# ANATOMY OF THE PRECORDILLERA (ARGENTINA) DURING CAMBRO-ORDOVICIAN TIMES: IMPLICATIONS FOR THE LAURENTIA-GONDWANA TRANSFER OF THE CUYANIA TERRANE

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## INTRODUCTION.

In recent discussions about the origin and provenance of the Argentine Precordillera, two basic models have been developed: 1) The Precordillera was part of Laurentia until Late Precambrian or Early Cambrian times, when it rifted away from Laurentia (Astini and others 1995) to form an indipendant microcontinent. During the Cambro-Ordovician, this microcontinent drifted across the Iapetus to finally collide with western Gondwana during the Middle Ordovician. 2) The Precordillera was integral part of Laurentia until the Middle/Upper Ordovician (Dalla Salda and others 1992, Dalziel and others 1994). The comparable history of the Appalachians and the Famatina System of South America are taken as evidence for a major continent-continent collision during Mid-Ordovician times.

Recently, the Precordillera was interpreted to be part of a much larger "Cuyania composite terrane" (Ramos 1995), which includes parts of the basement of the Sierras Pampeanas of western Argentina and several limestone outcrops in the provinces of Mendoza and La Pampa. The Cuyania terrane in turn is thought to represent part of the "Texas plateau" (Dalziel in press), a promontory of Laurentia and the crucial link between Laurentia and Gondwana to form the Mid-Ordovician supercontinent of "Artexia" (Dalziel in press).

In all models, the Ouachita Embayment along the southern margin of present-day North America is favoured as the almost unique candidate which might have accomodated the Cuyania Terrane until its separation from Laurentia.

In this paper, the Cambro-Ordovician sedimentary history of the Cuyania terrane is described and interpreted in order to discuss the Lower Paleozoic geotectonic history of the Precordillera.

## THE SEDIMENTS OF THE CUYANIA TERRANE

Basically, three different types of sedimentary successions can be distinguished during Cambro-Ordovician times: A "cratonal" setting, where carbonate platform rocks onlap crystalline basement during the Early Ordovician; a "miogeoclinal" setting showing a thick Lower Cambrian through early Middle Ordovician carbonate platform; and Ordovician slope and basin deposits.

A cratonal section is present near San Rafael (province of Mendoza), where about 80m of dolomites and limestones are exposed. These carbonates of Tremadocian through Mid-Arenigian age (Bordonaro and others in press) rest directly on crystalline basement yielding a Grenvillian age (Ramos pers. comm.). The succession starts with coarse dolomites of probable algal origin which upward grade

into microbial laminites. Upsection, limestones with an abundant marine fauna are present. Most important is a reef-mound horizon which can be correlated to coeval strata in the Precordillera. The top of the preserved succession consists of nodular chert-bearing limestones.

The best documented sections of the miogeoclinal setting are the classical sections around San Juan. Continuous sections are present from late Middle Cambrian times onward. More than 500m of limestones with intercalations of siltstones were deposited towards the Middle/Upper Cambrian boundary (La Laja Fm.). The succession shows various 3rd and 4th order cycles and environments from the subtidal towards the lower intertidal. The Upper Cambrian mainly consists of dolostones. The Zonda Fm. (300m) is composed of mudstones and microbial laminites, the overlying La Flecha Fm. (400m-700m) of more than 100 small-scale peritidal shallowing-upward cycles. In the southwestern corner of the Precordillera (Cerro Pelado), these cycles are drowned and covered with deep-water limestones and marls during the uppermost Cambrian. Elsewhere, sedimentation continues during the Tremadocian with limestones (La Silla Fm.: 300m-400m) of a shallow-water environment. Dominant rocktypes are mudstones and wackestones with gastropods and nautiloids, together with peloidal and intraclast grainstones. Near the Tremadoc/Arenig boundary, there is a change towards sedimentation of limestones (San Juan Fm.: 300m-350m) with an abundant and diverse fauna indicating open marine conditions. In the northern part of the Precordillera, carbonate sedimentation stops during the Mid-Arenig, whereas further south this event occurs during the earliest Llanvirn. One important feature of the San Juan Fm. are reefs and reef mounds. Near the base of the formation, sponge-algal-receptaculitid mounds are present, which correlate to the mounds in the cratonal section. In the upper part of the San Juan Fm., stromatoporoid-dominated mounds developed with minor participation of sponges and algae.

