PALEOSURFACES AND RELIEF EVOLUTION IN CRATONIC AREAS OF THE WESTERN PAMPEAN RANGES (PROVINCE OF SAN JUAN, ARGENTINA)

Graciela Mabel SUVIRES

CONICET and Universidad Nacional de San Juan, San Juan, Argentina. E-mail: graciela_suvires@yahoo.com.ar

ABSTRACT – The present investigation was developed in the area of Sierra de Pie de Palo, located at approximately 31º 30' S and 68°00' W, in the central eastern portion of San Juan province, Argentina. The main objective is to analyze the ancient flat surfaces located in the mountain block of Precambrian-lower Paleozoic metamorphic rocks of the Western Pampean Ranges System. In the Sierra de Pie de Palo, situated in central western Argentina, five ancient surfaces were determined at altitudes of 3000, 2500-2400, 1900, 1500-1400, and 1200-1000 m a.s.l., respectively, the oldest one being the highest. These nearly flat five surfaces are arranged in a steplike pattern and are approximately concentric with respect to the central part of the range. Relict and exhumated reliefs coexist in this area. The megafault systems of Valle Fértil (NNW), Tulum (NNE) and Salinas Grandes (ENE) have played an important role in the relief evolution of this area.
Keywords: Sierra de Pie de Palo, Western Pampean Ranges System, Paleosurfaces, San Juan province, Argentina.

RESUMEN – *G.M. Suvires - Paleosuperficies y relieve evolución en las zonas cratónicas de las Sierras Pampeanas Oeste (Provincia de San Juan, Argentina)*. Cinco niveles de paleosuperficies fueron determinados, ubicados a los 3000, 2500-2400, 1900, 1500-1400 y entre los 1200 a 1000 m.s.n.m., dispuestos en forma escalonada y aproximadamente concéntrica a la porción central de la Sierra de Pie de Palo. Estas superficies disminuyen en edad a medida que descienden en altura, coexistiendo los relieves relictuales y exhumados. Los megasistemas de fracturación de Valle Fértil (NNO), de Tulum (NNE) y de Salinas Grandes (ENE) juegan un rol importante en la evolución de este relieve pampeano.
Palabras claves: Sierra de Pie de Palo, Sistema Pampeano Occidental, Paleosuperficies, San Juan, Argentina.

INTRODUCTION

The present paper is the result of the investigation of several relict surfaces situated at different heights in the Sierra de Pie de Palo (PPR). These paleosurfaces were analyzed by the elaboration of three sections oriented transversal to the N-S trending range axis, and a fourth section along the range strike.

The regional geologic analysis has been extended to nearby ranges situated to the east of Pie de Palo, which also are included in the Western Pampean System (WPS): the Valle Fértil-La Huerta range and alineation of lower and smaller ranges, namely Las Imanas, Guayaguás and Catantal. The presence of elevated paleosurfaces in these mountain ranges was extrapolated and correlated with other relict surfaces detected in the Central Pampean Ranges by different authors (Carignano et al., 1999; Beltramone, 2006; Carignano and Cioccale, 2008; Rabassa et al., 1996). The analysis of similar surfaces in cratonic areas has also been carried out in Australia, Africa and Brazil (King, 1949; Bigarella & Ab' Saber, 1964; Twidale, 1994; Schmidt et al., 1995; Partridge & Maud, 1987).

The Pampean Ranges are characterized by widespread relict paleosurfaces at their mountain tops, which attracted attention of numerous researchers and which at the beginning were considered as a single exhumed erosion surface that was dismembered by the Andean orogeny. Nevertheless, recent studies (Carignano et al., 1999; Beltramone, 2006) state that the surfaces are different and different in age and origin, and have been exposed from the very time they were formed.

Among the mountain chains that form the Western Pampean System (WPS) the Sierra de Pie de Palo is a significant place to carry out the study of these paleosurfaces, because this Pampean range is the westernmost cratonic area of central Argentina and, moreover, in its western part it is the boundary between the WPS and the Eastern Precordillera. The Tulum tectonic depression separates both mountain systems. In this depression, the Tulum fault system, which trends NNE, is located. The limit between the Pampean ranges and the Precordillera, because of this fault system trend, gradually deviates nearer the latter mountains towards the south and west, and the Pampean basement crops out again in the Cerro Salinas. From this place to the SSW surface, some features show that the Tulum fault system continues as far south as the Montecito, where this system is interrupted by the great fault with Quaternary activity that makes up the eastern limit to the Las Peñas mountains, which are found in the Central Precordillera. This continuation of the Tulum fault system, then, divides the Tulum tectonic depression in two sub-basins since it bounds the Pampean Ranges and the Precordillera in the subsurface (Zambrano & Suvires, 1987, 2008).

THE SIERRA DE PIE DE PALO RANGE (PPR)

This range is situated between 31º 05' and 31º 48' South latitude, and from 67º 45' to 68º 20' West longitude. It is elongated from north to south, and its length is about 80 km, whilst its width averages 30 km. It covers, then, an extension surpassing 2400 km^2. The highest summit is in the north central part of this range: 3162 m above sea level (m a.s.l., Mogote Los Corralitos) (Figure 1).

