Trilobites and sedimentary facies of the upper Coquena Formation (late Tremadocian; *Notopeltis orthometopa* Zone), Cordillera Oriental, northwestern Argentina

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TORTELLO, M.F., BENÍTEZ, M.H. & ESTEBAN, S.B., 2016:??:??. Trilobites and sedimentary facies of the upper Coquena Formation (late Tremadocian; *Notopeltis orthometopa* Zone), Cordillera Oriental, northwestern Argentina. *Australasian Palaeontological Memoirs 49*, 1-19. ISSN 2205-8877.

The area west of Purmamarca is a classic locality of the upper Tremadocian (Lower Ordovician) of the central Cordillera Oriental, northwestern Argentina. There, the upper member of the Coquena Formation documents the vertical passage of offshore to shoreface settings affected by storm activity. Updated information on the stratigraphic distribution of the trilobites from the *Notopeltis orthometopa* Zone in the Quebrada de Chalala is provided. Offshore facies from the lower part of the succession contain high diversity assemblages including *Asaphellus jujuanus*, *Geragnostus callaveiformis*, *G. callaveiformis*?, *G. nesossii*, *Conophrys* sp., *Bienvillia rectifrons*, *Parabolinella triarthroides*, *Apatokephalus tibicen*, *Ceratopyge forficuloides*, *Pyrimetopus pyrifrons* and *Rossaspis*? sp. In contrast, shoreface deposits of the upper part of the formation have very low diversity faunas, which are composed almost exclusively of *Notopeltis orthometopa* and *Mekynophrys nanna*. The FAD of *N. orthometopa* and *M. nanna* are located well above the first records of *Asaphellus jujuanus* and other trilobites. This fact may assist in refining the current biostratigraphic scheme of the upper Tremadocian of Argentina.

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Keywords: Trilobites, sedimentary facies, upper Tremadocian, Coquena Formation, Cordillera Oriental, Argentina.

THE Cordillera Oriental in northwestern Argentina contains thick lower Palaeozoic fossiliferous successions that represent a wide variety of sedimentary environments. The shales and sandstones of the Santa Rosita Formation and equivalents (late Furongian-Tremadocian) are well represented in the eastern part of the Cordillera Oriental along Santa Victoria, Nazareno, Iruya, Huacalera, east of Tilcara, and Sierra de Mojotoro (Eastern Belt *sensu* Astini 2003; Fig. 1), displaying fluvio-estuarine, shoreface and offshore sediments which accumulated on a gently dipping shelf (e.g., Astini 2003; Buatois & Mángano 2003 and references therein; Moya 2008). Trilobites are particularly abundant in this formation, a fact that allowed the definition of the upper Furongian *Parabolina* (*Neoparabolina*) *frequens argentina* Zone and the Tremadocian *Jujuyaspis keideli*, *Kainella andina*, *K. meridionalis*, *K. teiichii*, *Bienvillia tetragonalis* and *Notopeltis orthometopa* zones (e.g., Harrington & Leanza 1957; Tortello *et al*. 2002; Waisfeld & Vaccari 2008; Vaccari *et al*. 2010 and references therein).

The area west of Purmamarca contains fossiliferous localities typical of the central region (=Central Belt *sensu* Astini 2003) of the Cordillera Oriental. From these localities Harrington (1937, 1938) and Harrington & Leanza (1957, p. 13) described shaly sandstones, siltstones, and silty shales of the "Coquena shales" with a diverse trilobite fauna [e.g., *Geragnostus callaveiformis* Harrington & Leanza, *Notopeltis orthometopa* (Harrington), *Mekynophrys nanna* Harrington, *Bienvillia rectifrons* (Harrington), *Parabolinella triarthroides* Harrington, and *Pyrimetopus pyrifrons* (Harrington)] of the late Tremadocian *Notopeltis orthometopa* Zone. Most of these fossils were collected from the Coquena and Las Juntas creeks, which are easily accessible, whereas the material from the Chalala Creek (=Quebrada de Chalala) (Fig. 1) was much scarcer (Harrington & Leanza 1957, p. 234). In all cases, however, information on the exact stratigraphic positions of the species was not provided.

Due to its biostratigraphic and palaeogeographic importance, further studies on the Coquena Formation (Harrington *in* Harrington & Leanza 1957 *nom. transl.* Ramos *et al.* 1967) have been carried out in recent decades. Benedetto & Carrasco (2002) divided the unit into a lower heterolithic member and an upper silty member, the latter corresponding to the "Coquena shales" of Harrington & Leanza (1957), and described late Tremadocian brachiopods from the Quebrada de Chalala. Similarly, Ottone *et al*. (1995) described an acritarch assemblage of ?late Tremadocian age, and Tortello (1996a) conducted a preliminary study on the agnostoid faunas.

In addition, Waisfeld & Vaccari (2003) illustrated specimens of trilobites (*Parabolinella triarthroides*, *Pyrimetopus pyrifrons*, *Notopeltis orthometopa*) from the *Notopeltis orthometopa* Zone of the Quebrada de Coquena,

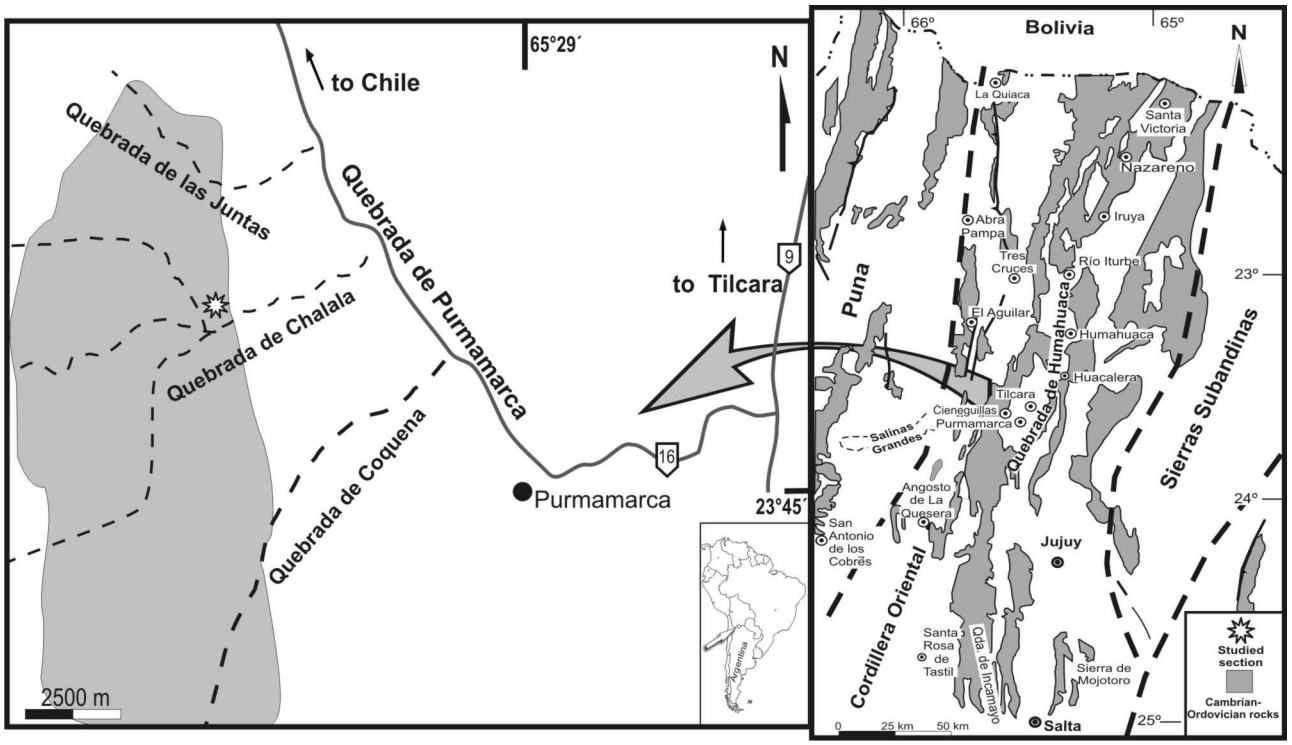


Figure 1. Location map of the studied area (based on Astini 2003 and Benítez 2013).

and Zeballo *et al*. (2008) and Zeballo & Albanesi (2013) presented a conodont study of that section and reported some trilobites from two levels of the conodont *Paltodus deltifer* Zone (*P. deltifer deltifer* Subzone). Benítez (2013) studied the sedimentology of the lower member of the Coquena Formation in detail and recognised five sedimentary facies reflecting storm-dominated platform environments, though a comprehensive analysis of the upper member was left pending futher work.

The aims of this paper are to describe the sedimentary facies and depositional environments of the upper member of the Coquena Formation in the Quebrada de Chalala, and to make available the latest data on the stratigraphic distribution of its trilobite faunas. In addition, complementary systematic information and illustrations of key species of the *Notopeltis orthometopa* Zone are provided. The highest trilobite diversity occurs in the lower part of the section studied, above levels documenting a drastic change in the environment, from a shoreface to an offshore setting. This occurrence is of regional importance, since it has also been described from upper Tremadocian levels of the Rosita Formation in the eastern Cordillera Oriental (Tortello & Esteban 2014; Esteban *et al*. in press). In contrast, the upper part of the Coquena Formation records a gradual transition to coarser-grained facies, indicating a lowering of sea level of broad significance in the Andean Basin.

STRATIGRAPHY

The stratigraphic framework of the lower Palaeozoic to the west of Purmamarca (Tumbaya Departament, Jujuy Province, northwestern Argentina) includes a Neoproterozoic-early Cambrian basement of slates and meta-greywackes of the Puncoviscana Formation, Cambrian quartzites of the Mesón Group, and late Tremadocian sandstones and shales of the Coquena Formation. In addition, Floian shales of the Cieneguillas Formation (Harrington & Leanza 1957) occur to the west, near Cieneguillas (Fig. 1) (Harrington 1938; De Ferrariis 1940; Harrington & Leanza 1957; Ramos *et al*. 1967; Amengual & Zanettini 1974; Benedetto & Carrasco 2002; Astini 2003; Benítez 2013 and references therein).

The Quebrada de Chalala is located about 4 km west of the town of Purmamarca (Fig. 1). There, the base of the Coquena Formation is faulted against a block of the Puncoviscana Formation, whereas the top is overlain by modern sediments. As stated above, the Coquena Formation comprises a lower heterolithic member and an upper silty member (Benedetto & Carrasco 2002). The 250 m thick section studied herein corresponds to the upper silty member, which is equivalent to the "Coquena shales" of Harrington & Leanza (1957, p. 13) (Fig. 2).

Sedimentary facies

The lower part of the succession is composed mainly of fine-grained sediments, whereas the middle and upper parts are dominated by sandstones. Five sedimentary facies have been defined on the basis of their distinctive lithology, contacts, bed geometry, sedimentary structures and fossil content (Figs 2–4).

Greenish grey mudstone (Facies A). This facies consists of greenish grey, unbioturbated, massive or thinly laminated mudstones (Fig. 3A). It is widely represented in the lower and middle parts of the succession, in association with Facies B (Fig. 2). The mudstones form laterally extensive packages 6–10 m thick. Trilobites are abundant in these deposits, with less common brachiopods, gastropods, bivalves, echinoderm sclerites, and scarce graptolites.

Facies A records suspension fallout deposition under low-energy conditions. The texture of the sediments, and the absence of current- and wave-generated sedimentary structures, indicate deposition well below storm wave base.

