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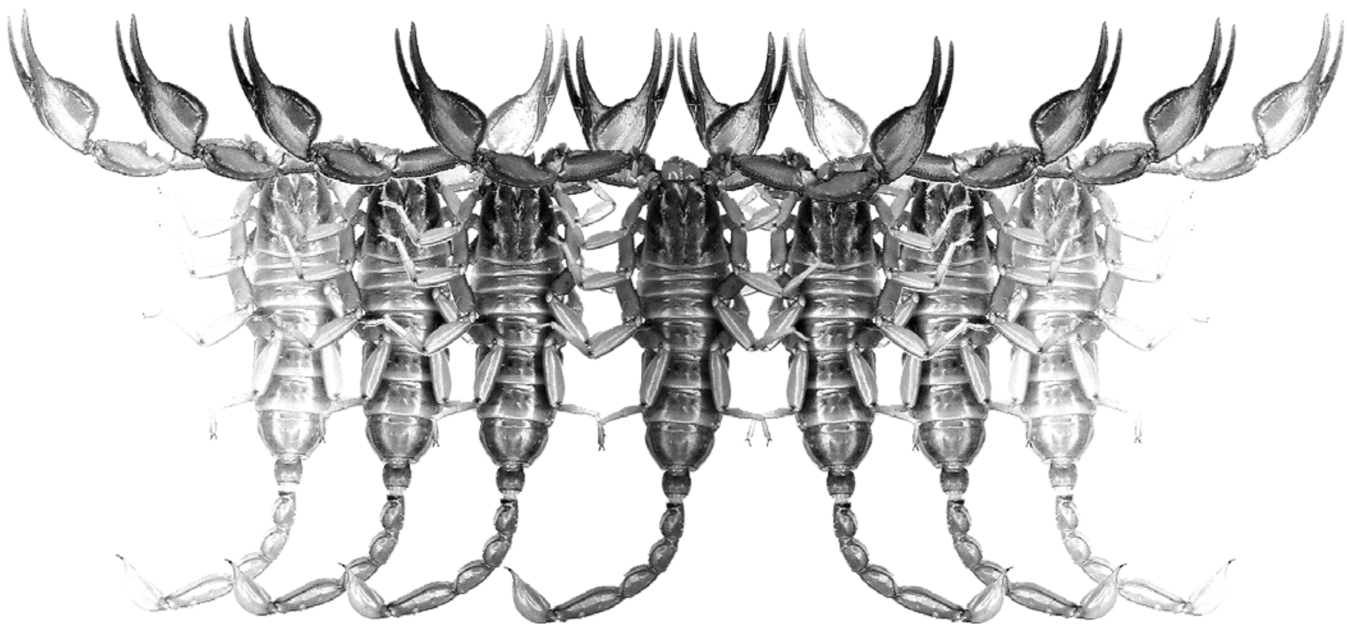

Constellation Array in Scorpion Genera *Paruroctonus*, *Smeringurus*, *Vejovoidus*, and *Paravaejovis* (Scorpiones: Vaejovidae)

Victor Fet, Michael E. Soleglad, Michael S. Brewer, David P. A. Neff & Michael L. Norton

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Constellation array in scorpion genera *Paruroctonus*, *Smeringurus*, *Vejovoidus*, and *Paravaejovis* (Scorpiones: Vaejovidae)

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Summary

The constellation array (a recently discovered sensory structure on the fixed finger of pedipalp; Fet et al., 2006) is analyzed for a large set of species belonging to four genera in the family Vaejovidae: *Paruroctonus*, *Smeringurus*, *Vejovoidus*, and *Paravaejovis*. It is shown that this structure is an important taxonomic character. Two distinct configurations are identified, a two-sensilla array for *Paruroctonus* + *Smeringurus* + *Vejovoidus* and a three-sensilla array for genus *Paravaejovis*, both differing from other vaejovid configurations so far investigated. The topology of these two array configurations are analyzed using *landmark setae* identified in this study.

Introduction

Fet et al. (2006) reported a sensory *constellation array* found on the external aspect of chelal fixed finger in scorpions, a curious array of tiny sensilla never described before. They described and illustrated this array for all major Recent scorpion groups: all four parvorders, all six superfamilies and 12 out of 13 families (only Microcharmidae was not represented) spanning 23 genera and 28 species. In addition, based on very limited sampling, the arrays were shown to be consistent in the number of sensilla and their configuration between genders as well as during ontogenetic growth, both qualities desired for a useful diagnostic character. As shown in this paper, the constellation array is proving to be important from a systematics perspective as well. We see overall consistency of the constellation array in its numbers of sensilla and their overall topology as determined by special "landmark setae" described in this paper.

Soleglad & Fet are currently involved in a major systematic revision of the family Vaejovidae (Soleglad & Fet, 2003, 2005, 2006, and in progress). Key to this revision is the identification of new diagnostic characters to be employed in their ongoing cladistic analysis. As stated above, we have reasons to believe that the constellation array could provide legitimate diagnostic characters. Therefore, this structure is investigated for a large related set of species in family Vaejovidae, the subject of this paper: ***Paravaejovis* + (*Paruroctonus* + *Smeringurus* + *Vejovoidus*)**, a topology originally suggested by Stockwell (1989). We demonstrate herein that this clade exhibits two unique constellation array topologies, both different from other vaejovid arrays so far studied. Of particular interest, these two topologies are congruent with the above clade, one topology seen in *Paravaejovis*, a three-sensilla configuration, and the other in *Paruroctonus* + *Smeringurus* + *Vejovoidus*, a two-sensilla configuration, thus providing additional evidence that *Paravaejovis* is distant from the three other more closely related genera. In addition, great consistency is shown in these two array configurations for the species so far examined, 15 species of *Paruroctonus*, 5 species and subspecies of *Smeringurus* (all taxa in this genus), and both species of the monotypic genera *Vejovoidus* and *Paravaejovis*. This observation is based on the analysis of over 80 digital SEM images of the four subject genera.

Methods & Material

Terminology and conventions

The systematics adhered to in this paper is current and therefore follows the classification as established in Fet & Soleglad (2005) and as modified by Soleglad & Fet (2006). Terminology describing the constellation array follows that described in Fet et al. (2006) and pedipalp chelal finger dentition follows that described and illustrated in Soleglad & Sissom (2001).

SEM microscopy

To investigate the chelal fingers, the structures were dehydrated in an ethanol series (50, 75, 95, and two changes of 100%) before being dried and coated with gold/palladium (ca. 10 nm thickness) in a Hummer sputter coater. Digital SEM images were acquired with a JEOL JSM-5310LV at Marshall University, West Virginia. Acceleration voltage (10–20 kV), spot size, and working distance were adjusted as necessary to optimize resolution, adjust depth of field, and to minimize charging.

Abbreviations

List of depositories: GL, Personal collection of Graeme Lowe, Philadelphia, Pennsylvania, USA; MES, Personal collection of Michael E. Soleglad, Borrego Springs, California, USA; VF, Personal collection of Victor Fet, Huntington, West Virginia, USA.

Other: ABDSP, Anza-Borrego Desert State Park, San Diego and Riverside Counties, California, USA.

Material examined

The following vaejovid material was examined for analysis and/or illustrations provided in this paper.

