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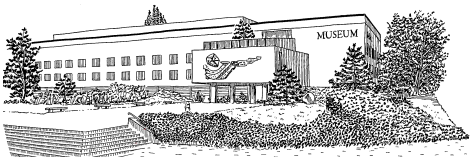

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Trilobites and graptolites from the Vargas Peña Formation (early Silurian), Paraná Basin, eastern Paraguay

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Abstract
Early Silurian trilobites and graptolites from the Vargas Peña Formation of the western Paraná Basin are described. The studied material comes from two successions (San Fernando and Galeano quarries) on the southwestern flank of the Ypacaraí graben, about 30 km southeast of Asunción city, eastern Paraguay. The faunas include *Calymene boettneri* HARRINGTON, *C. harringtoni* TORTELLO sp. nov., *Trimerus* sp., *Dalmanites ypacarayensis* (BALDIS & HANSEN), *Dalmanites* sp., *Guaranites paraguayensis* BALDIS & HANSEN, *Eophacops* sp., *Normalograptus* cf. *ajjeri* (LEGRAND), *N.* aff. *rectangularis* (MCCOY), *Metaclimacograptus* cf. *asejradi* LEGRAND, *Paraclimacograptus innotatus* (NICHOLSON), and *P. brasiliensis* (RUEDEMANN). The taxa recognized suggest a ?late Rhuddanian to late Aeronian/early Telychian age for the Vargas Peña Formation. The graptolites constitute a low diversity, oxygen tolerant fauna that would be indicative of shallow water conditions, an environment that is also supported by the occurrence of the trilobite genus *Trimerus*.

Keywords
Trilobites, Graptolites, early Silurian, Vargas Peña Formation, Paraguay.

I. INTRODUCTION

The Itacurubí Group (HARRINGTON, 1972) documents a ?latest Ordovician-early Silurian transgressive-regressive cycle that took place in the western intracratonic Paraná Basin, eastern Paraguay. The group comprises the siliciclastic Eusebio Ayala, Vargas Peña and Cariy formations (WOLFART, 1961; HARRINGTON, 1972), which are exposed east and southeast of Asunción city. The clay-shales and fine sandstones of the Vargas Peña Formation were deposited during the maximum flooding of the transgressive event and contain abundant marine invertebrates of Malvinokaffric affinity. This formation is represented by a series of isolated outcrops on the southwestern flank of the Ypacaraí graben (Fig. 1), as well as discontinuous, poorly developed exposures in the Colonia Mompox, Itacurubí, and Valenzuela areas (e.g., HARRINGTON, 1972; DEGRAFF *et al*., 1981; DYCK, 1991; BENEDETTO *et al*., 1992).

Macrofossils proved to be useful biostratigraphic tools within the Vargas Peña Formation. HARRINGTON (1950, 1972) originally described the trilobite *Calymene boettneri* HARRINGTON from the type locality of the unit (Galeano quarry =Vargas Peña clay pit, Fig. 1) and assigned it to the *aspera-blumenbachi* group, pointing out the lower Silurian aspect of this species. In addition, BULMAN & TURNER (*in* HARRINGTON, 1950) and TURNER (1959) reported the graptolites *Diplograptus modestus* LAPWORTH and *Climacograptus innotatus brasiliensis* RUEDEMANN from that locality, indicating an early Llandovery ("Valentian") age.

A few years after the pioneer work of HARRINGTON and TURNER, WOLFART (1961) described additional specimens of trilobites (*Calymene* BRONGNIART, *Dalmanites* BARRANDE and *Eophacops* DELO) and graptolites (*Climacograptus innotatus brasiliensis*) from the Vargas Peña Formation. Similarly, RICKARDS *in* COCKS (1972) identified a graptolite assemblage [*Monograptus lobiferus* (M'COY) and *Monograptus* aff. *sedgwickii* (PORTLOCK)] of late Aeronian/early Telychian age, and BALDIS & HANSEN (1980) described in detail new dalmanitids including the endemic genus *Guaranites* BALDIS & HANSEN. The fossil record of the formation also comprises brachiopods, tentaculitids, gastropods, bivalves, hyolitids, cephalopods, conularids and crinoids (HARRINGTON, 1950; WOLFART, 1961; GODOY CIGUEL,

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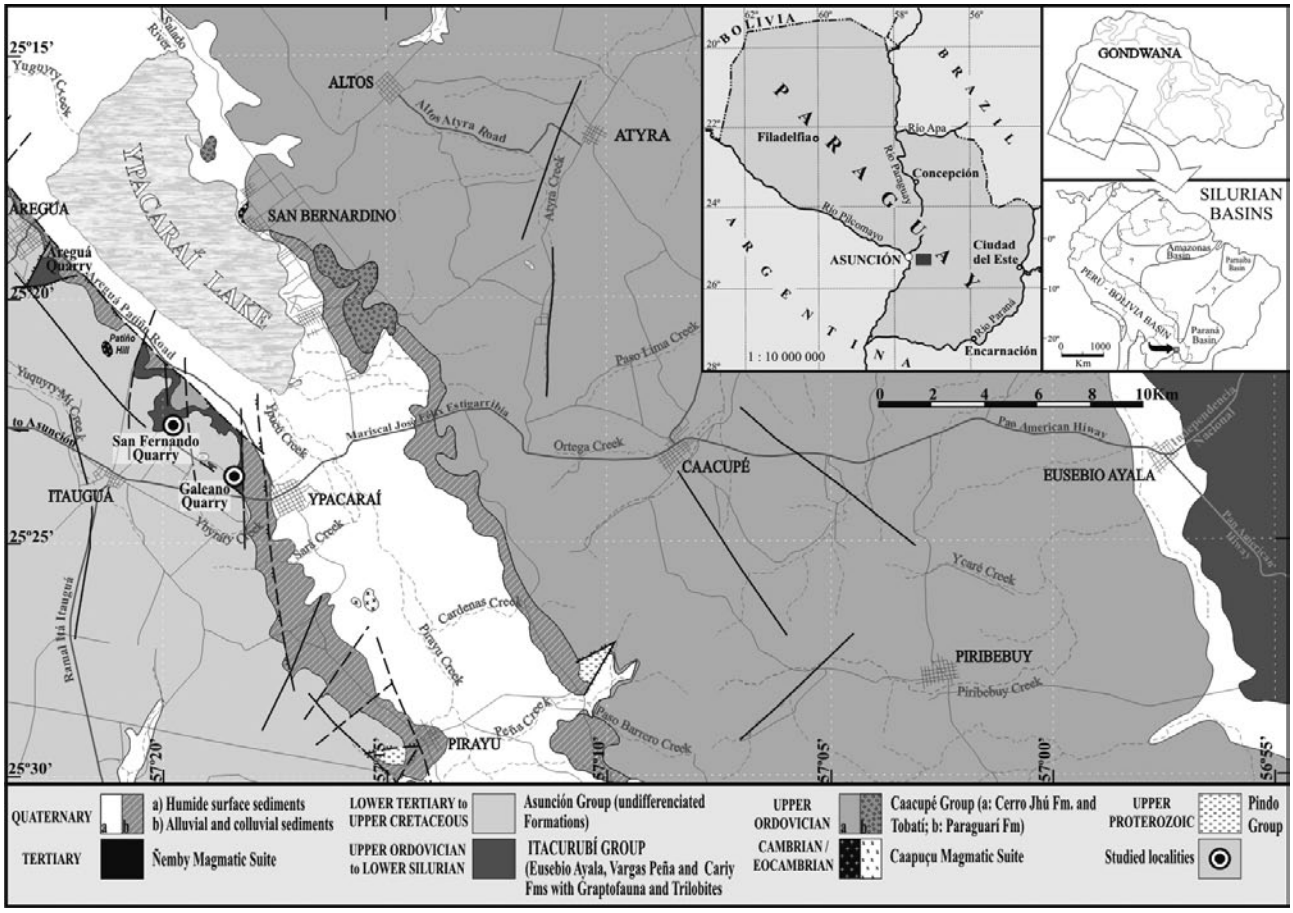

Fig. 1: Location map.

1988; BABCOCK *et al*., 1990; DYCK, 1991; BENEDETTO, 2002), as well as Llandovery organic-walled microfossils (WOOD & MILLER, 1991; GODOY CIGUEL & FERREIRA DAEMON, 1992; GRAY *et al*., 1992; GRAHN *et al*., 2000; GRAHN & GUTIÉRREZ, 2001; MENDLOWICZ MAULLER *et al*., 2004; GRAHN, 2005a).

The above cited studies provided vital information about the palaeontology and biostratigraphy of the Vargas Peña Formation, although there are aspects which still deserve further attention. The trilobite specimens described by HARRINGTON (1950) and WOLFART (1961) are not abundant (e.g., see HARRINGTON, 1950, p. 9) and, like those studied by BALDIS & HANSEN (1980), they lack precise data about their stratigraphic provenance. Similarly, the graptolites examined by BULMAN & TURNER (*in* HARRINGTON, 1950) and TURNER (1959) come from a few, disconnected samples, and are imperfectly preserved (HARRINGTON, 1950, p. 23). URIZ *et al*. (2008) studied a monograptid assemblage from the top of the formation at the San Fernando quarry (Fig. 1), whereas TORTELLO *et al*. (2008a, b) preliminary illustrated some trilobites of that locality. On the basis of new collections, trilobites and graptolites from the Vargas Peña Formation are fully revised herein (excluding the monograptids already described in URIZ *et al*., 2008). The material examined comes from two sections along the western border of the Ypacaraí graben: San Fernando and Galeano quarries (Figs. 1, 2). We update information about the systematics and vertical distribution of their calymenids, dalmanitids, homalonotids and normalograptids, report some graptoloids in the western Paraná Basin for the first time, and give an overview of the stratigraphic and palaeoecologic significance of the faunas.

II. GEOLOGICAL SETTING

The study area is located about 30 km southeast of Asunción city between the villages of Itauguá and Ypacaraí in eastern Paraguay. In this area, the Vargas Peña Formation is mainly composed of soft, little-cemented light gray shales altered to white and yellow clay, in places stained brown, pink and purple because of pigmentation by iron oxide (HARRINGTON, 1950, 1972). These rocks rest on fine-grained micaceous sandstones and red to violet shales of the Eusebio Ayala Formation, and are overlain by yellow to brown micaceous sandstones associated with tempestites of the Cariy Formation. Beds

are affected by secondary faults related to the main fault zone forming the western border of the Ypacaraí graben (HARRINGTON, 1972, p. 50; BALDIS & HANSEN, 1980; DEGRAFF *et al*., 1981). A complete picture of the geology of the area was depicted by HARRINGTON (1950, 1972) and summarized in Fig. 1.