Siltstone with interbedded silty sandstone (Facies B). This facies consists of greenish grey to grey, massive to parallel

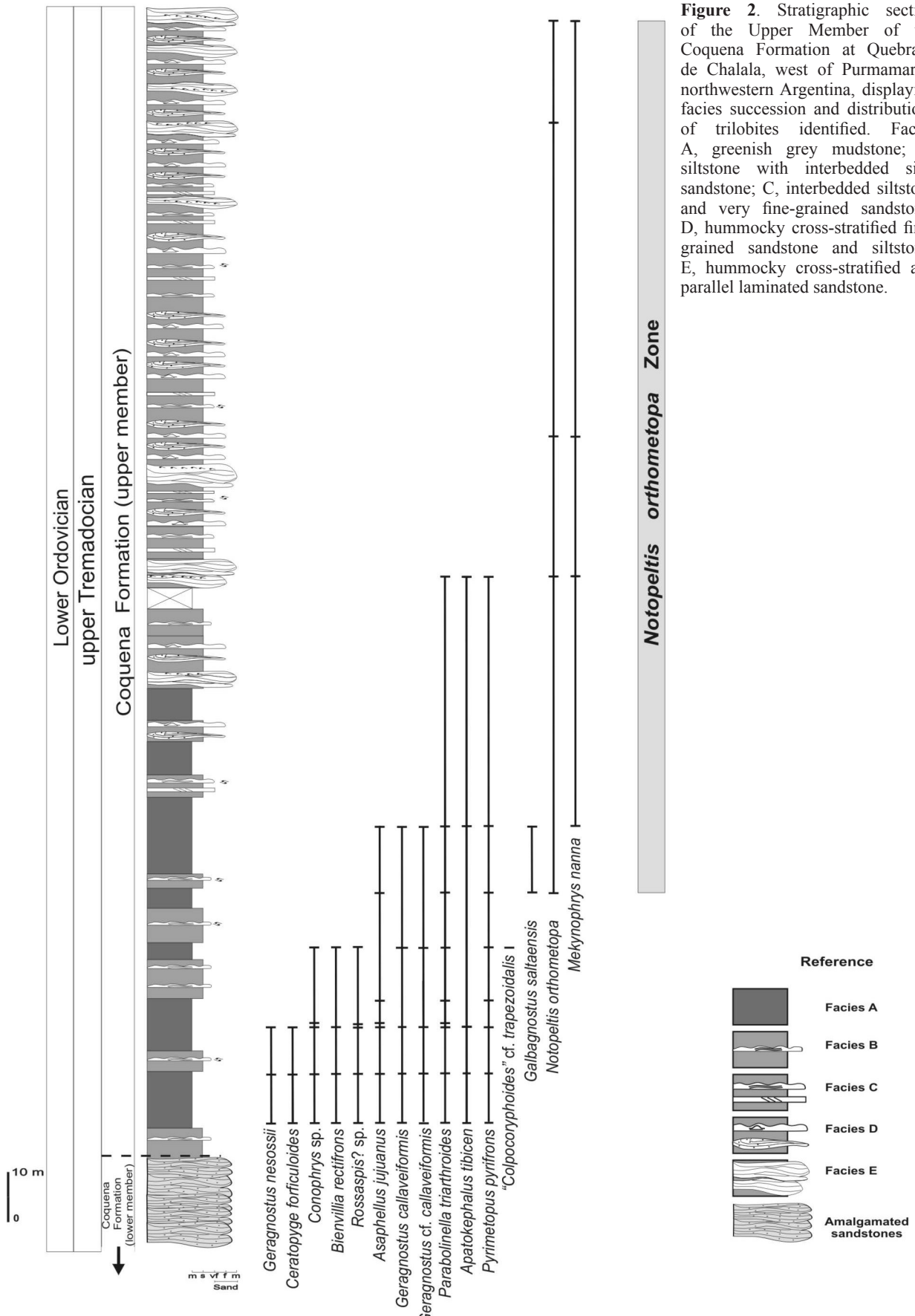


Figure 2. Stratigraphic section of the Upper Member of the Coquena Formation at Quebrada de Chalala, west of Purmamarca, northwestern Argentina, displaying facies succession and distributions of trilobites identified. Facies A, greenish grey mudstone; B, siltstone with interbedded silty sandstone; C, interbedded siltstone and very fine-grained sandstone; D, hummocky cross-stratified fine-grained sandstone and siltstone; E, hummocky cross-stratified and parallel laminated sandstone.

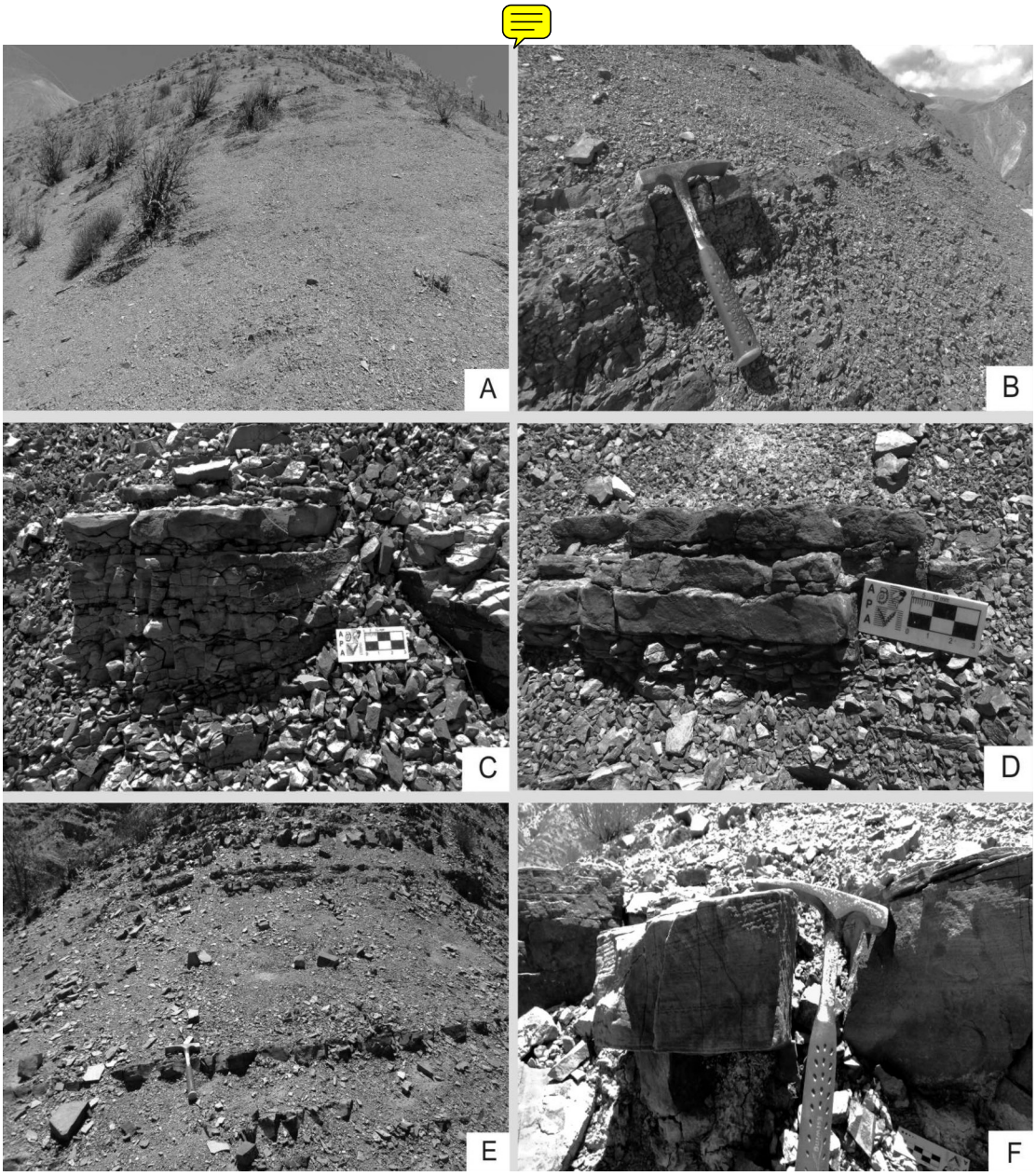


Figure 3. **A**, General view of the greenish grey mudstones of Facies A. **B**, Facies B showing a laterally continuous silty sandstone bed. **C**, Greenish, thinly stratified siltstones of Facies B. **D**, Bioclastic concentrations in Facies B. **E**, General view of Facies C. **F**, Very fine-grained sandstone bed displaying cross-lamination (Facies C).

-laminated siltstones and occasional interbedded grey, fine-grained silty sandstones (Figs 3B, C). It is well represented in the lower and middle intervals of the section, forming laterally extensive packages 3–9 m thick (Fig. 2). The silty sandstones form tabular beds which normally do not exceed 2 cm in thickness, with planar to undulating boundaries. Internally, they are massive or display ripple lamination.

Thin (< 3 cm thick) skeletal concentrations showing a loosely packed biofabric (matrix supported) are present in these beds (Fig. 3D). Bioclasts include disarticulated but not fragmented specimens of trilobites and brachiopods, which are oriented parallel to the bedding planes and lie preferentially in a convex-up position.

This facies records low-energy, suspension fallout deposition below storm wave base. However, the interbedded silty sandstone layers may have been formed by distal storm flows, which disrupted the background sedimentation. The presence of ripple lamination and the taphonomic signatures of the bioclastic concentrations (Simões *et al*. 1996; Simões & Torello 2003; Fürsich & Oschmann 1993) display evidence for weak bottom-current activity.

Interbedded siltstone and very fine-grained sandstone (Facies C). Facies C is characterised by heterolithic intervals 7 to 10 m thick, with greenish grey to grey siltstone and grey, very fine-grained sandstone (Fig. 3E). It is well represented in the middle and upper parts of the section, in association with Facies D (Fig. 2). The siltstones are closely similar to those of Facies B, whereas the sandstone beds are thicker and more abundant. They are laterally-extensive, up to 10 cm thick, and display parallel-, cross- and ripple-lamination, as well as planar to undulating bases and tops (Fig. 3F). No hummocky cross-stratification was observed in this facies.

Facies C reflects an environment influenced by storm

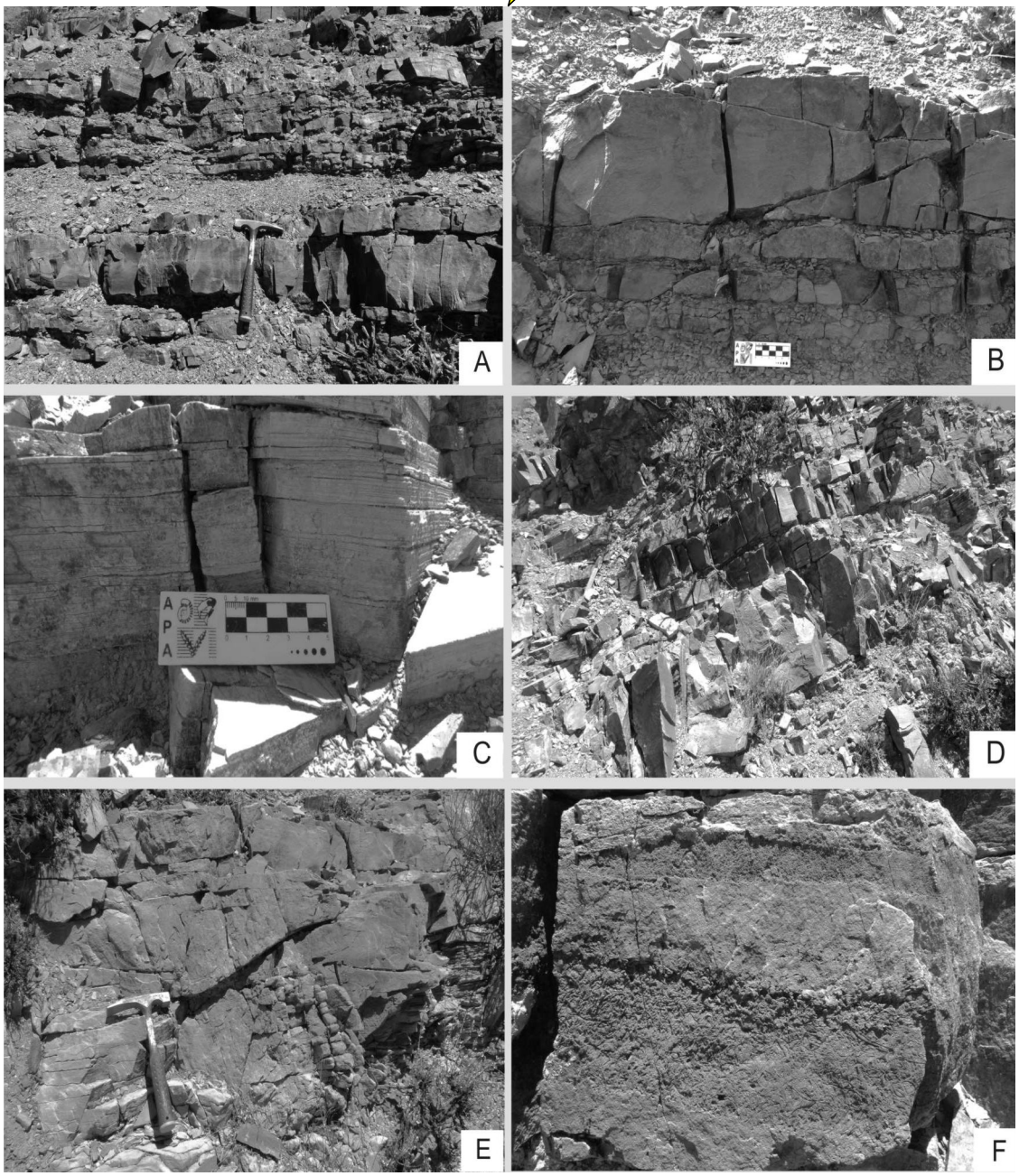


Figure 4. **A**, General view of a heterolithic sequence of sandstones and interbedded siltstones of Facies D. **B**, Sandstone bed showing hummocky cross-stratification (Facies D). **C**, Sandstone beds with parallel lamination (Facies D). **D**, Thick sandstone beds of Facies E. **E**, Sandstone bed showing hummocky cross-stratification (Facies E). **F**, Bioclastic lens in sandstone beds of Facies E.

activity. The presence of erosive-based sandstone layers indicates event deposition. Additionally, the record of tractional structures such as cross-lamination suggests deposition above the storm wave base.

