical distribution - The genus *Platypeltoides* is found in the Upper Cambrian, Tremadocian and Floian of Morocco, United Kingdom, Czech Republic, Sweden, Russia, Kazakhstan, China and Mauritania.

The oldest known species is *Platypeltoides marginatus* Appolonov & Chugaeva, 1983 from the Upper Cambrian of Kazakhstan. *Platypeltoides serus* Tjernvik, 1956 from Hunnenberg in Sweden has an early Arenig age because of the occurrence with *Ekeraspis armata* and is the youngest membre of this genus. Furthermore, *Platypeltoides* sp. is reported from the Arenig of Mauritania [51, 52]. Most species are from the Tremadoc. Outside of Morocco, the following species are known:

Platypeltoides brevis (nomen nudum?) – Shineton Shales, Garmston, Shropshire, UK

Platypeltoides croftii (Callaway, 1877) – Shineton Shales, Shropshire, UK

Platypeltoides perseis Mergl, 2006 – Millina Formation, Olesna, Bohemia, Czech Rep.

Platypeltoides primaevus (Lake, 1942) – Tynllan Beds, Porthmadog, Wales, UK

Platypeltoides sibirica Ogienko, 1992 – Siberian Plattform, Russia

Platypeltoides uralicus Antsygin, 2001 – South Ural, Russia

Platypeltoides sp. Mergl, 2006 – Trenice Formation, Holoubkov, Czech Republic

The assignament of the fragmentary cranidium to *Platypeltoides*, described by Peng, Geyer & Hamadi [53] at the Mila Formation (Elbur's Mountains, Iran) is not certain. *Platypeltoides* has seven thoracic segments whereas *Troedssonia* has eight. Most of the species from China assigned to *Platypeltoides* belongs therefore to *Troedssonia*.

3.1. Platypeltoides magrebiensis Rábano, 1990

1969 *Platypeltoides* Destombes *et al.*, pag. 152, plate 5, figure 1; plate 4, figure 14

1990 *Platypeltoides magrebiensis* Rábano, pag. 23, figure 1

2016 *Platypeltoides magrebiensis*? Corbacho & López-Soriano, pag. 15, plate 2

Diagnosis – This species of the genus *Platypeltoides* is characterized by its large size, moderate relief, absence of a frontal border and a glabellar tubercle on the cephalon, and because it presents large eyes in the juvenile holaspis. The pygidium is smooth, showing only a poorly defined axial ring and a wide pygidial doublure, whose internal line develops in parallel to the pygidial margin [15].

Material – Three specimens are presented. The holotype nº MGM901X (holaspis) has a total carapace length of 53 mm and the paratype nº MGM902X (false specimen) has a total carapace length of 277 mm; they were used for the description of the species and are kept in the Museo Geominero de Madrid (Spain) [15]. The third specimen, with a total carapace length of 235 mm, belongs to the collection of Joan Corbacho kept in Museo Geológico del Seminario de Barcelona (Spain) under the entry MGSB-JC224 (authentic specimen).

Geographical distribution – Upper part of the Lower Fezouata Formation. The studied locality exposes blue green argillites from the Upper Tremadocian, Lower Ordovician (Figure 1, locality nº1). The locality yielding the new trilobite is located approximately 32 km of the SE of Agdz and 14 km of the south of Tansikht, Dra Valley, Morocco. The coordinates of the excavation were 30º 33' 58" N - 6º 9' 55" W - Altitude 860 m.

The following trilobite species also appear in this outcrop: *Platypeltoides magrebiensis*? Rábano, 1990; *Asaphellus stubssi* Fortey, 2009; *Dikelokephalina brenchleyi* Fortey, 2010; *Hungioides* sp.; *Platypeltoides hammondi* Corbacho & López-Soriano, 2016; and A*saphellus* sp.