Because of the development of profuse vegetation in the area, the Vargas Peña Formation is better exposed in a series of clay quarries known as San Fernando and Galeano (Figs. 1-3). The San Fernando quarry (=Itauguá quarry *sensu* BALDIS & HANSEN, 1980) (25º22'44''S, 57º19'46''W) is about 2.5 km northeast of San Fernando Ceramics Factory, which is at the km 30.5 of National Route 2. The front of the quarry is characterized by a monotonous succession of white clays c. 55 m thick having trends of N140º-N145º and slight dips of 12º to 20º to SE. Trilobites, graptolites, brachiopods, bivalves, gastropods, and tentaculitids are very abundant in different levels of the section. URIZ *et al*. (2008) reported the monograptid graptolites *Stimulograptus* aff. *sedgwickii* (PORTLOCK), *Monograptus* aff. *priodon* (BRONN) and *?Demirastrites* sp. from the upper part of the quarry, which indicates a late Aeronian/early Telychian age. The succession is underlain by red to purple, thinly bedded mudstones, fine-grained sandstones and clays of the uppermost part of the Eusebio Ayala Formation, in which ?latest Ordovician-Rhuddanian graptolites were recently identified (ALFARO *et al*., 2010), and is overlain by brown to yellowish-brown, micaceous sandstones stratified in tabular layers 20 to 40 cm thick, belonging to the lower part of the Cariy Formation. The outcrop studied is covered by Quaternary deposits.

The Galeano quarry (25º23'29''S, 57º18'27''W) is 2 km northwest of Ypacaraí village, very close to an industrial complex of ovens for brick fabrication (Galeano Factory). This quarry is known by different names in the literature ["Vargas Vila" (HARRINGTON, 1950); "Vargas Peña" (HARRINGTON, 1972; BALDIS & HANSEN, 1980); "locality D1" (WOLFART, 1961); "Santa Teresa" (DEGRAFF *et al*., 1981; GODOY CIGUEL & FERREIRA DAEMON, 1992)]. HARRINGTON (1972, p. 49) designated it as the type locality of the Vargas Peña Formation under the name of "Vargas Peña clay pit", although it is better known these days as Galeano quarry. The existence of a complex system of faults, as well as signs of deterioration caused by erosion processes, makes it difficult to describe the Itacurubí Group in the Galeano quarry. The Eusebio Ayala Formation is represented by 9 to 10 m of purple, ferruginous, fine-grained sandstones and mudstones. Its lower 3 meters contain abundant graptolites (ALFARO *et al.*, 2010), whereas the top is either truncated by erosion or, in some sectors, covered by modern deposits. The

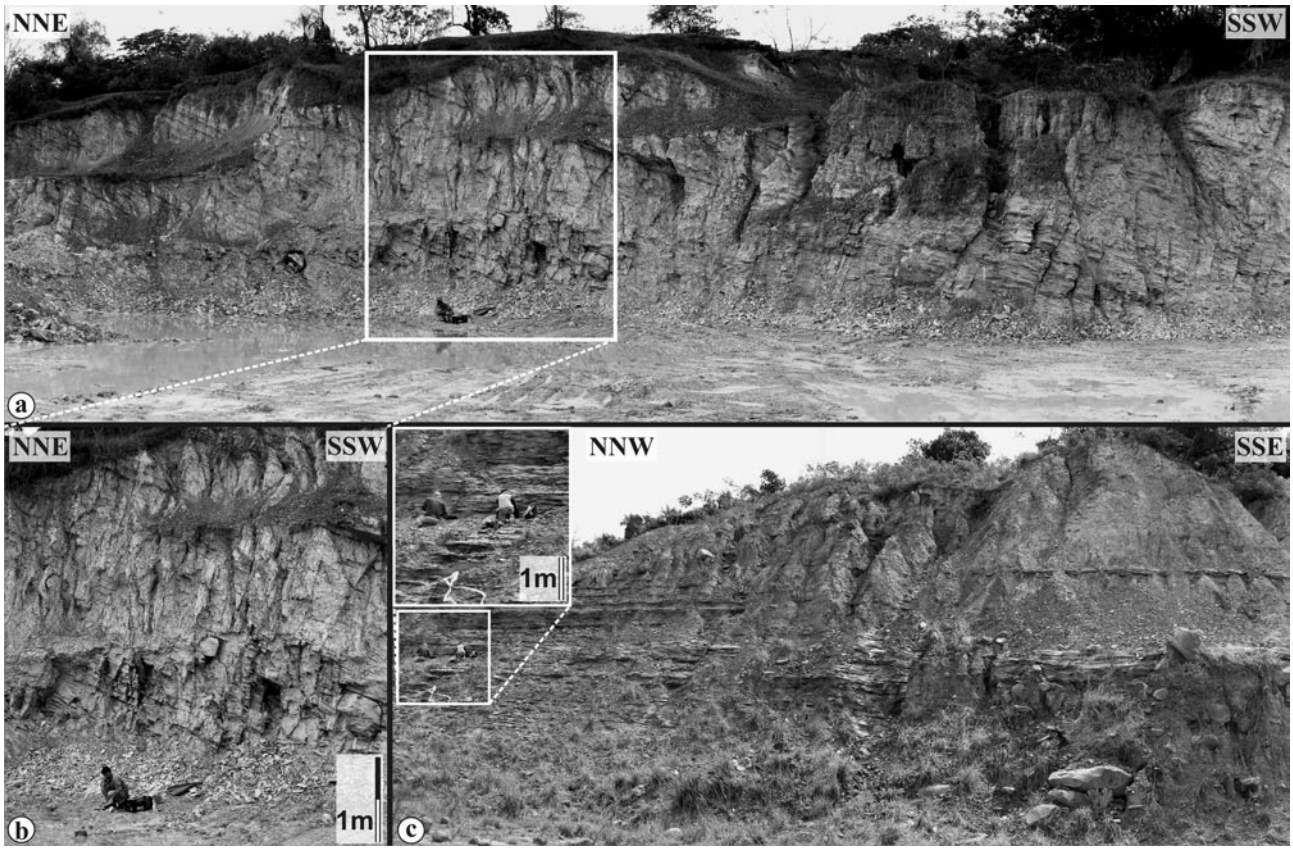

Fig. 2: View of the lower part of the Vargas Peña Formation at the San Fernando (a, b) and Galeano (c) quarries.

Vargas Peña Formation is 18 to 20 m thick and comprises highly fossiliferous, gray to brown shales, with sporadic intercalations of mudstones and fine-grained sandstones in beds 5 to 30 cm thick. The base and the top of the unit are not exposed. Numerous invertebrate fossils previously described from the formation were collected in this section (HARRINGTON, 1950; TURNER, 1959; WOLFART, 1961; BALDIS & HANSEN, 1980; DYCK, 1991; GODOY CIGUEL & FERREIRA DAEMON, 1992). On the other hand, the Cariy Formation is not represented in the Galeano locality.

The Areguá quarry (=Caacupé-Mi quarry, BALDIS & HANSEN, 1980) is located at the northernmost corner of the western border of the Ypacaraí graben (Fig. 1) and, according to BALDIS & HANSEN (1980), probably embraces levels of the Eusebio Ayala and Vargas Peña Formation containing dalmanitid trilobites. Unfortunately, this locality could not be included in the present study because it has become private property recently, and direct access is not allowed.

Outside the study area, isolated outcrops of the Itacurubí Group are exposed along the Km 77 of Route 2 near Eusebio Ayala town. These isolated sections, characterized by brown, yellow and purple sandstones, belong to the Eusebio Ayala Formation and contain the ?latest Ordovician-Rhuddanian trilobites *Mucronaspis itacurubensis* (BALDIS & HANSEN, 1980; see also EDGECOMBE *in* JELL & ADRAIN, 2003) and *Mucronaspis* sp.

III. BIOSTRATIGRAPHY

The trilobites of the Vargas Peña Formation mostly include long ranging genera (*Calymene*, *Dalmanites*, *Trimerus*) and endemic species from Paraguay [e.g., *Calymene boettneri* HARRINGTON, 1950; *C. harringtoni* sp. nov.; *Dalmanites ypacarayensis* (BALDIS & HANSEN, 1980); *Dalmanites* sp.; *Guaranites paraguayensis* BALDIS & HANSEN, 1980], so they are not especially useful for biostratigraphy. On the other hand, the graptolite faunas consist of low-diversity assemblages dominated by significant biserial forms, followed by a small number of monograptids recorded in the upper part of the San Fernando quarry (Fig. 3). As mentioned above, the latter comprise *Monograptus* aff. *priodon* (BRONN, 1835), *Stimulograptus* aff. *sedgwickii* (PORTLOCK, 1843) and ?*Demirastrites* sp. (URIZ *et al*., 2008), which indicate a late Aeronian/early Telychian age (*S. sedwickii* / *S. turriculatus* zones) for the upper Vargas Peña Formation (see URIZ *et al*., 2008).

The best-represented biserial graptolites in the sections studied are *Paraclimacograptus brasiliensis* (RUEDEMANN, 1929 in MAURY, 1929) and *P. innotatus* (NICHOLSON, 1869), which occur from the base to the upper part of the formation (Fig. 3). *Paraclimacograptus brasiliensis* is one of the first lower Silurian macrofossils from the western Paraná Basin that allowed correlation with other South American basins (HARRINGTON, 1950; TURNER, 1959; LOCZY, 1963; JAEGER, 1976). The type locality of this species at Río Trombetas (Estado do Pará, Amazonas Basin, Brazil) belongs to the lower part of the Pitinga Formation (Trombetas Group), a succession that contains chitinozoans and acritarchs ranging from the late Rhuddanian to the Telychian (GRAHN & PARIS, 1992; GRAHN, 2005b and references therein; CARDOSO, 2005). *Paraclimacograptus brasiliensis* is also known from the Rhuddanian of Cerro del Fuerte in the Argentine Precordillera (La Chilca Formation, San Juan Province) (RICKARDS *et al.*, 1996), whereas its most closely allied species *P. lybicus* (DESIO, 1940) occurs in the Aeronian (*Coronograptus gregarius* Zone to *Demirastrites convolutus* Zone) of western Murzuq Basin, Libya (ŠTORCH & MASSA, 2006).

Similarly, *Paraclimacograptus innotatus* is widely known from the Rhuddanian of the Canadian Arctic (*Coronograptus cyphus* Zone), the Southern Urals, Russia (*C. vesiculosus* and *C. cyphus* zones), and Scotland (*C. acuminatus*, *C. vesiculosus* and *C. gregarius* zones) (RUSSEL *et al*., 2000), as well as the lower Aeronian (*Demirastrites triangulatus* Zone) of the Czech Republic (PŘYBIL, 1947). Also, this taxon was described from the western flank of the Cordillera Oriental in northwestern Argentina, in association with *Clinoclimacograptus retroversus* (BULMAN & RICKARDS, 1968), *Stimulograptus sedgwickii* (PORTLOCK, 1843), and palynomorphs of middle to late Aeronian age (*Demirastrites convolutus* Zone and ?*S. sedgwickii* Zone) (TORO, 1995; RUBINSTEIN & TORO, 2006).

In addition, three forms classified in open nomenclature provide supplementary biostratigraphic information on different parts of the Vargas Peña Formation. *Normalograptus* cf. *ajjeri* (LEGRAND, 1977) occurs only in the basal part of the formation, below layers containing most of the trilobites identified. It is important to point out that this graptolite is highly comparable to *Normalograptus ajjeri*, which is well-known from the Rhuddanian of North Africa, southern France and Jordan (LEGRAND, 1977; ŠTORCH & FEIST, 2008; LOYDELL, 2007). *Normalograptus* aff. *rectangularis* (MCCOY, 1850) is punctually recorded in the middle part of the San Fernando section, and shows major affinities with material of late Rhuddanian-early Aeronian age (e.g., RICKARDS, 1970; PIÇARRA *et al*., 2009). On the other hand, *Metaclimacograptus* cf. *asejradi* LEGRAND, 1993 is restricted to the upper half of the Vargas Peña Formation. Most of the studied specimens of this taxon occur with *Monograptus* aff. *priodon*, *Stimulograptus* aff. *sedgwickii* and ?*Demirastrites* sp. in the uppermost part of the succession. *Metaclimacograptus* cf. *asejradi* has also been identified in the upper Llandovery of Spain (middle Telychian; GUTIÉRREZ-MARCO & ŠTORCH, 1998) and the Argentinian Precordillera (lower or middle Telychian; LENZ *et al*., 2003).

