Sociedade & Natureza
ISSN: 0103-1570
sociedadenatureza@ufu.br
Universidade Federal de Uberlândia
Brasil

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Sociedade & Natureza, vol. 1, núm. 1, mayo, 2005, pp. 243-254
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THE CONDITIONING FEATURES OF DITCHES PROCESSES AT THE SEDIMENTARY STRUCTURES OF THE PERIPHERAL DEPRESSION IN RIO GRANDE DO SUL

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ABSTRACT: Aiming to define the conditioning features responsible for the different erosion processes actuating at the drain heads between Jacuí and Ibicuí rivers - at Peripheral Depression in Rio Grande do Sul, we analysed the geologic/geomorphologic aspects defining a set of marks due to the relief evolution, in which the details are presented as interfluvial depressions – pseudokarstic forms, rill erosion and large burrows, all of them interlaced to the hydrodynamic system. Based on a cartographic chart, satellite images, structural analysis of the sedimentary components and the examination of the hardness presented by several samples of water collected at, approximately, 15 and 48 meters deep, we verified the existence of complex surface structures (approximately 30 meters deep) associated to the apparently simple topographic forms (hills with ample areas of captivation and long ramps), geological events as fault lines and the stratigraphic arrangement of the sedimentary materials. These are the predisposing elements of the erosion forms here analysed, showing that the origin of these forms is beyond the anthropogenic action scale, becoming necessary the realization of systematic interconnected stratigraphic and surface geometry studies.
Key-Words: erosion factors, burrows, landscape evolution.

INTRODUCTION

In Rio Grande do Sul, the Peripheral Depression is place for a series of events that actuating in a set, account for a regional landscape constituted by ample hills (locally called coxilhas) sectioned by the drainage, where the topographic conditions and other relevant

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factors for relief formation permit varied forms of water action in the processes of modeling and remodeling the topographical forms.

Among many manifestations that currently express the relief evolution constituted by sedimentary materials from the Parana Basin, the processes of gully erosion in drain heads are pointed out, revealing the succession of phenomena related to the actuating accelerated erosion.

In this article, the questions related to the intensity of gully erosion in the drain heads of the morphostructural set that forms the topographic water divide from Ibicui and Jacui rivers in the Peripheral Depression were analyzed facing the main factors for the development of the relief forms, that means, the physical conditions contemplated by the characteristics (I) of the surface component structures; (II) the main fault lines in the region; (III) the litologic components; (IV) the hardness conditions of the subsurface waters and (V) the morphologic position of the gully erosion system.

Peripheral Depression - interfluvial area between Ibicui and Jacui rivers

Between the scarp of the Basalt-Sandstonic Plateau (end of the Mezozoic) and the crystalline core of the Sulriograndense Southern Plateau (Archaean) the Paleozoic formations appear. These formations were shaped by the processes of peripherical denudation, creating the different topographic levels that define some particularities of the regional relief, which constitute the Peripheral Depression in Rio Grande do Sul, excavated in the lands of the Mezozoic.

Since the Tertiary, the dry weather conditions identified in the whole Brazilian territory also reached the evolution of the regional model through arid periods, during which the relative stability of the crust favored the development of generalized levels of sedimentation, by means of removal, transport and deposition of the modified materials in the precedent humid phases. Thus, the levels of pediplanation were elaborated under superficial drainage, with torrential characteristics, being observed until the meridional borders of Rio Grande do Sul. (Ab' Saber, 1960; Menegat *et al.*, 1999; Holz, 1999).

Under the subtropical weather conditions, the pedogenetic evolution has geomorphologic implications that result in thicker intemperism covers. Porous, the sandy formations are easily penetrated by infiltration water, which takes to deeper strata the humic compounds and iron oxide from the superficial horizons. In the leveled topographies, this process causes the enrichment of horizon B and the attack to the subjacent rocky formations.

On another side, in general, the chemical action derived from the water percolation in the sand compounds in the field areas is intense, increasing the characteristics of acidity and poorness of the soil. (Bigarella *et al.*, 1996).