The PPR longitudinal shape resembles slightly that of a dome, and the line of summits descends gradually towards the south, with an angle between 25º to 30º. This profile, which resembles a whaleback, is asymmetric in both ends: to the south it is covered by the Médanos Grandes field of dunes, which extends into the piedmont bajada (Suvires, 1984 a and b). To the north, this profile is interrupted by a transverse fault

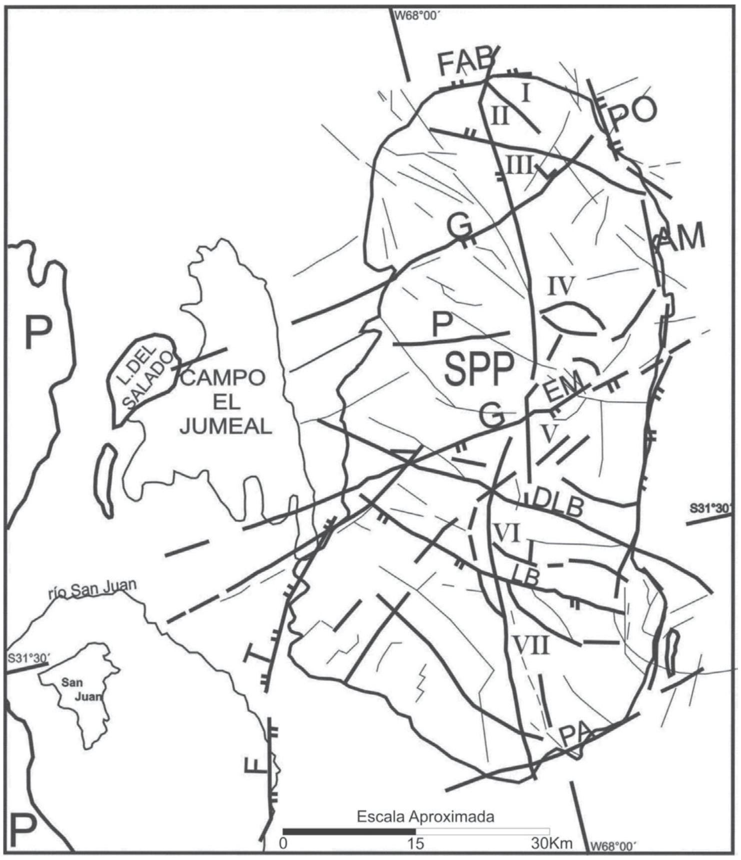

FIGURE 1. Morphostructures in the Western Pampean System of the Sierra de Pie de Palo (PPR). I to VII: blocks limited by main fractures. P: Precordillera. G-L: Guayaupa-Lima ravine fracture. GEM: Grande-El Molle ravine fracture. DLB: Los Burros ravine fracture. LB: Las Bayas ravine fracture. FAB: Agua Brava fault. FT:Tulum System fault. FC: Central fracture. LF: La Fortuna ravine fault. P: Potrerillos ravine fault. PO: Porongos fault. PA: Pajaritos fault. AM: Ampacama fault. (Nomenclature after Costa et al., 2008).

with the upthrowing block to the south. This fault, named Agua Brava in the inventory of Quaternary deformation of Argentina, makes up the northern limit of the Sierra de Pie de Palo with the Bermejo tectonic depression. The northeastern limit of the PPR is the Porongos fault, whereas the Ampacama, Niquizanga, La Posta and Pajaritos faults make up its eastern and southeastern boundaries (the nomenclature of these faults is after Costa et al., 2008).

The PPR can be considered an uplifted block surrounded by tectonic depressions. The Tulum depression (unit A) lies to the west and southwest and is drained by the Río San Juan. It is closed to the north by the Mogna structural high (unit B) (Zambrano & Suvires, 2005). To the north and east, the PPR is limited by the Zanjón-Río Bermejo depression (unit C) which separates this range from the Valle Fértil-La Huerta Mountains (unit D).

The PPR, which is a fractured basement block, is limited to the west by the Tulum megatrace. It is crossed in its central part by the ENE-WSW trending Salinas Grandes megatrace and limited to the east by the Valle Fértil megatrace. The tectonic activity of these regmagenic fracturing megasystems continues in the present time and gives rise to deformation in the Quaternary covers and reliefs. (Figure 1).

STUDIED LANDSCAPES

The PPR relief shows an endless number of crests and secondary elevations with different orientations and heights from 600 to 3100 m a.s.l. As a whole, it has an elliptic shape, with a curved and slightly sigmoidal central axis. The range has a zone with high summits running from north to south, which divides the surface runoff to the east and west. The drainage system is hierarchically arranged, with a centrifugal radial pattern and a dominant tectonic control. The longitudinal and transversal valley sections are broken. The fluvial forms are polycyclic (Suvires, 1991) (Figures 2A and B).