GRAHN *et al*. (2000) and GRAHN (2005a) postulated a late Rhuddanian to early Telychian age for the Vargas

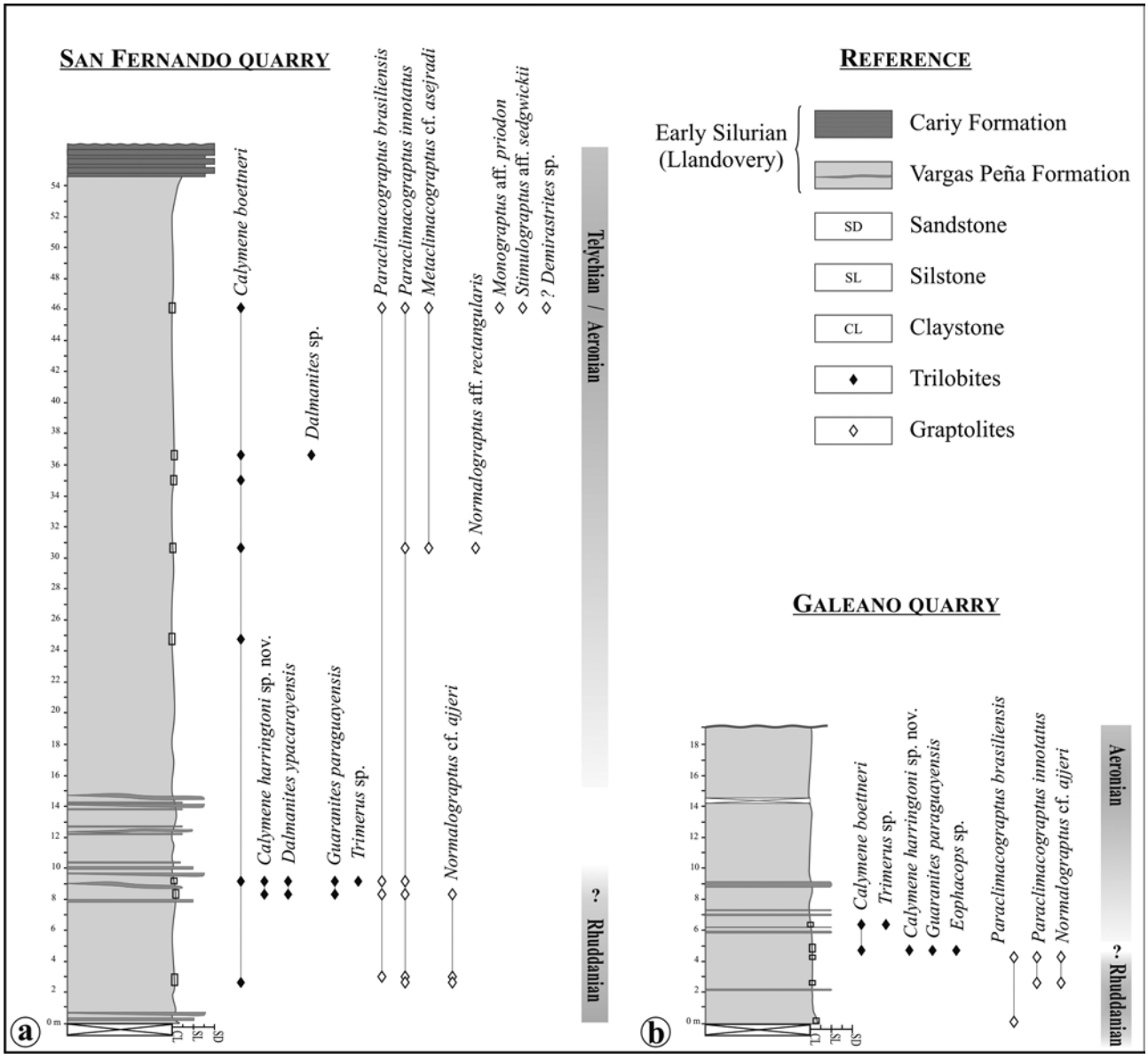

Fig. 3: Columnar sections of the Vargas Peña Formation at the San Fernando (a) and Galeano (b) quarries, showing distributions of trilobites and graptolites identified. The monograptids of the upper part of the succession (*Monograptus* aff. *priodon*, *Stimulograptus* aff. *sedgwickii,* ?*Demirastrites* sp.) were described by URIZ *et al*. (2008).

Peña Formation on the basis of its chitinozoan record, and the graptolite faunas provide additional stratigraphic evidences to support this correlation. On the other hand, the low taxonomic diversity of the graptolites described herein did not allow recognition of the boundaries of the classic Aeronian biozones within the formation.

IV. PALAEOECOLOGY

ŠTORCH (1998a) recognized three depth-related graptolite assemblages across the early Silurian shelves and basins of the cool water peri-Gondwanan Europe Province. He pointed out that the shallower shelf deposits (mudstones, sandy tempestites, limestones) bear a characteristic low diversity, oxygen tolerant fauna ("sub-fauna 1") represented by surface-dwellers: *Normalograptus*, *Rhaphidograptus*, *Retiolites* and *Monograptus*, typically recorded in association with macrofossils such as brachiopods, gastropods, bivalves and nautiloids. During the Llandovery, a transgression covered part of the Brazilian and Paraguayan territories in the Paraná Basin. The occurrences of scarce biserial graptolites and monograptids in the Itacurubí Group indicate an ecological correspondence with the sub-fauna 1 of ŠTORCH (1998a), suggesting relatively shallow water conditions (URIZ *et al*., 2008).

Among the trilobites represented in the Vargas Peña

Formation, the occurrence of the genus *Trimerus* has key palaeoecologic implications. The palaeoenvironmental significance of the Family Homalonotidae has been widely discussed in the literature (e.g., GILL, 1948; WHITTINGTON, 1993; SANDFORD, 2005; SIMÕES *et al*., 2009 and references therein). The trilobite biofacies of many Silurian-Devonian marine shallow-water platforms are characterized by *Trimerus*, *Digonus* and *Burmeisteria* (e.g., FORTEY & OWENS, 1997), taxa that are mainly abundant in inner-shelf siliciclastic sediments deposited close to storm wave base.

V. SYSTEMATIC PALAEONTOLOGY

The specimens studied are included in soft, friable rocks, so they demanded careful preparation. Many graptolite colonies are preserved in relief and partially replaced by iron oxides, whereas others constitute flattened carbonized films. The trilobites are very fragile external and internal moulds, which were blackened with graphite powder, and then whitened with magnesium oxide vapors before photographing. The short synonymies of the graptolites described include the most important bibliographic references and also refer to recent papers with more extensive lists of mentions. The fossils are housed in the Palaeontology collections of the Museo de Ciencias Naturales de La Plata (MLP), Argentina.

TRILOBITES

Order Phacopida SALTER, 1864
Suborder Calymenina SWINNERTON, 1915
Family Calymenidae MILNE EDWARDS, 1840
Subfamily Calymeninae MILNE EDWARDS, 1840
Genus *Calymene* BRONGNIART, 1822
Type species: *Calymene blumenbachii* BRONGNIART.

***Calymene boettneri* HARRINGTON, 1950**
Figs. 4.1-4.12, 5.1-5.12

1950. *Calymene boettneri* HARRINGTON, p. 73-76, pl. 1, figs. 1-3.
1961. *Calymene boettneri* HARRINGTON. WOLFART, p. 72-73, pl. 4, fig. 3 (only).
non 1961. *Calymene boettneri* HARRINGTON. WOLFART, pl. 4, figs. 4, 5 (=*Calymene harringtoni* TORTELLO sp. nov.).
1961. *Calymene* sp. WOLFART, p. 71-72, pl. 4, fig. 2.

Material examined: Eleven complete specimens, 42 axial shields, 3 cephala, 13 cranidia, 4 thoracic fragments, 21 thoracopygidia and 5 pygidia (MLP 31869-31903, 31905, 31907, 31908, 31910-31913, 31917, 31919, 31928, 33608-33618, 33622, 33623, 33630-33647, 33653, 33656, 33657, 33662, 33664-33670). Vargas Peña Formation, San Fernando and Galeano quarries.

Holotype: axial shield (nº 643), paratypes: cranidium (nº 645) and two axial shields (nº 638) from Cerro Aparipí, housed in the Universidad de Buenos Aires, Argentina. In the original description of *C. boettneri*, there is contradictory information about the designation of the holotype of the species, which is emended herein. The valid holotype is the almost complete specimen referred to as such by HARRINGTON (1950, caption of pl. 1, fig. 2) and in the collection cards attached to the material, and not the cranidium indirectly regarded as the holotype in HARRINGTON (1950, p. 76, see reference to "Lámina 1, fig. 1").

Discussion: *Calymene boettneri* is the best represented trilobite in the Vargas Peña Formation. Due to the action of differential weathering, the material collected includes acceptably (e.g., Figs. 4.1, 4.12), fairly (e.g., Figs. 5.1, 5.7), and badly (Fig. 5.12) preserved specimens. In several axial shields, it is possible to see that weathering of the cephalon is more pronounced than that of the thoracopygidia (e.g., Figs. 5.3, 5.5, 5.10). HARRINGTON (1950) mentioned the presence of fine and numerous granules on the external surface of the exoskeleton, a feature that can only be noticed in well-preserved external moulds (Fig. 5.11). In addition, many isolated axial shields from the San Fernando quarry can be interpreted as discarded exuvia produced by moulting processes. Following HENNINGSMOEN (1973) and BUDIL & BRUTHANSOVÁ (2005) criteria, the partially disarticulated specimen illustrated in Fig. 5.8 may have also had a similar origin.

Calymene boettneri was previously reported from the Galeano quarry (HARRINGTON, 1950; WOLFART, 1961) as well as from Cerro Aparipí, north of the Tobati locality (BEDER & WINDHANSEN, 1918; HARRINGTON, 1950, 1972). HARRINGTON (1950) provided a very complete diagnosis of the species, though the description of its ventral morphology was pending. As is common in calymenid trilobites, the hypostome of *Calymene boettneri* (Fig. 4.10) is characterized by having a conspicuous rhynchos that is located forwards of the midpoint of the hypostomal median body, close to the centre of the anterior lobe. The rhynchos is oval in outline and strongly projected ventrally. The anterior hypostomal border is very short (sag., exsag.) and weakly separated from the median body by a very shallow furrow. Its anterolateral corners are converted into prominent anterior wings, which are clearly differentiated from the rest of the hypostome.

