

Lower Ordovician volcanism in North West Argentina

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Outcrops of Lower Ordovician volcanic rocks occur over large areas of north west Argentina and are best studied in the regions of Famatina and Puna. In the former region the rocks vary from andesites to rhyolites in composition and form tuffs, lava flows and volcanic breccias. The main outcrops are found in the El Chuschin–Cuchilla Negra, El Cachiyuyo, Narvaez-Chaschuil and Les Planchadas. Volcanics occur in the Suri Fm. (*s.l.*), called locally the Morado and Las Planchadas formations. Lower levels contain *Tetragraptus approximatus* and upper levels *Hoekaspis* (= *Merlinia*) *megacantha*. The volcanics are therefore of Arenig age. In the Puna region the volcanics are mesosilicic and acid to alkaline forming lavas, often with pillows, tuffs, ignimbrites and spilites. In the Quichagua area the volcanic sequence is 600 m thick. Similar outcrops to the above occur in southern Bolivia and Peru.

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Volcanic rocks and associated Ordovician sediments in north west Argentina were first known through the work of Stelzner (1885) who noted the occurrence of quartz porphyry and intercalated tuff in the Sistema de Famatina rocks then thought to be of Silurian age. Bodenbender (1916) recognised "interbedded diorites" in similar rocks and Penck (1920) described vulcanites of "Devonian" age from the northern part of Famatina. Recent studies by Schwab (1973), Coira (1973), Koukarsky & Mirre (1974) at La Puna, and by Lavndao (1973) and Maisonave (1973) at Famatina, now consider the volcanic rocks and associated sediments to be of Ordovician age.

These studies, together with those of Aceñolaza & Toselli (1977), allow the recognition of major Ordovician volcanic events in north west Argentina and other parts of South America including Bolivia and Peru.

Ordovician Palaeogeography

In order to interpret the palaeogeographical situation of the Ordovician volcanic events it is convenient to take into account the structural framework in which the Ordovician basin in

north west Argentina developed. The principal emergent areas in the west-central region of South America was the craton of Arequipa, made up of Precambrian crystalline rocks giving radiometric ages of between 600 and 1900 million years. This probably extended between the regions of Paracas in Peru and Antofagasta in Chile. In the east the continent was defined by the Dorsal or Cratogeno Central Argentino (Bracaccini 1960), consisting of igneous and low grade metamorphic rocks of Upper Precambrian to Lower Cambrian age (Aceñolaza & Toselli 1981), and by the Dorsal Charata-Asuncion of similar age and composition. The Dorsal Central Argentino formed a long wedge which divided the marine basin into the Cuenca de Pampasia on the east and the Cuenca de la Puna, Famatina and Precordillera (Cuyo) to the west.

In the Cuenca de Pampasia the sedimentological and palaeontological evidence suggests shelf conditions with deposition of fine and medium clastic sediments. In the Puna region the combination of turbidite facies and ophiolites indicates a deeper unstable basin with the formation of rhyolite-keratophyre-type volcanics adjacent to the shelf. In Famatina a shelf-slope

