# Cerro La Silla Field Trip: Cambrian and Lower Ordovician carbonate deposits of the Cerro La Silla Section, northern Precordillera, Province of San Juan. Stratigraphy and faunas (conodonts and trilobites)

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In northern Precordillera, near Jáchal city, located 150 km north of San Juan Downtown, two significant outcrops of the Cambrian rocks can be recognised: the first one at the cerro San Roque, south of Jáchal city, and the second, the cerro La Silla section which is the aim of this Guide, located 15 km to the Southeast of Jáchal, at the north-easte of the Niquivil village, (see figure 1) within the structural setting of the Central Precordillera (Baldis and Chebli,1969). Hence, a thick upper Cambrian to lower Ordovician carbonate sequence outcrops dipping to the west, which comprises, from the base upwards, the La Flecha Formation, La Silla Formation, and San Juan Formation, overlay by siliciclastic Silurian deposits. In this section, detailed look of the upper part of the La Flecha dolomites, of the La Silla restricted carbonates and of the open-marine carbonates of the San Juan Formation, as well as the unit boundaries, dominant lithologies, structures, cyclicity and faunas (trilobites, conodonts, brachiopods, sponges, gastropods, nautiloids, bryozoans, receptaculitids), and also, details of reef mounds will be observed.

**La Flecha Formation (Baldis *et al., 1981):***

Its name is derived from the Quebrada de la Flecha, to the south of the Sierra Chica de Zonda (Fig.1), where its type section has been established (Baldis et a1.,1981) with a thickness of 400 m. Its lower boundary is marked by the first beds with abundant true stromatolites (LLH and SH types) and trombolites (Keller et a1.,1994). In general, in many sections the boundary is also marked by the change from predominantly white dolomites towards yellow or brown dolomites and calcareous dolomites. In the Quebrada de La Flecha section its upper boundary is drawn , where the content of stromatolites rapidly decreases and limestones predominate over dolomite lithologies.

The La Flecha Formation is almost entirely composed of small-scale shallowing upward cycles (1-5 m), which exhibit a great variety of stromatolites, trombolites and cryptalgal laminites, together with subtidal to supratidal lithologies, characterized by arid tidal flats (Cañas,1986,1990; Keller et al., 1989). A high amount of chert and chalcedony seldom replaces the biogenic structures as well as oolite beds. The shallowing upward cycles are peritidal in origin and conform small scale stacked successions. The San Roque and the Los Sapitos Formations are time equivalent units which out crops toward the north of the Precordillera and their type areas are in the surroundings of the town of Jáchal and Guandacol, respectively. The stromatolitic and thrombolitic carbonates are the main components of the time-equivalente of the La Flecha Formation: San Roque and Los Sapitos Formation, and in every one of this units the whole carbonate succession is composed of several superimposed small-scale peritidal shallowing-upward cycles (Keller et al.,1989; Cañas,1986,1990), showing typical association of stromatolites,

thrombolites and biolaminated structures, arranged in comparable small-scale shallowing-upward peritidal dolomite-dominated cycles.

In the dolomite deposits of the La Flecha Formation, a varied trilobite fauna occurs which suggest in the type area a Franconian to at least Late Trempeleauan age (Saukia Zone). Hence, Plethopeltis .saratogensis, which indicates a late Franconian age, was found near of the base of the formation. In the middle part of the La Flecha Formation Stenopilus convergens (Raymond) (Saukia Zone) occurs, which indicates a late Trempealeau age. On the other hand in the northern Precordillera a Dresbachian age is supported, on the basis of trilobite faunas occurrence composed of Madarocephalus laetus Rasetti, Komaspidella laevis Raseti and Crepicephalus cf. C. scilisis Resser, together with other new species. In the upper part of the formation Dytremacephalus.strictus (Apbelaspis Zone) occurs (Keller et al., 1994); near the top. In Gualcamayo section, at the northern end of the Precordillera, in the upper part of the La Flecha Formation Plethopeltis cf P. armatus appears, indicating the upper part of the Saukia Zone (Keller et a1.,1994).

