DEVONIAN AND CARBONIFEROUS STRATIGRAPHY OF SIERRA DE ALMEIDA NORTHERN CHILE, PRELIMINARY RESULTS

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ABSTRACT

New biostratigraphic discoveries made in the Paleozoic sequences exposed in Sierra de Almeida, northern Chile, are presented here. Early works suggested a Silurian or Devonian age for the sedimentary units (Zorritas Formation) present in the region. New collections of brachiopod faunas suggest that both Devonian and Carboniferous strata are present in the Zorritas Formation. Devonian brachiopods were found in the Lower Member (quartz arenites with occasional volcanic cobbles); they include *Tropidoleptus* and *Australocoelia*, which compared with better-studied Bolivian faunal assemblages, seem to suggest an Eifelian (Middle Devonian) age. The Carboniferous brachiopods, present in the Upper Member (siltstones, sandstones, mudstones, and conglomerates) include *Septosyringothyris, Riphidomella* and *Rugosochonetes*(?), an assemblage that indicates a Tournaisian (Early Carboniferous) age. Depositional environment and paleogeography of the Zorritas Formation is discussed and compared with Devonian-Carboniferous sediments cropping out in Bolivia, Argentina and the Chilean Coastal Range.

Key words: Brachiopods, Stratigraphy, Devonian-Carboniferous, Sierra de Almeida, Chile.

RESUMEN

En este artículo se dan a conocer recientes hallazgos bioestratigráficos efectuados en el Paleozoico de Sierra de Almeida (Cordillera de Antofagasta). Trabajos anteriores sugirieron una edad silúrica a devónica para las secuencias sedimentarias (Formación Zorritas) que allí afloran. El estudio de una nueva colección de fauna fósil de braquiópodos, encontrada en la Formación Zorritas, indicó que en ella está representado tanto el Devónico como el Carbonífero. Los braquiópodos devónicos provienen del Miembro Inferior de la formación (areniscas cuarcíferas con algunos clastos volcánicos) e incluyen formas de *Tropidoleptus* y *Australocoelia* que, al ser comparados con las asociaciones faunísticas de Bolivia, parecen indicar una edad eifeliana (Devónico Medio) para los estratos que los contienen. Los braquiópodos carboníferos se encuentran en el Miembro Superior (limonitas, siltitas, areniscas y conglomerados) y entre ellos se han reconocido: *Septosyringothyris, Riphidomella* y *Rugosochonetes* (?), que señalan una edad tournasiana (Carbonífero Inferior). Considerando los datos anteriores se discute el ambiente de depositación de la Formación Zorritas y se efectúa una comparación con formaciones de edad similar, expuestas tanto en Argentina y Bolivia como en la Cordillera de la Costa del norte de Chile.

Palabras claves: Braquiópodos, Estratigrafía, Devónico-Carbonífero, Sierra de Almeida, Chile.

INTRODUCCION

The discovery of series of sedimentary fossiliferous Paleozoic rocks in the Sierra de Almeida area and southern Salar de Atacama, northern Chile, was first reported by Cecioni and Frutos (1975), who suggested a Silurian age for the fossiliferous rocks at Quebrada Zorritas (Zorritas Formation) and by Marinovic (1978) who, based on Covacevich's determinations, assigned them to the Early Devonian.

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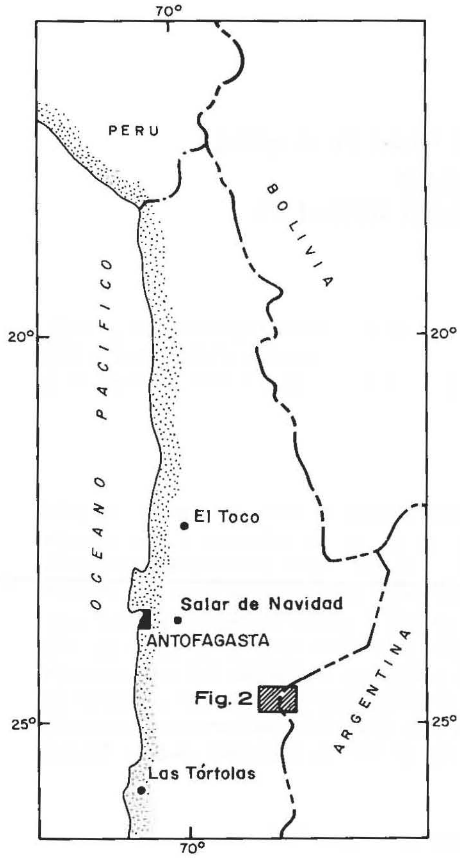


FIG. 1. Location of Paleozoic outcrop areas, northern Chile, discussed in the text. Area of Fig. 2 indicated. El Toco: Late Devonian turbidites, described by Bahlburg (1985). Salar de Navidad-problematic area with possible allochthonous Devonian (Eastern Americas Realm brachiopod fauna?). Las Tórtolas: Devonian (?) deep-sea basin plain deposits (Bell, 1982).

Subsequent to these reconnaissance works, geologists from the Servicio Nacional de Geología y Minería (SERNAGEOMIN), Chile, have systematically mapped the entire length of Devonian rocks that crop out from the southern tip of the Salar de Atacama to the foot-hills of Llullaillaco volcano (Fig. 1). Unpublished field information reported by students of the University of Chile (Czollak *et al.*, 1981) communicate the presence of Devonian assemblages all along a section measured at Quebrada El Salto, north of Quebrada Zorritas locality. Late Ordovician-Early Silurian plutons (Mpodozis *et al.*, 1983) constitute the basement over which the marine sequences lie. Davidson *et al.* (1981) identified several sedimentary structures within equivalent sequences along the strike of the same outcrop and suggested a prodelta depositional environment. Based on the fossiliferous content of these rocks, it is now apparent that a Malvinokaffric Realm brachiopod of Devonian age, comes from the basal sandstones of the formation, at Quebrada Zorritas. Moreover, Early Carboniferous fossils (see bellow) appear in the upper siltstones, at Quebrada El Salto. It can therefore be inferred that there are different lithostratigraphic units characterized by different lithofacies and ages, as shown by the faunal association.