HARRINGTON (1950) assigned *Calymene boettneri* to the *"blumenbachi-aspera*" group from the lower Silurian of Europe, indicating its high similarity with *C. aspera* SHIRLEY from the Wenlockian of England and Wales (SHIRLEY, 1936; SIVETER, 1996, figs. 5e, l-r, 6a-q). Indeed, the latter hardly differs from the Paraguayan species by having a more strongly tapered glabella, a less rounded preglabellar furrow, and a wider (sag.) anterior part of cephalic area. Similarly, *C. boettneri* is distinguished

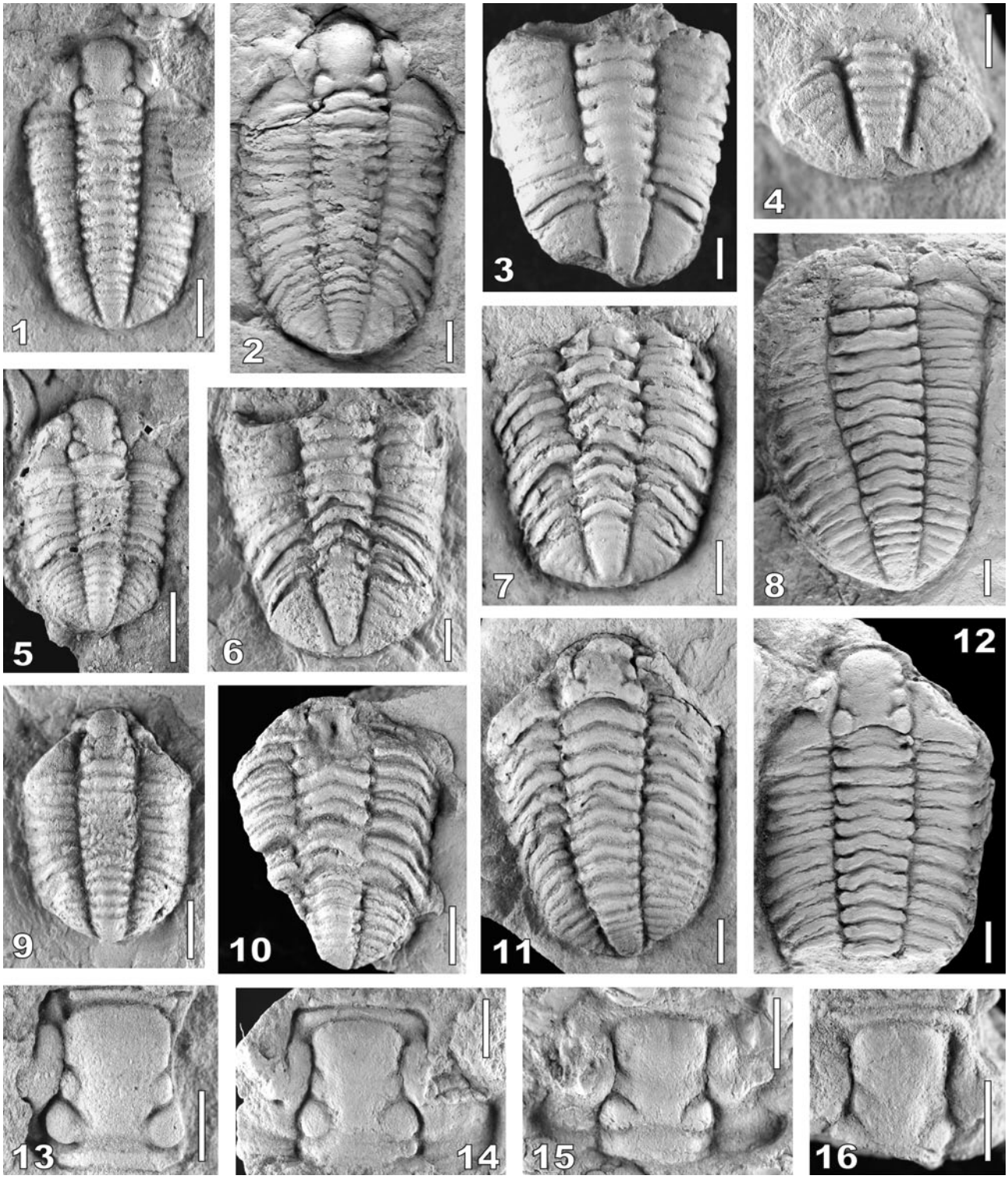

Fig. 4: **1-12**, *Calymene boettneri* HARRINGTON, San Fernando quarry; **1**, axial shield, MLP 31888; **2**, axial shield, MLP 31877; **3**, thoracopygidium, MLP 31869; **4**, pygidium, MLP 31874; **5**, axial shield, MLP 31879; **6**, thoracopygidium, MLP 31873; **7**, thoracopygidium, MLP 31896; **8**, thoracopygidium, MLP 31917; **9**, axial shield, MLP 31885; **10**, hypostome (slightly displaced from the original position) and thoracopygidium, MLP 31910; **11**, axial shield, MLP 31902; **12**, axial shield, MLP 31919. **13-16**, *Calymene harringtoni* TORTELLO sp. nov., cranidium, San Fernando quarry; **13**, MLP 31906; **14**, MLP 31904; **15**, MLP 31916 (holotype); **16**, MLP 31909. Scale bars 5 mm.

from *C. ferrifera* BALDIS & BLASCO (*in* BALDIS *et al*., 1976, pl. 1, figs. 1-3), from the Silurian of the Lipeón Formation (Sierras Subandinas, northwestern Argentina), in showing a narrower glabella, a more rounded anterior glabellar margin, a more convex glabellar frontal lobe, subquadrate L1 and L2 lobes, and an occipital furrow of uniform width (sag., exsag.). *Calymene boettneri* further differs from *C. vallecitoensis* WAISFELD *et al*. (1988, pl. 1, figs. 1-8), from the Silurian of the Los Espejos Formation (Precordillera Basin, western Argentina), by its longer (sag.), anteriorly rounded glabella, a forwardly-curving occipital furrow, a less convex (sag., tr.) pygidial axis, and its narrower pleural fields having more delicate pleural furrows.

The specimens illustrated in Figs. 4.12, 5.6 and 5.9 exhibit a little convex frontal glabellar lobe, as well as a L1 that is slightly less tumid than that of most specimens of *C. boettneri*. Since this material comes from lower levels of the Vargas Peña Formation, these minor variations may be related to the stratigraphic position of the samples. On the other hand, a cranidium and a pygidium from the Galeano quarry referred to *C. boettneri* by WOLFART (1961, pl. 4, figs. 4, 5) clearly differs from the type material of this species. The latter specimens are reassigned to a new taxon, which is described below.

Calymene harringtoni TORTELLO sp. nov.
Figs. 4.13-4.16, 5.13, 5.14

1950. *Calymene* sp. indet. HARRINGTON, p. 76-77, pl. 3, fig. 4.
1961. *Calymene boettneri* HARRINGTON. WOLFART, p. 72, pl. 4, figs. 4, 5 (only).

Material examined: Seven cranidia and 1 pygidium (MLP 31904, 31906, 31911, 31914, 31916, 31935, 33655, 33660). Vargas Peña Formation, San Fernando and Galeano quarries.

Holotype: Cranidium (MLP 31916, Fig. 4.15), San Fernando quarry.

Etymology: To Dr. Horacio HARRINGTON, who pioneered the studies on the Silurian fossils of Paraguay.

Diagnosis: *Calymene* with a glabella having a constricted L2 and a slightly forwardly expanded, anteriorly truncate frontal lobe. Anterior cranidial margin straight to broadly rounded. Frontal area faintly convex, occupying about 12-14% of the total length of the cephalon. Occipital ring of uniform width (sag., exsag.), not bowed forward, delimited by a very shallow, medially widened (sag.) occipital furrow. Pygidium transversely elongated, with an indentation on the posteromedian margin. Pygidial axis strongly tapered backward. Pleural furrows deep, with their distal parts strongly curving backward. Posterior pleural furrow associated with a subtriangular depression which reaches pygidial margin.

Description: Glabella subrectangular, moderately convex, somewhat elevated above genal region, length about 1.2 times its maximum width; it is characterized by having a constricted L2, slightly divergent anterior axial furrows, and a truncate distal part; occipital ring as wide (tr.) as preoccipital lobe, constant in length (sag., exsag.), straight, occupying about 15% of the total length (sag.) of the glabella; occipital furrow low, shallower and wider (sag.) on midline; L1 conspicuous, triangular-semicircular in outline, projected laterally; S1 curved backward, in contact with the axial furrow; L2 oval in outline, small, delimited by a very short S2; S3 poorly developed, only visible in well-preserved specimens; frontal lobe subquadrate, anteriorly truncate. Frontal area moderately developed, slightly convex, occupying 12-14% of the total length of the cephalon. Anterior cranidial margin straight to slightly rounded forward. Palpebral area of the fixigena moderately wide (tr.), 0.5 to 0.6 width of adjacent glabella. L2 connected to a very faint, narrow (tr.) genal buttress. Palpebral lobe slightly anterior of glabellar midpoint.

Pygidium transversely wide (tr.). Axis convex, strongly tapered backward, clearly delimited by deep axial furrows; it is composed of 7 or 8 axial rings and a rounded terminal piece. Pleural fields crossed by 5 deep pleural furrows, which have their distal parts curving backward and terminating just short of pygidial margin; fifth pleural furrow associated with a long (exsag.), sub-triangular depression which reaches pygidial margin. Posteromedian pygidial margin having a well defined indentation.

Discussion: *Calymene harringtoni* TORTELLO sp. nov. closely resembles *Calymene boettneri*, but differs in showing a straight to slightly rounded anterior cephalic margin, a longer (sag.) frontal area, a truncate frontal glabellar lobe, a marked glabellar constriction at L2, a shallower occipital furrow, deeper pygidial pleural furrows that curve backward distally, a shallow, elongate depression associated with the posterior pleural furrow, and an indentation on the posterior pygidial margin. In addition, specimens of the new species seem to reach a larger size than *C. boettneri*.

One cranidium and one pygidium from the Galeano quarry, originally referred to *Calymene boettneri* by WOLFART (1961, pl. 4, figs. 4, 5), are indistinguishable from *C. harringtoni* TORTELLO sp. nov. and therefore are reassigned to this species. Similarly, a pygidium from the Cantera Cariy Loma locality, 3 km east of Itacurubí, assigned by HARRINGTON (1950, pl. 3, fig. 4) to *Calymene* sp. indet., could also be conspecific.

Family Homalonotidae CHAPMAN, 1890
Subfamily Homalonotinae CHAPMAN, 1890
Genus *Trimerus* GREEN, 1832

Type species: *Trimerus delphinocephalus* GREEN

Trimerus sp.
Figs. 5.15-5.18

Material examined: Three pygidia (MLP 31939, 31940, 33654). Vargas Peña Formation, San Fernando and Galeano quarries.

Description: Pygidium subtriangular in outline, highly convex (tr.), as wide as long. Axis faintly elevated above level of pleural fields, anterior width 45-60% maximum width of pygidium, tapered backward at anterior half and subparallel-sided to slightly tapered posteriorly, surrounded by very narrow, shallow axial furrows; it is composed of 9 to 10 smooth rings, which are delimited by weak ring furrows; the anterior 5-6 ring furrows are clearly curved forward. Pleural fields strongly convex, crossed by 6 to 8 delicate, curved backward pleural furrows terminating just short of pygidial margin; border furrow indistinct; posteromedian margin of pygidium with a short caudal prolongation.

