MESOZOIC EXTENSION AND CRUSTAL THICKENING IN THE PERUVIAN ANDES.

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Abstract: The subsidence history of the peruvian continental margin shows the western areas to be floored by a thin stretched crust overlain by thick sedimentary wedges. Subsequent Andean shortening of such structures can explain a significant part of the present-day observed crustal thickening.

Introduction.

Most of the studies carried out in the Central Andes were concerned with the Cretaceous-Tertiary magmatism, with the Andean orogeny, or with the present-day geodynamic processes. However, very few is known so far about the Mesozoic evolution of the continental margin of the Central Andes. The scope of this note is to analyse the behaviour of the Peruvian active margin during the pre-orogenic period (i.e. Jurassic and Cretaceous), and to examine its effects during the Tertiary orogeny.

Geological setting.

Since the latest Jurassic, the Peruvian margin was subjected to the nearly continuous subduction of the Farallon oceanic plate. During this period, the Peruvian margin can be divided into: 1) a coastal zone which is badly known and is not discussed in this paper; 2) a western basin which received a thick eastward-thinning wedge of mainly marine deposits during the Cretaceous, 3) an axial positive Cordillera with condensed Mesozoic sedimentation; and 4) an eastern area, in-filled by an eastward-thinning wedge of marine to continental Cretaceous deposits.

Method and limits.

This study is based on several subsidence curves obtained along two large-scale palaeogeographic profiles, in northern (= 5-7° S) and southern Peru (= 14-17° S) respectively. The curves have been computed using method and parameters of Sclater and Christie (1980). However some uncertainties arise from local unaccurate stratigraphic ages, and from uncomplete sections (basal décollements and/or subsequent erosions). Moreover, published data which have been used for some sections are often estimated. Hence, the presented curves must be considered as approximated.

Subsidence patterns.

The subsidence curves exhibit three patterns according to their palaeogeographic setting.

- In the western areas, the curves show an upward concavity which strongly suggests an extension/thermal-controlled subsidence (Mc Kenzie 1978). Tectonic subsidence can reach as much as 2000 m during latest Jurassic-Cretaceous times. In northern Peru, it allowed the deposition of a thick sedimentary wedge that reach 8 km toward the West, and can be considered as progressively thinning eastwards, so that it represents 1 km near the axial

Cordillera. In southern Peru, the same pattern is observed, with a 4 to 1 km-thick sedimentary wedge.

- The axial positive swell recorded a linear tectonic subsidence curve which does not exceed 500 m. Thickness of the Kimmeridgian-Cretaceous sedimentary cover varies from 1 to 0,2 km. Though this palaegeographic feature is clearly inherited from the complex earlier evolution of the Peruvian margin (Jaillard et al. 1990), its tectonic significance remains unclear.

- In the eastern basin, the subsidence curves also show a linear shape which indicates a continuous flexion of the substrate through time, whithout evidences of significant extension. They are interpreted as resulting from the westward tilting of the South American craton, related to the oceanic subduction (Mitrovica et al. 1989). Tectonic subsidence is less than 1200 m for the considered period, and the sediment accumulation results in an eastward tappering wedge that reaches 3 km toward the West.

Hence, before the beginning of the Andean orogeny, the Peruvian margin comprised: 1) a mobile western area with a thick sedimentary wedge floored by a thinned continental crust, 2) a positive swell, and 3) a stable eastern zone with a thin sedimentary cover resting on a continental crust with normal thickness.

Palaegeographic control of the Andean thrust sheets.

In the western areas, most of the extension was accomodated by SW-ward dipping normal faults (e.g. Loughmann & Hallam 1982, Jaillard 1987), the most important of which governed the palaeogeographic framework. Stratigraphic and structural studies show the main Andean thrusts to be located along the major, fault-controlled palaeogeographic boundaries (Janjou et al. 1981, Mourier 1988), thus indicating that the Mesozoic extensional features have been tectonically inverted during the Andean orogeny.

Mesozoic crustal thinning, sediment accumulation and present-day crustal structure.

In northern Peru, gravimetric profiles indicate a significant crustal thickening (Fukao et al. 1989). Crustal thickness reaches as much as 45 km beneath the western area, progressively decreases eastwards (= 38 km beneath the axial Cordillera), and becomes normal (= 35 km) beneath the eastern domain (Fukao et al. 1989). On the other hand, the minimum value for Andean shortening has been estimated as averaging 30 % in the western area, 10 % in the axial Cordillera, and 25 % in the eastern domain (Mourier 1988).

If the sedimentary wedge of the western area has been shortened by about 40 % (i.e. thickened by about 67 %), its thickness becomes 13 to 1,7 km from W to E. On the other hand, it can be supposed that the continental crust of the western area had been restored to its normal thickness (= 32 km) owing to the tectonic inversions of the extensional structures. Therefore, the presently observed thickness beneath the western area (= 45 km) can be accounted for by the presence of the deformed sedimentary wedge on a restored, normal-thick continental crust . However, beneath the axial Cordillera the observed thickness exceeds the calculated estimation (= 4 km).

In contrast, the 25 % shortening estimated for the cover of the eastern basin is not associated with crustal thickening. It must be therefore considered as the result of the foreland deformation related to a major reverse fault located beneath the axial Cordillera. The estimated 40 km-shortening (Mourier 1988) could represent the movement along this fault. The thickness discrepancy observed beneath the axial Cordillera could be explained by the play of this basement fault.

In Southern Peru, gravity anomalies indicate a very important thickening beneath the western area (up to = 65 km), the axial Cordillera and beneath the western part of the eastern domain (= 55 km)(Fukao et al. 1989).