Genera *Paravaejovis*, *Paruroctonus*, *Smeringurus*, and *Vejovoidus* (40 specimens): *Paravaejovis pumilis* (Williams, 1970), Ciudad Constitución, Baja California Sur, Mexico, 3 ♂ (MES); *Paruroctonus arenicola nudipes* Haradon, 1984, Kelso Dunes, San Bernardino Co., California, USA, ♂, juv. (GL); *Paruroctonus arnaudi* Williams, 1972, El Socorro, Baja California, Mexico, ♂ topotype (MES); *Paruroctonus bantai saratoga* Haradon, 1985, Death Valley, Inyo Co., California, USA, juv. (GL); *Paruroctonus becki* (Gertsch & Allred, 1965), San Bernardino Co., California, USA, ♂ (VF); *Paruroctonus boreus* (Girard, 1854), Mercury, Nevada, USA, ♂ (MES); *Paruroctonus borregoensis* Williams, 1972, Palo Verde Wash, ABDSP, California, USA, ♂ (MES); *Paruroctonus gracilior* (Hoffmann, 1931), New Mexico, USA, ♂ (MES), Cuatro Cienegas, Coahuila, Mexico, ♂ ♀ (MES), Lajitas, Brewster Co., Texas, USA ♂ (GL), Lordsburg, Hidalgo Co., New Mexico, USA, ♂ (GL), Big Bend National Park, Brewster Co., Texas, USA, ♂ (VF); *Paruroctonus hirsutipes* Haradon, 1984, Algodones Dunes, Imperial Co., California, USA juv. (GL); *Paruroctonus luteolus* (Gertsch et Soleglad, 1966), Palo Verde Wash, ABDSP, California, USA, ♂ (MES); *Paruroctonus silvestrii* (Borelli, 1909), Chihuahua Road, ABDSP, California, USA, ♀ (MES); *Paruroctonus stahnkei* (Gertsch et Soleglad, 1966), Mesa, Maricopa Co., Arizona, USA, ♂ (MES), La Paz Co., Arizona, ♂ (VF); *Paruroctonus surensis* Williams et Haradon, 1980, Las Bombas, Baja California Sur, Mexico, ♂ (MES); *Paruroctonus utahensis* (Williams, 1968), Samalayuca, Chihuahua, Mexico, ♂ (MES), Kermit, Winkler County, Texas, USA, ♀ ♂ (VF); *Paruroctonus ventosus* Williams, 1972, El Socorro, Baja California, Mexico, ♀ topotype (MES); *Paruroctonus xanthus* (Gertsch & Soleglad, 1966), Algodones Dunes, Imperial Co., California, USA, ♂ (GL); *Smeringurus aridus* (Soleglad, 1972), Palo Verde Wash, ABDSP, California, USA, ♂ ♀ (MES); *Smeringurus grandis* (Williams, 1970), Oakies Landing, Baja California, Mexico, ♂ (MES); *Smeringurus mesaensis* (Stahnke, 1957), Palo Verde Wash, ABDSP, California, USA, 3 ♀ (MES); *Smeringurus vachoni immanis* (Soleglad, 1972), 1000 Palms, Riverside Co., California, USA, ♀ (MES); *Smeringurus vachoni vachoni* (Stahnke, 1961), San Bernardino Co., California, USA, ♀ (VF); *Vejovoidus longiunguis* (Williams, 1969), Las Bombas, Baja California Sur, Mexico, 3 ♂, 2 ♀ (MES).

Additional comparative material (14 specimens): *Pseudouroctonus andreas* (Gertsch et Soleglad, 1972), Penasquitos Carmel Mtn. Rd., San Diego Co., California, USA, juv. ♂ (VF); *Pseudouroctonus reddelli* (Gertsch et Soleglad, 1972), Travis Co., Texas, USA, ♀ (VF); *Serradigitus gertschi gertschi* (Williams, 1968), San Diego, California, USA ♀ (VF); *Serradigitus joshuaensis* (Soleglad, 1972), Borrego Springs, San Diego Co., California, USA ♀ (VF); *Serradigitus minutis* (Williams, 1970), Cabo San Lucas, Baja California Sur, Mexico, ♀ (VF); *Stahnkeus subtilimanus* (Soleglad, 1972), Borrego Springs, San Diego Co., California, USA, ♀ (VF); *Vaejovis carolinianus* (Beauvois, 1805), Tishomingo State Park, Mississippi, USA, ♀ (VF); *Vaejovis confusus* (Stahnke, 1940), San Bernardino Co., Arizona, USA, ♂ (VF); *Vaejovis eusthenura* (Wood, 1863), Cabo San Lucas, Baja California Sur, Mexico, ♀ (VF); *Vaejovis hirsuticauda* (Banks, 1910), ABDSP, California, USA, ♀ (VF); *Vaejovis punctipalpi* (Wood, 1863), Cabo San Lucas, Baja California Sur, Mexico, ♀ (VF); *Vaejovis puritanus* Gertsch, 1958, ABDSP, California, USA, ♂ (VF); *Vaejovis viscainensis* Williams, 1970, Las Bombas, Baja California Sur, Mexico, ♀ (VF); *Vaejovis vittatus* Williams, 1970, Cabo San Lucas, Baja California Sur, Mexico, ♂ (VF).

Results and Discussion

Constellation array: the sensillum

The tiny sensillum of the constellation array has a somewhat complex structure: there is an outer areola which is formed as a small shallow depression in the cuticle with a low profile outer lip and sometimes

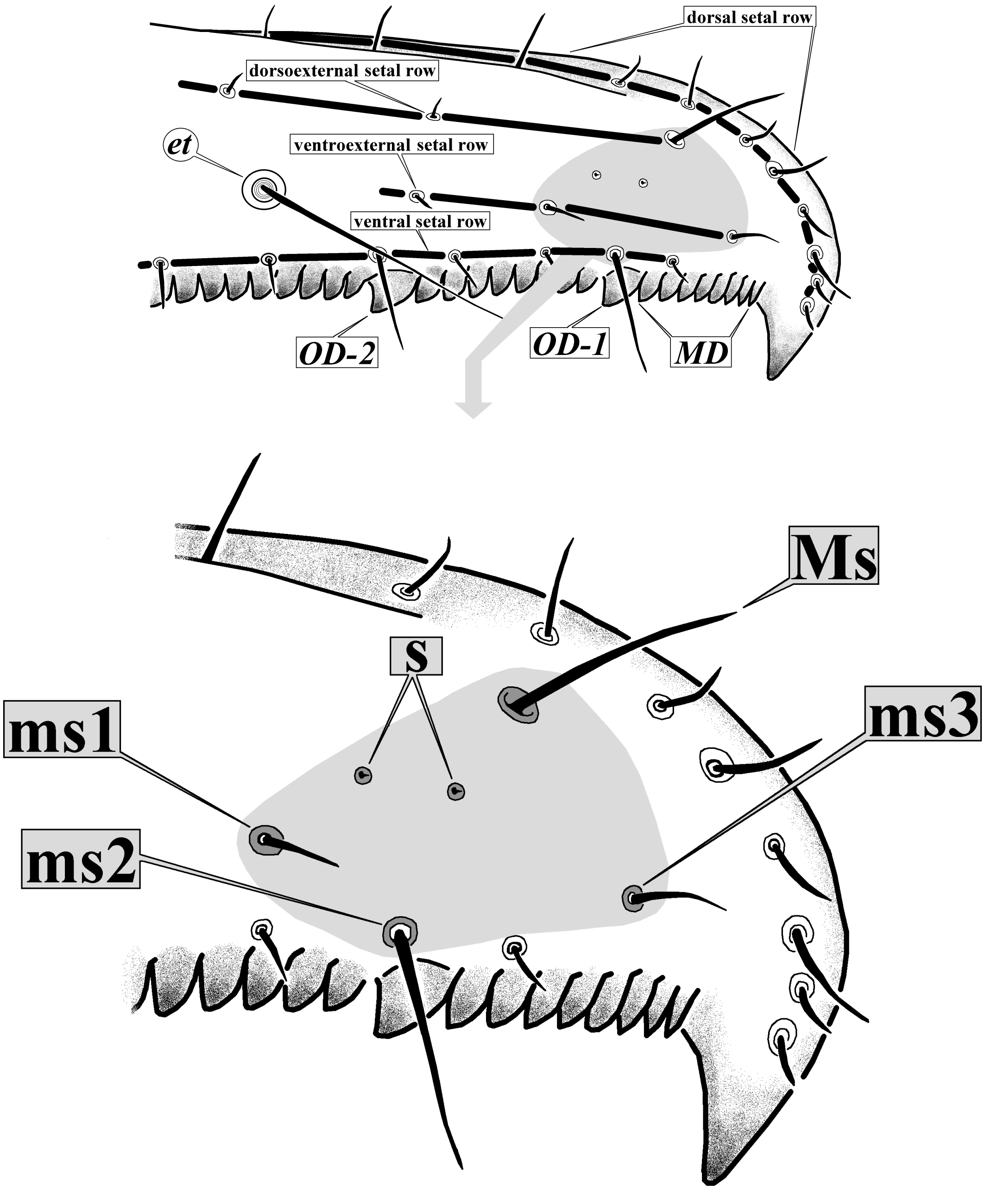


Figure 1: Distal one-third of chelal fixed finger, external view, of *Paruroctonus becki* showing general layout of constellation array sensilla, setal rows, *landmark* setae, trichobothria, and finger denticles. In **top** figure the four setal rows are identified (setae of each row are connected with black lines) as well as trichobothria and finger denticles of importance. Constellation array and landmark setae region are indicated by a gray polygon. In **bottom** figure the constellation array sensilla and landmark setae region (with darkened areolae for emphasis) are shown in closeup and identified. **s** = sensilla; **Ms** = major seta; **ms1–3** = minor setae 1–3; *et* = external terminal trichobothrium; *OD–1* & *2* = outer (*OD*) denticles 1 & 2; *MD* = distal median (*MD*) denticles.

exhibiting additional subtle concentric rings in its concavity (Figs. 23–26, 28–30). Within this outer areola is an even smaller deeper areola located at its center, its diameter roughly one-third that of the outer areola. Internally the second areola is composed of successive concentric ridges extending into the areola. Extending from this second areola is a short, stout, highly tapered seta, its external length being less than the diameter of the outer areola. At the base of some seta we see the evidence of striations, which is commonly found on leg setae. Table 1 provides measurements of sensillar size for 21 studied species.