Discussion: The general outline of the pygidium, the shape and dimensions of the pygidial axis, and the degree of expression of the axial rings and pleural furrows suggest morphological correspondence with *Trimerus* GREEN. The axial rings are nearly effaced on outer surface of the exoskeleton, but are weakly developed on internal mould (see Figs. 5.17 and 5.18). Scarce materials of this genus, consisting only of cranidia, have been previously described from sandstones of the Cariy Formation at the Cerro Peró locality (WOLFART, 1961, figs. 6-8; HARRINGTON, 1972). Although these specimens may belong to *T.* (*Ramiotis*) SANDFORD (see SANDFORD, 2005), further material is necessary to allow a confident identification.

Suborder Phacopina STRUVE *in* RICHTER, RICHTER & STRUVE, 1959
Family Dalmanitidae VODGES, 1890
Subfamily Dalmanitinae VODGES, 1890
Genus *Dalmanites* BARRANDE, 1852

Makaspis BALDIS & HANSEN, 1980.

Type species: *Trilobus caudatus* BRÜNNICH.

Dalmanites ypacarayensis (BALDIS & HANSEN, 1980)
Figs. 6.1-6.3, 6.10

1961. *Dalmanites*? sp. WOLFART, p. 74, pl. 4, fig. 8.
1980. *Makaspis ypacarayensis* BALDIS & HANSEN, p. 53-54, pl. 1, fig. A, pl. 2, fig. a.

Material examined: Two cephala, 2 thoracopygidia and 3 pygidia (MLP 31922, 31930-31933, 31937, 31938). Vargas Peña Formation, San Fernando quarry.

Description of pygidium: Pygidium subtriangular in outline (excluding terminal spine), slightly convex. Axis conical, slightly tapered backward, little elevated above pleural fields, containing 8 to 9 smooth rings and terminal piece; pleural field somewhat convex, crossed by 7 to 8 sets of faint, narrow, oblique pleural furrows and delicate interpleural lines; distal parts of pleural furrows curving backward and terminating close to pygidial margin. Border very narrow, slightly concave. Posteromedian margin bearing terminal spine with a wide (tr.) proximal portion.

Discussion: The cephala studied are characterized by having a slightly convex glabella, narrow lateral glabellar furrows, a frontal glabellar lobe comprising approximately 50% sagittal glabellar length in dorsal view, a S2 glabellar furrow slightly posterior of eye midpoint, eyes occupying a third of the cephalic length (exsag.), and a distally widened posterior border. These features are characteristic of *Makaspis ypacarayensis*, which was originally described on the basis of a single cephalon from the Vargas Peña Formation of the Areguá quarry (BALDIS & HANSEN, 1980, pl. 2, fig. a). EDGECOMBE (*in* JELL & ADRAIN, 2003) suggested that *Makaspis ypacarayensis* could be transferred to *Dalmanites*. The pygidum of this taxon, which is described herein for the first time, provides further evidence in favour of such reassignment.

As previously suggested by BALDIS & HANSEN (1980, p. 53), *D. ypacarayensis* is regarded as conspecific with a poorly preserved cranidium from the Vargas Peña Formation that was assigned by WOLFART (1961, pl. 4, fig. 8) to *Dalmanites*? sp. *Dalmanites ypacarayensis* differs from *D. sudamericanus* BENEDETTO & MARTEL in BALDIS *et al*. (1976, pl. 3, figs. 1-3), from the Silurian Lipeón Formation (NW Argentina), mainly in having transverse, fainter glabellar furrows S1 and S2, and a narrower (sag.) occipital ring. In addition, it differs from the type species *D. caudatus* (BRÜNNICH, 1781), from the early Silurian of Great Britain, by showing a lower number of pygidial axial rings and shallower pleural furrows.

Dalmanites sp.
Figs. 6.4-6.9, 6.11

Material examined: Nine cephala, 1 thoracic fragment, 2 thoracopygidia and 5 pygidia (MLP 33619-33621, 33624-33629, 33648-33652). Vargas Peña Formation, San Fernando quarry.

Description: Cephalon semicircular in outline, moderately convex; sagittal cephalic length 50% of maximum cephalic width. Glabella slightly convex, expanded forward, surrounded by narrow, gently divergent axial furrows which are strongly deflected at S3; lateral glabellar furrows disconnected at middle; S1 and S2 short, normal to axis; S1 straight to slightly bowed backward, reaching the axial furrows; S2 slightly bowed forward, with faint lateral parts; S3 somewhat wider than S1 and S2, straight and directed obliquely backward-inward, reaching the axial furrows; L2 slightly wider (tr.) and longer (exsag.) than L1. L3 much wider (tr.) and longer (exsag.) than L1 and L2, with strongly curved outward lateral margins; glabellar frontal lobe sub-elliptical in outline, somewhat elevated above the rest of the cephalon, more than one-half length of the glabella; preglabellar furrow rounded, weakly impressed; occipital ring convex, as large as L1, delimited by a straight occipital furrow that is deepest laterally and shallow on midline.

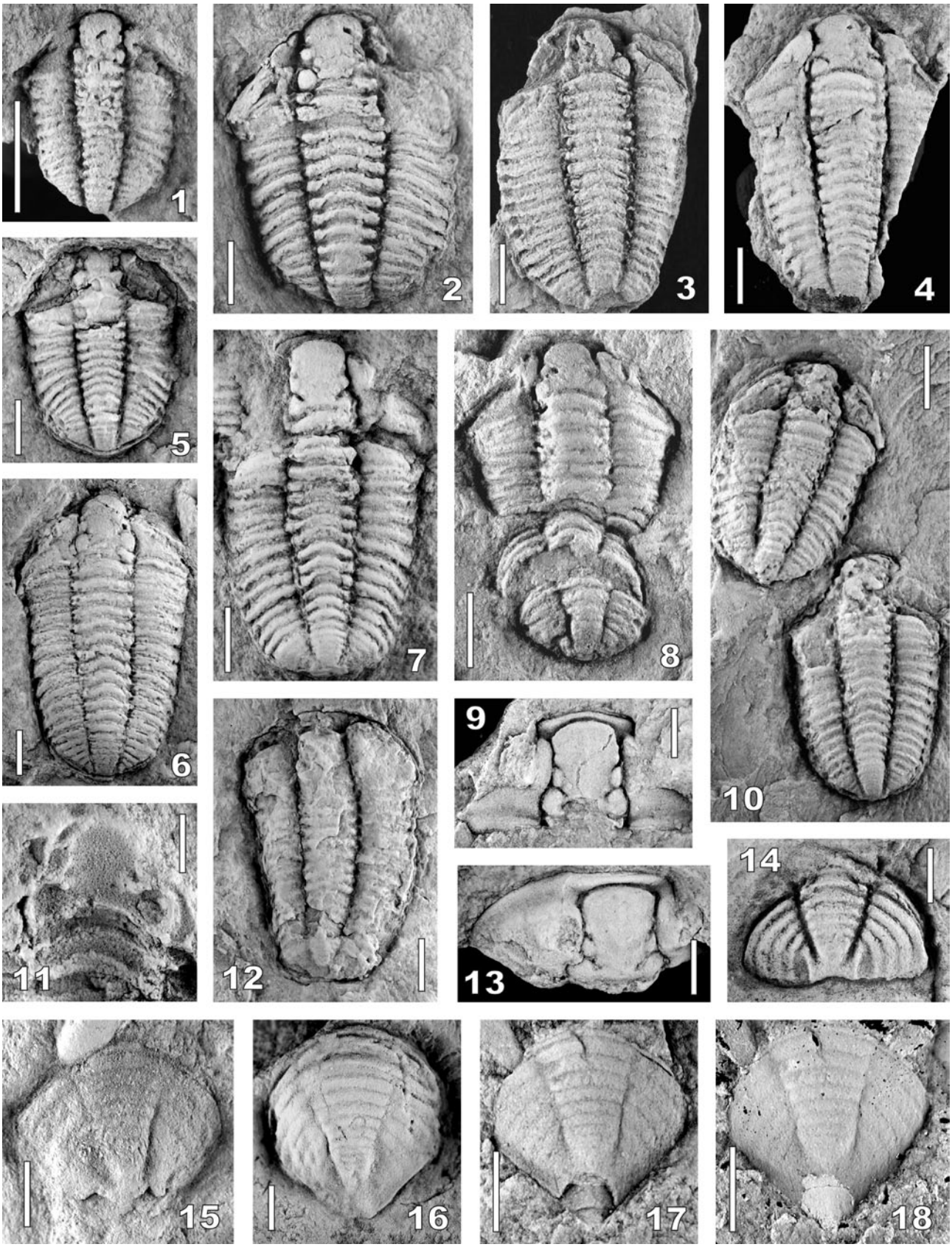
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Fig. 5: **1-12**, *Calymene boettneri* HARRINGTON; **1**, axial shield, San Fernando quarry, MLP 33608; **2**, axial shield, San Fernando quarry, MLP 33610; **3**, exoskeleton, San Fernando quarry, MLP 33614; **4**, axial shield, San Fernando quarry, MLP 33638; **5**, exoskeleton, San Fernando quarry, MLP 33640; **6**, axial shield, San Fernando quarry, MLP 33634; **7**, axial shield, San Fernando quarry, MLP 33643; **8**, axial shield, San Fernando quarry, MLP 33615; **9**, cranidium, Galeano quarry, MLP 33653; **10**, exoskeleton and axial shield, San Fernando quarry, MLP 33645; **11**, glabella and anterior part of thorax, external mould, San Fernando quarry, MLP 33636; **12**, highly weathered exoskeleton, San Fernando quarry, MLP 33623. **13**, **14**, *Calymene harringtoni* TORTELLO sp. nov., Galeano quarry; **13**, cranidium, MLP 33660; **14**, pygidium, MLP 33655. **15-18**, *Trimerus* sp., pygidium; **15**, San Fernando quarry, MLP 31940; **16**, San Fernando quarry, MLP 31939; **17**, **18**, Galeano quarry, internal mold and latex cast, respectively, MLP 33654. Scale bars 5 mm.

