LITHOSPHERIC MODELING OF THE ORDOVICIAN FORELAND BASIN IN THE PUNA OF NW ARGENTINA: IMPLICATIONS FOR THE INTERPRETATION OF EARLY PALEOZOIC TERRANES

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Resumen

La cuenca Ordovícica de la Puna septentrional argentina se desarrollo de una posición de tras-arco a una de antepais. Modelos litosfericos demuestran que la interpretación original basada en datos sedimentológicos, volcanológicos y el cálculo de tazas de subsidencia tectónica corresponde a procesos fisicos vigentes en la evolución de cuencas de antepais. Sin embargo, los resultados de la modelación soportan dos procesos e interpretaciones distintos: (i) La evolución de la cuenca controlada por compresión asociada a un aumento del espesor de la litósfera, o (ii) la construcción de un arco sobre corteza continental de un margen pasivo anterior. Las dos alternativas tienen consecuencias geológicas distintas referiendose al mosáico de los terranes del Paleozoico temprano.

Key Words

Argentina, Ordovician, basin modeling, terranes

Introduction

Most studies of Early Paleozoic sedimentary basins in NW Argentina and N Chile led to qualitative reconstructions of their geotectonic evolution. Here I present the results of a lithospheric modeling approach towards a quantitative interpretation of the Ordovician basin in the Puna of NW Argentina which combines theoretical considerations with data obatined in the field.

The Early Palaeozoic Basin of NW Argentina

After the Pampean Orogeny in the early Cambrian, the Early Paleozoic evolution of marine basins starts in the Late Cambrian. The Late Cambrian Mesón Group overlies the Pampean Orogen with an erosional unconformity. It is c. 3000 m thick and consists predominantly of shallow marine, partly tidally influenced quartz-sandstones and shales. They were deposited on a west-facing marine platform (Kumpa and Sanchez, 1988). With a further erosional unconformity, the Mesón Group is overstepped to the E and W by the quartz-rich sandstones and shales of the Santa Victoria Group (Latest Cambrian to Early Llanvirn).

Restricted to the Arenig, a magmatic arc became active farther W in the western Puna region and in N Chile. It is mainly evidenced by basaltic to andesitic lavas of geochemical volcanic arc affinity, and associated volcanoclastic apron deposits of c. 3500 m thickness (Koukharsky et al., 1988; Breitkreuz et al., 1989; Bahlburg, 1990). At this time, the Puna basin and the siliciclastic platform of the Santa Victoria Group were in a back-arc position. Tectonic subsidence analysis indicates a major loading event in the western Puna during the Arenig which transformed the Puna basin into a foreland basin (Bahlburg, 1990). This was accompanied by the emergence of the Cordillera Oriental in the Early Llanvirn. In the Middle Ordovician, a c. 3500 m thick volcanoclastic turbidite complex was deposited in the Puna basin. Presently available data suggest that the Arenig arc had been extinct by this time.

In modification of earlier subduction models for the Andean margin in the Ordovician (Coira et al., 1982; Hervé et al., 1987), the evolution of the Ordovician basin in the puna and Cordillera Oriental was interpreted as connected to the collision of the Arequipa Terrane (Ramos, 1988; Forsythe et al., 1993), leading to the Early Ordovician arc being thrust eastward over its back-arc basin (Bahlburg, 1990). This interpretation was able to explain tectonic subsidence rates of up to 600 m/Ma associated with high sedimentation rates in the developing foreland basin. However, there is no positive evidence of the respective thrust fault, and alternative interpretations have to be tested.

According to the recently revived hypothesis of the Late Proterozoic supercontinent in the Cambrian (Bond et al., 1984; Dalziel, 1991; Dalla Salda et al., 1992), eastern North America rifted away from western South America during the Cambrian. This may be reflected in NW Argentina by the Late Cambrian-Early Ordovician potential rift-to-drift succession in the Argentinian Cordillera Oriental represented by the Mesón and Santa Victoria Groups (see above). Consequently it would be likely that a passive margin stage in the Late Cambrian and possibly Tremadoc preceded the development of the Arenig arc as part of an active margin.

In order to test both interpretations, an infinite beam elastic plate lithospheric loading model was applied which is able to take account of 1st order features observed in the evolution of the Ordovician Puna basin in NW Argentina. Two scenarios were testet: (i) that of lithospheric thickening through thrusting of the existing arc over its back-arc basin (Tectonic Scenario), and (ii) that of arc construction on a previously passive margin (Arc Scenario). Numerical details of the model will be discussed elsewhere (Bahlburg and Furlong, in prep.).

Model Scenarios

Arc Scenario: The first loading event in the Arenig (max. 6000 m load thickness) is taken to be dominated by early volcanic products of basic chemistry with a density of 2900 kg/m^3. The sediment shed from this evolving source is taken to be of corresponding increased density, i.e 2700 kg/m^3. On the far side of the basin, sediment input reflects metamorphic and plutonic sources, the sedimentary rocks of the eastern Puna basin are quartz-rich, and their density is assumed as 2500 kg/m^3. At the time of the second loading event in the Llanvirn (max. 2000 m load thickness), the arc is assumed to have evolved to upper crustal compositions with a density of 2800 kg/m^3, with a corresponding density of the eroded sediment of 2600 kg/m^3. For the third timestep in the Llandeilo no additional loading event is assumed as there is no record of active volcanism. The sediment is taken to reflect erosion to deeper levels of the arc, cutting into granitoids, and a density of 2500 kg/m^3 is used.

