Euscorpius

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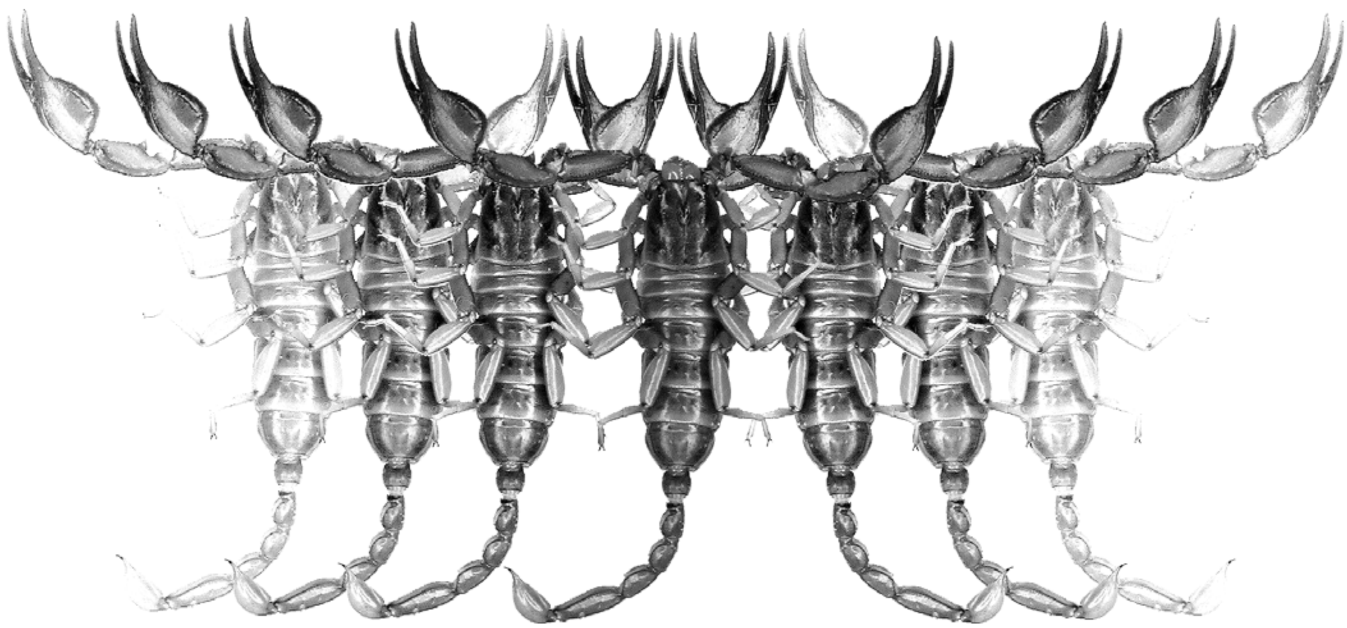

Laterobasal Aculear Serrations (LAS) in Scorpion Family Vaejovidae (Scorpiones: Chactoidea)

Victor Fet, Michael E. Soleglad and Michael S. Brewer

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- **ZISP**, Zoological Institute, Russian Academy of Sciences, St. Petersburg, Russia
- **WAM**, Western Australian Museum, Perth, Australia
- **NTNU**, Norwegian University of Science and Technology, Trondheim, Norway

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Laterobasal aculear serrations (LAS) in scorpion family Vaejovidae (Scorpiones: Chactoidea)

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"... The tactile delights of precise delineation, the silent paradise of the camera lucida, and the precision of poetry in taxonomic description represent the artistic side of the thrill which accumulation of new knowledge, absolutely useless to the layman, gives its first begetter."

Vladimir Nabokov interview,
Wisconsin Studies in Contemporary Literature, 1967, 8(2).

Summary

The discovery of a new structure on the laterobasal aspect of the telson aculeus is described here for the first time. This structure, termed the *laterobasal aculear serrations* (LAS), is a row of minute denticles located on each side of the aculeus base, found exclusively in scorpion family Vaejovidae, thus potentially providing a new synapomorphy for this New World family. The LAS structure of major representative vaejovid genera and *Vaejovis* groups is illustrated with SEM micrographs. Also provided is a comprehensive list of non-vaejovid Recent scorpion genera examined where the LAS structure was found to be absent.

Introduction

In this contribution we describe and illustrate for the first time a new scorpion structure, termed the *laterobasal aculear serrations* (LAS), a minute serrated row located on each side of the base of the scorpion's aculeus. Results presented in this paper show that the LAS structure is only found in the New World scorpion family Vaejovidae, implying that this structure may be an important taxonomic character.

Needless to say, the telson, where scorpion's toxic gland resides, with its spectacular "stinger" (aculeus) has always received a very close attention in literature—and not only in the important studies of toxic gland anatomy (Pavlovsky, 1913). Historically, external anatomy of the telson has provided a number of important taxonomic characters in scorpions, e.g. commonly found parallelisms such as subaculear tooth/tubercle (protuberance), or rare synapomorphies such as enigmatic male glands in some *Hadrurus* and *Hoffmannihadrurus* (Williams, 1970) and some Bothriuridae (Sissom, 1990). Granulation, carination, coloration, setation patterns, size, and the shape of telson, vesicle/aculeus ratio, aculeus curvature all are standard descriptive characters in scorpion systematics (Sissom, 1990), although functional/selective role of such variation in scorpion's most important "working end" has rarely if ever been addressed. In addition, sexual dimorphism is often quite prominent in telson anatomy, so that in some Chactoidea (e.g. Euscorpiidae) and Scorpionoidea (e.g. Hemiscorpiinae) adult males are readily diagnosed by their exaggerated vesicle.

However, it appears that a minute in size but important diagnostic feature (which has a good chance to be a family-level synapomorphy) has been simply overlooked in the scorpion family Vaejovidae.

In this study we have analyzed 80 vaejovid species, spanning all genera and *Vaejovis* groups, using both SEM and regular microscopy. In most cases, multiple species of a genus and specimens per species were examined in order to determine whether this curious LAS structure was found exclusively in Vaejovidae. Inline with this hypothesis, we also analyzed non-vaejovid specimens from over 70 genera representing all parvorders, superfamilies, and families in Recent scorpions in order to determine if the LAS structure was indeed absent in non-vaejovid scorpions. During this study, over 140 SEM images of the telson aculeus, with or without the LAS structure, were obtained and analyzed.

Methods & Material

The discovery of the LAS is a byproduct of an ongoing reevaluation of the diagnostic characters used in scorpion systematics today, with much of this effort being conducted through SEM microscopy. The use of SEM microscopy has been invaluable in this re-evaluation as evidenced by the recent discovery of the *constellation array* sensilla in all scorpions (Fet et al., 2006a, 2006b) as well as the detailed description of key diagnostic characters in the definition of vaejovid tribe Stahnkeini (Soleglad & Fet, 2006). In the same fashion, the LAS structure was first discovered using SEM microscopy. Since that first discovery, in addition to further SEM analysis, we were able to study this structure using a regular dissection microscope (80x magnification being quite adequate). Regular microscopy was used to accumulate much of the statistical data presented in this paper.

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 pedipalp chelal carinae and finger dentition follows that described and illustrated in Soleglad & Sissom (2001).

SEM microscopy

To investigate the scorpion telson, the structures were sonicated in water, and then 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 Scanning Electron Microscope at Marshall University, Huntington, 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: AMNH, American Museum of Natural History, New York, New York, USA; BH, Personal collection of Blaine Hébert; BMNH, British Museum of Natural History, London, England; CAS, California Academy of Sciences, San Francisco, California, USA; FMNH, Field Museum Natural History, Chicago, Illinois, USA; GL, Personal collection of Graeme Lowe, Philadelphia, Pennsylvania, USA; MES, Personal collection of Michael E. Soleglad, Borrego Springs, California, USA; MHNG, Muséum d'Histoire Naturelle de Genève, Geneva, Switzerland; NHMW, Naturhistorisches Museum Wien, Vienna, Austria; USNM, United States National Museum, Smithsonian Institution, Washington, D.C., 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 material was examined for analysis and/or illustrations provided in this paper. In particular, for family Vaejovidae all genera and *Vaejovis* species groups were examined including many species per genus as well as multiple specimens per species. In these cases, statistical data for the LAS structure was gathered. For other Recent scorpions, all families were examined, including most major genera, but in general, only one species per genus was studied. The LAS structure was *not* detected in any of these cases.

Superfamily Pseudochactoidea

Pseudochactidae: *Pseudochactas ovchinnikovi* Gromov, 1998, Babatag, Uzbekistan, 2 ♀ (VF).

Superfamily Buthoidea

Buthidae: *Alayotityus nanus* Armas, 1973, El Cobre, Santiago de Cuba Province, Cuba, ♀ (VF); *Androctonus bicolor* Ehrenberg, 1828, Lhav, Israel, ♂ (MES); *Anomalobuthus rickmersi* Kraepelin, 1900, Bukhara, Uzbekistan, 1 ♂ 1 ♀ (VF); *Buthacus macrocentrus* (Ehrenberg, 1828), Abu Dhabi, United Arab Emirates, ♂ (VF); *Buthus occitanus* Amoreux, 1789, Casablanca, Morocco, (MES); *Centruroides exilicauda* (Wood, 1863), Cabo San Lucas, Baja California Sur, Mexico, ♀ (MES); *Centruroides suffusus* (Pocock, 1902), Durango, Mexico, ♂ (VF); *Compsobuthus matthiesseni* (Birula, 1905), Baghdad, Iraq, ♀ (VF); *Grosphus hirtus* Kraepelin, 1901, Tamatave Province, Perinet, Madagascar, ♀ (MES); *Hottentotta minax* (L. Koch, 1875), Eritrea, ♂ (VF); *Isometrus maculatus* (DeGeer, 1778), Vaite Pava, Makatea, French Polynesia, ♂ (USNM); *Leiurus quinquestriatus* (Ehrenberg, 1828), Saudi Arabia, ♀ (VF), Negev, Israel, ♀ (VF); *Liobuthus kessleri* Birula, 1898, Chardara, Kazakhstan, ♀ (VF); *Lychas* sp., Indonesia, ♀ (VF); *Lychas mucronatus* (Fabricius, 1798), Hanoi, Vietnam, ♀ (VF); *Mesobuthus caucasicus* (Nordmann, 1840), Chardara, Kazakhstan, ♀ (VF); *Mesobuthus eupeus* (C.L. Koch, 1839), Kzyl-Orda, Kazakhstan, ♀ (VF); *Microbuthus* sp., Rusail, Oman, ♂ (GL); *Microtityus jaumei* Armas, 1974, San Juan

Botanical Garden, Santiago de Cuba Province, (VF); *Orthochirus gromovi* Kovařík, 2004, Repetek, Turkmenistan, ♀ (VF); *Parabuthus* sp., Kenya, ♀ (VF); *Polisius persicus* Fet, Capes et Sissom, 2001, Zahedan, Iran, ♂ (USNM); *Razianus zarudnyi* (Birula, 1903), Gachsaran, Fars, Iran, ♀ (USNM); *Rhopalurus junceus* (Herbst, 1800), Sibanicú, Camagüey, Cuba, ♀ (VF); *Tityus nematochirus* Mello-Leitão, 1940, Bucaramango, Colombia, ♂ (MES); *Uroplectes vittatus* (Thorell, 1876), Doddiebum, Zimbabwe, ♂ (VF).

Microcharmidae: *Microcharmus hauseri* Lourenço, 1996, Lokobe Natural Reserve, Île Nosy Be, Madagascar, holotype ♂ (MHNG).

Superfamily Chaeriloidea

Chaerilidae: *Chaerilus variegatus* Simon, 1877, Indonesia, ♂ (MES); *Chaerilus celebensis* Pocock, 1894, Mapur Island, Indonesia, juvenile ♀ (VF).