Hummocky cross-stratified fine-grained sandstone and siltstone (Facies D). This facies comprises intervals 6 to 16 m thick, in which grey fine-grained sandstones with tabular or lenticular geometry are dominant (Fig. 4A). Facies D is mainly represented in the upper part of the succession, in association with Facies C and E, and to a lesser extent in the middle part of the section (Fig. 2). Tabular sandstone beds are 6 to 17 cm thick and exhibit undulating boundaries. Lenticular bodies are 5 to 8 cm thick and have lateral extensions of 1 m to 1.3 m. Internally, sandstones are characterised by hummocky cross-stratification and, to a lesser degree, parallel-lamination, ripple-lamination or a massive aspect (Fig. 4B, C). Occasionally, the upper parts of the beds show irregular disruption of the sediments (bioturbation).

Brachiopod rich-bioclastic concentrations, 5 to 8 cm thick, are included in massive sandstone units. The shell packing is usually loose in the base and dense towards the top of the beds. The orientation is generally random, though some elongate bioclasts are arranged concordant to stratification. In some cases, nested and stacked shells have been observed. Fossil remains are poorly sorted. Most of the shells are disarticulated and fragmentary.

The presence of hummocky cross-stratification indicates

a storm origin for the sandstone beds. In addition, the presence of stacked and nested shells is interpreted to indicate rapid deposition as a result of storm episodes (Fürsich & Oschmann 1986, 1993; Kidwell & Bosense 1991). Sedimentary structures and the sandstone/siltstone ratio suggest that Facies D was formed in a high-energy setting at or above the storm wave base.

Hummocky cross-stratified and parallel laminated sandstone (Facies E). Facies E is dominated by grey to light grey, hummocky cross-stratified, fine to medium-grained sandstones (Fig. 4D). This facies is mainly present in the upper part of the succession, forming amalgamated packages (70 cm to 3 m thick) in association with Facies D (Fig. 2). Contacts are sharp and planar or undulating, and tops are bioturbated. Internally, sandstone beds exhibit hummocky cross-stratification, cross lamination and parallel to sub-parallel lamination (Fig. 4E). Synsedimentary ball-and-pillow structures are also observed in this facies.

Another important feature of Facies E is the presence of complex brachiopod-rich bioclastic concentrations, which consist of sharp-based lenses with a thickness of 3 to 8 cm and lateral extent of 20 to 45 cm (Fig. 4F). The skeletal remains are disarticulated, highly fragmented and densely packed. They are poorly sorted and display concordant, oblique or random orientations relative to the bedding plane.

The presence of amalgamated sandstone beds with hummocky cross-stratification, ball-and-pillow structures, and poorly developed or absent siltstone intervals are consistent with a shallow environment affected by repeated storm events. The bioclastic concentrations described above also suggest storm activity. Most of the shell concentrations exhibit sharp bases, pointing to erosion before deposition. High degrees of fragmentation and disarticulation indicate reworking of the shells before their final burial (Fürsich & Oschmann 1993). The biofabric reflects high-energy processes of concentration and rapid depositional events (Kidwell & Bosence 1991; Fürsich & Oschmann 1993).

Depositional environment

The upper member of the Coquena Formation is interpreted as having formed in offshore to shoreface settings affected by storm activity. The coarsening- and thickening-upward trend of the succession indicates a progressive increase in energy and shallowing of the depositional environment. The fine-grained facies of the lower part of the section (Facies A and B) record offshore deposition below storm wave base, whereas the sandstones of the middle and upper parts (Facies C, D and E) represent transition from offshore to shoreface conditions.

The massive and thinly parallel-laminated mudstones of Facies A record background sedimentation in a low-energy offshore environment. The main process responsible for deposition of this facies was suspension fallout in the absence of waves and currents. However, thin, laterally extensive silty sandstone beds are occasionally interbedded with the laminated muds and siltstones of the Coquena Formation (Facies B), reflecting episodic sedimentation. The association of Facies A with both silty sandstone beds and bioclastic concentrations of simple fabric and geometry suggests distal storm flow activity (cf. Brenchley *et al*. 1986; Fürsich & Oschmann 1993).

The middle part of the succession documents a transition to higher-energy, shallower-water settings. The increase in the number of the sandstone beds, and the development of cross-lamination and hummocky cross-stratification (Facies C and D) are indicative of traction currents which were responsible for the transport and accumulation of sediments and bioclasts. Facies C and D are interpreted as having been deposited in offshore transition environments, where alternating background suspension fallout and distal storm deposition above the storm wave base are common processes (Buatois & Mángano 2003).

In the upper part of the succession, the hummocky cross-stratified sandstone beds become dominant (Facies E). The record of amalgamated beds and ball-and-pillow structures suggest a high sedimentation rate. These types of deposits are common in shoreface environments, where recurrent storms remove most of the very fine-grained sediments (Brenchley *et al*. 1993). The numerous bioclastic concentrations described from the upper and middle parts of the section show high levels of disarticulation and fragmentation, and therefore are also compatible with a shallower setting above storm wave base.

TRILOBITE ASSEMBLAGES

Based on material collected from the Chalala and Coquena creeks by J. Keidel (Dirección de Minas y Geología) and C. De Ferrariis (Universidad Nacional de La Plata) respectively, Harrington (1937, 1938) first assigned the trilobite faunas from west of Purmamarca to the upper Tremadocian because of their general similarity with those of the *Conophrys pusilla* and *Apatokephalus serratus* zones of Europe. Subsequently, Harrington & Leanza (1957, p. 28) formally erected the *Notopeltis orthometopa* Zone on the basis of material from several localities of the Cordillera Oriental, with the great abundance and widespread occurrence of *Notopeltis orthometopa* (Harrington 1938) and *Basiliella carinata* Harrrington 1938 (=*Mekynophrys nanna* Harrington 1938) as the most characteristic taxa of the zone. In addition, Harrington & Leanza (1957) pointed out the widespread distribution of *Geragnostus callaveiformis* Harrington & Leanza 1957 and its strong resemblance to *G. callavei* from the upper Tremadocian of Great Britain. They also noted the presence of *Triarthrus rectifrons* Harrington 1938 (=*Bienvillia rectifrons*), which resembles *Bienvillia angelini* (Linnarsson 1869) from the upper Tremadocian of Scandinavia; and of *Asaphellus jujuanus* Harrington 1937, which is comparable with the type species, *A. homfrayi* (Salter 1866) from the United Kingdom (Harrington & Leanza 1957, p. 27).

After its original definition, the *Notopeltis orthometopa* Zone has been widely cited in the literature on the stratigraphy of northwestern Argentina (e.g., Ramos *et al*. 1967; Amengual & Zanettini 1974; Aceñolaza & Baldis 1987; Moya 1988, 1998, 1999, 2002; Moya *et al*. 1994, 2003; Tortello 1996a, b; Waisfeld & Vaccari 2003; Albanesi & Aceñolaza 2005; Zeballo *et al*. 2008) and southern Bolivia (Suárez-Soruco 1976; Přibyl & Vaněk 1980). In addition, the associated non-trilobite faunas recently received further attention. Albanesi *et al*. (2008 and references), Zeballo *et al*. (2008) and Zeballo & Albanesi (2013) partially correlated the *N. orthometopa* Zone with both the graptolite *Aorograptus victoriae* Zone and the conodont *Paltodus deltifer deltifer* Subzone (*Paltodus deltifer* Zone) (Fig. 5), and Benedetto & Carrasco (2002) described the brachiopods *Nanorthis brachymyaria*, *N. purmamarcaensis*, *Lipanorthis andinus* and *Astraborthis quebradensis*.

Though much progress has been made in the

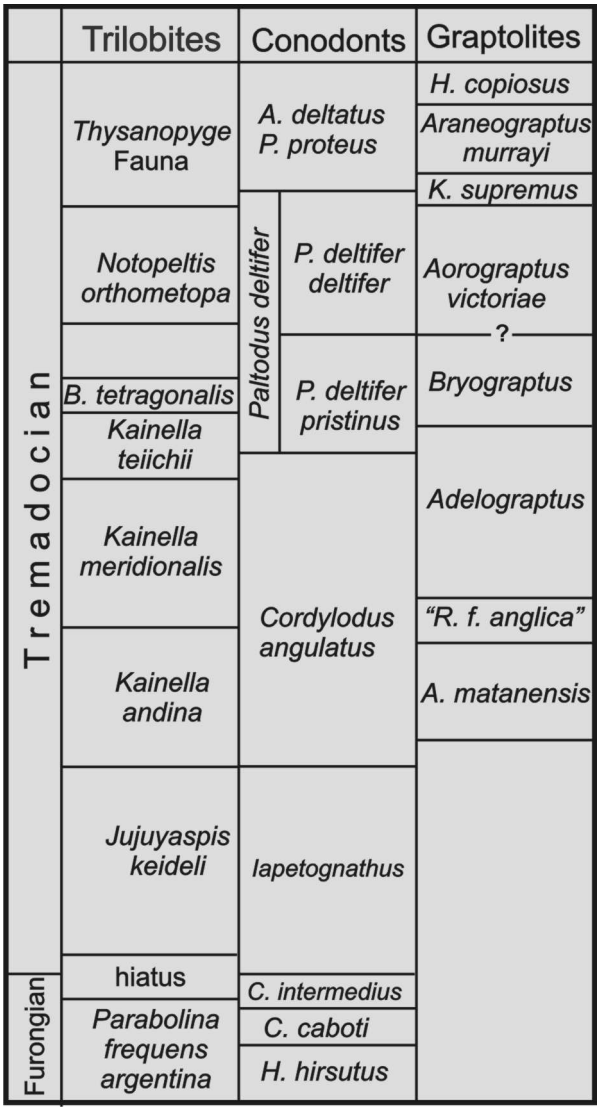


Figure 5. Trilobite, conodont and graptolite biostratigraphic chart of the upper Furongian-Tremadocian of the Cordillera Oriental (after Albanesi *et al*. 2008; Waisfeld & Vaccari 2008; Vaccari *et al*. 2010; Zeballo & Albanesi 2013 and references therein).

understanding of the *Notopeltis orthometopa* Zone in recent decades, Waisfeld & Vaccari (2003, 2008) pointed out the need to establish its precise limits, to improve the taxonomic knowledge of several index species and to verify their stratigraphic ranges. Indeed, in most of the outcrops assigned to this zone the exact stratigraphic positions of the trilobites are unknown. An exception is the Santa Victoria section, where there are well documented records of *N. orthometopa* and *Mekynophrys nanna*, among others, in the upper part of the Santa Rosita Formation (see Harrington & Leanza 1957, p. 28). In addition, Zeballo *et al*. (2008) reported stratigraphically controlled trilobite occurrences from two levels of the upper Coquena Formation in the Quebrada de Coquena.

