Don Braulio Creek, Villicum Range and Rinconada Area, Chica de Zonda Range, Eastern Precordillera

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Introduction

The stratigraphy of the siliciclastic marine succession of the Villicum–Zonda "Arch" in the Eastern Precordillera of San Juan (Ortiz & Zambrano, 1981), is known since Garrigou's work (see Baldis & Blasco, 1975), who noticed the occurrence of Ordovician shelly faunas. At present, the classical section for the Ordovician succession of the eastern slope of the Sierra de Villucum (Villicum Range), is recognized at Don Braulio Creek, where a complete Lower Ordovician–Upper Silurian succession is known. The Lower Ordovician succession includes fourth main discontinuities. The first one is placed at the base of the La Cantera formation, which is assigned to an early Late Ordovician event. The second one, at the base of the La Pola Formation, evolved during the Caradoc–Lower Asghill in accordance with the data provided by Astini (2001). This can only be seen toward the south of the Don Braulio Creek, at La Pola Creek. The third discontinuity occurs at the base of the Don Braulio Formation, and it is related to a Gondwanan glacial event, which took place during the late Ashgill. The fourth one, at the base of the Rinconada Formation (= Mogotes Negros Formation), is in turn is related to the tectonic event that probably took place during the Upper Silurian (Ludlow) (Peralta, 1993).

Lower Paleozoic strata forms a homoclinal structure striking N–S, and dipping 40°– 80° to the E. In the Don Braulio Creek, the base of the sedimentary pile is the fossiliferous limestone of the San Juan Formation, although further to the west, a carbonate succession of Cambrian age is exposed (outside the reach of present field trip). Limestones are succeeded by Llanvirn graptolite–rich black shales, Caradoc siliciclastic platformal deposits, probably Upper Caradoc to Ashgill coarse–grained deposits of the La Pola Formation, Hirnantian glaci–marine diamictite, fossiliferous muddy–shelf deposits bearing the Hirnantia Fauna, Lower Llandovery ironstone and bioturbated phosphate–rich mudstones, and a probable Upper Silurian sedimentary mélange. The succession is completely covered by Neogene continental deposits.

Stratigraphy

The San Juan Formation, Arenigian to lower Llanvirnian in this section, is represented by the so–called Upper Lajoso Member, which is composed by thin bedded fossiliferous limestones with intercalations of K–bentonite levels, up to 15 cm thick. This Lower Ordovician succession apparently evolved in a warm carbonate platform developed in the Eastern and Central belts of the Precordillera Geological Province (Furque & Cuerda, 1979) or Cuyo Precordillera (*sensu* González Bonorino & González Bonorino 1991). To the north of the Quebrada de Don Braulio, a red ocher unit occurs in the uppermost part of the San Juan Formation, in the Quebrada Gustavo (Martínez 1987). This unit, classically named as Upper Member of the San Juan Formation (Baldis & Beresi 1981; Sarmiento 1985, among others), 9 m thick, is mainly composed of marls and calcarenites, and interbeds K–bentonite layers, which predominates in the upper part of the unit. Calcareous upper strata bears conodonts of the *E. suecicus* Zone, early Llanvirn in age (Sarmiento 1985, 1991). This is a new locality for the occurrence of volcanic ash layers in the eastern thrust belt of the Precordillera, similar to other K–bentonite bearing intervals previously discovered in other localities of the Precordillera (e.g., Huff *et al.,* 1995; Bergström *et al*., 1998).

In the Gustavo Creek, the upper member of San Juan Formation is concordant with the underlying nodular gray limestone lithofacies. Rhythmic marlstones, thin dark limestones interbedded with black and metallic gray shales occur in this unit. The latter association, named as "transfacies" (Baldis & Beresi 1981), belongs to the Lower Member of the Gualcamayo Formation, which in this area is 30 m thick in this area (Peralta 1993). The black shales and dark hemipelagic mudstones of the Gualcamayo Formation regionally onlap diachronically shallow–marine carbonates of the San Juan Formation. In the Villicum range, the rhythmic package (transfacies) overlies the limestones through a widespread omission surface. Lower Ordovician carbonate production stopped during a regional flooding event that covered the platform with diachronous late Arenig–early Llanvirn black shales (Heredia & Beresi, 1995, Albanesi *et al*., 1998).

In this section, the upper Member of the San Juan Formation differs from the underlying nodular gray limestones and from the overlying argillaceous mudstones and graptolitic gray–black shales by both color and the aspect of the outcrop. It is also characterized by a diverse and abundant of fossil fauna in the first 5 m, above which occurs a 4 m thick interval that includes nine K–bentonites beds. Several K–bentonite beds also occur in the lower part of the overlying Gualcamayo Formation. The thickness of individual K–bentonite beds ranges from 2 to 25 cm, carbonate beds range in thickness from 7–35 cm thick. Prevalent rock type in the Gustavo Creek section is a burrowed bioclastic wackestone with an abundant and diversified fauna of sponges, articulated brachiopods, gastropods nautiloids, ramose bryozoans, and conodonts. Bioturbated wackestones were deposited under a low–energy warm water zone, in open marine environment, below the storms wave base. This unit exhibits a degree of community succession. According to Peralta & Beresi (1999), three characteristic assemblages can be distinguished in this unit, based on major percentages of fossil fauna. Thet occur within the first 5 m of this unit, and from bottom to top are as follows:

Assemblage I: Composed of trilobites (*Annamitella. Illaenus)*, big asaphids, articulated brachiopods (*Paralenortis, Tritoechia, Platystrophia, Pleurorthis, Sanjuanella)*, crinoids, diverse morphotypes of small–sized sponges, ostracods, gastropods (*Ozarquispira)* pelecypods, and a small number of ramose bryozoans.

Assemblage II: Sponges represent the dominant group in this assemblage. It mainly consists predominantly of calcified sponges of dishes, domical and cup forms; there are also bowl–shaped sponges. Characteristic taxa are *Psarodyctium, Patellispongia, Hudsonospongia, Lissocoelia, Calycocoelia.* Other less represented taxa are *Archaeocyphia* and *Rhopalocoelia.* Lithistids sponges are predominant and occur as dishes, discoid or palmate–shapes. These lithistids baffled and trapped fine sediment and are particularly important, comprising about 60% of the total biological volume. The presence of lithistid sponges in dish form and life position implies a low–energy level environment in which the assemblage developed. Demosponges normally grow in a shallow subtidal environment, within the photic zone where organic nutrients are most abundant, and below the fair–weather wave base. Although sponges are also found in the nodular gray limestones (wackestones) of the San Juan Formation, the greatest diversity occurs at the top, immediately underlying the K–bentonite layers.

Assemblage III: This assemblage is dominated by diversified and abundant nautiloid fauna. It is mainly composed of longiconic orthocones (Endocerids, Orthoceratids and Ellesmerocerids) of middle and small shell length, and scarce breviconic orthocones and cyrtocones.

A predominant bentonite limestone interval occurs above these three assemblages. It is 4 meters thick and represents a section of lesser thickness than those previously described. This interval is characterized by argillaceous mudstone interlayered with thin yellowish clays (K–bentonitic layers), and for the decreasing fossil fauna. There are several reasons for this decreasing fauna. Abiotic factors such as the effect of a regional sea level rise, the increasing of water turbidity, and excess of nutrients from volcanic activity in the Early Llanvirnian, have all been postulated as main factors involved in the disappearance of the typical fauna from the top of the San Juan Formation limestone (Carrera 1997a, b; Carrera & Astini, 1998; Carrera *et al.*, 1998). The sudden rise of sea level, plus the effect of the volcanic activity, could have contributed to the demise of the San Juan platform.

