



# Significance of the Early Jurassic Garamilla formation in the western Nordpatagonian Massif

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## ABSTRACT

By means of facial, stratigraphic, petrographic, geochemical and geochronological studies we characterize the Garamilla Formation, cropping out in the western Nordpatagonian Massif.

The studies of these volcanic rocks reveal an Early Jurassic volcanic episode formed by three volcanic units that change from normal calc-alkaline to high-K calc-alkaline series. Other geochemical features reveal a progressive change from an initial subduction-related volcanism to one intraplate-related volcanism.

This volcanic episode is temporally and geochemically equivalent to those volcanic units located in half-grabens in several areas of the Neuquén Basin.

The volcanic units were erupted into different structural designs. A portion of its depocenter was interpreted as a transtensional half-graben, whereas the other exhibits a trapdoor structure. The lineament trends that bound the volcanic system were also recognized in western Nordpatagonian Massif, and were assigned to the Gondwanide Orogeny.

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## 1. Introduction

The Early Mesozoic tectonic history of the southern South America region is closely linked to the rupture and separation of the Gondwana Supercontinent, which began in the Triassic with the formation of intracontinental rifts. Later, in the Lower Jurassic, the western margin of South America was affected by the development of subduction systems. As a result, oblique batholiths (Pankhurst et al., 1992; Rapela and Pankhurst, 1992; Rapela et al., 2005) appear in the western margin of Patagonia, due to convergent conditions during the Early Jurassic. Therefore, the major crustal extension in the Andean margin was related to a trench roll-back, which would be responsible for the associated subduction extension that characterizes most of this period (Mpodozis and Ramos, 2008).

The extra-Andean Mesozoic volcanism in Patagonia is related to large-scale half-grabens, mainly oriented NNW–SSE as suggested by Gust et al. (1985), Homoc et al. (1996) and Féraud et al. (1999).

Specifically, the western Nordpatagonian Massif was subject to major extensional stress, related to the break-up of Gondwana during Triassic times, with the development of continental rifts.

During the Early Jurassic, ENE–WSW oriented extensional conditions prevailed in this area, promoting the development of extensive volcanism and the opening of the marine Neuquén Basin located immediately west of the Nordpatagonian Massif. In the eastern Nordpatagonian Massif, the Jurassic volcanic pile is composed of extensive ignimbrite deposits of the Marifil Complex, which are chemically, petrologically and isotopically uniform. The overall activity persisted over some 20 Ma. Pankhurst and Rapela (1995) suggest that rifting and break-up of the Gondwana supercontinent produced extensive melting of the lower crustal, necessary for the development of this huge magmatism.

In the western Nordpatagonian Massif, the Jurassic units outcrop between Piedra del Aguila, Comallo, and the La Esperanza localities, and are represented by volcanic and subvolcanic rocks. Due to the absence of detailed mapping, profiling, radiometric dating, and geochemical data, these rocks were compared with apparently similar volcanic sequence outcrops more than 200 km south. Therefore they were assigned to the Garamilla Formation by Cuccchi et al. (1998).

For the first time, this paper documents facies characteristics, stratigraphy and the geochemistry of the volcanic and subvolcanic sequences erupted in a key area represented by the boundary between the western Nordpatagonian Massif and the Neuquén Basin. The study focuses on analysis of the volcanic rocks outcropping in the area east of the Limay River between

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69°47'–70°00' W and 40°04'–40°10' S. This paper also reports geochronological studies, which allow comparison with coeval sequences recognized in the Neuquén Basin and the eastern Nordpatagonian Massif. In addition, we aim to better understand the geochemical and petrologic evolution of the volcanism, its tectonic setting and the interrelationship between volcanism and the regional lineaments. Ultimately, we attempt to correlate equivalent volcanic events of the central area of the Neuquén Basin and central Nordpatagonian Massif.