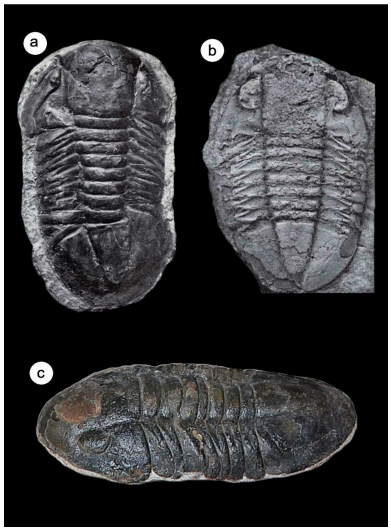


Figure 2. Platypeltoides magrebiensis*? Outcrop n° 1, Tansikht, Dra Valley. (a) Paratype n° MGM902X and (b) Holotype n° MGM901X (pictures taken from [15]; (c) Topotype n° MGSB-JC224.*

3.2. Platypeltoides hammondi Corbacho & López-Soriano, 2016

2016 *Platypeltoides hammondi* Corbacho & López-Soriano, pag. 13, plate 1

Diagnosis – Large-sized *Platypeltoides* with long genal spines, large eyes located slightly before of the transversal medium line of the cranidium and a completely smooth pygidium [1].

Material – Only a single individual (holotype) is presented. This is a moderately well-preserved individual which is kept in the collections of the Museo Geológico del Seminario de Barcelona (Spain), under the entry MGSB82122. Its total carapace length is 165 mm.

Geographical distribution – Upper part of the Lower Fezouata Formation. The studied locality exposes blue green argillites from the Upper Tremadocian. The locality yielding the trilobite is located approximately 32 km of the SE of Agdz and 14 km of the south of Tansikht, Dra Valley, Morocco (Figure 1, locality nº1). The coordinates of the excavation were 30º 33' 58" N - 6º 9' 55" W - Altitude 860 m.

The following trilobite species also appear in this outcrop: *Platypeltoides magrebiensis*? Rábano, 1990; *Asaphellus stubssi* Fortey, 2009; *Dikelokephalina brenchleyi* Fortey, 2010; *Hungioides* sp.; *Platypeltoides hammondi* Corbacho & López-Soriano, 2016; and A*saphellus* sp.

Figure 3. Platypeltoides hammondi*. Outcrop n° 1, Tansikht, Dra Valley. Holotype n° MGSB82122. Picture taken from [1].*

3.3. Platypeltoides carmenae Corbacho *et al.*, 2017

2017 *Platypeltoides carmenae* Corbacho *et al.*, pag. 21, plates 1 – 4

Diagnosis – *Platypeltoides* of large size, with a slightly subtriangular-shaped cephalon and medium-sized genal spines, large eyes located in the transverse median line of the cranidium, a thin anterior border and a slightly subtriangular pygidium with three axial rings and a terminal axial piece [2].

Material – Only a single individual (holotype) is presented. Total carapace length of 220 mm, is kept in the collections of the Natural History Museum of London (UK), under the entry NHMUK-it29220.

Geographical distribution – The studied locality consists of grey-blue ferruginous sandstones which have been assigned to the Upper part of the Lower Fezouata Formation, Lower Ordovician (Upper part of Tremadocian). The studied site is located approximately 710 km of the SW of Rabat, in the administrative area of Agadir and NW of Assa in Guelmim area; Western Anti-Atlas, Morocco (Figure 1, locality nº 3). The coordinates of the site are N 28º 43’ 31’’ and W 009º 36’ 31’’ - Altitude 689 m.

The following trilobite species also appear in this outcrop: *Lehua tahirii* Corbacho, 2008; *Lehua* sp. and *Megistaspis* (*E.*) *hammondi forteyi* Corbacho & Vela, 2010; *Platypeltoides cuervoae* (Corbacho & López-Soriano, 2012); and *Parabathycheilus gallicus* Dean, 1965.