**La Silla Formation** (**keller et al, 1994):**

Its name is derived from the Cerro La Silla (Southeast of Jáchal) located in the northern Precordillera of San Juan (Fig. 1), and where its type section outcrops, with 350 m in thickness. The main differences with the under-and overlying formations are its thick-bedded, dark gray to bluish gray limestones. Its lower boundary is drawn at the level where the coarse sparitic dolomites abruptly change towards lime-mudstones and -wackestones. The upper boundary is given by limestones with the appearance of an abundant open marine fauna of brachiopods, trilobites, echinoids and sponges typical of the San Juan Formation. The La Silla Formation can be traceable from northern Precordillera (Guandacol area) in the Province of La Rioja) to the south, at the Sierra Chica de Zonda, in the Province of San Juan.

The age of this unit is assigned on basis of trilobites and conodonts to the lowermost Iberian (M. depressa Subzone up to P. deltifer Zone) (Vaccari,1994; Lehnert, 1995a, b). In the lower levels of this unit a Plethopeltis biofacies was recognised (Vaccari,1994). In this way, a Late Cambrian (uppermost Trempealeau to uppermost Tremadoc (deltifer Zone) age is accepted. The trilobite and conodont faunas allow a correlation with North American and Baltoscandic zonations (Keller et al., 1994). Trilobite fauna is characterised by well preserved remains of Plethopeltis obtusus (Rasetti), well known from Saukia serotina to the Missiquoia depressa Subzone of North America (Ludvigsen,1982). On the other side, the oldest conodont fauna found in La Silla Formation yield Clavohamulus Miller, Oneotudus cf .simplex (Furnish) and Teridontus nadamurai (Nogami), which indicates C. hintzei Subzone of the Cordylodus intermedius Zone (Miller, 1988).

In the middle part of the La Silla Formation the conodont fauna is composed by `Acodus" oneotensis and `Oneotodus"gracilis, which are typical elements of Midcontinent fauna of Ethington and Clark (1971). Higher in the section were found Scalopodus cf floweri-Repetski, Paroistoudus numarcuatus (Lindström), Rossodus aff. Manitouensis Repetski and Ethington, Acontiodus cf propinguus Furnish and Glyptoconus quadraplicatus(Brandson and Mehl). G.

quadraplicatus indicates Fauna D of Ethington and Clark, whereas S. flouweri indicates Faunas C and D (Repetski,1982). P. numarcuatus typical of theCeratopyge beds from Baltoscandia, correlative of the Paltodus deltifer Zone (Stouge and Bagnoli, 1988). In this area, the latter is regarded as the youngest unit of the Tremadoc (Lindstrdm, 1971; Iófgren,1978). At the top of the La Silla Formation, Glyptoconus quadriplicatus, Paroirotudus. numarcuatus, Parapanderodus striatus (Grave and Ellison), `O. "inaequalis. This conodont fauna índicates M dianae Zone (Lehnert, 1995). In agree with this biostratigraphic record, five fossiliferous levels can be recognised in La Silla Formation (Fig. 2):

1. The lowermost bearing Missiquoia depressa Subzone with Plethopeltias obtusus, sp.

2 Cordylodus intermedius Zone, Clavohamulus hintzei Subzone (C. hintzei, T. nakumurai, Oneotodus. aff. O. simplex).

3. Rossodus manitouensis Zone; "oneotodus" gracilis, "Acantiodus" oneotensis

4. Rossodusmanitouensis Zone?/low diversity interval, R. aff. Manitouensis, G. quadriplicatus, A. aff. Propinquurs, S. cf, floweri, P. numurcuatus.

5. Low diversity interval/ M. dianae Zone, G.quadriplicatuc, P numurcuatus P. striatus, "O." inaequalis.

The La Silla Formation is predominantly composed of calcareous deposits, with dolomites occurring mainly in sparse biolaminated horizons (Fig. 3). It is mainly composed of an alternation of peloidal grainstones, intraclast grainstones and mudstones, often with abundant bioturbation. Subordinated conodont yielding wackestones with nautiloids and gastropods and cross bedded, oolite shoals are scattered. Distribution of facies seems to be random and no cycles or sedimentary rhythms could be demonstrated to date. The La Silla Formation shows evidences of restricted subtidal rimmed shelf (Keller et al., 1994, Cañas, 1995). Is made up by restrictive limestones and minor dolomites.