Considering the elements responsible for the regional standard of hydrographic system, the tributaries to the Uruguai River are carved in the western watershed of the Basaltic Plateau, and among them the Ibicui River. There, a slight water divide is separating the waters from the basins of Ibicui and Vacacai rivers and, then, the drainages of Uruguai and Jacui Rivers. (IBGE, 1977).

The morphopedogenetic processes actuate concomitantly in the relief transformation at the interfluvial area between Ibicui and Jacui rivers. The sediments from Rosario do Sul Group, subjected to the currently weather conditions, and to the biological and anthropic actions, respond showing big gullies in the landscape.

In this area, associating the occurrence of gully erosion to litology, it is observable that the appearance of gullies is not confined to one specific litology. Their depth and surface measures reach proportions that exceed at least two different sedimentary and/or pedologic sequences. A superior one, ocre-red colored, constituted of agglutinated sand and ferruginous material, friable and of high permeability. This material is covering the hills since the altitudes of approximately 100 to 200 meters. Underlying this material, the other litology is constituted of rosy-red sandstone, structured and very friable.

The contact between these two sedimentary units sometimes appears with the occurrence of gravel lines[5] together with iron oxide concretions, sometimes only with iron oxide concretions[6] and sometimes without any of them, presenting only the differential limit between the sedimentary units.

As well as the sandification processes in the Southwest border of Rio Grande do Sul, Suertegaray (1998), the gully erosion systems are also related to a higher weather humidification, since the middle to current Holocene. The climatic change would have progressively altered the morphogenetic system, intensifying the processes of fluvial carving and the processes of convexization of the watersheds, typical of humid weather. The actual situation of these processes justifies the rounded shapes (semimamelonated) as much in the compartments.

[5] Constituted by rolled pebblestones with polished surface, angular; iron oxide concretions and fragments of silicificated trees of Angiosperms of the triassic.

[6] The iron oxide concretions are paleopavements that show the occurrence of dry weather in the Triassic period.

level of old surface of levelling (regionally called *campanha*), as in the level of lower

METHODOLOGICAL PROCEDURE

Methodologically, the text as a whole had support on researches that followed the line of investigation developed in the Anglo-german Schools. (Abreu 1983)

This research model has its origins in the empirical work of the German naturalists, that was later improved by Penk (1953), that following his own assumptions inserted into the geomorphologic analysis the concepts of morphostructure and morphosculpture, previously stipulated by Guerasimov (1946, 1959) and cited by Moura Fujimoto (1994).

The interpretation of the relief shapes correspond to the first level[7] of analysis, with the topographic compartmentation and the description of morphology and morphometrics of the relief units identified in the satelite image Landsat 7, TM 3, 4 e 5 : 28/05/2000, with support on the topographic maps DSG, in the 1:50000 scale and in the consulted literature. The second and third levels, which regard to the superficial structures and the landscape physiology, were obtained by means of field surveys and laboratorial analysis of the components identified in the interfluvial area and the hardness of the water of some conventional and blowing wells that were in the unit.

To verify the variation of water hardness according to the pluviometric behavior, the collection of hard water samples was done after both winter of 2002 and summer of 2003.

The main mechanisms of the gully erosion process and its geographical individualization

According to the argumentation of Ponçano & Prandini (1987), based on the data from Tricart & Cailleux (1965), the erosive processes result from the morphogenetic action caused by azonal and zonal factors. The former factor is linked to the different morphogenetic processes by means of fundamental physical elements, while the latter refers to the different characteristics of morphogenesis that occur in many places on Earth caused by the variation of different environments. The interactions between these two factors intensify the geomorphic processes.

The succession of the current erosive processes begins with the pluviometric events

[7] Ab Saber (1969).

that somehow change chemically and mechanically the materials that constitute the surfaces.

The intensity of one process in relation to the other, chemical or mechanic, will depend on a series of factors, like: vegetal cover, duration and intensity of rains, kind of

material that constitutes the surface, geologic/morphologic aspects of relief and the biologic and anthropic action, among others.

The local and regional geologic question

The basement of the Paraná Basin is constituted of brasiliano granitic bodies and associations of polydeformed gneisses. The Basin has two main kinds of structures, that is, the ductile shear zones of direction N 60 – 70 E and the fractures system with direction N 20 – 50 W.

