Relationships between Geomorphology and Palaeoweatherings on the hercynian basement in central Spain. A mineralogical and geochemical approach

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Abstract: The hercynian basement of the Iberian Peninsula exhibits remnants of weathering profiles that in many cases exceed 20 m in thepth. In the Montes de Toledo region (Central Spain) remnants of these profiles appear fossilized by the Rañas, which represent systems of alluvial fans and/or piedmont alluvial plains expanded just before the development of the terrace systems of the curent rivers. In the region studied there are different levels of Rañas, the highest being some 200 m above the current drainage system. They fossilize remnants of a deep and old weathering mantle enriched in smectites. Remnants of similar weathering mantles have been dercribed in other parts of the hercynian basement fossilized by sedimentary covers of different ages. By contrast the lowest Rañas are located some 60-90 m below the older ones. They lie on a basement whose palaeoweathering mantle has been eroded. After sedimentation, the Rañas underwent new weathering processes under more or less acid conditions. In some cases, these processes affected not only the sedimentary covers but also the upper parts of the hercynian basement. These new processes gave rise to: 1) a certain enrichment in kaolinite and strong leaching of the fine fractions in the upper horizons, 2) the plugging of pores in the lower horizons, leading to the development of strong hydromorphic conditions and, 3) the destruction of the inherited sedimentary structures

Key Words: Geomorphology, Palaeoweathering, Hercynian Basement, Mineralogy, Geochemistry

Resumen: Sobre el zócalo hercínico de la Península Ibérica aparecen restos de importantes perfiles de alteración que en muchos casos sobrepasan los 20 m de profundidad. En la región de Montes de Toledo restos de estos perfiles aparecen fosilizados bajos las Rañas las cuales representan abanicos y/o llanuras aluviales de piedemonte cuyo desarrollo es inmediatamente anterior al establecimiento del actual sistema de terrazas fluviales. En la región estudiada se localizan varios niveles de Rañas estando los más altos a unos 200 m por encima de los cauces fluviales actuales. Estas Rañas altas fosilizan los restos de un antiguo y potente manto de alteración rico en esmectitas. Restos de mantos de alteración similares al aquí estudiado han sido señalados en otros lugares de este zócalo hercínico fosilizados por coberteras sedimentarias de distintas edades. Por su parte, las Rañas bajas se localizan unos 60-90 m por debajo de las más antiguas, apoyándose sobre un basamento en el que el antiguo manto de alteración ha sido erosionado. Una vez depositados los materiales de las Rañas han sufrido procesos de alteración bajo condiciones más o menos ácidas. Estos procesos han afectado en muchos casos no sólo a la cobertera sedimentaria sino incluso a la parte más superior del zócalo hercínico fosilizado. Estos nuevos procesos han originado: 1) un enriquecimiento en caolinitas y un fuerte lavado de las fracciones finas en los horizontes superiores, 2) el taponamiento de poros en los horizontes inferiores, lo que ha dado origen al desarrollo de importantes condiciones hidromorfas y, 3) la destrucción de las antiguas estructuras sadimentarias heredadas .

Palabras clave: Geomorfología, Paleoalteraciones, Basamento Hercínico, Mineralogía, Geoquímica

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The Iberian Hercynian Massif occupies most of the western half of the Iberian Peninsula (Fig. 1 A). It is divided into a set of tectonic blocks that were unleveled during the Tertiary by the Alpine Orogeny (Solé and Llopis, 1952; Parga, 1969). This geological evolution is the origin of the Tajo sedimentary basin, located in the middle of Spain and bordered by two elevated blocks of the hercynian basement: the Sistema Central range to the North, and the Montes de Toledo massif to the South. Fig 1, B is a geological sketch of this contact along the

