

Upper Cambrian – Arenig stratigraphy and biostratigraphy in the Purmamarca area, Jujuy Province, NW Argentina

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Introduction

The region of Purmamarca is a classical locality for geological studies in the Argentine literature. Many authors have recognized and analyzed the Ordovician strata and its paleontological heritage (eg. Keidel, 1917; Kobayashi, 1936, 1937; Harrington, 1938; De Ferraris, 1940; Harrington and Lanza, 1957; Ramos *et al.*, 1967 and Tortello, 1990).

However, strata are several times sliced by longitudinal faults of submeridional trend, cropping out in narrow belts alternating with Precambrian/Cambrian, Cambrian and Mesozoic units. As long ago stated by Harrington (1957), no continuous section is displayed, recording isolated Ordovician blocks of different stratigraphic position.

Several Lower Ordovician units crop out in the Purmamarca area. The Casa Colorada Formation (Uppermost Cambrian – Lower Tremadocian) is widely represented by the eastern flank of the Quebrada de Humahuaca when meeting the Quebrada de Purmamarca. The Coquena and Cieneguillas shales (Upper Tremadocian), and the Sepulturas Formation (Arenig) are nicely displayed in the tributaries of the Quebrada de Purmamarca.

Finally, it is worthwhile to mention that a paleontological collection from this South American locality was given to the renowned Japanese paleontologist Teiichi Kobayashi in the first decades of the XX century (Kobayashi, 1936). Within the material was a new trilobite genus, defined by him as *Jujuyaspis* (after Jujuy province). At that time, the senior author could not preview the importance of the cosmopolitan olenid trilobite *Jujuyaspis* for the Lower Ordovician biostratigraphical scheme. Nowadays, the genus has become one of the reference fossils for the base of the Ordovician System worldwide (Nordford, 1969; Nikolaisen and

Henningsmoen, 1985; Bruton *et al.*, 1988; Aceñolaza and Aceñolaza, 1992; Miller and Stitt, 1995; Miller and Taylor, 1995; Shergold, 2000; Tortello *et al.*, 2002).

Stratigraphy and Biostratigraphy

The Quebrada de Purmamarca exposes different levels of the ichnofossiliferous Vendian/Tommotian Puncoviscana Formation; the Cambrian Mesón Group and the Tremadoc-Arenig Coquena, Cieneguillas and Sepulturas formations.

The Puncoviscana Formation crops out extensively by the access route to the village of Purmamarca, and few km westwards La Ciénaga. This unit is represented by interbedded greenish grayish slates and fine sandstones up to 1 meter thick. Frequent sedimentary structures have been found on these sequences.

Strata is highly folded and tectonically in contact with other units.

Sandstones and quartzites of The Mesón Group (Mid-Upper Cambrian) are widely distributed in the region. The unit is unconformably lying over the Puncoviscana Formation (Pampean Orogeny = Tilcaric phase). Trace fossils are the most abundant elements among these strata, while scarce shelly fauna is recorded in very few localities (Aceñolaza G., 2003 with references).

Ordovician strata is represented by an uncontinuous sequence of sandstones and shales of the Casa Colorada Formation; the Coquena and Cieneguillas shales and the Sepulturas limestones cropping out mainly around the locality of La Ciénaga (Harrington, 1957, Aceñolaza, 1996; Tortello, 1996; Tortello and Aceñolaza, 1999).

Stop 1 - Quebrada del Salto Alto

(Upper Cambrian – Lower Tremadocian Casa Colorada Formation)

The Quebrada del Salto Alto is a small gorge descending westwards from the Sierra Alta. A highly fossiliferous sequence of the Casa Colorada Formation (Harrington, 1957, *emend.* López and Nullo, 1969) crops out in the lower sector of the Sierra. Strata are a faulted slice of the Cambro-Ordovician sequences, tectonically placed between quartzites of the Cambrian Mesón Group. Ichnofossils and a rich trilobitic shelly fauna dominate the fossiliferous record (Aceñolaza, 1996; Mángano *et al.*, 1996; Tortello and Aceñolaza, 1999).

