QUANTITATIVE ANALYSIS OF ASYMMETRICAL FLUVIAL PATTERN TO STUDY ACTIVE DEFORMATIONS IN SUBANDES BASINS

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RESUME: Les plaines alluviales dissymétriques metent en évidence la déformation de la surface d'un bassin. Le cas du bas Ucayali est abordé ici à partir de l'analyse quantitative de forme réalisée sur une images SPOT.

KEY WORDS: Fluvial pattern, foreland basins, Ucayali River, Remote sensing, Quantitative analysis.

INTRODUCTION

Neotectonic analysis of alluvial floodplain may be done using two types of fluvial patterns: sinuosity, which changes is related to longitudinal slope variations (Schumm 1986), and asymmetrical floodplain related to lateral tilting (Von Bandat 1964). The case of asymmetrical fluvial patterns from the lower Ucayali River (East Marañón Basin) has been previously described (Dumont et al., 1988; Dumont in press). We present here new developments from this case, in the aim to provide a method for the analysis of short term fluvial response to active deformation.

GEOLOGICAL SETTING

The Marañón and Ucayali rivers cross the Marañón foredeep basin, and join at the eastern border of the basin, in a triangle shaped graben edged by the uplands of the Brazilian Craton. The existence of the graben is documented by recurrent normal faulting in the upland (Dumont et al., 1988). In the graben the Ucayali River has an asymmetrical floodplain. The recent evolution of the Ucayali River is also clearly asymmetric: meanders are simple on the upland side (Fig.1,R) and compound on the floodplain one (Fig.1, L1 and L2 successively). Meander development is clearly related to the trend of the river and the local direction of the upland border (Fig.1, A and B respectively). The channel of the Ucayali River is limited on the upland side by the cohesive silts and clay of the Pebas formation which crop out below the erodible Pleistocene deposits, whereas banks on the floodplain side are made of non consolidated and easily erodible silts and fine sands of late Holocene age.

GENERAL STUDY METHODS

Asymmetrical floodplain is the most classical criterion of the effect of lateral tilting over a valley, evidenced early from aerial photography (Von Bandat 1962). The river channel tends to migrate down the slope of the tilt, abandoning meander loops on the upper side of the floodplain, which are all concave toward the migrating direction of the river. According to the Van Bandat criterion, the observation of tectonic activity is only possible if the process of lateral sliding of the meandering river is effective during a relatively long time, and over a floodplain three or four time wider than the amplitude of the river sinuosity.

It may be inferred from the continuity of the phenomenon that at any time during the period of lateral migration the effect of tectonics over the river behavior is active. So that, it should be possible to get evidence for tectonic activity investigating short time parameters of the floodplain morphology.

We provide here an example from the Ucayali River, on the eastern border of the Marañón Basin. Short time evolution of meanders is studied using the ridge and swale pattern, which is closely related to the recent development of meanders. We have developed a quantitative approach using SPOT image analysis.

EXTRACTION OF RIDGE AND SWALE PATTERN BY IMAGE ANALYSIS

Our objective here is to delimit shape entities that are thematically significant, that is to say the ridge and swale pattern of alluvial floodplain, from the initial SPOT XS scene. The pattern is evidenced by morphological and botanical contrast between the swampy grassland in the swales and the forested ridges. In order to extract these forms, widely-known techniques of multispectral classification is of no use since these objects have no characteristic spectral signature when they have a specific sub-circular shape. On Grey level images such as any of the XS channel (here XS3), one can visually perceive these objects as very thin sub-circular lines of light tone. The scope here is to filter these lines and to obtain a final binary image containing only the specified objects. Many criteria may be used for image analysis: the specific tone of the line (lighter tan the neighborhood), their thickness (one pixel wide) and their shape (subcircular). Experiments have shown that on square grids such as that of satellite images, well-known gradient techniques based on convolution with numerical masks leads to enhance rectilinear shapes and break curvilinear ones. Moreover they transform all contrast lines into very thick ones (Pratt 1978). We prefer here to employ nonlinear methods (Serra 1986). We first transform the initial digital grid into an hexagonal one which respects isotropy and where the euclidian distance between the pixels can be assimilated to the digital grid.

From the grey-tone image on the hexagonal grid (Fig.2A) one first filter thin and light lines by a *Top Hat* Transformation with a linear structuring element of given direction among the six possible ones of the grid (Meyer 1978). The resulting Grey tone image has a narrow histogram, but the lines of the image have the higher values which allows to obtain a pertinent binary image by threshold of the grey-tone function. This binary image contains small lines with wrong directions and disconnected to the desired ones. The "cleaning up" of the binary image is done by a *thinning* followed by a *geodesic reconstruction*: The thinning eliminates groups of pixels having a given configuration inside an elementary hexagon (it may be three pixels on a line or one isolated pixel on the center) and the geodesic reconstruction restores the initial connected components which have not totally disappeared with the previous thinning. At the opposite, lines can be connected along a given direction with a *closing* or a *thickening* Transformation with a linear structuring element, which both fill up the holes inside the hexagon according to the specific direction. This type of sequences enables to clean up the initial binary image and to preserve the "good" lines. Finally, in order to submit to geometric description one pixel-width structure,