**San Juan Formation (Kobayashi, 1937; Keller et al., 1994)**:

Its name is derived from Province of San Juan and was originally used for the whole succession of platform carbonates. Its type section is located in the Cerro La Chilca where a thickness of approximately 350 m was determined. The lower boundary is marked by the appearance of abundant open marine fauna. Whereas the upper boundary is given by an alternation of black shales and plary marlstones or by grptolitic black shales, the Gualcamayo or Los Azules Formations, respectively. Abundant fossils can be recovered from this unit, among which sponges, brachiopods, echinoids, trilobites, gastropods, bryozoans and nautiloids are the most frequent. Its age ranges between the Late Tremadoc (mid-upper Ibexian) to early Llanvirn (lowermost Whiterockian); although its upper boundary is regionally diachronous, being late

Arenig in the northern Precordillera and early Llanvirn in the southern-central Precordillera. This unit is mainly composed of limestones (wackestones and packstones) and minor marlstones near the top. Yellowish tobrownish dolomites are nearly absent and are related with pressure solution or with burrow filling.

A drastic change into the wide spread muddy fossiliferous carbonates is represented in the Precordillera by the lower section of the San Juan Formation of Late Tremadoc and Early Arenig, composed by open shelf subtidal limestones of thin to medium-bedded burrowed skeletal wackestones and packstones with thin intercalation of coarse-grrained storm deposits and widespread metazoan build-ups (sponges, receptaculitid Calathium, Girvanella and microbial structures) associated with grainstones (Carrera, 1991; Cañas and Keller, 1993; Cañas and Carrera, 1993). By then, the Precordillera platform had many of the attributes of an epeiric sea (sensus Shaw,1964). The massive limestones of the middle section of the San Juan Formation with scarce fauna, which comprise the Monorthis Zone (Herrera and Benedetto, 1991), are capped by stromatoporoid and sponge-algal-stromatoporoid reefs typical of very shallow warm water (Cañas and Keller, 1993). The upper style-nodular wackestones contain characteristic platform faunas of the San Juan Formation *(Ahtiella* Zone, Herrera and Benedetto, 1991). Recently, Kolata *et al.* (1994) and Huff *et al.* (1995) have discovered horizons of K-bentonites for an interval of several meters in the top of this unit in severall sections of the Precordillera

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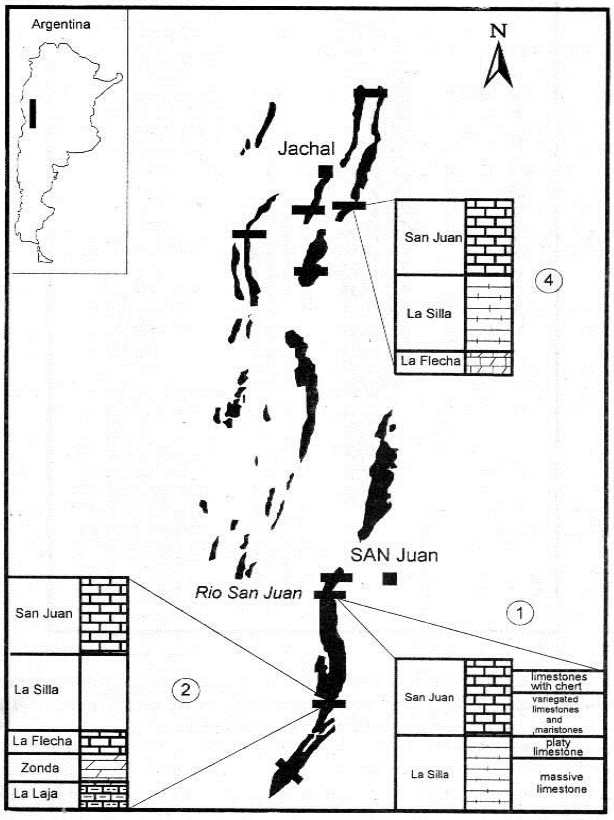


**Fig 1.** Distribution of the Cambrian deposits in the Precordillera, showing lithostratigraphic arrangement. 1: Quebrada de Zonda; 2 : Quebrada de La Flecha. 3 : Cerro La Silla. (Modified from Keller *et al.*,1994 ).