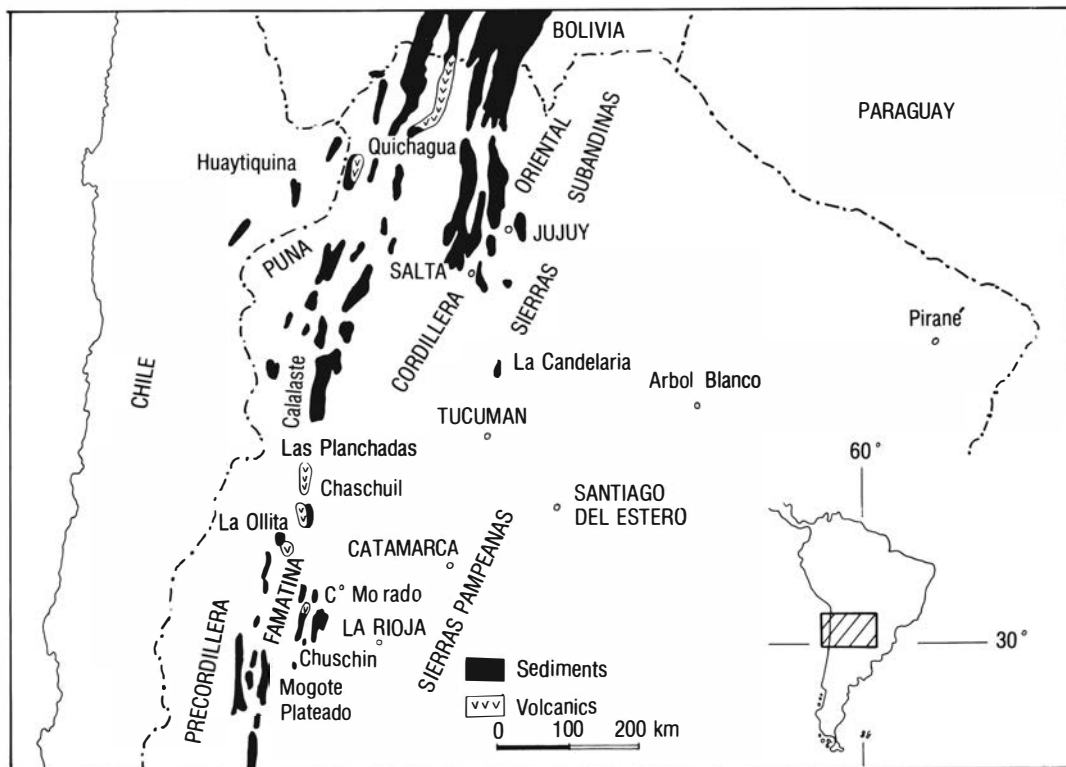


Fig. 1. General map of north west Argentina showing distribution of outcrops of sedimentary and volcanic rocks and position of localities mentioned in the text.

sequence with volcanics is present while in the Precordillera a shelf carbonate sequence grades into a flysch ophiolite facies along the western border (Baldi 1978).

Outcrops of volcanic rock

Outcrops of Ordovician volcanic rocks occur in several sections in north west Argentina extending from the Precordillera (33°S) to the border with Bolivia (22°S).

Puna of Salta and Jujuy areas

The studies of Schwab (1973), Coira (1973, 1975, 1979), Koukarsky & Mirré (1974) and Arganaraz *et al.* (1973) include detailed descriptions of the petrography of the Ordovician volcanic rocks in these areas. Spilite-keratophyre sequences are known in the Cochinoca-Escaya, Quichagua-Queta, Cauchari-Huaitiquina ranges

and San Antonio de los Cobres, but one ophiolite is known from the Salar de Pocitos.

Quichagua-Queta and Cochinoca-Escaya ranges (66°00'W–22°40'S)

Outcrops of Ordovician volcanic rocks in these ranges are almost continuous down their length. Although known for several decades, it is only from the recent studies of Coira (1973, 1975, 1979), that their composition and genetic aspects have been evaluated. These rocks are associated with a sequence of greywackes and shales (Formacion Acoite) of Arenig age and contain *Didymograptus nitidus* (see Steinmann & Hoek 1912), *D. protobifidus* and *Tetragraptus fruticosus* (see Aceñolaza 1981). Coira estimated the thickness of the Ordovician sedimentary sequence to be some 200 m consisting of grey-green greywackes interbedded with lavas, tuffs of spilitic, dacitic and rhyolitic composition.