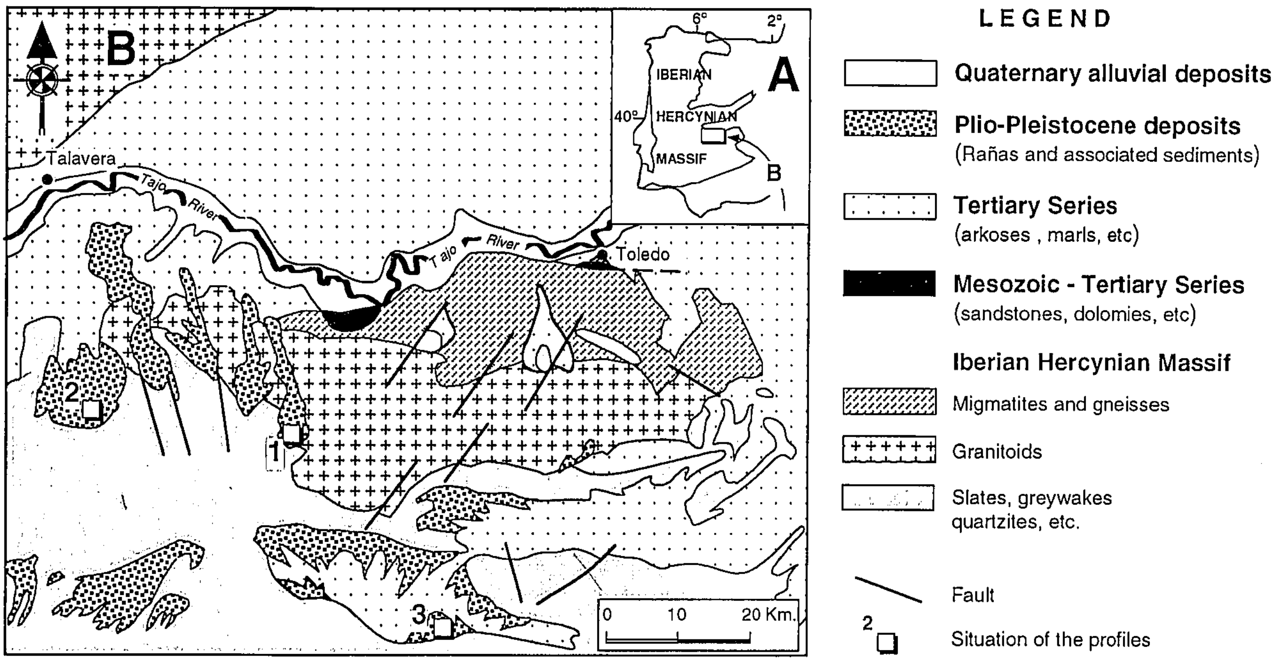

Figura 1.- (A) Situation of the Iberian Hercynian Massif within the Iberian Peninsula. (B) Geological scheme of the zone where profiles, 1, 2 and 3, were chosen.

Tajo river valley between Toledo and Talavera (Central Spain). With respect to the latter border, in some areas it is evident that the Montes de Toledo block overthrusts sediments of Upper Mesozoic to Lower Tertiary age (Rodas *et al*, 1990; Fort *et al.*, 1992; Calvo *et al.*, 1993). Both the hercynian basement and the Mesozoic-Tertiary transitional sediments were uncomformably covered by younger Tertiary deposits. Plio-Pleistocene erosive processes are exhuming many palaeo morphologies, structures and features, one of these being the weathering mantles developed over the hercynian basement. Profiles 1, 2, and 3 (Fig. 1, B) are three examples.

One of the most typical features of the landscape developed on the hercynian basement in the central "Meseta" of the Iberian Peninsula is the existence of extensive piedmont platforms higher than the Quaternary terrace system and about 150-200 m above current river valleys. These platforms commonly display a sedimentary cover 3-5 m thick called "Raña" which overlaps all basements. Rañas are detritic sediments corresponding to the alluvial fans and/or piedmont alluvial plains which developed during the Upper Neogene and Lower Pleistocene (Hernández Pacheco, 1950; Aguirre *et al.*, 1976; Espejo Serrano, 1987; Martín Serrano, 1991). They stem from old reliefs developed over the hercynian basement; their lithology is formed of pebbles and gravels of quartzite and some quartz, all embedded within a clayey matrix, more or less rich in the sand fraction, and displaying strong signs of hydromorphy.

Descriptions and studies of remnants of palaeoweathering mantles overlying the hercynian basement and appearing under covers of different ages have been reported by many authors (Kubiena, 1954; Daveau, 1969; Riedel, 1973; Molina and Blanco, 1980; Martín Serrano, 1988; Molina *et al.*, 1991; Vicente *et al.*, 1991). In the northern piedmont of the Montes de Toledo range (Fig. 2) it is common to find remnants of palaeoweathering mantles beneath different sedimentary covers. In this region the relief is defined by:

- the remains of an old mountain range of Palaeozoic and pre-Paleozoic series (namely quartzites and slates) folded during the Hercynian Orogeny. Their summits are never higher than 1500 m.
- the remnants of a pre-Rañas surface which forms a pediment sloping to the N. and NE. It is modeled on granitoids and metamorphic rocks, between 850-700 m in height. Important inselbergs emerge from this surface.
- the Rañas system, which is situated below this surface, between 800-600 m, sloping towards the main river valleys.
- the emplacement of the current drainage network of the tributaries of the Tajo and Guadiana rivers to the N. and S., respectively.