During the Middle and Upper Ordovician, the former carbonate platform area accommodated several very different sedimentary successions. Locally, a carbonate slope environment (Las Aguaditas Fm.) developed above the San Juan Fm. and persisted until the Caradoc. Northeast of San Juan (Don Braulio section), a succession of siliciclastic rocks is present which starts with a prominent conglomerate unit (La Cantera Fm.) Upsection, mainly turbidites are developed and, after a hiatus, glaciomarine diamictites (Don Braulio Fm.) are found, attributed to the Ashgillian Gondwana glaciation. In the San Juan valley, a Caradocian pelagic carbonate platform rests on top of the deeply eroded San Juan Fm. West of Mendoza a 600m thick succession of shales with debris-flows and olistoliths is present (Empozada Fm.). To the west and to the east, carbonate platform rocks are present. The top of the succession shows shallow water calcareous sandstones which most probably are Ashgillian in age. In many places in the Precordillera, a chert-pebble conglomerate (latest Ordovician) seals these different successions.

Autochthonous slope and basin sediments older than Middle Ordovician have not yet been documented. A regional slope developed during latest Llanvirnian through Early Caradoc (?) times, where several 100m of shales and marlstones were deposited. They host a variety of mass flow deposits in which the entire spectrum of carbonate platform rocks is present. In addition, there are Middle and Upper Cambrian olistoliths consisting of deeper-water agnostid bearing limestones. These olistoliths may be as large as 300 thick and more than 1km long. In one section, they are associated with a boulder bed which consists of angular basement clasts up to 60cm across. Although the structural and age relations between the remaining slope and basin deposits are not always clear, the overall picture shows continental slope deposits along the western margin of the former carbonate platform. These sediments gradually pass into more distal turbitic successions and finally into basinal shales and siltstones. Rift-related pillow-basalts are intercalated into Caradocian graptolite shales.

## ANATOMY OF THE PRECORDILLERA DURING THE CAMBRIAN AND EARLY ORDOVICIAN

The Early Cambrian is only represented by some isolated outcrops. A redbed-evaporite succession is interpreted to be a rift-related graben fill, whereas the other occurrences are already attributed to a passive margin sequence. No paleocurrent data are available to interprete the provenance of the abundant siliciclastic rocks. During the Middle Cambrian, limestone-siltstone sequences are observed which closely resembling Depositional Grand Cycles. Depositional Grand Cycles are typically

developed all around Laurentia at that time. During the Late Cambrian, mainly peritidal conditions prevailed on the platform, which led to the accumulation of almost 1000m of rocks. Middle and Upper Cambrian deep-water limestone olistoliths in the western slope facies are of local origin (Keller 1995) which implies that the carbonate platform passed into deeper water environments towards the west. This is also shown by the sudden drowning of platform rocks at Cerro Pelado, an event not observed on the remainder of the platform.

Both, grain size and abundance of the siliciclastic input onto the platform decreased during the Cambrian. An eastern or southeastern source area is most likely. There, the basement of the Cuyania terrane was exposed at that time. In the Lower Ordovician rocks no siliciclastics are found. This is explained by the ongoing onlap of the carbonates onto the basement which finally shut off sediment supply. The expansion of the carbonate platform is well documented in the cratonal section of San Rafael, where 80m are correlative to more than 400m in the Precordillera. Nevertheless, these 80m still show all major events present in the miogeoclinal setting.

Along the western margin of the platform, carbonate breccias and turbidites, in erosional contact with Middle Cambrian limestones, indicate the evolution of a local carbonate slope from the Cambro-Ordovician boundary on. In general, the Early Ordovician shows a relative rise in sea level, which culminates in the drowning of the platform during the Early Llanvirn. Until that time, more than 2100m of carbonates had accumulated around San Juan representing a thick passive margin succession (Baldis and others 1982).

