Finisterra, XIX, 37, Lisboa, 1984, p. 37-49.

PEDIMENTATION IN SOUTH PORTUGAL

REINHARD GAIDA

In 1951 FEIO published his fundamental study about the geomorphology of southern Portugal. Since then the part of the south-portuguese province Baixo Alentejo that lies south of the line Santiago do Cacém-Beja has not been the object of a detailled geomorphological study. In the recent past the author examined the geomorphological meaning of a widespread type of sediment that can be found in the Baixo Alentejo (1). This sediment can be characterized in the following way:

Subangular quartz pebbles lie in a red matrix. The sediment lies either upon the peneplain that has been cut into paleozoic rocks or upon paleogene and neogene sediments in the Sado bassin. The surface of the sediments is plain, the undersurface uneven. The thickness reaches from 0,5 to 27 metres. The highest occurence of the sediment is the Tacão (242 m, near Casével) on the peneplain; the lowest lies at Panasqueira (78 m, near Canhestros) in the Sado bassin.

The sediments were first mentioned by C. RIBEIRO in 1866 and described by O. RIBEIRO and FEIO (1949) and FEIO (1951). O. RIBEIRO and FEIO called it *Raña* using a term that has been established by geologists and geomorphologists who worked in central Spain. Sheet-floods and tectonical movements were responsible for the genesis of these sediments that were deposited under arid circumstances in the Villafranca. The Rañas in the northern part of the Baixo Alentejo (Bacia de

(1) Author thanks Prof. Dr. T. M. AZEVEDO (Lisboa), Prof. Dr. M. FEIO (Évora) and Prof. Dr. G. WENZENS (Düsseldorf) for usefull discussions.

Marmelar) were studied by ALVES in 1971. The existing cartography of the red sediments of the central and southern regions of the Baixo Alentejo is insufficient. The enclosed map (fig. 1) is the reduction of a map that has been drawn after detailled field research in the Baixo Alentejo (GAIDA, 1984). The author proposes to use the designation *Formação de Panoias* (FP). Panoias is a village in the south-west of Aljustrel which has been built on a rest of the described sediment. The older name Raña could lead to misunderstandings (cf. text). The designation *Formação de Rio de Moinhos* which is used on the unpublished geological maps of the Serviço do Fomento Mineiro in Beja should also be omitted. The Formação de Rio do Moinhos is a very heterogenous group that contains, besides the FP, two different subjects:

— Neogene sediments that have been reddened superficially,

— (Red) soils that contain angular quartzes. These quartzes sometimes are rounded slightly by weathering (Pseudorounding according to GEHRENKEMPER, 1978).

Furthermore the FP should neither be mixed up with slope deposits that just document local transportation nor with red fluvial sediments.

THE REDDENING

The most impressive aspect or the FP is the intensively reddened matrix (usually silty loam, sandy clay or clayey loam). The hue of the colours can be classified according to Munsell soil color charts as 2,5 YR or 5 YR. X-ray diffractometer analysis yields information about the nature and the significance of the red colour.

The minerals of the FP are shown in Table 1. The percentage of the different clay minerals is calculated according to the semiquantitative method of LEWANDOWSKI (1982).

The results can be interpreted in the following way: The dominant clay minerals of the source rocks (greywackesand mudstones) are Muscovite/Illite and Chlorite. Kaolinite occurs but in a relatively small quantity. In the FP Kaolinite dominates slightly over Muscovite/Illite. The reddering is, as expected, caused by Hematite that exists beside Goethite. Hematite was

