GEOMORPHOLOGICAL EVOLUTION OF THE PIURA RIVER FLUVIAL FAN, NORTHERN PERU, PRELIMINARY STUDY

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INTRODUCTION

The presented text includes results of the first year of an international cooperation project between the Czech Republic and Perú that focuses on documentation of natural hazards in a lower part of the Piura River catchment in the Piura Region, Northern Perú. This river represents one of the two most important rivers draining western area of the Andes to the Pacific in the area of the Piura Region and causing catastrophic damages during floods associated predominantly with the ENSO.

The study area is located in the equatorial area of South America, but its climate does not correspond to its geographical location due to fundamental factors such is Andean Mountain Range and a cold marine current of Humboldt (locally Peruvian current). The Andean Mountain Range blocks precipitation transfer from the Amazon and the cold current of Humboldt is responsible for reversal temperature stratification as it forms significant rain cloudiness and blocks the intertropical convergence zone in this part. The average annual precipitation over the whole Piura River catchment exceeds slightly 600 mm.

This very dry warm climate is presented in the area between Piura and Tumbes in the northern coast of Peru. The situation changes from December to April as result of summer warming of Pacific costal water but a dramatic change appears mainly during the ENSO event, when the increase of surface oceanic water is more significant. Storm rainfalls typical for intertropical convergence zone are common during these events and great amounts of surface water cause huge damages on infrastructure, agriculture and in other spheres of human lives in the study area.

The Piura River fluvial fan is a ~680 km^2 large sedimentary system that is formed in a point, where the Piura River enters its flat lowermost part of the catchment, the so-called Sechura Desert (Fig. 1). The Piura River fluvial fan overlies littoral sandy Miocene sediments of the Miramar Formation of the Sechura Basin (Caldas et al., 1980; Palacios, 1994) and the youngest accumulation marine terrace called Tablazo Lobitos (Caldas et al., 1980).

GEOMORPHOLOGICAL CHARACTERISTIC AND CONTROLS OF THE PIURA RIVER FLUVIAL FAN

Six main natural geomorphological features were distinguished in the area of the Piura River fluvial fan: i) fluvial channels, ii) natural levees, iii) crevasse splays, iv) floodplains, v) lakes and vi) aeolian sand dunes and fields. However, the morphology of these landforms is significantly affected by intensive agricultural activities in the area.

The fluvial system is characterised by one principal channel (Fig. 2A), several minor ones and numerous abandoned channels, which are active only during strong floods (Fig. 2B). The fluvial channels are characterised by relatively low sinuosity with sinuosity index (P_{ind}; *sensu* Brice, 1964) of 1,11 to 1,23 and could be generally interpreted as straight channels. The width/depth ratio (*w/d*) is usually about 20. The average annual discharge of the Piura River was 47,9 m^3/s for the time period from 1969 to 1999 (Vera & Ordóñez, 2006). However, the discharge is very irregular with highest rates in the January-May period and lowest from August to November. In the Piura City, the bankfull discharge (Q_{bf}) is ~2400 m^3/s and the maximum discharge (Q_{max}) of 4420 m^3/s corresponds to its maximum during the ENSO in 1998. The predominantly fine-grained sand material is deposited within the channels in a form of inchannel bars in a scale of tens of metres (Fig. 2C) and in a form of lateral bars and point bars in a corresponding scale (Fig. 2A). Bifurcations and avulsions are typical processes of the channels evolution, documented by the interpretation of remote sensing satellite data.