In the western area of southern Peru, structural data are too scarce to allow an estimation of the average shortening. However, studies carried on in the eastern areas of Bolivia indicate a very important shortening (e.g. Baby et al. 1989). Assuming a shortening of 50 % in the western zone, the sedimentary wedge would become 8 to 2 Km-thick from W to E, thus representing 12 % of the observed crustal thickness (i.e. 25 % of the observed thickening).

Hence, though the density of the deformed sedimentary wedge should be slightly different, neither the crustal extension nor the associated sedimentary accumulation can be ignored when dealing with the Andean crustal thickening.

Conclusions.

The analysis of the history of the Andean margin shows that the crustal extension and the associated sediment accumulation played an important part in the structural style during the Andean orogeny, and in the observed thickening of the continental crust. In Northern Peru, the inversion of the crustal extensional structures and the related shortening of the superimposed sedimentary wedge can explain the whole observed crustal thickness, whereas in southern Peru, it acted as a minor but no negligible parameter.

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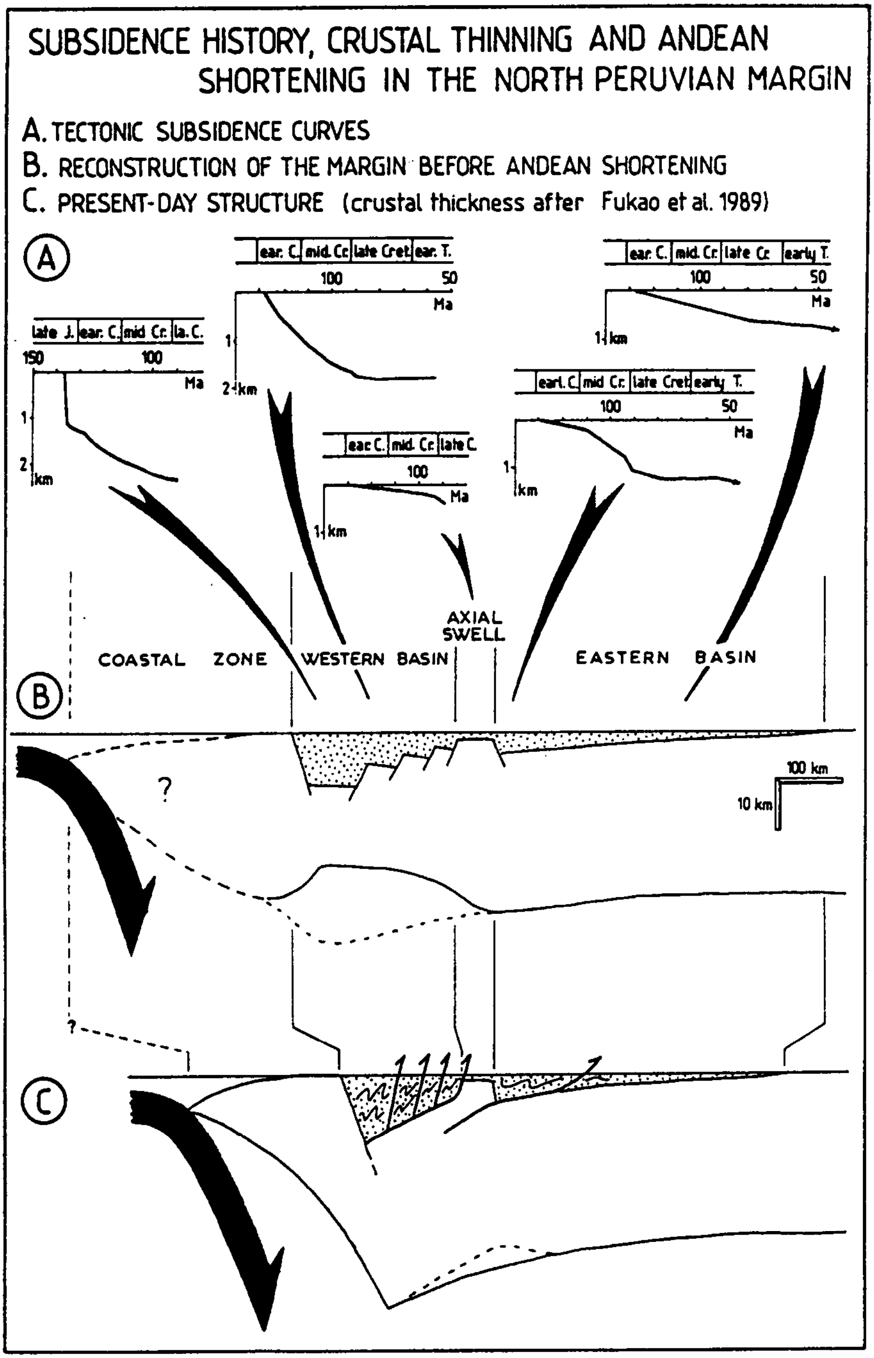
SUBSIDENCE HISTORY, CRUSTAL THINNING AND ANDEAN SHORTENING IN THE NORTH PERUVIAN MARGIN
A. TECTONIC SUBSIDENCE CURVES
B. RECONSTRUCTION OF THE MARGIN BEFORE ANDEAN SHORTENING
C. PRESENT-DAY STRUCTURE (crustal thickness after Fukao et al. 1989)
A
late J. ear. C. mid Cr. la. C.
150 100 Ma
ear. C. mid. Cr. late Cret. ear. T.
100 50 Ma
eac C. mid. Cr. late C.
100 Ma
earl. C. mid Cr. late Cret. early T.
100 50 Ma
ear. C. mid. Cr. late Cr. early T.
100 50 Ma
km
COASTAL ZONE
WESTERN BASIN
AXIAL SWELL
EASTERN BASIN
B
?
100 km
10 km
C