In terms of structure, the Parana Basin has its sedimentation marked by intense reactivations of the lineaments inherited from the brasiliano cicle.

During the Juro-Cretaceous Period, with the event of the separation of South America from the African continent, rhyolitic and basaltic lava fluxes occurred. The dykes examination with direction NE – SW, perhaps indicates the main axle of crust rupture in the occasion of this fact.

The prolongation of the axle NE – SW to the interior of the Parana Basin crosses with E – W lineaments, the case of the Uruguai River in Rio Grande do Sul. The result of this interlaced disposition of fragile lines in the land is the intense tectonic movement in the region of the basin as a whole.

The lift in the continental border was followed by tectonic activity, which promoted the intense recurrence of volcanisms during the end of the Mesozoic and the beginning of the Cenozoic Period.

The Jacui and Ibicui rivers follow an alignment E – W, similar to the North and South section of the Uruguai River. The preferential direction E – W of these two important drainage nets in the State shows the organization of the sedimentary substrate of the Parana Basin, reflecting in the erosion processes, mainly the mechanic. The Arc of Rio Grande alignment presents a series of fractures, where are established the courses that form the hydrographic basin of the Santa Maria and Jaguari rivers, tributaries of the middle course of the Ibicui River.

In lithologic terms, the main structural sequences that exist in the interfluvial area (between the Jacui and Ibicui rivers in the Peripheral Depression) are the sediments of the Rosario do Sul Group, constituted by materials from fluvial and eolian environments.

The origin and the evolution of linear erosion processes have a strong link with the geologic aspects, because the infiltration or runoff water finds ways for its easy locomotion in

the fractures and in the structural distribution of the sediments with grain size variability. Removing material, the infiltration/runoff water creates fragility zones in the land.

In general, the drainages in the studied aerea have a strong tectonic control and, as the gully erosion and ravines system is connected to the drainage net, we conclude that the main factor of their development is something related to the dynamics of the regional physic system.

The faults and the fractures constitute important mechanic and hydraulic discontinuities that mark the occurrence of advanced erosive processes. On the other side, the lithologic variation of the fluvial and eolian sediments of the Rosario do Sul Group determines the intensity of the erosion factors in the landscape from this part of the Peripheral Depression.

Checking the signs of this fact, it was observed that the deep gullies are developed where we find very homogeneous and thin sandstone with a red color, and with light yellow shades. They present long strata, corresponding to the eolian structures of the Rosario do Sul Group.

Very frequent in the region, the erosive processes in shapes of gullies are situated where there are sedimentary structures of fluvial origin. This material, for presenting lower clay content and sometimes because of the occurrence of mudstones intercalations, offers a higher resistance to the agents responsible for the deepening of the erosion.

Among with these materials, it is very common the occurrence of levels of ferruginous concretions that also establish variation in the permeability dynamics in some locations in the area. (Cabral *et al.,* 2003)

In the interception of the alignments marked by the drainage of the Ibicui and Santa Maria rivers, the anticline of the Arc of Rio Grande, under reactivations during the Tertiary, controlls the drainage system of the region and promotes the occurrence of intrusion of alkaline materials, besides intensifying the processes of silicification**,** responsible for the origin of the relief shapes designated as cerros in the region.

Among the different sediments that exist in the area, indications of material outlet by infiltration of the pluviometric water were determined by the water hardness analysis in eight samples that were taken from conventional wells[8] and one blowing well[9] located between the city of Cacequi and the localities of Paula Gomes and Timbauva. The results of this analysis, table 1 and 2, showed a considerable variation in water hardness between the seasons of winter and summer, related to a higher or lower presence of water in the sedimentary interstices between the extreme seasons of the year.