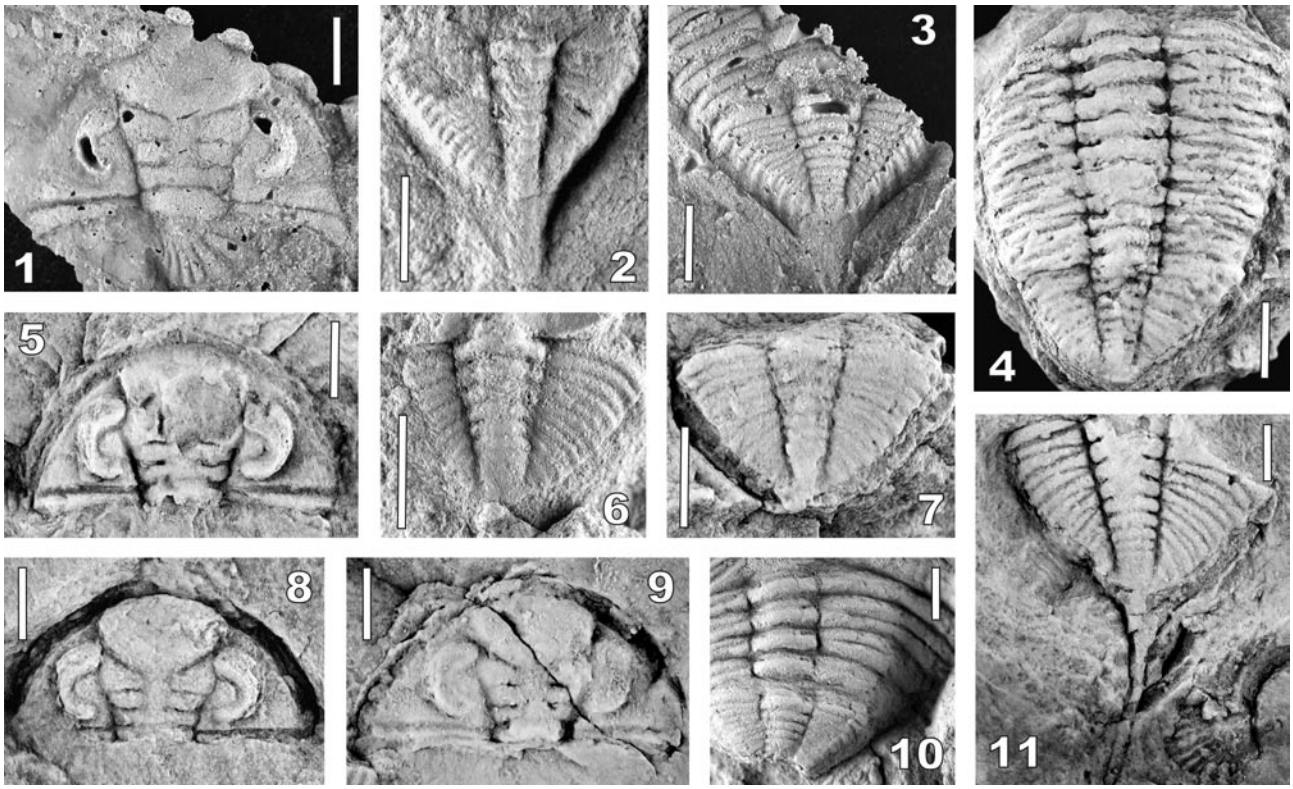

Fig. 6: **1-3, 10**, *Dalmanites ypacarayensis* (BALDIS & HANSEN), San Fernando quarry; **1**, cephalon, MLP 31922; **2**, fragmentary thoracopygidium, MLP 31930; **3**, pygidium, MLP 31932; **10**, thoracopygidium, MLP 31938. **4-9, 11,** *Dalmanites* sp., San Fernando quarry; **4**, thoracopygidium, MLP 33651; **5**, cephalon, MLP 33629; **6**, pygidium, MLP 33628; **7**, pygidium, MLP 33620; **8**, cephalon, MLP 33624; **9**, cephalon, MLP 33628; **11**, pygidium, MLP 33652. Scale bars 5 mm.

Facial suture of proparian dalmanitiform type; preocular section of facial suture tangential to the anterior margin of the glabella; postocular section with its proximal part oblique frontward and outward forming an angle of 45º with the sagittal line, and its distal part directed obliquely outward and backward, reaching lateral cephalic margin near genal angle. Eyes very large, crescentic, prominent, strongly raised above fixigena, extending between levels of S3 and L1, with their anterior margins contacting the axial furrows. Anterior cephalic border visible in dorsal view, slightly convex, surrounded by a delicate border furrow; anterior border and anterior border furrow occupy about 15% of the total cephalic length (sag.). Posterior cephalic border straight, normal to axis, slightly widened (exsag.) distally, clearly delimited by a distinct posterior border furrow. Genal spines and thorax of the material examined poorly preserved.

Pygidium subtriangular in outline, wider than long (excluding terminal spine). Axis very long, gently tapering, slightly elevated above level of pleural fields, occupying almost the total pygidial length (excluding terminal spine), surrounded by narrow axial furrows; axis composed of 9-10 rings, which are delimited by straight to slightly bowed forward axial furrows; anterior axial width one fourth maximum width of pygidium. Pleural fields slightly convex, crossed by 7 to 8 slightly oblique, moderately deep pleural and interpleural furrows reaching pygidial border. Border narrow, somewhat concave. Postaxial region composed of a delicate, long spine, circular in section.

Discussion: *Dalmanites* sp. and *D. ypacarayensis* are recorded in the same locality (San Fernando quarry), although the former occurs in younger levels. *Dalmanites* sp. is distinguished from *D. ypacarayensis* (BALDIS

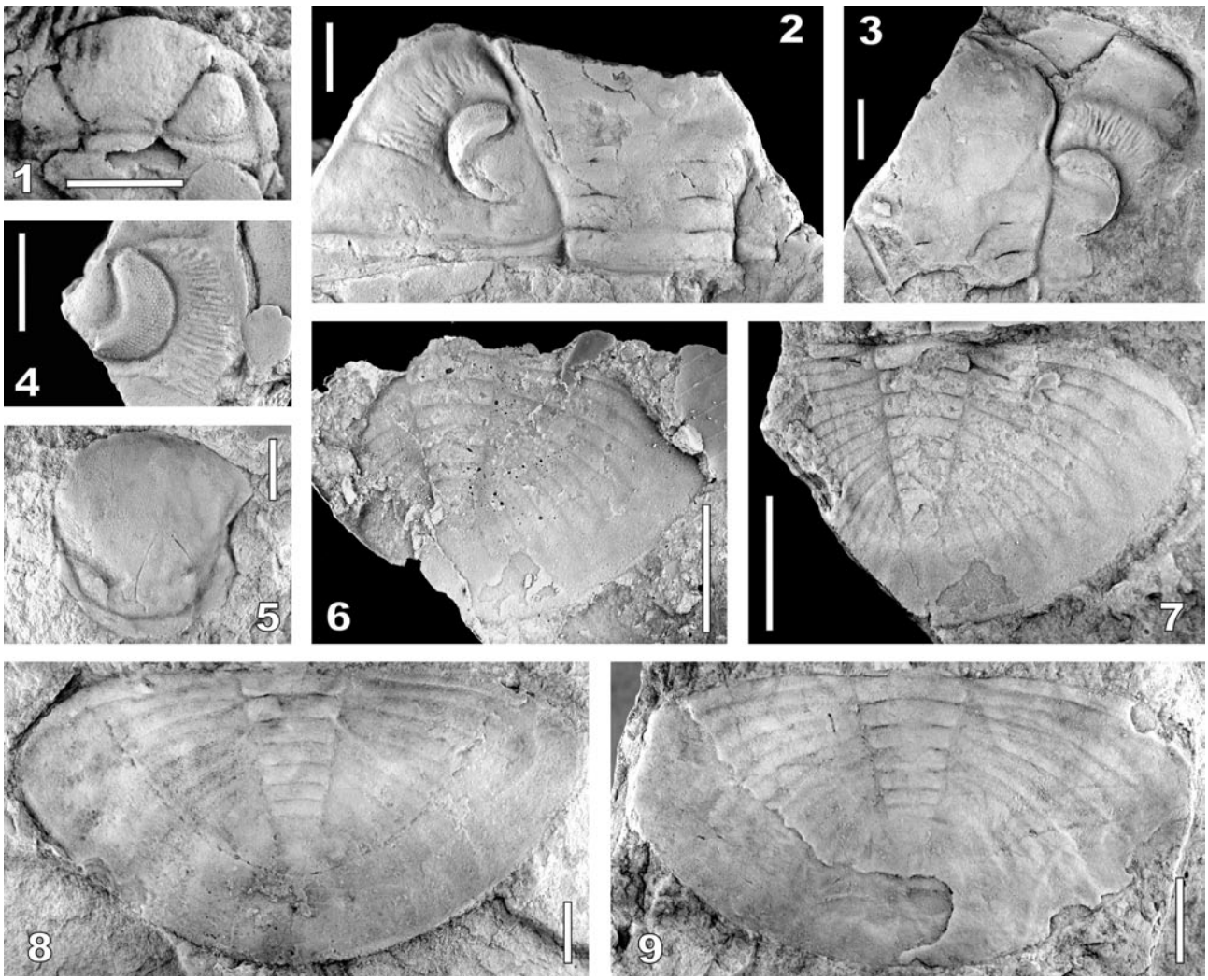

Fig. 7: **1**, *Eophacops* sp., cephalon, Galeano quarry, MLP 33658. **2-9**, *Guaranites paraguayensis* BALDIS & HANSEN; **2**, incomplete cephalon, San Fernando quarry, MLP 31923; **3**, incomplete cephalon, San Fernando quarry, MLP 31929; **4**, ocular area, San Fernando quarry, MLP 31927; **5**, hypostome, San Fernando quarry, MLP 31926; **6**, pygidium, latex mold, Galeano quarry, MLP 33663; **7**, pygidium (neotype), Galeano quarry, MLP 33663; **8**, pygidium, San Fernando quarry, MLP 31921; **9**, pygidium, San Fernando quarry, MLP 31920. Scale bars 10 mm (excepting **1**, 5 mm).

& HANSEN, 1980, pl. 2, fig. a) by having a little more convex glabella, a shorter (sag.) posterior part of the glabella (occipital lobe + L1, L2, L3), longer (exsag.) eyes showing their posterior margins very close to the posterior cephalic border furrow, and a narrower caudal spine. *Dalmanites* sp. differs from *D. sudamericanus* BENEDETTO & MARTEL in BALDIS *et al*. (1976, pl. 3, figs. 1-3), from the Silurian Lipeón Formation of northwestern Argentina, because the latter shows slightly oblique forward S1 and S2 glabellar furrows, and wider pleural furrows on the pygidium. *Dalmanites limurus* (GREEN, 1832) has, in addition, small eyes and a shorter posterior spine.

Subfamily Guaranitinae BALDIS & HANSEN, 1980
Genus *Guaranites* BALDIS & HANSEN, 1980
Type species: *Guaranites paraguayensis* BALDIS & HANSEN

***Guaranites paraguayensis* BALDIS & HANSEN, 1980**
Figs. 7.2-7.9

1980. *Guaranites paraguayensis* BALDIS & HANSEN, p. 60-62, pl. 1, fig. C, pl. 3, figs. a-d.

Material examined: Six fragmentary cephala, 1 hypostome, 2 thoracic fragments and 4 pygidia (MLP 31920, 31921, 31923-1927, 31929, 31936, 33659, 33661, 33663). Vargas Peña Formation, San Fernando and Galeano quarries.
Discussion: *Guaranites paraguayensis* is a giant dalmanitid that was fully described by BALDIS & HANSEN (1980) on the basis of material from an undetermined formation of the Itacurubí Group in the Galeano quarry. Although *Guaranites* was tentatively regarded as a junior synonym of *Dalmanites* (JELL & ADRIAN, 2003; TORTELLO *et al*., 2008a), its particular combination of cephalic and pygidial features supports the validity of the genus (TORTELLO *et al*., 2008b). *Guaranites* is a dalmanitid characterized by having a large, slightly convex exoskeleton, radial furrows on the librigena, an ellipsoidal pygidial outline, shallow pygidial axial furrows, a narrow (tr.), gently tapering pygidial axis, faint pleural and interpleural furrows, and a very wide border (BALDIS & HANSEN, 1980).
The type materials were originally housed in the Palaeontological Laboratory of the Instituto de Ciencias Básicas de la Universidad de Asunción, Paraguay, under the sigla ICB-CHH1 (holotype) and ICB-CHH2-4 (paratypes) (BALDIS & HANSEN, 1980, p. 61-62). Unfortunately, these specimens are missing and therefore a neotype is elected herein (pygidium MLP 33663, Galeano quarry -type locality-, Fig. 7.7).