Constellation array topologies

Constellation array fixed finger orientation. As shown in Figure 1, the constellation array is located on the extreme distal aspect of the chelal fixed finger external surface (see Fet et al., 2006 for an illustrated survey of this array across the entire scorpion order). To precisely determine the location of the sensilla as well as conduct comparative studies of their topology, we have identified a set of "landmarks" on the fixed finger comprised of both setae and outer (*OD*) denticles. In order to state exactly the location of the *four landmark setae* for the four genera studied in this paper we have divided the external surface of the fixed finger into four regions, each region occupied by a setal row extending along the finger:

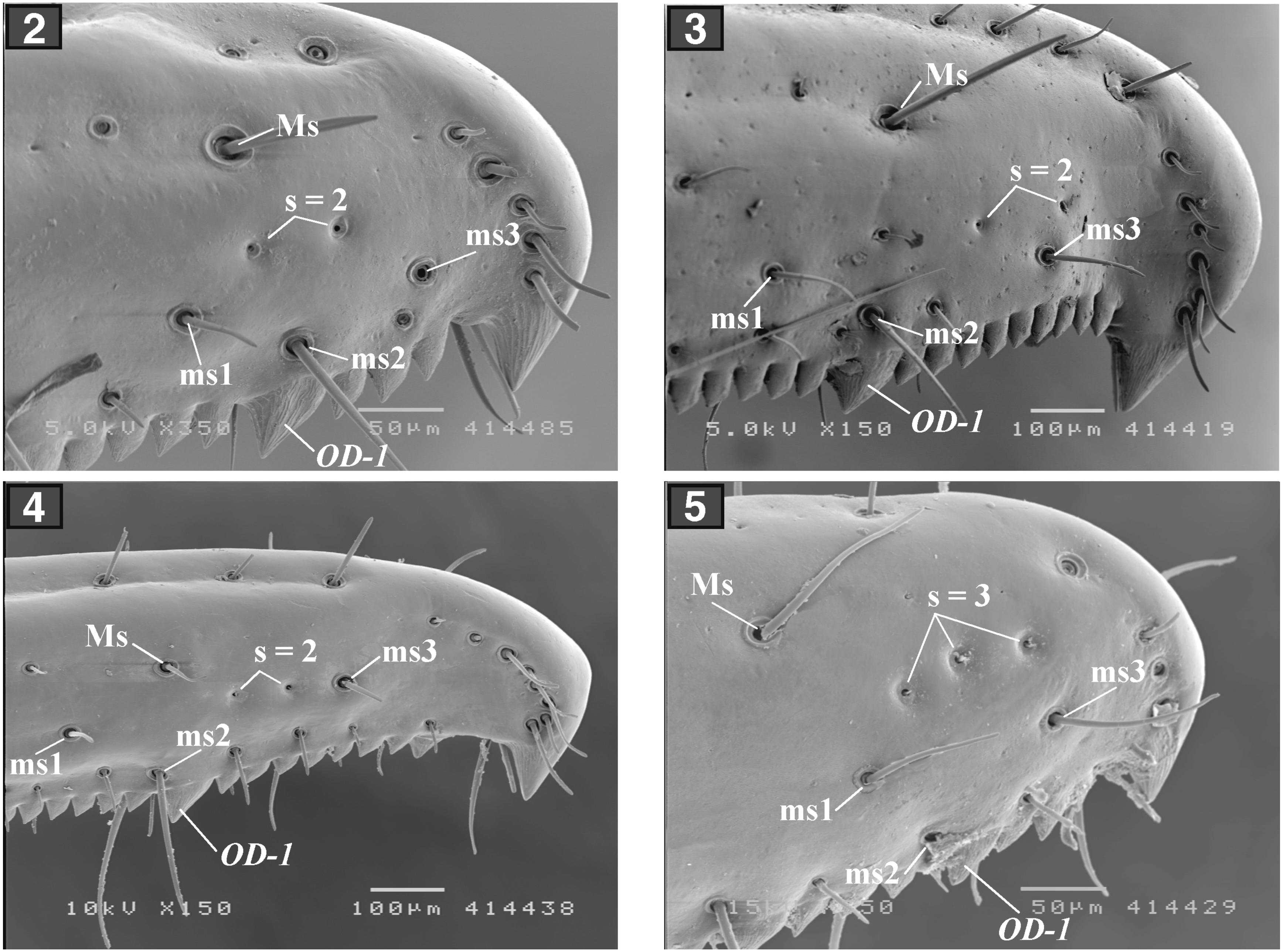
dorsal setal row is located on the dorsal edge of the finger beginning at the dorsoexternal aspect of the distal tip, following the curve of the distal tip, and continuing along the dorsal edge, inline with trichobothrium *dt* — contains no landmark setae;
dorsoexternal setal row is located on the dorsoexternal surface, dorsal of trichobothrium *et* and the constellation array sensilla — contains landmark seta **Ms**;
ventroexternal setal row is located on the ventroexternal surface of the finger, ventral of trichobothrium *et* and the constellation array sensilla — contains two landmark setae, **ms1** and **ms3**;
ventral setal row is located on the extreme ventroexternal surface, just above the finger denticle edge; in this row the single seta located above *OD* denticles is larger than those setae found above median (*MD*) denticles — contains landmark seta **ms2**, which is situated adjacent to the *OD–1* denticle base.

We establish four setae as landmarks for sensilla charting (Fig. 1), all distal of the most distal trichobothrium *et* and ventral of the dorsal trichobothrium *dt*. The major seta (**Ms**) is a large isolated seta situated on the dorsal half of the fixed finger, being the largest and most distal seta in the *dorsoexternal setal row*. The minor seta-2 (**ms2**) is positioned close to the denticle edge in the *ventral setal row*, adjacent to the base of outer (*OD*) denticle-1. The minor seta-1 (**ms1**) is positioned just proximal of **ms2** in the *ventroexternal setal row*, angling more dorsally on the finger. Finally, the minor seta-3 (**ms3**) is the most distal seta in the *ventroexternal setal row*, aligned horizontally with **ms1**, and is situated just proximal of several *dorsal setal row* setae arranged in a curved line along the distal denticle tip. The three minor setae are usually larger than other setae in the vicinity of the finger denticle edge but not as large as **Ms**. These four landmark setae, when connected, form an irregular four-sided polygon, essentially enclosing the constellation array sensilla thus providing a means for evaluating their position. The exact positions of these landmark setae are, of course, genus- and species-specific and do show some variability even within a species. Figures 2–5 specifically identify these landmark setae in the four genera discussed in this paper, but they are quite visible in the other figures as well, representing a large number of species.

Constellation array configurations. Figures 2–5, 7–22, 27 show the constellation arrays of 13 species of *Paruroctonus* and all species and subspecies of genera *Smeringurus*, *Vejovoidus*, and *Paravaejovis*. In these figures, we see two basic configurations of sensilla in our vaejovid study group: assemblage *Paruroctonus* (Figs. 2, 7–18) + *Smeringurus* (Figs. 3, 19–22, 27) + *Vejovoidus* (Fig. 4) with two sensilla, and genus *Paravaejovis* (Fig. 5) with three sensilla. In addition, we also see positional differences within these two configurations with respect to the landmark setae.