At the top of the Gustavo Creek section a distinct, laterally persistent, 37–cm thick grainstone interval with crinoids occurs. It represents a high–energy shallow carbonate setting. Bioclastic calcarenites are present in other localities of the Precordillera (Carrera 1997b). On the bedding planes of grainstones a fossil accumulation (shell pavement) mostly monotypic, occurs. The accumulation consists of large longiconic orthoconids in a low diversified nautiloid fauna, which show preferential alignments. Dominant nautiloids in this accumulation are endoceratids, large shells with lengths up to 1 m. This assemblage shows transportation and reorientation due to a stable hydrodynamic condition, and can be classified as a sedimentological fossil concentration. Fossil accumulations in these grainstones have been interpreted as generated during an initial transgressive event (Astini 1998c). This type of nautiloid accumulations could also reflect the action of catastrophic volcanic events, which took place during the upper Arenig–lower Llanvirn in the Eastern Precordillera. Several authors (*e.g.* Huff *et al.* 1992) have marked the volcanic–induced stress conditions as having a strong impact on the faunal composition, diversity and paleocommunity structure, for other regions of the world. The volcanic ash would have increased water turbidity and phytoplankton, critically reducing the photic zone in this interval (Huff *et al.* 1995). Because of the relatively instantaneous deposition over an extremely wide area, K–bentonites are excellent dating time planes or isochronous lines for the area. They can be used as stratigraphic tools for biostratigraphic correlation within the Precordillera, and for global correlation.

The Gualcamayo Formation (Furque, 1963) was formerly recognized in the eastern slope of the Sierra de Villicum, Don Braulio Creek, by Baldis *et al.* (1982), and its graptolite fauna was considered by Monetta (1978) and Peralta (1993). In this section, the mentioned unit is 39 m thick, and it is mainly composed of graptolite–rich black shales and mudstones. Graptolites are associated with trilobites and conodonts, which are early Llanvirnian in age. In accordance with Peralta (1993), the Gualcamayo Formation has been divided in this section into two members: the Lower Member is equivalent to the so called "transfacies" in the sense given by Baldis & Beresi (1981), composed by rhythmic alternation of fossilifeorus mudstones and black shales bearing trilobites, graptolites and conodont assemblages. It conformably overlies the flagstone upper limestones of the San Juan Formation, and is unconformably overlies (erosional surface) by the basal psefites of the La Cantera Formation (Early Caradoc).

From a biostratigraphic viewpoint, the conodont assemblage indicates the *Eoplacognathus suecicus* Zone (Sarmiento, 1985, 1991). The graptolite fauna belongs to the *tentaculatus* Zone (Peralta, 1993, 1995) and trilobites to *Mendolaspis* Fauna (Baldis & Beresi, 1981). According to Peralta (1995), the graptolite fauna from the Lower Member includes *Undulograptus austrodentatuts, Paraglossograptus tentaculatus, Isograptus caduceus, Isograptus* aff. *I. primulus, Dichograptus* cf. *D. separatus, Glossograptus hincksii, Pterograptus?* sp., *Amplexograptus arctus, Tristichograptus ensiformis, Tetragraptus bigsbyi, Azygograptus* sp., *Glyptograptus* sp.,*Cryptograptus antennariu,* among others. The trilobite fauna mentioned by Baldis & Beresi (1981) and Baldis *et al.* (1984) includes: *Anamitella tellecheai, Mendolaspis subtrapezoidalis, Mendolaspis sp., M. triangularis, Illaenus* sp.*, Triarthus* sp., which are referred as a *Nileid* to *Olenic* trilobite biofacies (Fortey, 1975). The graptolite fauna from the Upper Member includes: *P. tentaculatus, Tristichograptus ensiformis, Glossograptus hincksii, Undulograptus austrodentatus, Amplexograptus* cf. *A. arctus, I. caduceus, Isograptus* aff. *caduceus primulus, Isograptus* sp., and *Pterograptus* sp. (Peralta, 1995).

The La Cantera Formation, 142 m thick, is a typical fining–thinning upward siliciclastic sequence, green coloured, which unconformably overlies (sharp, erosive surface) the Llanvirn Gualcamayo Formation. This surface is interpreted as a result of the Guandacol tectonic phase activity (Baldis *et al*., 1982). In the Don Braulio Creek, the formation is unconformably overlain by the Ashgill diamictites of the Don Braulio Formation; to the north it is overlain by the Middle Caradoc–Upper Ashgill coarse–grained deposits of the La Pola Formation, which in turn underlies Don Braulio Formation. According to Peralta (1993), the La Cantera Formation is divided into three members: The lower one is mainly composed of channel–fill conglomerate and/or sandstones, interbedded with pebbly sandstones, pebbly mudstones and mudstones. From a petrographic viewpoint clasts from the psefitic deposits are well–rounded and indicate sedimentary and igneous source provenance, while clasts of metamorphic provenance are absent. The conglomerate correlates with Las Vacas Formation, that crops out to the north, at the Guandacol area, were has been described by Astini (1998a, b). Its age correlate *C. bicornis* Zone (Astini & Brussa, 1997).

According to Albanesi *et al.* (1995), the pebbles of the conglomeratic member have yielded a diverse fauna composed by conodonts, brachipods, trilobites, bryozoans, gastropods, and ichthyoliths (i.e, *Sacabambaspis janvieri* Gagnier *et al.,* the oldest pteraspidomorph from South America). The occurrence of*Erismodus asymmetricus, Panderodus gracilis*, and *Eoplacognathus lindstromi* indicates a Late Llanvirn age. Brachiopod fauna of the clasts is dominated by *Paralenorthis* sp., *Sowerbyella*? sp., *Dalmanella* cf. *parva* and undetermined plectambonitaceans. egistered conodonts exhibit a colour alteration index of ca. 3. This value suggests paleotemperatures lower than 200° C. Beds of similar lithology and fauna have not been found *in situ* in other Early Ordovician

The La Pola Formation, 47.35 m thick, Middle Caradoc–Late Ashgill (Astini, 2001), is a fossiliferous, mainly siliciclastic, conlomerate–dominated erosive remnant of the Late Ordovician glaciation, exposed in the easternmost range of the Argentine Precordillera. The type section of the La Pola Formation is located at La Pola Creek, to the south of Don Braulio Creek. It is composed of a succession of thick–bedded coarse–grained debris flows, ranging from mud– to clast–supported, with interbedded pebbly mudstones, amalgamated lenticular quartz–bioclastic–rich sandstone, few turbidites, and silty shales. Its age is constrained by graptolite from the underlying La Cantera Formation and the overlying Don Braulio Formation, which are Early Caradoc and Late Ashgill (Hirnantian), respectively. Paleontological work may better constrain its age better. A preliminary account of the age provided by graptolite faunas from the debris flows suggests a Mid–Late Caradoc age (Astini, 2001).

Recognition of this unit is particularly significant from both, litho–paleontological and paleogeographical, viewpoints. Slumping, by pass–channeling, and base of slope facies associations suggest that the depositional environment was a proximal deep–marine throat. This sequence sharply contrasts with the underlying thin–bedded turbidites and green shales of the La Cantera Formation, and with overlying glacial diamictites of the Don Braulio Formation. This suggests that the formation is unconformity bounded. The provenance was probably a high–energy, quartz–rich shelf with coeval, reef–like carbonate build–ups. Its faunal content it mostly allochthonous, although remains are well preserved and show little abrasion. A highly varied assemblage of bryozoans and thalli of red algae constitutes a previously unknown association for the Late Ordovician of the Argentine Precordillera. Paleocurrent data, directed toward the west–northwest, together with the provenance point to a much larger east–west extension of the Precordillera basin (present coordinates) than has traditionally been suggested (Astini, 2001).

