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Research paper

Palynostratigraphy of the Zorritas Formation, Antofagasta Region, Chile: Insights on the Devonian/Carboniferous boundary in western Gondwana

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ABSTRACT

The Middle Member of the Zorritas Formation in the Antofagasta Region of northern Chile, yielded terrestrial and marine palynomorph assemblages which span the Devonian/Carboniferous boundary. The assemblages show a clear predominance of terrestrial palynomorphs with 70 miospore species, 18 marine phytoplankton species, two non-marine algae and one chitinozoan species, all coming from 15 productive levels. Palynomorphs are poorly preserved and most of them are reworked. Three palynological associations are recognized based on miospores. These are assigned to the Tournaisian–Visean, Tournaisian and probable latest Famennian. Age assignments are discussed in the frame of the spore zonal schemes established for Euramerica and western Gondwana. The stratigraphical distribution of spores allows the identification of the probable position of the Devonian/Carboniferous boundary within the Zorritas Formation. This system boundary is proposed for the first time in Palaeozoic sedimentary rocks of northern Chile. The presence of Gondwanan typical miospore species indicates affinities with this palaeocontinent even though the Tournaisian and Tournaisian–Visean miospore associations support the cosmopolitanism already suggested for the early Carboniferous flora. The significant number of reworked palynomorphs together with the sedimentological analysis of the studied sections, suggest that these deposits were severely impacted by the climatic change and major sea level fluctuations. Similar conditions were recorded in coeval western Gondwana basins.

1. Introduction

Sedimentary Palaeozoic rocks are very scarce in northern Chile. Cecioni and Frutos (1975) were the first to provide information about the Zorritas Formation, a nearly 2600 m thick siliciclastic sequence deposited in a mainly marine environment. Next, Davidson et al. (1981) and Boucot et al. (2008) suggested a Devonian age for this formation. Isaacson et al. (1985) and Dutro and Isaacson (1990) distinguished a transition, based on braquiopod determinations, between the Devonian and the Carboniferous into the Zorritas Formation. Niemeyer et al. (1997) distinguished and mapped three members in this stratigraphic unit (Fig. 1a,b,c) and proposed the presence of the Devonian/Carboniferous transition within the Middle Member. The presence of the systemic boundary in the upper part of the Middle Member of the unit was suggested by Rubinstein et al. (1996) based on palynological studies.

The studied section of the Zorritas Formation ranges from the latest Devonian to the early Carboniferous. During this time interval, important changes in the biosphere and therefore in the biota took place. Climatic change and major sea level fluctuations are revealed by stratigraphic discontinuities and large amounts of reworked palynomorphs, particularly in South American basins.

Even though the Devonian was climatically interpreted as a relatively warm period, the latest Devonian displayed the first evidences of long-term and intermittent upper Palaeozoic glaciations that extend until the Permian (Torsvik and Cocks, 2013). The earliest glaciogenic rocks were found in the Famennian of South

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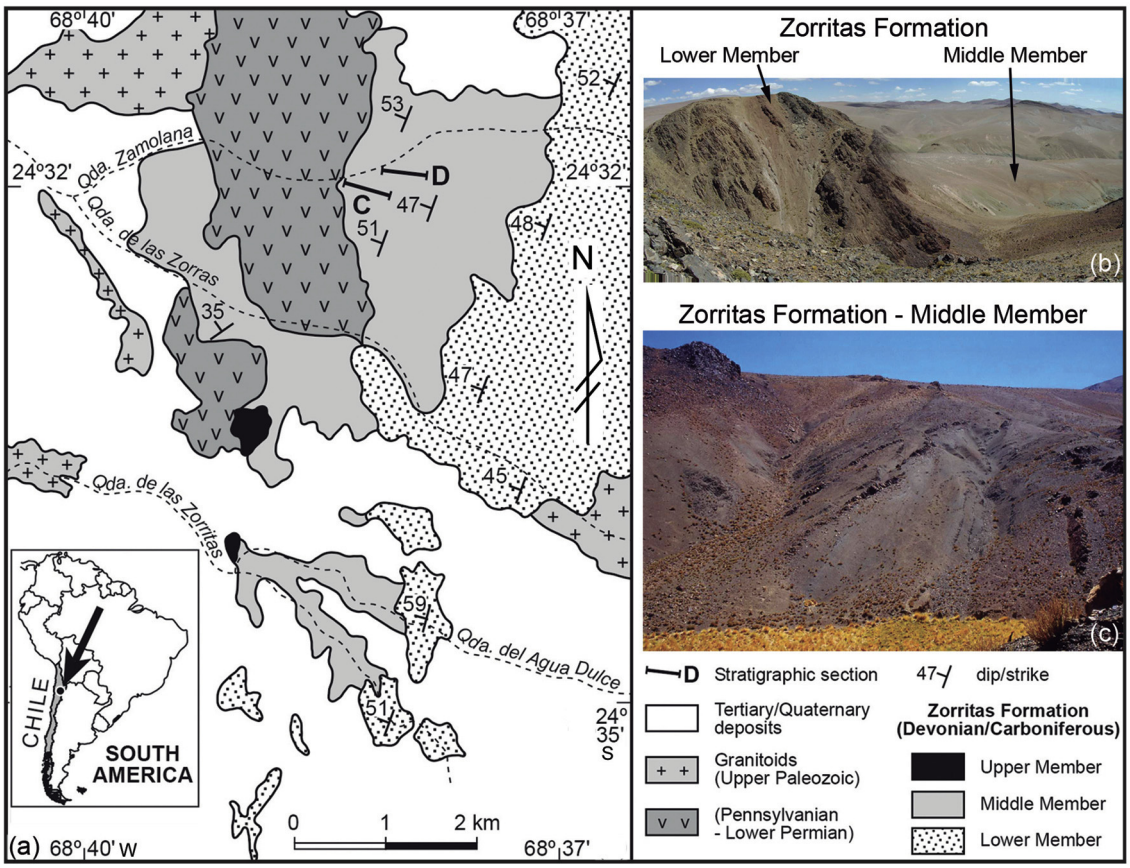

