XII Congreso Geológico Argentino y II Congreso de Exploración de Hidrocarburos
Actas T° I (235-240)

SOME PLATE-TECTONIC ASPECTS OF EARLY ORDOVICIAN REEFS, WESTERN ARGENTINE PRECORDILLERA

Martin Keller (1); Osvaldo Bordonaro (2) & Fernando Cañas (1)

(1) Institut für Geologie und Mineralogie, Universität Erlangen-Nürnberg, Schlossgarten 5, 91054 Erlangen, Alemania; (2) Centro Regional de Investigaciones Científicas y Técnicas, C.C. 131, 5500 Mendoza, Argentina

ABSTRACT. In the Late Arenig of the Argentine Precordillera several types of reefs occur. Stromatoporoids are among the most important frame-builders, whereas sponges, algae and some problematica are major constituents of biostromal accumulations. Sedimentology and carbonate textures point to a shallow-water origin of the reefal accumulations.
In comparison with occurrences of similar reefs on the North American craton, a low-latitude position of the carbonate platform during the Late Arenig is inferred, which is in agreement with recent plate-tectonic reconstructions.
Finally, some observations with respect to the question of autochthony vs. allochthony of the Precordillera are presented.

INTRODUCTION

Stromatoporoids are among the first metazoans, which contribute to the formation of reefs. Appearing during the Early Ordovician, their importance succesively increased towards the Upper Devonian. In the Gondwana realm, Ordovician stromatoporoid reefs only have been reported from the Caradoc of Australia (WEBBY 1984). The occurrence of stromatoporoid reefs in the Arenig of the western Argentine Precordillera, therefore, is an important fact for local and regional paleogeographic reconstructions as well as for plate tectonic considerations about Gondwana and its position relative to the paleo-equator.

GEOLOGICAL SETTING AND THE AGE OF THE REEFS

The Precordillera of western Argentina is a high-level thrust-and-fold-belt, mainly composed of paleozoic sediments. During Cambro-Ordovician times a carbonate platform existed to the east, which laterally passed into clastic slope and basin deposits to the west. Carbonate sedimentation started during the Early Cambrian (La Laja Formation) and persisted until the Early Llanvirn. The uppermost unit of the platform sequence is the San Juan Formation, which according to brachiopod (Herrera & Benedetto 1990) and conodont data (Hunicken & Sarmiento 1982; Hunicken & Ortega 1987) was deposited during the Arenig and Early Llanvirn. Sponge-algal mounds are observed at the base of the formation, whereas the stromatoporoid reefs occur in several beds in the upper part of the formation.

Although the San Juan is well studied (e.g. Beresi 1981, 1986), the reef mounds hitherto were unknown. The existence of the mounds and the composition of the accompanying fauna is of great importance for the interpretation of the sedimentary basin of the Precordillera during Early Ordovician times and its position relative to the palaeo-pacific margin of Gondwana.

According to conodont data (fig.1), the beds below and above the lower sponge-algal mounds were deposited near the Tremadoc / Arenig boundary (*Paroistodus proteus* Zone of the standard Baltoscandic conodont zonation), what at the same time gives a preliminary age for the base of the San Juan limestones in this area. In the upper part of the formation conodonts indicate an Upper Arenig age of the stromatoporoid accumulations (fig.1; Lehnert & Keller 1993). According to these data (*Baltoniodus navis / B. triangularis* to *Microzarkodina flabellum parva* Zones), the stromatoporoid reefs of the Precordillera are among the oldest known in the world.

THE SEDIMENTARY SUCCESSION OF THE SAN JUAN FORMATION

The San Juan Formation is the unit of the carbonate platform, that has the most widespread lateral distribution. Nevertheless, it lacks any definition that is valid throughout the Precordillera (e.g. Kobayashi I 1937; Espisua 1968, Beresi & Bordonaro 1984; Beresi 1986). For the purpose of this study the base was drawn at those levels where a diverse marine fauna appears (fig.2), that is characteristic of the San Juan Formation These levels coincide more or less with the base of the "Miembro de Calizas y Margas Varicolores" of Beresi & Bordonaro (1984). This member was deposited below fair weather wave base and most probably even below storm weather wave base, because it lacks nearly any indication of current- or wave-induced structures and proximal / medial tempestites. Other indications of a quiet depositional environment are the clay content (marlstones) and the good preservation of the fossils. This unit is rather sharply overlain by 100-150m of predominantly pelmatozoan grainstones and packstones (fig.2), which in turn pass into several metres of nodular limestones and some marlstones with an open marine fauna of crinoids, brachiopods, trilobites and *Nuia* (fig.2), similar to that of the lower unit.