Preliminary studies (Tortello 1995, 1996a, b) and recent resampling in the Quebrada de Chalala allowed a more complete picture of the trilobites from the upper member of the Coquena Formation (Fig. 2). The offshore assemblages from the lowermost part of the section exhibit the greatest diversity. These faunas are dominated by *Asaphellus jujuanus*, which is represented by numerous specimens having an easily identifiable morphology (Tortello & Esteban 2014), and also include *Geragnostus callaveiformis* Harrington & Leanza, *Parabolinella triarthroides* Harrington, *Apatokephalus tibicen* Přibyl & Vaněk, *Bienvillia rectifrons* (Harrington), *Rossaspis*? sp., and *Pyrimetopus pyrifrons* (Harrington). On the other hand, *Geragnostus nesossii* Harrington & Leanza, *Conophrys* sp., and *Ceratopyge forficuloides* Harrington & Leanza are much rarer.

It is important to note that the key species, *Notopeltis orthometopa* and *Mekynophrys nanna,* do not occur in the basal part of the succession, but they first occur at about 44 m and 58 m above the first appearance datum (FAD) of *A. jujuanus*, respectively (Fig. 2). Both trilobites dominate the middle part of the section, and are the only species recognised in bioclastic concentrations of the upper part of the Coquena Formation. As stated above, the upper part of the unit is dominated by amalgamated hummocky cross-stratified sandstones assignable to a storm-dominated shallow-water environment. This sea level fall is assigned herein to the *Notopeltis orthometopa* Regressive Event (NORE) (Moya 1997), which was previously recorded at the top of the *Notopeltis orthometopa* Zone in the eastern Cordillera Oriental (Moya 1997, 2002; Moya *et al*. 1998, 2003). The NORE apparently correlates with the global *Ceratopyge* Regressive Event of Erdtmann (1986) (Moya *et al*. 2003). According to Moya *et al*. (2003), the uppermost levels of the *N. orthometopa* Zone in Huacalera, Tilcara and Sierra de Mojotoro are characterised by having impoverished fossil assemblages that are composed almost exclusively of the index species that is also described herein from the Quebrada de Chalala.

Recently, Tortello & Esteban (2014) and Esteban *et al*. (in press) described the upper part of the Santa Rosita Formation in the Nazareno area, where a vertical passage from high energy, shallow water environments to offshore settings is recorded. The lower part of that succession is characterised by having a low-diversity trilobite assemblage (*Leptoplastides* sp.; *Asaphellus* sp.; unnamed zone), whereas the upper part includes diverse late Tremadocian associations which mostly resemble those from the upper member of the Coquena Formation. As in the Quebrada de Chalala, *Asaphellus jujuanus*, *Geragnostus callaveiformis*, *G. nesossii*, *Conophrys* cf. *pusilla*, *Parabolinella triarthroides*, *Bienvillia rectifrons*, *Apatokephalus tibicen*, *Pyrimetopus pyrifrons* and *Rossaspis*? sp. first occur in the initial offshore shales of the Nazareno section. Besides, the FAD of *Notopeltis orthometopa* and *Mekynophrys nanna* are located well above the first records of most other trilobites recognised. Levels containing *Notopeltis orthometopa* in Nazareno represent deeper environments than those described from the Quebrada de Chalala, a fact that can be partly explained by the topography of the Northwest Argentina basin. Moya (1988, 1999, 2008) postulated that an intra-basin swell of northeast-southwest trend (present coordinates) ("umbral de Lipán" of Moya, 1999) would have controlled sedimentation in the Tremadocian of the Central Cordillera Oriental, whereas relatively deeper settings are more characteristic of the Eastern Belt.

Although there is a need to analyse in detail further upper Tremadocian sections of northwestern Argentina, the data obtained from Nazareno and Quebrada de Chalala suggest the need to review the range of the classic *Notopeltis orthometopa* Zone. *Asaphellus jujuanus* is the

species that best characterises the levels immediately below the FAD of *Notopeltis orthometopa* and *Mekynophrys nanna*. To assess whether it is appropriate to define a new biostratigraphic unit spanning a few tens of metres below *N. orthometopa*, additional studies in supplementary sections of the Cordillera Oriental (e.g., Coquena, Las Juntas and Huichaira creeks) are in progress.

SYSTEMATIC PALAEONTOLOGY

All specimens studied come from the upper Coquena Formation (upper Tremadocian) of the Quebrada de Chalala, Cordillera Oriental, northwestern Argentina (Fig. 2). Because many taxa recognised herein were previously described by Harrington & Leanza (1957) and Tortello & Esteban (2014) from west of Purmamarca and the Nazareno area, respectively, they are treated only briefly below.

The specimens illustrated were whitened with magnesium oxide prior to photography. The morphological terms used in this paper have been mostly defined by Moore (1959), Robison (1964), Shergold *et al*. (1990), and Whittington & Kelly (1997). The material is housed in the Facultad de Ciencias Naturales e Instituto Miguel Lillo, San Miguel de Tucumán (PIL), and the Museo de Ciencias Naturales de La Plata (MLP), Argentina.

Order AGNOSTIDA Salter 1864
Superfamily AGNOSTOIDEA M'Coy 1849
Family METAGNOSTIDAE Jaekel 1909

Geragnostus Howell 1935

Type species. *Agnostus sidenbladhi* Linnarsson 1869, pl. 2, figs 60, 61.

Geragnostus callaveiformis Harrington & Leanza 1957 (Fig. 6A–J)

1957 *Geragnostus* (*Micragnostus*) *callaveiformis*; Harrington & Leanza, p. 71, figs 13.1–13.5, 14.
2014 *Geragnostus callaveiformis* Harrington & Leanza; Tortello & Esteban, p. 929, fig. 3.1–3.3 (see for further synonymy).

Material. 25 cephala and 26 pygidia [PIL 14061, 14069, 14074(1, 3–5); MLP 34685b, 34690, 34691a, 34705a, 34712, 34745, 34746a, 34747a, 34751, 34759, 34770, 34771, 34786b, 34792, 34815, 34833, 34834, 34844–34846, 34848, 34850, 34851, 34853, 34855, 34857–34859, 34860a,b, 34862, 34865, 34870, 34873, 34875, 34877, 34890, 34891b, 34893, 34898a, 34904, 34909, 34925a,c, 34936].

Remarks. As stated by Harrington & Leanza (1957) and Tortello & Esteban (2014), *G. callaveiformis* is characterised by having proportionally wide border furrows, weakly forwardly curved lateral portions of the transglabellar furrow, a conspicuous axial pygidial node, a large and semiovate posteroaxis, and minute posterolateral spines. This species is well represented in the Coquena Formation to the west of Purmamarca. Harrington & Leanza (1957, figs 13.1–13.5, 14) figured two cephala and three pygidia from the Quebrada Las Juntas, while eleven additional specimens from the Quebrada de Chalala are illustrated herein. The latter exhibits variations in the length of the posteroaxis, which occupies 58–65% of the total length of the axis. The pygidia showing a relatively long M3 (Fig. 6F, G) are especially similar to that of *G. callavei* (Raw *in* Lake 1906), from the upper Tremadocian of the United Kingdom (Rushton 1988, pl. 66, figs 1, 2, 4, 5, 11); however, the cephalon of the British species is distinguished by having a slightly longer (sag.) glabella, and strongly forwardly curved outer ends of F3 (cf. Harrington & Leanza 1957; Tortello & Esteban 2014).

Geragnostus callaveiformis? Harrington & Leanza 1957 (Fig. 6K–N, V)

1996a *Geragnostus*? sp.; Tortello, p. 208, pl. 1, figs 10–12.

Material. 1 complete specimen and 10 cephala [PIL 14073, 14074(2), 14075, 14076; MLP 34710, 34811, 34847, 34863, 34866b, 34914, 34921].

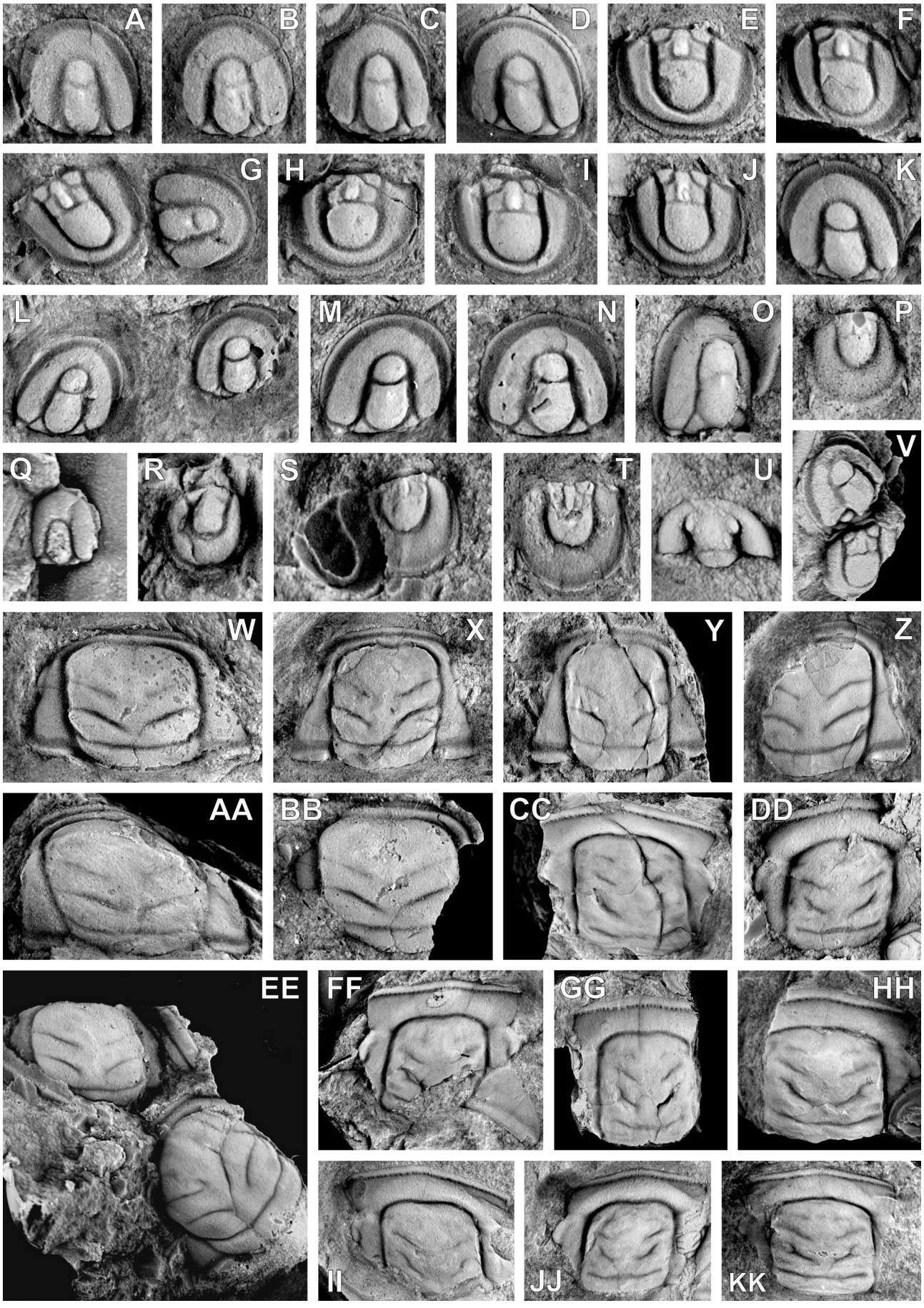
Remarks. This material compares very well to *Geragnostus callaveiformis*, with which it occurs in several levels of the upper member of the Coquena Formation. The pygidium (see complete specimen in Fig. 6V) cannot be differentiated from that of *G. callaveiformis*, whereas the cephalon differs slightly in having a more rounded anteroglabella, a deeply incised transglabellar furrow showing a transverse median portion, and a wider border furrow (Fig. 6K–N). These variations, however, may lack specific significance.

