NEOTECTONIC OF SUBSIDING BASINS. CASE STUDIES FROM MARAÑON AND BENI BASINS, PERU AND BOLIVIA

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ABSTRACT

Climatic conditions make the fluvial processes very sensitive in the extended flood plain of subandean basins, giving typical morphostructures. Because of high subsidence rate, these basins are case studies for the understanding of neotectonics in subsiding basins.

Recent and ancient fluvial traces are used in combination with sub surface structures, neotectonic and seismotectonic data to study the neotectonic evolution of the Peruvian and Bolivian active foreland basins. These basins, the Marañón Basin to the north and the Beni Basin to the south, are located near the ends of the Peru-Bolivia Andean segment. Small rivers in the basins have underfit patterns and represent abandoned belts of the large rivers. Using successive abandonment of the river traces, it is possible to identify successive shifting of the large rivers, up to their present position.

In the Marañón Basin the Ucayali River and its ancient courses are first controlled by the front of Andean structures, then the rivers turn sharply to the east, flowing parallel to basement and neotectonic faults. In the Beni Basin the Beni River and Rio Grande are characterized by an anti clockwise shifting, related to rising of the craton margin and block tectonics in the basin.

Two different styles of deformation of the basin surface are inferred from the comparison between the fluvial network and the structural data. 1- Near the foothills (proximal part of the basin), rivers tend to be maintained along flexural or piggyback depocenters formed by the ongoing Andean deformations of thrust and fold belt style. 2- In front of the thrust and fold belt (distal part) basement structures control the river network. This structural control suggests the reactivation of these basement structures, before the area is eventually incorporated in the belt of Andean deformation.

INTRODUCTION

The areas of active subsidence in the subandean regions are interesting for two points: 1- they are characterized by a structural setting related to the neotectonic evolution of the foreland regions since the late Tertiary, and 2- climatic conditions make the fluvial processes very sensitive, giving typical morphostructures. These basins are case studies for the understanding of neotectonics in subsiding basins.

A symmetrical neotectonic pattern of the subandes controls the drainage network.

The Peru-Bolivian Andean segment trends NW-SE between the Huancabamba deflexion (north) and the Bolivian orocline (South). Two sub segments, a NNW-SSE "Peruvian" segment to the north, and a NW-SE "Peru-Bolivian" segment to the south are apart from the Fitzcarrald Arch, a structural interfluve trending ENE-WSW. The Fitzcarrald Arch splits the east-Andean drainage in two parts, the rivers flowing respectively north to the Marañón Basin and southeast to the Beni Basin (Fig.1). Between these two large basins, the other foreland basins are narrow and elongated near the front range (Ucayali and Madre de Dios Basin, respectively). This feature is related to the rising of the Sierra de Moa by the end of the Tertiary. This change in the structural evolution is interpreted as a consequence of a flat slab subduction beneath the central Peru (Jordan *et al.*, 1983).

Neotectonics in subsiding basins: surface deformation versus external processes.

External processes are dominated by a wet tropical climate generating active fluvial processes. At the outlet of the Subandean basins toward the Brazilian craton, the upper Amazon River in Iquitos and the Upper Madeira River in Guajá Mirim are already among the largest rivers on earth (Guyot 1992) contributing 15% of the total discharge of the Amazon River. Precipitations in the Amazonian plain results in extensive wetlands drained by small "black water" rivers, rich in organic acids. Flooding of the flat lands by local precipitation, and upper water stage of large rivers occur frequently simultaneously. Thus levées cannot easily develop on the margins of the rivers, and topographic rising or river belt by sedimentary aggradation is limited.