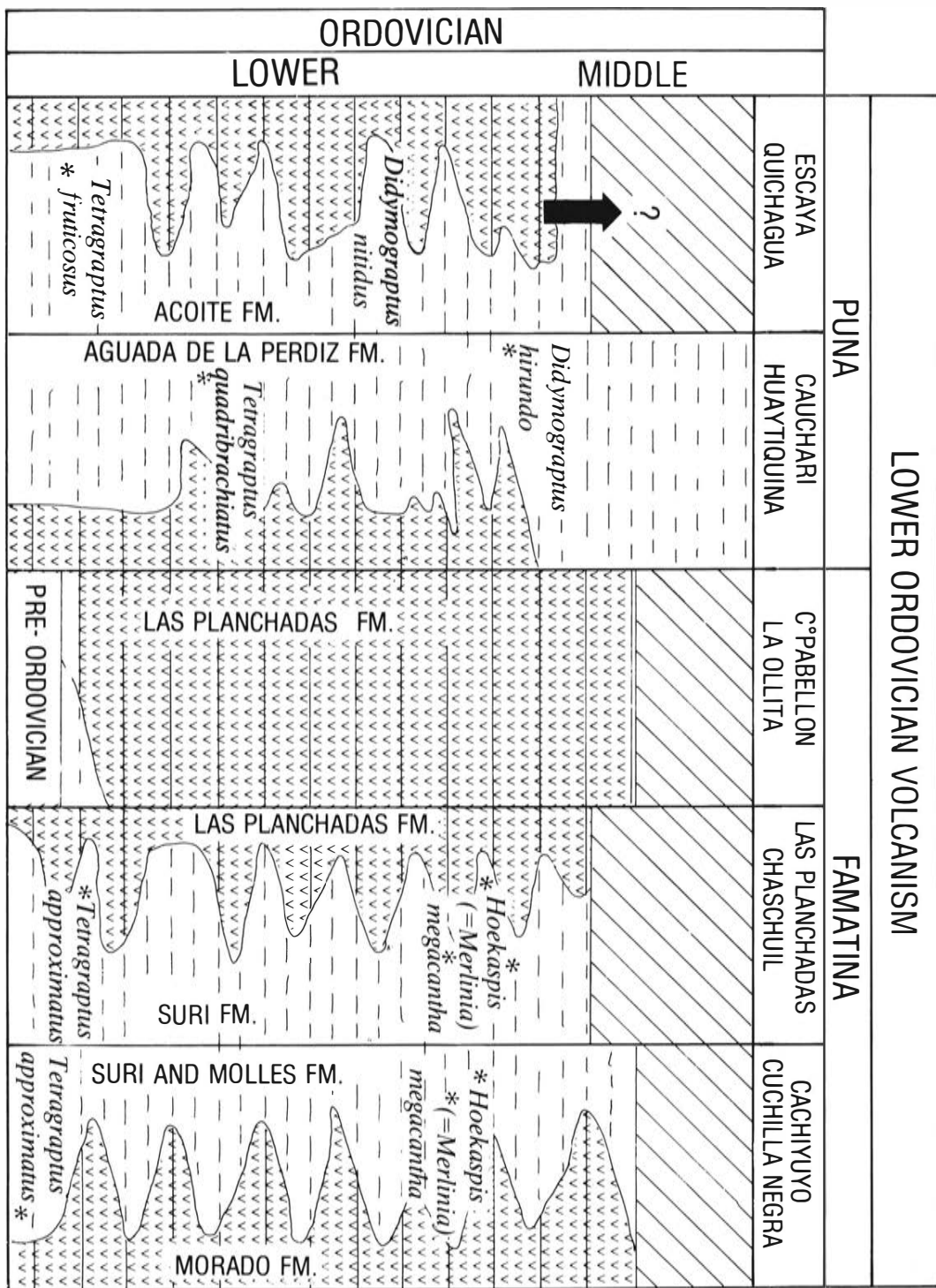


Fig. 2. Summary of Lower Ordovician stratigraphy and vulcanology and occurrence of Arentz graptolites and trilobites.