Superfamily Iuroidea

Caraboctonidae: *Caraboctonus keyserlingi* Pocock, 1893, Chile, ♂ (MES); *Hadruroides charcasus* (Karsch, 1879), Peru, ♀ (MES); *Hadruroides maculatus* (Thorell, 1876), Huancayo, Peru, ♀ (MES); *Hadrurus concolorous* Stahnke, 1969, Santa Rosalía, Baja California Sur, Mexico, ♀ (MES); *Hadrurus obscurus* Williams, 1970, Pinyon Mountain, ABDSP, California, USA, ♂ (MES); *Hoffmannihadrurus aztecus* Pocock, 1902, Tehuacán, Puebla, Mexico, ♂ (MES).

Iuridae: *Calchas nordmanni* Birula, 1899, Anamur, Turkey, ♂ (NHMW); *Iurus dufoureius* (Brullé, 1832), Turkey, ♂ (MES).

Superfamily Scorpionoidea

Bothriuridae: *Bothriurus araguayae* Vellard, 1934, Minas Gerais, Brazil, ♀ (VF); *Bothriurus burmeisteri* Kraepelin, 1894, Gobernador Costa, Chubut, Argentina, ♂ (VF); *Brachistosternus ehrenberghii* (Gervais, 1841), Lima, Peru, ♀ (VF); *Centromachetes pocockii* (Kraepelin, 1894), Lebu, Arauco, Chile, ♀ (VF); *Cercophonius squama* (Gervais, 1843), Engadine, Sidney, Australia, ♀ (VF); *Lisposoma josehermana* Lamoral, 1979, Waterberg, Namibia, subadult ♀ (CAS); *Phoniocercus pictus* Pocock, 1893, Valdivia, Ñancul, Fundo El Linque, Chile, ♀ (VF); *Urophonius granulatus* Pocock, 1898, Chile, (VF).

Hemiscorpiidae: *Cheloctonus* sp., St. Lucia, Kwazulu, Natal, South Africa, ♀ (VF); *Hadogenes troglodytes* (Peters, 1861), Johannesburg, South Africa (MES); *Heteroscorpion goodmani* Lourenço, 1996, Reserve Naturelle Integrale d'Andohahela, Toliara Province, Madagascar, ♂ paratype (FMNH); *Liocheles australasiae* (F., 1796), Bangor, Java, Indonesia, ♀ (VF); *Liocheles karschii* (Keyserling, 1885), Guadalcanal, Solomon Islands, ♂ (MES); *Opisthacanthus lepturus* (Beauvois, 1805), Aguacate, Panama, ♀ (MES).

Scorpionidae: *Bioculus comondae* Stahnke, 1968, Loreto, Baja California Sur, Mexico, ♂ (MES), La Paz, Baja California Sur, Mexico, ♂ (VF); *Didymocentrus leseurii* (Gervais, 1844), Martinique, ♀ (VF); *Heterometrus longimanus* (Herbst, 1800), Mindanao, Philippines, ♂ (MES); *Nebo hierichonticus* (Simon, 1872), Haifa, Israel, ♀ (VF); *Opistophthalmus wahlbergii* (Thorell, 1876), Kalahari Gemsbock Park, Twee Rivieren, South Africa, ♂ (VF); *Pandinus imperator* (C. L. Koch, 1841), ♀ (MES); *Scorpio maurus* Linnaeus, 1758, Tel-Yezucham, Israel, ♀ (MES), Agadir, Morocco, ♀ (VF); *Urodacus manicatus* (Thorell, 1876), Australia, (VF).

Superfamily Chactoidea

Chactidae: *Anuroctonus pococki pococki* Soleglad et Fet, 2004, San Dimas Canyon, Los Angeles County, California, USA ♀ (AMNH); *Anuroctonus pococki bajae* Soleglad et Fet, 2004, ABDSP, California, USA, ♂ (MES), ♂ (VF); *Belisarius xambeui* Simon, 1879, Vall d'en Bas, Girona, Catalunya, Spain, ♀ (VF); *Broteochactas porosus* Pocock, 1900, Mt. Roraima, Venezuela, ♂ paratype (BMNH); *Brotheas granulatus* Simon, 1877, Grande Île, French Guiana, ♂ (MES); *Chactas exsul* (Werner, 1939), Darién, Panama, ♂ (MES); *Hadrurochactas schaumii* (Karsch, 1880), Petite Île, French Guiana, ♂ (MES); *Neochactas delicatus* (Karsch, 1879), Grande Île, French Guiana, ♂ (MES); *Nullibrotheas allenii* (Wood, 1863), Cabo San Lucas, Baja California Sur, Mexico, (MES); *Teuthraustes oculatus* Pocock, 1900, Latacunga, Ecuador, ♀ (WDS); *Uroctonus mordax mordax* Thorell, 1876, Yosemite National Park, California, USA, 1 ♂ 1 ♀ (MES), Weott, California, USA, ♂ (MES); *Uroctonus mordax pluridens* Hjelle, 1972, Santa Clara Co., California, USA, ♂ (MES); *Vachoniochactas* sp., Alto Rio Mavaca, Amazonas, Venezuela, ♂ (CAS).

Euscorpiidae: *Alloscorpiops lindstroemii* (Thorell, 1889), Tak Province, Umphang, Thailand, ♀ (CAS); *Chactopsis insignis* Kraepelin, 1912, Loreto, Peru, ♀ (MNHN); *Euscorpiops* sp. Doi Sutep, Thailand, ♀ (WDS); *Euscorpius flavicaudis* (DeGeer, 1778), Banyuls, France, ♀ (MES); *Euscorpius gamma* Caporiaco, 1950, Postojna, Slovenia, ♀ (VF); *Euscorpius italicus* (Herbst, 1800), Agarone, Ticino, Switzerland, ♂ (MES); *Euscorpius mingrelicus* (Kessler, 1874), Batumi, Georgia, ♂ (MES); *Euscorpius sicanus* (C. L. Koch, 1837), Spilia, Mt. Ossa, Greece, ♀ (VF); *Megacormus gertschi* Díaz Nájera, 1966, Las Vigas, Veracruz, Mexico, ♂ (MES); *Neoscorpiops tenuicauda* (Pocock, 1894), Maharashtra, Bhimashankar, India, ♂ (CAS); *Plesiochactas dilutus* (Karsch, 1881), Portillo Nejapa, Oaxaca, Mexico, ♂ (AMNH); *Scorpiops* sp., Landeur, India, ♀ (USNM); *Troglocormus willis* Francke, 1981, Cueva de la Llorona, Yerbabuena, Tamaulipas, Mexico, ♀ (WDS).

Superstitioniidae: *Superstitionia donensis* Stahnke, 1940, Chariot Canyon, ABDSP, California, USA, ♀ (MES).

Vaejovidae: *Franckeus minckleyi* (Williams, 1968), Cuatro Ciénegas, Coahuila, Mexico, 1 ♂ 2 ♀ (CAS); *Franckeus peninsularis* (Williams, 1980), San Raymundo, Baja California Sur, Mexico, 3 ♂ 1 ♀ paratypes (CAS); *Paravaejovis pumilis* (Williams, 1970), Ciudad Constitución, Baja California Sur, Mexico, 16 ♂ 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 et Allred, 1965), San Bernardino Co., California, USA, 1 ♀ 1 ♂ (VF); *Paruroctonus boreus* (Girard, 1854), Mercury, Nevada, USA, ♂ (MES); *Paruroctonus borregoensis* Williams, 1972, Palo Verde Wash, ABDSP, California, USA, ♂ (MES), ♀ (VF); *Paruroctonus gracilior* (Hoffmann, 1931), Cuatro Ciénegas, Coahuila, Mexico, 12 ♂ 1 ♀ (MES); *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, 10 ♂ 4 ♀ (MES), ♂ (VF); *Paruroctonus stahnkei* (Gertsch et Soleglad, 1966), Mesa, Maricopa Co., Arizona, USA, ♂ (MES), ♀ (VF), La Paz Co., Arizona, USA, ♂ (VF); *Paruroctonus surensis* Williams et Haradon, 1980, Las Bombas, Baja California Sur, Mexico, 2 ♂ (MES); *Paruroctonus utahensis* (Williams, 1968), Samalayuca, Chihuahua, Mexico, ♂ (MES), Kermit, Winkler County, Texas, USA, 1 ♀ 1 ♂ (VF); *Paruroctonus ventosus* Williams, 1972, El Socorro, Baja California, Mexico, ♀ topotype (MES); *Paruroctonus xanthus* (Gertsch et Soleglad, 1966), Algodones Dunes, Imperial Co., California, USA, ♂ (GL); *Pseudouroctonus andreas* (Gertsch et Soleglad, 1972), Chariot Canyon, ABDSP, California, USA, 6 ♂ 1 ♀ (MES); *Pseudouroctonus angelenus* (Gertsch et Soleglad, 1972), Ventura Co., California, USA, ♂ (BH); *Pseudouroctonus apacheanus* (Gertsch et Soleglad, 1972), Pinaleno Mt., Arizona, USA, ♀ (VF); *Pseudouroctonus iviei* (Gertsch et Soleglad, 1972), Little French Creek, Trinity Co., California, USA, 1 ♀ 1 ♂ (MES); *Pseudouroctonus minimus castaneus* (Gertsch et Soleglad, 1972), Vista, California, USA, ♂ (MES); *Pseudouroctonus minimus thompsoni* (Gertsch et Soleglad, 1972), Santa Cruz Island, Santa Barbara Co., California, USA, 2 ♀ 2 ♂ (GL); *Pseudouroctonus reddelli* (Gertsch et Soleglad, 1972), Gem Cave, Conal Co., Texas, USA, 2 ♀ 2 ♂ (MES); *Serradigitus adcocki* (Williams, 1980), Isla Cerralvo, Baja California Sur, Mexico, ♀ (CAS); *Serradigitus baueri* (Gertsch, 1958), West San Benito Island, Baja California, Mexico, ♂ (CAS); *Serradigitus calidus* (Soleglad, 1974), Cuatro Ciénegas, Coahuila, Mexico, ♀ paratype (MES); *Serradigitus gertschi gertschi* (Williams, 1968), Chariot Canyon, ABDSP, California, USA, 2 ♀ (MES); *Serradigitus gertschi striatus* (Hjelle, 1970), Coloma, California, USA, ♀ (VF); *Serradigitus joshuaensis* (Soleglad, 1972), Indian Gorge, ABDSP, California, USA, ♀ (MES), Cottonwood Springs, Joshua National Monument, California, USA, 11 ♀ topotypes (MES); *Serradigitus littoralis* (Williams, 1980), Isla Danzante, Baja California Sur, Mexico, ♀ (CAS), Isla Smith (Coronado), Baja California, Mexico, ♀ (VF); *Serradigitus minutis* (Williams, 1970), Cabo San Lucas, Baja California Sur, Mexico, ♀ (MES); *Serradigitus torridus* Williams et Berke, 1986, Nine Mile Canyon Rd., Kern Co., California, USA, 2 ♀ (GL); *Serradigitus wupatkiensis* (Stahnke, 1940), Wupatki National Monument, Coconino Co., Arizona, USA, ♀ topotype (MES); *Smeringurus aridus* (Soleglad, 1972), Palo Verde Wash, ABDSP, California, USA, 1 ♂ 1 ♀ (MES); *Smeringurus grandis* (Williams, 1970), Oakies Landing, Baja California, Mexico, ♂ (MES); *Smeringurus mesaensis* (Stahnke, 1957), Palo Verde Wash, ABDSP, California, USA, 5 ♀ 11 ♂ (MES); *Smeringurus vachoni immanis* (Soleglad, 1972), 1000 Palms, Riverside Co., California, USA, ♀ (MES); *Smeringurus vachoni vachoni* (Stahnke, 1961), San Bernardino Co., California, USA, ♀ (VF); *Stahnkeus deserticola* (Williams, 1970), Saratoga Springs, Death Valley, California, USA, ♀ (MES); *Stahnkeus harbisoni* (Williams, 1970), Oakies Landing, Baja California, Mexico, ♀ (MES); *Stahnkeus subtilimanus* (Soleglad, 1972), Split Mountain, ABDSP, California, USA, 2 ♀ (MES); *Syntropis macrura* Kraepelin, 1910, Los Aripes, Baja California Sur, Mexico, 1 ♂ 3 ♀ (MHNG); *Uroctonites giulianii* Williams et Savary, 1991, Lead Canyon, Inyo Co., California, USA, 1 ♂ 2 ♀ (CAS); *Uroctonites huachuca* (Gertsch et Soleglad, 1972), Huachuca Mountains, Cochise Co., Arizona, USA, 1 ♀ 1 ♂ (MES); *Uroctonites montereus* (Gertsch et Soleglad, 1972), Hastings National History Reservation, Monterey Co., California, USA, ♂ (MES); *Vaejovis bruneus* Williams, 1970, Loreto, Baja California Sur, Mexico, ♂ (MES); *Vaejovis carolinianus* (Beauvois, 1805), Haralson Co., Georgia, USA, 5 ♀ (MES); *Vaejovis cazieri* Williams, 1968, Cuatro Ciénegas, Coahuila, Mexico, ♂ (MES); *Vaejovis coahuilae* Williams, 1968, Cuatro Ciénegas, Coahuila, Mexico, ♂ (MES); *Vaejovis confusus* Stahnke, 1940, Mesa, Maricopa Co., Arizona, USA, ♂ (MES); *Vaejovis davidi* Soleglad et Fet, 2005, Cuelzalan, Puebla, Mexico, ♀ holotype (AMNH); *Vaejovis decipiens* Hoffmann, 1931, Chínipas, Chihuahua, Mexico, ♀ (MES); *Vaejovis diazi* Williams, 1970, Ciudad Constitución, Baja California Sur, Mexico,