If compared to coeval passive margin successions around Laurentia (e.g., Skehan 1988), the Precordillera platform is highly incomplete: Along its present-day eastern margin 2100m of miogeoclinal rocks are present and in a tectonically separated outcrop, 80m of a cratonal section are preserved. In the Appalachians, comparable sections are separated by about 600km. This distance results from slow but continuous transgression onto the craton. Even if regional differences are considered, timing and rate of onlap/transgression ought to be in the same order of magnitude.

Another clue to the dimensions of the carbonate platform are the Arenig reef mounds. Almost identical eco-systems are present along the southern margin of Laurentia where they are typical of a relatively narrow belt along the shelf edge (Alberstadt & Repetski 1989). Cratonward, a broad zone (several 100s of kilometers) of "continental interior shelf environments" is present. Except for the outcrops near San Rafael, this interior zone is not preserved in the Cuyania terrane. According to the present-day coordinates, this zone might have been developed to the east and in consequence might have been a thin cover of the basement of the Sierra Pie de Palo. Hence, there are several lines of evidence suggesting that the dimensions of the platform and, in consequence, of the Cuyania terrane must have been much larger and might have been in the order of 1000km in length and 600 to 800km in width.

## ANATOMY OF THE PRECORDILLERA DURING THE MIDDLE AND UPPER ORDOVICIAN

The main characteristics of the Precordillera during the Middle and Late Ordovician are the presence of highly varied sedimentary successions including a local carbonate slope, a pelagic carbonate platform, thick turbidite successions, and basinal shales with pillow basalts. An important feature is the development of a continental slope along steep escarpment faults which follow more or less the former carbonate platform margin. Along these faults, Middle and Upper Cambrian limestones and basement were exposed and gravitationally transported into the basin. Although collision between the Sierras Pampeanas and the eastern border of the Cuyania terrane is documented during the Middle Ordovician (Ramos 1988) no compressional structures of that age are present in the Precordillera. Instead, the highly varied sedimentary successions and the strongly varying thicknesses preserved underneath the pre-Silurian unconformity indicate an extensional regime responsable for the formation of horst and graben structures in the former platform area. Some of the grabens accomodated up to 600m of sediment (Empozada Fm.), whereas in a horst position, a pelagic carbonate platform developed during the Caradoc. Crustal extension culminated during the Llandeilo/Caradoc when huge amounts of pillow basalts extruded into the basin.

## CONCLUSIONS

During Cambrian and Early Ordovician times a passive continental margin developed on the Cuyania terrane. Comparisons with the Cambro-Ordovician margins of Laurentia show, that the original dimensions of the Precordilleran carbonate platform must have been much larger. The carbonates onlapped the Laurentian basement of the western Sierras Pampeanas during the Early Ordovician, hence the platform might have extended several 100 kms to the east or southeast. The Cuyania terrane was large enough, so that the effects of the collision at its eastern margin are hardly visible in the Precordillera.

During the Late Cambrian, the carbonate platform starts to disintegrate along its western margin (Cerro Pelado) where an isolated block was downfaulted and drowned. Similar events are observed in the Early Ordovician (slope facies, drowning at Guandacol) what is regarded as a precursor of the subsequent rifting. During the Middle and Upper Ordovician, sedimentation in the Precordillera was triggered by crustal extension. The formation of horst and graben structures accounts for the different sedimentary successions in the Precordillera. The relative movements of several 100m over a short time period together with the extrusion of basic magmas are interpreted as a result of rifting which marks the final separation of the Cuyania terrane from Laurentia. There are no indications that a major ocean was present prior to this time.

Hence, sedimentologic evidence supports the ideas of Dalla Salda and others (1992) and Dalziel and others (1994) about plate-tectonic constellations which place Laurentia and western Gondwana in close proximity.

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