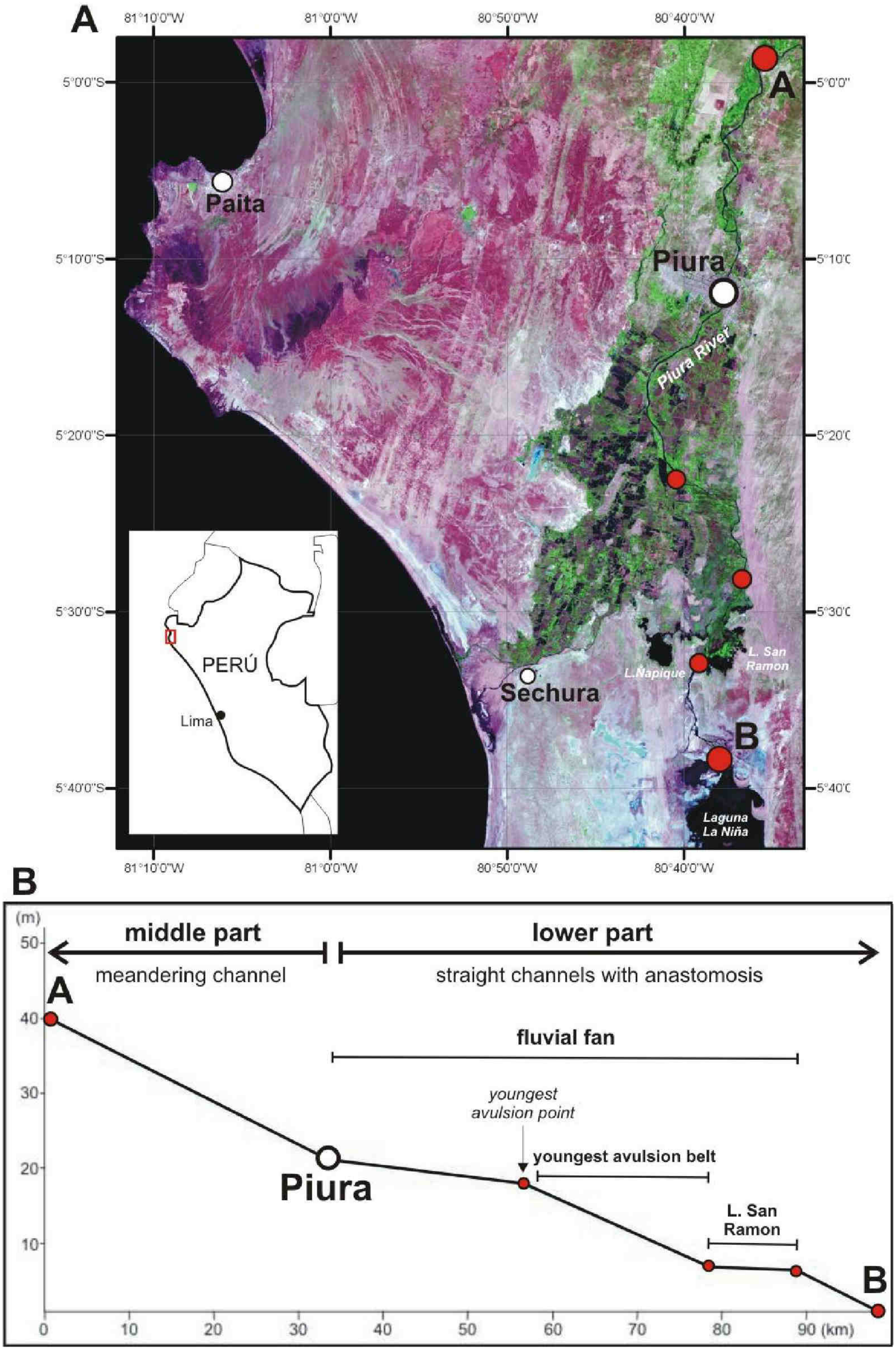

Fig. 1: (A) Landsat TM7 image from 2001 showing the Piura River fluvial fan situated southwards from the Piura City. (B) Generalised longitudinal profile of the Piura River in the fluvial fan area and its surroundings. The location of the youngest avulsion point, the youngest avulsion belt and the Laguna San Ramon are displayed in the profile. For the location of the longitudinal profile see the satellite map in (A).