STRATIGRAPHY

The Zorritas Formation was defined by Cecioni and Frutos (1975, p. 192-194) as "rocks exposed along the western flank of Sierra de Almeida, east of Salar de Punta Negra". The original definition was only accompanied by a short description of its lithology, fossiliferous content and depositional environment. Type section, outcrop distribution and clear stratigraphic relations were not presented. Recent mapping on these rocks, enables us to: a) establish a type section that is located at Quebrada El Salto, 20 km north of Quebrada Zorritas (B locality in Fig. 2); b) define its present distribution along Sierra de Almeida; c) define top and bottom relationships; d) understand its environmental depositional setting and facies changes; and e) determine a relative age according to its fossiliferous content.

The type section of the Zorritas Formation is about 2,780 m thick, including Devonian and Early Carboniferous rocks. From bottom upwards, it consists of a Lower Member composed by more than 1,000 m of coarse to fine-grained sandstones and a 1,600 m thick silty-muddy Upper Member with upward increasing of sandstone, shale and volcaniclastic intercalations. Between Quebrada El Salto and Quebrada Zorras (B and C localities in Fig. 2) the top of the formation is composed by conglomerates and red sandstones.

All along the western flank of Sierra de Almeida, the base of the Zorritas Formation is intruded by Late Paleozoic granitic rocks. However, in Alto del Inca (10 km northwest of Monturaqui railroad station D locality in Fig. 2), and at the eastern flank of Sierra de Almeida, the Lower Member overlies

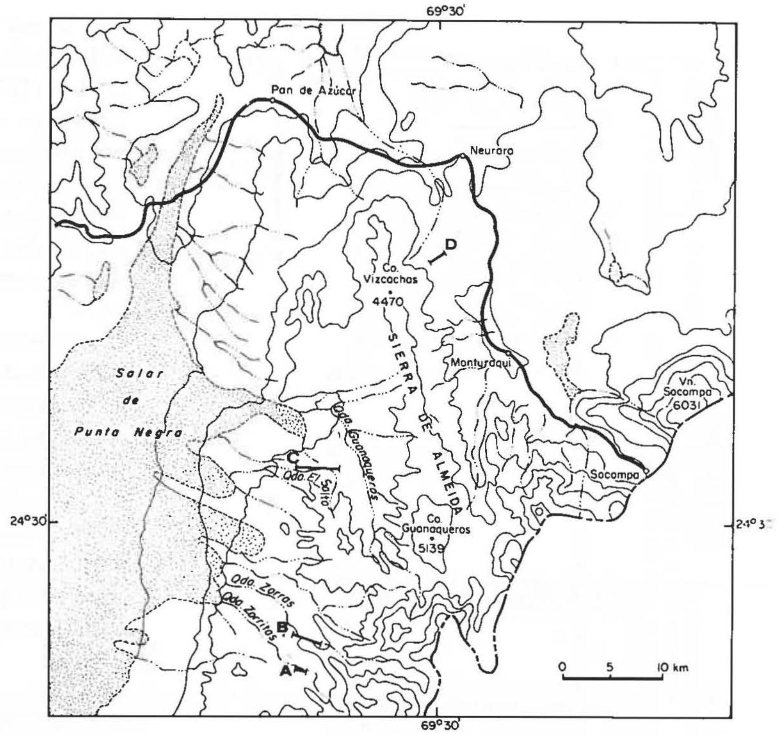


FIG. 2. Areas within the Sierra de Almeida where stratigraphic sections were measured. A. Quebrada Zorritas (Cecioni and Frutos, 1974) (Middle Devonian); B. Quebrada Zorras, with both members of Zorritas Formation exposed; C. Quebrada El Salto, type locality for the Zorritas Formation (Middle Devonian-Early Carboniferous); D. Alto del Inca, with the Lower Member overlying Late Ordovician-Early Silurian plutonic rocks.

dated Late Ordovician-Early Silurian plutonic rocks (Mpodozis *et al.*, 1983). The Zorritas Formation, at the type section in Quebrada El Salto, is unconformably overlain by massive rhyolites and ignimbrites that yielded Late Carboniferous–Early Permian K-Ar ages in several localities within the Sierra de Almeida region (Davidson *et al.*, 1985). Rock sequences similar in age and composition to those in the type area of the Zorritas Formation crop out at Cerros de Lila, Cerros Cuyugas, and Cerro Chinchilla, south and east of Salar de Atacama. All these have been mapped as the Lila Formation (Ramírez and Gardeweg, 1982).

In order to establish an adequate correlation between the proposed Quebrada El Salto type section and the locality, we assume corresponds to Cecioni and Frutos's type locality (not located in their publication), we constructed detailed stratigraphic sections of the formation, at Quebrada Zorritas and Quebrada El Salto. Both sections are located in figure 2 and shown in figure 3.