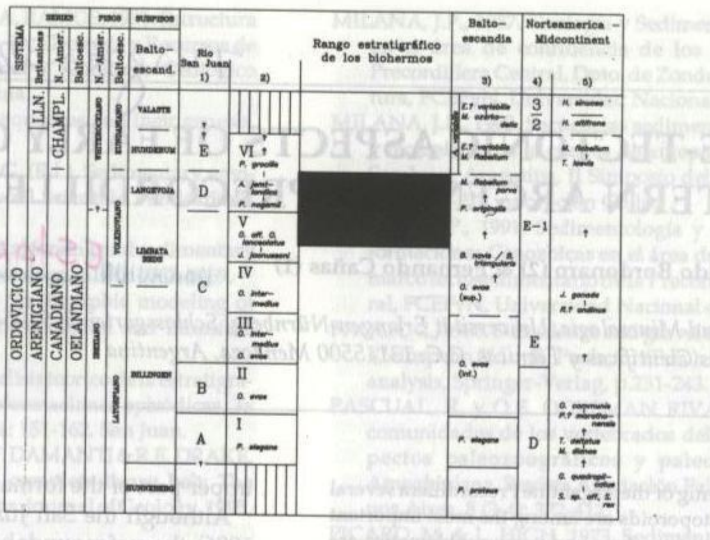

Figura 1: Stratigraphic position of the stromatoporoid reefs (black solid) according to conodonts. 1) Conodont Zones of SERPAGLI (1974); 2) Zones of conodont associations according to LEHNERT (1993); 3) Standard Baltoscancdic conodont zonation; 4) North America Midcontinent zonation after ETHINGTON & CLARK (1971), SWEET *et al.* (1971), SWEET & BERGSTRÖM (1976); 5) North America Midcontinent zonation after ETHINGTON & CLARK (1981), SWEET (1984, 1988).

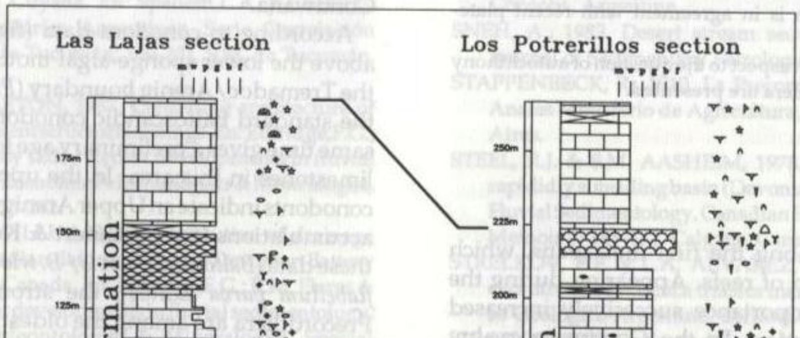

Figura 2: Sections of the San Juan Formation, faunal content and position of reef accumulations. Bold lines mark lower and upper boundaries of grainstone sequence with reef accumulations.

In terms of relative changes of sea-level, the San Juan Formation can be interpreted as a transgressive-regressive-transgressive sequence. It starts with the intertidal and shallow subtidal mudstones and pellet grainstones. Sea-level rise leads to the deposition of subtidal, open marine fossiliferous limestones. The transition from wackestones towards the grainstone sequence marks a sudden drop of sea-level. As a consequence, packstones and grainstones formed in shallow, agitated water, which provided good living conditions for stromatoporoids and for the construction of bioherms and biostromes in the zone of good aeration and light penetration. The return to deeper water marks the beginning of a global sea-level rise during the uppermost Arenig and Early Llanvirn (cf. Fortey 1984), which culminates in the drowning of the San Juan carbonate platform during the Early Llanvirn.