Geragnostus nesossii Harrington & Leanza 1957 (Fig. 6O, P, S, T)

1957 *Geragnostus* (*Geragnostus*) *nesossii* Harrington & Leanza, p. 65–67, figs 9.1–9.5, 10.
2014 *Geragnostus nesossii* Harrington & Leanza; Tortello & Esteban, p. 929, fig. 3.1–3.3 (*cum syn*.).

Material. 3 cephala and 7 pygidia (PIL 14029–14031, 14036, 14037; MLP 34749b, 34753, 34925b).

Figure 6. **A–J**, ***Geragnostus callaveiformis*** Harrington & Leanza; **A**, cephalon, PIL 14061, x5.9 (after Tortello, 1996a, pl. 1, fig. 6); **B**, cephalon, MLP 34860a, x7.3; **C**, cephalon, PIL 14074(1), x6.6; **D**, cephalon, MLP 34925a, x7; **E**, pygidium, MLP 34860b, x8; **F**, pygidium, MLP 34859, x7; **G**, cephalon (right) and pygidium, MLP 34846, x6; **H**, pygidium, PIL 14074(3), x7; **I**, pygidium, MLP 34904, x6.8; **J**, pygidium, MLP 34925c, x2.8. **K–N, V, *Geragnostus callaveiformis?*** Harrington & Leanza; **K**, cephalon, MLP 34921, x7.4; **L**, two cephala, MLP 34847, x4.8; **M**, cephalon, MLP 34863, x7.3; **N**, cephalon, MLP 34914, x6; **V**, complete specimen, MP 34866b, x7. **O**, **P**, **S**, **T**, ***Geragnostus nesossii*** Harrington & Leanza; **O**, cephalon, MLP 34925b, x6.1; **P**, pygidium, latex cast, PIL 14030, x7.8; **S**, cephalon (left; external mould) and pygidium, PIL 14036, x6.9 (after Tortello, 1996b, fig. 4.7); **T**, pygidium, PIL 14029, x7.1 (after Tortello, 1996b, fig. 4.10). **Q**, **R**, ***Galbagnostus saltaensis*** (Harrington & Leanza); **Q**, cephalon, PIL 13994, x4.4 (after Tortello, 1996a, pl. 1, fig. 2); **R**, pygidium, PIL 13998, x5.3 (after Tortello, 1996a, pl. 1, fig. 4). **U**, ***Conophrys* sp.**, cranidium, MLP 34670, x9. **W–Z**, **AA**, **BB**, **EE**, ***Bienvillia rectifrons*** (Harrington); **W**, cranidium, MLP 34740, x4.4; **X**, cranidium, MLP 34872, x3.3; **Y**, cranidium, MLP 34827, x3.8; **Z**, cranidium, MLP 34868, x2.9; **AA**, cranidium, PIL 14327, x3.5; **BB**, cranidium, MLP 34723, x5; **EE**, two cranidia, latex cast, MLP 34803, x4.1. **CC**, **DD**, **FF–KK**, ***Parabolinella triarthroides*** Harrington; **CC**, cranidium, MLP 34798, x2.2; **DD**, cranidium, latex cast, MLP 34762, x4.6; **FF**, cranidium, MLP 34884, x2.1; **GG**, cranidium, MLP 34799, x2; **HH**, cranidium, MLP 34825, x2.5; **II**, cranidium, MLP 34880, x2.1; **JJ**, cranidium, MLP 34820, x3.7; **KK**, cranidium, MLP 34812, x2.6.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Remarks. *Geragnostus nesossii* is easily recognisable because of its semiovate cephalon, its long (sag.) and conical glabella showing a weak F3, and its broad cephalic border furrow (Harrington & Leanza 1957; Tortello 1996b). Originally described from the upper Tremadocian around Salta city (type locality, Quebrada de Pingüiyal, Sierra de Mojotoro) and the Incamayo area by Harrington & Leanza (1957), this species was recognised subsequently in other localities of the Cordillera Oriental (Santa Victoria; Nazareno; west of Purmamarca) as a rare element in late Tremadocian fosssil assemblages (Tortello & Esteban 2014 and references therein). Harrington & Leanza (1957, fig. 9.1, 9.3, 9.4) noted that the specimens from the Quebrada de Pingüiyal show a variably developed pygidial M3, which is also documented in material from the Quebrada de Chalala (Fig. 6P, S, T).

Galbagnostus Whittington 1965

Type species. *Agnostus galba* Billings 1865; Whittington (1965, pl. 3, figs 1, 2, 4).

Galbagnostus saltaensis (Harrington & Leanza 1957) **(**Fig. 6Q, R)

1957 *Trinodus*? *saltaensis*; Harrington & Leanza, p. 74, figs 17.2a–e, 18.
1996a *Arthrorhachis saltaensis* (Harrington & Leanza); Tortello, pl. 1, figs 1–4.
1997 *Galbagnostus saltaensis* (Harrington & Leanza); Nielsen, p. 481.
2003 *Galbagnostus saltaensis* (Harrington & Leanza); Waisfeld & Vaccari, pl. 19, figs 10, 11, 14.

Material. 6 cephala and 3 pygidia (PIL 13991–13999).

Remarks. This specimens are characterised by having a relatively short glabella, a short and tapered pygidial axis, a distinct pygidial tubercle, and a transverse, trapeziform posteroaxis, which indicate affinities with *Galbagnostus* Whittington 1965 (Fortey 1980; Shergold *et al*. 1990; Nielsen 1997). In addition, the specimens examined show a slightly tapering glabella, confluent genae which are widened sagitally, small and inflated basal lobes, a weak pygidial F2 furrow, a short (sag.) and posteriorly truncate posteroaxis, and an obvious pygidial border; therefore, they conform with the diagnosis of *G. saltaensis*.

This species was originally described in detail by Harrington & Leanza (1957) from the upper Tremadocian (*Notopeltis orthometopa* Zone) of the Incamayo area (Cordillera Oriental), in association with taxa such as *Notopeltis orthometopa* (Harrington), *Mekynophrys nanna* Harrington, *Apatokephalus tibicen* Přibyl & Vaněk, *Pyrimetopus pyrifrons* (Harrington), *Ceratopyge forficuloides* Harrington & Leanza and *Rossaspis*? sp. that are also recognised in the Quebrada de Chalala.

Galbagnostus saltaensis differs from *Galbagnostus* sp., from the upper Tremadocian of the Nazareno area, Cordillera Oriental (Tortello & Esteban 2014, fig. 3.4, 3.5), in having a shorter pygidial axis with an extremely faint F2 and a posteriorly truncate M3. It differs from the type species *Galbagnostus galba* (Billings 1865), from western Newfoundland, Canada (Whittington 1965, pl. 2, fig. 24, pl. 3, figs 1–15, pl. 4, figs 1–10, text-fig. 2; Shergold *et al*. 1990, fig. 18.1.a, b), mainly in having a shorter and narrower glabella.

Order PTYCHOPARIIDA Swinnerton 1915
Suborder PTYCHOPARIINA Swinnerton 1915
Family SHUMARDIIDAE Lake 1907

Conophrys Callaway 1877

Type species. *Conophrys salopiensis* Callaway 1877; Fortey & Rushton (1980, figs 16, 17).

Conophrys sp. (Fig. 6U)

Material. 8 cranidia [PIL 14310(1), 14315; MLP 34646b, 34670, 34721, 34729, 34733, 34735].

Remarks. Several cranidia from the lower part of the section represent a shumardiid with a long (sag.) glabella, well defined teardrop-shaped anterolateral glabellar lobes, a faint but perceptible preglabellar furrow, indistinct S1 and S2, a shallow and straight occipital furrow, and a broadly rounded posterior glabellar margin. It is especially similar to *C. pusilla* (Sars 1835), from the upper Tremadocian (*C. pusilla* and *Apatokephalus serratus* zones) of Norway (e.g., Bulman & Rushton 1973, pl. 6, figs 1–4; Fortey & Owens 1991, fig. 8s–w; Ebbestad 1999, figs 24.A–J, 25A), as well as to *C.* cf. *pusilla* from the upper Tremadocian of the Nazareno area, Cordillera Oriental (Tortello & Esteban 2014, fig. 3.6–8). However, until the corresponding pygidium is found, this material is left in open nomenclature.

Suborder OLENINA Burmeister 1843
Family OLENIDAE Burmeister 1843
Subfamily TRIARTHRINAE Ulrich 1930

Bienvillia Clark 1924

Type species. *Dikelocephalus*? *corax* Billings 1865, fig. 322.

Bienvillia rectifrons (Harrington 1938) (Fig. 6W–Z, AA, BB, EE)

1938 *Triarthrus angelini* var. *rectifrons*; Harrington, p. 209–212, pl. 8, figs 17, 19–21.
1957 *Triarthrus rectifrons* Harrington; Harrington & Leanza, p. 115, fig. 43.2a–g (*cum syn*.).
2003 *Bienvillia rectifrons* (Harrington); Waisfeld & Vaccari, p. 329, pl. 31, figs 15–17.
2014 *Bienvillia rectifrons* (Harrington); Tortello & Esteban, p. 932–933, fig. 3.16–3.23, 3.25 (*cum syn*.).

Material. 23 cranidia [PIL 14327(1), 14327(3); MLP 34723, 34726b, 34734, 34736, 34738, 34740a, 34764, 34774, 34776, 34803, 34804, 34814, 34827, 34840, 34868, 34872, 34888].

Remarks. *Bienvillia* specimens having a short (sag.) preglabellar field and moderately long (exsag.) palpebral lobes are confidently assigned to *B. rectifrons* (Harrington 1938). This species was revised in detail by Harrington & Leanza (1957, fig. 43.2a–g) on the basis of material essentially from west of Purmamarca and from Santa Victoria (Cordillera Oriental). Waisfeld & Vaccari (2003, pl. 31, figs 15–17) and Tortello & Esteban (2014, fig. 3.16–3.23, 3.25) illustrated additional specimens from the type locality (Quebrada de Coquena) and the Nazareno area, respectively.

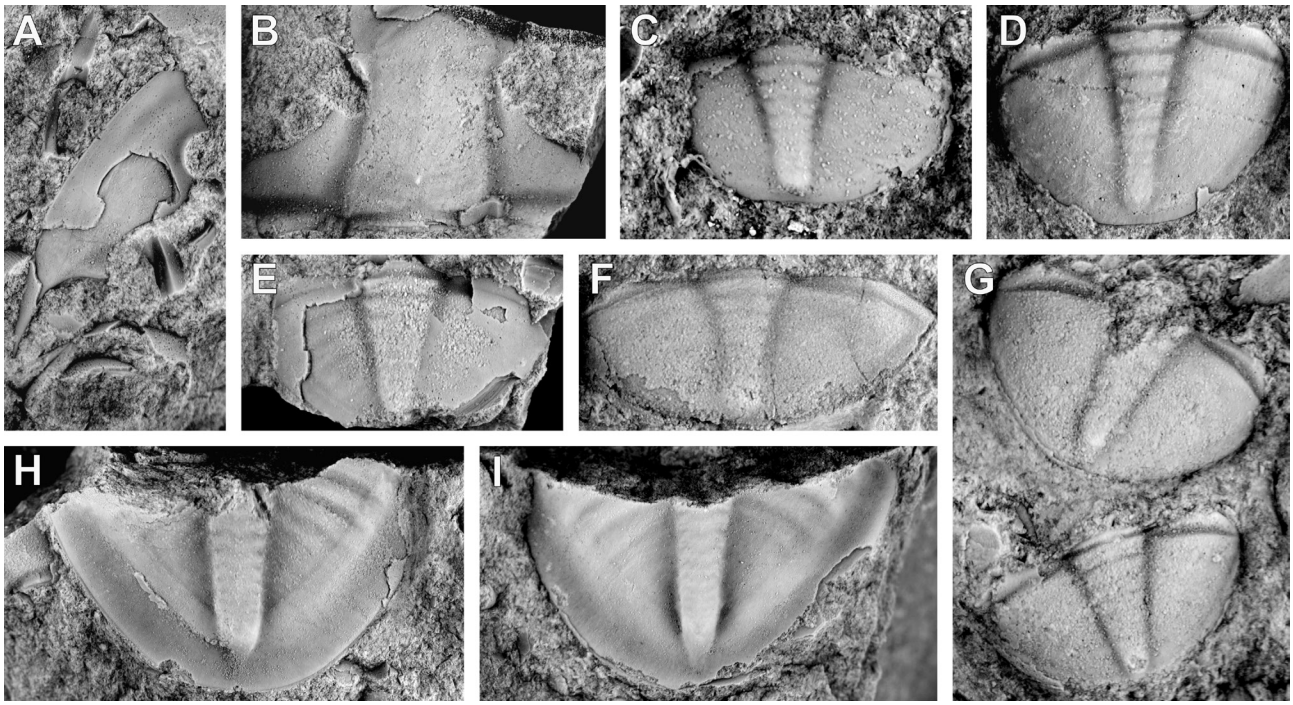

Figure 7. **A–G**, ***Notopeltis orthometopa*** (Harrington); **A**, librigena, MLP 34949, x1.8; **B**, cranidium, MLP 34950, x1.7; **C**, pygidium, latex cast, MLP 34954a, x7.3; **D**, pygidium, MLP 34954b, x2.7; **E**, pygidium, MLP 34946a, x3.6; **F**, pygidium, PIL 13996(1), x4.8; **G**, two pygidia, MLP 34945, x3. **H**, **I**, ***Mekynophrys nanna*** Harrington; **H**, pygidium, MLP 34948, x2.1; **I**, pygidium, MLP 34947, x2.1.