The Don Braulio Formation (Late Asghill–Early Llandovery), was formerly defined by Baldis *et al.* (1982), and subsequently reviewed by considering the basal stratigraphic characteristics (Peralta & Baldis, 1990). The type section is located in the Don Braulio Creek, western flank of the Villicum range, Eastern Precordillera of San Juan Province. The Late Asghill age of the Don Braulio Formation was formerly provided by the *Dalmanitina–Eohomalonothus* Fauna described by Baldis & Blasco (1975), besides the brachiopod assemblage described by Levy & Nullo (1974). Subsequently, the brachiopod fauna was reviewed by Benedetto (1986) who referred it to *Hirnantia* Fauna. The Llandovery age of the upper part of the Don Braulio Formation was provided by Volkheimer *et al.* (1981) on the basis of the palynomorphs, mainly chitinozoan records. Later, Peralta (1985), based on graptolites studies, established that the upper part of the Don Braulio Formation belongs to the Lower Llandovery, and Peralta & Baldis (1990), recorded *Normalograptus persculptus* near the top of the *Hirnantia* Fauna levels. The biostratigraphic features of the Don Braulio Formation cannot be considered for the Ordovician–Silurian boundary study, such as is the case for the basal part of the La Chilca Formation, in Talacasto Creek area (Cuerda *et* al., 1988) due to the lack of diagnostic fossils between the *persculptus* and *Atavograptus atavus* Zones occurring therein.

Two stratigraphic discontinuities have been recognized in the Don Braulio Formation: The first one, at the base of the "Fossiliferous Member", which bears the *Hirnantia and Dalmanitina–Eohomalonotus* faunas. It is related to a transgressive event produced when the Ashgill glacial event was waning. The second one is at the base of the "Ferriferous Member", related to a shallowing event during the early Landovery. Present Field Guide the lithostratigraphic arrangement suggested by Peralta (1993) who recognizes four members into the Don Braulio Formation. Sedimentological descriptions for the diamictite given by Peralta & Carter (1990, 1999) and Peralta (1993) are as follows:

– The Lower Diamictite Member is 15 to 20 m thick, and its erosional basal contact with the underlying La Cantera Formation is partly weathered. The contact is clear due to the contrast between the thin and uniform bedding of underlying unit and the massive nature of the diamictite. This contact is an irregular paleorelief. At the top, the diamictite is characterized by persistent, clast–supported polymictic conglomerate with a variable thickness the decimetric order. The diamictite is mainly made up of greenish grey pebbly mudstones deposits including complex channel–fill conglomerates and sandstones (wackes) and bioclastic debris. The pebbly mudstones are massive, predominantly silty, and contain scattered, but oriented, clasts suspended in the matrix, that is cut by channels. In general, the matrix constitutes 80 to 90 % of the deposits. The gravel size clasts display evidence of glacial processes: striations in one or more directions, faceted and polished surfaces, percussion marks, and flat–nosed forms. The gravel size clasts range from granule to boulder with a mean of medium–coarse pebble. The outstanding characteristic of the clasts is their dispersed, but oriented nature. In general, the clasts are randomly distributed in the matrix without sorting or gradation. The most notable feature of the fabric is the primary orientation (61%) of the long ("a") axes in an east–west direction with the a–b planes of the clasts parallel to the overall stratification, and a secondary orientation (26%) of the long axes in a north–south direction also with the a–b planes of the clasts parallel to the overall stratification. The principal east–west orientation coincides with two measurements of channel axes in the mudstones that show a paleocurrent direction to the west. There are local concentrations of clasts that make up to 20 % of the deposits, and there is an inverse textural relationship, with well rounded pebble and cobble–size clasts and sub–angular to sub–rounded boulder–size clasts. In places, there is also soft sediment deformation at the base of some of the boulder–size.

A count of 50 clasts ranging in size from pebbles to boulders shows the following characteristics: the clasts consist of 68 % sandstones, 20 % igneous rocks, and 12 % chert, calcilutites, vein quartz, and minor limestone and lithic conglomerates. They have oblate (disc–like) and prolate (rod–like) shapes, and have flat iron and minor flat–nosed form (faces oriented at nearly 90° angles and the ends with pyramidal faces). About 60% of the clasts are rounded to well rounded and 40% sub–rounded– to sub–angular. 72% exhibit striations, 66% abrasion surfaces, and 64% faceted faces. In general, the striations on abrasion surfaces lie parallel to the long axis although on some surfaces there are striations in 2 or 3 directions, especially in the green sandstones and blocks of calcilutites in which the striations and abrasion surfaces correspond to the stratification of the rock. The channel associated with pebbly mudstones has lateral extensions of meters to 100's of meters and thicknesses of 2 or 3 m in thickness. They are filled with gravel–size clasts and in places exhibit normal grading. These conglomerates are intercalated with thin to medium beds of sandstones and pebbly mudstones. The upper surfaces of the channel fill are commonly rippled. Ocasionally, the filling contains bioclastic detritus of brachiopods, bryozoans, crinoids, which belong to *Hirnantia* Fauna.

The glacial features of the basal diamictite of the Don Braulio Formation were studied by Peralta & Carter (1990) who pointed out the relation with the Gondwanan glacial event, which took place during the late Ordovician. Subsequently this unit was considered by Astini & Buggish (1993), Buggish & Astini (1993), and Astini (1993), providing additional sedimentologic information. Regional, continental and global correlation of these diamictite deposits have been summarized by Peralta & Baldis (1992). A marine sedimentary setting was assigned to diamictite (Peralta & Carter, 1990; Buggish & Astini 1993; Peralta 1993), and interpreted as acquatill deposits by Peralta (1998b). Despite this, Astini & Buggish (1993), and

Astini (1993) interpreted the diamictite as continental in origin on the basis of sedimentological criteria.

– The Fossiliferous Mudstones and Sandstones Member, 10 to 12 m thick, is composed mainly of greenish grey mudstones and fine–medium grained sandstones, including ochre calcareous and marly fossiliferous lenses. At the base this member starts with a conspicuous thin and coarse grained conglomerate beds which overlain the diamictite deposit, and is related to a post–glacial transgressive event (Peralta, 1993). At the tope of this member, the silty deposits pass transitionally to the upper member. This unit is very fossiliferous, bearing trilobites, *Dalmanitina sudamericana* and *Eohomalonothus villicunensis*, described by Baldis & Blasco (1975). Brachiopod assemblages were formerly described by Levy & Nullo (1974), and reviewed by Benedetto (1986), who firstly recognized the *Hirnantia* Fauna in Sud America. Subsequently, Peralta and Baldis (1990) described a monotypic graptolite assemblage (*Normalograptus persculptus*) from the uppermost levels of the *Hirnantia* Fauna. Certainly, the Hirnantian age of this member is indicated by recorded species. The bioturbated mudstones and sandstones, bearing the *Hirnantia* and *Dalmanitina* Faunas, were deposited in a shallow water environment.

– The Ocher Mudstones Member, 12 m thick, is composed of monotonous and massive yellowish red bioturbated mudstone deposits. This member transitionally overlies the Hirnantian deposits; and paraconformably underlies ironstones deposits of the Lower Llandoverian Upper Member. The age of the Ocher Member is established on the basis of its stratigraphic relations. It is placed between upper Ashgill and lower Llandovery deposits. Paleobiologically, this unit is characterized by the bioturbated fabric, showing abundant limonite infill burrows; some burrows contain poorly preserved biserial graptolite structures, as well as polychaete structures. In both cases the fossil body has been replaced by limonite material. Described features make this member not suitable to study the Ordovician–Silurian boundary, although biostratigraphic data could support that such boundary is located in this unit.