QUEBRADA ZORRITAS SECTION

A 300 m thick sequence of quartz arenites was measured at Quebrada Zorritas (A locality in Fig. 2). It is an outcrop separated from other by Miocene volcanics. Most of the section consists of coarse-grained gray to white quartz arenites. Occasional cross-bedding occurs as well as pebbly conglomerates. Pebbles are mostly formed by quartz arenite and shale. In the middle part of the section, there is a tuffaceous level formed by volcanic (andesite) and quartz arenite cobbles. Bed thickness varies from 30 to 250 cm. Within the sandstones, the quartz grains are well-sorted and well-rounded, iron-staining being abundant. Silt content increases upwards. Brachiopod casts occur abundantly in four thin beds, at 228, 234, 238, and 260 m from the base of the outcrop. Their modes of preservation and occurrence are discussed in a later section.

QUEBRADA EL SALTO SECTION

A 2,778 m thick, west dipping sequence of coarse to fine-grained sandstones, with siltstone, mudstone and conglomerate intercalations crop out at Quebrada El Salto (C locality in Fig. 2).

As it has been noted, the base of the section is intruded by a Late Paleozoic pluton while the top underlies Late Carboniferous volcanics (Cas Formation). The section was measured in detail along the southern flank of Quebrada El Salto. The Zorritas Formation can there be divided into two members: 1) a lower, white, sandy member; and 2) an upper, green, sandy-silty member. Correlation between both members and the Quebrada Zorritas section is shown in figure 3.

The Lower Member is composed by two units (1 and 2) with a total thickness of 1,190 m.

Unit 1 (720 m): Coarse-grained, olive-green to light-gray, micaceous quartz arenite, locally showing cross-bedding quartz arenite. At 443 m from the base, a 5 m thick, very coarse, matrix supported conglomerate occurs. The rest of the unit shows bedding varying from 50 cm to 200 cm, where grains are well sorted and rounded.

Unit 2 (470 m): The lower part is tan to greenish, with abundant iron-staining. The thickness varies from 10 cm to 50 cm with occasional beds up to 200 cm thick. Trace fossils and assymmetrical ripple marks are frequent. The upper part consists of white and iron-stained coarse-grained massive sandstones. When bedding is observed, thickness varies from 100 cm to 300 and cross-bedding is not frequent. Possible *Skolitos* trace fossils occur near the top of the unit.