Family Phacopidae HAWLE & CORDA, 1847
Subfamily Phacopinae HAWLE & CORDA, 1847
Genus *Eophacops* DELO, 1935
Type species: *Phacops handwerki* (WELLER).

***Eophacops* sp.**
Fig. 7.1

1961. *Eophacops* n. sp. A. WOLFART, p. 75-76, pl. 5, figs. 1, 2.

Material examined: One cephalon (MLP 33658). Vargas Peña Formation, Galeano quarry.
Discussion: This cephalon seems to be conspecific with a phacopid from the Galeano quarry that was assigned to *Eophacops* sp. by Wolfart (1961, pl. 5, figs. 1, 2). Because the specimen studied is poorly preserved, it is left in open nomenclature.

GRAPTOLITES

Order Graptoloidea LAPWORTH, 1875
Suborder Virgellina FORTEY & COOPER, 1986
Superfamily Diplograptoidea LAPWORTH, 1873
Family Normalograptidae ŠTORCH & SERPAGLI, 1993
Genus *Normalograptus* LEGRAND, 1987
Type species: *Normalograptus scalaris* var. *normalis* LAPWORTH.

***Normalograptus* cf. *ajjeri* (LEGRAND, 1977)**
Figs. 8.1-8.4

cf. 1977. *Climacograptus (Climacograptus) normalis ajjeri* LEGRAND, p. 171, fig.-text. 9a-d, 10a-b.
cf. 2008. *Normalograptus ajjeri* (LEGRAND). ŠTORCH & FEIST, p. 943, figs. 6.14, 7.22 (see for further synonymy).

Material examined: Four flattened, well-preserved specimens comprising complete rhabdosomes as well as proximal and distal fragments (MLP 29222-29225). Vargas Peña Formation, San Fernando and Galeano quarries.
Description: The rhabdosome attains a maximum length of 20.4 mm, and gradually widens from 0.7-0.8 mm at first thecal pair to a maximum rhabdosome width of 1.2-1.4 mm. The 2TRD is 1.5 mm at th2[1], increasing to 1.8 mm distally (after HOWE, 1983). The sicular length ranges from 1.4 to 1.5 mm, and the sicular aperture is 0.25-0.30 mm wide. Proximal end asymmetric, with a virgella up to 0.7 mm long. Early astogeny is of pattern H (normalis). Thecae climacograptid in type, with short (*c*. 0.5 mm) and straight supragenicular walls parallel to rhabdosome axis, as well as sharp genicula and conspicuous excavations. Thecae 13 in 10 mm proximally, and 11-12 in 10 mm distally. Many of the rhabdosomes studied show a complete median furrow that extends distally into a nema up to 2.3 mm long.
Discussion: *Normalograptus* cf. *ajjeri* is largely documented in the lower half of the Vargas Peña Formation. The specimens studied conform in several thecal and rhabdosomal features with those of *Normalograptus ajjeri* described by LEGRAND (1977,

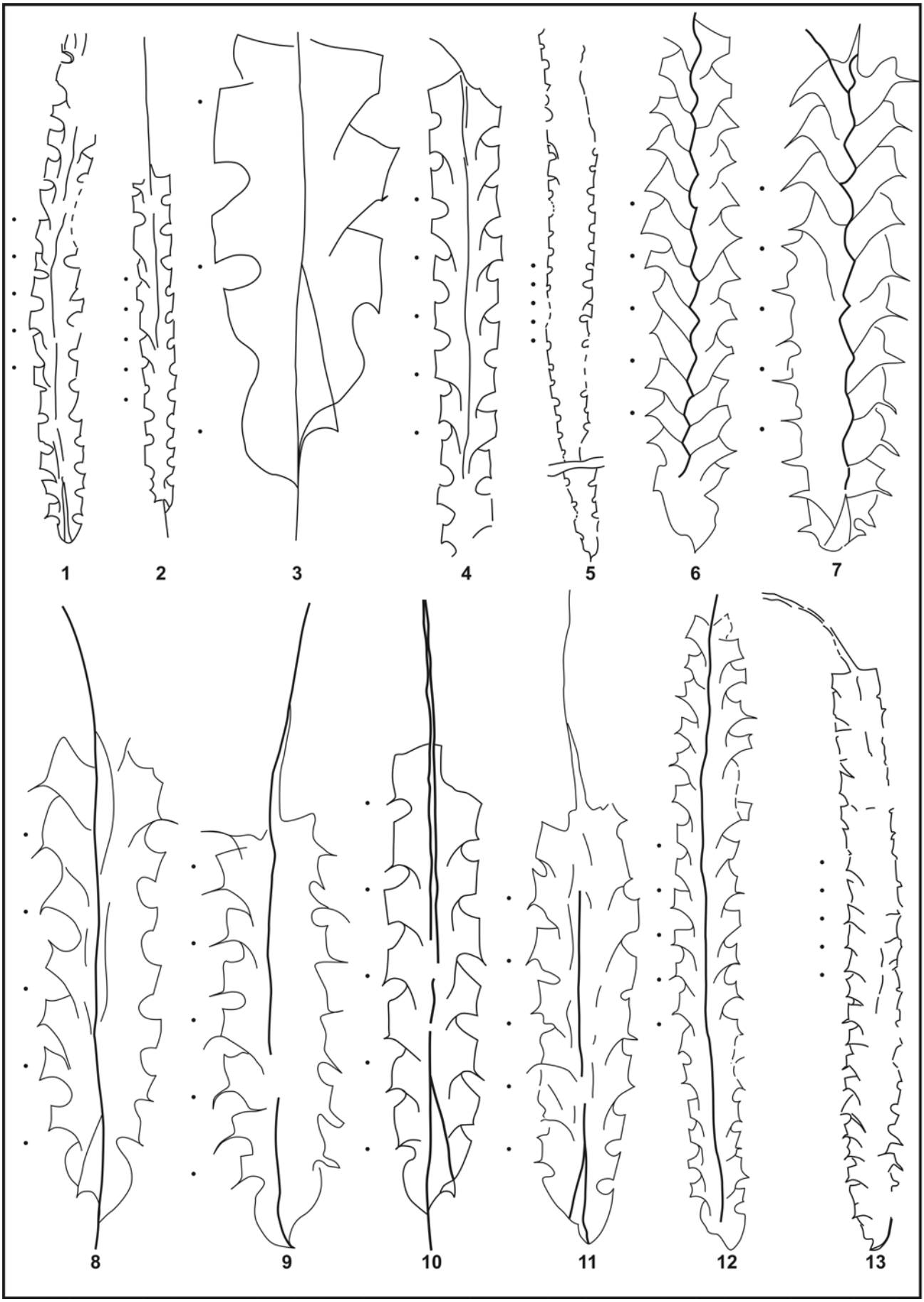
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fig.-text. 9a-d, 10a-b), LOYDELL (2007) and ŠTORCH & FEIST (2008, figs. 6.14, 7.22) from the lower Llandovery of North Africa, Jordan and southern France, respectively. However, the Paraguayan specimens differ from the Mediterranean material mainly in having a rhabdosome with a slightly narrower proximal end.

Normalograptus aff. *rectangularis* (McCOY, 1850)
Fig. 8.5

aff. 1970. *Climacograptus rectangularis* (McCOY). RICKARDS, p. 30, pl. 3, fig. 1, text-fig. 13, fig 5.
aff. 1974. *Climacograptus rectangularis* (McCOY). HUTT, p. 19, pl. 1, figs. 4, 5.
aff. 2008. *Normalograptus rectangularis* (McCOY). ŠTORCH & FEIST, p. 945, figs. 6.5, 6.13, 8.3.

Material examined: One flattened, distally truncate specimen, moderately well-preserved as a carbonized film (MLP 29235). Vargas Peña Formation, San Fernando quarry.

Description: The rhabdosome studied, which is distally broken, is 28 mm long. It is 0.8 mm wide at the level of the first thecal pair, then gradually widens to the maximum of 2.3 mm attained at the fifth millimeter of the rhabdosome. The 2TRD is 1.5 mm at $th2^1$, increasing to 2.0 mm distally (after HOWE, 1983). The proximal rhabdosomal end is rounded and the sicular aperture is 0.2 mm wide, furnished with a tiny virgella. Early astogeny of pattern H (normalis). Thecae climacograptid in type, with short, straight supragenicular walls which are slightly inclined to the rhabdosome axis in the proximal part of the specimen and parallel-sided distally. Thecae number 12 in 10 mm in the proximal part of the rhabdosome and 10 in 10 mm distally. A median septum is partially preserved.

Discussion: The specimen mostly resembles *Normalograptus rectangularis*, a widespread lower Silurian taxon fully described by RICKARDS (1970), HUTT (1974) and ŠTORCH & FEIST (2008), among others. The rhabdosome from the Vargas Peña Formation is characterized by having a relatively narrow proximal end, attaining its maximum width at the fifth mm (measured from the proximal end of the rhabdosome). Its proximal and distal thecal concentrations are similar to those of *N. rectangularis*, from the Llandovery of northern England (RICKARDS, 1970, pl. 3, fig. 1, text-fig. 13, fig 5), but the latter differs by possessing much deeper thecal excavations. Unfortunately, the internal features of the material from Paraguay are not adequately preserved, so this specimen is left in open nomenclature.

Genus *Metaclimacograptus*
BULMAN & RICKARDS, 1968
Type species: *Diplograptus hughesi* NICHOLSON.

Metaclimacograptus cf. *asejradi* LEGRAND, 1993
Figs. 8.6, 8.7, 9.1

cf. 1993. *Metaclimacograptus* (?) *asejradi* LEGRAND, p. 423, fig. 5e-f.
1998. *Metaclimacograptus* cf. *asejradi* LEGRAND. GUTIÉRREZ-MARCO & ŠTORCH, fig. 10e, f.
cf. 1998b. *Metaclimacograptus asejradi* LEGRAND. ŠTORCH, p. 114, pl. 1, fig. 1, text-fig. 3.9.
2003. *Metaclimacograptus* cf. *M. asejradi* LEGRAND. LENZ, CUERDA & PERALTA, p. 1200, fig. 3.7-9.

Material examined: 14 moderately well preserved specimens, often complete, either flattened or preserved in relief (MLP 29226, 29227). Vargas Peña Formation, San Fernando quarry.

Description: The rhabdosome attains a maximum length of 11 mm. Width depends upon the mode of preservation; the rhabdosome widens very rapidly from 0.7-0.9 mm at the level of $th1^1$ – $th1^2$ to 1.4-1.8 mm at the second or third thecal pair, then it widens slowly. Early astogeny is of pattern H (normalis). Thecae strongly geniculated in most of the specimens, although a few rhabdosomes exhibit a hood instead of a strong geniculum in some of their thecae. The supragenicular thecal walls are straight to weakly convex, and the apertures occupy $^1/_3$ – ¼ of rhabdosome width. Interthecal septa strongly sigmoidal. Median septum weakly to strongly undulatory. Thecae number 14 in 10 mm.