The idea commonly held is that fluvial dynamics and avulsions act randomly on the surface of subsiding basins. High subsidence rate, evidenced by more than 500 m of Quaternary sediments in the axial regions of the Marañón and Beni Basins leads to challenge this idea. Due to active subsidence about 60% of the sedimentary charge of the Mamore River is trapped in the Beni Basin (Guyot 1992). It may be inferred that large rivers on a flat flood plain are sensitive to any change in the position of the area of subsidence. Internal and external processes will combine to give the present pattern of the flood plain, but we hypothesize that subsidence control the fluvial network in the basin.

Fluvial morphostructures as a neotectonic tool .- *Three space-time related elements form the active fluvial belt (Dumont and Fournier, in press):*

The scroll pattern.- Is formed of ridge and swale morphology, resulting of point bar construction. Rivers with low migration rate have a tight scroll pattern quickly shadowed by subsequent flood plain deposits. On the contrary, rivers with high migration rate develop contrasted scroll pattern which is emphasized by ecological discrepancies. Building and abandonment of a scroll element occurs within four to six years. The evolutionary trend of successive scroll lines leads to identify asymmetrical migrations related to fault activity (Dumont et al, in press).

Mosaic elements.- Represent area of continuous meander evolution, until a neck cutoff occurs. An element cut and partly (or completely) erases the previous ones. Mosaic elements are mapped and used as structural elements for the kinematics study of river migration. The map which is obtained is a basic document for the study of the structure of the meander belt, and for sampling of river bank deposits. This map allows the identification and dating of long term directional tendencies of river migration related to block tilting, and/or fault activity (Dumont et al., in press).

Fluvial belts: A common characteristic of subsiding basins is the occurrence of both actives (present) and inactives (abandoned) meander belts. The inactive meander belts are remarkable for their geometry, especially sinuosity, wavelength, and side traces like oxbows, which does not fit with its present discharge. They are interpreted as previous courses of the active rivers. The observation of upstream and downstream links with active rivers testifies to the abandonment by shifting of the main trunk of the river (Dumont 1992). Other elements not presented here may be considered, such as lake pattern (Dumont (1993). Mapping of the position and directional shifting of the successive river belt is a basis for the interpretation of basin surface deformation or other fluvial processes (Dumont 1992).

Neotectonic study of subsiding basin.- *Involves the combination* of three sets of data: fluvial morphology, subsurface structures and neotectonic/sismotectonic data.

Marañón Basin: In the west part of the Marañón Basin (Fig.2), rivers tend to be parallel to the structures of the Andean tectonic front, which extend in the basin northward of the Tapiche fault (except the Marañón River which cross straight the basin). East of the Andean front (AF, Fig.2) active and abandoned rivers trend differently, parallel to faults of the Marañón Structural Zone (Laurent 1975) a belt of high density faults. The control may be effective through a process similar to tensional jointing, without a significant offset of faults. Nevertheless, block tectonic and active subsidence is evidenced by elongated lakes (Dumont 1993). This results for example in the local shifting of the Tapiche river toward the Punga lake (Fig.2).

Normal faults in the Quaternary fluvial deposits of the Craton margin, near the outlet of the basin (Jenaro Herrera, Fig.2), show a NNW-SSE extension (Dumont, 1993). Most of the faults trend N55E, parallel to the faults reported for the Marañón Structural Zone, just to the west. In this area rivers trend parallel to faults. Seismotectonic data from the east and west of the south Marañón Basin (Fig.1) show a NE-SW orientation of P-axes (Assumpção, 1992). The maximum stress direction is compatible with neotectonic faults, and support the interpretation of tensional structures in the basin, *also the occurrence of down dropped blocks giving elongated* lakes (Dumont, 1993). The southward migration of the bends of the successive stages of the Ucayali River (A, B and C, fig. 2) suggests *a weak control of the Tapiche fault with respect to what it was* during the Pleistocene.