TABLE 1 - Parameters analyzed to the water of wells with characteristics of brackish water. Winter of 2002

Samples	Analysed parameters			
	pH	Ca (mg/l)	Mg (mg/l)	Hardness[10] (mg $CaCO_3$/l)
Medianeira[11]	5,09	1,80	1,00	8,60
Cledy	4,52	11,7	5,10	50,2
Cedro	5,57	35,9	13,6	145,5
Cacequi	4,34	16,2	7,30	70,4
Taquara	7,43	15,0	1,70	44,5
Triângulo	6,48	8,90	3,90	38,2
Tia Leonor	5,29	61,3	1,60	159,8
Povo Novo Blowing Well	7,84	5,60	3,00	26,3

TABLE 2- parameters analyzed to the water of wells with characteristics of brackish water. Summer of 2003

Samples	Analysed parameters			
	pH	Ca (mg/l)	Mg (mg/l)	Hardness (mg $CaCO_3$/l)
Medianeira	5,16	2,50	0,82	9,60
Cledy	4,67	13,2	5,40	55,2
Cedro	7,40	27,3	10,2	110,7
Cacequi	4,73	10,3	4,53	44,3
Taquara	7,58	70,4	1,60	182,5
Triângulo	5,80	14,8	6,30	62,8
Tia Leonor	5,14	6,20	3,10	28,4
Povo Novo Blowing Well	8,17	44,5	3,10	123,8

The winter, with longer precipitations and lower temperatures, thus with more infiltration and less evaporation, makes possible that a larger quantity of water settle in the interior of the surfaces, causing the dissolution of calcium and a bigger dispersion of it. The summer, with more torrential rains and higher temperatures reduces the subsurface water and makes it go to the deeper strata of the soil, possibly concentrating the dissolved products during the winter or during periods of rains with more durability**.**

Finally, these data prove the action of the subsurface water in the diversified structures that constitute the relief from this part of the Peripheral Depression, under particular conditions established by the facts cited in the beginning of the this item.

4.2 – The morphology and the gully erosion system in the interfluvial area

The interaction of the pluvial behavior (Barros Sartori, 1993; Cabral, 2004) and the other climatic elements (temperature, insolation and others) with the kind of material that constitutes the surface of the interfluvial area between the Ibicui and Jacui rivers, makes possible the perceptile pluviometric action decurrent of the rainfall behavior during the year.

As the components of the surface are essentially sedimentary, sandstones and siltites of the Rosario do Sul Group, Cenozoic and/or of alteration cover, among the presence of structural

[8] Wells with 12 to 15 meters deep.
[9] Well with 48 meters deep.
[10] According to the verbal declarations from Prof. Valderi Luiz Dressdressler, all the samples, except the first one, will have soap precipitations. This confirms the questions that were brought up by the local people about the presence of brackish water in some wells, even in the artesian ones. PS: the local people call brackish water that which precipitates soap, thus it is the water that presents a relative concentration of calcium carbonate.
[11] The sample from Medianeira Farm is a freshwater sample, and can be used as standard for comparisons.

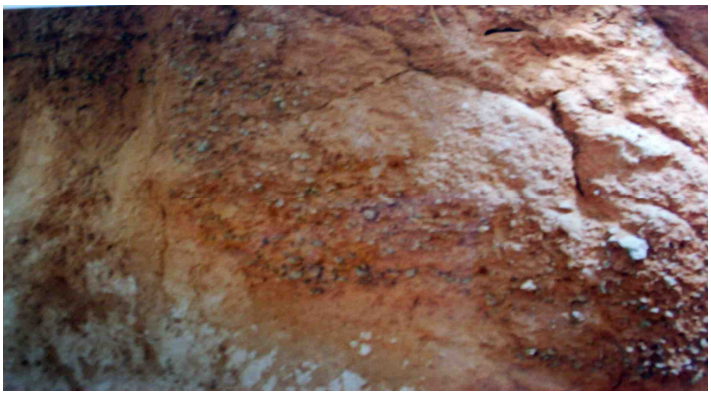
lines, the climatic conditions, mainly in relation to the pluvial index, these will reflect on the larger or smaller quantity of water and its time of durability in the surface and subsurface of the local and regional headwater supplies.

In terms of action by dissolution and/or oxidation, the water in the interior of the sandy sedimentary compounds transforms the preexisting material and reduces the cohesion of the particles of larger size, mainly the quartz grains, reorganizing them in a microscale washout process.