THE REEFS

There are three principal types of reefs in the San Juan Formation: patch reefs and mounds with an organic framework of stromatoporoids, biostromal accumulations of stromatoporoids, algae and sponges and sponge-algal mounds.

In the patch reefs, globular stromatoporoids make up up to 90% of the framebuilders. They are accompanied by few laminar individuals and bioclastic sediment. This is mostly a grainstone or a packstone with fragments of trilobites, brachiopods and pelmatozoans. Nautiloids and gastropods (*Maclurites* sp.) may be concentrated in patches on top of the mounds. The patch reefs form structures with a diameter of up to 10m across near the base and a height of 5m. They are true framestones and obviously were wave-resistant structures, because there is no debris in the surrounding sediment. The mounds have steeply inclined walls, which often show onlap structures of the reef-flank sediment, but no interfingering between the flank sediment and the mound. The reef-flank sediment consists of pelmatozoan grainstone to packstone and served as a settling substrate for globular and laminar stromatoporoids, which occur in equal amounts. The organisms had a sediment-binding and -fixing function. The reef-flank deposits laterally pass into bioclastic packstones and grainstones. Stromatoporoids are rare in this facies, some of them occurring still in life-position, others are reworked. The sediment is cross-bedded and sometimes shows intraclastic channel-fills (tidal channels?). Cross-bedding is due to the formation of wave-ripples and dune-like deposits.

Patch reefs of stromatoporoids are restricted to the eastern ranges of the Precordillera (Sierra Chica de Zonda: Las Lajas and Los Berros section; fig.3), which are believed to parallel the ancient coast. However, there is no terrigenous influx visible in the sediments.

Stromatoporoids are also major constituents of biostromal sediment accumulations. In the section of Los Potrerillos (fig.2,3) columnar stromatoporoids occur, which according to their growth form are similar to SH-stromatolites of Logan et al. (1964). Their base has a diameter of up to 15cm and they easily reach a height of 60cm. Most of them are preserved in

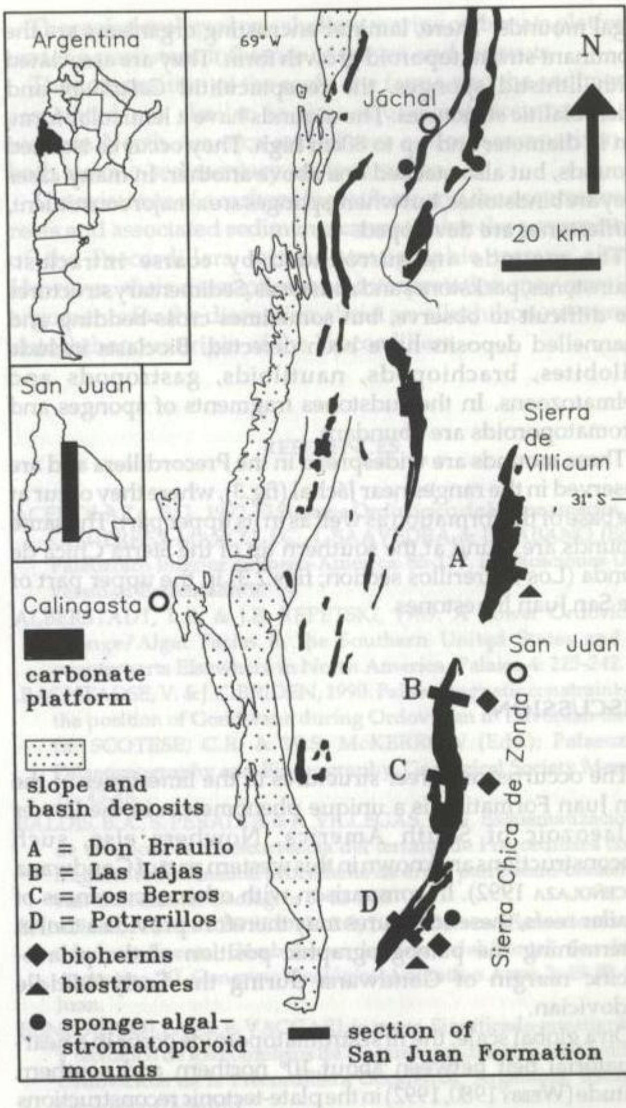

Figura 3: Simplified geological map of the Precordillera of San Juan with distribution of Cambro-Ordovician sediments and the different types of reef accumulations.

life-position, but they were also observed in a parautochthonous preservation. They acted as sediment bafflers, but it was probably a mixture of baffling and sediment trapping. The sediment trapped is highly varied. Wackestones show a diverse marine fauna, among which calcareous algae are noteworthy. Packstones and grainstones are bioclastic and here again concentrations of nautiloids and *Maclurites sp.* are found. In the biostromal complex also small sponge-algal mounds occur, which are similar to those described above.