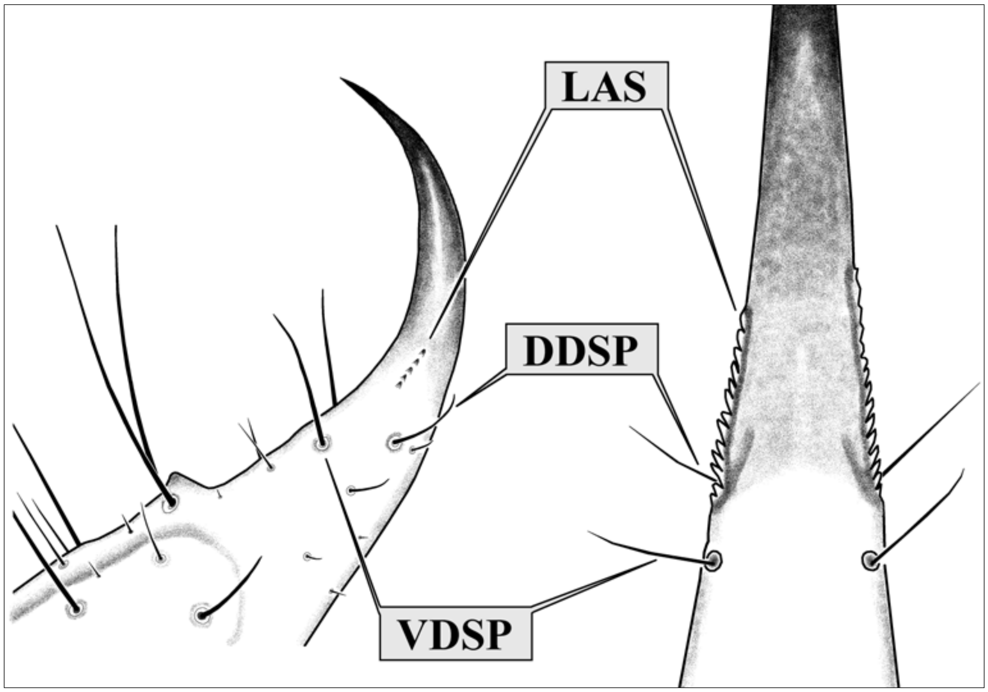


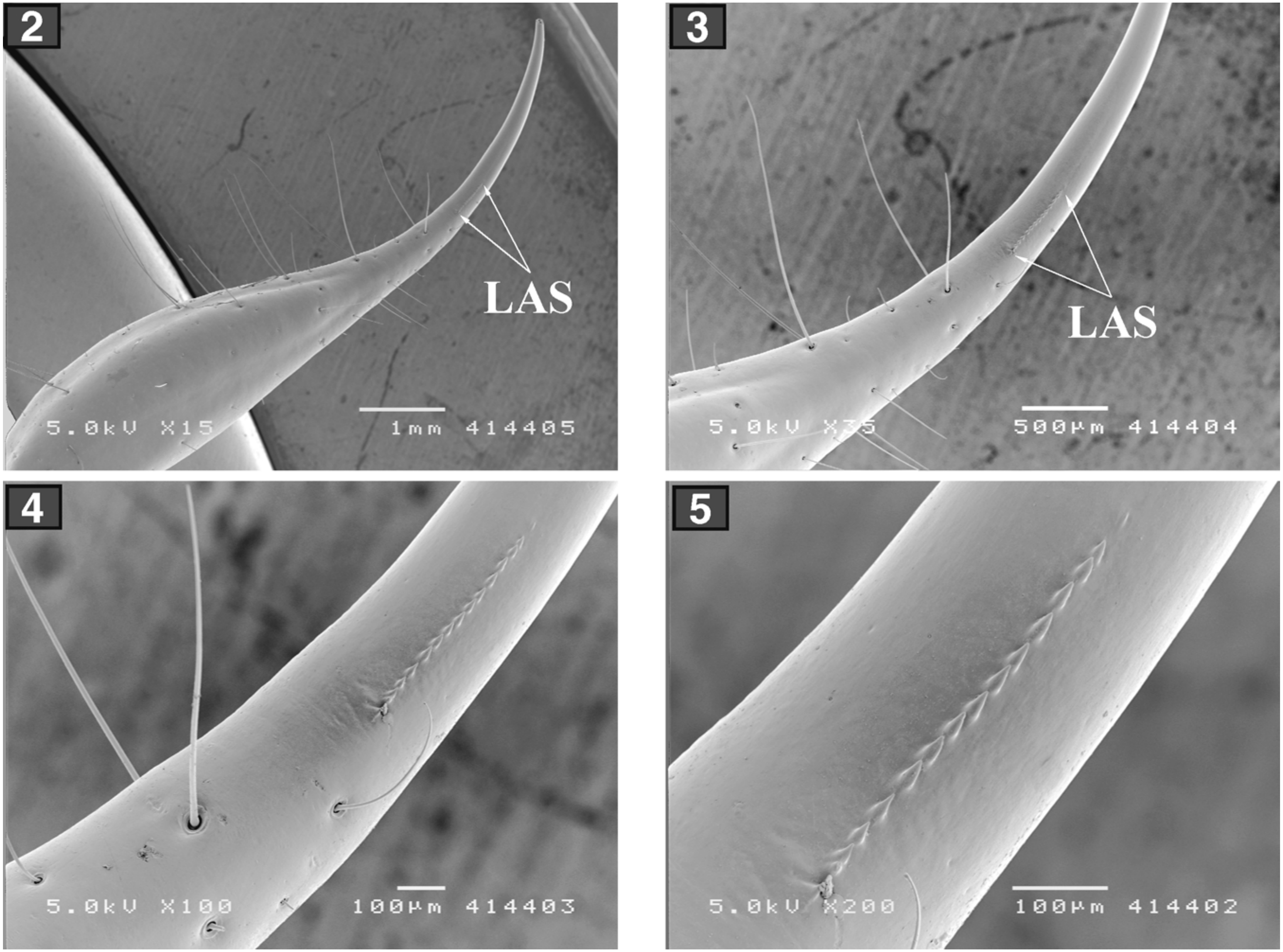
Figure 1: Telson (partial view) of female *Serradigitus joshuaensis* (left), right lateral view, and male *Vaejovis viscainensis* (right), ventral view, showing the position of the Laterobasal Aculear Serrations (LAS) as it relates to landmark setae and aculear pigmentation. VDSP = ventral distal setal pair, DDSP = dorsal distal setal pair.

♀ (MES); *Vaejovis eusthenura* (Wood, 1863), Cabo San Lucas, Baja California Sur, Mexico, ♂ (MES), ♀ (VF); *Vaejovis globosus* Borelli, 1915, Zacatecas, Zacatecas, Mexico, ♀ (MES); *Vaejovis granulatus* Pocock, 1898, Hidalgo, Mexico, ♀ (MES); *Vaejovis gravicaudus* Williams, 1970, Santa Rosalía, Baja California Sur, Mexico, ♀ (MES); *Vaejovis hirsuticauda* Banks, 1910, Indian Gorge Canyon, ABDSP, California, USA, ♀ (MES), Indian Gorge Canyon, ABDSP, California, USA, ♀ (VF); *Vaejovis hoffmanni* Williams, 1970, Rancho Tablón, Baja California Sur, Mexico, 1 ♂ 2 ♀ (MES); *Vaejovis intrepidus cristimanus* Thorell, 1876, Acatlán, Jalisco, Mexico, 2 ♂ (MES); *Vaejovis janssi* Williams, 1980, Isla Socorro, Mexico, 3 ♂ 1 ♀ (MES), 2 ♂ 2 ♀ 4 juv. (CAS); *Vaejovis jonesi* Stahnke, 1940, Sedona, Coconino Co., Arizona, USA, 2 ♀ (MES); *Vaejovis lapidicola* Stahnke, 1940, Williams, Coconino Co., Arizona, USA, ♂ (MES); *Vaejovis magdalensis* Williams, 1971, Los Aripes, Baja California Sur, Mexico, 7 ♂ (MES); *Vaejovis mexicanus* (C. L. Koch, 1836), Aculco, Distrito Federal, Mexico, 2 ♀ (MES), Tlaxcala, Tlaxcala, Mexico, 2 ♂ 2 ♀ (MES); *Vaejovis nigrescens* Pocock, 1898, Pachuca, Hidalgo, Mexico, 2 ♀ (MES); *Vaejovis occidentalis* Hoffmann, 1931, Acapulco, Guerrero, Mexico, ♀ (MES); *Vaejovis paysonensis* Soleglad, 1973, Payson, Arizona, USA, 3 ♀ topotypes (MES); *Vaejovis pococki* Sissom, 1991, Rioverde, San Luis Potosí, Mexico, ♂ (MES); *Vaejovis punctatus* Karsch, 1879, Acatlán, Puebla, Mexico, 11 ♂ 6 ♀ (MES); *Vaejovis punctipalpi* (Wood, 1863), Cabo San Lucas, Baja California Sur, Mexico, ♀ (MES); *Vaejovis puritanus* Gertsch, 1958, Jasper Trail, ABDSP, California, USA, 13 ♂ 1 ♀ (MES); *Vaejovis russelli* Williams, 1971, Deming, Luna Co., New Mexico, USA, ♀ (MES); *Vaejovis solegladi* Sissom, 1991, Cuicitlán, Oaxaca, Mexico, 2 ♀ (MES), Teotitlán, Oaxaca, Mexico, 2 ♀ (MES); *Vaejovis spinigerus* (Wood, 1863), Alamos, Sonora, Mexico, ♀ (MES); *Vaejovis viscainensis* Williams, 1970, Las Bombas, Baja California Sur, Mexico, 8 ♂ 4 ♀ (MES); *Vaejovis vorhiesi* Stahnke, 1940, Huachuca Mountains, Cochise Co., Arizona, USA, 2 ♂ 5 ♀ topotypes (MES); *Vaejovis waeringi* Williams, 1970, Indian Gorge Canyon, ABDSP, California, USA, ♂ (MES); *Vejovoidus longiunguis* (Williams, 1969), Las Bombas, Baja California Sur, Mexico, 4 ♂ 8 ♀ (MES).