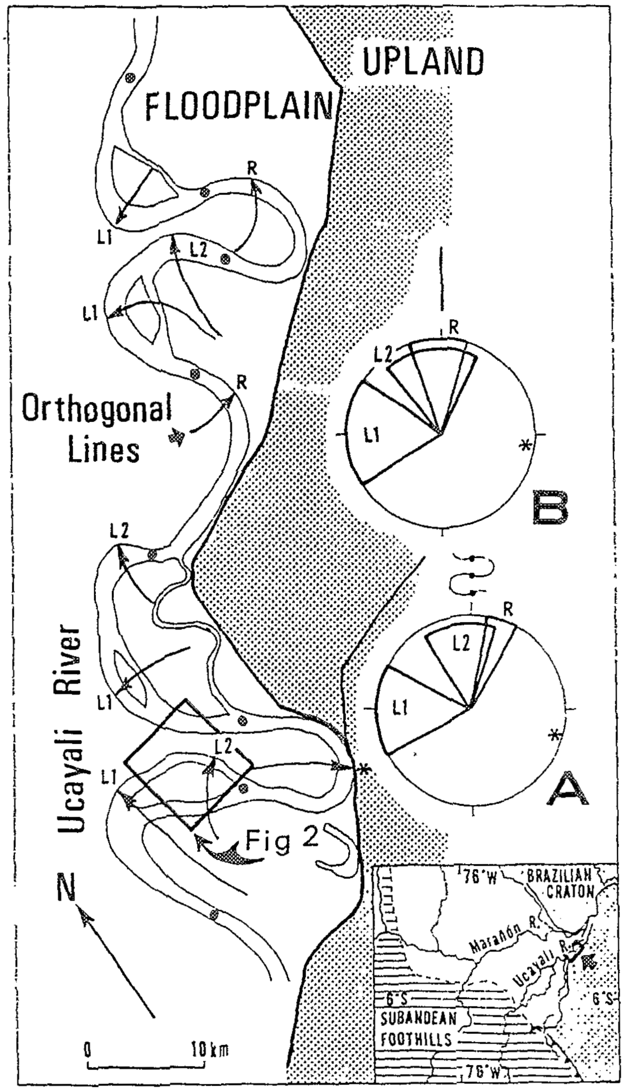
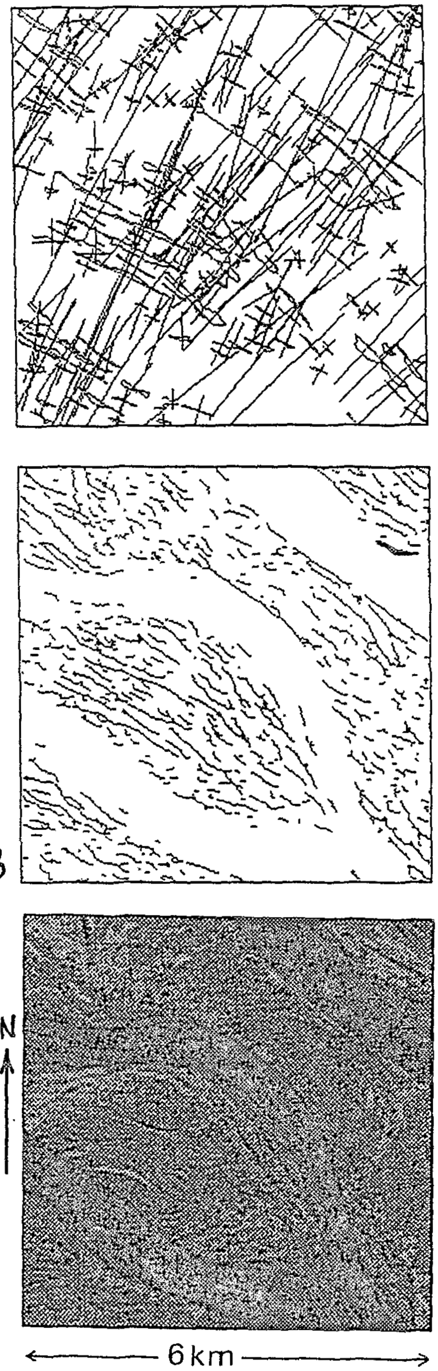


Fig. 1



C

B

Fig.2 A

Fig. 1. Lower reach of the Ucayali River near Jenaro Herrera. "Orthogonal lines" are the longer lines orthogonal to the ridge and swale pattern. See commentary in text.

Fig.2. See commentary in text

we have computed a *skeleton by thinning* (Lantuejoul 1980) which preserves the connectivity of the initial set (Fig.2B).

SETTING STRUCTURAL PARAMETERS

In order to make quantitative description of the structural features previously detected, specific parameters are computed using the Adonis method (Parrot and Taud 1992): each curve is individualized and approximated by a circular arc which is called reference circle (RC). A set of parameters defined by the curve and its reference circle enables the characterization of the structures. These parameters mainly concern the position of the center and the value of radius of RC, the number of pixels belonging to the curve, the direction of the normal to the chord, and different coefficients (chord, intersections, symetry, etc...). Sorting of these parameters get evidence of different families among the structures encountered.

Fig.2C shows the individualized structures, their chords, and the normal to the chord which passes through the center of the reference circle. According to the radius of the curves, the relative position of reference circle and the direction of orthogonal lines we can characterize the evolution of meanders and obtain quantitative evidence for asymmetrical patterns using automatic analyze.

CONCLUSION

Semi circular patterns derived from active and abandoned meandering rivers cover extended areas of foreland basins. Quantitative image analysis appears to be very effective for quick analysis of large portions of river. Here, we apply the method to asymmetrical pattern, but others fluvial patterns which are related to neotectonics, like sinuosity and river bed width can also be analyzed.

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