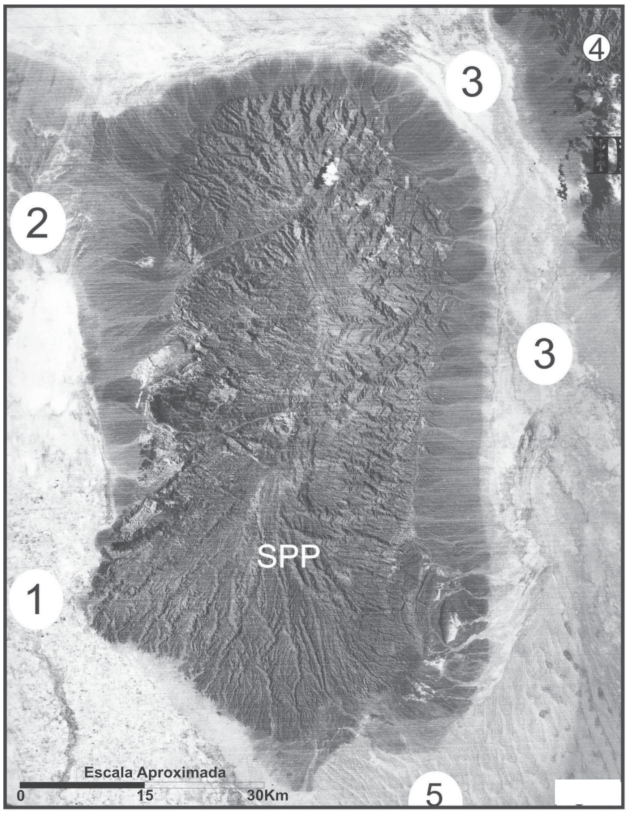

FIGURE 2A. Satellite image of the Sierra de Pie de Palo (PPR). **1**. Tulum depression; **2**. Mogna structural high; **3**. Zanjón-Bermejo depression; **4**. Valle Fértil-La Huerta range; **5**. Médanos Grandes dunes.

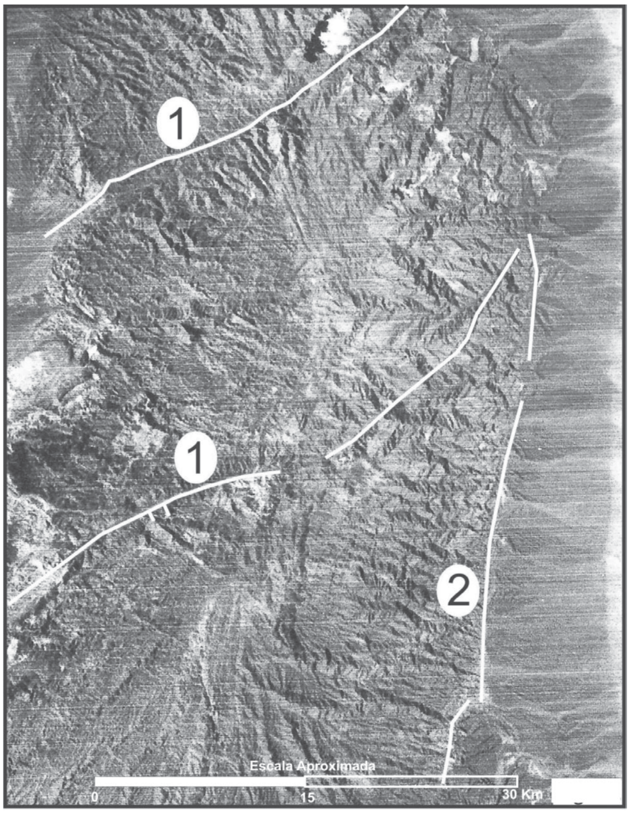

FIGURE 2B. Paleosurfaces and fractures in the PPR mountains. **1**. Salinas Grandes megafracture (Guayaupa-Lima and El Molle-Grande faults); **2**. PPR eastern edge megafracture (Porongos, Ampacama, Niquizanga and La Posta faults).

The central part of the PPR has nearly flat elevated surfaces, arranged is steps both from north to south and west to east, which are analyzed in the present article.

The PPR was defined by Ortiz & Zambrano (1981) as a structure made up by uplifted basement blocks limited by reverse faults. The profile of the range indicates that the fractures between these blocks have been active up to the present time. The maximum altitude difference between this range and the Tulum depression is 2500 meters.

Many water courses exist in the area, some incised meander shaped, which flow in present day deep gorges. The longitudinal profile of some gorges, as in the Piedras Blancas, is described by Castro (1980) as sinuous, with steep slopes in the headwaters, moderate downstream and, at few km from the outlet it becomes a narrow valley with steep banks.

In the mountain area, Suvires (1991) indicated the existence of incised valleys and of places where the present day valley level has been carved in earlier cyclic surfaces. The vertical incission in some valleys, as in the El Molle-Grande gorge is 500 m deep.

The relief differences in the mountainous area are a result of the characteristics of the stream courses, interfluves, erosion, drainage texture, density + frequency), all of which can easily be observed in the south, east, northeast, west and north flanks, and also in the central part.

The earthquake that took place on November 23, 1977 (M = 7.3, Richter scale), in the province of San Juan, had its epicenter in the studied area. It produced crustal deformations in the surface, which were recorded by accurate geodetic levelling done before this seism, in 1938, 1967, 1975-76, and after the quake, in 1978, 1979, 1980, 1981 and from 1991 to 1995 (Robles & Sisterna, 1980; Sisterna et al., 1993; Suvires et al., 1995).

