

# The Purmamarca Area, Eastern Cordillera, Jujuy Province

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## Introduction

### Stratigraphic framework

The Purmamarca village is placed *ca* 50 km to northwest of Jujuy City, on the western side of the Quebrada de Humahuaca, Tumbaya Department, Jujuy Province (Figure 5). Within the general context of the Quebrada de Humahuaca, it is one of the most picturesque areas of the Argentina for tourism, and was recently declared by UNESCO cultural heritage of the humanity. From a geological point of view, it is a classical locality for the study of lower Paleozoic rocks of the Eastern Cordillera (*e.g.*, Keidel, 1917; Kobayashi, 1936, 1937; Harrington, 1938; De Ferrariis, 1940; Harrington & Leanza, 1957; Ramos *et al.*, 1967; Rao *et al.*, 1994; Tortello, 1996; Tortello & Aceñolaza, 1999).

Graywakes, quartzites and slates of the Puncoviscana Formation (Upper Precambrian – Lower Cambrian) constitute the basement of the Eastern Cordillera. Ichnofossils of Vendian/Tommotian age were recorded in this formation by Aceñolaza *et al.* (1999). These authors described the ichnogenus *Protichnites* from strata of the Puncoviscana Formation exposed at Purmamarca (Aceñolaza *et al.*, 1999).

The dominantly sandstone sequences of the Mesón Group (Lower Cambrian), unconformably overlie the Puncoviscana Formation (Tilcara unconformity) (Turner & Méndez, 1975; Moya, 1999). The Iruya unconformity (Turner, 1960) separates the successions of the Mesón Group from the Lower to Middle Ordovician Santa Victoria Group (Santa Rosita and Acoite formations) (Turner, 1960), and equivalent units.

Upper Cretaceous to Tertiary rocks (Salta Group) unconformably cover ancient units. The stratigraphic column is completed with continental rocks of the Salta Group (Upper Cretaceous – Tertiary), and Quaternary alluvial deposits.

Ordovician rocks crop out in several sections throughout the Purmamarca area; *e.g.*, Salto Alto, Coquena, and Chalala creeks (tributaries of the Purmamarca creek), and beside the Provincial road 16 to Chile at the Cuesta de Lipán. The Ordovician succession is composed by the Purmamarca Shale and Chañarcito Limestone (Lower Tremadocian), Coquena Shale (Upper Tremadocian), Cieneguillas Shale (Arenig) and Sepulturas Limestones (Llanvirn) (Harrington & Leanza, 1957). No continuous section is displayed in the area, whereas all

contacts between Ordovician units are tectonics. Exposed rocks bear a rich fossil assemblage that mostly consist of trilobites and ichnofossils (*e.g.*, Harrington & Leanza, 1957; Mángano *et al.*, 1996; Tortello 1996; Tortello & Aceñolaza, 1999). The significance of the cosmopolitan *Jujuyaspis* genus was remarked by Kobayashi (1936). *Jujuyaspis keideli* Kobayashi was described for the Lower Tremadocian Purmamarca Shale, and recently, the *J. keideli* Subzone (*Parabolina* (*Neoparabolina*) *frequens argentina* Zone) was formally proposed by Tortello *et al.* (2002). The occurrence of this fossil provides valuable information about the Cambrian–Ordovician boundary in northwestern Argentina (Eastern Cordillera and Famatina System) (Aceñolaza & Aceñolaza, 1992; Tortello *et al.*, 2002).

Trilobites of the *Notopeltis orthometopa* Zone (Upper Tremadocian) were identified in the Las Juntas, Coquena, and Chalala creeks (Harrington & Leanza, 1957; Tortello, 1996). The occurrence of *Conophris minutula* (Harrington), *Orometopus pyriformis* Harrington, *Apatokephalus serratus* (Boek), *Notopeltis orthometopa* (Harrington), and *Asaphellus catamarcensis* Kobayashi, among others, was registered in the Coquena Shale.

A conodont assemblage occurring in calcareous levels with the *N. orthometopa* was documented for the same formation at Chalala creek (Rao *et al.*, 1994; Rao & Hünicken, 1995). It is composed of *Drepanodus arcuatus* Pander, *Drepanoistodus* sp. cf. *D. inaequalis* (Pander), *Monocostodus sevierensis* (Miller), *Oneotodus simplex* (Furnish), and *Semiacontiodus bicostatus* (Miller), among others, indicating a late Tremadocian age for the bearer beds. Rao & Hünicken (1995) also recorded a lower conodont assemblage referred to the lower part of the section, integrated by *Cordylodus drucei* Miller, *Eoconodontus notchpeakensis* Miller, *Phakelodus elongatus* (An), *P. tenuis* (Müller), and *Teridontus nakamurai* (Nogami). This fauna verifies a Late Cambrian age for the lower part of the Santa Rosita Formation (Santa Victoria Group).