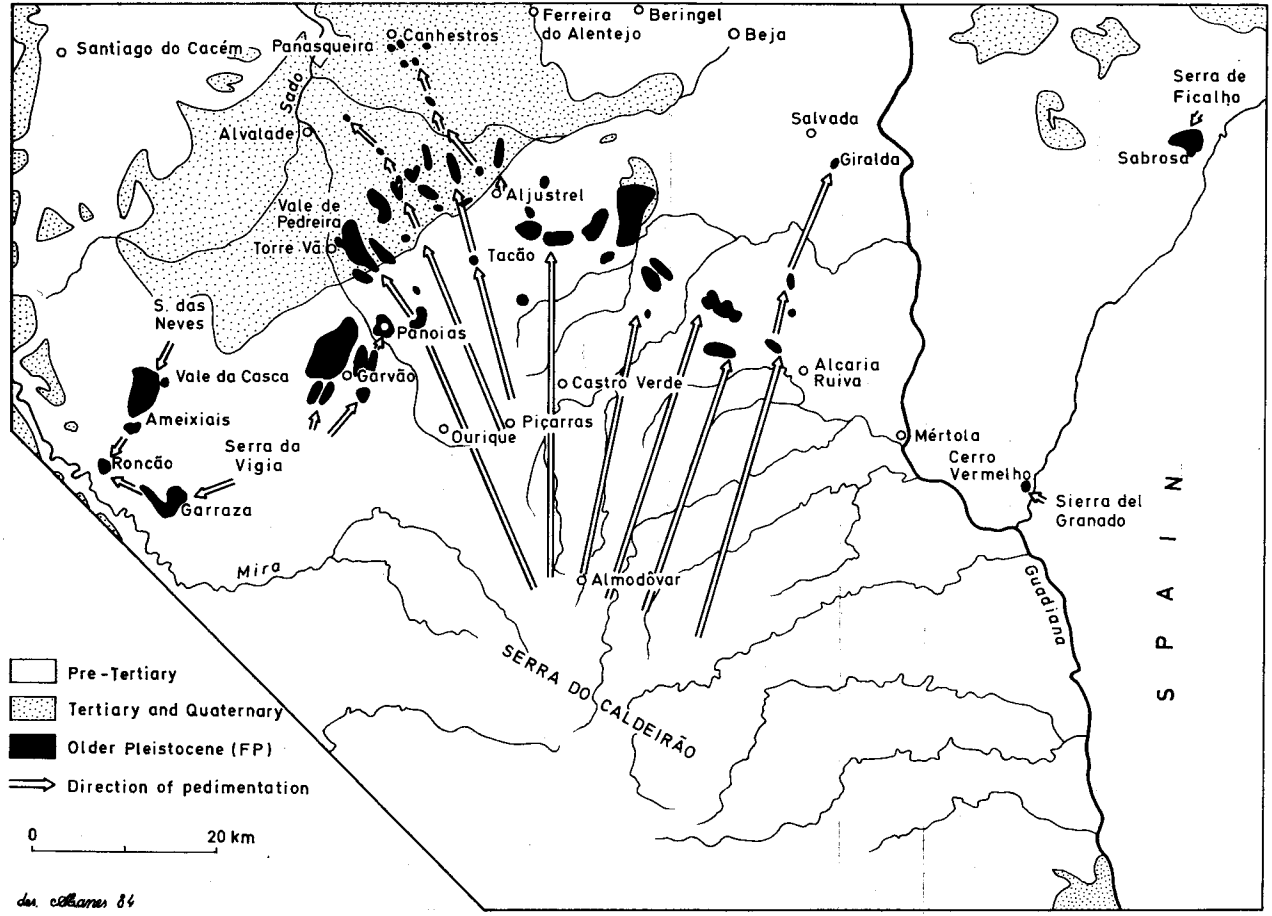

Fig. 1 — Geological Map of the Baixo Alentejo (Survey).

TABLE 1

Results of X-ray examinations of samples of the *Formação de Panoias*

Sample	Q.	O.	P.	M./I.	K.	V.	M.	A.	G.	H.	L.	C.
Roncão	+++	(+)		45 %	55 %					(+)		
Ameixias	++			25 %	75 %				++			
Besteiros	++			65 %	35 %					+		
Panoias A	++			60 %	40 %				+	+		
Panoias B	+	+		45 %	45 %	10 %			(+)	(+)		
Vale de Pedreira	+++			40 %	60 %				+			
Pego	+	(+)		30 %	65 %	5 %			+	+		
Outeiro do Negro	+++			30 %	70 %				+			
Tacão	++			55 %	45 %				+			
Panasqueira	++			40 %	20 %		40 %		+			
Poceirão	++			20 %	80 %				++	+	+	
Madruga	+	(+)		30 %	45 %		25 %					
Giralda	++			40 %	55 %	5 %			+			
Sabrosa	+++			55 %	45 %				+	+		
Cerro Vermelho	+++			35 %	65 %				+	+		

Q. = Quartz, O. = Orthoclase, P. = Plagioclase, M./I. = Muscovite/Illite, K. = Kaolinite, V. = Vermiculite, M. = Montmorillonite, A. = Attapulgite, G. = Goethite, H. = Hematite, L. = Lepidokrokite, C. = Calcite.

not found in every sample but its existence in these samples could be assumed because small contents of Hematite cause reddening. The knowledge of the dominant clay minerals (Kaolinite, Muscovite/Illite) leads to the determination of the soil typus. DUCHAUFOUR (1977) subdivides sesquioxid rich soils into three main groups:

— Fersiallitic soils (Dominance of three-layer clay minerals),

— Ferruginous soil (Dominance of Kaolinite, sometimes even of Gibbsite),

— Ferallitic soils (Dominance of Gibbsite).