However, the reconstruction of abandoned channels is complicated as humans have reworked most of the channels to the straight irrigations channels with artificially elevated levees.
The channels are flanking by natural levees composed of fine-grained sand to silt and commonly vegetated by trees and bushes. Width of the levees is mostly ~50 m and relieve above the surrounding floodplain is up to several metres with maximum along the convex banks. In cases of the levees breaching the crevasse splays form. Generally, they are characterised by fan shape body of lateral extent in a scale of 0.X to X0 km^2. They are composed of fine-grained sand and surface of the splays is truncated by bifurcating system of shallow crevasse channels (Fig. 2D).
Floodplains characterize wetlands and small seasonal lakes, where the finest muddy to sandy material is deposited (Fig. 2E).

Based on a channel pattern, the presented sedimentary system could be interpreted as a fluvial system with short-lived anastomosis (*sensu* Makaske, 2001), where avulsion channels have a form of anastomosing network of channels within an avulsion belt that is produced by progradation of crevasse splays. However, during low discharges, one principal channel is established and the other ones are abandoned, showing temporal activity only during flood episodes. Extreme discharges characteristic for the ENSO period, aggradation of the fluvial ridge and formation of crevasse splays are the principal causes of the Piura River avulsions. Recent observations show that the principal channel of the Piura River tends to move eastward (Fig. 3). Although it could be partially explained by autocyclic evolution of the system associated with vertical aggradation of the fluvial ridge (*cf.* Mackey & Bridge, 1995), the tectonic tilting of the sedimentary surface, caused by subsidence on normal fault(s) merging the Sechura Basin from the east, could be also speculated (Fig. 3; for similar studies cf. Bridge & Mackey, 1993; Peakall et al., 2000).

RECENT EVOLUTION OF THE PIURA RIVER FLUVIAL FAN

The youngest marine regression after the accumulation of the Tablazo Lobitos triggered the initial fluvial erosion of this levelled surface followed by the fluvial fan deposition of the Piura River. Although the western margin of the South America is recently characterised by regression (e.g. Machare & Ortlieb, 1993) the evolution of the active part of the Piura River fluvial fan is controlled by a local erosion base represented by a lake level of the Lagunas Ñapique and San Ramon. Based on current studies the origin of these lakes could be associated with the accumulation of the aeolian dunes along southern margin of the fluvial system that create natural dam of these perennial lakes (Figs. 2F, 3B). The Laguna San Ramon is rapidly filled by sediments of the youngest avulsion belt especially during the ENSO events. Its area was ~35 km^2 in 1973 but decreased to ~15 km^2 in 2001 (Fig. 3). On the contrary, Laguna Ñapique does not change its extent as it is not affected by direct sedimentary infill but only by wash-over flow from the Laguna San Ramon. Only one channel enables limited outflow into the Pampa Las Salinas, where the seasonal playa lake called Laguna La Niña forms. Predominantly regressing water from the extensive irrigation in the Piura River fluvial fan area continues to the ancient river mouth near to the Sechura City on the Pacific Ocean coast (Fig. 2B). The water flow during the flood periods disembogues from the Laguna La Niña into the Pacific through two mouths: the Virrila estuary and the Ñamuc valley.

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Fig. 2: (A) Example of a sandy lateral bar within the principal channel of the Piura River (puente de Independencia, April 2008). (B) Aeolian dunes filling an abandoned channel of the Piura River near the Sechura Town(October 2007). (C) A vegetated inchannel bar within the minor channel on a surface of a large crevasse splay progradating into the Laguna San Ramon (April 2008). (D) A small-scale channel on the surface of a crevasse splay (October 2007). (E) Mud cracks within fine-grained lacustrine deposits of an ephemeral lake that communicates with the Laguna San Ramon during great floods (October 2007). Vegetated barrier of aeolian deposits is visible along the horizon. (F) Vegetated complex of aeolian dunes forming natural damp of the Laguna Ňapique (October 2007).