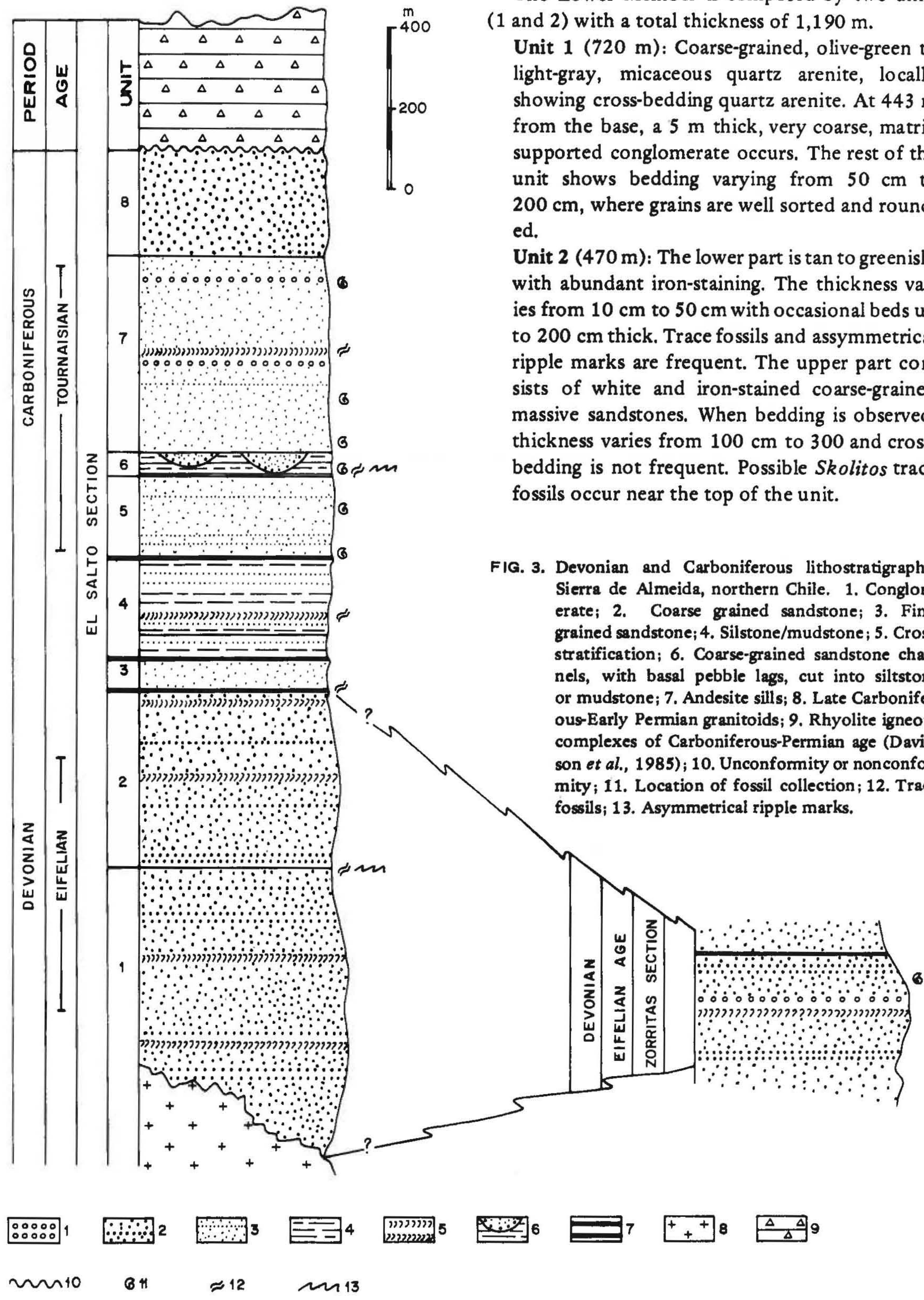


FIG. 3. Devonian and Carboniferous lithostratigraphy, Sierra de Almeida, northern Chile. 1. Conglomerate; 2. Coarse grained sandstone; 3. Fine-grained sandstone; 4. Silstone/mudstone; 5. Cross-stratification; 6. Coarse-grained sandstone channels, with basal pebble lags, cut into siltstone or mudstone; 7. Andesite sills; 8. Late Carboniferous-Early Permian granitoids; 9. Rhyolite igneous complexes of Carboniferous-Permian age (Davidson *et al.*, 1985); 10. Unconformity or nonconformity; 11. Location of fossil collection; 12. Trace fossils; 13. Asymmetrical ripple marks.

The Upper Member is about 1,600 m thick and is characterized by its green color and decreasing upward silt content. It is composed by six units: (3 to 8).

Unit 3 (100 m): Fine-grained quartz arenite and sandy siltstone. The lower part of the unit consists of blue-green and iron-stained massive sandstone, where thickness varies from 20 to 100 cm. The upper part (bellow a 3 m thick andesite sill) is composed by olive-green 50 cm thick sandy siltstones.

Unit 4 (240 m): Olive-green and occasionally medium gray, rarely cross-bedded laminated siltstones with fine sand filled channells. Beds are 15 cm thick, with abundant trace fossils, symmetrical ripples and coal-rich horizons. The upper contact is cut by a 10 m thick andesite sill.

Unit 5 (255 m): The unit is composed by alternating micaceous siltstones and quartz sandstones The former have a blue-green color, in beds 2 to 15 cm thick. Abundant trace fossils are present as well as *Zoophycus* sp., brachiopods and possible conularids. Towards the top of the unit, lag pebble-sized deposits with graded bedding (up side up) matrix-supported, coarse sandstone and conglomerate are deposited on scoured contact with white, coarse-grained, planar cross-stratified quartz arenites. Bed thickness varies from 50 to 100 cm. Fossils were collected in three beds, at 1,711; 1,760 and 1,858 m from the base of the formation. Their modes of preservation and occurrence are mentioned below, in the subsequent section.

Unit 6 (55 m): This unit consists of very coarse-grained sandstones and pebble-sized conglomerates in a coarse to medium-grained olive-green micaceous sand matrix. The sandstone is lenticular, suggesting a channel deposit. Interbedded are fine-grained olive-green sandstones with the presence of abundant iron-staining scours.

Unit 7 (520 m): This unit is formed by fine to medium-grained sandstone with occasional coarse grained beds. Near the top of the unit, shale and volcaniclastic intercalations occur. The sandstones are olive-green, micaceous and occasionally cross-bedded or laminated. Its thickness varies from 10 to 50 cm. This unit contains abundant fossils, including traces. Brachiopods, conularids, bivalves, gastropods, and pelmatozoan columnals are formed in four beds, at 2,011; 2,107; 2,386, and 2,501 m above the base of the formation.

Unit 8 (270 m): This unit consists of medium to coarse grained brown to white iron-stained quartz sandstone. Bedding is tabular and thickness varies from 20 to 50 cm. The upper contact corresponds to extensive hydrothermal alteration and brecciation and contact metamorphism with silica flooding, below the angular unconformity with the overlying Late Paleozoic volcanics (Cas Formation).

PALEONTOLOGY

Two faunal assemblages are briefly discussed as "Devonian" and "Carboniferous" faunas. Detailed analyses of faunal abundant communities and paleoenvironmental reconstructions based upon such analyses will be the subject of a future paper. Chronostratigraphy of both members of the Zorritas Formation, based on the following discussion, is shown in figure 4.

DEVONIAN FAUNAS

In the Zorritas section the following brachiopods: *Tropidoleptus carinatus* (Conrad, 1939), *Australocoelia palmata* (Morris and Sharpe, 1846), and possibly *Derbvina* sp. have been identified. As described by Isaacson (1977a), *Tropidoleptus* is abundant in the upper part of the Devonian sequence in Bolivia. It has been found in the Upper Belén Member of the Belén Formation, in the Santary Sandstone Member of the Sicasica Formation, and in the Carinatus Shale Member of the Huamampampa Formation. Other occurrences in South America are the Floresta Formation of Colombia (Caster, 1939; Morales, 1965), the Precordillera Sanjuanina of Argentina (Thomas, 1905), and the Amazonas Basin (Carvalho, 1972).

The other taxon present is *Australocoelia*, which is relatively long-ranging throughout the Bolivian Devonian sequence (Isaacson, 1977b), and is not diagnostic of a Devonian stage. *Australocoelia* is ubiquitous throughout the Malvinokaffric Realm. It is found in the Icla, Belén, Huamampampa, Gamo-