Figure 6 presents constellation array topology charts where the fixed finger denticle edge is aligned horizontally to the plane thus allowing consistent positional analysis of the sensilla with respect to landmark setae and outer denticles. In genus *Paruroctonus* (Fig. 6, showing charts of 15 species), sensilla are always proximal of **ms3**, usually inline vertically with **Ms** and **ms2**. Within this configuration, we see alignment differences that appear to be related to the number of distal *MD* denticles which is also, in part, a function of the species adult size: in species with small numbers of distal *MD* denticles (i.e., 2–3 *MD* denticles), such as *P. surensis* (Fig.7), *P. borregoensis* (Fig. 9) and *P. luteolus* (Fig. 2), **Ms** is positioned slightly proximal of **ms2** and the sensilla are either proximal of **ms2**, or if not both, then the most basal sensillum is situated proximally. As the number of distal *MD* denticles increases (i.e., 4–6), we see **Ms** distad of **ms2**, and both sensilla usually distal of **ms2** as well. In species with large numbers of distal *MD* denticles, *P. gracilior* and *P. xanthus* (i.e., 10–11), we see the sensilla are considerably distal of **Ms** and **ms2**. Only species *P. becki* (Fig. 17) with *MD* = 8 violates this trend. Since these topology differences seem to be related, in part, to the species size, we are hesitant at this time to attach systematic importance to these observations.

In the assemblage *Smeringurus* + *Vejovoidus* (Fig. 6, showing charts of five species) the sensilla are placed considerably distad of **ms2**. This more distal placement of the sensilla may be due to the larger number of distal MD denticles (i.e., 6–13), similar to that seen in *Paruroctonus arnaudi*, *P. xanthus*, and *P. gracilior*. In



Figures 2–5: Orientation of constellation array sensilla with respect to landmark setae for four genera. **2.** *Paruroctonus luteolus*, male, ABDSP, California, USA. **3.** *Smeringurus mesaensis*, male, ABDSP, California, USA. **4.** *Vejovoidus longiunguis*, female, Las Bombas, Baja California Sur, Mexico. **5.** *Paravaejovis pumilis*, male, Cuidad Constitucion, Baja California Sur, Mexico. Note that genus *Paravaejovis* is unique in these configurations, exhibiting *three* sensilla (not two). See Fig. 1 for definition of annotations.

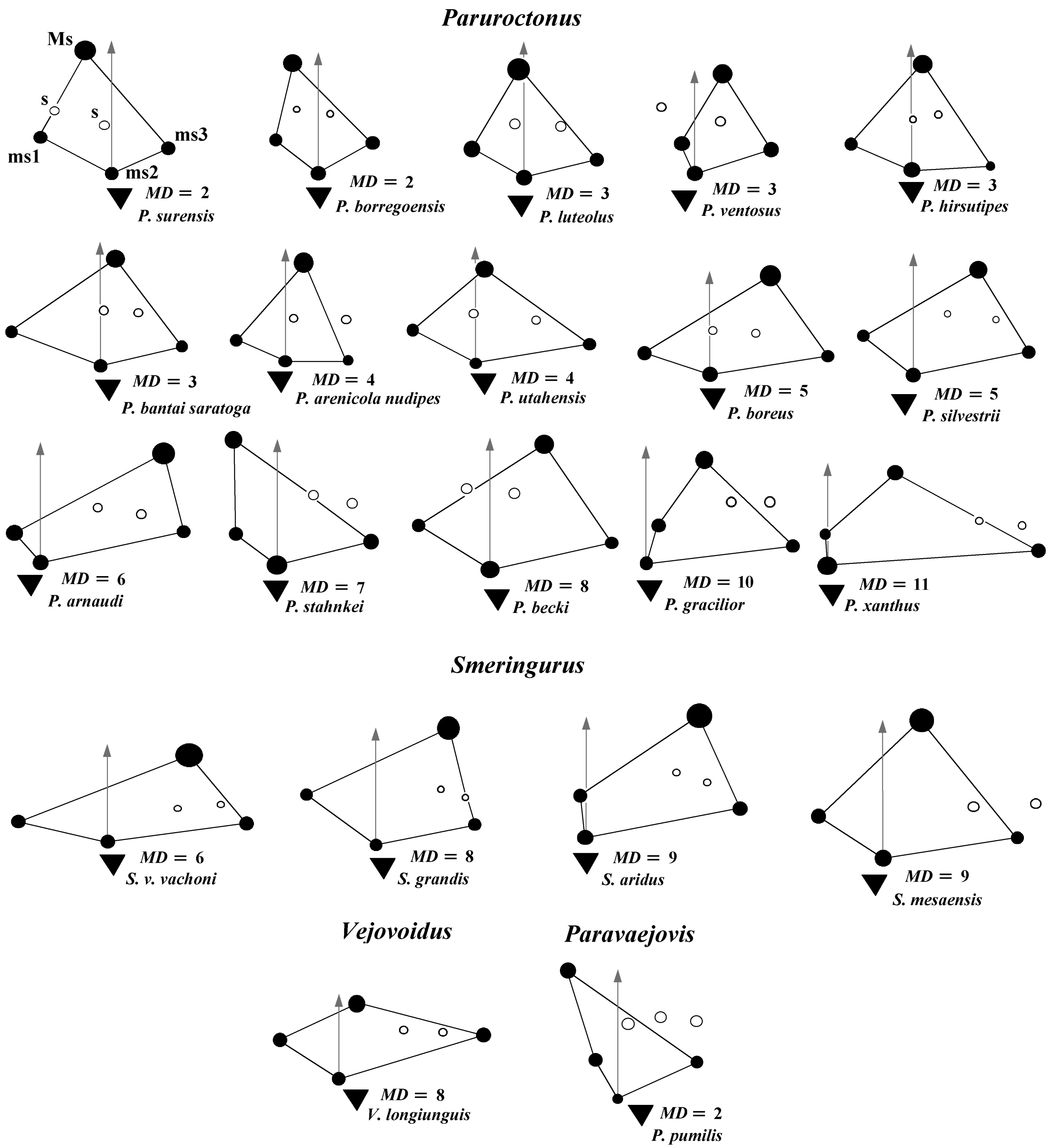


Figure 6: Constellation array **topology charts** for vaejovid genera *Paruroctonus*, *Smeringurus*, *Vejovoidus*, and *Paravaejovis*. Open circles depict sensilla, closed circles depict major and minor landmark setae (connected by black lines) and the triangle depicts outer (*OD*) denticle-1. Vertical arrow provides alignment perspective for landmark setae **ms2** and **Ms**, and the sensilla. Individual charts within genera are ordered by increasing number of distal median (*MD*) denticles (i.e., the number of *MD* denticles located between *OD–1* and the distal denticle tip of the chelal fixed finger). It is important to note here in these charts (unlike those images show in figures Figs. 2–5, 7–22, 27) the fixed finger denticle edge is aligned horizontally, therefore perpendicular to the vertical arrow.

genus *Vejovoidus* we see an unusual, somewhat elongated distal tip on the fixed finger (Fig. 4) where the distal *MD* denticles do not extend completely to the distal denticle. In general, however, the topologies are strikingly similar in *Smeringurus* and *Vejovoidus*.

The constellation array in genus *Paravaejovis* (Fig. 6) is quite distinct from the other three genera, exhibiting *three sensilla* rather than two. In addition, the three sensilla are positioned on the dorsal one-third of the fixed finger, whereas in the other three genera the

	Sensilla Number	Array Diameter	Sensillum Diameter	Distance to Distal Tip	Distal *MD* Number	Reference Figures
Paruroctonus arenicola nudipes	2	80.6	14.2	226.7	4	Fig. 16
Paruroctonus arnaudi	2	67.2	15.7	286.7	6	Figs. 9, 29
Paruroctonus bantai saratoga	2	55.2	13.4	231.1	3	Fig. 8
Paruroctonus becki	2	54.5	10.8	238.8	8	Fig. 15
Paruroctonus boreus	2	85.8	15.7	386.7	5	Fig. 11
Paruroctonus borregoensis	2	44.8	13.4	177.8	2	Fig. 7
Paruroctonus gracilior	2–3 (2)*	62.5	15.4	228.6	10	Fig. 13
Paruroctonus hirsutipes	2	34.3	10.5	208.9	3	–
Paruroctonus luteolus	2	51.2	10.4	145.0	3	Fig. 1
Paruroctonus silvestrii	2	96.3	14.9	295.5	5	Figs. 10, 24
Paruroctonus stahnkei	2	64.5	13.3	197.5	6–7	Fig. 14
Paruroctonus surensis	2	63.6	12.5	222.5	2	Figs. 5, 23
Paruroctonus utahensis	2	115.0	14.9	288.9	4	Fig. 12
Paruroctonus ventosus	2	85.1	14.9	191.1	3	Fig. 6
Paruroctonus xanthus	2	70.2	12.7	213.3	11	–
Smeringurus aridus	2	95.1	14.4	405.7	7–9	Figs. 19, 30
Smeringurus grandis	2	78.8	15.4	445.7	8–9	Figs. 18, 25
Smeringurus mesaensis	2	62.7	12.0	233.7	9	Figs. 2, 17
Smeringurus vachoni immanis	2	128.9	23.1	233.7	13	Figs. 27, 28
Smeringurus vachoni vachoni	2	67.9	14.2	328.1	6	Fig. 20
Vejovoidus longiunguis	2	73.1	12.5	405.7	7–8	Figs. 3, 26
Paravaejovis pumilis	3	35.5	13.3	137.5	2–3	Fig. 4
Mean ± SD		**72.1 ±24.9**	**13.9 ±2.8**	**262.3 ±92**		