Jujuyaspis is by far the most abundant species in the Cambro-Ordovician pyritiferous black shales of this locality. Olenid trilobites of the *Parabolina* (N.) *frequens* *argentina* zone (*Jujuyaspis keideli* subzone of Tortello *et al.*, 2002) is represented in the fossiliferous assemblage: *Parabolina* (N.) *frequens* *argentina*, *Beltella ulrichi*, *Parabolinella*

argentinensis, *Angelina hyeronimi*, *Anglagnostus* sp. and *Micragnostus* sp. are mentioned among the most frequent elements.

Even though strata are disrupted by faulting, the sequence displays a few interesting elements to be analyzed. Aceñolaza (1996) and Mángano *et al.* (1996), describe the trace fossil association and sedimentary facies of the lower sector of the sequence (tide dominated shelf), presenting *Conostichus* isp., *Cruziana omanica*, *C. semiplicata*, *C. cf. tortworthi*, *Cruziana* isp., *Helminthopsis abeli*, *Monomorphichnus bilinearis*, *M. multilineatus*, *Palaeophycus tubularis*, *Rusophycus carbonarius*, *R. latus*, and *R. polonica*. Three ichnocoenoses have been distinguished: *Cruziana*, *Skolithos* and *Planolites*. The first one is preserved on soles of thin-bedded planar cross-stratified quartzose sandstones; the *Skolithos* ichnocoenosis is represented by high to low density *Skolithos linearis* burrows, while the *Planolites* one consists exclusively of *Planolites montanus* within mudstones overlying wave rippled sandstones (Mángano *et al.*, 1996).

Material described by Kobayashi (1936) most probably came from one of these small gores descending the Sierra Alta, as the Quebrada del Salto Alto.

Following sedimentary characters and paleontological evidence, the Casa Colorada Formation is interpreted as shoreface sedimented strata, within an upper offshore / middle shoreface setting. Deposit feeders are the dominant group reflected by trace fossils with a proportional less participation of suspension feeders (Di Cunzolo *et al.*, 2003). An ichnoassociation dominated by elements of the "*Cruziana* and *Skolithos* ichnofacies" is recorded in the sandstones and quartzites of the sequence. On the basis of the sedimentological patterns and ichnological record, the sandstone intercalations