Results and Discussion

Laterobasal Aculear Serrations (LAS): its location and structure

The LAS structure is composed of a row of minute denticles located on each side of the laterobasal aspect of the telson aculeus (Fig. 1). The LAS occurs in the region where the aculeus starts narrowing and darkening in color, its surface becoming shiny, always just distal of the ventral and dorsal distal setal pairs (VDSP and DDSP) found on the aculeus base. In addition, just preceding, or sometimes at the LAS base, ventrally we see a wrinkled area in the aculeus cuticle (see Figs. 6–9, 11–13, 14, 16–17, 19–20, 22). These denticles, situated in a straight line essentially parallel with the aculeus, are



Figures 2–5: Laterobasal Aculear Serrations (LAS), right lateral view, *Vejovoidus longiunguis*, female, Viscaino Desert, Baja California, Mexico. **2 & 3.** Showing LAS general location on lateromedial aspect of telson aculeus. **4 & 5.** Successive closeups of LAS. Note the distal position of the LAS with respect to the ventral distal setal pair (VDSP) and dorsal distal setal pair (DDSP) (readily visible in Fig. 4), see Fig. 1 for orientation of these setal pairs.

Vaejovidae Species	LAS: Right/Left	Vaejovidae Species	LAS: Right/Left
Vejovoidus, Smeringurus, Paruroctonus, Paravaejovis		***Vaejovis* "eusthenura" group and *Syntropis***	
***Vejovoidus longiunguis* * (S)**	9–21 (11.833) [24]	***Vaejovis coahuilae***	4/6
***Smeringurus aridus* (S)**	traces of 2	***V. confusus* (S)**	9/7
S. grandis	1/1, 2/2, 3/3, 3/3	***V. diazi* (S)**	6/5, 7/6, x_6
***S. mesaensis* * (S)**	4–10 (7.406) [32]	***V. eusthenura* (S)**	8/7, 5/6
S. v. immanis	4/x	***V. globosus* (S)**	6/4, 2/3
***Paruroctonus arnaudi* (S)**	9/11, 12/11, 13/12	***V. gravicaudus* (S)**	8/9, 3/4
P. arenicola nupides	6/6	***V. hoffmanni***	6/5, 6/7, 4/7
P. bantai saratoga	2/2, 3/3	***V. punctatus* * (S)**	2–8 (4.727) [33]
***P. becki* (S)**	5/5, 8/8	***V. puritanus* * (S)**	3–12 (7.714) [28]
***P. boreus* (S)**	4/4, 7/x	***V. spinigerus* (S)**	4/x, 5/3, 7/5, x/3
P. borregoensis	7/8	***V. viscainensis* * (S)**	6–15 (9.385) [26]
***P. gracilior* * (S)**	4–9 (6.240) [25]	***V. vittatus* (S)**	7/x
P. hirsutipes	ABSENT	***V. waeringi* (S)**	6/11, 5/7
***P. luteolus* (S)**	7/6, 6/7	***Syntropis macrura***	5/6, 10/8, 6/7, 3/3
***P. silvestrii* * (S)**	1–10 (6.643) [28]	***Franckeus* and *Vaejovis* "nigrescens" group**	
P. stahnkei	6/7	***Franckeus minckley***	9/8, 7/5, 6/5
***P. surensis* (S)**	9/8, 11/10, 8/12	***F. pennisularis***	8/7, 3/4, 5/6, 3/3
***P. ventosus* (S)**	14/10, 10/11	***Vaejovis davidi***	ABSENT
***P. utahensis* (S)**	5/6, 3/4	***V. decipiens***	ABSENT
P. xanthus	1/1	***V. janssi***	x/2, 3/5, 5/4, 7/6, 7/9, 2/4
***Paravaejovis pumilis* * (S)**	1–7 (4.306) [36]	***V. nigrescens***	traces of 2
Stahnkeus* and *Serradigitus		***V. pococki***	ABSENT
Stahnkeus deserticola	4/x	***V. solegladi***	ABSENT
S. harbisoni	2/5	***Vaejovis* "mexicanus" group**	
S. subtilimanus	1/1, 4/3	***Vaejovis carolinianus***	2/x
Serradigitus adcocki	2/1	***V. granulatus* (S)**	3/2
S. baueri	5/6	***V. jonesi***	5/5, 4/5
S. calidus	5/4	***V. lapidicola***	3/3
***S. gertschi* (S)**	7/6, 10/11	***V. mexicanus***	ABSENT
***S. joshuaensis* * (S)**	3–8 (5.409) [22]	***V. paysonensis***	7/5, 8/7, 4/5
***S. littoralis* (S)**	3/3, 4/4	***V. vorhiesi* ***	1–7 (5.000) [14]
S. minutis	6/7	***Pseudouroctonus* and *Uroctonites***	
S. torridus	4/4, 5/5	***Pseudouroctonus andreas* * (S)**	2–5 (3.643) [14]
S. wupatkiensis	5/5	***P. angelenus***	2/x
***Vaejovis* "punctipalpi" group**		***P. apacheanus* (S)**	ABSENT
V. bruneus	6/7	***P. iviei***	ABSENT
***V. cazieri* (S)**	4/4, 4/5	***P. minimus castaneus***	traces x/3
***V. hirsuticauda* (S)**	7/9, 8/x	***P. minimus thompsoni***	3/2, 4/3, 3/3
V. intrepidus	4/7, 4/5	***P. reddelli***	3/x
***V. magdalensis* * (S)**	4–8 (5.357) [14]	***Uroctonites guiliani***	ABSENT
V. occidentalis	ABSENT	***U. huachuca* (S)**	ABSENT
V. punctipalpi	4/5	***U. montereus***	ABSENT
V. russelli	8/10		

Table 1: Laterobasal Aculear Serrations (LAS) statistics for family Vaejovidae showing number of denticles per lateral surface. Although numbers were determined from ventral view of telson, right/left delineation is from a dorsal perspective. * Indicates species where larger number of specimens were examined thus a min/max (mean) [number of samples] is provided (see Table 2 for additional data). Note, each side of the aculeus is considered a sample. (S) = LAS presence/absence verified with SEM.

quite minute in size; individual denticles are between 17 and 36 micrometers in length. An individual denticle is shaped as a rounded tooth basally narrowing distally into a point, angled approximately 35 degrees from the surface of the aculeus, pointing towards the aculeus tip (Figs. 30–33). The longest line of denticles, found in *Vejovoidus longiunguis* (Figs. 2–5) whose aculeus is quite long and slender, was less than 0.5 mm in length and consisted of 14 serrated denticles. Since the LAS is positioned in the area where the aculeus starts darkening, we see that the base of the denticle row is darkened as well, giving a somewhat overall pigmented look to the LAS.

The composition and spacing of individual denticles is quite variable. There are cases where the individual denticles are densely organized basally and then the spacing becomes larger at the distal aspect, sometimes the most distal denticle being quite separated from the previous ones (Fig. 22). Individual denticles are sometimes smaller basally, or they can be irregularly doubled as seen in Fig. 33 for *Paruroctonus ventosus*.

It must be stressed here that the LAS structure does not necessarily occur at the same relative position on the aculeus. Instead, its location is consistently at the region where the narrowing and darkening of the aculeus occurs, and is always distal of the VDSP and DDSP,

Species/Genders	Number of Denticles in LAS
Paravaejovis pumilis	1-7 (4.306) (±1.238) [36] {3.068-5.544}→ 0.288
Males	2-7 (4.500)
Females	1-4 (3.333)
Vejovoidus longiunguis	9-21 (11.833) (±3.031) [24]{8.802-14.865}→ 0.256
Males	10-21 (13.500)
Females	9-16 (11.000)
Smeringurus mesaensis	4-10 (7.406) (±1.720) [32]{5.686-9.126}→ 0.232
Males	5-10 (7.944)
Females	4-9 (6.875)
Paruroctonus gracilior	4-9 (6.240) (±1.332) [25] {4.908-7.572}→ 0.213
Males	4-9 (6.261)
Females	6 (6.000)
Paruroctonus silvestrii	1-10 (6.643) (±2.264) [28] {4.379-8.907}→ 0.341
Males	1-10 (6.350)
Females	5-8 (7.375)
Vaejovis viscainensis	6-15 (9.385)(± 2.210) [26]{7.174-11.595}→ 0.236
Males	6-15 (9.944)
Females	6-12 (8.125)
Vaejovis punctatus	2-8 (4.727) (±1.506) [33] {3.222-6.233}→ 0.319
Males	2-8 (5.190)
Females	2-6 (3.917)
Vaejovis puritanus	3-12 (7.714) (±1.630) [28] {6.085-9.344}→ 0.211
Males	3-12 (7.579)
Females	9-10 (9.500)
Vaejovis magdalensis	4-8 (5.357) (±1.277) [14] {4.080-6.635}→ 0.238
Males	4-8 (5.357) [14]
Females	-
Serradigitus joshuaensis	3-8 (5.409) (±1.368) [22] {4.041-6.777}→ 0.253
Males	-
Females	3-8 (5.409)
Vaejovis vorhiesi	1-7 (5.000) (±1.569) [14] {3.431-6.569}→ 0.314
Males	5-7 (5.500)
Females	1-7 (4.800)
Pseudouroctonus andreas	2-5 (3.643) (±0.745) [14] {2.898-4.388}→ 0.204
Males	2-5 (3.583)
Females	4 (4.000)

Table 2: Statistical data of the number of denticles in the Laterobasal Aculear Serrations (LAS) structure for select species of family Vaejovidae spanning major genera and *Vaejovis* groups. Statistical data group = minimum-maximum (mean) (±SDEV) [N] {mean-SDEV – mean+SDEV} → coefficient of variability (i.e., SDEV/mean).

whose location is also dependent on the aculeus narrowing. Therefore, for those species with long thin aculeus with little curving (e.g., *Vejovoidus longiunguis*), the LAS occurs more "mid-stinger" (Figs. 2–5). However, on short highly curved stinger scorpions (e.g., *Pseudouroctonus andreas*), the LAS is located towards the distal tip, just where the aculeus abruptly curves.

LAS statistical analysis

The LAS is found on both males and females as well as on juveniles, even instar-2 individuals. There is no indication that the number of denticles per lateral side increases as a scorpion matures. For example, in *Smeringurus mesaensis*, the largest denticle number (for one side of the LAS) encountered was ten, found both on adults and instar-2 juveniles. In some groups, as indicated elsewhere, we noticed that the LAS structure was more prevalent in juveniles, sometimes not visible in the limited number of adults examined. Although one detects gross trends in the number of denticles across the various vaejovid groups, the number of denticles is quite variable within a species even specimens from the same locality (see Tables 1 and 2). The number of denticles per LAS side exhibits asymmetry in many cases, the largest mismatch encountered was five in *Vaejovis viscainensis* (LAS denticle numbers 7/12).

Table 2 presents statistical data on the number of denticles in the LAS for twelve vaejovid species. From these data, it is immediately apparent that there is great variability in the number of denticles within a species, reflecting relatively large standard deviations and coefficients of variability. In many of the species we see that males exhibit on an average higher LAS denticle numbers than females, showing a 14.6 to 35.0 % higher number (based on comparison of the means).