In the Beni Basin, Plafker (1964) suggested that the Beni River flowed previously to the northeast, and shifted anticlockwise to the present position. Five successive stages have been identified (Fig.3). Formerly the Beni River was flowing to the ENE, *turning abruptly at* the outlet from the foothills. The bend of the river to the northeast shifted northward as the anticlockwise shifting progressed in the basin (C' and B', Fig. 5). This feature suggests that the shifting of the Beni River has been initiated from the foothills, and progressed toward the basin by increment along a line interpreted as an active fault. Similarly, the Rio Grande migrated of about 100 km to the west (Fig. 1).

Analyzing the drainage network, Allenby (1988) pointed out the occurrence of a basinal uplift along a belt previously occupied by an ancient course of the Beni River (B, Fig.3), suggesting a topographic inversion. This axis extends northeast from Reyes, along the main alignment of rectangular lakes, and crosses the Mamore River north of Puerto Siles (Fig. 1). Crossing the structure, the channel of the Mamore River has a significant reduction of sinuosity and is broken by several rapids.

Mercier *et al.* (1992) remarked that there was neither seismic nor field evidence about the tectonic regime along the Subandean margin of the northern segment of the Bolivian orocline, suggesting relative tectonic quiescence. According to Assumpção and Araujo (1993) a stress rotation of 30 degrees is detected in the north part of the Altiplano, around the Bolivian orocline. This deviation is interpreted as the border effect of the Altiplano due to a decrease of the rate of plate convergence since about 10-20 Ma (Assump__o and Araujo, 1993). *Small variations in the dual and non coaxial effects of respectively high topography and plate motion, can reactivate* diversely basement structures, generating radial river shifting. The present morphostructures *suggest active tectonic (probably normal* faulting) along the upper Beni River, on the eastern margin of the Pando block (Fig.3), and uplift tendency of the craton margin, increasing probably toward the apex of the orocline.

CONCLUSION

Two different styles of deformation of the basin surface are inferred from the comparison between the fluvial network and the structural data. 1- Near the foothills (proximal part of the basin), rivers tend to be maintained along flexural or piggyback depocenters formed by the ongoing Andean deformations of thrust and fold belt style. 2- In front of the thrust and fold belt (distal part) basement structures control the river network. This structural control suggests the