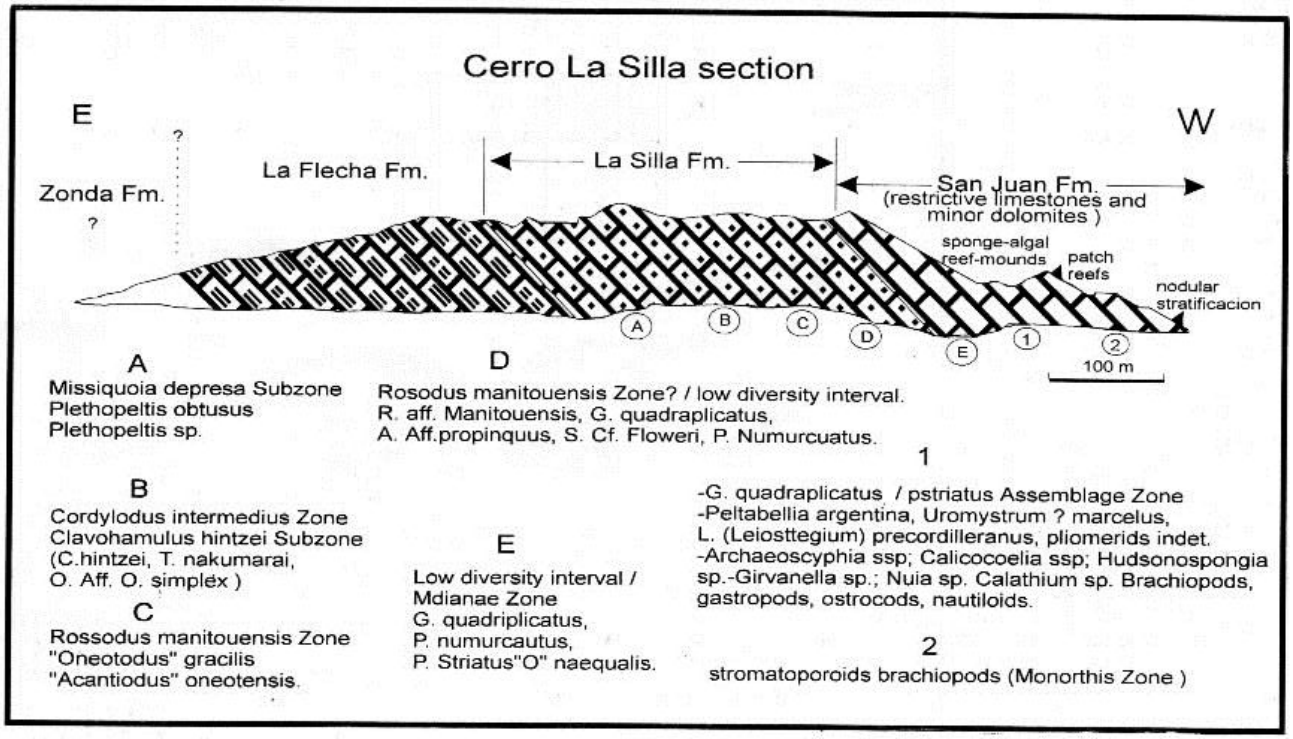


**Fig 2:** Sketch of the Cerro La Silla section with the main boundaries between formations and faunal intervals.Trilobites (Vaccari, 1994), conodonts (Lehnert,1995), brachiopods (Herrera and Benedetto, 1991), reef community (Cañas and Carrera, 1993 ).