The largest LAS denticle number was found in a male *Vejovoidus longiunguis* exhibiting 19/21, with the species averaging 11.833 [24]. *Vaejovis viscainensis* exhibited the next highest number, a male with 15/12, and an average of 9.385 [26]. Although these two species are medium to large in size, we also see somewhat high LAS denticle numbers in the smaller species: *Paruroctonus surensis*, males 11/10 and 8/12, and *P. ventosus*, a male with 14/10. As expected, however, some of the smaller species in Vaejovidae do exhibit somewhat small LAS denticle numbers, *Pseudouroctonus andreas* with an average of 3.643 [14], *Serradigitus joshuaensis* with numbers ranging 3 to 8, and *S. littoralis* with 3 to 4.

We calculated the average length of an individual LAS denticle by dividing the length of the LAS row by the number of denticles found in that row (note, this length includes the spacing between denticles which can be variable). Species with the largest average individual denticle are *Smeringurus mesaensis* (35.5 micrometers) and *Vejovoidus longiunguis* (32.6), and species with the smallest average denticle are *Pseudouroctonus andreas* (17.0) and *Paruroctonus ventosus* (20.8). Across the family, the denticle row length ranged 68–456 (184.67) [30] micrometers and the length of an individual denticle (including spacing) ranged 17–35.5 (25.98) [30] micrometers.

LAS trends within Vaejovidae

Table 1 presents a complete synopsis of LAS denticle numbers for all vaejovid species analyzed in this study. In many cases, multiple specimens were examined, and for those cases where larger numbers of specimens were examined, we show the statistical data group as stated in Table 2. The species in Table 1 are organized in established and/or presumed related genera and/or *Vaejovis* groups.

For genera *Vejovoidus*, *Smeringurus*, *Paruroctonus*, and *Paravaejovis* (Figs. 2-13, 30-31, 33), we detected the LAS structure in all examined species except for *Paruroctonus hirsutipes* (the latter based on a single specimen), in total 21 species. Genus *Vejovoidus* had the largest number of LAS denticles among all species examined, with a standard deviation range of 9–15 (Figs. 2–5, 7). Interestingly, the LAS development was somewhat reduced in the large species genus *Smeringurus*, with only *S. mesaensis* exhibiting somewhat average to high numbers, with a standard deviation range of 6–9 (Fig. 9). Other *Smeringurus* species, especially *S. aridus* and *S. vachoni*, showed highly reduced LAS structures in some specimens, and it was absent in others. *S. grandis* consistently exhibited LAS denticles but in small numbers, 1–3. Species of *Paruroctonus*, especially where multiple specimens were available, had a well developed LAS structure with numerous denticles (Figs. 8, 10–13). The lithophiles *P. arnaudi*, *P. ventosus*, and *P. surensis* had somewhat high numbers of 9–13, 10–14, and 8–12, respectively. For two species of *Paruroctonus*, we calculated statistical data from multiple specimens providing standard deviation ranges of 5–8 for *P. gracilior* and 4–9 for *P. silvestrii*. The small monotypic genus *Paravaejovis* also exhibited a well developed LAS structure (Fig. 6) with a standard deviation range of 3–6.

All species examined in tribe Stahnkeini (12 species) had the LAS structure (Figs. 1, 18–19, 27, 32) spanning a somewhat moderate denticle number ranging 1–11, the highest number being found in *Serradigitus gertschi striatus*. We provide statistical data on a series of specimens of *S. joshuaensis* (Tab. 2), one of the smallest species in Vaejovidae, showing a standard deviation range of 4–7. Interestingly, the larger species of the genus *Stahnkeus* and of *Serradigitus adcocki* had somewhat small LAS denticle numbers, ranging from 1 to 5 in the material examined.

We examined eight species in the *Vaejovis* “punctipalpi” group where the LAS structure was found in all species except for *V. occidentalis* (based on the examination of a single adult) (Figs. 20–21, 29). The LAS structure development (determined by its number of denticles) is a little more pronounced in this *Vaejovis* group than in tribe Stahnkeini, exhibiting numbers 4–10 (5.677) [31]. For the species *V. magdalensis* we examined several specimens which had a standard deviation range of 4–7.

Fourteen species of the *Vaejovis* “eusthenura” group and genus *Syntropis* were examined, all exhibiting the LAS structure (Figs. 14–17, 22–23, 26, 28). The LAS development of this group of species was the same as that seen in the “punctipalpi” group, with LAS denticle numbers ranging from 2–13. The species *Vaejovis viscainensis* (Figs. 1, 22) exhibited the largest number of denticles, otherwise; the number of denticles ranged 2–11. Of these species, *V. viscainensis* is a psammophile, exhibiting some elongation of the pedipalps, metasomal segments and the telson. There seems to be a trend in psammophiles having more developed LAS structures as evidenced in *Vejovoidus*, with the most developed LAS, *Paruroctonus arnaudi* (Fig. 10), and even some of the smaller *Paruroctonus* species, such as *P. ventosus* (Fig. 11) and *P. surensis* (Fig. 12). We calculated statistical data for three species in this group, exhibiting standard deviation ranges of 7–12 for *V. viscainensis*, 3–6 for *V. punctatus*, and 6–9 for *V. puritanus*. For genus *Syntropis*, a lithophile, we see a similarly developed LAS with denticle numbers ranging 3–10 (6.000) [8].

Pseudochactida: Pseudochactoidea
Pseudochactidae: *Pseudochactas ovchinnikovi* **(S)**
Buthida: Buthoidea
Buthidae: *Alayotityus nanus*
Androctonus bicolor
Anomalobuthus rickmersi
Buthacus yotvatensis
Buthus occitanus
Centruroides exilicauda
Centruroides suffusus **(S)**
Compsobuthus matthiesseni
Grosphus hirtus
Hottentotta minax
Isometrus maculatus
Leiurus quinquestriatus **(S)**
Liobuthus kessleri
Lychas sp.
Lychas mucronatus **(S)**
Mesobuthus caucasicus
Mesobuthus eupeus **(S)**
Microbuthus sp.
Microtityus jaumi
Orthochirus gromovi **(S)**
Parabuthus sp.
Polisius persicus
Razianus zarudnyi
Rhopalurus junceus **(S)**
Tityus nematochirus
Uroplectes vittatus
Microcharmidae: *Microcharmus hauseri*
Chaerilida: Chaeriloidea
Chaerilidae: *Chaerilus celebensis* **(S)**
Chaerilus variegatus
Iurida: Iuroidea
Caraboctonidae: *Caraboctonus keyserlingi*
Hadruroides charcasus
Hadruroides maculatus
Hadrurus concolorous
Hadrurus obscurus
Hoffmannihadrurus aztecus
Iuridae: *Calchas nordmanni*
Iurus dufourensis
Iurida: Scorpionoidea
Scorpionidae: *Bioculus comondae* **(S)**
Didymocentrus leseurii
Heterometrus longimanus
Nebo hierichonticus
Opistophthalmus wahlbergi
Pandinus imperator
Scorpio maurus **(S)**
Urodacus manicatus
Hemiscorpiidae: *Cheloctonus* sp.
Liocheles australasiae **(S)**
Liocheles karschii
Hadogenes troglodytes
Heteroscorpion goodmani
Opisthacanthus lepturus
Bothriuridae: *Bothriurus araguayae* **(S)**
Bothriurus burmeisteri
Brachistosternus ehrenberghii
Centromachetes pocockii
Cercophonius squama
Lisposoma josehermana
Phoniocercus pictus
Urophonius paynensis
Iurida: Chactoidea
Chactidae: *Anuroctonus pococki bajae* **(S)**
Anuroctonus pococki pococki
Belisarius xambeui
Brotheas granulatus
Broteochactas porosus
Chactas exsul
Hadrurochactas schaumii
Neochactas delicatus
Nullibrotheas allenii **(S)**
Teuthraustes oculatus
Uroctonus m. mordax **(S)**
Uroctonus m. pluridens
Vachoniochactas sp.
Euscorpiidae: *Alloscorpiops lindstroemii*
Chactopsis insignis
Euscorpiops sp.
Euscorpius flavicaudis
Euscorpius gamma **(S)**
Euscorpius italicus
Euscorpius mingrelicus
Euscorpius sicanus **(S)**
Megacormus gertschi
Neoscorpiops tenuicauda
Plesiochactas dilutus
Scorpiops sp.
Troglocormus willis
Superstitioniidae: *Superstitionia donensis* **(S)**
Vaejovidae: (see Table 1)

Table 3: List of non-vaejovid scorpions where Laterobasal Aculear Serrations (LAS) is *absent*. All parvorders, superfamilies and families are represented (see Table 1 for Vaejovidae). The 73 genera examined are grouped alphabetically. (S) = LAS absence verified with SEM.

Eight species of genus *Franckeus* and the *Vaejovis* “nigrescens” group were examined, among which the two *Franckeus* species and two species of the “nigrescens” group exhibited the LAS structure. In *Franckeus*, we detected well developed LAS, with denticle numbers ranging 3–9 (5.643). For the species *Vaejovis janssi*, only juveniles exhibited the LAS structure, some with somewhat high numbers of denticles (e.g., 7/6, 7/9). For the other “nigrescens” group species the number of specimens examined was quite limited, some only represented by a solitary specimen, and all were adults. Examination of additional species and material is required for these groups, especially small subadults and juveniles.

In the *Vaejovis* "mexicanus" group (seven species examined, Fig. 25) we encountered the LAS structure in all species, except *V. mexicanus*, which was represented by adults only. For the "vorhiesi" subgroup (i.e., *V. vorhiesi*, *V. paysonensis*, and *V. lapidicola*), all somewhat small species, we see moderately developed LAS, with denticle numbers ranging 1–8 (5.091).

For genera *Pseudouroctonus* and *Uroctonites* (ten species examined) we found the LAS structure in five of the species. *Pseudouroctonus andreas* (Fig. 24) had an average of 3.543 denticles (see Tab. 2) and *P. minimus thompsoni*, 2–4 (found only on juveniles). Species *P. angelenus*, *P. reddelli*, and *P. minimus castaneus* exhibited only traces of denticles (2–3). The LAS structure was not found on genus *Uroctonites* but this was based on limited material for two of the species, mostly adults.

Systematic observations

Table 3 provides a list of non-vaejovid scorpions examined in this study that did *not* exhibit the LAS structure. This list includes representatives of all parvorders, superfamilies, and families of Recent scorpions, spanning over 70 genera. Unlike our analysis of family Vaejovidae, we typically only checked a single species of a genus and not all genera are evaluated, especially in family Buthidae. However, in the families belonging to superfamily Chactoidea, where Vaejovidae resides, we examined almost all genera (except family Supersititioniidae). We can conclude from this examination, though not exhaustive, that the LAS structure in all probability ***occurs only in family Vaejovidae.***

We consider this result important since the LAS structure may be a synapomorphy for the family. This conclusion cannot be completely realized until additional material is examined in the *Vaejovis* "nigrescens" and "mexicanus" groups as well as in genera *Pseudouroctonus* and *Uroctonites*. Although we see absence of the LAS in genus *Uroctonites*, additional material must be examined, especially subadults and juveniles. It is clear based on the evidence discussed throughout this paper that the LAS structure does not appear randomly within a species, a species group, or a genus. However, as the statistical analysis also shows, it is highly variable in its number of denticles, and therefore in the length of a denticle row. Due to its very small size, LAS denticles are probably vulnerable to damage or complete destruction due to the scorpion's stinging mechanism, although we know nothing about the LAS function itself. This would explain why it is more observable in juveniles in some of the groups discussed above.