A biostromal horizon was also found in the Don Braulio section (fig.3), up to 4m thick and with a spectactular concentration of large globular stromatoporoids. Some of them nearly reach 1m in diameter. They grew in and above grainstones, which often show steep cross-bedding, channel-structures as indicators of an high-energy environment. The grainstones mainly consist of pelmatozoan debris but again, nautiloids and gastropods are present.

Stromatoporoids also occur as a major component in sponge-algal mounds. There, laminar encrusting organisms are the dominant stromatoporoid growth form. They are associated with lithistid sponges, the receptaculitid *Calathium* and microbialitic structures. The mounds have a lenticular form, 1m in diameter and up to 80cm high. They occur as isolated mounds, but also stacked one above another. In many cases they are bindstones, but where sponges are a major constituent, bafflestones are developed.

The mounds are surrounded by coarse intraclast-grainstones, packstones and rudstones. Sedimentary structures are difficult to observe, but sometimes cross-bedding and channelled deposits have been detected. Bioclasts include trilobites, brachiopods, nautiloids, gastropods and pelmatozoans. In the rudstones fragments of sponges and stromatoporoids are abundant.

These mounds are widespread in the Precordillera and are observed in the ranges near Jáchal (fig.3), where they occur at the base of the formation as well as in its upper part. The same mounds are found at the southern tip of the Sierra Chica de Zonda (Los Potrerillos section; figs.2,3) in the upper part of the San Juan limestones.

DISCUSSION

The occurrence of reef structures in the limestones of the San Juan Formation is a unique phenomenon in the Lower Palaeozoic of South America. Nowhere else, such bioconstructions are known in this western part of Gondwana (Aceñolaza 1992). In comparison with other occurrences of similar reefs, these structures may therefore provide a tool in determining the paleogeographic position of the palaeo-pacific margin of Gondwana during the Early/Middle Ordovician.

On a global scale, the first stromatoporoids occur in a near-equatorial belt between about 10° northern and southern latitude (Webby 1980, 1992) in the plate-tectonic reconstructions of Scotese & McKerrow (1991). They are associated to small mounds, often with the participation of sponges, receptaculitids, algae and some problematical organisms (e.g. *Pulchrilamina*). These mounds are very common during the Early Ordovician and near the Arenig/Llanvirn boundary (fig.4), especially in the western United States (Rigby 1966; Church 1974; Ross 1972; Toomey & Ham 1967; LeMone 1982, 1988; Alberstadt & Repetski 1989). These mounds always formed in a shallow water, wave-agitated environment, and some of them even show relicts of subaerial exposure (LeMone 1988). The depositional environment is thus comparable to that of the corresponding part of the San Juan Formation. Another mutuality is their position on the shelf. They always occur as isolated mounds in an intra-shelf position, neither at the shelf-break nor in a nearshore environment.

Another important fact is the composition of the faunas and floras in the reef horizons, which also shows an high degree of coincidence. Among the stromatoporoids and related problematica, only *Pulchrilamina* is reported from the Precordillera (Keller & Flügel in prep; Cañas & Carrera in press) and from western North America (e.g. Toomey & Ham 1967; Toomey & Nitecki 1979; LeMone 1988). Similarities on generic and species level exist in the sponge faunas (e.g. Beresi 1985, 1990; Alberstadt & Repetski 1989), as well as in the faunas of conodonts, as recently demonstrated by Lehnert & Keller (in press). Another problematica, the receptaculitid *Calathium*, also occurs in both realms (Carrera 1991).

Finally, although there are still no systematic descriptions, very similar floras of algae and related microproblematica are observed, among which are the genera *Girvanella, Halysis, Wetheredella, Sphaerocodium* and *Nuia*, which is widely distributed in Cambro-Ordovician sediments (e.g. Toomey 1970; Ross et al. 1988; Alberstadt & Repetski 1989; Gnoli & Serpagli 1980).