– The Ferriferous Upper Member, 10 to 12 m thick, is mainly composed of oolitic ironstones, ferriferous fine–grained sandstones with interbedded shales and massive siltstones. This member paraconformably overlies the Mudstone Ocher Member, and is overlain (erosive contact) by olistostrome deposits of the Rinconada Formation, late Silurian in age. Scatter phosphate and ferriferous–phosphate nodules and concretions occur within the ferriferous sandstones. Oolitic beds were described by Peralta *et al.* (1985), and by Astini (1992). This deposit contains sparsely rounded clasts of chert and, exceptionally, sedimentological bioclastic accumulations at the base, exhibiting wave reworking on the top of the beds. Also bears palynomorphs (chitinozoans) recorded by Volkheimer *et al.* (1980) and assigned the Llandovery. Subsequently, Peralta (1985) collected graptolites from shales, which indicate the *Atavograptus atavus* Zone. The oolitic ironstone bed and interbedded graptolite shale are interpreted as storm–dominated shelf sequence, where the oolitic deposits were transported by storms, from proximal to distal environment. Ferriferous deposits have been related to both, temperate to warm climate by Peralta *et al.* (1985), and cool–water seas in high southern latitudes by Astini (1992).

According to Peralta (1993) The Rinconada Formation is a 3.750 m thick, Upper Silurian unit. It is composed by a sedimentary mélange (olistostrome) including huge olistoliths from the underlying San Juan Formation, and also from the siliciclastic Early to Late Ordovician succession, besides of others Ordovician and Upper Silurian rocks, not exposed in the area due to the erosive pre–Rinconada Formation event that evolved during the Ludlow, considered by Borrello (1969). The characteristic Ludlow shelly fauna of the Central Precordillera occurs in the sedimentary mélange of the Rinconada Formation (Peralta, 1984). This fauna indicates the maximum age of that depositial event. Additional studies are necessary to provide long distance correlations of this event, whose age is not clearly defined. The sedimentary or tectonic origin of the chaotic deposits of the Rinconada Formation is discussed by Peralta (1993). The sedimentological evidence supports a sedimentary origin, and the olistostrome concept is applicable to the described deposits. Therefore the tectonic "melange" concept is ruled out. All calcareous olistoliths contained in the Rinconada Formation are derived from the Early Ordovician limestones of the San Juan Formation. No Cambrian allochthonous blocks from underlying carbonate units have been identified from the sedimentary mélange. The largest olistoliths, over 1 km in length, occur towards the south, in the eastern flank of the Sierra Chica de Zonda at La Rinconada locality, and in the Cerro Pedernal.

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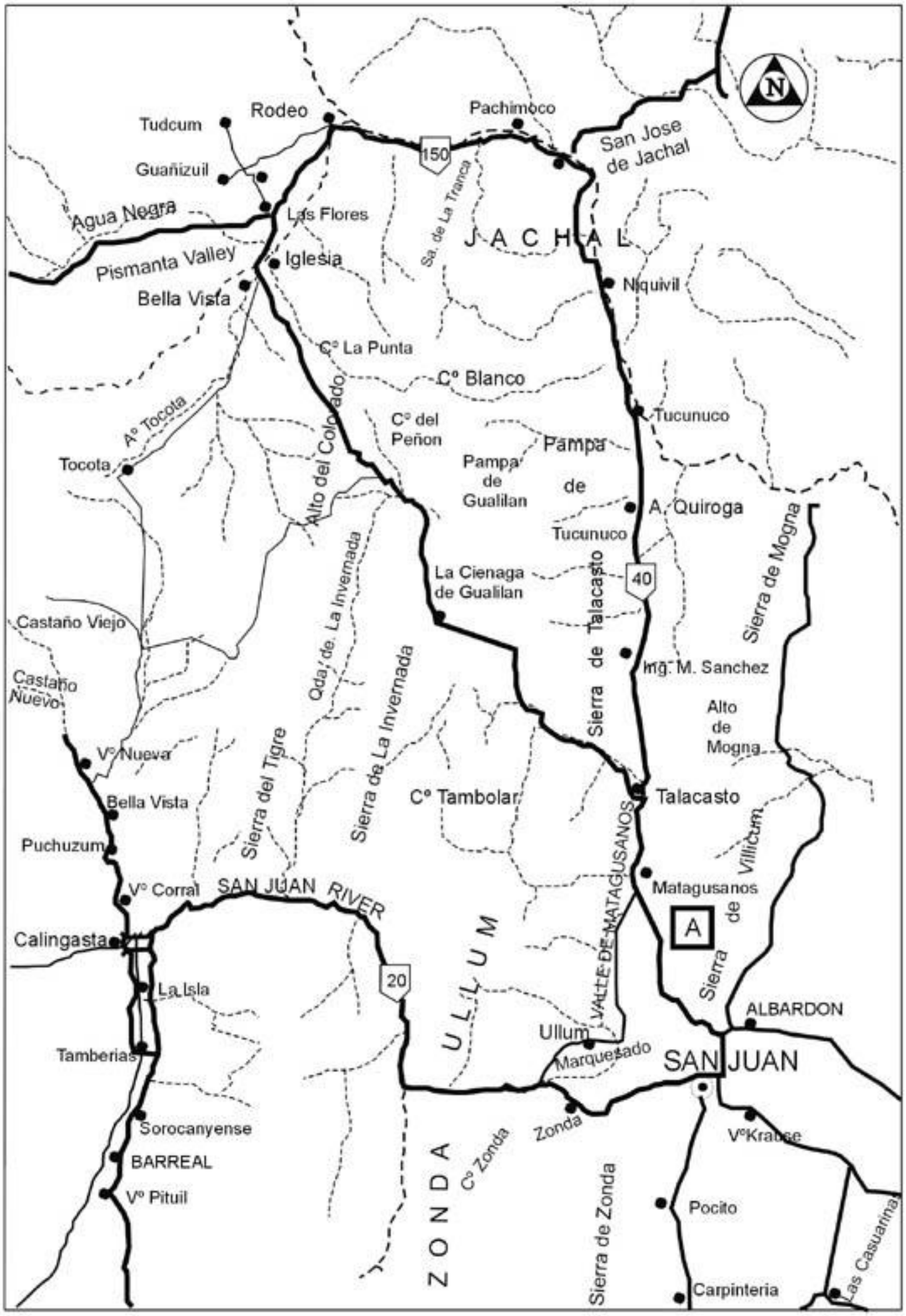

Figure 1. Location map of the Villicum area (A).