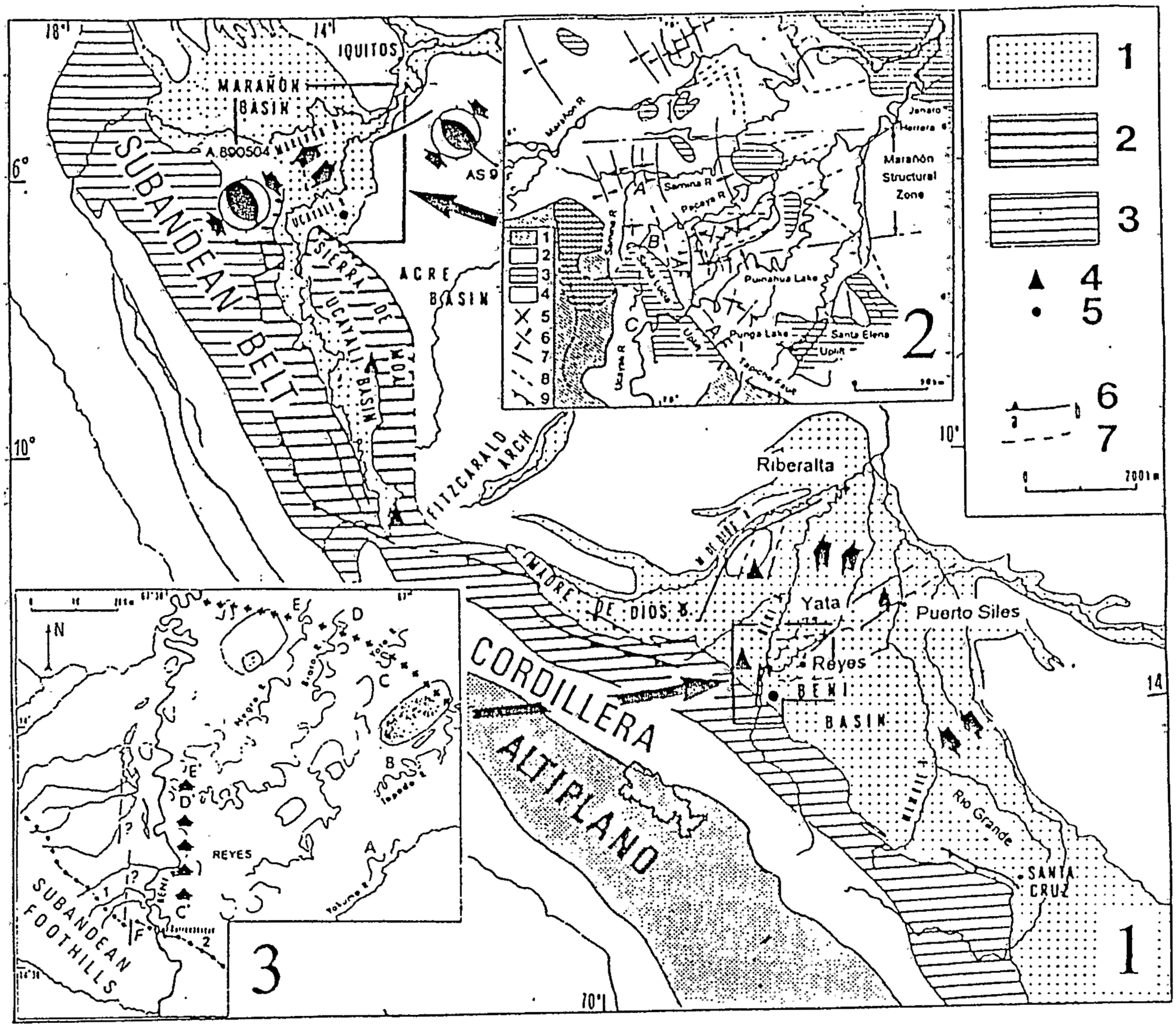
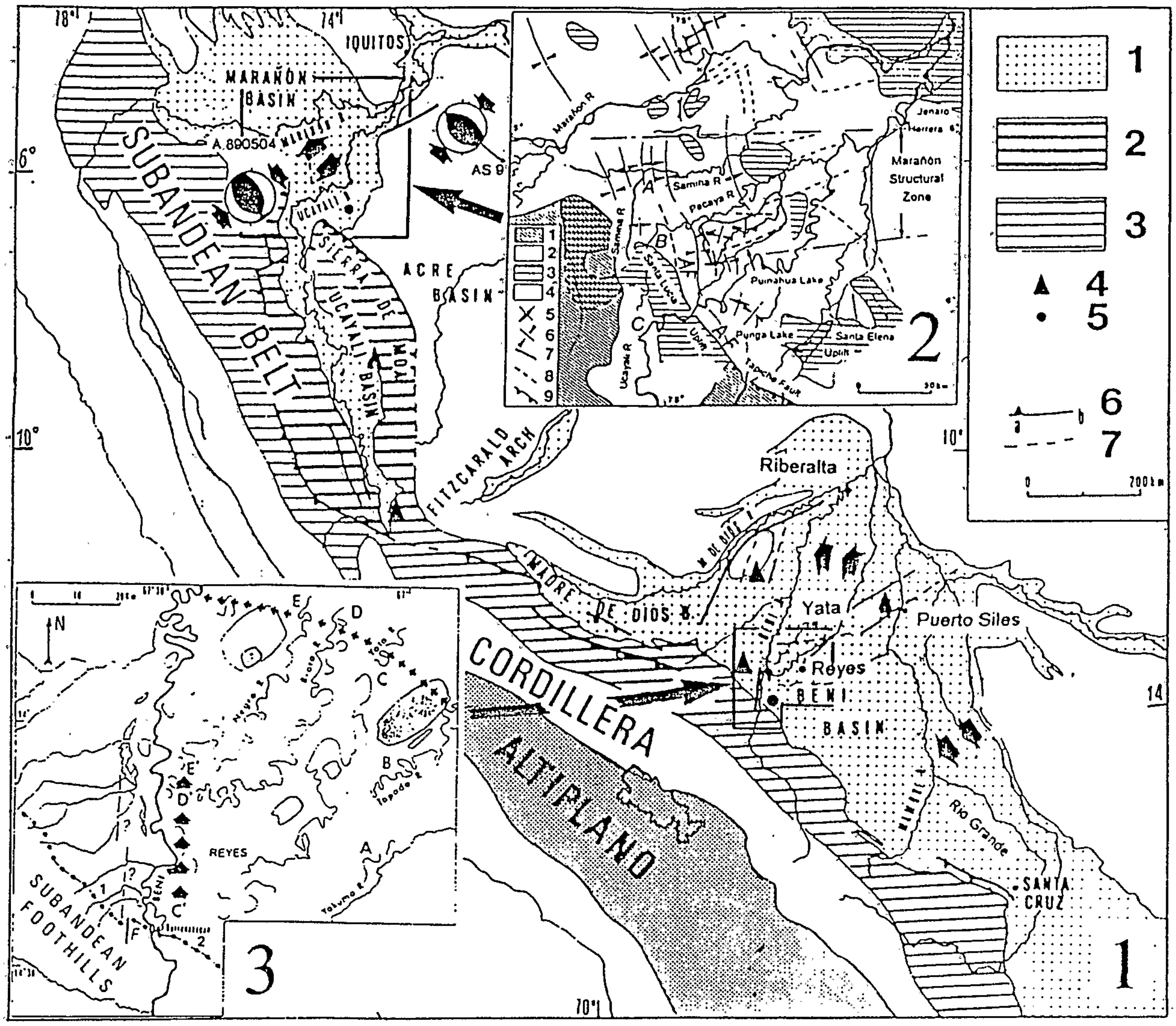