Subfamily OLENINAE Burmeister 1843

Parabolinella Brøgger 1882

Type species. *Parabolinella limitis* Brøgger 1882, pl. 3, fig. 2.

Parabolinella triarthroides Harrington 1938 (Fig. 6CC, DD, FF–KK)

1938 *Parabolinella triarthroides*; Harrington, p. 194–196, fig. 9, pl. 7, figs 10, 11.
1957 *Parabolinella triarthroides* Harrington; Harrington & Leanza, p. 105, 107, fig. 39.1a,b.
2003 *Parabolinella triarthroides* Harrington; Waisfeld & Vaccari, p. 330, pl. 32, figs 14–18.
2008 *Parabolinella triarthroides* Harrington; Zeballo, Albanesi & Ortega, fig. 5.8.
2014 *Parabolinella triarthroides* Harrington; Tortello & Esteban, p. 933, fig. 3.24, 3.26–3.33.

Material. 1 cephalon, 46 cranidia, 1 cephalothorax and 1 fragmentary thorax [PIL 14324(1), 14327(2, 4–6), 14329(1); MLP 34691b, 34698a, 34716, 34717, 34727, 34728, 34730, 34739, 34744, 34750, 34752, 34754–34758, 34760–34763, 34766, 34769, 34772, 34773, 34775, 34777, 34778, 34797–34799, 34801, 34802, 34810b, 34812, 34813, 34820, 34822, 34824, 34825, 34867, 34880, 34884, 34895].

Remarks. *Parabolinella triarthroides* Harrington is characterised by its small size, subparallel-sided glabella, slightly inflated preglabellar field, obvious ocular ridges and palpebral lobes, and very wide (tr.) posterior fixigenae. Although Harrington (1938, pl. 7, figs 10, 11) and Harrington & Leanza (1957, fig. 39.1a,b) illustrated only two small cranidia from the Quebrada de Coquena type locality, additional specimens, which include two complete exoskeletons, have been figured by Waisfeld & Vaccari (2003, pl. 32, figs 14–18) from that locality. Further cranidia from the Quebrada de Chalala are illustrated herein. It is interesting to note that some of them attain a relatively large size for the species (13 mm in length) (Fig. 6CC).

Parabolinella triarthroides is very similar to *P. lata* Henningsmoen from the upper Tremadocian of Norway (Henningsmoen 1957, pl. 12 fig. 8; Ebbestad 1999, fig. 38.A–G), but differs in having a narrower (tr.) palpebral area of the fixigena (cf. Rushton 1988). Similarly, it is distinguished from *P. triarthra* (Callaway), from the Shineton Shales of Shropshire, England (e.g., Henningsmoen 1957, pl. 12, figs 6, 7; Owens *et al*. 1982, pl. 1, fig. k), only by its more clearly defined palpebral lobes.

Order ASAPHIDA Salter 1864 emend. Fortey & Chatterton 1988
Superfamily ASAPHOIDEA Burmeister 1843
Family ASAPHIDAE Burmeister 1843

Notopeltis Harrington & Leanza 1957

Type species. *Megalaspidella orthometopa* Harrington 1938, pl. 12, figs 1–8.

Notopeltis orthometopa (Harrington 1938) (Fig. 7A–G)

1938 *Megalaspidella orthometopa*; Harrington, p. 239–241, pl. 12, figs 1–8.
1957 *Notopeltis orthometopa* (Harrington); Harrington & Leanza, p. 155–156, figs 67, 68.1–68.11, 69.1–69.5 (*cum syn*.).
2008 *Notopeltis orthometopa* (Harrington); Zeballo, Albanesi & Ortega, fig. 5.5–5.6.
2014 *Notopeltis orthometopa* (Harrington); Tortello & Esteban, p. 934, figs 4.1–4.18, 5.1–5.18 (*cum syn*.).

Material. 5 cranidia, 1 librigena and 38 pygidia [PIL

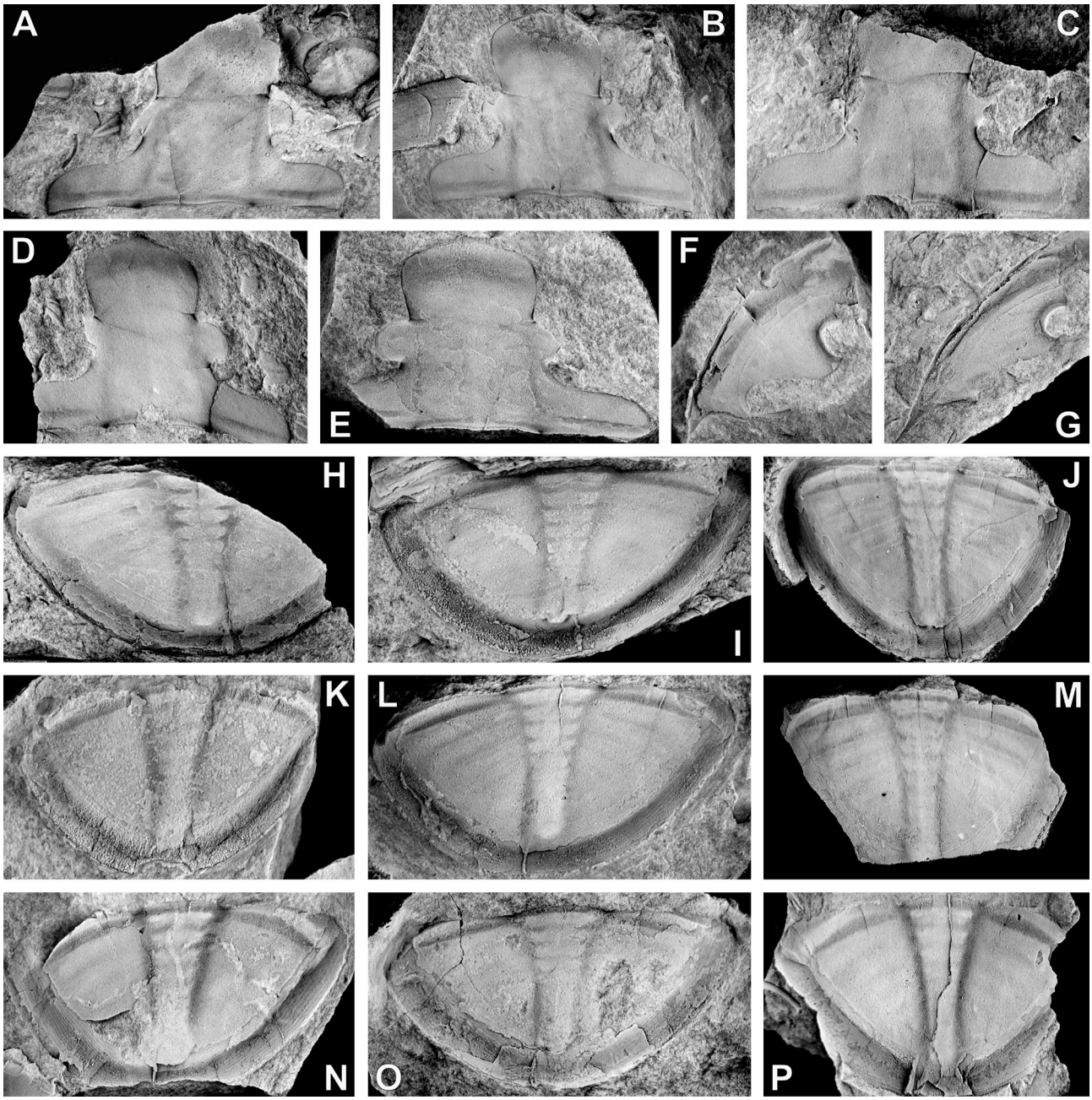

Figure 8. ***Asaphellus jujuanus*** Harrington; **A**, cranidium, MLP 34699, x1.4; **B**, cranidium, MLP 34902, x1.2; **C**, cranidium, MLP 34819, x2.1; **D**, cranidium, MLP 34885, x2.8; **E**, cranidium, MLP 34832, x2.7; **F**, librigena, MLP 34911, x1.3; **G**, librigena, MLP 34718b, x1.7; **H**, pygidium, MLP 34831, x2.7; **I**, pygidium, MLP 34806b, x2.3; **J**, pygidium, MLP 34903, x1.3; **K**, pygidium, MLP 34662, x2.3; **L**, pygidium, MLP 34905, x2; **M**, pygidium, MLP 34892, x1.1; **N**, pygidium, MLP 34891a, x1.9; **O**, pygidium, MLP 34939, x1.9; **P**, pygidium, MLP 34930, x1.9.

13996(1), 14333(2); MLP 34943–34946, 34949–34960, 34961a, 34962a, 34963, 34964].

Remarks. Since Harrington & Leanza (1957) described *Notopeltis orthometopa* (Harrington) in detail and illustrated numerous specimens from the Quebrada de Coquena in the west of Purmamarca, only a few individuals of this species are figured herein. They clearly show the diagnostic features of the taxon, such as a long glabella, a narrow (tr.) palpebral area of the fixigena, distinct genal spines, and a weakly differentiated pygidial border. The material occurs in both sandstones and shales from the middle and upper parts of the studied section. The specimens preserved in marly sandstone usually retain their original convexity, whereas those preserved in shale exhibit clear signs of compression and distortion (Fig. 7F); a fact also documented in other localities of the Cordillera Oriental (see Harrington & Leanza 1957; Tortello & Esteban 2014).

Mekynophrys Harrington 1938

Type species. *Mekynophrys nanna* Harrington 1938, pl. 6, figs 7, 16–18; Harrington & Leanza (1957, fig. 44.3).

Mekynophrys nanna Harrington 1938 (Fig. 7H, I)

1938 *Mekynophrys nanna*; Harrington, p. 207–209, pl. 6, figs 7, 16–18.

1938 *Basiliella carinata*; Harrington, p. 247–249 (partim), pl. 13, figs 12, 14, 15, 18 (only).
1957 *Mekynophrys nanna* Harrington; Harrington & Leanza, p. 119, 120, fig. 44.3.
1957 *Basiliella carinata* Harrington; Harrington & Leanza, p. 145, 146, figs 61.1–61.9, 62.1–62.9 (*cum syn*.).
2003 *Mekynophrys nanna* Harrington; Waisfeld & Vaccari, p. 320, 321, pl. 23, figs 9–12.
2008 *Mekynophrys nanna* Harrington; Zeballo *et al*., fig. 5.12.
2014 *Mekynophrys nanna* Harrington; Tortello & Esteban, 934, 936, fig. 6.1–6.21 (*cum syn*.).