An interesting point of the North American occurrences is their position on the shelf. As demonstrated by Alberstadt & Repetski (1989), sponge-algal mounds and their associated sediments (including some stromatoporoid appearances) do

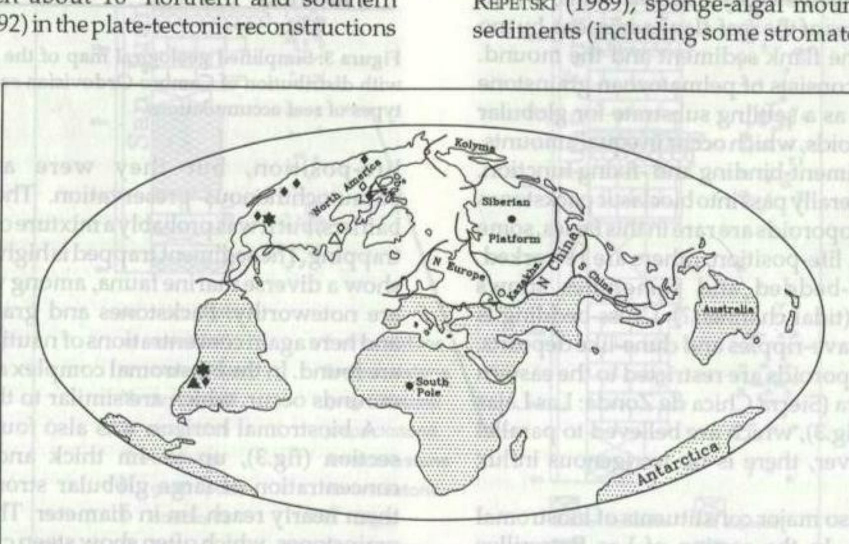

Figura 4: Worldwide distribution of different types of Arenig and Early Llanvirn reefs and reefs mounds. Solids: Arenig; open symbols: Llanvirn.

not occur in a near-shore position but are located near the shelf edge. The shelf interior is occupied by a belt of several 100 km of restricted dolostone facies, bound by 10 to 100 km of sponge-algal facies towards the open marine shelf, which in turn passes into slope and basin deposits.

If this constellation is transferred to the Precordillera, only two of the three facies belts are recognized: the sponge-algal belt and the slope facies, which is well known from the Central Precordillera (e.g. CINGOLANI et al. 1989; BANCHIG & BORDONARO 1990; BORDONARO 1990; BENEDETTO & VACCARI in press). However, the dolostone facies, i.e the nearshore depositional environment is absent.

As demonstrated above, there is a surprising similarity between the Arenig deposits of the Argentine Precordillera and Early Ordovician sediments of the western United States. Seen from a conservative point of view, this is rather easily explained by a palaeogeographic situation with North America and western Gondwana in an equatorial position (ZIEGLER et al. 1979; SCOTESE & MCKERROW 1991). If the two continents were not separated by an ocean too wide and too deep for shelf fauna migration, then this similarity indeed is not surprising.

However, the presumed plate-tectonic constellation does not take into account a possible strike-slip transport of the Precordillera in the range of several 100 to 1000 km (BALDIS et al. 1989; GONZALEZ BONORINO & GONZALEZ BONORINO 1991; LOSKE 1992) during Late Palaeozoic times from what today is Patagonia towards its present day position. This lateral shift would suggest a position in higher latitudes, from where reports about sponge-algal mounds and stromatoporoid mounds are scarce to absent (cf. ALBERSTADT & REPETSKI 1989), if the position of Gondwana is considered as constant. Solutions to the problem of the latitudinal position are speculative: either the position of Gondwana is not determined correctly, what seems to be unlikely in the light of a good database for palaeomagnetical (e.g. BACHTADSE & BRIDEN 1990) and palaeoclimatological (WITZKE 1990) considerations. Or stromatoporoid reefs and the associated sediments occurred in other than equatorial latitudes, for what there is no evidence.