These precision records permitted to observe the discontinous type of relief generation, both in height and horizontal shortening, produced by the earthquake, as well as the displacement of slopes and differences in elevation in the land surface. The range height rose 100 cm from 1978 to 1980, but after four years stress relaxing took place, which caused a several cm height reduction of the uplifted places and a similar elevation of the depressed zones (Tulum and Bermejo valleys). The geodetic records carried out during 18 years after the earthquake show a positive increase in elevation in the PPS mountainous area and a loss in height in both mentioned valleys (Suvires et al., 1995).

PALEOSURFACE LEVELS

The paleosurfaces studied have been elaborated in the Precambrian metamorphic and Paleozoic granitoid rocks exposed in the PPR. The four profiles where these paleosurfaces are represented were prepared by using the topographic sheet 20d of the National Institute of Geology and Mining of Argentina, on the scale 1:200,000, with available structural geologic information on the area, fieldwork and land digital models done by the present author (Figures 3 and Plate 1).

The PPR averages 79 km in length and 35.5 km in width. The longitudinal morphology is asymmetric, with its northern slope steeper (about 12 %) than the southern (5 to 6 %) (Suvires, 1984 a). In the longitudinal profile (B-B') seven blocks were identified (I to VII) with different sizes and altitudes. These blocks are limited by fractures running parallel to transverse ephemeral stream courses, such as Fortuna, Guayaupa-Lima, El Molle-Grande, Durazno, de los Burros and Las Bayas (Figure 1).

In block I, the range summits rise sharply from 500 meters to 2000 meters a.s.l., from north to south. Blocks II and III are still higher, up to 2400 meters a.s.l. Block IV is the highest and reaches 3160 meters in the Mogote Los Corralitos. It is in the north central part of the range. To the south thereof, block V reduces its height in about 500 meters, at the El Molle-Grande ravine. This gorge, as well as the Guayaupa-Lima and El Durazno ones, is the geomorphologic expression of the passage of the Salinas Grandes megafracture across the PPR (Baldis et al., 1990).

Block VI extends between the De Los Burros and the Las Bayas ravines, and its altitudes decrease from 2000 to 1500 meters a.s.l. from north to south. South of the latter, block VII begins, the heights of which are 1500 meters in the north and 700 meters in the south (Figure 1). The PPR shows a regional altitude reduction to the SSW along its longitudinal axis.

The sections transverse to the range axis show the asymmetry of their profiles, with 12 % in the western and 20 % in the eastern slopes. From the central axis of the range to the west the number and proximity of the erosion paleosurfaces are higher than to the east thereof. In section AA', 8 paleosurfaces are found in the west compared to 5 in the eastern slope. Section CC' shows 11 surfaces in the west versus 8 in the east and, in section DD', 11 are in the west but only 4 in the east (Plate 1).

The integral analysis of these sections as well as the observation of land digital models (LDM) indicate that summits and valley bottoms keep a height regularity and clearly show five surface levels at altitudes of 3000, 2500-2400, 1900, 1500-1400 and 1200-1000 m a.s.l.