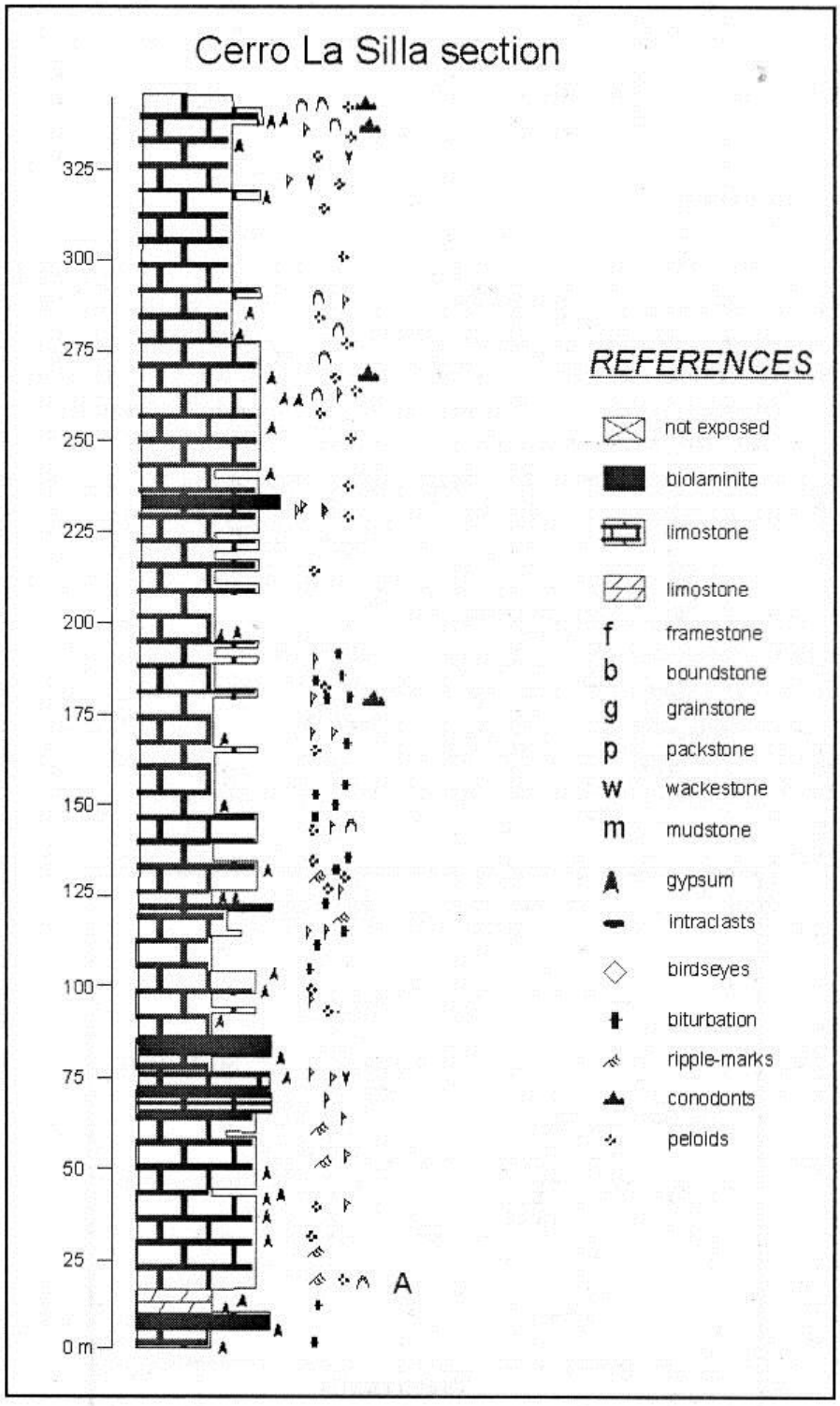


**Fig 3.** Stratigraphy of the La Silla Formation at the Cerro La Silla section, showing lithostratigraphy and position of faunas. Modified from Keller *et al.*, (1994).

The facies types of Cambrian-Ordovician carbonate deposit in Precordillera matches the Southern Appalachian platform, suggesting the origin of Precordillera from Laurentia.[8]. The Precordillera formation ranging from Early Cambrian to Late Ordovician would be introduced as follows:[7][9]. Cerro Totora Formation (Early Cambrian). The Cerro Totora Formation with a thickness of 340 m contains red marine sandstone and siltstone at the lower section. At upper section, the red evaporites are interbedded with carbonate sandstone and siltstone. ^ "precordillera". Diccionario de la lengua espaÃ±ola - EdiciÃ³n del Tricentenario (in Spanish). Retrieved 6 February 2017. ^ a b "OrografÃa de Mendoza".Â  The separation of the Precordillera started around the early Cambrian; the mass collided with Gondwana around Late Ordovician period.Â  The facies types of Cambrian-Ordovician carbonate deposit in Precordillera matches the Southern Appalachian platform, suggesting the origin of Precordillera from Laurentia; the Precordillera formation ranging from Early Cambrian to Late Ordovician would be introduced as follows: The Cerro Totora Formation with a thickness of 340 m contains red marine sandstone and siltstone at the lower section. At upper section, the red evaporites are interbedded with carbonate siltstone.