Figure 4. Platypeltoides carmenae*. Outcrop n° 3, NW de Assa in Guelmim area. Holotype n° NHMUK It 29220. Picture taken from [2].*

*3.4. Platypeltoides cuervoae (*Corbacho & López-Soriano, 2012*)*

2012 – *Asaphellus cuervoae* Corbacho & López-Soriano, pag. 4, plates 1 - 3

2014 – *Asaphellus cuervoae* Corbacho & Calzada, pag. 22, plate 1

2018 - *Asaphellus cuervoae* Lebrun [54], pag. 83, fig. D

Diagnosis – *Platypeltoides* species of medium size, characterized by large eyes (approximately 30% of the glabellar length), with long and wide genal spines extending perpendicularly from the cephalon and making a 90º angle with the axis (sag.); the spines slightly towards their terminal

part. The other characteristics are typical of the genus *Platypeltoides.*

Material – Four specimens are presented. The holotype, with a length of 125 mm, is kept in the Natural History Museum of London (UK) under the annotation NHMUK-it28944. A paratype, with a length of 115 mm, is kept in the Natural History Museum of London (UK) under the annotation NHMUK-it28945. Two additional paratypes, with a total length of 120 mm and 95 mm, are kept in the collection of Joan Corbacho in the Museo Geológico del Seminario de Barcelona (Spain), under the annotations MGSB-JC76 and MGSB-JC77 respectively.

Geographical distribution – The studied locality consists of grey-blue ferruginous sandstones which have been assigned to the Upper part of the Lower Fezouata Formation, Lower Ordovician (Upper part of Tremadocian). The studied site is located approximately 710 km of the SW of Rabat, in the administrative area of Agadir and NW of Assa in Guelmim area; Western Anti-Atlas, Morocco (Figure 1, locality nº 3). The coordinates of the site are N 28º 43' 31'' and W 009º 36' 31'' - Altitude 689 m.

The following trilobite species also appear in this outcrop: *Lehua tahirii* Corbacho, 2008; *Lehua* sp. and *Megistaspis* (*E.*) *hammondi forteyi* Corbacho & Vela, 2010; *Platypeltoides carmenae* Corbacho *et al.* 2017; and *Parabathycheilus gallicus* Dean, 1965.

Discussion – When this species was first described, the extremely long genal spines and other particular characteristics caused us to underestimate the importance of the number of segments, and for this reason it was assigned to the genus *Asaphellus*. With the study of new complete and well-preserved specimens, it has been proven that they only have 7 thoracic segments, so they should be assigned to the genus *Platypeltoides*.

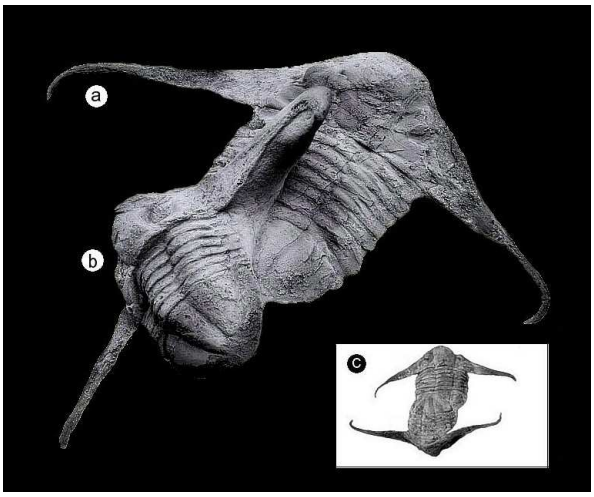


Figure 5. Platypeltoides cuervoae*. Outcrop nº 3, NW de Assa in Guelmim area. (a) paratype nº MGSB-JC76, (b) paratype nº MGSB-JC77, (c) holotype nº NHMUK-it28944 and paratype nº NHMUK-it28945. Picture taken from [48].*

3.5. Platypeltoides aff. carmenae Corbacho *et al.,* 2017

2017 *Platypeltoides* aff. *carmenae* Corbacho *et al*., pag. 21

Diagnosis – *Platypeltoides* of large size, with a slightly subtriangular-shaped cephalon and medium-sized genal spines, large eyes located in the transverse median line of the cranidium, a narrow border and a subtriangular pygidium with three axial rings and a terminal axial piece [2].

Material – A single specimen with a total carapace length of 155 mm is included. It is kept in the collection of Keith Hammond in the Museo Geológico del Seminario de Barcelona (Spain), under the annotation MGSB-KH2b.