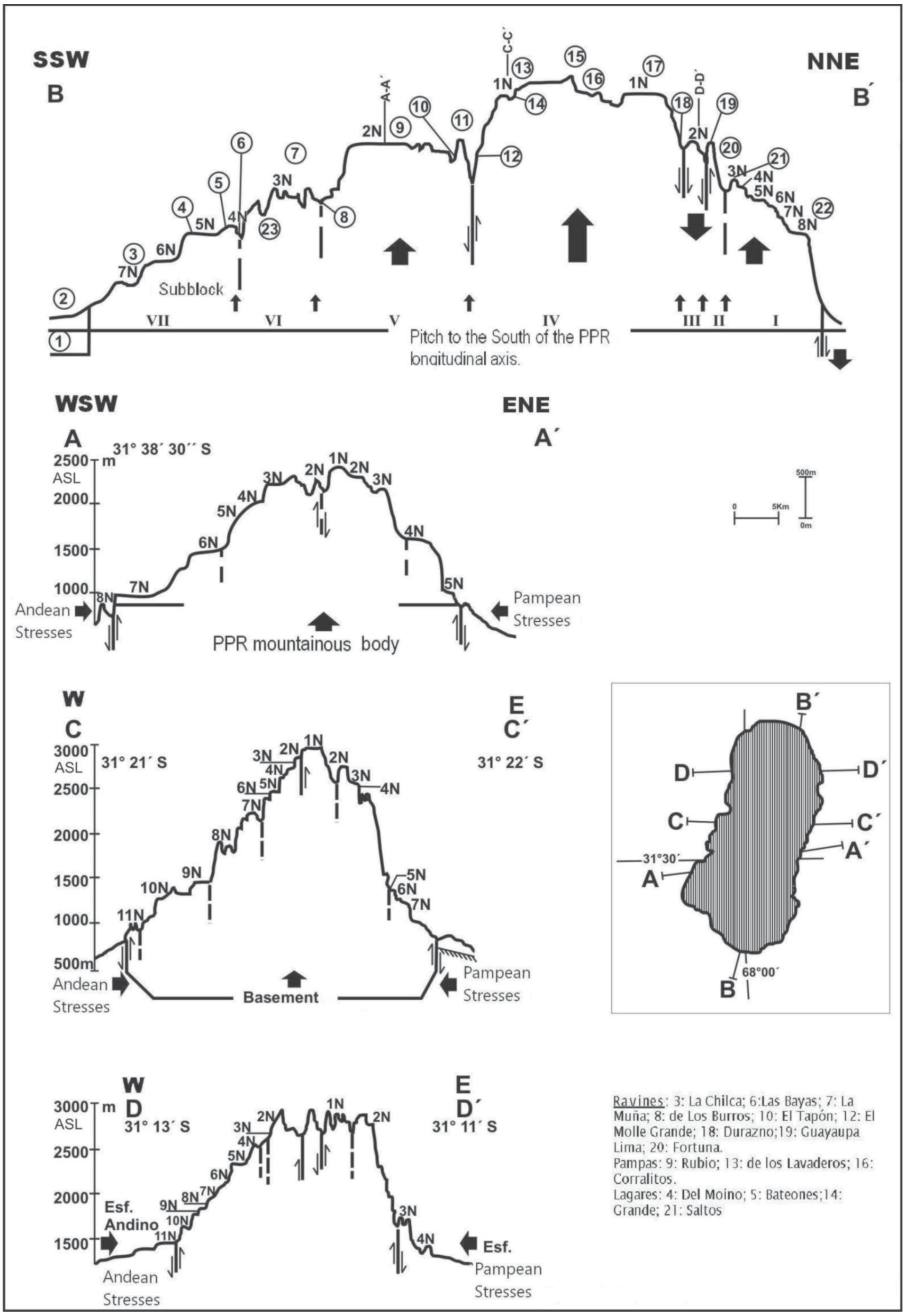

FIGURE 3. Longitudinal and transversal profiles. Pitch to the south of the PPR longitudinal axis. Section BB' oriented from SSW to NNE. Section AA' oriented from WSW to ENE. PPR mountain body. Section CC' oriented from W to E. Basement. Section DD' oriented from W to E.

PLATE 1. Photos showing the paleosurfaces on the south and southeastern sector of the PPR.

All these surfaces are arranged approximately concentric to the range center.

The central sector of the high summits of PPR (Figure 2 B) shows an important flattening at the mountain tops, which are remnants of ancient planar surfaces interrupted by subsequent fluvial valleys that follow the range axis and have experienced deep vertical erosion.

The paleosurface reliefs, particularly the higher, are flat and have been named "pampas" by the local inhabitants. These reliefs are interrupted by promontories in those places where the rocks have not been completely eroded. Such elevations are locally given the name of "mogotes". For instance, the Lavaderos and Corralitos pampas, in the highest sector of the range, are interrupted by the Los Corralitos and Piedras Paradas mogotes. Other local place names can be read in longitudinal and transversal profiles.

The formation of these erosion surfaces should have been favored by weathering conditions and high thermal amplitudes since Paleozoic times up to the present. The nearness of the PPR to the Eastern Precordillera permits to assume that both areas could have shared similar paleoclimatic conditions. According to Martos (2008), the morphoclimatic stages rose and descended during the Quaternary, giving origin to a high Periglacial Stage with semiarid climate in the Central and Western Precordilleras, and a Nival or Cryonival Stage in the Eastern Precordillera, perhaps with periglacial features in its higher summits.

The PPR, particularly in its north central block, shows that it is frequent to observe snow capped tops during the current winter seasons in its maximum elevations. The fallen snow feeds the water courses and springs that come to the surface in its eastern and western slopes. It is highly probable that dominant cold paleoclimatic conditions in the higher mountains favored the formation of the intense cryo-clastism observed in basement rocks. The detrital regolith layer made up by clasts of different metamorphic rocks, partly in huge blocks, and by abundant rounded quartz pebbles, can be observed along the road to Mogote Los Corralitos.

ANALYSIS, DISCUSSION AND INTERPRETATION OF THE EROSION SURFACES

The steplike arrangement of the erosion surfaces probably indicates different ages and genesis in their formation along the complex tectonic and climatic history of the PPR relief.

Carignano and Cioccale (2008) determined four paleosurface levels in the North and Ambargasta ranges, in the provinces of Córdoba and Santiago del Estero. These levels are situated at about 900-800, 750-600, 650-550 and 500-350 m a.s.l. Because of the step arrangement and regular distribution of the paleosurfaces these authors indicate a common origin for each level, and younger age of their formation with reduction of altitudes.

This was confirmed by the relation between the surfaces and the correlative sediments that cover them. This situation is not easy to prove in the PPR Pampean block, since there is no information about the existence of neither Paleozoic nor Mesozoic sedimentary covers in this range. Even though the highest paleosurfaces are capped by detritic layers of clasts of metamorphic rocks and abundant quartz, very probably of Quaternary age, no detail studies have been carried out on them up to date or of their weathering profiles.