Table 1: Constellation array statistics for vaejovid genera *Paruroctonus*, *Smeringurus*, *Vejovoidus*, and *Paravaejovis*. "Array Diameter" = distance between sensilla centers (note for genus *Paravaejovis*, distance is measured from the two most proximal sensilla). "Distance to distal tip" = distance from the most distal sensillum to distal edge of distal denticle. Number of distal *MD* denticles is counted from *OD–1* to distal denticle. *OD–1* = outer denticle-1; *MD* = median denticles. Measurements in micrometers. * range (mode).

two sensilla are located on the ventral half of the finger, definitely ventrad of the horizontal midpoint**.** The major seta **Ms** is positioned proximad of both **ms1** and **ms2**, whereas in the other three genera we see **Ms** is always distad of **ms1** and usually **ms2** as well. In those small species of *Paruroctonus* that have minimal number of distal *MD* denticles (i.e., 2–3), **Ms** may be slightly proximad of **ms2** (species *P. surensis*, *P. borregoensis* and *P. luteolus*).

In summary, the sensilla are positioned more distad from the setal landmark region in species whose distal denticle tip is more removed from this region, that is, the area between outer (*OD*) denticle-1 and the distal denticle contains more median (*MD*) denticles. This may imply that the sensilla must be at a certain distance from the finger tip in order to adequately "perform their function". Also important about this data is the fact that the number of sensilla remained the same across a sizable, diverse species set whose adult size ranged from small species at 30 mm to large species exceeding 90 mm. Table 1 provides measurements of constellation array size for 21 studied species (we measured the distance between two sensilla, diameter of a sensillum, and the distance from the finger tip).

Systematic observations

Stockwell (1989: 287, fig. 257), in his important unpublished Ph.D. thesis, suggested the following topology for our study group: ***Paravaejovis*** + (***Paruroctonus*** + ***Smeringurus*** + ***Vejovoidus***). Under Stockwell's (1989) scheme, this assemblage formed a major clade within family Vaejovidae (he assigned it its own tribe under subfamily Syntropinae). Based on preliminary cladistic analysis, we agree that this clade as suggested by Stockwell is monophyletic and is quite removed from the other vaejovid aggregates (even more so than that shown by Stockwell, 1989: fig. 257). We also agree with Stockwell's split into two primary subclades, therefore ***Paruroctonus*** + ***Smeringurus*** + ***Vejovoidus*** is also monophyletic in our opinion. In addition to the major neobothriotaxy found on the chelal palm, the monotypic genus *Paravaejovis* exhibits important differences in the location of orthobothriotaxic trichobothria. In this paper we have demonstrated yet another character that separates the two subclades, the constellation array, with different number of sensilla and different landmark setal topologies. The taxonomic placement of these four genera within the framework of family Vaejovidae will be established in an upcoming paper (Soleglad & Fet, in progress).

Comparison to other vaejovids. Based on preliminary analysis (Fet et al., in progress) we have also detected a certain consistency in the number of constellation array sensilla in other closely related vaejovid genera and groups. Here is a list of groups and species so far examined:

Tribe Stahnkeini with five to seven sensilla: *Serradigitus gertschi gertschi* and *S. joshuaensis* with five sensilla, *S. minutis* with six sensilla, and *Stahnkeus subtilimanus* with seven sensilla

"punctipalpi" group of *Vaejovis* with six sensilla: *Vaejovis hirsuticauda* and *V. punctipalpi*

"eusthenura" group of *Vaejovis* with three to five sensilla: *Vaejovis confusus*, *V. eusthenura*, and *V. puritanus* with five sensilla; *V. viscainensis* and *V. vittatus*, with three sensilla

"mexicanus" group of *Vaejovis* with three sensilla: *Vaejovis carolinianus*

Pseudouroctonus with three sensilla: *Pseudouroctonus andreas* and *P. reddelli*

These data are very preliminary and the number of species examined quite small but we expect, after the evaluation of several more species and additional specimens of a species, that these trends will show the same consistency as that exhibited in the four genera discussed in this paper. In addition, we also suspect that the occurrence and/or location of the four landmark setae defined in this study will also exhibit different configurations in the other vaejovid groups and genera thus providing additional characters for future cladistic analysis. Compared to these limited but diverse data, one general trend that can be already seen in *Paruroctonus* and allied genera, is the *reduction* of sensilla number (with *Paravaejovis* an outgroup with three sensilla). It appears that this trend is exhibited at the systematic level higher than genus, and can thus be synapomorphic feature for a tribe or a subfamily. Indeed, two sensilla are the lowest number so far confirmed in scorpions (as one sensilla in *Vejovoidus* appears to be an aberration) while the highest number reaches 15 (genus *Calchas*, Iuridae; Fet et al., 2006). Note that another, unrelated chactoid genus, *Nullibrotheas* (Chactidae) has two sensilla while other chactids have higher number (up to 14; Fet et al., 2006); thus, reduction trend seems to be derived.

Following the examination of a reasonably representative set of constellation array sensilla in all major scorpion groups, the next step will be to hypothesize possible homology among individual sensilla, thus providing even further information on their evolution and increasing their impact on the overall systematic revision of extant scorpions.

Variability and aberrations in sensilla occurrence

In our material, several analyzed specimens of *Paruroctonus gracilior* presented an example of variability in number of sensilla within a species. Out of six investigated specimens, four possessed two sensilla as in all other studied *Paruroctonus* species; these were a male and a female from Cuatro Cienegas (Coahuila, Mexico), a male from Brewster Co., Texas, and a male from Hidalgo Co., New Mexico. On the other hand, two specimens (another male from Texas and another male from New Mexico) had *three* sensilla. At this moment, the only observation we can make is that this variability does not seem to be gender-related, or geographically specific. We must remember that systematically *P. gracilior* is separated in a group of its own from all other 28 known species of the genus *Paruroctonus* (Sissom, 2000: 506). It is also geographically unique, being the most southern species in this genus.

At the same time, we stress the overall consistency in the many specimens of *Paruroctonus*, *Smeringurus*, and *Vejovoidus* examined, with two sensilla found across this diverse group everywhere. These specimens were selected randomly from both genders, and across several sources and localities, where two sensilla was the norm. In 14 our of 15 examined species of *Paruroctonus* (except *P. gracilior*), we observed a solid consistency of two sensilla in constellation array.

We also have to mention observed occurrences of “missing”, petite, or partially formed sensilla as aberrations. We need to stress the delicate nature of an individual sensillum thus suggesting it can be easily damaged, especially in older adult specimens. As an example of this, our observation (Fet et al., 2006: fig. 23) of *Vejovoidus* exhibiting only one sensillum was incorrect; in fact, the second sensillum is visible in this figure in a “modified” (damaged?) form. We have seen also occurrences of petite, or partially formed, sensilla – in the same sense as petite trichobothria known in many scorpion species (Vachon, 1974; Soleglad & Fet, 2003). It seems reasonable to assume that a petite sensillum is underdeveloped, compared to fully developed sensillum of specific size.

Finally, in many images taken, surrounding setae (including landmark setae) are often broken off, especially in old specimens, and under a low magnification the broken stubs of these setae could be confused with the sensilla of the constellation array.