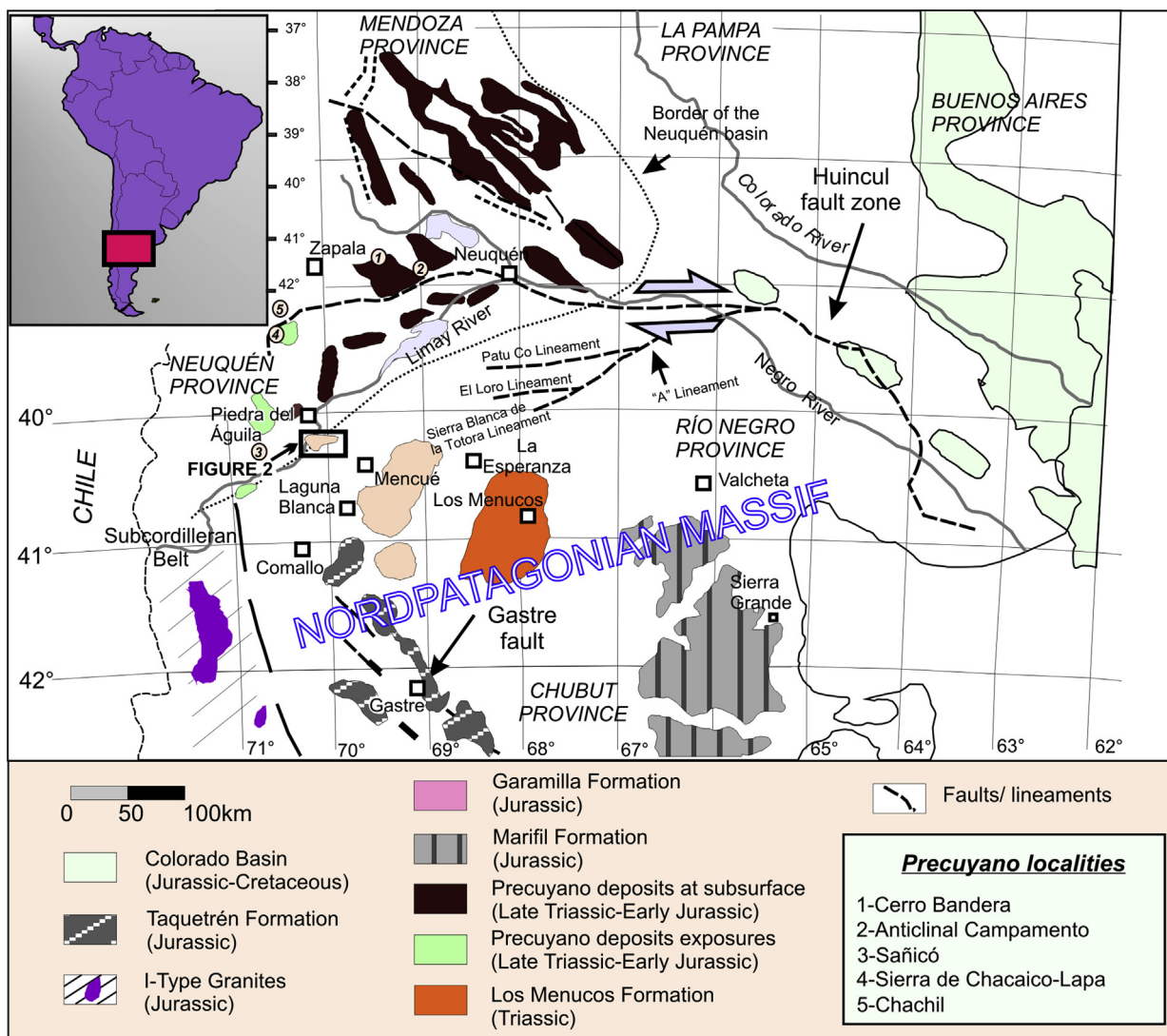
## 2. Local geology

The study area is located in the western sector of the Nordpatagonian Massif that mostly occupies northern Patagonia (Fig. 1) where three tectonomagmatic cycles can be recognized. The older one belongs to the Pampean Orogeny (Vendian–Middle Cambrian) and is represented by low-degree micaceous schists, quartzites and phyllites of the Cushamen Formation (Volkheimer, 1964). However, new dating of detrital zircons in equivalent rocks outcropping in

the area of Río Chico by Hervé et al. (2008) demonstrated a Carboniferous age for this metasedimentary sequence.

The low-degree metamorphic rocks were intruded by tonalite, granodiorite and granite of the Mamil Choique Formation (Volkheimer, 1964; Sesana, 1968; Ravazzoli and Sesana, 1977; Nullo, 1979; Núñez and Cucchi, 1990, 1997). This unit represents the Famatinian Orogeny and forms near all the pre-Triassic outcrops in the Limay River area in the western Nordpatagonian Massif. Radiometric dating, using Rb–Sr isochrones (Linares et al., 1988; Cingolani et al., 1991; Dalla Salda et al., 1994), indicates a Silurian–Devonian age for the type of area. Later studies by López de Luchi et al. (1999, 2000), Cerredo et al. (2000) and Pankhurst et al. (2006) show that this magmatic event can be related to the Gondwana Orogeny. Neither the Pampean nor the Famatinian rocks are displayed in Fig. 1 in order to avoid confusion.

Covering in non-concordance the above described units appears the Triassic Los Menucos Formation, which represents a continental rift. Above all the described units appears a set of rhyolitic and dacitic ignimbrites, rhyolitic lava-flows, and tuffs, which were



**Fig. 1.** Geological sketch of northern Patagonia showing the distribution of principal outcrops of the Jurassic volcanoclastic units, as well as the Jurassic–Cretaceous Colorado and Neuquén Basins that border the Nordpatagonian Massif. The Huincul (according to Orchueta and Ploszkiewicz, 1984; Kostadinoff et al., 2005; Gregori et al., 2008) and Gastre fault zones, also considered as boundaries of the Nordpatagonian Massif, are shown. The older volcanoclastic units are the Triassic Los Menucos Formation and Late Triassic–Early Jurassic Precuyano deposits. Jurassic magmatism is represented by the Marifil, Garamilla and Taquetrén Formation. The Jurassic Subcordilleran Batholith, located west of the Nordpatagonian Massif includes arc-related intrusive rocks. Location of Fig. 2 is also displayed.

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