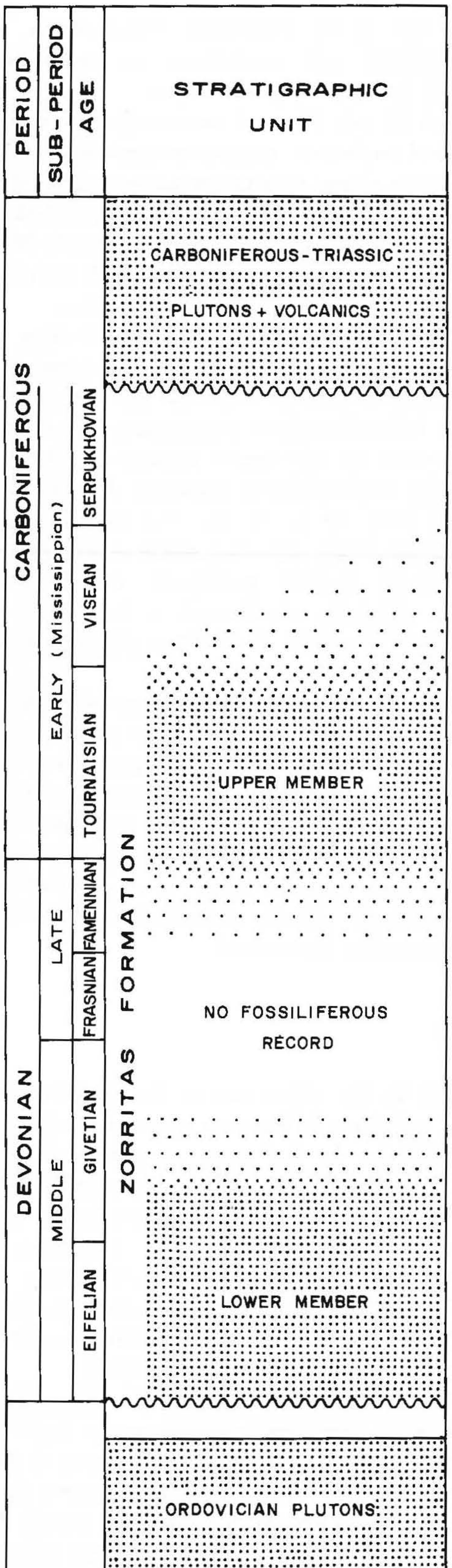


FIG. 4. Time-stratigraphic chart showing preliminary age assignations for both members of the Zorritas Formation, Sierra de Almeida, northern Chile.

neda, and Sicasica Formations in Bolivia (Isaacson, 1977b). It is also found in Argentina (Thomas 1905; Castellaro, 1966), Brasil (Clarke, 1913), Uruguay Méndez-Alzola, 1938), South Africa (Reed, 1925), Perú (Lisson and Boit, 1942), and the Malvinas Islands (Baker, 1923).

CARBONIFEROUS FAUNAS

Dr. J. Thomas Dutro, Jr., of the U.S. National Museum (Smithsonian Institution), has provided a preliminary identification of the Carboniferous brachiopods collected from the Upper Member at El Salto section. Further work is required on these taxa, including formal descriptions. However, certain genera are indicative of a Tournaisian (Early Carboniferous) age. The diversity of the brachiopods is difficult to assess at this point. Some taxa, however, appear to be similar to those described by Amos (1958) from the Precordillera Sanjuanina of Argentina. Specifically, a prominent and abundant taxon is *Septosyringothyris* sp., described by Amos (1958, Plate 108, Fig. 8-10). Amos felt that limited specimens did not permit to create a new species, or adequate comparisons with *Septosyringothyris keideli* (Harrington). The specimens discussed here, however, suggest a possible new species. Collected specimens of *Rugosochonetes* are similar to *Chonetes* sp. *cf. C. chesterensis* Weller mentioned by Amos (1958). Other Carboniferous brachiopod taxa include *Riphidomella* sp., a possible costate terebratulid, perhaps two additional spiriferid genera, a large rhynchonellid, and a fascicostellate strophomenid. Other fossils within the El Salto section include disarticulated pelmatozoan columnals, conularids, bivalves, high-spired gastropods, and trace fossils.

BRACHIOPOD PRESERVATION AND PALEOECOLOGY

Brachiopods of the Quebrada Zorritas section are mostly disarticulated, and few exhibit significant abrasion. *Tropidoleptus* specimens collected at four thin beds in the section occur in a very low diversity assemblage, typical of its occurrence throughout the Circum-Atlantic region, as discussed by Isaacson and Perry (1977). Occurrence of this genus in such low diversity assemblages, as well as its high degree of disarticulation support the previously noted conclusion that the genus inhabited nearshore, often turbulent, clastic depositional environments. Other South American occurrences of *Tropidoleptus* are in similarly coarse clastic lithologies, in which there are very low diversity brachiopod communities. A preliminary paleoecological assessment of the Zorritas Formation would place it in the Benthic Assemblage 3 (shallow subtidal) position *(sensu* Boucot, 1982), in a paralic setting. Being an eurythermal organism (Isaacson and Perry, 1977), *Tropidoleptus* withstood a variety of paleo-oceanographic conditions, although its occurrence in the cold water Malvinokaffric Realm in adjacent Bolivia and other South American localities, would necessitate cold water circulation in the Sierra Almeida localities. Isaacson (1975, 1977a), moreover, noted that *Australocoelia* can occur with *Tropidoleptus* in Bolivia, although it is usually a minor constituent of the *Tropidoleptus* community.

Contrary to what has been discussed above, Carboniferous brachiopods demonstrate a variety of morphological adaptations for a variety of depositional environments, which is consistent with the lithologies represented by the Upper Member of Zorritas Formation at Quebrada El Salto section. *Rugosochonetes* occurs, largely disarticulated, in mudstones adjacent to sandstone bodies of possible distributary channel origin. *Septosyringothyris* specimens, approximately 50% articulated, occur within the sandstone bodies. Apparently, the sedimentation events that produced distributary channels were episodic and dislodged the organisms periodically, although transport distance was not sufficient to disarticulate and abrade the specimens. Organisms living adjacent to the channels, on silt-mud substrates, include the chonetids and other strophomenids, and echinoderms. The brachiopods possibly were free-lying in order to maximize surface area in contact with the substrates. The abundant, strongly biconvex, possible terebratulids are mostly articulated, and occur in fine-grained sandstones, apparently adjacent to the possible distributary channels. Their posterior regions with thickened secondary shell material, maintained their commissure-up positioning. This feature is necessary because the pedicle appears atrophied in the studied specimens.