It might also be observed that the vaejovid genera and *Vaejovis* groups where an absence of this structure has been noted (we exclude *Paruroctonus hirsutipes* and *Vaejovis occidentalis* from this discussion since they involve only a single specimen in a genus or group where all other species examined exhibited LAS), all share many important taxonomic characters in family Vaejovidae. The "mexicanus" and "nigrescens" groups, in particular, are certainly closely related, the latter's delineation probably more a product of its lithophilic adaptation than important evolutionary derivations, share the following characters: Chela trichobothria *ib-it* are located basally on the fixed finger, proximal of the last inner denticle (*ID*); chelal palm trichobothrium *Dt* is located proximal of palm midpoint; the genital operculum of the female is separated on the posterior one-fifth; the leg tarsus is equipped with a single pair of ventral distal spinule pairs (with some exceptions in the "mexicanus" group); carapace anterior edge with well developed widely formed indentation; the terminus of the hemispermatophore sperm plug is smooth (after Stockwell, 1989). Genera *Pseudouroctonus* and *Uroctonites* are very closely related, the latter only being diagnosed by "heavier developed" setal pairs on the ventral aspect of leg tarsus, clearly a "character of degree" and probably dubious at best. These two genera share the same characters as the previous two *Vaejovis* groups just discussed, except their leg tarsus is equipped with 2–4 pairs of ventral distal pairs of setae. In addition these two genera have a reduced pectinal tooth count and the ventral median (*V2*) carina of the chela is essentially obsolete.

It is clear from the data presented in this paper that the LAS structure has evolved basally or at least near basally in the family Vaejovidae. Of course, depending on the "final" results of further analysis of the genera and groups discussed above and where the species and/or genera lacking these denticles occur in the topology of the family, will determine whether the LAS structure is a synapomorphy for the family. However, having said this, and based on preliminary cladistic analysis, genus *Uroctonites* does not appear to be a basal taxon in the family and therefore the LAS structure in all likelihood is a synapomorphy for family Vaejovidae.

Other aculear structures

It seems relevant to note here that the basal aculear area, where LAS reside in Vaejovidae, occasionally bears other enigmatic but distinctive, macroscopic structures in scorpions, specifically in the superfamily Chactoidea. One of such structures is an "annular ring" in *Troglocormus*, *Euscorpiops*, and *Alloscorpiops* (Euscorpiidae), found both in males and females (Soleglad & Sissom, 2001, p. 67, figs. 189-191), most prominent in *Alloscorpiops*. Another basal aculear structure is a spectacular inflated "bulb" present in the males of *Anuroctonus* (Chactidae) (Soleglad & Fet, 2004, fig. 20). The functional roles of these structures are not known.

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References

FET, V., M. S. BREWER, M. E. SOLEGLAD & D. P. A. NEFF. 2006a. Constellation array: a new sensory structure in scorpions (Arachnida: Scorpiones). *Boletín de la Sociedad Entomológica Aragonesa*, 38: 269–278.

FET, V. & M. E. SOLEGLAD. 2005. Contributions to scorpion systematics. I. On recent changes in high-level taxonomy. *Euscorpius*, 31: 1–13.

FET, V., M. E. SOLEGLAD, M. S. BREWER, D. P. A. NEFF & M. L. NORTON. 2006b. Constellation array in scorpion genera *Paruroctonus*, *Smeringurus*, *Vejovoidus*, and *Paravaejovis* (Scorpiones: Vaejovidae). *Euscorpius*, 41: 1–15.

(PAVLOVSKY, E. N.) PAWLOWSKY, E. N. 1913. Skorpiotomische Mitteilungen. I. Ein Beitrag zur Morphologie der Giftdrüsen der Skorpione. *Zeitschriift für Wissenschaftliche Zoologie*, 105: 157–177.

SISSOM, W. D. 1990. Systematics, biogeography and paleontology. Pp. 64–160 *in* G. A. Polis (ed.), *Biology of Scorpions*. Stanford, California: Stanford University Press.

SISSOM, W. D. 2000. Family Vaejovidae Thorell, 1876. Pp. 503–552 *in* Fet, V., W. D. Sissom, G. Lowe & M. E. Braunwalder. *Catalog of the Scorpions of the World* (1758–1998). New York, NY: New York Entomological Society, 690 pp.

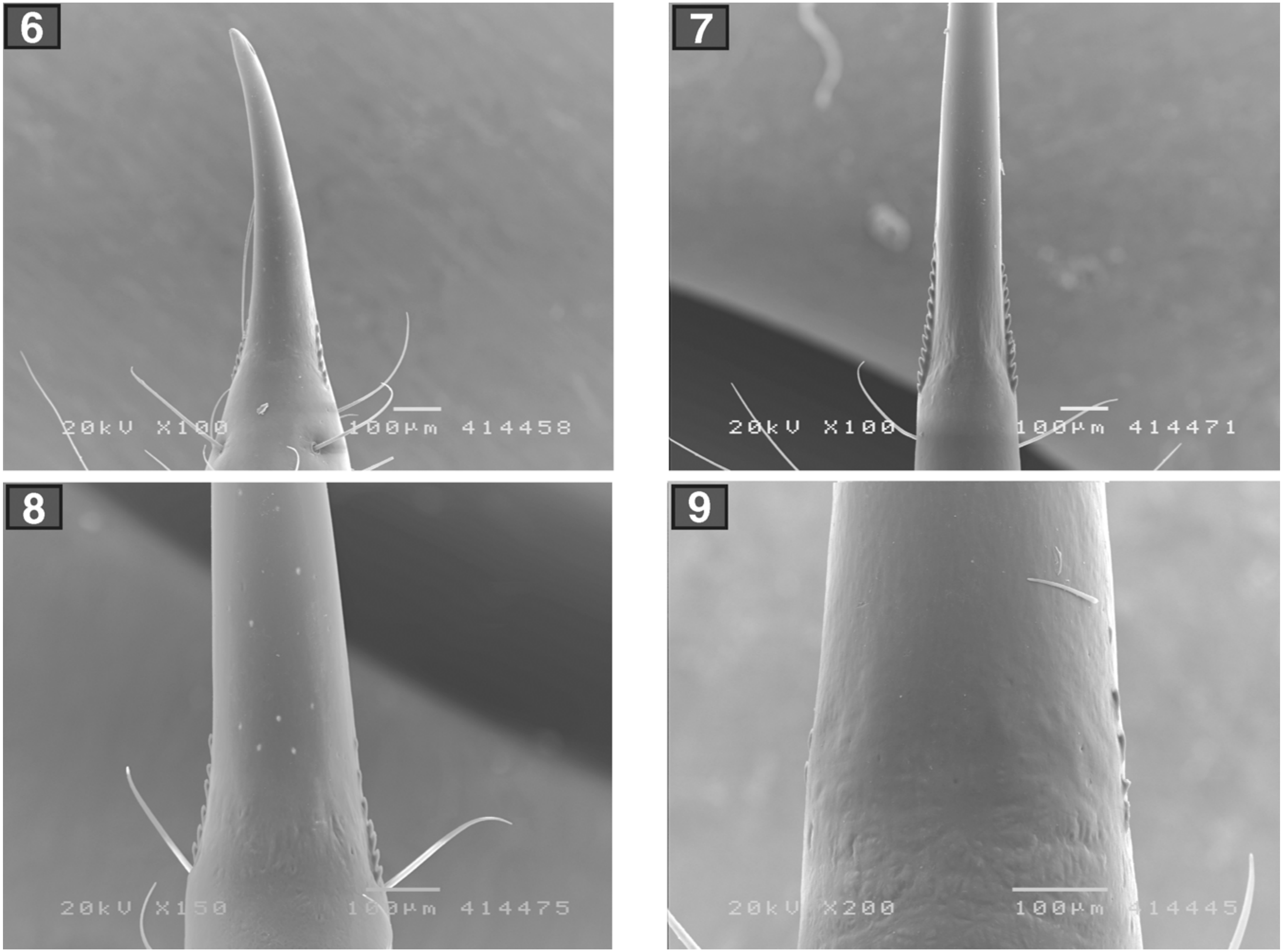
SOLEGLAD, M. E. & V. FET. 2004. The systematics of scorpion subfamily Uroctoninae (Scorpiones: Chactidae). *Revista Ibérica de Aracnología*, 10: 81–128.

SOLEGLAD, M. E. & V. FET. 2006. Contributions to scorpion systematics. II. Stahnkeini, a new tribe in scorpion family Vaejovidae (Scorpiones: Chactoidea). *Euscorpius*, 40: 1–32.

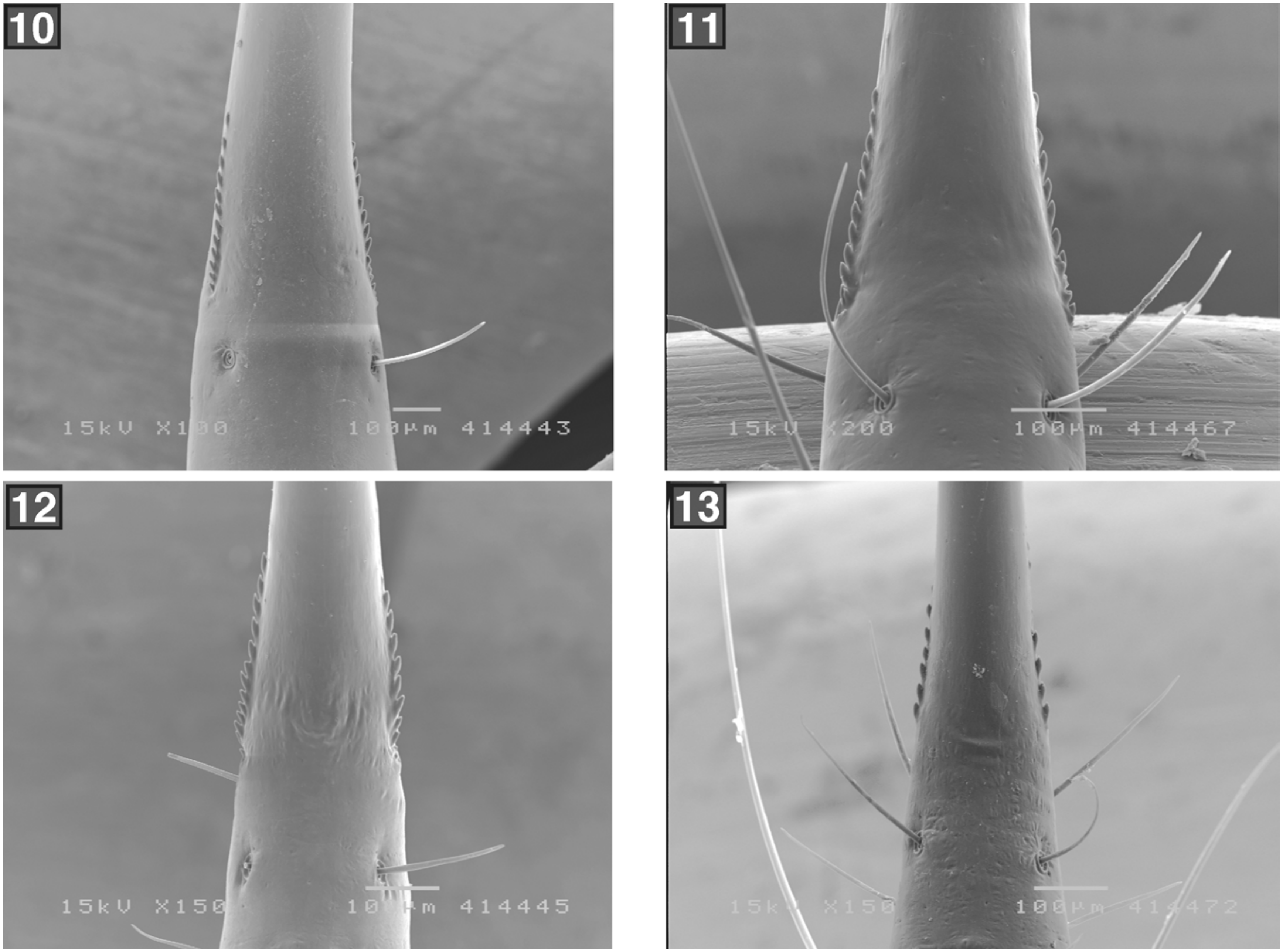
SOLEGLAD, M. E. & W. D. SISSOM. 2001. Phylogeny of the family Euscorpiidae Laurie, 1896: a major revision. Pp. 25–111 *in* Fet, V. & P. A. Selden (eds.). *Scorpions 2001. In memoriam Gary A. Polis*. Burnham Beeches, Bucks: British Arachnological Society.