In relation to the mechanic action of the rainfall water, it presents itself in the creation and enlargement of gullies directly related to the drainage system, besides superficial erosion. This way of water action was inventoried and the data will be presented and discussed as follows.

Morphologically, the surfaces of the interfluvial area between the Ibicui and Jacui rivers present certain details that contribute and allow the installation of the gully erosion system in the headwaters of streams/rivers.

The iron oxide and the gravel lines, for instance, collaborate to the installation of gullies, because at the same time that they provide a certain support to the relief shapes, they also interfere in the system of internal circulation of infiltration water. The infiltration water, being stopped in these levels, promotes the leaching of the concretions of iron oxide and other dissolvable materials responsible for the cohesion of the sands, occasioning, this way, the formation of weakness zones in the land, areas that are taken by the gully erosion systems, as shown in pictures 1 and 2.



PICTURE 1 – Concretionary levels in nodules.

PICTURE: Ivaniza L.L Cabral; PLACE: Near the center of Angico's Farm; DATE; 21/08/2002

PICTURE: Ivaniza L.L Cabral; PLACE: Near the center of Fazenda Boa Vista; DATE: 21/04/2003

PICTURE 2 – Concretionary levels in blocks.

In relation to the density of courses, in general terms, there is a big interaction between it and the relief ondulations. The surfaces with high density of courses are more dissected and present a more hilly relief with the smaller dimensions of the interfluvial areas[12], corresponding to the section of springs, as much the tributaries to the Ibicui River, as the tributaries to the Jacui River.

The analysis of these facts subsidized the interpretations of the infiltration system in the interfluvial area as a whole, that is, the infiltration fields in a relief of ample hills[13] under the current environmental conditions among the structural characteristics and the presence of fault lines are collaborating to the action of the water in the interior of the sedimentary components, forming the weakness zones where the drainage is organized, creating large gullies.

The carving values of the valleys of 40 and 60 meters are another fact that expresses the surface dynamics, which is linked not only to the superficial runoff water, but also to the subsurface displacement water, that prepares the ways to the creation and development of gullies.

The particularities related to the kind of watershed and its inclinations are in the own value and distribution of the clinografic classes. Surfaces with low declivity, around 1 to 6 %, present the lower indexes in the higher and lower sections of the relief, while the surfaces with high declivity are confined to the carving surfaces of the drainage.

The very low clinografic indexes in the water divide surfaces establish conditions that, in general, make possible the pedogenetic activity in the higher sections of the land, and in the section of watersheds where we find a more accentuated declivity, the soils present a sandy

[12] Dimensions around 300 to 400 meters.
[13] Hills with dimensions that vary from 800 to 2000 meters.

structure, moderately developed and very friable, causing a certain desestabilization in the watersheds' system.

In topographic terms, the relief of this area presents a difference in level of 160 meters, distributed in distances that may reach one or more kilometers.

The topographic distribution of the gullies in the area express, in general terms, the altimetric level of the land that has been attacked by the infiltration/runoff water.

A detailed analysis of the Lansat satelite image,along with the topographic maps of the region, revealed that the gully erosion system is part of the altimetric level between the quotas of 120 to160 meters, and the level of their higher frequency correspond to 140 – 160 meters.

Considering the two modalities of gully erosion in terms of vegetal cover, details like the higher concentration of gullies without vegetal cover in the level of 140 to 160 meters and the distribution of gullies with vegetal cover between the level that goes from 120 to 160 meters or even up to 180 meters, express stabilization cicles and restart of erosion in the interfluvial area.

This fact can be related to possible neotectonic events in the region. The occurrence of reactivation of gully erosion processes inside older gullies, as registered in picture 3, and the carving of terraces by the drainage system, mainly of the Ibicui River, is something that gives argument to the discussion of this hypothesis.

PICTURE 3 – Reactivation process of physical erosion in "stabilized" gullies.

Picture: Ivaniza L.L Cabral. Place: near the center of Estância do Repouso. Date: April of 2003.