In the remnants of the pediment and beneath the Rañas deposits the basement is always weathered, the thickness of the weathered zone ranging from a few meters to more than 20 m. Thus, two main questions arise: 1) what are the relationships among the weathered basement, the pediment surface and the Rañas ? and, 2) is it possible to distinguish different phases or periods of weathering under this landscape?

This work attempts to elucidate these questions.

Description of the Profiles

In the three profiles chosen for this study (Fig.1 and 2) the Raña deposits rest over different lithologies. Profiles 1 (Navahermosa) and 2 (Sangrera) are in the Northern piedmont of the Montes de Toledo; the former lies over a deeply weathered basement of granodiorites and the lat-

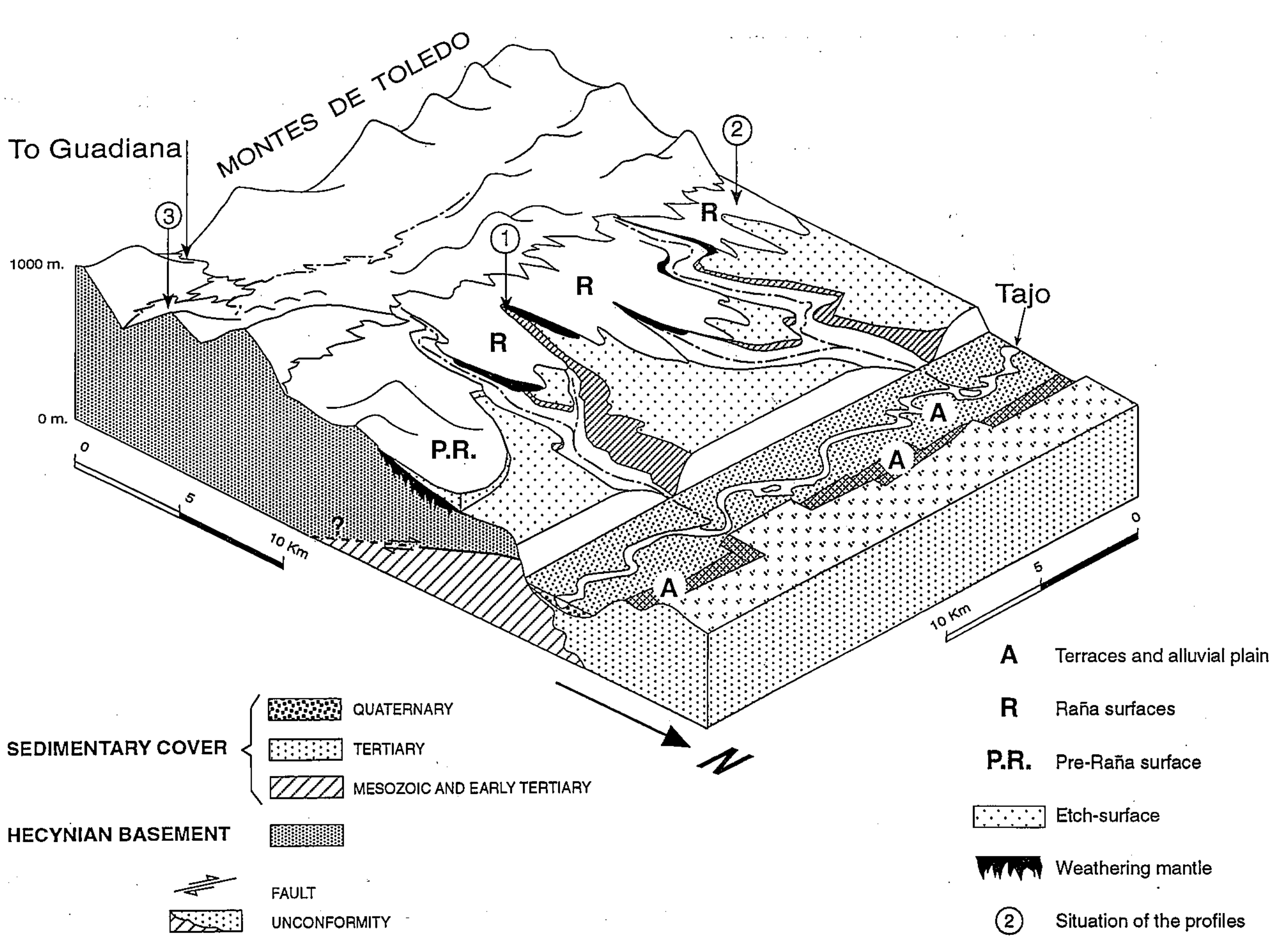

Figura 2.- Idealized sketch of the morphostructure of the Northern Piedmont of the Montes de Toledo range, between Toledo and Talavera. The geomoephological positions of the profiles studied are represented.