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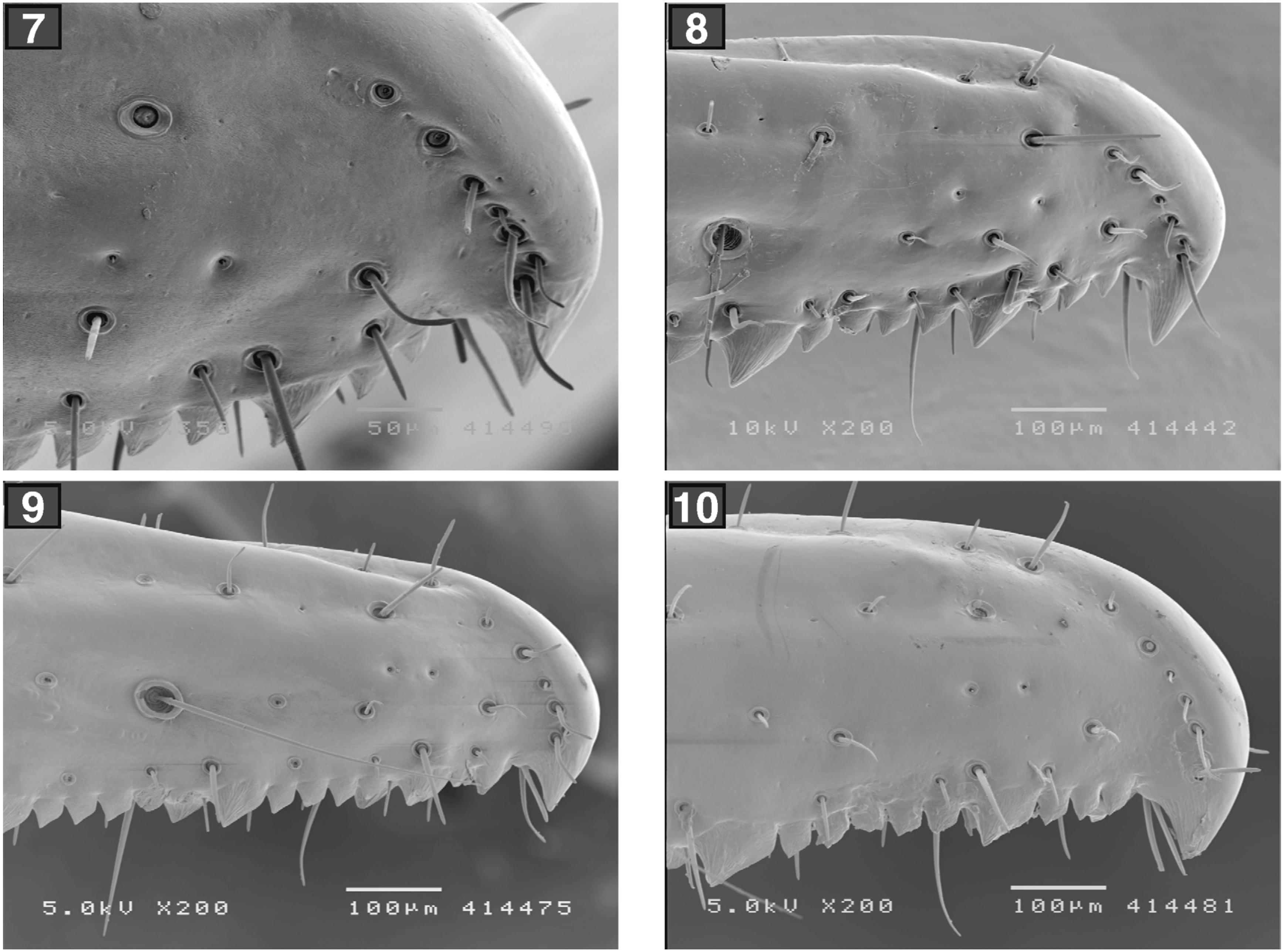
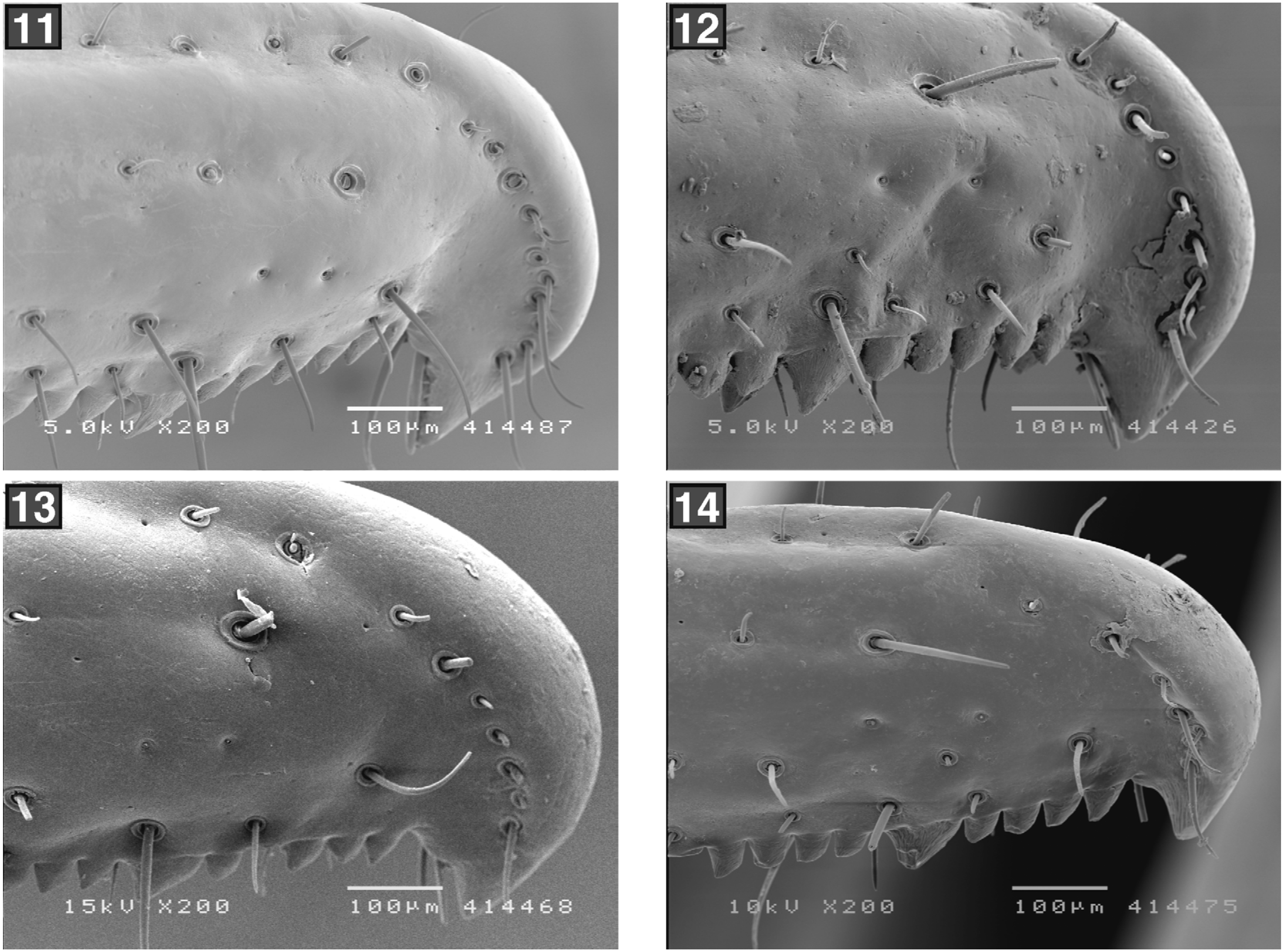
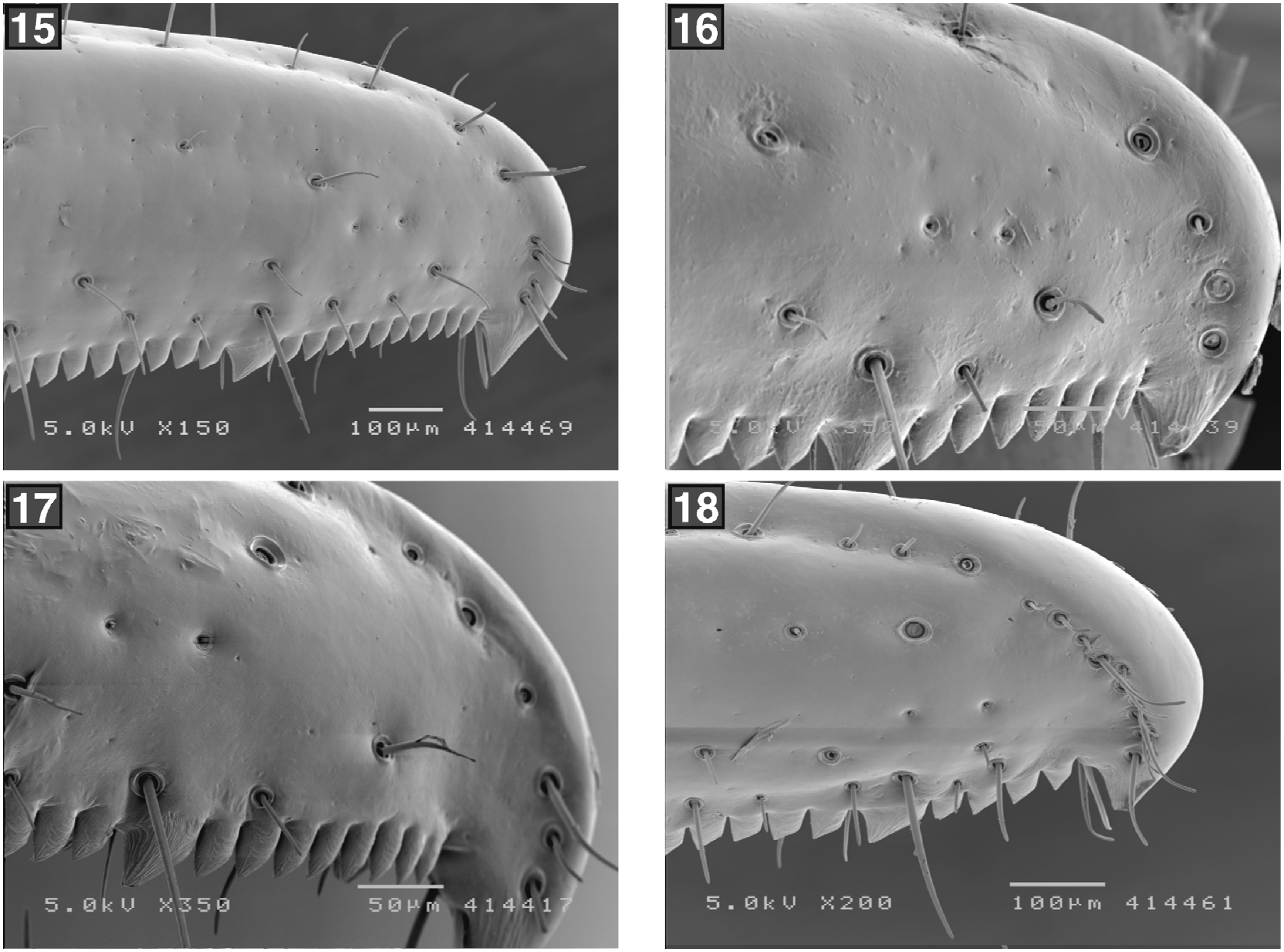