Given the prodelta setting suggested by Davidson *et al.* (1981) for these rocks at the area of Sierra de Almeida, the variety of depositional environment within such a locale would account for the diversc observations on the brachiopod occurrences. The thicker shelled forms would occupy areas of active sedimentation, while more fragile, thinner-shelled forms would live adjacent to those areas. These interpretations may be refined when the brachiopod taxonomy is better studied.

SUGGESTED PALEOGEOGRAPHY

Devonian paleogeography remains difficult to assess. If a direct time-stratigraphic correlation of the Zorritas Formation with the beds of El Toco, Salar de Navidad and the Las Tórtolas Formation can be demonstrated, a west-facing shoreline during Devonian time is probable. Late Ordovician-Early Silurian deformation along the Chilean-Argentine border (Ocloyic phase; Coira *et al.*, 1982), apparently produced highlands that formed the shoreline in northern Chile, along which the shallow-water *Tropidoleptus* fauna lived.

Bell (1982) interpreted the Devonian-Early Carboniferous turbidites of the Las Tórtolas Formation exposed 250 km southwest of the Zorritas Formation outcrops, as deep-sea basin plain deposits. Although the Zorritas Formation is probably Middle Devonian-Early Carboniferous, the relative positions of the two formations suggest a deepening away from Argentine-Chilean border. In any case, we suggest that a marine connection into the Andean intracratonic basin of Bolivia or the Precordillera Sanjuanina of Argentina is required, so *Tropidoleptus* and the Malvinokaffric Realm brachipods could migrate into Chile.

Several paleogeographic and biogeographic questions arise with the discovery of Devonian-age

Malvinokaffric fossils in northern Chile. First, the suggested Devonian stratigraphy at Salar de Navidad (Fig. 1), described by Ferraris and Di Biase (1978) contains probable Eastern Americas Realm Devonian faunas. Covacevich determined *Mucrospirifer* (?) within the faunal assemblage that is a possible *Acrospirifer*, which is found at Cocachacra, Perú, as described by Boucot *et al.* (1980). This would necessitate a biogeographic boundary between the Sierra de Almeida and the Coastal Ranges during Devonian. Another problem is the occurrence of Silurian cosmopolitan brachiopods very near the Chilean border in Argentina, at Salar del Rincón (Isaacson *et al.*, 1976). Rather than invoke suspect terranes, we suggest that a complex paleogeographic development of the western South American margin during Silurian and Devonian times, permitted cosmopolitan (Silurian) and Eastern Americas Realm (Devonian) faunas to move along the present western margin; possibly land and paleo-oceanographic (warm- and cold-water currents) barriers isolated them temporally from the Malvinokaffric Realm faunas.

Following suggestion of Davidson *et al.* (1981), we recommend further investigation of a prodelta depositional paleoenvironment for the Devonian-Carboniferous rocks. Apparent subsidence or sea level rise is suggested by the slightly deeper depositional paleoenvironment shown by the Upper Member of Zorritas Formation. Tentative correlation of this member with the El Volcán Formation of the Precordillera Sanjuanina (Amos, 1958) and the Itacúa and Tupambí Formations in northern Argentina and southern Bolivia (Rocha-Campos, 1976; Caputo and Crowell, 1985) would futher imply a marine connection into Argentina. Considering the very preliminary nature of the field data, however, further speculation on Devonian-Early Carboniferous paleogeography is not yet possible.

ACKNOWLEDGEMENTS

AMOCO Production Company, Houston, Texas, and the Explorers Club, New York, provided P. Isaacson and L. Fisher with field support for this project. BID, University of Chile (Grants E083 and E886) and the Servicio Nacional de Geología y Minería (SERNAGEOMIN), Chile, supported J. Davidson. Vladimir Covacevich, SERNAGEOMIN, provided valuable assistance in recognizing and identifying the abundant trace fossils in the field as well as a revision of the text. A.J. Boucot, Oregon State University, J.T. Dutro, Jr., U.S. National Museum, José Corvalán, University of Chile, Constantino Mpodozis and Jorge Skarmeta, SERNAGEOMIN, reviewed and improved an early draft of the manuscript.

This is a contribution to the IGCP projects Nrs. 193 and 211, Siluro-Devonian of Latín America and Late Paleozoic of South America, respectively.

REFERENCES

AMOS, A.J. 1958. Some Lower Carboniferous brachiopods from the Volcán Formation, San Juan, Argentina. J. Paleontol., Vol. 32, No. 5, p. 838-845.

BAHLBURG, H. 1985. Sedimentological aspects of the El Toco Formation (Paleozoic; Coastal Cordillera) NW of Quillagua, northern Chile. *In* Congr. Geol. Chileno, No. 4, Actas, Vol. 1, p. 17-28.

BAKER, H.A. 1923. Final report of the geological investigation in the Falkland Islands. Goverment Printing Press, 55 p., Port Stanley.

BELL, C.M. 1982. The Lower Paleozoic metasedimentary basement of the Coastal Ranges of Chile between 25°30' and 27°S. Rev. Geol. Chile, No. 17, p. 21-29.

BOUCOT, A. J. 1982. Ecostratigraphic framework for the Lower Devonian of the North American Appohimchi Subprovince. Neues Jahrb. Geol. Palaeontol., Abh., Vol. 163, No. 1, p. 81-121.