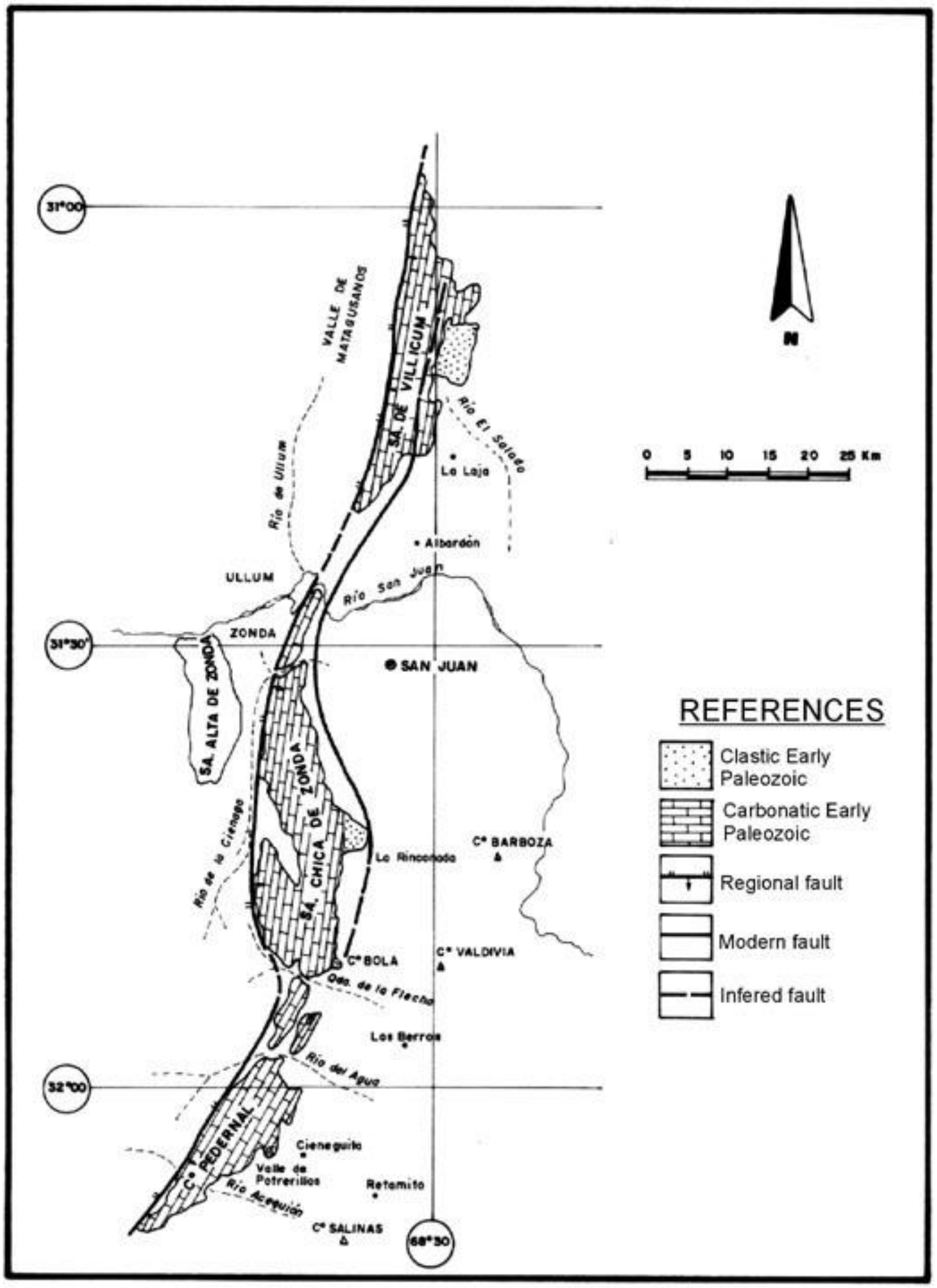

Figure 2. Regional map showing the Villicum–Zonda structural arch and lower Paleozoic clastics bordering the western flank of the Villicum and Zonda ranges. After Peralta (1993).

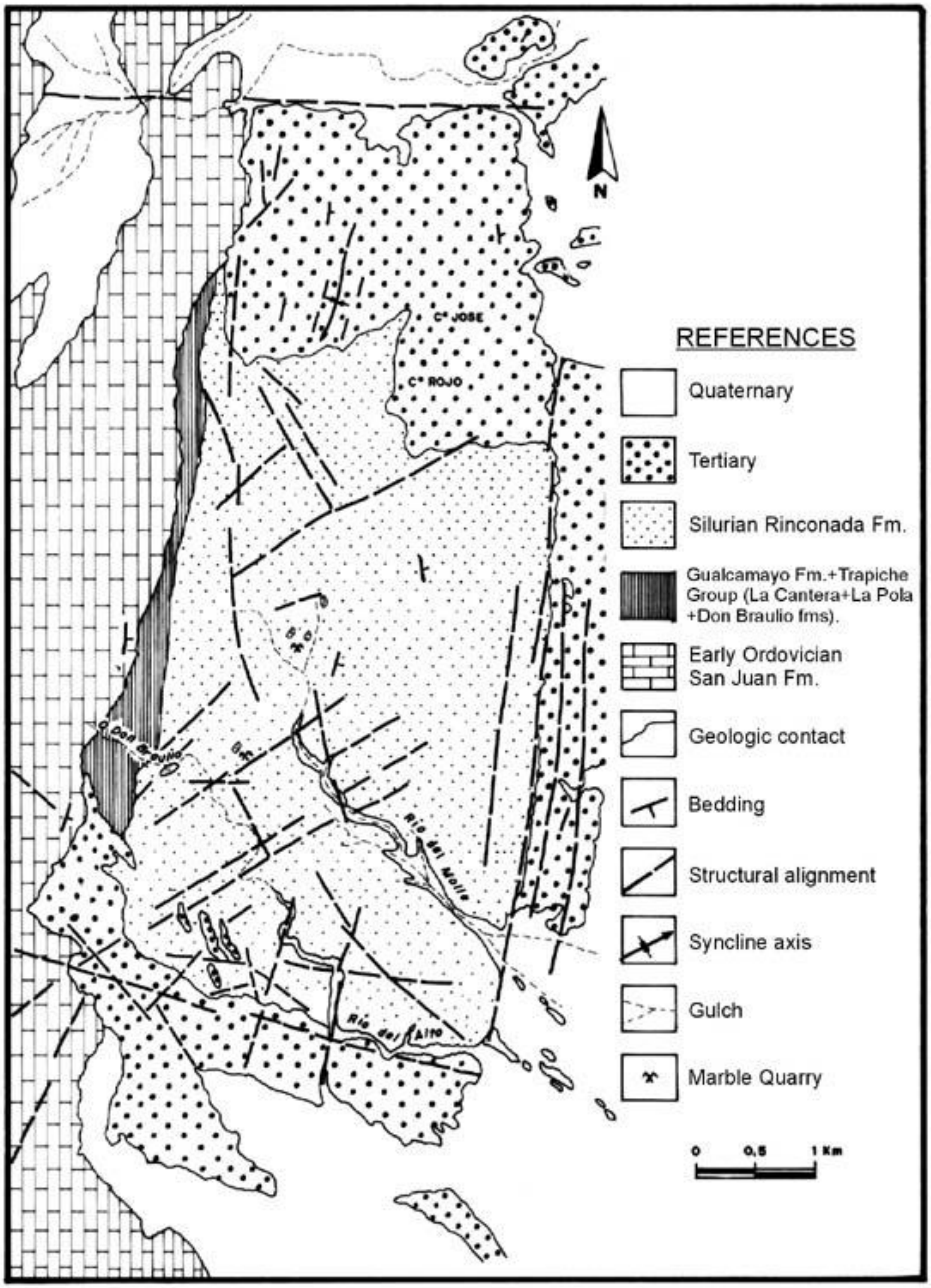

Figure 3. Geology of the Ordovician and Silurian units in the western flank of the Sierra de Villicum, showing the location of the Quebrada de Don Braulio (Don Braulio Creek). After Peralta (1993).