ter over pre-Cambrian slates (Aparicio Yagüe, 1971; Moreno and Gómez Pérez, 1989), also strongly weathered. Profile 3 (Torre de Abraham) is located on a piedmont surface in the interior valleys of the Montes de Toledo. Here, the basement is formed of Ordovician sandstones and slates (Martín Serrano and Nozal Martín, 1989) which are weathered to a depth of no more than 3-4 m.

Over the last few years some studies on the soils developed in this region have been carried out by different authors (Monturiol, 1984; Pardo *et al.*, 1993). One of the conclusions is the "palaeic" character of the soils developed on the Raña surfaces.

The profiles studied will be described from top to bottom according, to the FAO nomenclature (FAO, 1977). The description of soil colours follows the Munsell system.

The Navahermosa profile.

This is situated on highway 401 close to the village of Navahermosa (province of Toledo) at an altitude of 750 m. (39°39'25"N; 4°28'10"W). Geologically, in the profile (Fig 3) two different parts can be distinguished: 1) an upper part formed by the Raña cover of some 3-4 m thick, and 2) a lower part formed by a weathered granodiorite at least 5-6 m thick. Westward, the unweathered granodiorite is observed some 20 m below the base of the profile. This means that the weathered basement is about 25 m thick.

In this profile the following horizons can be distinguished:

Ap (0-0'4 m). Concentration of coarse fractions (pebbles and gravels of quartzite) displaying a rind of black to dark red colours (10 R 3/4) within a sandy yellow (10 YR 7/3) matrix. It is mainly an elluvial horizon.

Btg 1 (0'40-1'5 m). Abundant intergranular clay fraction of yellow (2'5 Y 7/2) to reddish (2'5 YR 6/2) hues. Frequent clay coatings arround burrows, on joint planes and on gravels and pebbles. Coarse to medium angular blocky structure.

Btg 2 (1'5-3'5 m). Most gravels and pebbles show a yellowish (2'5 Y 7/6) to greyish (5 Y 6/2) rind with different degrees of disintegration giving rise to a sandy fraction which is integrated within the matrix of the horizon. Downward, the structure becomes progres sively coarse blocky to massive and even platy in some lower parts. Nodules of calcium carbonate may appear in some parts of the horizon .

Btr (3'5-3'8 m). This is not a continuous horizon. When present, it is formed of strong enrichment in clay of greyish olive (7'5 Y 5/3) hues in which it is possible to find some organic coatings and slickenside planes.

