Erosive forms in river systems

E. de Uña Álvarez [(1)], J.R. Vidal Romaní[(2)], R. Rodríguez Martínez-Conde[(3)]

(1) Departamento de Historia, Arte y Geografía, Universidad de Vigo, Campus de As Lagoas, 32.004 Ourense (Galicia, España). E-mail: edeuna@uvigo.es

(2) Instituto Universitario de Geología "Isidro Parga Pondal", Universidad de A Coruña, Campus de Elviña, 15.071 A Coruña (Galicia, España). E-mail: xemoncho@udc.es

(3) Departamento de Geografía, Universidad de Santiago de Compostela, Plaza de la Universidad, Santiago de Compostela (Galicia, España). E-mail: rafael.rodriguez@usc.es

ABSTRACT

The purpose of this work is to analyze the geomorphological meaning of the concepts of stability/change and to study its influence on a fluvial erosion system. Different cases of "fluvial potholes" in Galicia (NW of the Iberian Peninsula) are considered. The work conclusions refer to the nature of the process and its morphological evolution in order to advance towards later contributions with respect of this type of systems.

Key words: Fluvial, Pothole, Granite, Galicia

RESEARCH FRAMEWORK

"Geomorphological regions (domains)...are represented by a particular type of landforms or processes" (Thornes, 1983). A network of fluvial potholes (erosive forms) is related to a series of erosive events so its present state will correspond to a complex history (Brunsden & Thornes, 1979). In the fluvial systems of granite terrains, the forms present in the bedrock are affected and correspond to the energy flow channelled during the geomorphological life of the channel. Any morphological element in an erosive landscape has been successively affected by the geomorphological processes that had acted in the considered zone and that had been influenced by very different factors such as climate, regional rocky structure, and variation of the local and general base level or fluvial competence. These changes are also related to the variations carried out along the time and space in the water flow regime, especially in the case of turbulent flows that in granite is influenced by the system of discontinuities and by the fact that changes are irreversible because the eroded rock cannot be restored to its original state. In the fluvial systems that have not reached the theoretical condition of equilibrium, potholes perpetuate by retro-feeding mechanisms (related to episodic erosive events) during hundreds or thousands of years. Their morphological properties and their spatial distribution allow to inferring the evolution of the erosive processes in the fluvial landscapes. The associations of fluvial potholes are complex systems subject to non-linear change until their eventual destruction (Thomas, 2001; Thornes, 2009).

BACKGROUND

Some authors have especially studied this type of forms establishing a series of morphological categories still in use in the interpretation of the evolution of potholes. Elston (1917) defines them as cavities with a circular or elliptical upper plane, which present parabolic cross sections in the incipient development stage; also, he underlines the network of rocky discontinuities, which determines the turbulent water flow, as important factor in their origin and development. Alexander (1932) defines three main models of water circulation according the entry angle in the cavities related to their morphology. Ives (1948) defines for the bedrocks subject to a gradient change three basic types irrespective of the present drainage regime. Other cases of potholes associated with rocky channels developed in granitic terrains of the Iberian Peninsula have been analyzed since 1980 (Lorenc & Saavedra, 1980; Nemec, Lorenc & Saavedra, 1982; Lorenc, Muñoz & Saavedra, 1994 y 1995); these authors propose an evolutionary model for potholes based on their dimensions and features of their cross section. Richardson & Carling (2005) have proposed a nomenclature for the fluvial erosion forms in different types of flow regimes.

STUDY AREA

This work was developed in a sector of the basin of the Miño River (Galicia, NW of the Iberian Peninsula). The rock basement is formed by granite and granodiorite. This sector is different from the rest of the Galician territory because of its greater annual temperature mean (14ºC) and a lower value of total rainfall (802 mmm). In the Ourense city, the Miño River (M) flows with direction ENE-WSW among several levels of terraces linked to – through pediments and/or slope breakings – residual weathering surfaces (mean altitude 400 m).The Reza station (100 m) is located at the most recent fluvial erosive level (2), hollowed out in the bedrock. The confluence of the Loña River (L) with the Miño appears in the northeast of the city. The Cachamuiña station (426 m) represent a sector of the incision of its lower channel (1) where it changes its general direction NE-SW to E-W downstream, in the residual surface of Sabadelle. The drainage network is oriented according to the general trend of the network in the southeastof Galicia – deeply incised in the previous surfaces – inherited from the whole Cainozoic times (Yepes & Vidal Romaní, 2004). Both the Miño in Ourense – mean annual contribution 607 Hm^3 – and the Loña in Cachamuiña - mean annual contribution 56 Hm^3- have been modified by the construction of reservoirs (Velle, Cachamuiña).