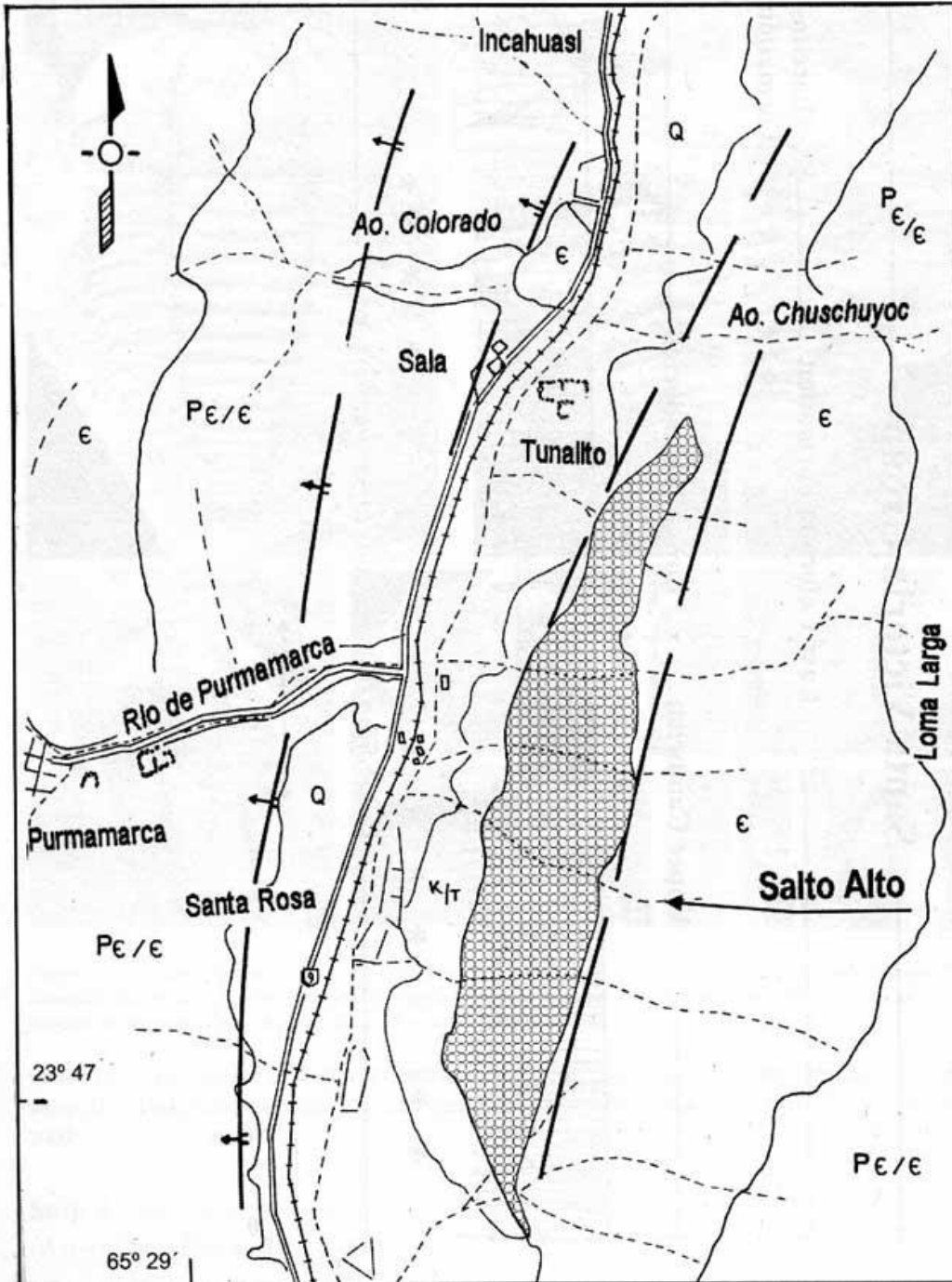


Figure 1. Geological sketch of the Quebrada del Salto Alto, Purmamarca region. Type area for the olenid trilobite *Jujuyaspis keideli* Kobayashi (modified from Aceñolaza, 1996).

