

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)

SILVIO H. PERALTA

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-east 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, overlain 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 al.*, 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 thrombolites (Keller *et al.*, 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, thrombolites 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 outcrop 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-equivalent of the La Flecha Formation: San Roque and Los Sapitos Formation, and in every one of these 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 Trempealeuan 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* Rasetti 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 al., 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. deltiifer 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 Missisquoiia depressa Subzone of North America (Ludvigsen, 1982). On the other side, the oldest conodont fauna found in La Silla Formation yield *Clavohamulus* Miller, *Oneotodus* 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, *Paroistodus numarcuatus* (Lindström), *Rossodus* aff. *Manitouensis* Repetski and Ethington, *Acontiodus* cf. *propinguus* Furnish and *Glyptoconus quadraplicatus* (Brandson and Mehl). G.

quadriplicatus indicates Fauna D of Ethington and Clark, whereas *S. floweri* indicates Faunas C and D (Repetski, 1982). *P. numarcuatus* typical of the Ceratopyge 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 (Lindström, 1971; Iófgren, 1978). At the top of the La Silla Formation, *Glyptoconus quadriplicatus*, *Paroirotodus numarcuatus*, *Parapanderodus striatus* (Grave and Ellison), *O. inaequalis*. This conodont fauna indicates *M. diana* 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. *Rossodus manitouensis* Zone?/low diversity interval, *R.* aff. *Manitouensis*, *G. quadriplicatus*, *A.* aff. *Propinquus*, *S.* cf. *floweri*, *P. numarcuatus*.
5. Low diversity interval/ *M. diana* Zone, *G. quadriplicatus*, *P. numarcuatus*, *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 play marlstones or by graptolitic 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 to brownish 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-grained 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 several sections of the Precordillera

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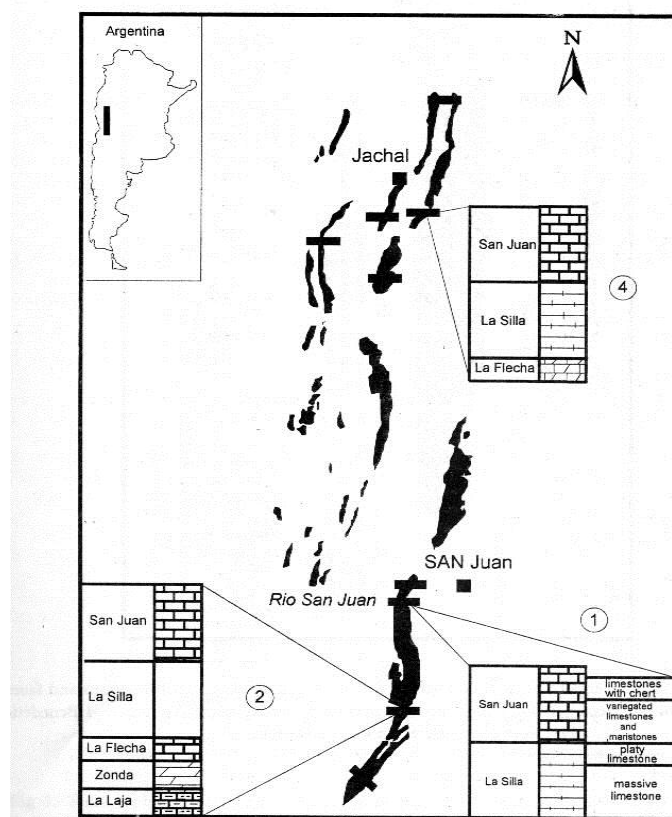


Fig 1. Distribution of the Cambrian deposits in the Precordillera, showing lithostratigraphic arrangement. 1: Quebrada de Zonda; 2: Quebrada de La Flecha. 3: Cerro La Silla. (Modified from Keller *et al.*, 1994).