The FP can be classified as intermediate between Fersiallitic and Ferruginous soils. The dominance of Kaolinite which is in part inherited is not clear enough to place these soils into the group of the Ferruginous soils.

It is possible to state that ferrallitic pedogenesis did not take place. Deducing from this fact one can say that lateritisation which must be regarded as a special case of ferallitic pedogenesis (DUCHAUFOUR, 1977) can be excluded despite its description in the sediments of the FP by ANDRADE and SCHERMERHORN (1971) and CARDOSO (1965).

The pedogenesis led to the nearly complete destruction of the instable heavy minerals (Augite, Amphibol, Granat and Epidot).

The existence of Hematite and the considerable percentage of Kaolinite allows a conclusion about the paleoclimate. The soil of the FP was formed under climatic conditions which were more humid and warmer than the actual climate. (In South Portugal actual soils and sediments contain neither newly formed Kaolinite nor Hematite).

Three possibilities may be considered when the reddening and the pedogenesis took place:

1) The reddening occured after the deposition of the sediments. This theory is favored by CARDOSO (1965). An objection to this thesis is this: An intense reddening that leads to red soils that are up to 27 m thick is rare but possible. This reddening would have led simultaneously to intense reddening of the neogene sediments in the Sado bassin. South of Alvalade and south-west of Ferreira do Alentejo neogene sediments lie flat. They have not been dissected during

the pleistocene. However they show only slight or even no reddening.

2) The reddening took place during the deposition of the sediments. It can be proved that the FP was deposited under semiarid conditions (text). The soils however were formed under subtropical humid conditions. Even a seasonal alternation (humid season allows reddening, semiarid season allows erosion, transport, and deposition) is also unable to explain the situation. A humid season that leads to the formation of red soils of the described kind would have certainly allowed the growing of a dense vegetation. These plants would have been able to protect the soil even during the semiarid season.

3) One comes to the conclusion that the soils were older than the sediment. The reddening probably was not very intense (0,5 to 1 m). It took place under a climate that was subtropical humid. After a change of the climate (reduction and concentration of precipitation) the red soils that contained angular quartzes were eroded, transported, and deposited as FP. The pebbles were slightly rounded. From the viewpoint of the pedologists the FP can be considered as an accumulated red soil.

The Sedimentation

After having gained information about the nature and the paleoclimatic significance of the reddening the process of sedimentation has to be examined.

The dominant mineral of the pebbles of the FP is quartz. Deducing from this fact two regions can be excluded from being the source areas:

1) The quartzitic Serras near Mértola (Serra de Alcaria Ruiva, Serra do Barão, etc.),

2) The Serra de Beringel between Beja and Ferreira do Alentejo. It is built of plutonic rocks.

The only possible source areas are the Serras da Senhora das Neves, da Vigia, do Caldeirão, de Ficalho and the Sierra del Granado in Spain on the opposite side of the Rio Chança. The dominant rock of these Serras are greywackes and slates. They weathered and produced the matrix. (The Serra de

Filcalho has a core of marble but also consists of slate and schist). The Serras contain innumerous quartz veins that delivered the pebbles.

It was easy to connect the localities of the FP in the foreland of the following four Serras to their source area:

Serra da Senhora das Neves: FP locality: Vale da Casca, Ameixias, Roncão,

Serra da Vigia: Garraza, Romão, Garvão, Panoias,

Serra de Ficalho: Sabrosa,

Sierra del Granado: Cerro Vermelho.

The position, and sometimes even the inclination of the sediments allows no other asscciation. But the source area of the majority of the occurences of sediments of the FP is still unknown. They form a big semicircle from Vale de Pedreira in the West (near Torre Vã at the Rio Sado) to Giralda in the East (near Salvada, south east of Beja). They have no relation to any Serra. Situmetric examinations did not lead to any satisfactory result, because of the scarcity of exposures.