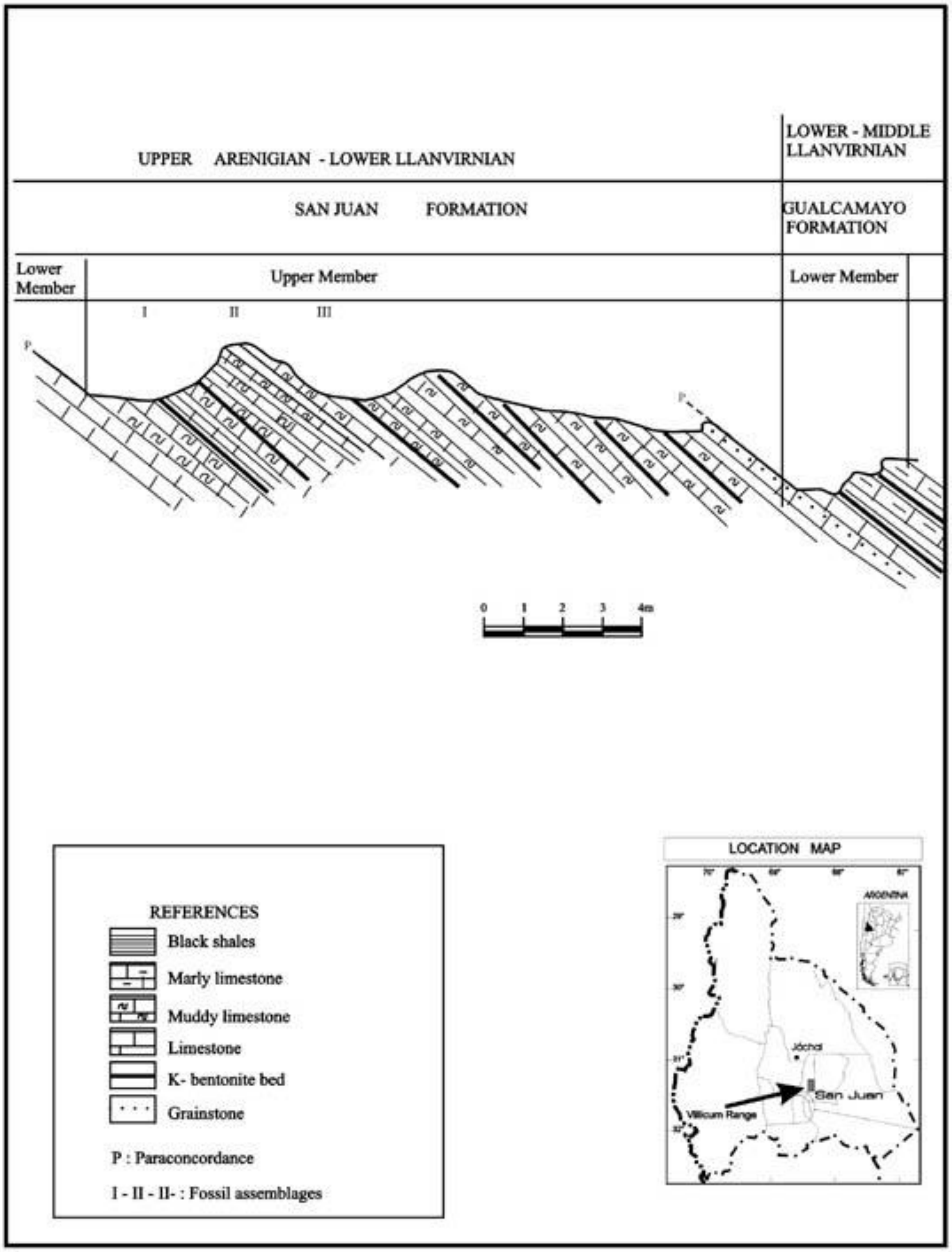

Figure 4. Stratigraphic section of the San Juan Formation, at Gustavo Creek, to the north of the Don Braulio Creek. After Peralta & Beresi (1999).

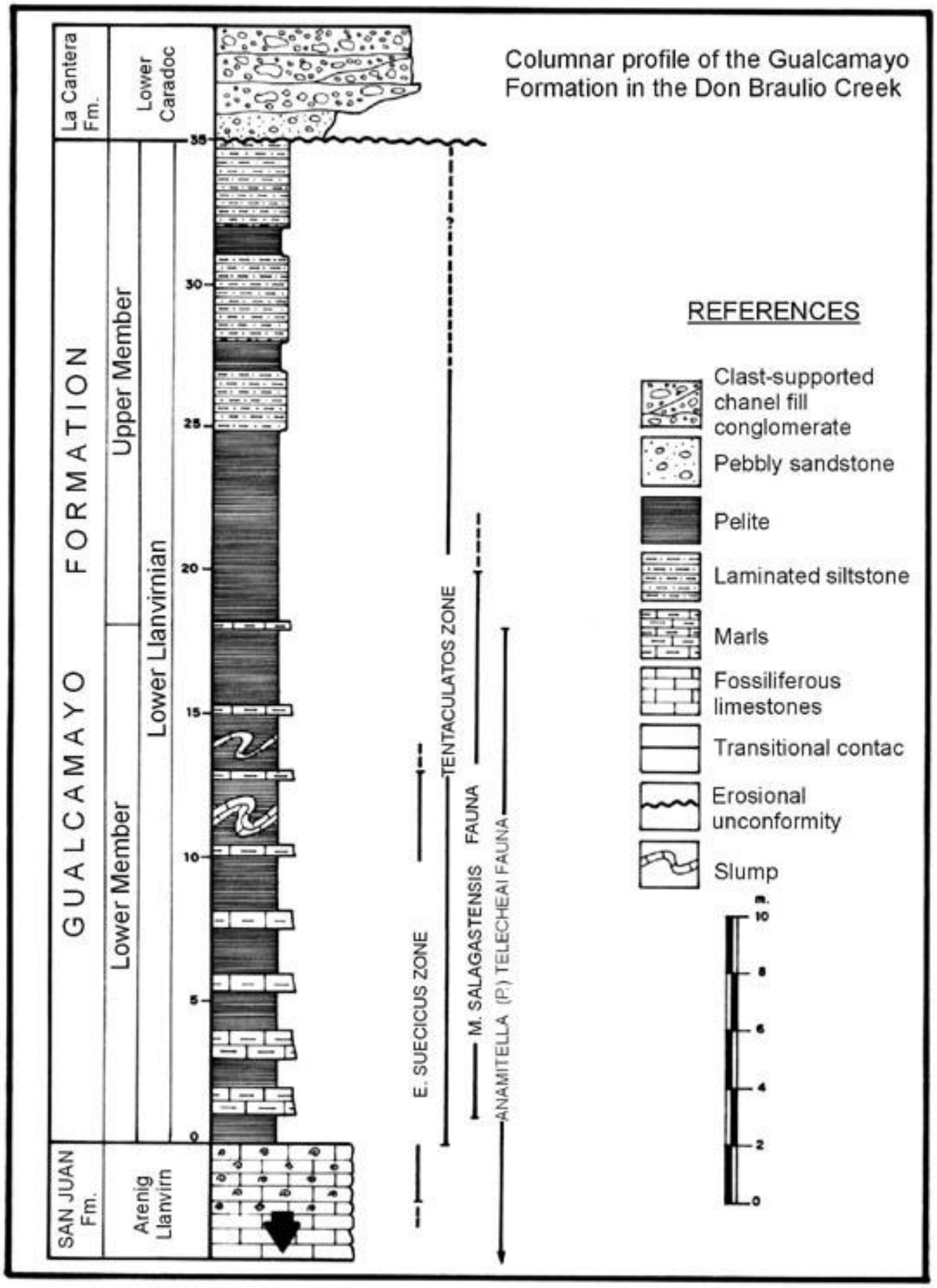

Figure 5. Stratigraphic column of the Gualcamayo Formation at Don Braulio creek.