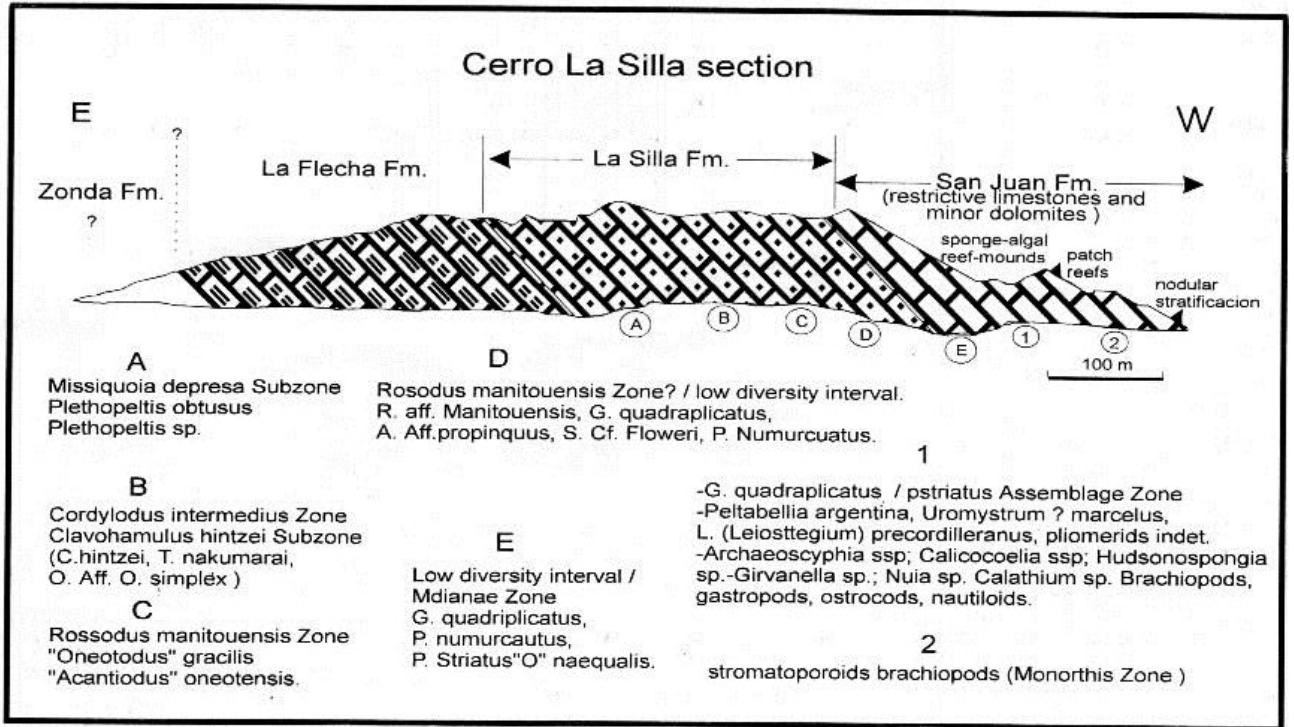


Fig 2: Sketch of the Cerro La Silla section with the main boundaries between formations and faunal intervals. Trilobites (Vaccari, 1994), conodonts (Lehnert, 1995), brachiopods (Herrera and Benedetto, 1991), reef community (Cañas and Carrera, 1993).

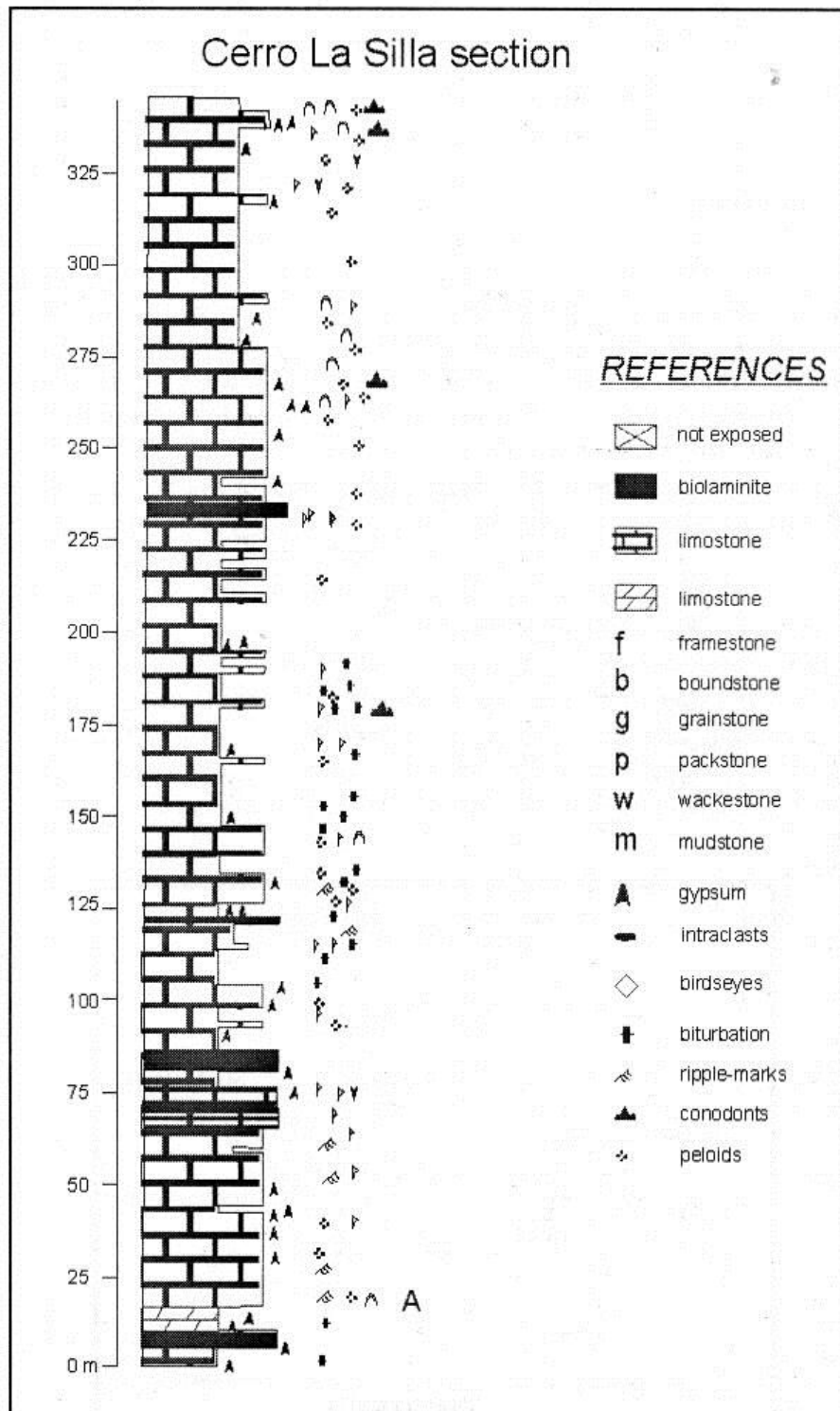


Fig 3. Stratigraphy of the La Silla Formation at the Cerro La Silla section, showing lithostratigraphy and position of faunas. Modified from Keller *et al.*, (1994).