Besides the Serra de Monchique the Serra do Caldeirão is the next highest elevation of the southern part of Portugal (Pelados: 589 m, Mú: 577 m). The drainage is centrifugal and consequent. But several rivers that instantly flow northwards were captured by affluents of the Rio Mira and the Rio Guadiana and directed towards the West, the North East and East (see fig. 1): Ribeira da Perna Seca, R. de Cachopo, R. da Maria Delgada, R. de Cobres, R. de Oeiras, R. de Carreiros, R. de Vascão, R. de Reveses, R. de Corte, R. de Mealha, R. de Foupana, and R. de Odeleite (GOUVEA, 1938). If one follows the old (abandoned) direction of these rivers one arrives exactly at the site of the FP between Vale de Pedreira and Giralda (see fig. 1).

To prevent a possible misunderstanding: It was not said that the old consequent precursors of the mentioned rivers were responsible for the sedimentation of the FP. It is just stated that an old direction of denudation existed which led from the Serra do Caldeirão northwards towards the Sado bassin and the region between Aljustrel and Mértola. This direction of denudation was later used by the consequent precursors of the mentioned rivers.

Another fact must also be considered: In all cases, especially in that of the Serra do Caldeirão, a region that is not covered with debris can be recognized between the Serra and the localities of the FP. In the case of the Serra do Caldeirão a well conserved plain without any considerable sediment can be observed between Ourique and Piçarras and between Castro Verde and Almodôvar.

The pebbles of the FP are poorly rounded. The index Z (according to CAILLEUX: $Z = \frac{?r}{L} 1000$) oscillates between 70 and 190. It is higher than that of the angular pebbles in the slope deposits and in the (non-transported) red soils. But the index and the degree of roundness is much lower than that of the fuvial sediments and that of the spanish «Raña»-pebbles.

So one has to keep in mind:

1) the missing of the FP in the proximal part of the foreland of the Serras,

2) the existence of the FP in the distal part of the foreland of the Serras,

3) the uncomplete roundness of the pebbles,

4) the corrading effect that was connected to the transport of the FP. The undersurface of the FP is — in contrast to the surface — uneven. This can be observed in the exposures in the northern part of Panoias. It can be assumed that the agents that transported the FP were able to form rills in the subsoil.

These four facts lead to the conclusion that the FP has been transported by anastomozing runs. They transported a lot of fine materials, hence the pebbles were poorly rounded.

The climate can be assumed as semiarid with reduced and concentrated precipitation. The whole process fits into the concept of pedimentation. A rock pediment without sediments was formed near the Serras. The pediments covered with debris in the remote areas are documentated today by the still existing rests of the FP.

The pedimentation was able to perfect the already existing polygenetic peneplain (FEIO, 1951) of the Baixo Alentejo. The FP is not the correlative sediment of the formation of the peneplain but indicates the last stage its retouching, before fluviatil erosion began to destroy it.

DATATION

The datation of soils and sediments is always difficult without disposing of absolute data or fossiles. In the case under consideration it is only possible to give approximative information.

The Reddening: The red soils formed under a subtropical humid climate. They contain an elevate percentage of Kaolinite. Sediments of the Pliocene of Central Portugal are characterized by the dominance of Kaolinite. (CARVALHO, 1968, 1972). They even contain lignite at times.

The Sedimentation: AZEVEDO (1979) describes red sediments on the peninsula of Setúbal, south of Lisbon, and named them Formação Vermelha de Marco Furado (= Red formation of MF). Aspect and position of these sediments are similar to that of the FP. Paleolithical material permits them to be dated as being of younger or middle villefrancian age.

To sum it up: It is highly probable that the sedimentation of the FP took place in the old Pleistocene. The reddening happened before the sedimentation, possibly during the Pliocene.

THE RAÑA QUESTION

Can the south-portuguese pediments covered with debris (FP) be considered as being the equivalent of the Spanish Rañas? The last named have been the object of intense studies of Spanish, French and German geologists and geomorphologists. In recent years WENZENS (1977), GEHRENKEMPER (1978), ROMMERSKIRCHEN (1978), FEY (1980) and OBDENBUSCH (1982) came unanimously to the conclusion that the Rañas have fluviatil origin. As it could be shown above, the FP is not the product of fluviatil processes but owes its existence to small, clay-burdened anastomozing runs.

Raña and FP are two different geomorphological phenomenona. It therefore seems unsuitable to use the term Raña to name the southern portuguese pediments covered with debris (FP).

POSTSEDIMENTARY PROCESSES

Finishing this note it seems appropriate to give some informations about the postsedimentary evolution of the FP.

Pedological Processes: The upper 50 to 120 cm of the FP were exposed to brunification during the warm periods of the Pleistocene and the Holocene. Therefore it is not always easy to detect the FP. Processes of pseudo-gleyification and stagno-gleyification sometimes descolourized parts of the red sediments.