Nevertheless, to the east, and in the Bermejo river depression, as well as in the La Huerta-Valle Fértil range, the crystalline basement is covered by continental sedimentary deposits of Carboniferous, Permian, Triassic, Cretaceous, and Cenozoic ages. The Cretacous deposits, named El Gigante Group by Yrigoyen (1975), extend from the Marayes basin to the north to Guayaguás range to the south.

The PPR is considered a doubly fractured basement block with an important antithetic faulting: faults with high angle in the surface, which reduce their angle, so that thedeeper faults become nearly tangential to the Moho (Valle Fértil, Pie de Palo and Valdivia; Baldis et al., 1990; Jordan & Allmendinger, 1986).

Beltramone (2006) indicated two groups of erosion levels for the Pampean Ranges of Córdoba; one restricted to the line of summits and the other related to the incission of the current fluvial system. This author considers these erosion surfaces as belonging to an ancient pre-Triassic peneplain, which was buried under Cretaceous deposits and thereafter exhumed and dissected by Andean orogeny tectonic phases. Rabassa et al. (1996), based on the methodology developed by Partridge & Maud (1987), correlated erosion surfaces in cratonic areas of Argentina, to which they assigned different ages and origins, with those situated in South Africa.

In the PPR, the "mogotes" that stand out in the "pampas" and the high altitudes of the upper paleosurfaces are two conditions which induce to think that these high surfaces have not been covered and have remained exposed from the time of their formation. In spite of their elevation and original position they have been, and are also being modified, due to the strong regional tectonic control produced by the western (Andean) and eastern (Pampean) stresses.

This means that the PPR relief expressed in these paleosurfaces, in the presence of valleys incised in deep ravines, in old elevated valleys incised by younger valleys, is the outcome of the action between periods dominated by erosion processes and periods of tectonic stability (elaboration of surfaces by weathering processes) on one hand and intermittent upheavals and other effects of the local and regional tectonics on the other.

It is beyond doubt the participation in the regional geomorphologic modelling of the Valle Fértil megafracture (VF) striking NNW (also named Bermejo-Desaguadero) since the Cretaceous rifting in the studied area. East of this megatrace two Triassic basins are situated: to the north of the Valle Fértil-La Huerta range, the Ischigualasto-Villa Unión basin, and to the south of this range, the Marayes-Catantal basin.

The Mesozoic outcrops in both basins were exhumed very likely by the action of the VF megafracture, which facilitated the dismantling and the generation of erosion and structural inverted reliefs (Suvires, 1986). The tectonic inversion processes have frequently been cited among the mechanisms that influence in the definition of the Andean orogeny, especially in NW Argentina after Grier et al. (1991), even though this had already been noted by Mingramm et al.(1979).

Generally the interpretations of tectonic reactivation indicate Cenozoic tectonic inversion processes in the normal faults, related to the Cretaceous rift (Grier et al., 1991; Carrera et al., 2000). Subsequently, Hongn et al. (2008), propose that the basement structures played a primary role in the emplacement of normal Cretaceous faults, which were reactivated and in some cases had a direct influence on the orientation of the Cenozoic structures (Hongn et al., 2006).

CONCLUSIONS

The integral analysis of the profiles, the observation of land digital models and field data indicate that summits and valley beds in the Pie de Palo range show five steplike paleosurfaces arranged approximately concentric to the range central part, and which are, respectively, at altitudes of 3000, 2500-2400, 1900, 1500-1400 and from 1200 to 1100 m a.s.l.

The paleosurfaces situated at high and medium altitudes in the PPR are likely to have been exposed since the time of their formation and the oldest ones are of erosion-relict type. The lower surfaces, due to the absence of overlying correlative sediments, are considered to be younger on the sole basis of regional correlations with paleosurfaces existing in the Central Pampean Ranges.

In the slope break between the mountain zone and the piedmont belt, the youngest erosion surfaces are in contact with dislocated pink Miocene deposits.

The elevations of the surveyed paleosurfaces are referred to the present day relief of the PPR, not to the relief existing at their formation. All the surfaces have been relocated as a result of the intermittent tectonic pulses from the Paleozoic to present that took place through the activity of the megafaults that surround the range: Valle Fértil in the east, the Salinas Grandes in the central part, Tulum in the west, Porongos-Ampacama-Niquizanga-La Posta in the east, and Los Pajaritos in the southeast.

According to observations of other authors in the Central Pampean Ranges (CPR), the higher stepped paleosurfaces are the older: their ages decrease in the lower ones.

The exhumed surfaces are better exposed east of the Valle Fértil megafault, where the basement underlies Mesozoic sedimentary rocks in areas with folded and highly eroded reliefs, by effects of tectonic inversion, as in both basins: Marayes-Catantal and Ischigualasto. To establish chronologic correlations between the ancient paleosurfaces of the Western Pampean Ranges and those in the Central Pampean Ranges, the activity of the megastructures in both morphostructural regions must be borne in mind, mainly those tranding NNW and NNE.