Tectonic Scenario: Throughout this scenario, an upper crustal density of 2800 kg/m^3 is assigned to the tectonic loads. Eroded sediment in all timesteps has a density of 2500 kg/m^3. No tectonic loads were added in the Llandeilo time step as tectonic subsidence data indicate a decrease in the subsidence rate at this time (Bahlburg, 1990).

Results And Discussion

The results obtained in the two different scenarios show only very minor differences between them. This is not surprising as the two runs differ only in the small density differences assigned to the various loads. These differences play only an insignificant role in comparison to the overriding interplay between the size of the loads and the flexural properties of the loaded lithosphere. Therefore it appears to be justified to ignore these minor discrepancies in the following discussion.

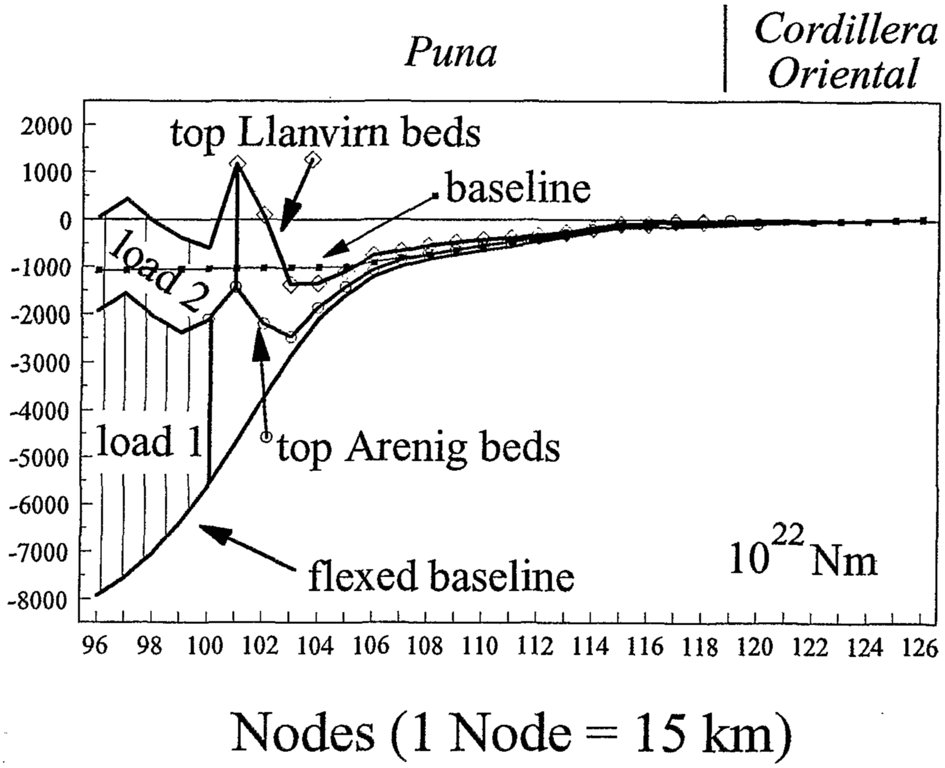

Fig. 1: Arc Scenario, results of timestep 2 (Llanvirn), assuming a flexural rigidity of the lithosphere of 10^{22} Nm. baseline: top of the lithosphere before loading; flexed baseline: top of the lithosphere after loading.

As the main conclusion from the model scenarios it can be stated that under both assumptions the geometry and facies patterns of the Ordovician Puna basin were reproduced well for a total load thickness of max. 8000 m, loading a lithosphere with a flexural rigidity of 10^{22} Nm, representing an equivalent elastic thickness of 13 km. This is a fitting value either for a thinned back-arc crust or a young leading edge at a previously passive margin (Karner and Watts, 1983; Erickson, 1993). The results are inconsequential in so far as no preference for either of the scenarios can be derived. However, they have distinctly different implications for interpretations of the geotectonic evolution of NW Argentina and N Chile.

According to Ramos (1988), the Arequipa Terrane docked to the Pampeanas Terrane in the Oclóyic Orogeny at the end of the Ordovician. Although there is no positive evidence of a major Ordovician suture in this region, the terrane boundary between the Pampeanas Terrane in the E, and the Arequipa Terrane in the W is assumed to be located along the border between the Cordillera Oriental and the Puna, or within the Puna. In either case, the Arenig arc would reside on the Arequipa Terrane. This interpretation corresponds to the Tectonic Scenario presented above. If, however, the Arenig arc was constructed on the previously passive margin of the Pampeanas Terrane, as is inherent to the Arc Scenario, the arc would reside on the former trailing edge of this terrane. The suture with the Arequipa Terrane would accordingly coincide with the position of the Ordovician subduction zone W of the Cordón de Lila in N Chile (Niemeyer, 1989). This interpretation is supported by the facies patterns and geometries of the Ordovician sedimentary rocks in the Cordillera Oriental which represent, from E to W, an uninterrupted shelf-slope-basin section (Bahlburg, 1991). Further field studies should be directed towards identifying the actual position of the suture between the Pampeanas and Arequipa Terranes.

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