Morphological Processes: They are more important than the pedological processes. Due to the intense linear fluviatil erosion in the middle and upper Pleistocene only rests of the FP have remained till now (see fig. 1). The intense erosion may be explained by three reasons:

1) The increase of precipitation,

2) The physical weathering caused by periglacial processes. They led to the formation of solifluidal slope deposits (DAVEAU, 1973 and BROSCHE, 1978) and angular pebbles resulting from the action of frost. The last named can be observed in the Mértola region (GAIDA, 1984),

3) The sinking of the sea level (FEIO, 1947).

High fluviatil accumulation terraces often contain reworked material of the FP. Clay minerals and iron oxides are inherited. Red fluviatil terraces can be mixed up with sediments of the FP, although their pebbles are better rounded.

Sediments of the FP were sometimes inclined tectonically after sedimentation. This can be observed very well in the Garvão area near Besteiros. The old abandoned road to Ourique offers excellent exposures (pl. I, A). This is a new proof of quaternay tectonical activity in Portugal.

BIBLIOGRAPHY

ALVES, C. O. (1971), «A Bacia de Marmelar. Aplicação de métodos sedimentológicos ao estudo da evolução do relevo», *Finisterra*, 6, 218-245.

ANDRADE, R. F. and SCHERMERHORN, L. J. G. (1971), «Aljustrel e Gavião». *In:* CARVALHO, D. *et al.*, «Principais jazigos minerais do Sul de Portugal», *1.° Congresso Hispano-Luso-Americano de Geologia Económica*, Madrid-Lisboa, Livro Guia Excurs, 4, 32-59.

AZEVEDO, T. M. (1979), «A Formação vermelha de Marco Furado (Península de Setúbal)», *Bol. Soc. Geol. Port.*, 21, 153-162.

BROSCHE, K. U. (1978), «Beiträge zum rezenten und vorzeitlichen Periglazialen Formenschatz auf der Iberischen Halbinsel», *Abhandlungen des Geographischen Institutes* (der Freien Universität Berlin), Sonderhefte 1, Berlin.

CARDOSO, J. C. (1965), *Os solos de Portugal. Sua classificação, caracterização e génese. 1 — A Sul de Rio Tejo,* Lisboa.

CARVALHO, A. M. G. (1968), «Contribuição para o conhecimento geológico da Bacia terciária do Tejo», *Memórias dos Serviços Geológicos de Portugal* (Nova Série), 15, Lisboa.

—— (1972), «Caracterização sedimentológica dos depósitos plio-plistocénicos da região de Leiria», *Revista da Faculdade de Ciências Naturais,* Sér. C. 17-1, 197-209.

DAVEAU, S. (1973), «Quelques exemples d'évolution quaternaire des versants au Portugal», *Finisterra,* 8, 5-47.

DUCHAUFOUR, P. (1977), *Pédologie,* T. 1, «Pédogenèse et classification», Paris.

FEIO, M. (1947), *Os terraços do Guadiana a jusante do Ardila,* Lisboa.

—— (1951), «A evolução do relevo do Baixo Alentejo e Algarve», *Com. Serv. Geol. Port.*, 32, 303-477.

FEY, M. (1980), «Fussflächenentwicklung und Rañasedimentation im Vorland der Montañas de Leon (Raum Astroga», *Düsseldorfer Geographische Schriften,* 15, 33-53, Düsseldorf.

GAIDA, R. (1984), «Die tertiäre und quartäre Reliefentwicklung des Baixo Alentejo». *Düsseldorfer Geographische Schriften,* 23, Düsseldorf.

GEHRENKEMPER, J. (1978), «Rañas und Reliefgenerationen der Montes de Toledo in Zentralspanien», *Berliner Geographische Abhandlungen,* 29, Berlin.

GOUVÊA, A. M. (1938), *Algarve (Aspectos fisiográficos),* Lisboa.

LEWANDOWSKI, J. (1982), *Sedimentpetrographische Untersuchungen des höheren Sandsteinkeupers bei Bad Königshofen/Unterfranken (Nieder-Bayern),* Diplomarbeit, Universität Bochum (unpublished).

OBDENBUSCH, H. (1982), «Die tertiäre und quartäre Reliefentwicklung des mittleren Tajograbens», *Düsseldorfer Geographische Schriften,* 20, Düsseldorf.

RIBEIRO, C. (1866), «Descripção do terreno quaternário das bacias dos rios Tejo e Sado», *Memórias da Commissão Geológica de Portugal,* 6, Lisboa.