STOCKWELL, S. A. 1989. *Revision of the Phylogeny and Higher Classification of Scorpions (Chelicerata).* Ph.D. Thesis, University of Berkeley, Berkeley, California. 319 pp. (unpublished). University Microfilms International, Ann Arbor, Michigan.

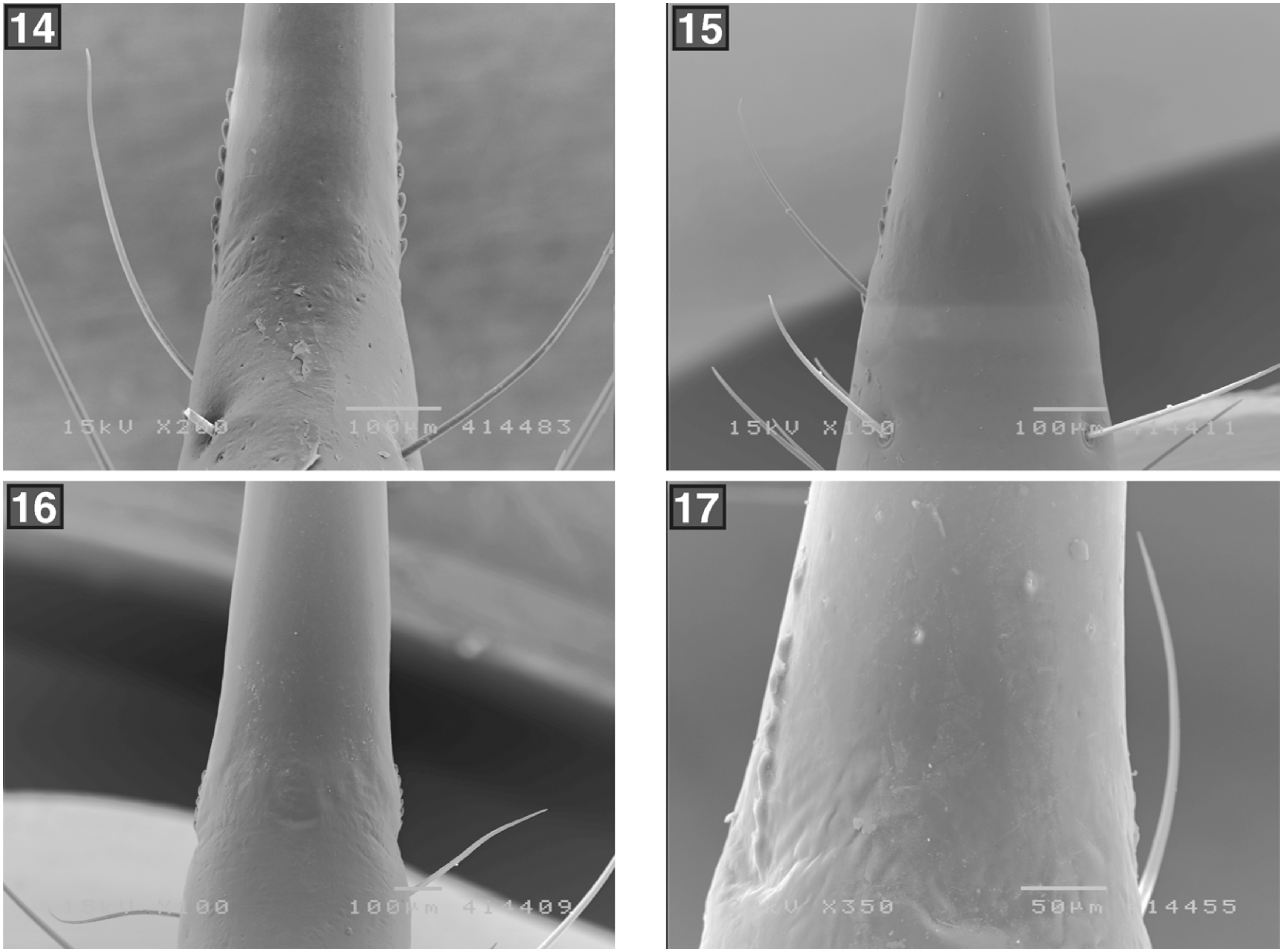
WILLIAMS, S. C. 1970. A systematic revision of the giant hairy scorpion genus *Hadrurus*. *Occasional Papers of the California Academy of Sciences*, 87: 1–62.



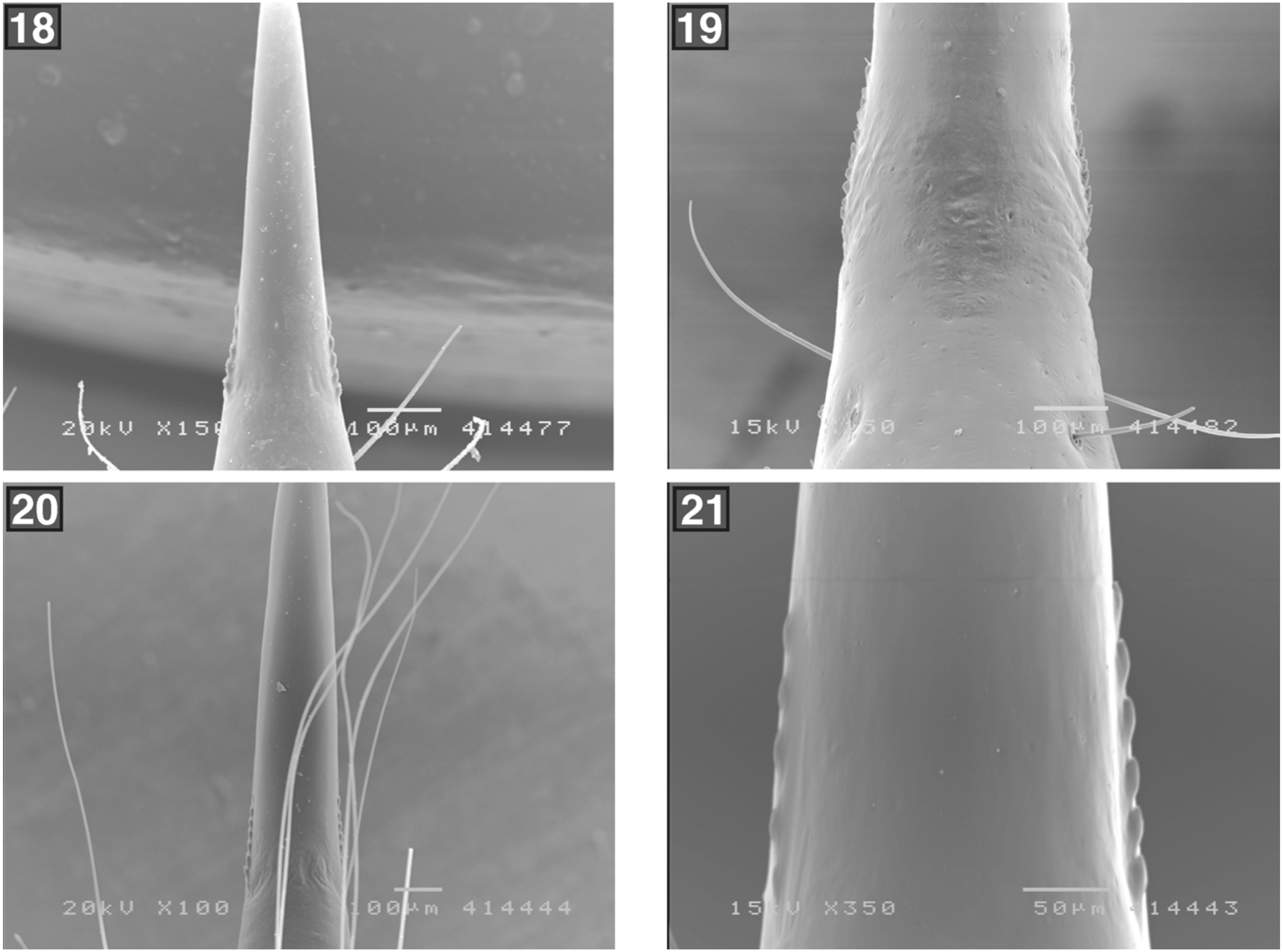
Figures 6–9: Laterobasal Aculear Serrations (LAS), ventral view of aculeus base. **6.** *Paravaejovis pumilis*, male, Ciudad Constitución, Baja California, Mexico. **7.** *Vejovoidus longiunguis*, female, Viscaino Desert, Baja California, Mexico. **8.** *Paruroctonus boreus*, male, Worland, Wyoming, USA. **9.** *Smeringurus mesaensis*, female, Palo Verde Wash, ABDSP, California, USA.



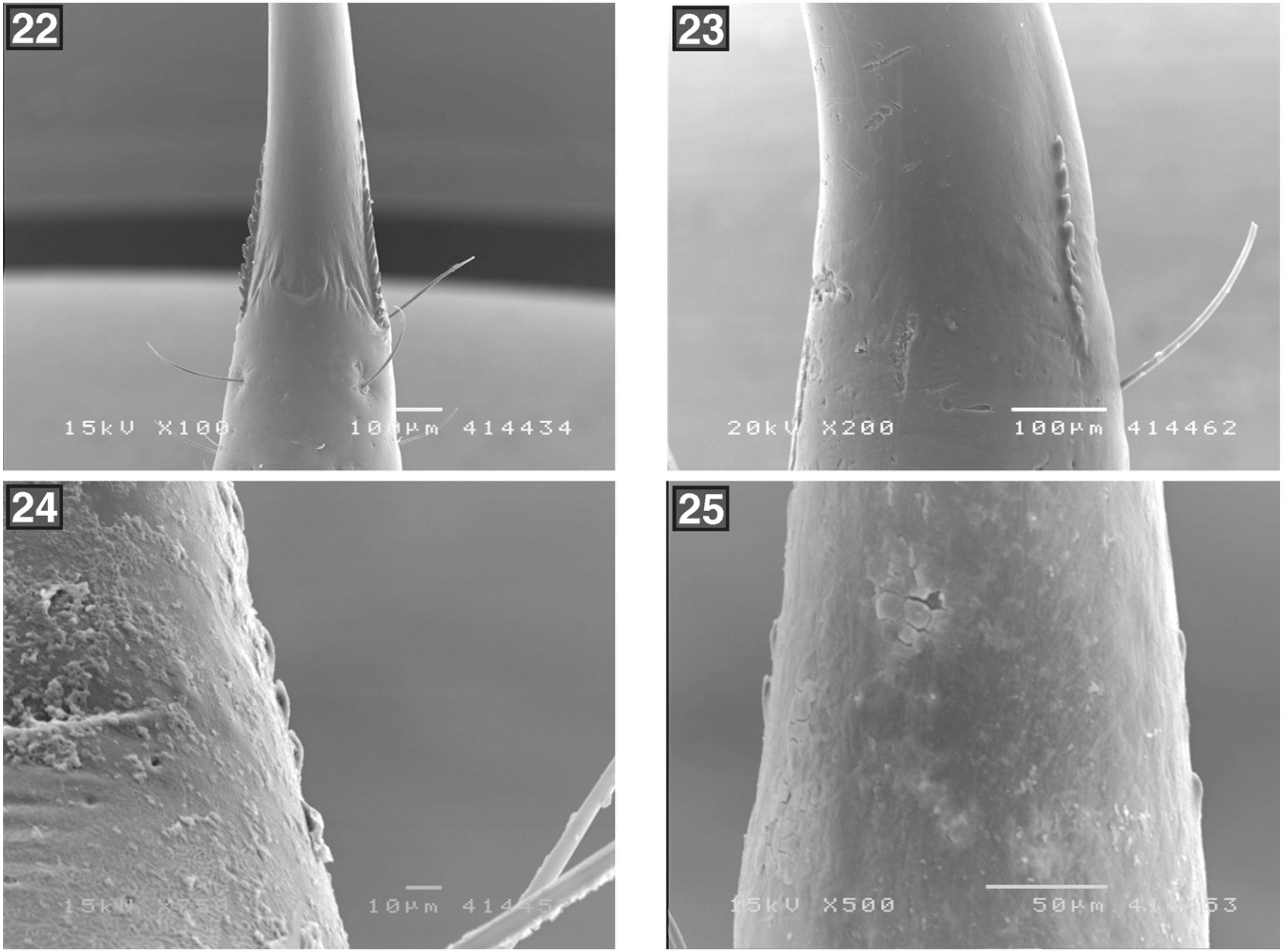
Figures 10–13: Laterobasal Aculear Serrations (LAS), ventral view of aculeus base. **10.** *Paruroctonus arnaudi*, male, El Socorro, Baja California, Mexico. **11.** *Paruroctonus ventosus*, female, El Socorro, Baja California, Mexico. **12.** *Paruroctonus surensis*, male, Las Bombas, Baja California Sur, Mexico. **13.** *Paruroctonus luteolus*, female, Palo Verde Wash, ABDSP, California, USA.