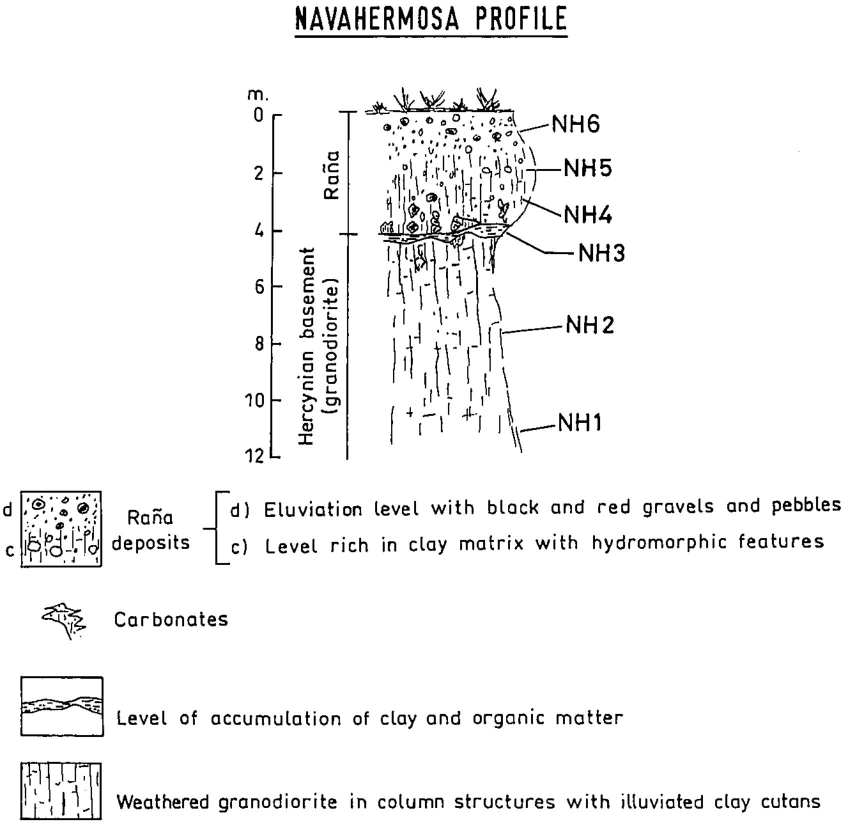

Figura 3.- Scheme of the Navahermosa profile and situation of the samples studied.

2 Bwb (3'8-6 m). Very weathered granodiorite with vertical fissuring leading to a column structure downward. Joint plains show thin olive grey (5 GY 5/1) clay and carbonate coatings. Most of the parent minerals are weathered, giving rise to a white mass in which the resistant minerals (quartz, muscovite and some K-feldspar)

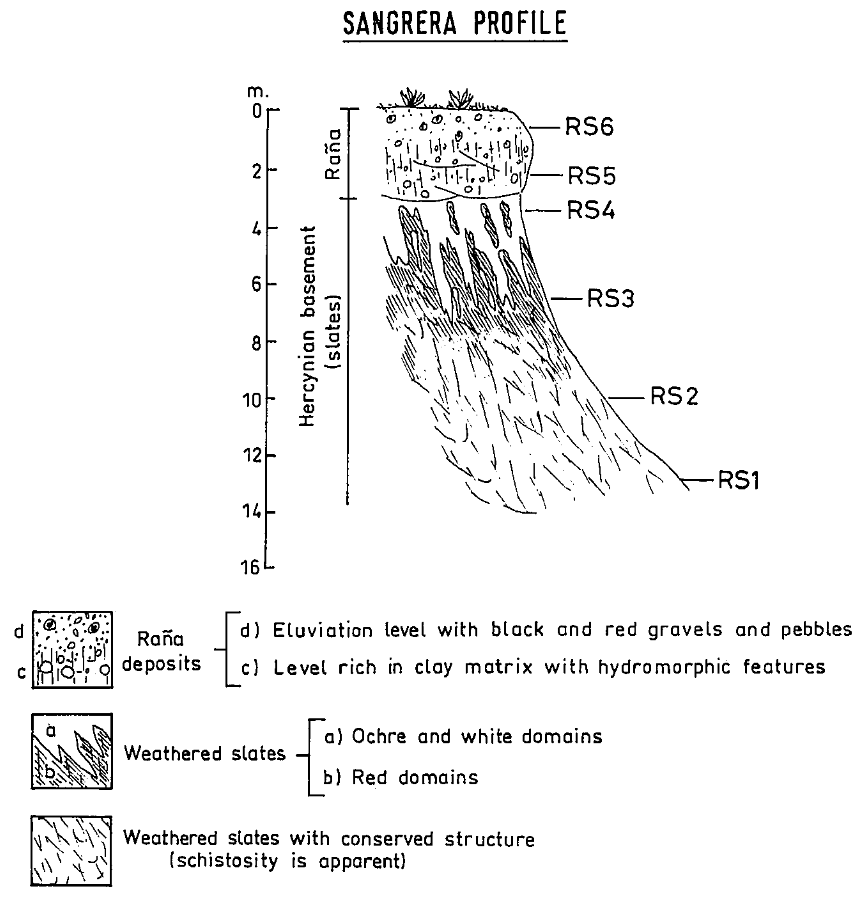

Figura 4.- Scheme of the Sangrera profile and situation of the samples studied.