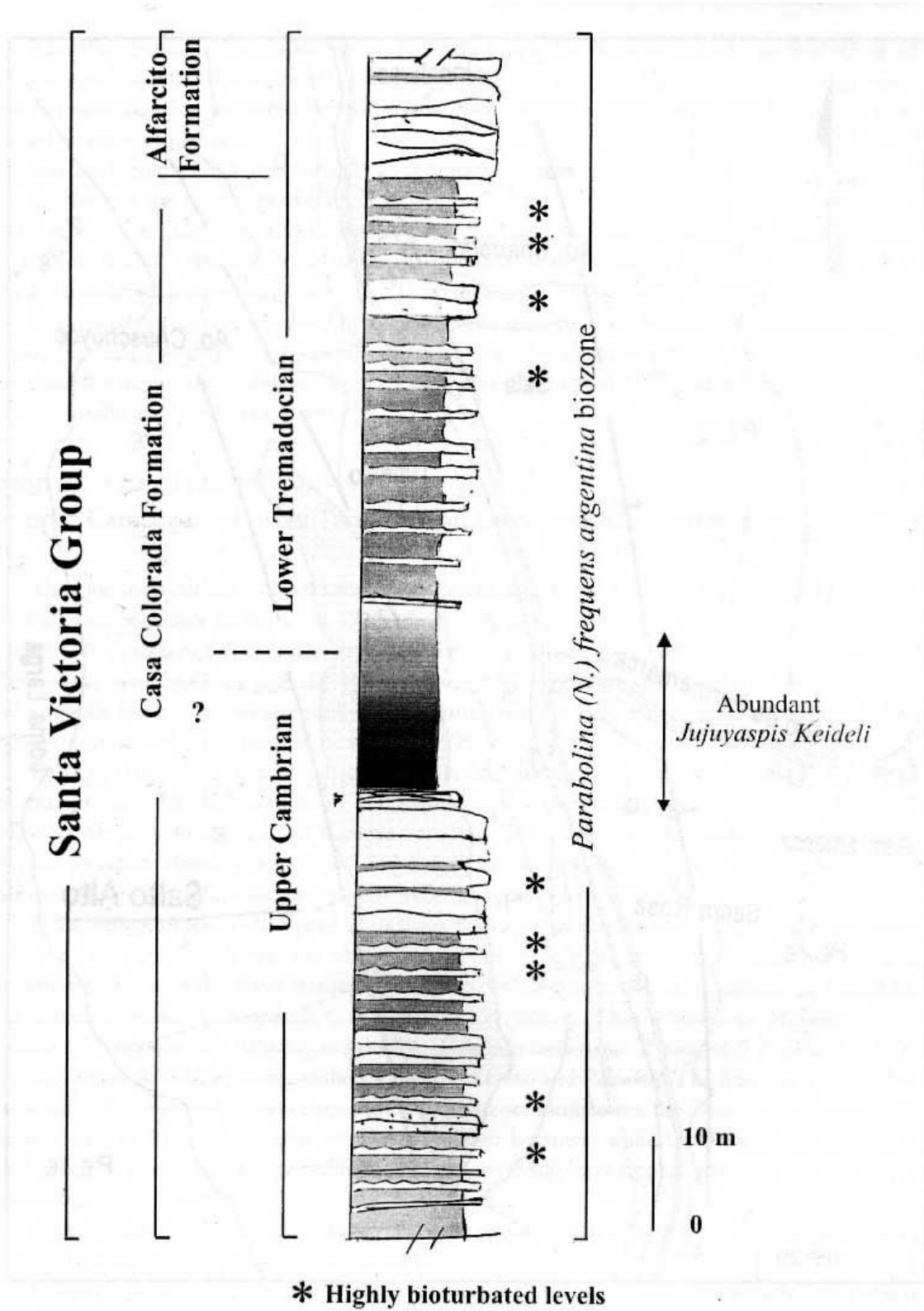


Figure 2. Stratigraphical section of the sequence cropping out at the Quebrada del Salto Alto (modified from Aceñolaza, 1996).