A third explanation is the assumption of a Precordillera (exotic) Terrane (e.g. RAMOS et al. 1984, 1986), welded to South America during the Late Ordovician and Silurian (DALLA SALDA et al. 1992a,b). This model could explain the absence of the dolostone facies (suppressed during collision between the Precordillera and the Sierras Pampeanas) as well as the similarities between North America and the Precordillera. And finally, there is no need to assume a contradiction between facies analysis and the occurrence of reefs in the Precordillera on one side, and the palaeogeographic position of the remainder of Gondwana based on palaeomagnetical and palaeoclimatological data on the other side.

CONCLUSIONS

During the Arenig, three different types of reefs occur on the carbonate platform of western Argentina: stromatoporoid patch reeefs and mounds, sponge-algal mounds and biostromal accumulations of stromatoporoids, sponges and algae.

The reefs developed on a shallow marine carbonate platform under a persistant influence of waves and currents.

The composition of the reefs, the fauna and the sediments associated are similar to time-equivalent occurrences in western North America and allows a direct comparison of both tectono-sedimentary environments.

The existence of a carbonate platform and the occurrence of reefs and associated sediments cannot solve the proveniance of the Precordillera tectono-stratigraphic terrane alone. However, their description and interpretation may provide arguments for the discussion about an allochthonous versus autochthonous origin of the Precordillera.

REFERENCES

ACEÑOLAZA, F.G., 1992. El Sistema Ordovícico de Latinoamérica. In: GUTIERREZ-MARCO, J.C., J. SAAVEDRA & I. RABANO (Eds.) Paleozoico Inferior de Ibero-América: 85-117, Publicaciones Universidad Extremadura.

ALBERSTADT, L.P. & J.E. REPETSKI, 1989. A Lower Ordovician Sponge/Algal Facies in the Southern United States and its counterparts Elsewhere in North America. Palaios 4: 225-242.

.BACHTADSE, V. & J.C. BRIDEN, 1990. Palaeomagnetic constraints on the position of Gondwana during Ordovician to Devonian times. In: SCOTESE, C.R. & W.S. McKERROW (Eds.): Palaeozoic Palaeogeography and Biogeography, Geological Society Memoir 12: 43-48.

BALDIS, B.A., S. PERALTA & R. VILLEGAS, 1989. Esquematizaciones de una posible transcurrencia del terrane de Precordillera como fragmento continental procedente de areas pampeano-bonaerenses. Correlación Geológica 5: 81-100.

BANCHIG, A.L. & O. BORDONARO, 1990. Nuevos afloramientos del talud continental Cámbrico en la Sierra del Tontal, San Juan, Argentina. XI. Congreso Geológico Argentino Actas 2: 49-52, San Juan.

BENEDETTO J.L. & N.E. VACCARI, in press. Significado estratigráfico y tectónico de los complejos de bloques resedimentados Cambro-Ordovícicos de la Precordillera Occidental, Argentina. Estudios Geológicos, Madrid.

BERESI, M.S., 1981. Fauna y ambiente en los sedimentos carbonáticos arenigianos de Talacasto, San Juan, Argentina. VIII. Congreso geológico Argentino Actas 2: 399-417, San Luis.

BERESI, M.S., 1985. Capas con archaeoscyphia (Porífera) en los sedimentos carbonáticos ordovícicos de la Precordillera de San Juan. Primeras Jornadas Geológicas de Precordillera Actas: 99-102, San Juan.

BERESI, M.S., 1986: Paleoecología y Biofacies de la Formación San Juan al sur del paralelo 30° sur, Precordillera de San Juan. PhD thesis (unpublished), 400pp., Universidad Nacional de San Juan.

BERESI, M.S., 1990. Las esponjas como indicadores paleoecológicos de la Formación San Juan, Precordillera. V. Congreso Argentino Paleontología y Bioestratigrafía Actas: 19-24, San Miguel de Tucumán.

BERESI, M.S. & O. BORDONARO, 1984. La Formación San Juan en la Quebrada de Las Lajas, Sierra Chica de Zonda, Provincia de San Juan. IX. Congreso Geológico Argentino Actas 1: 95-107, San Carlos de Bariloche.

BORDONARO, O., 1990. El Sistema Cámbrico en la Provincia de San Juan. XI. Congreso Geológico Argentino Relatorio: 18-30, San Juan.