Tremadocian graptolites and conodonts were found in the La Ciénaga locality, few kilometers west of Purmamarca village (Rao *et al.*, 1994; Ortega & Rao, 1994) (see below).

### **Stop 1.** Salto Alto creek.

The type locality of *Jujuyaspis keideli* is placed in the Salto Alto creek on the western flank of the Alta Range (Kobayashi, 1936; Aceñolaza & Aceñolaza, 1992; Tortello *et al.* (2002). The sequence, made up of black shales and subordinated sandstones and quartzites, is strongly affected by tectonics. Specimens of *J. keideli*, *Angelina hyeronimi* (Kayser), *Parabolinella argentinensis* Kobayashi, *Plicatolina* sp., *Micragnostus* sp., and *Anglagnostus* of the *J. keideli* Subzona (*P. (N.) frequens argentina* Zone) occur in the black shales.

### **Stop 2.** The Patacal.

The Patacal locality is placed a few kilometers to the west of Purmamarca village, near La Ciénaga. At Patacal, we will look at the upper Tremadocian succession, composed of purple shales, sandstones, and gray violate–rosy quartz–calcareous sandstones. These deposits (Coquena Shales; Harrington, 1957) bear *Notopeltis orthometopa* (Harrington), *Ceratopyge forficuloides* Harrington & Leanza, *Basiliella carinata* Harrington, *Bienvillia rectifrons* Harrington, *Pharostomina*

*trapezoidalis* (Harrington), *Parabolinella triarhroides* Harrington, *Asaphellus jujuanus* Harrington, and *Asaphellus catamarcensis* Kobayashi.

The *Notopeltis* Regressive Event begins with these deposits (NORE), which probably correlates with the *Ceratopyge* Regressive Event (CRE), since *C. forficuloides* is frequently associated with *N. orthometopa*, and is constrained to the homonymous biozone.

### Stop 3. La Ciénaga.

The type section of the Cieneguillas Formation crops out at La Ciénaga locality, 8 km west of Purmamarca village, on Provincial Road 16 (Figure 34). The formation, ca. 260 m thick, is composed of dark grey shales, subordinate sandstones, calcarenites, and calcareous concretions. The lower boundary is not registered in the study area. The succession is tectonized and contacts by fault with Cretaceous rocks (Yacoraite Formation) (Figure 35). A fossil assemblage with trilobites, molluscans, bryozoans, ostracods, conodonts, graptolites, and ichnites is present in these strata (Harrington & Leanza, 1957; Rao *et al.*, 1994; Ortega & Rao, 1994). *Thysanopyge argentina* Kayser, *Zuninaspis acuminata* Harrington & Leanza, and *Geragnostus* sp. occur in the shales, associated to *Baltograptus vacillans* (Tullberg), *Didymograptus* (s.l.) sp. aff. *D. demissus* Törnquist, *D.* (s.l.) sp. cf. *D. simulans* Elles & Wood, and *Didymograptus* (s.l.) sp. cf. *D. rigoletto* Maletz *et al.* (Figure 36).

Calcareous levels yielded a conodont fauna integrated by *Gothodus costulatus andinus* (*Baltoniodus crassulus andinus sensu* Rao & Hünicken, 1994), *Cornuodus longibasis* (Lindström), *Drepanoistodus basiovalis* (Sergeeva), *D.* sp. aff. *D. pitjanti* (Cooper), and *Trapezognathus argentinensis* Rao & Hünicken (Rao *et al.*, 1994). The age of the unit was referred to the Middle Arenig according with conodont records. However, the occurrence of *Baltograptus vacillans*, a common form in the *Didymograptus balticus* Zone of Scandinavia (*e.g.*, Lindholm, 1991; Maletz, 1994; Maletz *et al.*, 1991) could suggest a slightly lower age for the bearer layers. The graptolite assemblage contains elements of the intermediate latitude shelf faunas (Cooper *et al.*, 1991; Maletz, 1994).

In the upper Purmamarca creek crops out gray limestones and marly limestones, with interbedded gray shales that bear *Hoekaspis schlagintweiti*. This rock package was defined as the "Sepulturas limestones" by Harrington & Leanza (1957). Following a recent revision by Aceñolaza (2003), strata of this unit are characterized by the presence of the trilobite *Pliomeridius sulcatus* Leanza & Baldis.

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