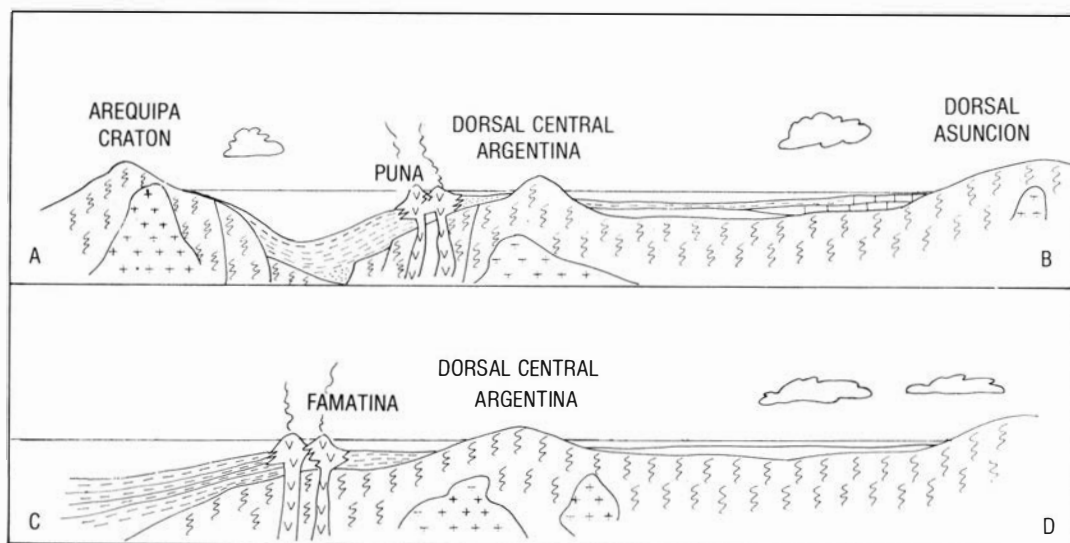
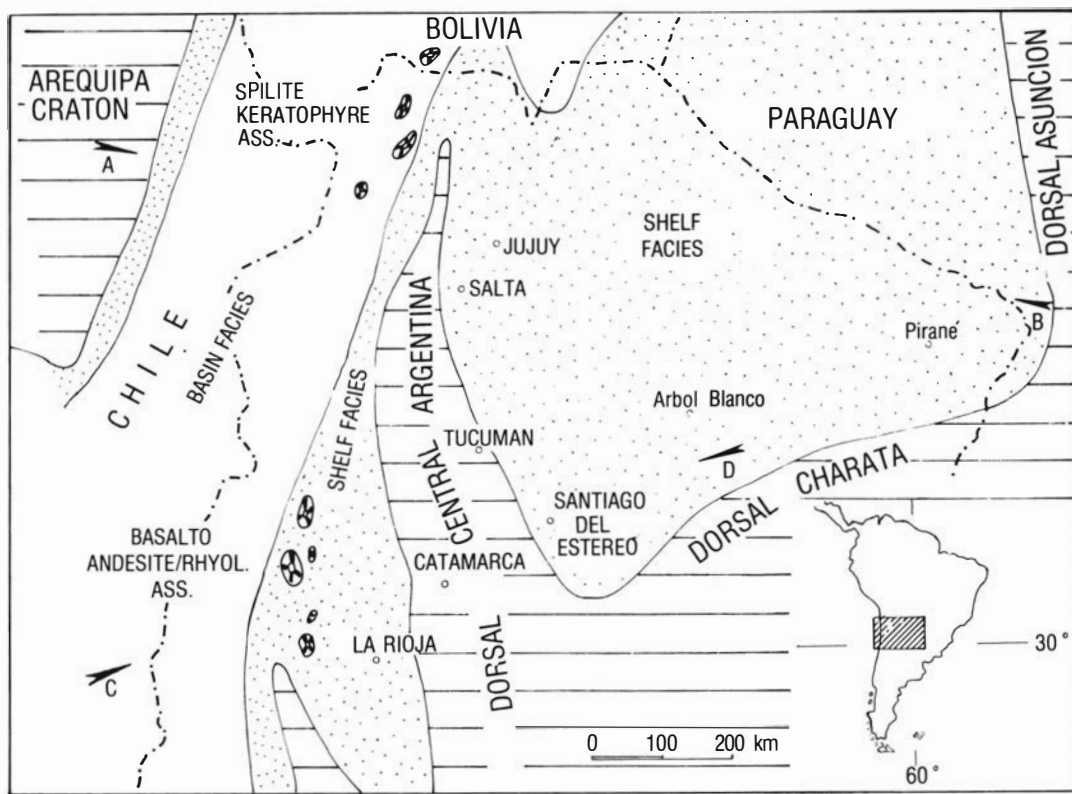


Fig. 3. A, Map of north west Argentina and adjacent areas to show general Lower Ordovician palaeogeography. B, Cross section profiles along line A-B and C-D.

Coira (1979) calculated the volcanic rocks to be about 600 m thick in the Sierra Quichagua. The outcrops of Sierra de Queta and Cochinoca are similar with massive green coloured spilite horizons up to 18 m thick and ash flow tuffs and lava flows with a total thickness of 550 m.

In general terms the spilites are described as porphyry rocks. Coira (1979) distinguished two types of tuff, fine to pumice and thick tuffs rhyolitic to dacitic in composition. The ash flow tuffs and lava flows constitute well differentiated massive bodies.