Discussion: Almost all of the specimens come from the upper part of the San Fernando quarry, with the exception of an isolated colony that was collected from the middle part of the section (Fig. 3). The material studied mostly resembles *M. asejradi* LEGRAND, from the lower Silurian of Algeria and Spain (LEGRAND, 1993, fig. 5e-f; ŠTORCH, 1998b, pl. 1, fig. 1, text-fig. 3.9), but the latter differs by having a narrower rhabdosome, which is 1.2-1.3 mm wide. Similarly, *Metaclimacograptus* cf. *asejradi*, from the Llandovery of Spain (GUTIÉRREZ-MARCO & ŠTORCH, 1998, fig. 10e, f), shows a rhabdosome 1.3-1.4 mm in width. *Metaclimacograptus* cf. *asejradi* from the upper Llandovery of the Precordillera of San Juan, Argentina (LENZ *et al*., 2003, fig. 3.7-9), differs from the

Fig. 8: **1-4**, *Normalograptus* cf. *ajjeri* (LEGRAND); **1**, San Fernando quarry, MLP 29222; **2**, Galeano quarry, MLP 29223; **3**, Galeano quarry, MLP 29224; **4**, Galeano quarry, MLP 29225. **5**, *Normalograptus* aff. *rectangularis* (McCOY), San Fernando quarry, MLP 29235. **6**, **7**, *Metaclimacograptus* cf. *asejradi* LEGRAND, San Fernando quarry; **6**, MLP 29226; **7**, MLP 29227. **8-11**, *Paraclimacograptus innotatus* (NICHOLSON), San Fernando quarry; **8**, MLP 29228; **9**, MLP 29229; **10**, MLP 29230; **11**, MLP 29232. **12**, **13**, *Paraclimacograptus brasiliensis* (RUEDEMANN); **12**, San Fernando quarry, MLP 29233; **13**, Galeano quarry, MLP 29234. Distance between adjacent dots: 1 mm.
⬅

material of Paraguay in showing a thecal spacing of 5.5-6 in 5 mm, and proximal thecal pairs with weak genicular hoods. *Metaclimacograptus flamandi* (LEGRAND, 1993), from the upper Llandovery of Libya (ŠTORCH & MASSA, 2007), further differs in having robust genicular hoods.

Genus *Paraclimacograptus* PŘIBYL, 1947
Type species: *Climacograptus innotatus* NICHOLSON.

***Paraclimacograptus innotatus* (NICHOLSON, 1869)**
Figs. 8.8-8.11, 9.3, 9.4

1869. *Climacograptus innotatus* NICHOLSON, p. 298, pl. 11, figs. 16, 17.
1995. *Paraclimacograptus innotatus* (NICHOLSON). TORO, p. 377, fig. 2.1-4 (see for further synonymy).
2000. *Paraclimacograptus innotatus* (NICHOLSON). RUSSEL, MELCHIN & KOREN', p. 85, figs. 1.3, 1.6, 1.7, 1.10, 2.2-2.4, 3, 4 (see for further synonymy).
2006. *Paraclimacograptus innotatus* (NICHOLSON). RUBINSTEIN & TORO, fig. 3.21, 3.22.
2008. *Paraclimacograptus innotatus* (NICHOLSON). ŠTORCH & FEIST, p. 947, figs. 5.11, 7.1, 7.2, ?7.14, 8.1.

Material examined: 43 flattened specimens, moderately to well-preserved as carbonized films (MLP 29228-29232). Vargas Peña Formation, San Fernando and Galeano quarries.

Description: Rhabdosome small, 6-7 mm long. It is 0.7-0.8 mm wide at the level of the first thecal pair, then gradually widens to the maximum of 1.1-1.4 mm (excluding genicular processes). Thecae number 14 in 10 mm. The 2TRD is 1.1-1.3 mm at th2, and 1.5 mm at th4 (after HOWE, 1983). The sicula is 1.3 to 2 mm long. The sicular aperture is 0.2 mm wide, furnished with a virgella. Early astogeny is of pattern H (normalis). The thecae are parallel or slightly inclined to rhabdosome axis. The thecae are strongly geniculated, a condition that is evidenced by the presence of spines which can be transformed into genicular flanges up to 0.4 mm long. The supragenicular walls are short, 0.4 mm long.

Discussion: These specimens match material of *P. innotatus* revised by RUSSEL *et al*. (2000), although the former can be distinguished by their less closely spaced thecae. In that sense, the material from the Vargas Peña Formation is particularly similar to that described from

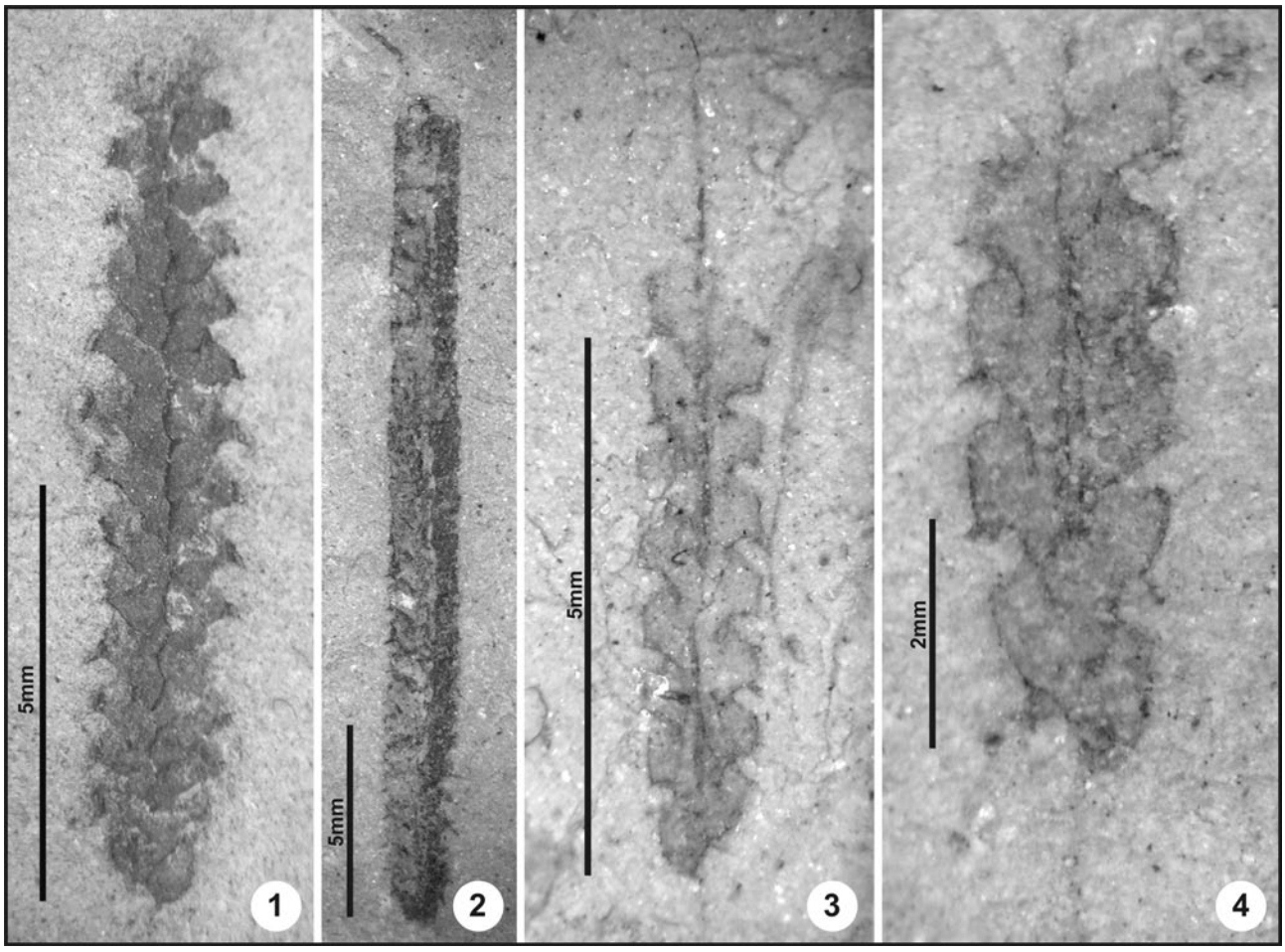

Fig. 9: **1**, *Metaclimacograptus* cf. *asejradi* LEGRAND, San Fernando quarry, MLP 29226. **2**, *Paraclimacograptus brasiliensis* (RUEDEMANN), Galeano quarry, MLP 29234. **3**, **4**, *Paraclimacograptus innotatus* (NICHOLSON), San Fernando quarry; **3**, MLP 29232; **4**, MLP 29231.

the Llandovery of southern France (Štorch & Feist, 2008, figs. 5.11, 7.1, 7.2, ?7.14, 8.1) and northwestern Argentina (Rubinstein & Toro, 2006, figs. 3.21, 3.22).

Paraclimacograptus brasiliensis (Ruedemann *in* Maury, 1929) Figs. 8.12, 8.13, 9.2

1929. *Climacograptus innotatus brasiliensis* Ruedemann. Maury, p. 21, figs. 1, 2, 3.
1947. *Climacograptus innotatus brasiliensis* Ruedemann. Ruedemann, p. 428.
1959. *Climacograptus innotatus brasiliensis* Ruedemann. Turner, p. 104, pl. 9, fig. 8.
1996. *Paraclimacograptus innotatus brasiliensis* Ruedemann. Rickards, Brusa, Toro & Ortega, figs. 4a–d, 9c.

Material examined: Two complete and three fragmentary rhabdosomes, mostly flattened, moderately well-preserved and replaced by coalified material (MLP 29233, 29234). Vargas Peña Formation, San Fernando and Galeano quarries.

Description: The rhabdosome attains a maximum length of 22.5 mm in a complete specimen, and 21 mm in a fragmented one. The rhabdosome is robust and paralell-sided, its width is 0.8 to 1 mm at the first thecal pair, and widens rapidly to 1.5-1.8 mm (excluding the dorsal apertural processes). The sicula is 1.7 mm long, having a 0.2-0.25-mm-wide aperture and a small virgella. Early astogeny is of pattern H (normalis). The thecae are strongly geniculated, showing hoods up to 0.3 mm long and/or flanges that project ventrally (except the first pair). The supragenicular thecal walls are short (0.4-0.5 mm long) and parallel to the rhabdosomal axis. Thecae number ranges from 14 in 10 mm in the proximal part of the rhabdosome to 13 in 10 mm distally. The 2TRD is 1.15 mm at th1, and 1.25 mm at th4. Thecae overlap for one- half of their length. The rhabdosome has a straight and complete medium septum which is projected distally as a nema *c*. 5 mm long.

Discussion: This species is widely represented in different levels of the Vargas Peña Formation. Our specimens conform in their overall features (e.g., rhabdosomal length, rhabdosomal width, thecal spacing and thecal processes) with those of *Paraclimacograptus brasiliensis* (Ruedemann), a typical lower Silurian taxon of South America. *Paraclimacograptus brasiliensis* was originally described by Ruedemann (*in* Maury, 1929; Ruedeman, 1947) as *Climacograptus innotatus brasiliensis* on the basis of specimens from Cashoeira Acaba Mundos, Trombetas River, Estado de Para, Amazon Basin (Brazil). Bulman & Turner (*in* Harrington, 1950) and Turner (1959) reported the occurrence of fragmented rhabdosomes in the Llandovery of the Galeano quarry in eastern Paraguay. In addition, Rickards *et al.* (1996) described this taxon from Cerro del Fuerte in the Argentine Precordillera (La Chilca Formation, San Juan Province).

Paraclimacograptus brasiliensis is almost indistinguishable from immature specimens of *P. lybicus* (Desio, 1940). *Paraclimacograptus brasiliensis* differs from *P. innotatus* in having a longer and wider rhabdosome.

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