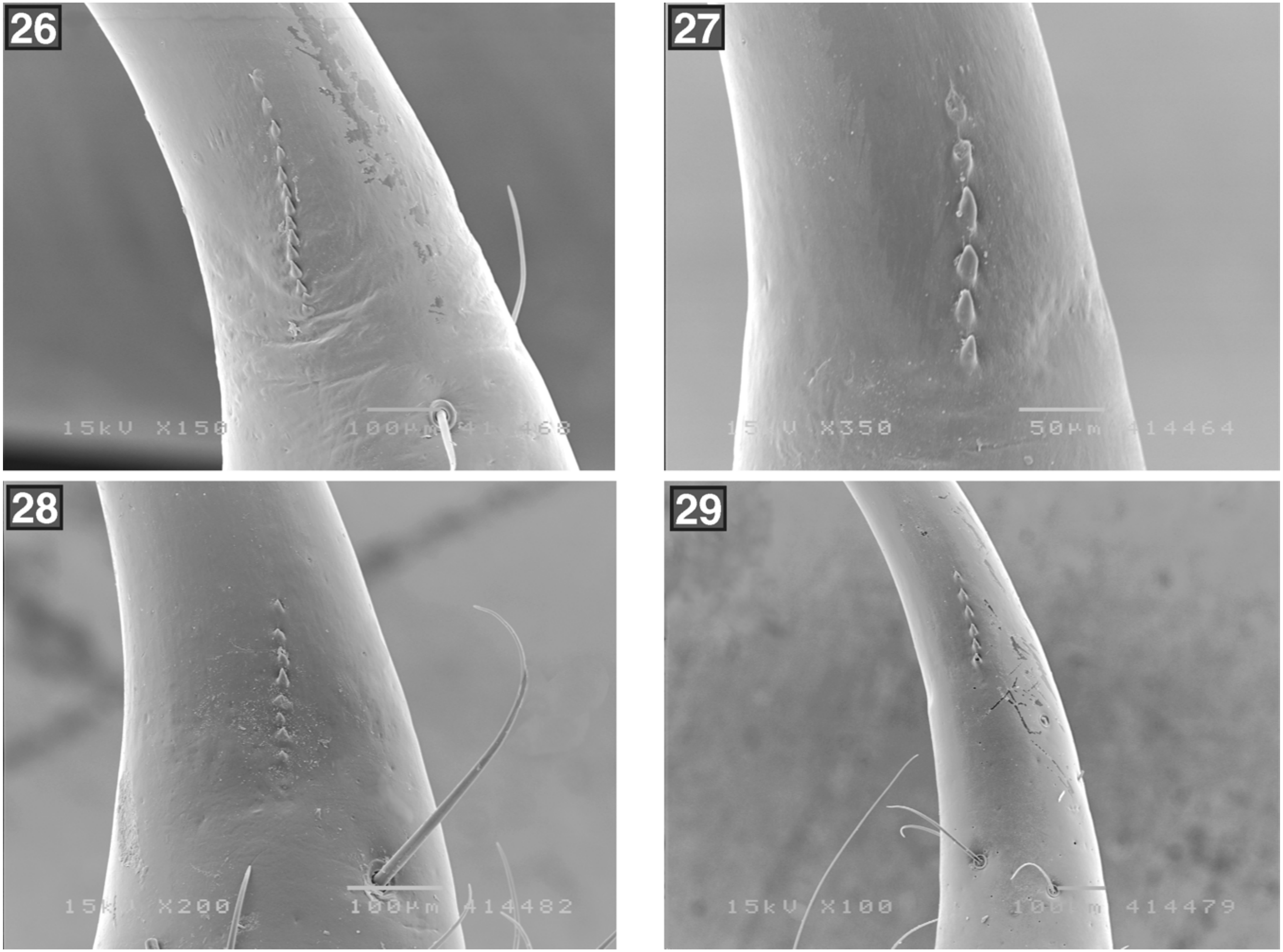
Figures 14–17: Laterobasal Aculear Serrations (LAS), ventral view of aculeus base. **14.** *Vaejovis waeringi*, female, ABDSP, California, USA. **15.** *Vaejovis gravicaudus*, female, Santa Rosalia, Baja California Sur, Mexico. **16.** *Vaejovis punctatus*, male, Acatlan, Puebla, Mexico. **17.** *Vaejovis vittatus*, female, Cabo San Lucas, Baja California Sur, Mexico.



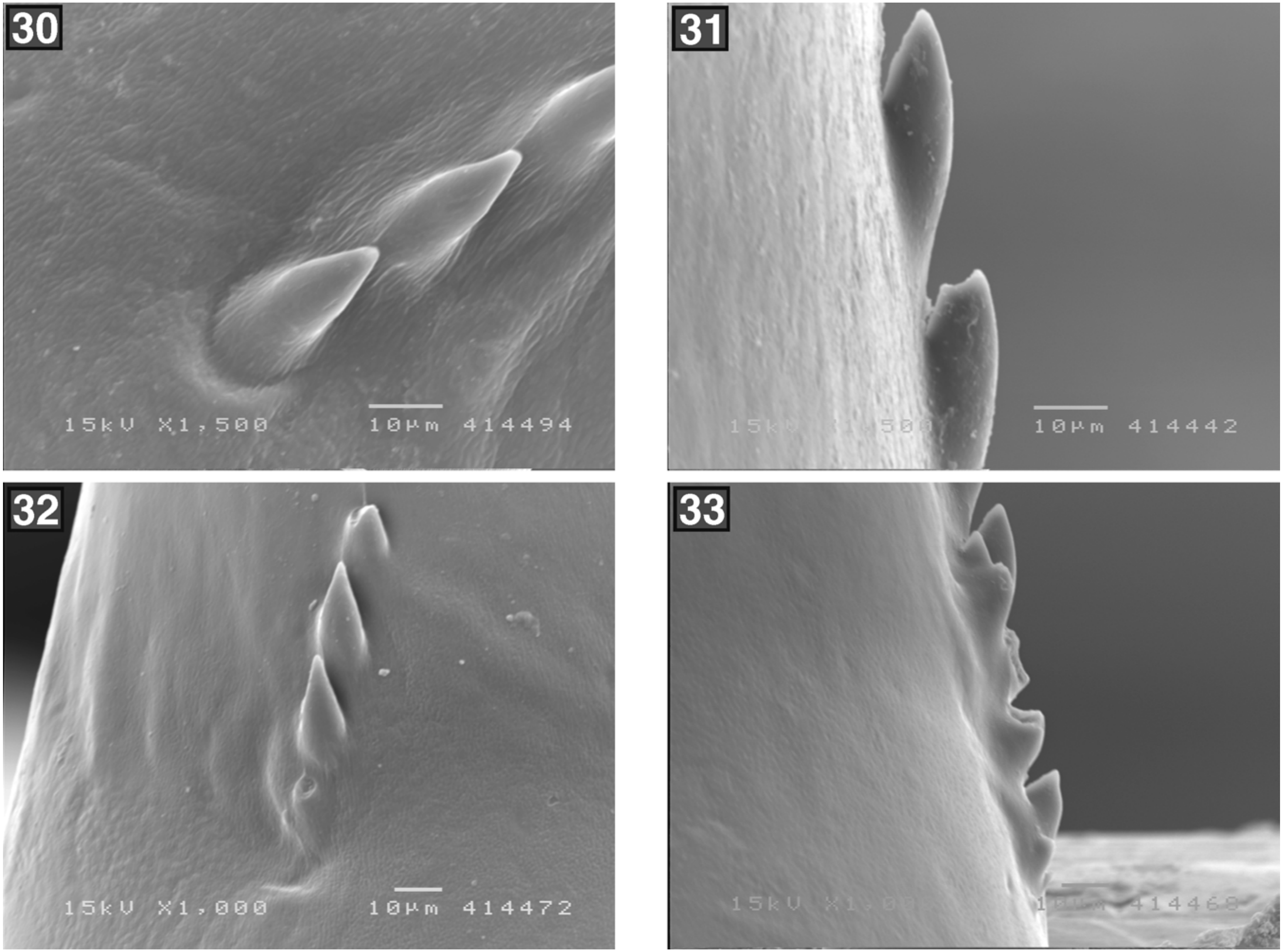
Figures 18–21: Laterobasal Aculear Serrations (LAS), ventral view of aculeus base. **18.** *Serradigitus joshuaensis*, female, ABDSP, California, USA. **19.** *Serradigitus gertschi*, female, San Diego, California, USA. **20.** *Vaejovis hirsuticauda*, female, ABDSP, California. **21.** *Vaejovis magdalensis*, male, Los Aripes, Baja California Sur, Mexico.



Figures 22–25: Laterobasal Aculear Serrations (LAS), ventral view of aculeus base. **22.** *Vaejovis viscainensis*, male, Las Bombas, Baja California Sur, Mexico. **23.** *Vaejovis puritanus*, male, ABDSP, California, USA. **24.** *Pseudouroctonus andreas*, male, Chariot Canyon, ABDSP, California, USA. **25.** *Vaejovis granulatus*, Pachuca, Hidalgo, Mexico.



Figures 26–29: Laterobasal Aculear Serrations (LAS), lateral view of aculeus base. **26.** *Vaejovis waeringi*, male, Indian Gorge Canyon, ABDSP, California, USA. **27.** *Serradigitus gertschi striatus*, female, Coloma, California, USA. **28.** *Vaejovis globosus*, female, Zacatecus, Zacatecus, Mexico. **29.** *Vaejovis magdalensis*, male, Los Aripes, Baja California Sur, Mexico.



Figures 30–33: Closeup of Laterobasal Aculear Serrations (LAS), right lateral view. **30.** *Paruroctonus boreus*, male, Worland, Wyoming, USA. **31.** *Paruroctonus arnaudi*, male, El Socorro, Baja California, Mexico. **32.** *Serradigitus joshuaensis*, female, ABDSP, California, USA. **33.** *Paruroctonus ventosus*, female, El Socorro, Baja California, Mexico, profile view showing *doubling* of some of the denticles.