CAÑAS, F. & M.G. CARRERA, in press. Early Ordovician sponge-algal reef mounds of the Precordillera basin, Western Argentina. Facies.

CARRERA, M.G., 1991. Los géneros *Selenoides* Owen y *Calathium* Billings (receptaculitaceae) en el Ordovícico de la Precordillera de San Juan, Argentina. Ameghiniana 28: 375-380.

CHURCH, S.B., 1974. Lower Ordovician patch reefs in western Utah. Brigham Young University Geological Studies 21: 41-62.

CINGOLANI, C.A., A.J. CUERDA, R. VARELA & O. SCHAUER, 1989. Geología de la Precordillera Occidental en la Comarca de la Sierra del Tontal, Provincia de San Juan, República Argentina. Revista Comunicaciones 40: 39-56.

DALLA SALDA, L., C.A. CINGOLANI & R. VARELA, 1992a. Early Paleozoic orogenic belts of the Andes in southwestern South America: Result of Laurentia-Gondwana collision ? Geology 20: 617-620.

DALLA SALDA, L., I.W.D. DALZIEL, C.A. CINGOLANI & R. VARELA, 1992b. Did the Taconic Appalachians continue into South America? Geology 20: 1059-1062.

ESPISUA, E., 1968. El Paleozoico Inferior del Rio de las Chacritas, Depto. de Jáchal, Prov. de San Juan, con especial referencia al Silúrico. Asociación Geológica Argentina Revista 23: 297-311.

FORTEY, R.A., 1984. Global earlier Ordovician transgressions and regressions and their biological implications. In: BRUTON, D.L.(Ed.) Aspects of the Ordovician System: 37-50, Universitetsforlaget, Oslo.

GNOLI, S. & E. SERPAGLI, 1980. The problematical microorganism *Nuia* in the Lower Ordovician of precordilleran Argentina and its paleogeographic significance. Journal Palaeontology 54: 1245-1251.

GONZALEZ BONORINO, G. & F. GONZALEZ BONORINO, 1991: Precordillera de Cuyo y Cordillera Frontal en el Paleozoico temprano: terrenos 'bajo sospecho' de ser autóctonos. Revista Geológica de Chile 18: 97-107.

HERRERA, Z.A. & J.L. BENEDETTO, 1990. Early Ordovician brachiopod faunas of the Precordillera Basin, Western Argentina: Biostratigraphy and paleobiogeographical affinities. In: MACKINNON, D.I., D.E. LEE & J.D. CAMPBELL (Eds.): Brachiopods through time: 283-301, Rotterdam.

HÜNICKEN, M.A. & G.C. ORTEGA, 1987. Lower Llanvirn-Lower Caradoc (Ordovician) conodonts and graptolites from the Argentine Central Precordillera. 4. European Conodont Symposium: 136-145, Nottingham.

HÜNICKEN, M.A. & G. SARMIENTO, 1982. La zona Baltoescandinava de *Oepikodus evae* Conodonto, (Arenigiano Inferior) en el perfil del Rio Guandacol, La Rioja, Argentina. V Congreso Latinoamericano de Geología Actas 1: 791-796, Buenos Aires.

KELLER, M. & E. FLÜGEL, (submitted). Early Ordovician stromatoporoid reefs from South America. Palaios.

KOBAYASHI, T., 1937. The Cambro-Ordovician Shelly Faunas of South America. Journal Faculty Science Imperial University Tokyo, section II: Geology, Mineralogy, Geography Seismology 4: 369-522.

LEHNERT, O., 1993. Bioestratigrafía de los conodontes Arenigianos de La Formación San Juan en la localidad de Niquivil (Precordillera Sanjuanina, Argentina) y su correlación intercontinental. Revista Española Paleontología 8: 153-164.

LEHNERT, O. & M. KELLER, 1993. Posición estratigráfica de los arrecifes Arenigianos en la Precordillera Argentina. Document du laboratoire de Géologie de l'Université de Lyon, 125: 263-275.

LEHNERT, O. & M. KELLER, in press. The Conodont Record of the Argentine Precordillera: Problems and Possibilities. Zentrablatt Geologie Paläontologie Teil 1, Lateinamerika Band.