Fig. 1. Structural scheme of the Subandes of Peru and Bolivia. 1: Quaternary deposits. 2: Subandean Zone of block tectonics . 3: Subandean Thrust and Fold Belt. 4: Uplift tendencies. 5: Area of active subsidence. 6: Main reverse (a) or vertical (b) faults. 7: estimated faults. Stereonets from from Assumpçáo 1992, same labels.

Fig. 2. Sketch of the basement structures of the Ucamara Depression, from Laurent (1985) and Laurent and Pardo (1975). 1: Subandean foothills. 2: Brazilian craton margin. 3: Late Hercynian uplifts of crystalline rocks overlain by Cretaceous deposits. 4: Major swamps. 5: Pre-Cretaceous anticlines, and 6, synclines. 7: Basement faults reactivated during late Tertiary tectonics, north part of the depression. 8: Pre-Cretaceous basement faults. 9: Tapiche fault. A-C: Successive positions of the bends controlled by Andean structures.

Fig. 3. Morphostructural scheme of the Northwest Beni Basin. Dotted line: foothills piedmont. A to E, successive stages of the Beni River, and C' to E' successive position of the bend. F: faults observed in the piedmont, and subdued northern extension of the fault.



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reactivation of these basement structures, before the area is eventually incorporated in the belt of Andean deformation. This suggests the occurrence of two different provinces of basin sedimentation: one with large and long lasting sedimentary bodies related to areas of flexural subsidence in proximal position, and the other with more scattered sedimentary bodies, disposed perpendicular to the front range over reactivated structures in distal position. Style and trends of deformation emphasize the effect of tensional deformation (Dumont, 1993), which develop onward and perpendicular to the Andean tectonic front. Rivers appear to flow along these tensional joints and are sometimes shifted toward more depressed areas.

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