Cauchari-Huaytiquina Ranges (67°00'W – 21°20' S)

These mountains are found to the west of Salar de Cauchari and extend to the Argentine–Chilean border. Schwab (1973) estimated the thickness of the Ordovician succession to be in the order of 3000 m of volcanics, cherts greywackes and shales, the latter containing the Arenig graptolites *Tetraraptus quadribrachiatatus* and *Dichograptus octobrachiatatus* in the zone of Catua (Acenolaza & Durand 1975) and *Didymograptus* cf. *D. hincksi* in the Filo Tropapete. The volcanic rocks include diabbases, diabase tuffs, porphyritic andesites and spilites.

San Antonio de Los Cobres (66°20' W – 24°20' S)

To the west and south west of San Antonio de los Cobres, Koukharsky & Mirre (1974) reported the occurrence of keratophyre tuffs near where Roller & Mingramm (1968) discovered Upper Arenig graptolites including *Didymograptus hirundo*.

Sistema de Famatina

The Sistema de Famatina includes a series of mountains extending from Llanos in La Rioja south to the Cordillera of San Buenaventura (27°25' S). Ordovician volcanic rocks occur in the zone of Las Planchadas-Chaschuil, Cerros Pabellon-La Ollita, Cachiuyuyo-Cerro Morado-Cuchilla Negra, el Chuschin-Miranda and el Mogote Plateado, and have been interpreted in a series of papers by Maisonave (1973, 1979) and Acenzola & Toselli (1977). The Las Plan-

chadas-Chaschuil Range outcrops extended in a north-south belt approximately 200 kms long by 20 km wide. The oldest rocks in Las Angosturas contain *Clonograptus* and consist of shales and sandstones interbedded with andesites (Acenolaza 1978). In the Chaschuil area the Suri Formation consists of shales, cherts and tuffs, the latter containing a shelly fauna including *Actinodonta*, *Proterocameroceras*, *Orthambonites*, *Annamitella* and *Merlinia* (see Acenolaza & Toselli 1977).

Cerros Pabellon – La Ollita (68°15'W – 28°05'S)

Extensive outcrops of volcanic rocks of a dacitic-rhyodacitic composition occur in the Catamarca–La Rioja area between the Cerro La Ollita and Las Lajitas. These extend for more than 15 km in a SE–NW direction with a width of 6 km. Maisonave (1979) referred them to the Planchadas Formation noting their similarity to the Suncho Formation in the region of El Suncho gully.

Cachiuyuyo–Cerro Morado–Cuchilla Negra (67°45'W – 28°45'S)

Outcrops occur in the Sierra de Famatina, in a region extending from La Cuchilla Negra to the west slope of Portezuelo de las Minutas, and from Cerro del Inca–El Tocino–Morado–El Pelado on the eastern flank of the range. The volcanic rocks consist of some 400 m of rhyodacites to trachytes assigned to the Morado Formation by Turner (1964). According to Turner these rocks in the region of Rio Cachiuyuyo are younger than those containing *Merlinia megacantha* but in the southern part they extend down to include levels with *Tetraraptus approximatus*.

El Chuschin–Miranda–Mogote Plateado

The sections here occur on the west flank and middle portion of the Sistema de Famatina and in the Chuschin area consist of a sequence of sandstones and black shales interbedded with tuffs and dacitic lavas (Schalamuk *et al.* 1981).

Interpretation

We agree with Coira (1979) that the Puna spilite-keratophyre sequence and associated sediments with graptolites, indicates a continental slope to basin facies belonging to an early orogenic suite. The presence of serpentinite bodies and gabbroic rocks in Salar de Pocitos, Vega del Cajero, Vega de Tamberias, Antofalla, Sierra de Calalaste and Filo de Copayo (Arganaraz *et al.* 1973; Allmendinger *et al.* 1982), are however associated with a later orogenic stage. Observations by Van Bemmelen (1963) and Souther (1967) on ash flow tuffs, indicate that these eruptions accompany periods of general elevation of the geanticline and related periods of strain and faulting. This stage coincides with the Famatina event. In the Sistema de Famatina, the sediments indicate a shallow shelf environment associated with a synorogenic rhyolite suite of volcanic rocks.

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