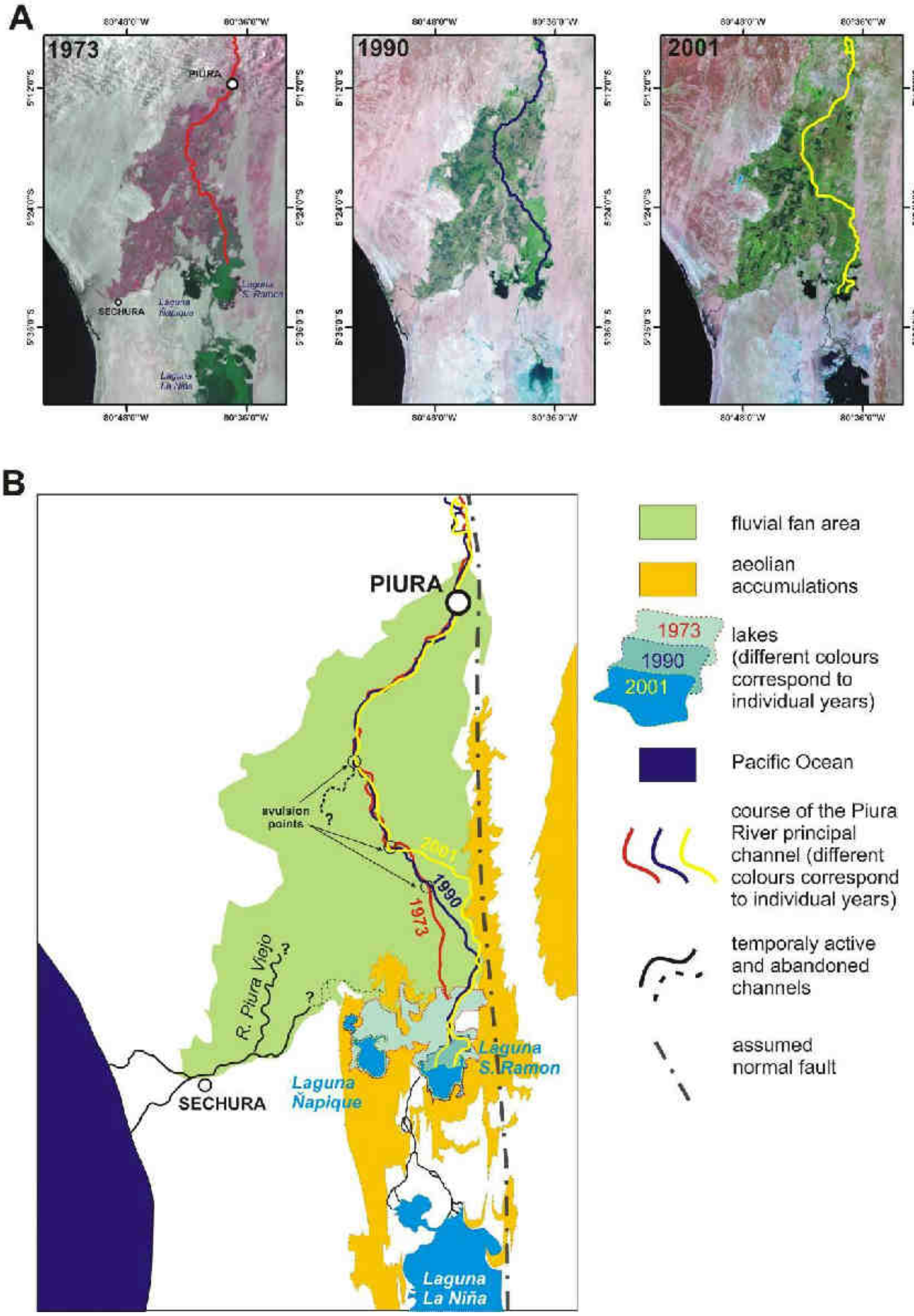

Fig. 3: (A) Landsat images showing position of the Piura River principal channel in the area of the fluvial fan (B) Schematic sketch illustrating interpreted changes of the principal channel position and extent of the lakes between the years 1973 and 2001. The relationship between the fluvial fan and aeolian accumulations is also shown. The course of the normal fault is generalised.

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