BOUCOT, A.J.; ISAACSON, P.E.; LAUBACHER, G. 1980. An Early Devonian Eastern Americas Realm faunule from the coast of southern Perú. J. Paleontol. Vol. 54. No. 2, p. 359-365.

CAPUTO, M.V.; CROWELL, J.C. 1985. Migration of glacial centers across Gondwana during Paleozoic Era. Geol. Soc. Am., Bull., Vol. 96, No. 8, p. 1020-1036.

CARVALHO, R.G. 1972. Braquiopodes Devonianos de Bacia do Amazonas. Tese. Inst. Geocienc., Univ. Sao Paulo, 140 p.

CASTELLARO, H. 1966. Guía Paleontológica Argentina. Parte I: Paleozoico., Cons. Nac. Invest. Cienc. y Tec., 164 p.

CASTER, K.E. 1939. A Devonian fauna from Colombia. Bull. Am. Paleontol., Vol. 24, No. 83, 218 p.

CECIONI, A.; FRUTOS, J. 1975. Primera noticia sobre el hallazgo de Paleozoico inferior marino en la Sierra de Almeida, norte de Chile. *In* Congr. Argent. Paleontol. Bioestrat., No. 1, Actas, Vol. 1, p. 191-207. Tucumán, 1974.

CLARKE, J.M. 1913. Fosseis Devonianos do Parana. Monogr., Serv. Geol. Min., Brazil, Vol. 1, 353 p.

COIRA, B.; DAVIDSON, J.; MPODOZIS, C.; RAMOS, V. 1982. Tectonic and magmatic evolution of the Andes of northern Argentina and Chile. Earth Sci. Rev., Vol. 18, p. 303-332.

CZOLLAK, C.; GONZALEZ, A.; VALENZUELA, M. 1981. Observaciones geológicas en la Sierra de Almeida, Cordillera de Antofagasta, II Región. Geología de Campo II. Univ. Chile, Depto. Geol., 79 p. Santiago.

DAVIDSON, J.; MPODOZIS, C.; RIVANO, S. 1981. El Paleozoico de Sierra de Almeida, al oeste de Monturaqui, alta cordillera de Antofagasta, Chile. Rev. Geol. de Chile, No. 12, p. 3-23.

DAVIDSON, J.; RAMIREZ, C.; GARDEWEG, M.; HERVE M.; BROOK, M.; PANKHURST, R. 1985. Late Paleozoic-Early Triassic calderas and related mineralization in the Cordillera de Domeyko, northern Chile. Comun. No. 35, p. 53-57.

FERRARIS, F.; DI BIASE, F. 1978. Hoja Antofagasta, Región de Antofagasta. Inst. Invest. Geol., Carta Geol. Chile, No. 30, 48 p.

ISAACSON, P.E. 1975. Faunal evidence for a Devonian transgression-regression in Bolivia. *In* Congr. Argent. Paleontol. Bioestrat., No. 1, Actas, Vol. 1, p. 255-273. Tucumán, 1974.

ISAACSON, P.E., 1977a. Devonian stratigraphy and brachiopod paleontology of Bolivia. Part A: Orthida and Strophomenida. Palaeontographica, Serie A, Vol. 155, p. 133-192.

ISAACSON, P.E. 1977b. Devonian stratigraphy and brachiopod paleontology of Bolovia, Part B: Spiriferida and Terebratulida. Palaeontographica, Serie A, Vol. 156, p. 168-217.

ISAACSON, P.E.; ANTELO, B.; BOUCOT, A.J. 1976. Implications of a Llandovery (Early Silurian) brachiopod fauna from Salta Province, Argentina. J. Paleontol., Vol. 50, No. 6, p. 1103-1112.

ISAACSON, P.E.; PERRY, D.G. 1977. Biogeography and morphological conservatism of *Tropidoleptus* (Brachiopoda, Orthida) during the Devonian. J. Paleontol., Vol. 51, No. 6, p. 1108-1122.

LISSON, C.I.; BOIT, B. 1942. Edad de los fósiles peruanos y distribución de sus depósitos. Cont. Geol., Perú, 320 p. Lima.

MARINOVIC, N. 1978. Geología de los Cuadrángulos Cerro Lila y Cordón Chinquilchoro, II Región Antofagasta. Inst. Invest. Geol. (inédito) 63 p. Santiago.

MENDEZ-ALZOLA, R., 1938. Fósiles devónicos del Uruguay. Bol. 24, 81 p.

MORALES, P.A. 1965. A contribution to the knowledge of the Devonian faunas of Colombia. Univ. Indust. Santander, Bol. Geol., Vol. 19, p. 51-115.

MPODOZIS, C.; HERVE, F.; DAVIDSON, J.; RIVANO, S. 1983. Los granitoides de Cerros de Lila, manifestaciones de un episodio intrusivo y termal del Paleozoico inferior de los Andes del norte de Chile. Rev. Geol. Chile, No. 18, p. 3-14

RAMIREZ, C.; GARDEWEG, M. 1982. Hoja Toconao, Región de Antofagasta. Serv. Nac. Geol. Miner. Carta Geol. Chile, No. 54, 122 p.

REED, F.R.C. 1925. Revision of the fauna of the Bokkeveld Beds. Ann. South African Mus., Vol. 22, p. 27-225.

ROCHA-CAMPOS, A.C. 1976. Glaciacoes Paleozoicas na America do Sul: uma revisao. *In* Congr. Geol, Chileno, No. 1, Actas, Vol. 3, p. L95-L142.

THOMAS, I. 1905. Neue Beitrage zur Kenntnis der devonische Fauna Argentiniens. Zeit. Deut. Geol, Ges., Vol. 57, p. 233-290.