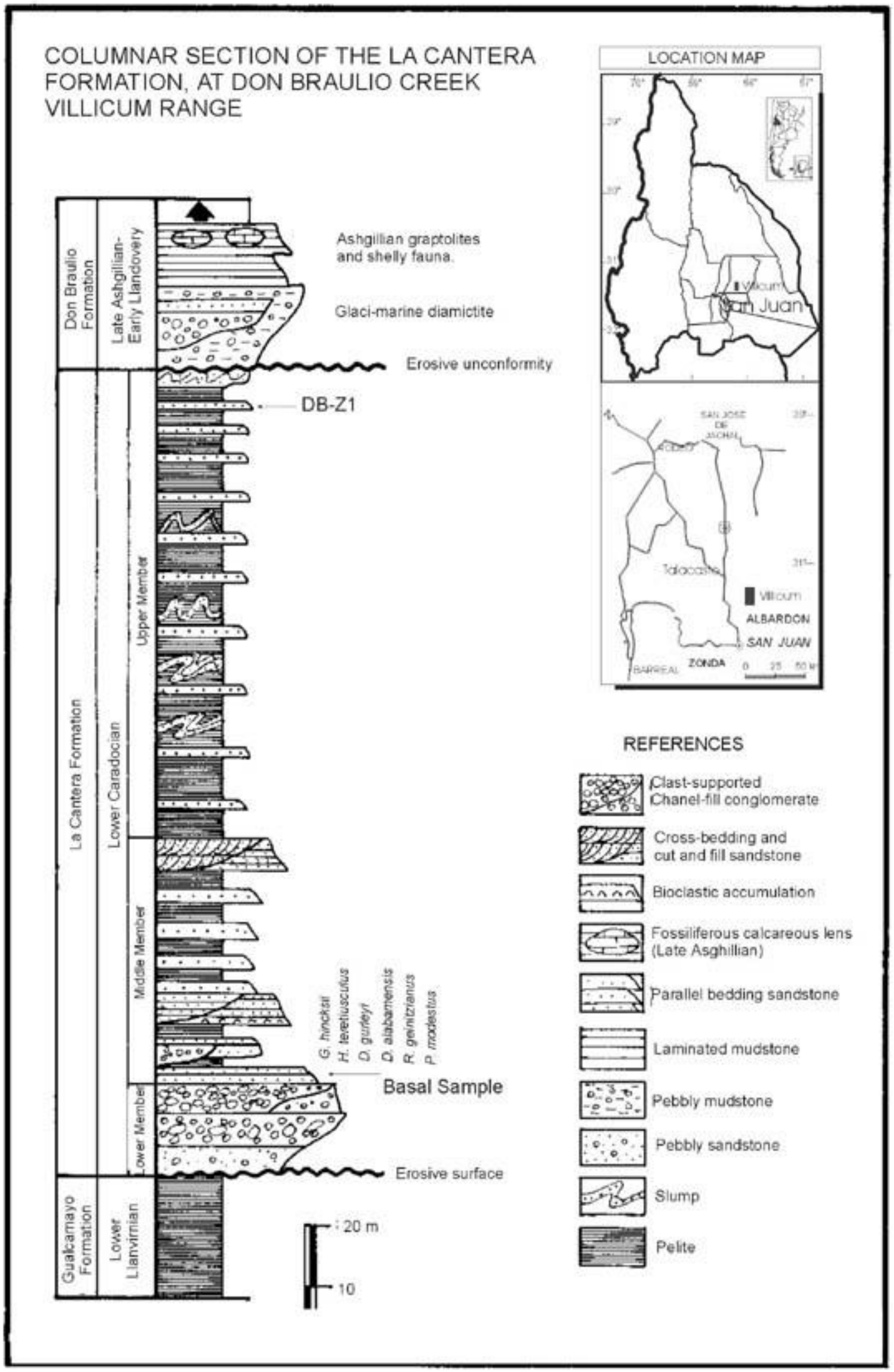

Figure 6. Stratigraphic column of the La Cantera Formation at Don Braulio creek.

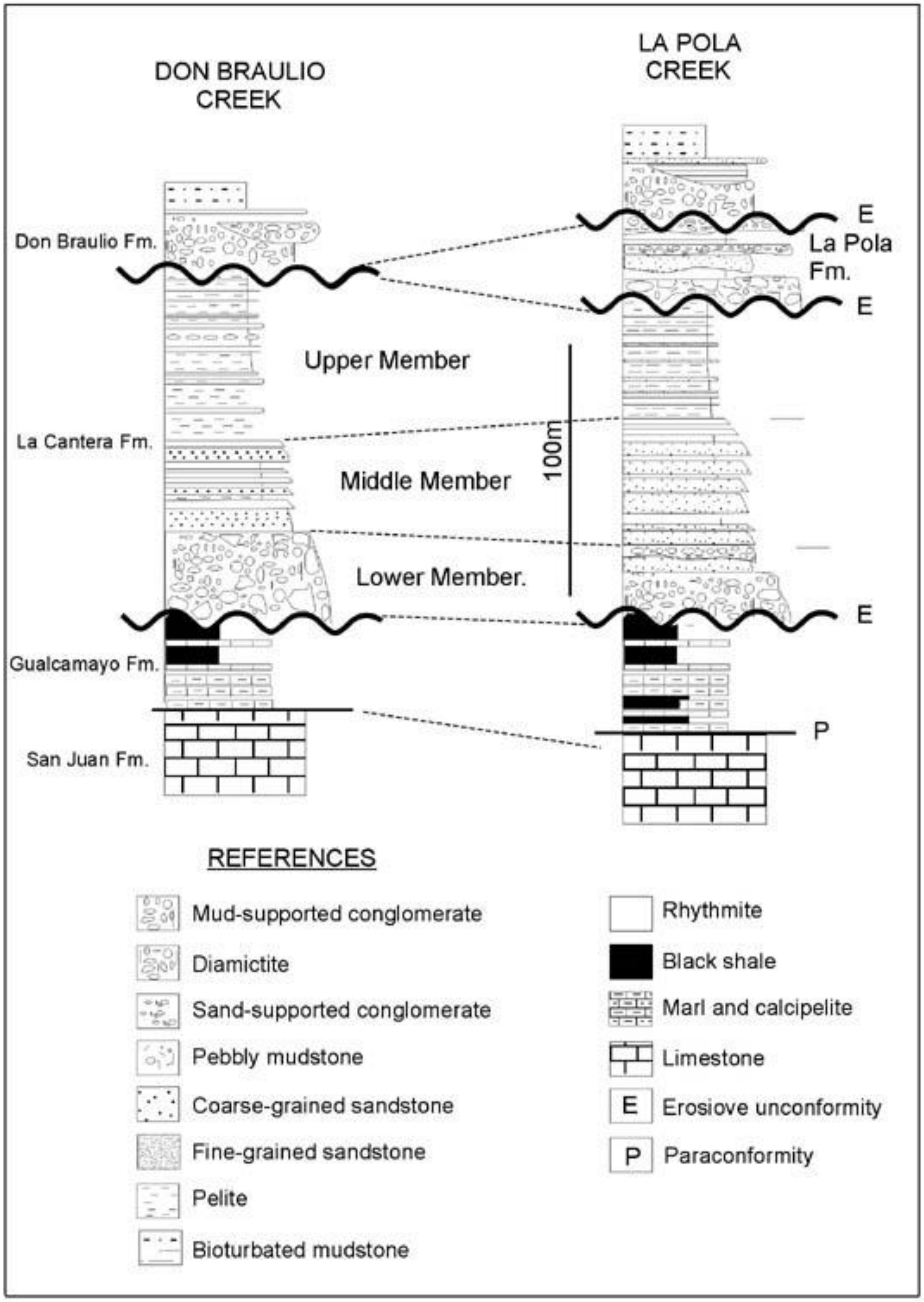

Figure 7. Stratigraphic relation of the Ordovician formations on the eatern slope of the Villicum range. After Astini (2001).