Material. 5 pygidia [PIL 14333(1); MLP 34947, 34948, 34961b, 34962b].

Remarks. Pygidia having a narrow (tr.) axis, wide and shallow anterior pleural furrows, a well differentiated concave border, and a wide doublure, are reported here from the middle and upper Quebrada de Chalala section, and assigned to *Mekynophrys nanna* Harrrington *sensu* Waisfeld & Vaccari (2003) (Harrington 1938; Harrington & Leanza 1957; Tortello & Esteban 2014). As originally stated by Harrington & Leanza (1957), this taxon typically occurs in association with *Notopeltis orthometopa* in west of Purmamarca and, also, in other localities of the Cordillera Oriental (e.g., Santa Victoria; Nazareno; Incamayo).

Asaphellus Callaway 1877

Type species. *Asaphus homfrayi* Salter 1866, pl. 24, fig. 6.

Asaphellus jujuanus Harrington 1937 (Fig. 8A–P)

1937 *Asaphellus jujuanus*; Harrington, p. 115–117, pl. 5, figs 5, 9, 10, 14.
2014 *Asaphellus jujuanus* Harrington; Tortello & Esteban, p. 936–937, fig. 7.1–7.19 (*cum syn*.).

Material. 1 complete specimen, 13 cranidia, 15 librigenae, 4 hypostomes, 1 fragmentary thorax, 2 thoracopygons and 86 pygidia [PIL 14314(1, 2), 14330(2, 3); MLP 34646a, 34647–34654, 34658, 34661–34669, 34671–34673, 34675–34680, 34683, 34686–34688, 34694, 34695a, 34696, 34697, 34699–34703, 34706, 34708, 34709, 34711, 34713, 34715b, 34718b, 34719, 34722, 34724, 34725, 34726a, 34731, 34732, 34737, 34743b, 34747b, 34779b, 34781, 34795b, 34806, 34807, 34808b, 34819, 34821, 34823, 34826, 34828, 34830, 34832, 34885, 34891a, 34892, 34902, 34903, 34905, 34911, 34920, 34922a, 34926, 34929, 34930, 34937, 34939].

Remarks. In spite of being very abundant in the Coquena Formation, only a few specimens of *Asaphellus jujuanus* Harrington were illustrated by Harrington (1937, 1938) and Harrington & Leanza (1957) (see also Waisfeld & Vaccari 2003). Based on copious material from the Santa Rosita Formation in the Nazareno area (Cordillera Oriental), Tortello & Esteban (2014) revised the diagnosis and synonymy of *A. jujuanus*, regarding its large size, the transverse posterior facial suture, its short genal spines, the narrow pygidial axis, and its well developed and depressed pygidial border, as the most diagnostic features. Additional specimens from the Quebrada de Chalala section are illustrated herein (Fig. 8A–P).

Family CERATOPYGIDAE Linnarsson 1869

Ceratopyge Hawle & Corda 1847

Type species. *Olenus forficula* Sars 1835, pl. 8, fig. 1a–f.

Ceratopyge forficuloides Harrington & Leanza 1957 (Fig. 9A–I)

1957 *Ceratopyge forficuloides*; Harrington & Leanza, p. 185, fig. 94.1–94.9.
2014 *Ceratopyge forficuloides* Harrington & Leanza; Tortello & Esteban, p. 939, fig. 9.1–9.10.

Material. 7 cranidia, 2 thoraces and 5 pygidia [PIL 14311(1–3), 14321 (1, 2); MLP 34655, 34849, 34856, 34887, 34889, 34896, 34897, 34906, 34915].

Remarks. The material studied represents a *Ceratopyge* species with a short (sag.) preglabellar field, imperceptible lateral glabellar furrows, a weak median glabellar node which is located close to the occipital furrow, and a pygidial axis composed of four rings and a terminal piece. Thus, it is assignable to *C. forficuloides* Harrington & Leanza; a species previously described only from the upper Tremadocian of the Santa Victoria, Incamayo and Nazareno areas (Cordillera Oriental) (Harrington & Leanza 1957, fig. 94.1–94.9; Waisfeld & Vaccari 2003; Tortello & Esteban 2014, fig. 9.1–9.10). A well preserved thorax from the Quebrada de Chalala (Fig. 9I) shows that the pleural spine of the sixth segment is much longer than those of the anterior segments.

Ebbestad (1999) provided updated information on the Tremadocian genus *Ceratopyge* and revised in detail the species from Scandinavia (*C. forficula*; *C. acicularis*; *C.* sp.). As originally stated by Harrington & Leanza (1957), *Ceratopyge forficuloides* compares closely with the type species *C. forficula* (Sars 1835), from the Tremadocian of Norway and Sweden (e.g., Ebbestad 1999, fig. 57), but differs mainly in having a wider (sag.) anterior cephalic border, effaced lateral glabellar furrows, a more posteriorly located median glabellar node, and a macrospine on the sixth thoracic segment.

Superfamily REMOPLEURIDIOIDEA Hawle & Corda 1847
Family KAINELLIDAE Ulrich & Resser 1930

Apatokephalus Brøgger 1896

Type species. *Trilobites serratus* Boeck 1838, p. 139.

Apatokephalus tibicen Přibyl & Vaněk 1980 (Fig. 9J–X)

1938 *Apatokephalus dubius* (Linnarsson); Harrington, p. 171–174, pl. 5, figs 6–10.
1957 *Apatokephalus serratus* (Boeck); Harrington & Leanza, p. 135–139, fig. 56.1, 56.3–56.8, 56.10.
1980 *Apatokephalus tibicen*; Přibyl & Vaněk, p. 23, 24, pl. 12, figs 3, 4.
2014 *Apatokephalus tibicen* Přibyl & Vaněk; Tortello & Esteban, p. 943–944, fig. 9.11–9.15, 9.19.

Material. 35 cranidia, 1 librigena and 25 pygidia [PIL 14062, 14318(4–6, 9, 10, 12); MLP 34684, 34693, 34695b, 34698b, 34704, 34705b, 34707, 34740b, 34767, 34780, 34782–34785, 34788–34791, 34793, 34796, 34800, 34805, 34809, 34816, 34829, 34835, 34836, 34841, 34842, 34843b, 34861, 34864, 34866a, 34869, 34878, 34882, 34883, 34886, 34898b, 34900, 34910, 34917–34919,

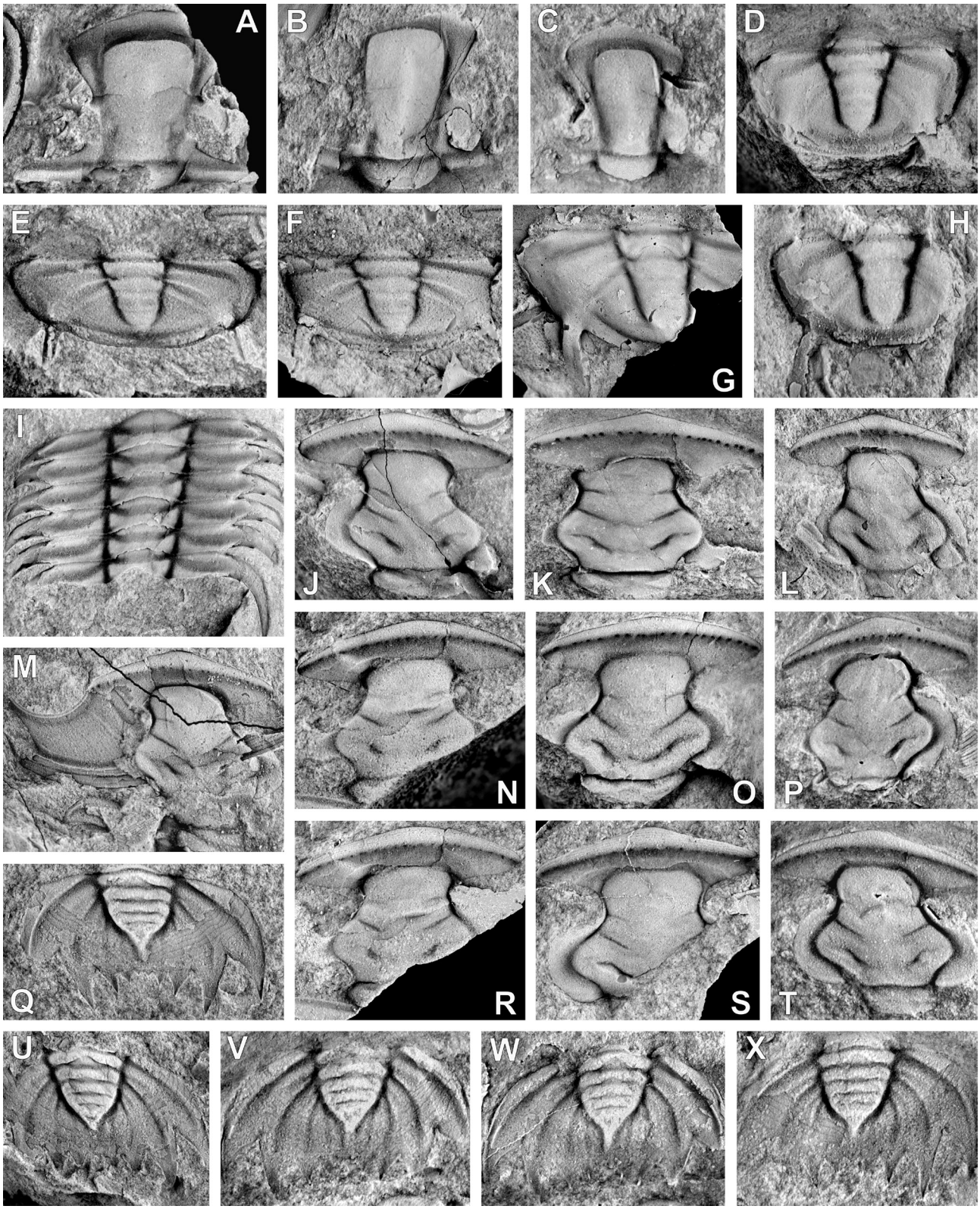

Figure 9. **A–I**, ***Ceratopyge forficuloides*** Harrington & Leanza; **A**, cranidium, MLP 34889, x4.5; **B**, cranidium, MLP 34887, x3.7; **C**, cranidium, MLP 34896, x5.3; **D**, pygidium, MLP 34856, x4.6; **E**, pygidium, MLP 34906, x4.8; **F**, pygidium, latex cast, MLP 34915, x4.8; **G**, pygidium, latex cast, PIL 14311b, x2.6; **H**, pygidium, MLP 34849, x5; **I**, partial thorax, PIL 14311a, x2.8. **J–X**, ***Apatokephalus tibicen*** Přibyl & Vaněk; **J**, cranidium, MLP 34866a, x3.1; **K**, cranidium, MLP 34788, x3.2; **L**, cranidium, MLP 34886, x3.2; **M**, cranidium and librigena, MLP 34816, x3.4; **N**, cranidium, MLP 34917, x4.7; **O**, cranidium, MLP 34883, x3.3; **P**, cranidium, MLP 34809, x4.6; **Q**, pygidium, MLP 34784, x3.9; **R**, cranidium, latex cast, MLP 34917, x4.9; **S**, cranidium, MLP 34861, x4.1; **T**, cranidium, MLP 34882, x4.3; **U**, pygidium, PIL 14318, x4.4; **V**, pygidium, MLP 34910, x5.6; **W**, pygidium, latex cast, MLP 34910, x5.3; **X**, pygidium, MLP 34918, x5.7.