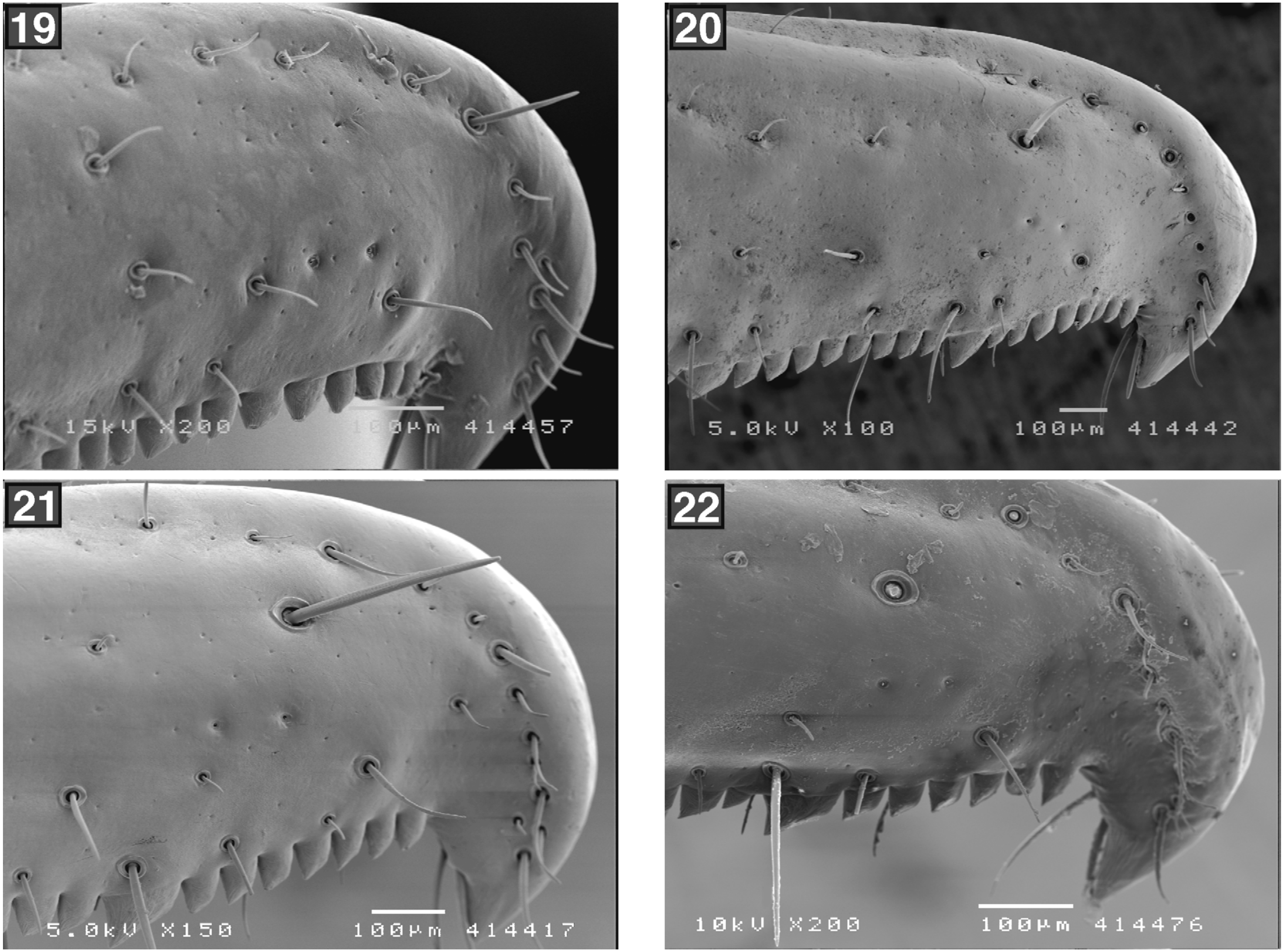
Figures 7–10: Closeup of distal aspect of chelal fixed finger, external view, showing *constellation array* in genus *Paruroctonus*. **7.** *Paruroctonus surensis*, male, Las Bombas, Baja California Sur, Mexico. **8.** *P. ventosus*, female, El Socorro, Baja California, Mexico. **9.** *P. borregoensis*, male, Palo Verde Wash, ABDSP, California, USA. **10.** *P. bantai saratoga*, juv., Death Valley, Inyo County, California, USA.