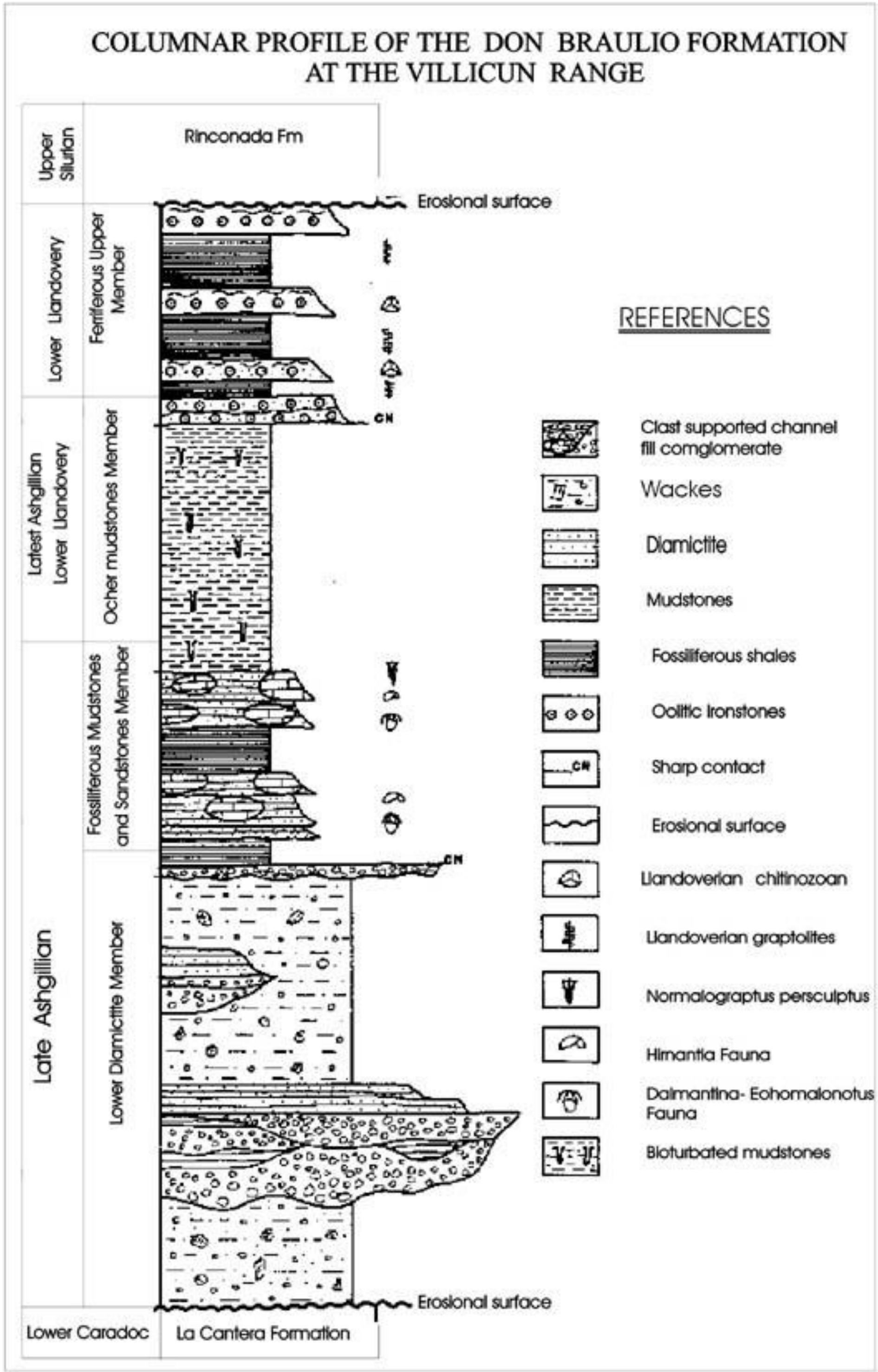

Figure 8. Stratigraphic column of the Don Braulio Formation at Villicum range. After Peralta (1993).

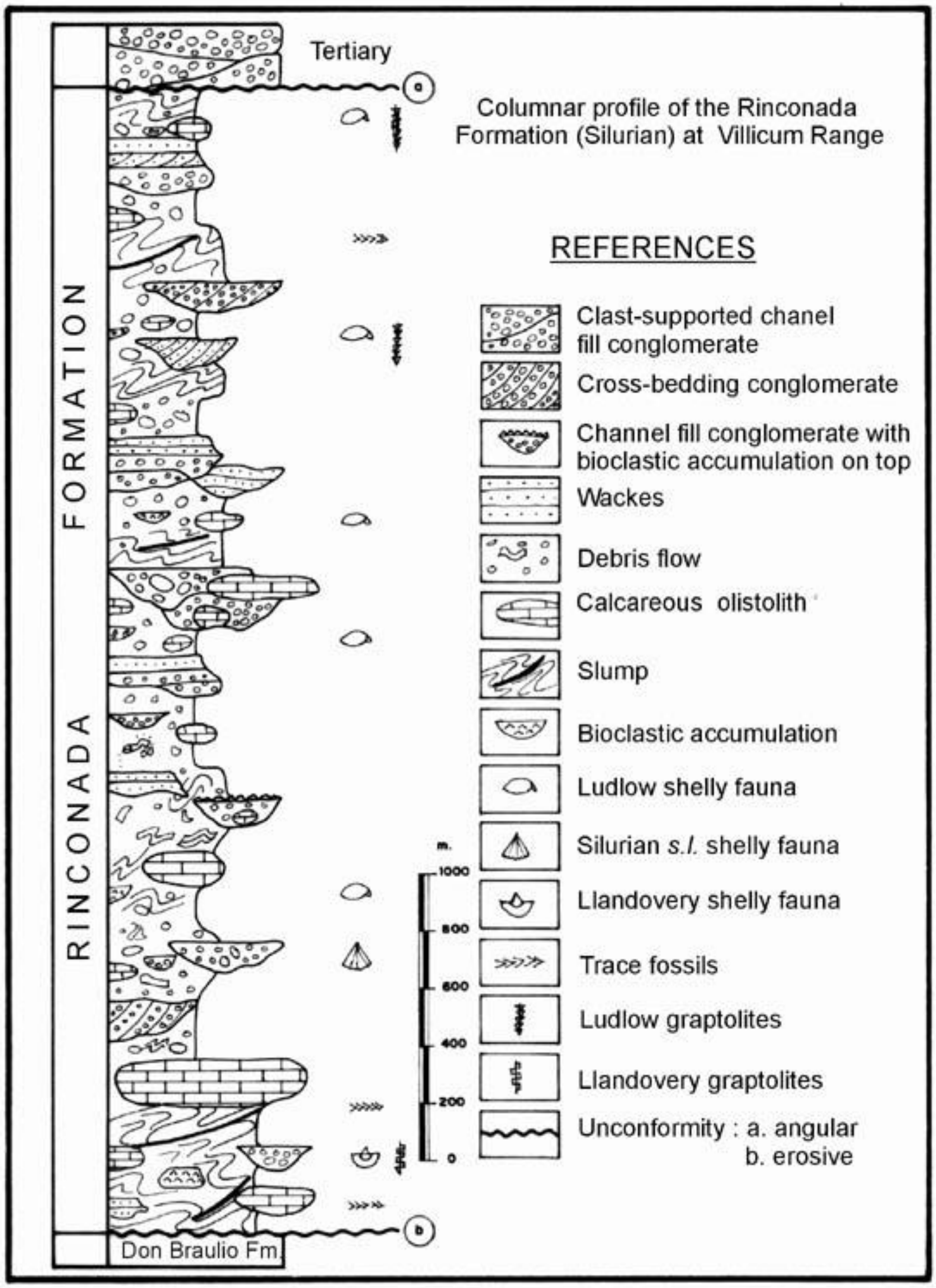

Figure 9. Stratigraphic column of the Rinconada Formation. After Peralta (1993).