Trabajo recibido: 04-03-86; aceptado: 04-06-86

PLATE 1

Zorritas Formation: Figures 1-6. Quebrada Zorritas

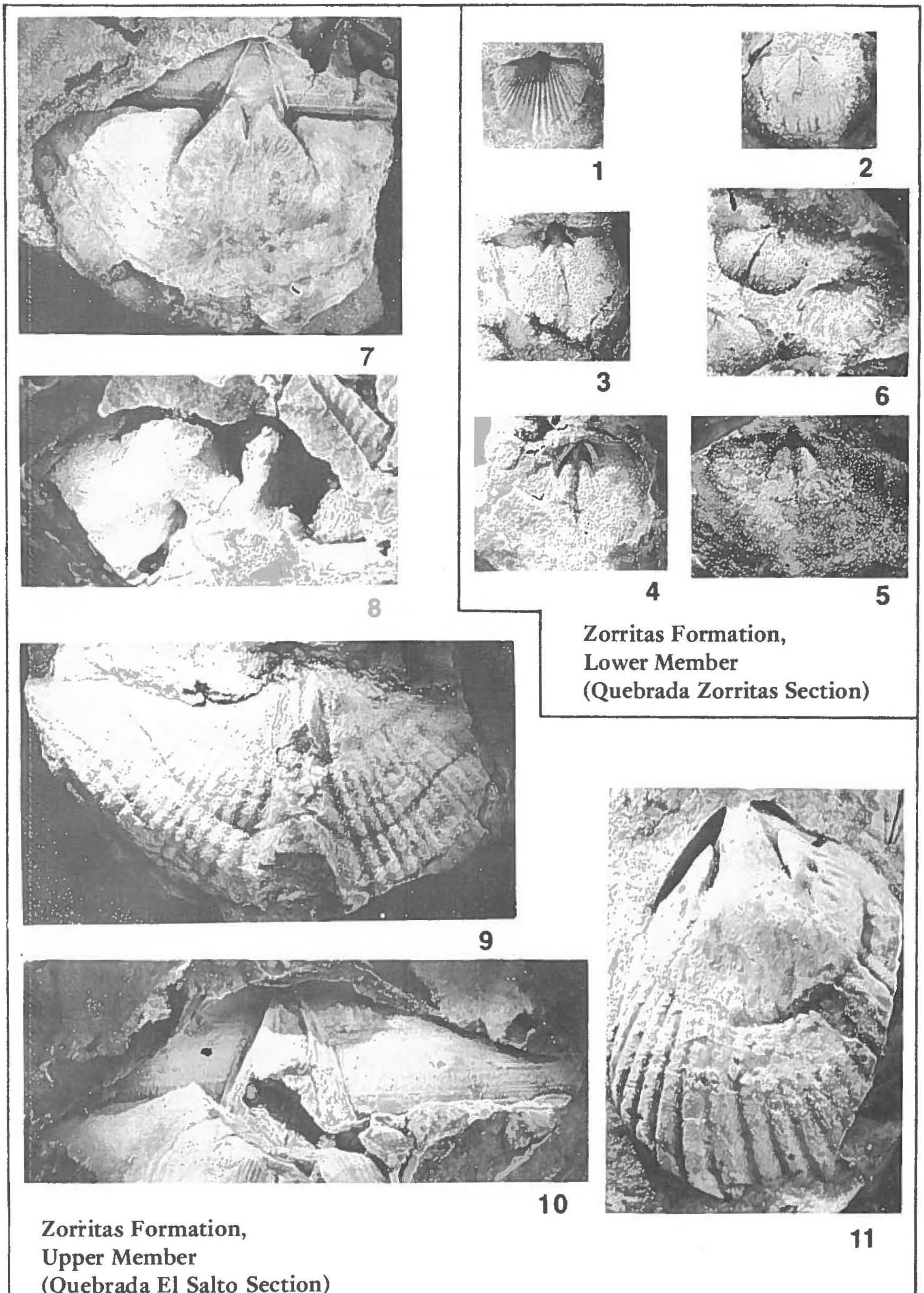
Figures 1-5: *Tropidoleptus carinatus* (Conrad, 1839), all x 1.0. Figs1-2, impression of exterior and interior of pedicle valve, respectively. Figs. 3, 4, 5, impression of interior of brachial valve.

Figure 6: Right-hand specimen, *Australocoelia palmata* (Morris and Sharpe, 1846), x 1.0. Impression of exterior of brachial valve. Left-hand specimen may be impression of interior of pedicle valve, *Tropidoleptus*.

Zorritas Formation: Figures 7-11. Quebrada Zorras and El Salto

Figures 7-10: Subfamily Siringothyridinae, possibly similar to *Septosyringothyris* sp. 8 (Amos, 1958, Plate 108, Figs. 8-10). Fig. 7, impression of interior of pedicle valve, showing well-developed delthyrial plate (x 1.25), Quebrada El Salto. Fig. 8, posterior view of impression of pedicle muscle field, showing syrinx (x 2.0), Quebrada El Salto. Fig. 9, impression of exterior of brachial valve (x 1.25), Quebrada Zorras. Fig. 10, impression of interior of pedicle valve, showing delthyrial plate (x 1.5), Quebrada El Salto.

Figure 11: Indet. rhynchonellid, possibly similar to *Camarotoechia chavelensis* (Amos, 1958, Plate 107, Figs. 1-8). Impression of interior of pedicle valve (x 1.75), Quebrada El Salto.



Zorritas Formation,
Lower Member
(Quebrada Zorritas Section)

Zorritas Formation,
Upper Member
(Quebrada El Salto Section)