BIBLIOGRAPHIC REFERENCES

1. BALDIS, B.; MARTÍNEZ, R.; VILLEGAS, R.; PEREYRA, M.; PÉREZ, M. Estructura, provincialismo geológico y unidades tectonoestratigráficas. In: CONGRESO GEOLÓGICO ARGENTINO, 10, 1990, San Juan. **Relatorio de Geología y Recursos Naturales de la provincia de San Juan**, 1990, v. 1, p. 186-211.
2. BELTRAMONE, C. Algunas consideraciones sobre las superficies de erosión en las Sierras Pampeanas de Córdoba. In: CONGRESO ARGENTINO DE CUATERNARIO Y GEOMORFOLOGÍA, 3, 2006, Córdoba. **Tomo II...** 2006, p. 505-513.
3. BIGARELLA, J. & AB´SABER, A. Palageographische und palaoclimatische Aspekteddes Kanozoikums in Sudbrasilien. **Zeitschrift für Geomorphologie**, v. 8, p. 286-312, 1964.
4. CARIGNANO, C. & CIOCCALE, M. Geomorfología de la sierra Norte-Ambargasta, Provincias de Córdoba y Santiago del Estero, Argentina. In: CONGRESO GEOLÓGICO ARGENTINO, 17, 2008, San Salvador de Jujuy. **Volumen...** San Salvador de Jujuy, 2008, n. 3, p. 1189-1190.
5. CARIGNANO, C.; CIOCCALE, M.; RABASSA, J. Landscapes antiquity of The Central Sierras Pampeanas (Argentina): Geomorphic evolution since the Gondwana times. **Zeitschrift für Geomorphologie**, Supp. Bd. v. 118, p. 245-268, 1999.
6. CARRERA, N.; MUÑOZ, J.A.; SÁBAT, F.; ROCA, E.; MON, R. The role of inversion tectonics in the structure of the Cordillera Oriental (NW Argentinean Andes). **Journal of Structural Geology**, n. 28, p. 1921-1932, 2006.
7. CASTRO, C.E. Estudio estratigráfico y estructural de las rocas carbonáticas de la Quebrada Piedras Blancas, Sierra Pie de Palo. **Unpublished Technical Report**, San Juan, Universidad Nacional de San Juan, Facultad de Ciencias Exactas, Físicas y Naturales, v. 1, p. 1-12, 1980.
8. COMÍNGUEZ, A.H. & RAMOS, V.A. La estructura profunda entre Precordillera y Sierras Pampeanas de la Argentina: Evidencias de la sísmica de reflexión profunda. **Revista Geológica de Chile**, v. 18, n. 1, p. 3-14, 1991.
9. COSTA, C.; CASA, A.; YAMÍN, M.; COPPOLECCHIA, M.; PÉREZ, I.; CISNEROS, H. Nuevo Mapa e Inventario de deformaciones cuaternarias argentinas. In: CONGRESO GEOLÓGICO ARGENTINO, 17, 2008, San Salvador de Jujuy. **Volumen...** San Salvador de Jujuy, 2008, n. 3, p. 1132.
10. GRIER, M.E.; SALFITY, J.A.; ALLMENDINGER, R.W. Andean reactivation of the Cretaceous Salta Rift, northwestern Argentina. **Journal of South American Earth Sciences**, v. 4, p. 351-372, 1991.
11. HONGN, F.; MON, R.; DEL PAPA, C.; PETRINOVIC, I.; POWELL, J. Herencia de anisotropías del basamento en las cuencas de rift cretácico y antepaís cenozoico en el noroeste argentino In: REUNIÓN DE TECTÓNICA, 13, 2006, San Luis. **Actas...** San Luis, 2006, p. 89.
12. HONGN, F.; MON, R.; PETRINOVIC, I.; DEL PAPA, C.; POWELL, J. Inversión tectónica en el Noroeste Argentino: Influencia de las heterogeneidades del basamento. In: CONGRESO GEOLÓGICO ARGENTINO, 17, 2008, San Salvador de Jujuy. **Actas...** San Salvador de Jujuy, 2008, n. 1, p. 25-26.
13. JORDAN, T. & ALLMENDIGER, R. The Sierras Pampeanas of Argentina: A modern analogue a rocky mountain foreland deformation. **American Journal of Science**, p. 286-290, 1986.
14. KING, L.C. On the ages of African Landscapes. **Quarterly Journal of the Geological Society of London**, v. 104, p. 439-459, 1949.
15. MARTOS, L. Evolución paleogeográfica, paleolimática y paleoambiental del piedemonte oriental y Sierra de Pedernal. Sector centro-austral. San Juan. Argentina. In: CONGRESO