FINAL COMMENTS

Conjugating the erosive processes that were observed to the features of interfluvial depressions – pseudokarstic forms, gullies and ravines – it is possible to establish the key

conditioning features responsible for the creation and evolution of the main erosion fronts in the area.

In geologic terms, the structural complexity, the presence of fracture lines, besides the probable neotectonic movements in the sedimentary substratum of the area, diversify all the dynamics of the subterranean or superficial water fluxes, in forms of reactivation, beginning or intensification of the erosive dynamics in the region.

Regarding to the geomorphologic questions, in first place, these erosive phenomena must be treated as a whole, that is, the choice of the area for the analysis must enbrace surfaces between rivers, so that the determination of facts and factors that are inherent to them can be specified in the ample context of the morphologic development.

This way, in relation to the morphologic subunits that constitute the general hilly set of the area, as much the gullies as the ravines are established in the higher sections of the land, in the hypsometric portion that is extended since the quota of 120 until 180 meters.

Thus, in a basic context of a morphology constituted by ample hills, washout and small tunnels forms appear in the surface where the intemperism cover and/or Cenozoic sedimentary deposits are thick, indicating that its formation process is directly associated to the chemical intemperism events and, in a second moment, to the subterranean erosion, responsible for the transport of disintegrated sedimentary materials.

Linked to this fact, it is also added the occurrence of barriers of low permeability related to the basement levels with concentration of iron oxide.

These levels, for appearing mostly in isolated spots in the interior of the sedimentary structures, may be developing zones with high hydraulic gradient in the outlet places of the subterranean water fluxes. The water outlet propitiates a remobilization of the sandy material that is present in many sedimentary strata of the Rosario do Sul Group via the liquefying of the sandy sediments and/or the dissolution by chemical processes, characterizing events associated to the processes of piping, generating the displatement and collapse not only of the soil, but the whole destabilized set.

REFERENCES

ABREU, A A A teoria Geomorfológica e sua edificação: Análise Crítica. Revista do Instituto Geológico _ IG. 4 (1/2), p 5 – 23. 1983.

AB' SABER, A. N. Nótula sobre as superfícies aplainadas do Rio Grande do Sul. Notícia Geomorfológica. Campinas - SP, 5: 54 – 6, 1960.

_____. Um conceito de Geomorfologia a serviço das pesquisas sobre o Quaternário. Geomorfologia n° 18, IGEOG- USP, São Paulo. 1969.

BARROS SARTORI, M da G. B. As variações pluviométricas e o regime das chuvas na Região Central do Rio Grande do Sul. Boletim de Geografia Teorética. 23 (45-46): 70 – 84, 1993.

CABRAL, I. L. L ; Robaina, L. E; Medeiros, E; Neto, S. F; Sangoi. D. S. Processos erosivos associados a formas pseudo-cársticas na Depressão Periférica do Rio Grande do Sul. Anais do X Simpósio Brasileiro de Geografia Física Aplicada. UERJ. Rio de Janeiro – RJ. 2003

HOLZ, M. Do mar ao deserto: a evolução do Rio Grande do Sul no tempo geológico. Porto Alegre: Ed. Universidade. UFRGS, 1999.

MENEGAT, R; PORTO, M.L; CARRARO, C. C & FERNANDES; L. A. D. Atlas Ambiental de Porto Alegre. Porto Alegre: Ed. Universidade/UFRGS, 1999.

MOURA FUGIMOTO, N. S. V. Análise Geomorfológica de Itapuã – RS: Contribuição ao conhecimento da margem norte da Laguna do Patos. FFLCH – Dep. de Geografia, USP/SP. Dissertação de Mestrado. 1994.

PENCK, W. Morphological Analysis of land form. Macmillan and CO, London. 1953.

PONÇANO, W. L & PRANDINI, F. L. Boçoroca do estado de São Paulo: Uma revisão. Anais do IV Simpósio Nacional de Controle de Erosão. Marília/SP. 1987.

SUERTEGARAY, D. M. A trajetória da natureza: Um estudo geomorfológico sobre os areais de Quarai – RS. Tese de Doutoramento. São Paulo – USP/FFLCH. Dep. de Geografia. 1987.