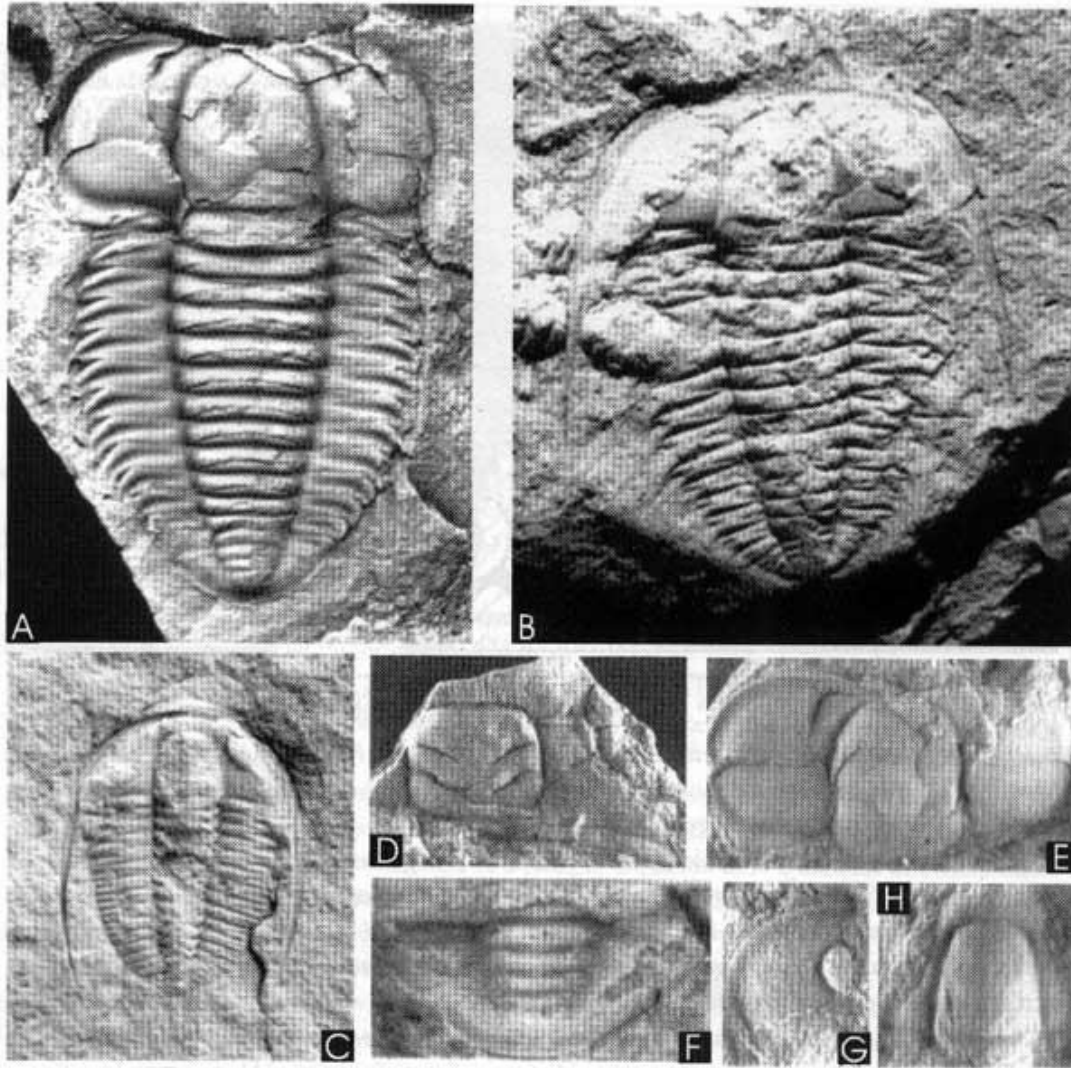


Figure 3. A-H. Some olenid trilobites recognized in the Quebrada del Salto Alto. A. *Jujuyaspis keideli* Kobayashi. B. *Parabolina* (N.) *frequens argentina* (Kayser). C. *Angelina lyeronimi* (Kayser). D. *Parabolinella argentinensis* Kobayashi. E-G. *Jujuyaspis keideli* Kobayashi. H. *Leptoplastides marianus* (Hoek).

within the shalier sector of the Casa Colorada Formation and equivalent units were interpreted as storm layers inhabited by oportunist faunas (Aceñolaza, 1996; Aceñolaza, 2001, Di Cunzolo *et al.*, 2003).

Stop 2 - La Ciénaga locality

(Arenig Sepulturas Formation)

By the route to the Chilean border, a few km westwards of Purmamarca village, Harrington (1957) describes the Coquena shales as composed by "*Dark gray to light yellowish-gray and greenish-gray thinly bedded, micaceous shaly sandstones, normally hard and*

lithified, alternating with thin layers of fine-grained sandstones, silstones, and silty shales". Brachiopods (*Obolus* sp., *Nannorthis* sp.), molluscs (*Bucania cyrtoglypha*) and trilobites: *Geragnostus callaveiformis*, *Trinodus jujuyensis*, *Shumardia (Conophrys) minutula*,