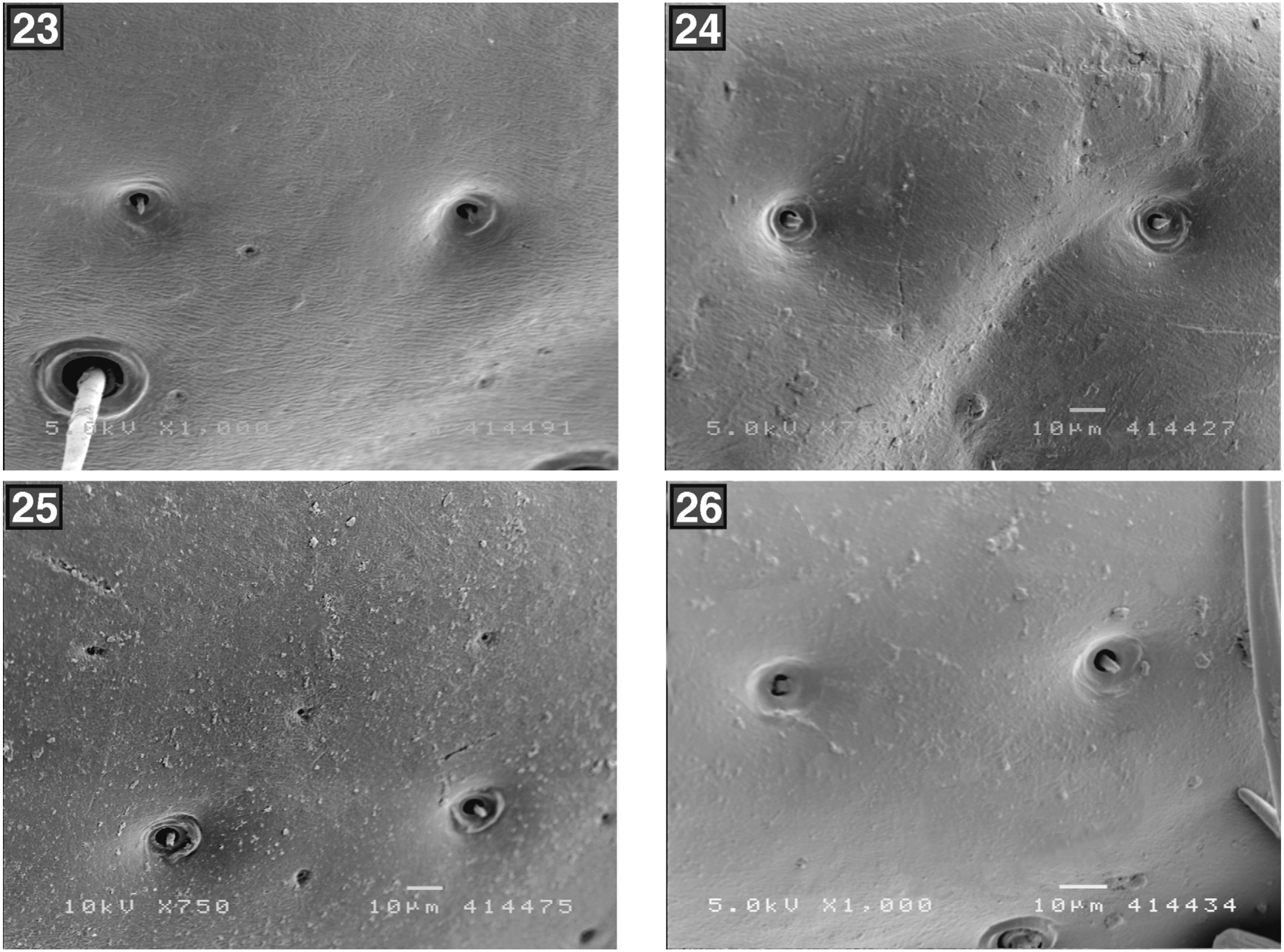
Figures 11–14: Closeup of distal aspect of chelal fixed finger, external view, showing *constellation array* in genus *Paruroctonus*. **11.** *Paruroctonus arnaudi*, male, El Socorro, Baja California, Mexico. **12.** *P. silvestrii*, male, Chihuahua Road, ABDSP, California, USA. **13.** *P. boreus*, male, Mercury, Nevada, USA. **14.** *P. utahensis*, female, Kermit, Winkler Co., Texas, USA.



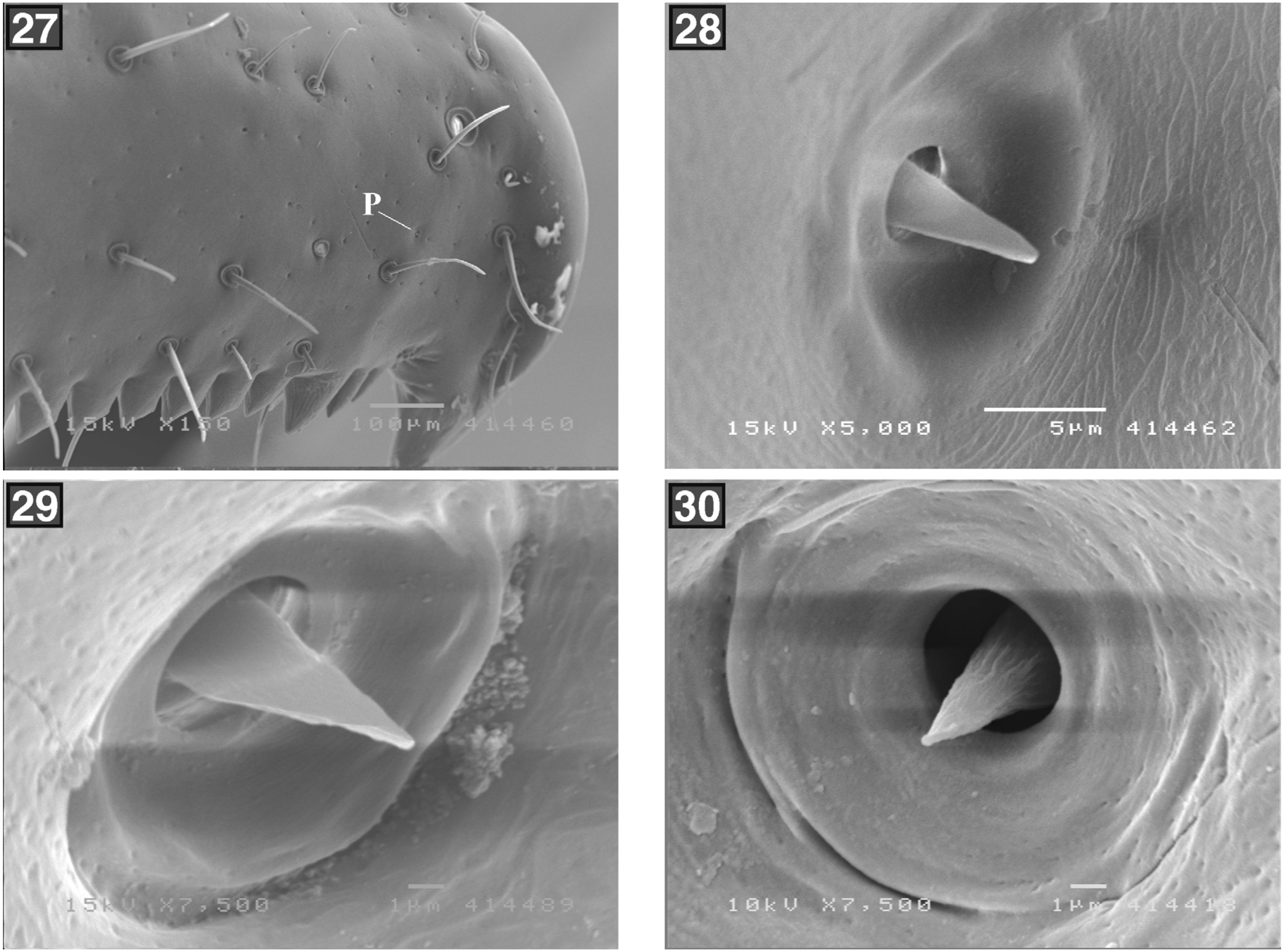
Figures 15–18: Closeup of distal aspect of chelal fixed finger, external view, showing *constellation array* in genus *Paruroctonus*. **15.** *Paruroctonus gracilior*, male, Cuatro Cienegas, Coahuila, Mexico. **16.** *P. stahnkei*, Mesa, Maricopa Co., Arizona, USA. **17.** *P. becki*, male, San Bernardino Co., California, USA. **18.** *P. arenicola nudipes*, male, Kelso Dunes, San Bernardino Co., California, USA.



Figures 19–22: Closeup of distal aspect of chelal fixed finger, external view, showing *constellation array* in genus *Smeringurus*. **19.** *Smeringurus mesaensis*, male, ABDSP, California, USA. **20.** *S. grandis*, male, Oakies Landing, Baja California, Mexico. **21.** *S. aridus*, female, ABDSP, California, USA. **22.** *S. vachoni vachoni*, male, San Bernardino Co., California, USA.



Figures 23–26: Closeups of sensilla pair. **23.** *Paruroctonus surensis*, male, Las Bombas, Baja California Sur, Mexico. **24.** *Paruroctonus silvestrii*, male, Chihuahua Road, ABDSP, California, USA. **25.** *Smeringurus grandis*, male, Oakies Landing, Baja California, Mexico. **26.** *Vejovoidus longiunguis*, female, Las Bombas, Baja California Sur, Mexico.



Figures 27–30: Closeups of individual sensilla. **27–28** *Smeringurus vachoni immanis*, female, 1000 Palms, California, USA. **27.** Distal aspect of fixed finger, external view, showing a petite sensilla (indicated by "**P**"). **28.** Closeup of petite sensilla. **29.** *Paruroctonus arnaudi*, male, El Socorro, Baja California, Mexico. **30.** *Smeringurus aridus*, female, ABDSP, California, USA.