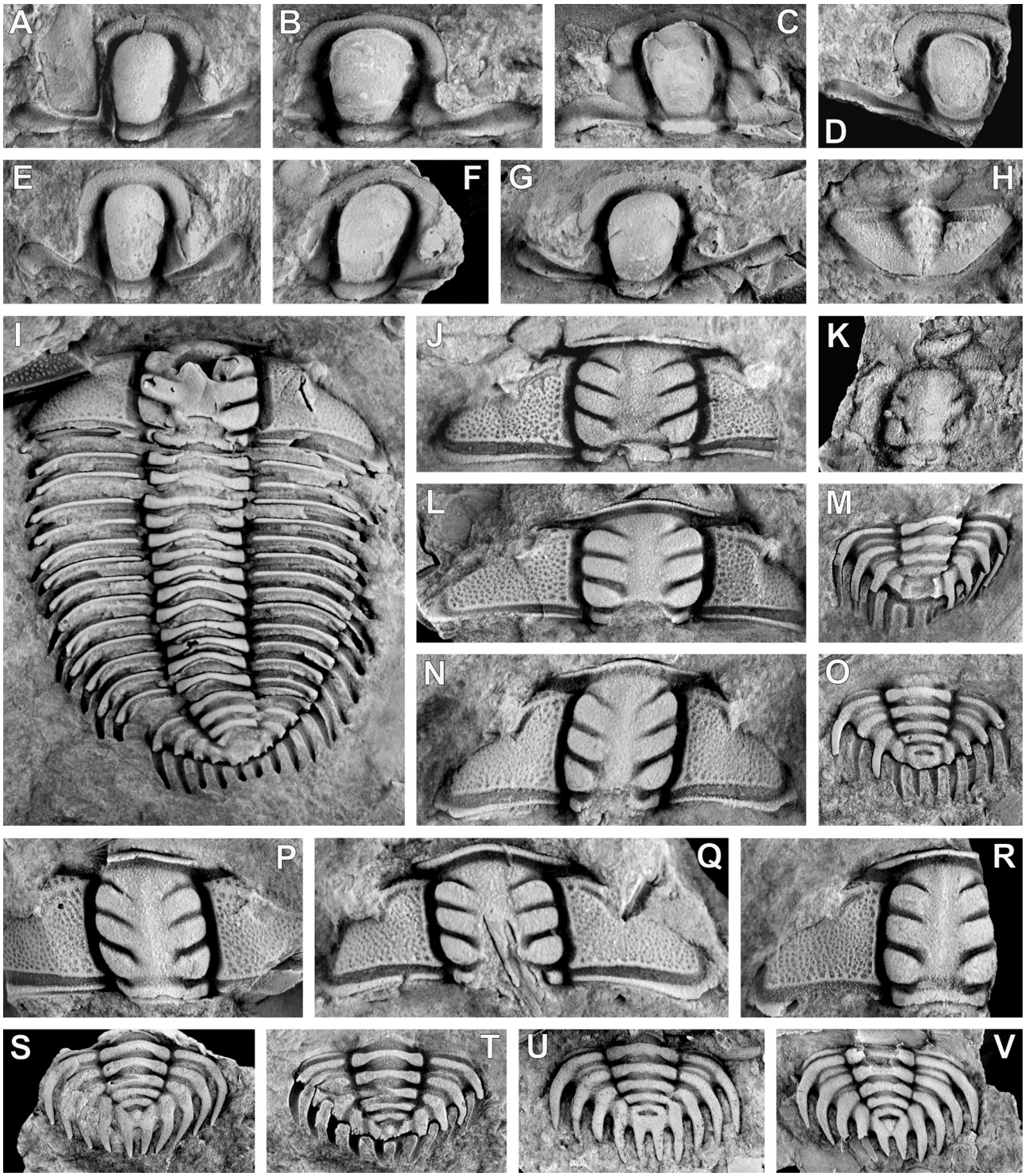

Figure 10. **A–H**, ***Pyrimetopus pyrifrons*** (Harrington); **A**, cranidium, MLP 34923, x4.7; **B**, cranidium, MLP 34810a, x5.2; **C**, cranidium, PIL 14310, x4.2; **D**, cranidium, PIL 14318, x4.3; **E**, cranidium, MLP 34931, x5; **F**, cranidium, latex cast, MLP 34941, x4.8; **G**, cranidium, MLP 34839, x4.6; **H**, pygidium, PIL 14318, x5.6. **I**, **J**, *Rossaspis*? sp.; **I**, almost complete specimen, MLP 34794, x3.2; **J**, cranidium, MLP 34656, x4.2. **K**, ***"Colpocoryphoides" trapezoidalis*** Harrington & Leanza, cranidium, latex cast, PIL 14304, x4.6. **L–V, *Rossaspis?* sp.**; **L**, cranidium, MLP 34899, x4.2; **M**, pygidium, PIL 14320, x3.2; **N**, cranidium, MLP 34907, x5.2; **O**, pygidium, MLP 34749, x3.2; **P**, cranidium, MLP 34874, x5; **Q**, cranidium, MLP 34934, x6.8; **R**, cranidium, MLP 34876, x4.8; **S**, pygidium, latex cast, MLP 34787, x2.8 ; **T**, pygidium, MLP 34817, x2.8; **U**, pygidium, latex cast, MLP 34741, x3.5; **V**, pygidium, MLP 34881, x3.2.

34922b, 34928, 34932, 34933, 34938, 34940, 34942].

Remarks. Přibyl & Vaněk (1980) erected *Apatokephalus tibicen* on the basis of a cranidium (holotype) from Rio Iturbe and additional specimens from western Tilcara, Quebrada de Coquena and Incamayo (Cordillera Oriental) that had been previously assigned to *A. serratus* (Boeck) by Harrington (1938) and Harrington & Leanza (1957). Since the material known from the Quebrada de Coquena is poorly preserved (Harrington 1938, pl. 5, figs 1–10; Harrington &

Leanza 1957, fig. 56.4,6,8,10), supplementary specimens from the Quebrada de Chalala are presented herein. They are characterised by having a slightly angulate anterior cranidial margin, a preglabellar field as wide (sag.) or slightly wider than the anterior cranidial border, a straight occipital furrow, four pygidial pleural furrows, and a tapering pygidial axis composed of 4 rings, an elongate posterior piece and a postaxial ridge. A well preserved pygidium (Fig. 9Q) clearly shows, in addition, five pairs of marginal spines of different size, as well as eight or nine terrace lines following the doublural contour.

Although many cranidia examined do not exhibit signs of ornamentation, some of them show a surface sculpture of crowded, fine granules on the glabella (e.g., Fig. 9S) which is apparently similar to that of the holotype of *A. tibicen* (Harrington & Leanza 1957, fig. 56.1), as well as that of the specimens from the Quebrada de Coquena illustrated by Harrington & Leanza (1957, fig. 56.8).

Comparisons of *A. tibicen* with the type species *A. serratus* (Boeck) and related species were recently provided by Tortello & Esteban (2014 and references) on the basis of material from the Nazareno area.

Superfamily TRINUCLEOIDEA Hawle & Corda 1847
Family OROMETOPIDAE Hupé 1955

Pyrimetopus Přibyl & Vaněk 1980

Type species. *Orometopus pyrifrons* Harrington 1938, pl. 10, figs 3–5, 8, 9, 13; Harrington & Leanza (1957, fig. 105.5).

Pyrimetopus pyrifrons (Harrington 1938) (Fig. 10A–H)

1938 *Orometopus pyrifrons*; Harrington, p. 219–222, pl. 10, figs 3–5, 8, 9, 13.
1957 *Orometopus pyrifrons* Harrington; Harrington & Leanza, p. 197, 198, fig. 105.1–105.7.
1980 *Pyrimetopus pyrifrons* (Harrington); Přibyl & Vaněk, p. 44, 45, text-fig. 13.
2003 *Pyrimetopus pyrifrons* (Harrington); Waisfeld & Vaccari, pl. 28, figs 11–15.
2008 *Pyrimetopus pyrifrons* (Harrington); Zeballo *et al*., fig. 5.10.
2014 *Pyrimetopus pyrifrons* (Harrington); Tortello & Esteban, p. 944, fig. 9.17, 9.18, 9.22.

Material. 16 cranidia and 4 pygidia [PIL 14310(1, 2), 14318(1–3, 7, 8, 11), 14332(1); MLP 34685a, 34715a, 34718a, 34720, 34746b, 34810a, 34839, 34916, 34923, 34931, 34941].

Remarks. The particular morphology and the generic affinity of *Pyrimetopus pyrifrons* have been discussed by Harrington (1938), Harrington & Leanza (1957), Přibyl & Vaněk (1980) and Waisfeld & Vaccari (2003). This species is a common element in late Tremadocian assemblages of the Cordillera Oriental (Harrington & Leanza 1957). In western Purmamarca, it was reported from the type locality (Quebrada de Coquena) (Waisfeld & Vaccari 2003 and references therein; Zeballo *et al*. 2008), while additional material from the Quebrada de Chalala is presented herein for the first time (Fig. 10A–H). Well preserved specimens show posteriorly directed ocular ridges, prominent and arcuate palpebral lobes (Fig. 10C), a pygidial axis with indications of five or six rings, and a straight posterior pygidial margin.

Order PHACOPIDA Salter 1864
Suborder CHEIRURINA Harrington & Leanza 1957
Family PLIOMERIDAE Raymond 1913

Rossaspis Harrington 1957

Type species. *Protopliomerops superciliosa* Ross 1951, pl. 32, figs 2–4, 7, 8.

Rossaspis? sp. (Fig. 10I, J, L–V)

1937 *Protopliomerops primigenus* (Angelin); Harrington, p. 120, pl. 5, figs 2, 3.
1938 *Protopliomerops primigenus* (Angelin); Harrington, p. 183, 184, pl. 6, figs 9, 12, 14, 15, 20.
2014 *Rossaspis*? sp.; Tortello & Esteban, p. 945, fig. 9.23–9.28.

Material. 2 axial shields, 30 cranidia and 28 pygidia [PIL 14316(1–5), 14320(1–6), 14322(1); MLP 34656, 34657, 34659, 34660, 34674, 34681, 34682, 34689, 34692, 34714, 34741, 34742, 34743a, 34748, 34749a, 34765, 34768, 34779a, 34786a, 34787, 34794, 34808a, 34817, 34818, 34837, 34838, 34843a, 34852, 34854, 34871, 34874, 34876, 34879, 34881, 34894, 34899, 34901, 34907, 34908, 34912, 34913, 34924, 34927, 34934, 34935].

Remarks. This pliomerine was originally reported from the Quebradas de Coquena and Chalala by Harrington (1937, pl. 5, figs. 2, 3; 1938, pl. 6, figs. 9, 12, 14, 15). Although it was referred to as *Protopliomerops rossi* (type locality, Potrero de Castillo, northwest of Salta city) by Harrington & Leanza (1957), Waisfeld & Vaccari (2003) consider that it represents a separate species, whose revision is in preparation (Waisfeld & Vaccari 2003, p. 319).

Suborder CALYMENINA Swinnerton 1915
Family PHAROSTOMATIDAE Hupé 1953

Colpocoryphoides Harrington & Leanza 1957

Type species. *Pilekia trapezoidalis* Harrington 1938, pl. 6, fig. 22; Harrington & Leanza (1957, fig. 123.6).

"**Colpocoryphoides**" **cf. trapezoidalis** (Harrington 1938) (Fig. 10K)

Material. 2 fragmentary cranidia (PIL 14312, 14326).

Remarks. Two small incomplete cranidia from the lower part of the Chalala section are characterised mainly by having a granulate surface, a convex and tapering glabella, conspicuous S1 and S2, and a raised, backwardly curved anterior border. Despite being fragmentary, these specimens are compatible with those from western Purmamarca that were assigned to "*Colpocoryphoides*" *trapezoidalis* (Harrington) (=*Pharostomina trapezoidalis*) by Harrington & Leanza (1957, p. 223, 276-addendum-, fig. 123.1, 3) and Zeballo *et al*. (2008, fig. 5.8). Since the scope and generic affinity of this species need to be revised on the basis of adequate material (see Waisfeld & Vaccari 2003), we provisionally assign the specimens studied to "*Colpocoryphoides*" cf. *trapezoidalis*.

ACKNOWLEDGEMENTS
We thank Guillermo Aceñolaza and Eric Gómez Hasselroth for their valuable help in the field. Michal Mergl, Jim Jago and an anonymous reviewer provided detailed and helpful comments on the manuscript. This work was supported by the CONICET (Consejo Nacional de Investigaciones Científicas y Técnicas), the Instituto Superior de

Correlación Geológica (Universidad Nacional de Tucumán – CONICET), and the Universidad Nacional de La Plata, Argentina.

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