Figure 1. (a) Geographical and geological map of the studied area, in the Antofagasta region of northern Chile. C and D: stratigraphic sections of the Quebrada Zamolana. (b) Upper part of the Lower Member composed of coarse quartzarenites and the Middle Member dominated by claystones and siltstones. (c) The Middle Member with intercalations of fine grained sandstones and a few conglomerate beds.

America (from Venezuela or northern Brazil to central Argentina), Africa and the United States (e.g. Appalachian Basin) (Caputo et al., 2008 and references therein), thus suggesting that the Neo-Devonian cooling was a global event involving most of western Gondwana and even partially reaching Laurussia. Consequently, the Rheic Ocean was narrower than previously supposed (Caputo et al., 2008). Noteworthy, in the Andean region of Argentina, Peru and Bolivia, Famennian glacially-influenced sediments have also been identified (Caputo and Ponciano, 2010). The only Tournaisian sediments of possible glacial origin in western Gondwana were recorded from Brazil thus making the extension of the glaciation in this region less evident during the early Mississippian (Caputo et al., 2008). Transgressive and regressive sequences of non-marine, nearshore or offshore deposits outside the glaciated areas may have been produced by the alternation of glacial and interglacial phases (Caputo et al., 2008). The precise timing of ice centres waxing and waning during the glacial episode has been interpreted as influenced by basin dynamics, topographic barriers, glaciation styles and other local factors (López-Gamundí and Buatois, 2010).

The first results related to the stratigraphy and palynology of the Devonian/Carboniferous boundary in the Zorritas Formation, were anticipated based on a single palynological productive level (sample Z128 in Fig. 2) by Rubinstein et al. (1996), Niemeyer et al. (1997), and Niemeyer and Rubinstein (2000). Even though this level yielded a badly preserved mainly terrestrial palynomorph assemblage, the contained spores allowed the assignment of this stratigraphic level to the Tournaisian, correlating it with the western European *Vallatisporites verrucosus-Retusotriletes incohatus* (VI) spore zone. This spore zone is considered the basal one of the Carboniferous (Higgs et al., 1988a). The marine phytoplankton was represented by scarce specimens of simple forms (*Michrystridium* sp., *Veryhachium* sp.) without any stratigraphic value.

The present contribution provides new information, displaying richer and more diverse palynological assemblages coming from 15 productive levels obtained from a new field work of the same stratigraphic unit. The palynological assemblages comprise miospores and subordinated organic-walled phytoplankton.

The biostratigraphic usefulness of miospores for the late Devonian–early Carboniferous has been recognized particularly in Euramerica, where most of the miospore biozonations utilized worldwide come from.

In fact, the Devonian/Carboniferous boundary is possibly the Palaeozoic systemic boundary best defined based on miospore biozonations. One of the most remarkable palynological events in coincidence with this boundary which can be recognized worldwide is the extinction of *Retispora lepidophyta* (Clayton, 1996).

Two main miospore zonation schemes have been erected for the Devonian. Firstly, the Richardson and McGregor (1986) one has been defined for the Old Red Sandstone Continent and Adjacent regions. Afterwards, the Streel et al. (1987) miospore zonation has been defined for the Ardenne-Rhenish regions. These schemes developed for Euramerica were subsequently applied for the Devonian of western Gondwana.

Streel and Loboziak (1996) correlated the upper Devonian miospore zonations of southern Euramerica, northern Euramerica and western Gondwana based on the schemes of Richardson and McGregor (1986), Streel et al. (1987) and Avkhimovitch et al. (1988).

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