Geographical distribution - Upper part of the Lower Fezouata Formation. The studied locality exposes blue green argillites from the Upper Tremadocian. The locality yielding the new trilobite is located approximately 21 km al N de Zagora, Dra Valley, Morocco (Figure 1, locality nº2). The coordinates of the site are N 30º30'54'' – W 5º45'24'' - Altitude 804 m.

The following trilobite species also appear in this outcrop: See figure 6.

Discusion – Because only one specimen is available, it is left in open nomenclature.

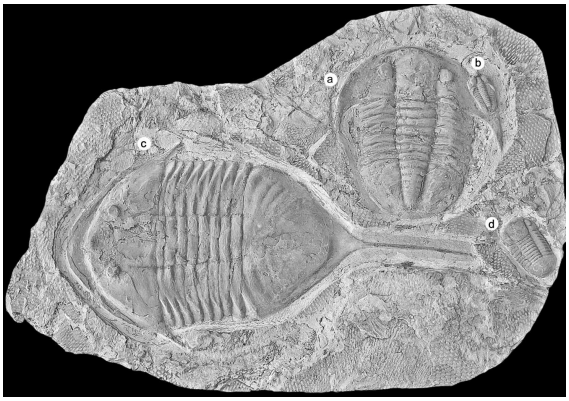


Figure 6. *(a)* Platypeltoides *aff.* carmenae*. Outcrop nº 2, North of Zagora, Dra Valley, nº MGSB-KH2a; (b)* Parathycheilus gallicus *Dean, 1965 nº MGSB-KH2b; (c)* Megistaspis (E.) hammondi *nº MGSB-KH2c and (d)* Symphysurus angustatus *Boeck, 1838 nº MGSB-KH2d.*

3.6. Platypeltoides sp.

Material – A single specimen with a total carapace length of 56 mm is included. It is kept in the collection of Joan Corbacho in the Museo Geológico del Seminario de Barcelona (Spain), under the annotation MGSB- JC561.

Geographical distribution - Upper part of the Lower Fezouata Formation. The studied locality exposes blue green argillites from the Upper Tremadocian. The locality yielding the new trilobite is located approximately 21 km al N de Zagora, Dra Valley, Morocco (Figure 1, locality nº2). The coordinates of the site are N 30º30'54'' – W 5º45'24'' - Altitude 804 m.

The following trilobite species also appear in this outcrop: *Megistaspis* (*E.*) *hammondi* Corbacho & Vela, 2010; *Platypeltoides* aff. *carmenae* Corbacho *et al*., 2017; *Parabathycheilus gallicus* Dean, 1965; and *Symphysurus angustatus* Boeck, 1838.

Figure 7. Platypeltoides *sp. nº MGSB-JC561. Outcrop nº 2, North of Zagora, Dra Valley.*

Discussion – Only one specimen is available. Here we propose that it could be a juvenile specimen because of the large size of its eyes, as it also occurs with the holotype of *P. magrebiensis*?, which is a holaspis (Plate 1, fig. b) since the length of their carapaces are almost equal. The small spines that it presents are normal in the juvenile specimens of some species of *Platypeltoides*, that are subsequently lost when arriving at the adult phase of development. For these reasons, it is left in open nomenclature.

4. Conclusion

Regarding the diversity of the genus *Platypeltoides*, four described species and two possible new species to be described are included in this report. In Morocco, until 2016, only *Platypeltoides magrebiensis*? was recorded in the Zagora region, but this study shows that the distribution of *Platypeltoides* is concentrated both in the Zagora region and in the Guelmim area. All them appear in the Lower Fezouata Formation (Tremadocian), Lower Ordovician. The presence of well developed genal spines in adult specimens is a very particular characteristic of the species *P. hammondi*, *P. cuervoae* and *P. carmenae*; they are the only three species in which this characteristic has been observed in this genus.

Acknowledgements

We would like to express our gratitude to the staff of the Museo Geológico del Seminario de Barcelona (Spain) for the constructive criticism of this document. We would like to thank Brahim Tahiri and Mohamed Ahchach of the Paleontological Museum Arfoud (Morocco), and Hassain of Taichoute (Morocco), for the obtaining, work of extraction of the studied specimens and their field aid. Also our thanks to all the staff of the Xaluca group for their support and hospitality.

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