LEMONE, D., 1982. Stratigraphy of the Franklin Mountains, El Paso County, Texas and Dona Ana County, New Mexico. In: ALLEN, R. (Ed.) Delaware Basin Guidebook, West Texas Geological Society: 42-72.

LEMONE, D., 1988. *Pulchrilamina*, the Early Ordovician labechiid stromatoporoid and its mound. In: LEMONE, D. (Ed.) Franklin Mountains, Tobosa Mountains related basins, El Paso Geological Society & American Associacion Petroleum Geology Southwest section, 142-156, El Paso.

LOGAN, B.W., R. REZAK & R.N. GINSBURG, 1964. Classification and environmental significance of algal stromatolites. Journal of Geology 72: 68-83.

LOSKE, W.P., 1992. Sedimentologie, Herkunft und geotektonische Entwicklung paläozoischer Gesteine der Präkordillere West-Argentiniens. Münchener Geologische Hefte 7: 1-155.

RAMOS, V.A., T.E. JORDAN, R.W. ALLMENDINGER, S.M. KAY, J.M. CORTES & M.A. PALMA, 1984. Chilenia: Un terreno alóctono en la evolución paleozoica de los Andes centrales. IX. Congreso Geológico Argentino Actas 2: 84-106, San Carlos de Bariloche.

RAMOS, V.A., T.E. JORDAN, R.W. ALLMENDINGER, C. MPODOZIS, S.M. KAY, J.M. CORTES & M.A. PALMA, 1986. Paleozoic terranes of the Central Argentine - Chilean Andes. Tectonics 5: 855-880.

RIGBY, K.J., 1966. Evolution of Lower and Middle Ordovician sponge reefs in western Utah. Geological Society of America Special Papers 87: 137.

ROSS, R.J., 1972. Fossils from the Ordovician bioherm at Meikeljohn Peak, Nevada. United Staes Geological Survey Professional Papers 685: 1-47.

ROSS, R.J., VALUSEK, J.E. & N.P. JAMES, 1988. *Nuia* and its environmental significance. New Mexico Bureau of Mines and Mineral Resources Memoir 44: 415.

SCOTESE, C.R. & W.S. McKERROW, 1991. Ordovician plate tectonic reconstructions. In: BARNES, C.R. & S.H. WILLIAMS (Eds.) Advances in Ordovician Geology, Geological Survey of Canada Papers 90-9: 271-282.

SERPAGLI, E., 1974. Lower Ordovician Conodonts from Precordilleran Argentina (Province of San Juan). - Bolletin Societá Italiana 13: 17-98.

TOOMEY, D.F., 1970. An unhurried look at a Lower Ordovician mound horizon, Southern Franklin Mountains, West Texas. Journal of Sedimentary Petrology 40: 1318-1334.

TOOMEY, D.F. & W.E. HAM, 1967. *Pulchrilamina*, a new mound-building organism from Lower Ordovician rocks of west Texas and southern Oklahoma. Journal Paleontolgy 41: 981- 987.

TOOMEY, D.F. & M.H. NITECKI, 1979. Organic build-ups in the Lower Ordovician (Canadian) of Texas and Oklahoma. Fieldiana 2: 1-181.

WEBBY, B.D., 1980. Biogeography of Ordovician stromatoporoids. Palaeogeography, Palaeoclimatology, Palaeoecology 32: 1-19.

WEBBY, B.D., 1984. Ordovician reefs and climate: a review. In: BRUTON, D.L.(Ed.) Aspects of the Ordovician System: 89-100, Universitetsforlaget, Oslo.

WEBBY, B.D., 1992. Global biogeography of Ordovician corals and stromatoporoids. In: WEBBY, B.D. & J.R. LAURIE (Eds.): Global Perspectives on Ordovician Geology, 261-276, Rotterdam.

WITZKE, B.J. 1990. Palaeoclimatic constraints for Palaeozoic palaeolatitudes of Laurentia and Euramerica. In: SCOTESE, C.R. & W.S. McKERROW (Eds.): Palaeozoic Palaeogeography and Biogeography, Geological Society Memoir 12: 57-74, London.

ZIEGLER, A.M., C.R. SCOTESE, W.S. McKERROW, M.E. JOHNSON & R.K. BAMBACH, 1979. Paleozoic paleogeography. Annual Reviews Earth Science 7: 473-502.