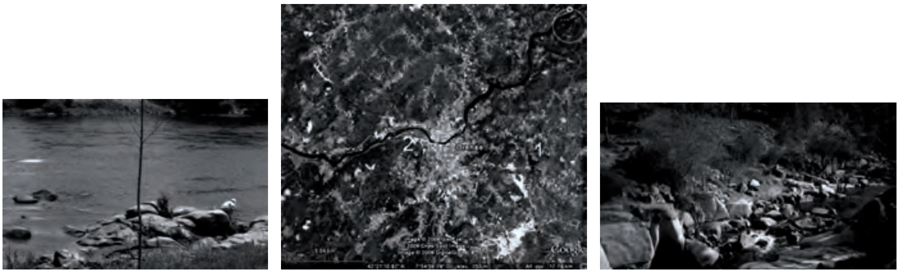
2  1

Figure 1. Study Area.

MATERIAL AND METHODS

Sampling

Field work 1999, 2002, 2003 and 2005 (spring & summer): Stratified method with recording of consecutive cases. The basic categories are landforms located in central and lateral bedrock channel. Potholes in Loña river (L): Cachamuiña station (n = 60). Potholes in Miño river (M): Reza station (n = 62).

Pothole Measures

Maximum depth, in the larger vertical axis (D = cm). Length of the top plane, in the larger horizontal axis (AM = cm). Width of the top plane, in the minor horizontal axis (Am = cm).

Data Processing

The best fit for the depth distribution (exploratory plot) is tested with standardized values of skewness and kurtosis. The central trend, the sample dispersion and their extreme tresholds are identified by robust statistics: quartiles and percentiles (box and whisker plot). The clustering of data depth (median method, Euclidean distance) is noted by their dendograms.

RESULTS

The depth values are not within the theoretical model of normal distribution. The resulting standardized skewness is 5.57 (L) & 6.55 (M). The standardized kurtosis is 6.16 (L) & 6.56 (M). The quartiles and percentiles values represent the limits of class intervals with regard to the intensity of the erosive processes. The robust statistics for the depth of the potholes show larger dimensions and more variety in the Loña River. The values far from the median are always complex and coalesced forms. The groups obtained by clustering show morphological patterns common for both samples, but less evolved in the sample of the Miño River.

Table 1. Potholes: Maximum Depth (cm).

Statistic	Stage	Loña River (L)	Miño River (M)
Percentile (5)		6,5	3,0
Quartile (1)	A/B	25,0	6,0
Median	B/C	59,5	11,5
Quartile (3)	C/D	110,0	21,0
Percentile (99)	D/E	245,0	50,0
Maximum		400,0	74,0

Table 2. Potholes: Trends of Change and Diversification

Class	D (cm)	A (cm)	P (%)	R (cm)
M (A)	3-6	5-60	50	-
M (B)	7-12	10-74	50	5
M (C)	13-21	11-90	55 & *87	14
M (D)	22-50	15-92	83 & *100	20
M (E)	62-74	40-100	95 & *124	35
L (A)	3-25	8-55	55	12
L (B)	21-60	21-60	100	15
L (C)	61–110	*23-170	166 & *192	35
*L (D)	115-245	40-200	238 & 425	48
*L (E)	260-400	55-251	315 & 343	>50

M=Miño River. L=Loña River. D=Maximum Depth. A=Range of Axis Measures. P=Maximum value of Depth (% Length). R=Maximum value of water/pebbles/sand trapped. Lateral Potholes*

CONCLUSIONS

Potholes associated with rock channels are forms coeval with the incision process of the fluvial network. However, their development is discontinuous and at long term is affected by the variations of the base level at local scale in the Loña River and/or general scale of the Miño River (determined by the eustatic changes). At short term they also depend on the conditions of the flow regime mainly linked to seasonality. At the same time they depend on the inherited character of the morphology on which the fluvial network is developed: in the Loña River the upstream erosion developed during the Caenozoic has generated the present system of potholes during several erosion events not finished due to the low flow values (it is so inherited forms) while in the Miño River the erosive events have been developed by a greater flow allowing a better regularization of its longitudinal profile. Finally, a third factor influences on the channel morphology and development of the minor forms, in our case the potholes. The system of discontinuities affecting the rock has influence on the development of the channel, both in plant and in vertical profile, and on the associated forms.

The depth data of the fluvial potholes with a non-linear trend show the co-existence of different populations in the sampling stations, more complex in the Loña River. Therefore, the statistics required by their internal and comparative analysis are robust or resistant. The increase of the dimensions is exponential. The evolution of the fluvial potholes corresponds to a process of morphological diversification. The main control variables of the evolution process are the local conditions of the flow and of the system of rock discontinuities, and also influence the nature of the infillings of the potholes and the previous inherited morphology due to the erosive competence of the turbulent flow during the geomorphological history of the channel. The resulting morphological groups represent the evolution of the erosive forms in these fluvial systems.

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