RIBEIRO, O. and FEIO, M. (1949), «Les dépôts de type raña au Portugal», *C. R. Congr. Int. Géogr.*, T. 2, 152-159.

ROMMERSKIRCHEN, E. (1978), «Morphogenese der Mancha und ihrer Randgebiete», *Düsseldorfer Geographische Schriften,* 10, Düsseldorf.

WENZENS, G. (1977), «Zur Flächengenese auf der Iberischen Halbinsel», *Karlsruher Geographische,* Hefte 8, 63-68, Karlsruhe.

RESUMO

Pedimentação no Sul de Portugal. No Baixo Alentejo desenvolveram-se solos vermelhos, num clima tropical húmido, provavelmente durante o Pliocénico. Segundo a classificação de DUCHAUFOUR trata-se de solos de tipo intermédio entre os solos ferrossialíticos e os solos ferruginosos: a caulinite é mais abundante que a ilite, a hematite aparece com a gœthite e não se observa lateritização.

No Pleistocénico inferior ocorreu uma mudança climática (redução e concentração das precipitações). Os solos vermelhos foram erodidos, transportados por torrentes anastomosadas e, em seguida, depositados. Os quartzos angulosos destes solos vermelhos foram ligeiramente arredondados, e o transporte provocou corrosão do subsolo; a planície do Baixo Alentejo foi abaixada por estes processos de *pedimentação*. Distinguem-se os pedimentos rochosos dos pedimentos com cobertura detrítica. A espessura dos sedimentos destes últimos chega a atingir 27 m. Fez-se a sua cartografia e propõe-se denominá-los *Formação de Panoias* (FP).

Observam-se estes sedimetnos nas áreas de sopé de cinco regiões de colinas: Serra da Senhora das Neves, Serra da Vigia, Serra do Caldeirão, Serra de Ficalho e Sierra del Granado. O pedimento mais importante é o que, a partir da Serra do Caldeirão, se estende sobre a bacia do Sado. Os sedimentos da FP em torno da Serra da Vigia foram inclinados após deposição.

A FP não deve ser considerada como o equivalente sul português das *rañas* espanholas. Os calhaus destas são mais rolados, devido ao transporte de tipo fluviátil.

A FP constitui uma marca saliente na evolução geomorfológica do Baixo-Alentejo. Coroando os sedimentos terciários da bacia do Sado, permite a reconstituição da paisagem existente antes das erosões do Pleistocénico médio e superior.

RÉSUMÉ

Pédimentation dans le Sud du Portugal. Dans le Bas Alentejo des sols rouges se sont développés, probablement durant le Pliocène, sous climat sub-tropical humide. Selon la classification de DUCHAUFOUR, il s'agirait de sols de type intermédiaire entre les sols fersiallitiques et les sols ferrugineux. La kaolinite est plus abondante que l'illite, l'hématite coexiste avec la gœthite; on n'observe pas de latéritisation.

Un changement de climat se manifesta au début du Pléistocène (réduction et concentration des précipitations). Les sols rouges furent érodés, transportés par ruissellement anastomosé, puis redéposés. Les quartz anguleux du sol rouge furent légèrement émoussés et le transport provoqua un rabotage des roches sous-jacentes; la plaine d'Alentejo fut abaissée par ces processus de pédimentation. On distingue des pédiments rocheux et d'autres couverts de débris. L'épaisseur des sédiments qui

couvrent ces derniers peut atteindre 27 m. Ils ont été cartographiés et on propose de les appeler *Formation de Panoias* (FP).

On les observe sur l'avant-pays de cinq régions de collines: Serra da Senhora das Neves, Serra da Vigia, Serra do Caldeirão, Serra de Ficalho et Sierra del Granado. Le principal pédiment est celui qui s'étend à partir de la Serra do Caldeirão et qui s'avance sur le bassin du Sado. Les sédiments FP ont été déformés après leur dépôt autour de la Serra da Vigia.

La formation FP ne doit pas être considérée comme l'équivalent sud-portugais des rañas espagnoles. Les cailloux de celles-ci sont mieux roulés, en raison d'un transport de type fluviatil.

La formation FP constitue un repère commode dans l'évolution géomorphologique du Bas Alentejo. Elle couronne les sédiments tertiaires du bassin du Sado et permet de reconstituer le paysage existant avant les érosions du Pleistocène moyen et supérieur.

PL. I, A — Sediments of the Formação de Panoias (FP, Panoias).

PL. I, B — Inclined sediments of the FP (Besteiros near Garvão).