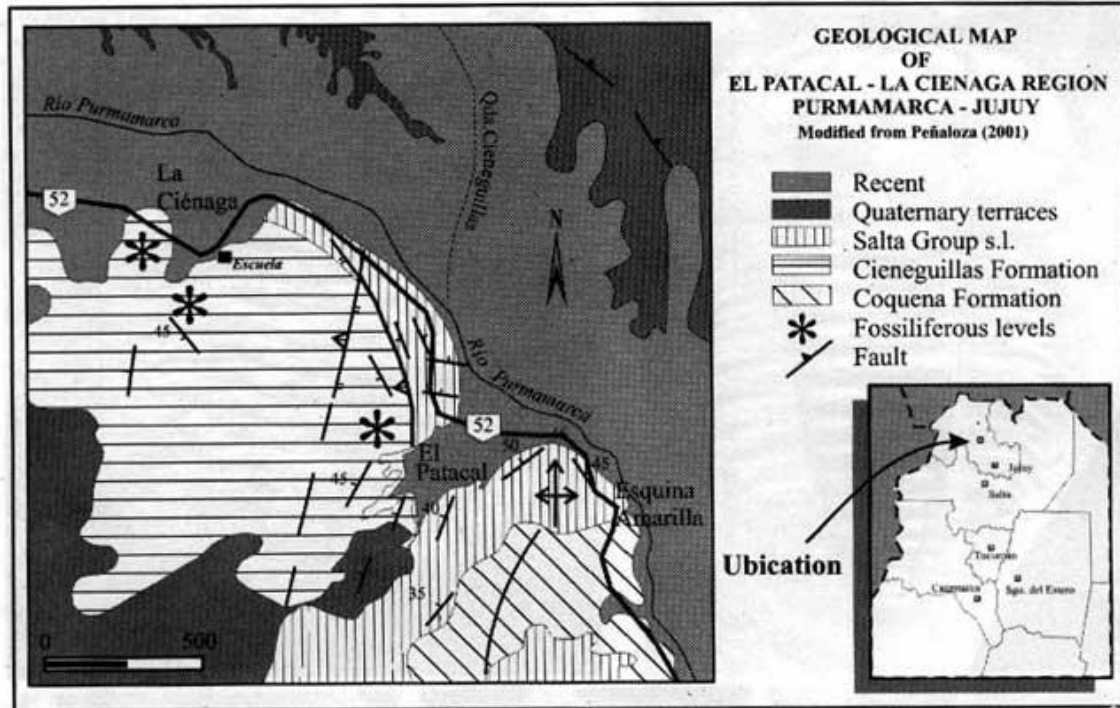


Figure 4. Location map and distribution of Ordovician strata around La Ciénaga locality.

Apatokephalus serratus, *Notopeltis orthometopa*, *Nannopeltis modesta*, *Pliomeroides deferraris*, *Orometopus pyriformis* etc. are mentioned as the most abundant fauna in these Upper Tremadocian levels [*Shumardia (Conophrys)*-*Notopeltis* trilobite biozone].

The earlier referred unit is tectonically followed by the Cieneguillas Formation. Strata was described by Harrington (1957) as "...Yellowish-green sandy shales with intercalated layers of greenish-gray sandstones and calcareous sandstones (exposed a little downstream from the *Sepulturas* limestones". Trilobites from this unit are represented by *Thyanopyge argentina*, *Megalaspidella kayseri* and *Nannorthis* sp. Rao *et al.* (1994) describes graptolites (*Didymograptus* (s.l.) aff. *demissus*, *D.* (s.l.) cf. *simulans*, *D.* (*Corymbograptus*) aff. *vacillans*) and conodonts (*Baltoniodus crassulus andinus*, *Cornuodus longibasis*, *Drepanodus?* sp., *Drepanoistodus basiovalis*, *Drepanoistodus pitjanti*, *Drepanoistodus* sp. 2, *Protopanderodus* sp.

The whole unit displays good outcrops along route 59, close to El Patacal and La Ciénaga area. In the last locality, Aceñolaza F. (2003) recognizes the type area for the *Sepulturas* Formation as defined by Harrington (1957) "...Light to dark gray limestones and marly limestones, with interbedded dark gray shales (exposed in the upper

Quebrada de Purmamarca)". Trilobites (*Hoekaspis schlagintweiti* and *Pliomeridus sulcatus*), graptolites, conodonts, trace fossils (*Monomorphichnus* isp, *Cruziana* isp.), nautiloids, brachiopods and bivalves are found in these strata.

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