GEOLÓGICO ARGENTINO, 17, 2008, San Salvador de Jujuy. **Volumen...** San Salvador de Jujuy, 2008, n. 2, p. 715-716.
16. MINGRAMM, A.; RUSSO, A.; POZZO, A.; CAZAU, L. Sierras Subandinas. In: SIMPOSIO DE GEOLOGÍA REGIONAL ARGENTINA, 2, 1979, Córdoba. **Anais...** Córdoba, 1979, p. 95-138.
17. ORTIZ, A. & ZAMBRANO, J.J. La provincia geológica Precordillera Oriental. In: CONGRESO GEOLÓGICO ARGENTINO, 8, 1981, San Luis. **Volumen...** San Luis, 1981, n. 3, p. 59-74.
18. PARTRIDGE, T.C. & MAUD, R.R. Geomorphic evolution of southern Africa since the Mesozoic. **South African Journal of Geology**, v. 90, n. 2, p. 179-208, 1987.
19. RABASSA, J.; ZÁRATE, M.; CIOCCALE, M.; CARIGNIANO, C.; PARTRIDGE, T.C.; MAUD, R.R. Paisajes relictuales Gondwanicos (Cretácico-Paleoceno) en áreas cratónicas de Argentina. In: CONGRESO GEOLÓGICO ARGENTINO, 13, 1996. **Actas...** 1996, v. 4, p. 219.
20. ROBLES, J.A. & SISTERNA, J. Variaciones de cotas producidas por el terremoto de Caucete del 23-11-1977. **Unpublished Technical Report**, Instituto Sismológico de Zonda, Universidad Nacional de San Juan, p. 1-65, 1980.
21. SCHMIDT, C.; ASTINI, R.A.; COSTA, CH.; GARDINI, C.E.; KRAEMER, P.E. Cretaceous rifting, alluvial fan sedimentation and Neogene inversion, Southern Sierras Pampeanas, Argentina. In: A.J. TANDKARD, R.S. SUÁREZ AND H. WELSINK (Eds.), **Petroleum basins of South America**. American Association of Petroleum Geologist, Memoir 62, p. 341-358, 1995.
22. SISTERNA, J.; QUIROGA, M.; ROBLES, J.A.; TRIEP, E.; YACANDE, M. **Deformaciones superficiales en los valles de Tulum y Bermejo. Instituto Sismológico F.S. Volponi**. PID 3-112800/88. San Juan, Universidad Nacional de San Juan, Informe, p. 1-145, 1993.
23. SUVIRES, G.M. **Geomorfología regional del extremo suroriental de la provincia de San Juan y Edafología del Cuaternario en un sector de la planicie del río Bermejo, San Juan, Argentina**. San Juan, 1984, Tomo I: 70-110. Doctoral Thesis – Facultad de Ciencias Exactas Físicas y Naturales, Universidad Nacional de San Juan. (a)
24. SUVIRES, G.M. Influencia de la erosión y de la tectónica fracturante en la elaboración de rasgos geomórficos en la sierra Pie de Palo. San Juan. In: SIMPOSIO NACIONAL SOBRE EROSIÓN Y SEDIMENTACIÓN, 1, 1984, Mendoza. **Tomo** I, Mendoza, 1984, p. 2-9. (b)
25. SUVIRES, G.M. Anticlinales aportillados, Cuestas y crestas homoclinales, valles ortoclinales y otras formas de relieves plegados delimitados con ayuda de imágenes de sensores remotos. In: SIMPOSIO LATINOAMERICANO DE SENSORES REMOTOS, 1, 1986, Gramado. **Anais…** Gramado, 1986, v. 1, p. 733-739.
26. SUVIRES, G.M. Paleoformas eólicas y fluviales en regiones desérticas del centro-oeste argentino. In: INTERNATIONAL CONFERENCE ON GEOMORPHOLOGY, 2, 1991, Frankfurt. **Boletim...** Bamberger Geographische Schriften, 1991, n. 11, p. 125-133.
27. SUVIRES, G.M.; SISTERNA, J.; QUIROGA, M.; ROBLES, J.A. Movilidad de la corteza terrestre y su importancia en los asentamientos y planes de ordenación territorial. Sector sudeste de San Juan, Argentina. In: SEMINARIO LA ARQUITECTURA EN ZONAS SÍSMICAS, 1995, San Juan, Argentina. **Actas…** San Juan, 1995, p. 93-98.
28. TWIDALE, C. Gondwanan (Late Jurassic and Cretaceous) paleosurfaces of the Australian craton. **Palaeogeography, Palaeoclimatology, Palaeocecology**, v. 112, p. 157-186, 1994.
29. ZAMBRANO, J.J. & SUVIRES, G.M. La estructura superficial y profunda del valle del Tulum. Provincia de San Juan. In: CONGRESO GEOLÓGICO ARGENTINO, 10, 1987, Tucumán. **Actas…** Tucumán, 1987, v. 1, p. 267-270.
30. ZAMBRANO, J.J. & SUVIRES, G.M. Aporte a la Geología del Alto de Mogna, al norte de la depresión del Tulum, provincia de San Juan. **Revista Asociación Geológica Argentina**, v. 60, n. 2, p. 425-427, 2005.
31. ZAMBRANO, J.J. & SUVIRES, G.M. Actualización en el límite entre sierras Pampeanas Occidentales y Precordillera Oriental, en la Provincia de San Juan. **Revista de la Asociación Geológica Argentina**, v. 63, n. 1, p. 110-116, 2008.
32. YRIGOYEN, M.R. La edad cretácica del Grupo del Gigante y su relación con cuencas Circunvecinas. In: CONGRESO ARGENTINO DE PALEONTOLOGÍA Y BIOESTRATIGRAFÍA, 1, 1975, Tucumán. **Actas…** Tucumán, 1975, v. 1, p. 1-8.

Manuscrito Recebido em: 18 de agosto de 2010
Revisado e Aceito em: 5 de outubro de 2010