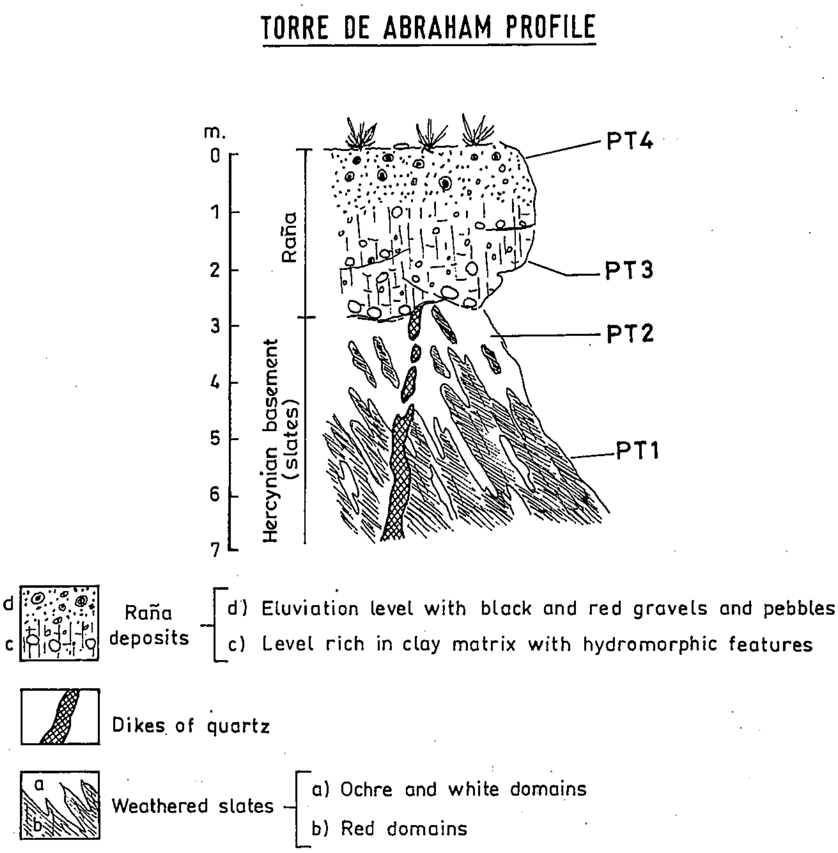

Figura 5.- Scheme of the Torre de Abraham profile and situation of the samples studied.

are encompassed.

2 Bw/C (6-11 m). Similar to the previous horizon the only significant differences being 1) a massive structure of the weathered granodiorite, and 2) the absence of clay coating and carbonate concentrations.

The Sangrera profile.

This is located on the right bank of the river Sangrera, about 2 km. south of the village of Espinoso del Rey (province of Toledo) at an altitude of 720 m (39°40'50"N; 4°46'13"W). The profile (Fig. 4) comprises a cover of Raña deposits about 3 m thick and a basement of very weathered Cambrian slates with a visible depth of 9-10 m. The description of the horizon is as follows:

Ap (0-0'3 m). Black and dark red gravels and pebbles of quartzite, and some quartz, in a sandy matrix, all with the same features described above.

Btg 1 (0'3-1'5 m). Enrichment in the clay fraction. Its colour changes fron reddish brown (2'5 YR 4/6) upward to orange (7'5 YR 6/6) downward. The structure changes from coarse blocky upward to coarse prismatic downward.

Btg 2 (1'5-3 m). As in the previous case the pebble and gravel fractions display the same decoloured rind, with strong processes of disintegration. The intergranular clay fraction features drastic changes in colour from red (10 R 4/8) to yellow (10 YR 7/ 6) and grey (2'5Y 8/1). The structure has bicome more or less massive.

2 Bwb (3-8 m). Very weathered slates giving rise to a muddy mass in which the schistosity and the structure of the parent rock is totalaly blurred. Just beneath the Raña the dominant hues are yellow (10 YR 7/6) changing downward to brown (7'5 YR 5/4). Whitish colours appear related with fisurres and cracks. Downward, a medium to coarse blocky structure begins to appear

2 Bw/C (8-14 m). Weathered slates showing a blocky structure in which the schistosity of the parent rock becomes progressively apparent. In the blocks it is possible to distinguish an external zone of 1-2 cm thick of reddish brown hues (5 YR 5/3) and an internal and yellow 10 YR 7/3) core.

The "fresh" parent rock appears laterally in the river bed some 13 m below the base of the profile studied.

The Torre de Abraham profile.

This profile (Fig. 5) is located on the secondary road 403, close to the Torre de Abraham reservoir (province of Ciudad Real) at an altitude of some 660 m (39°23'05"N; 4°13'50"W). As in the previous cases, it is formed by a Raña cover about 3 m thick and a basement of strongly folded Ordovician sandstones and slates crossed by some quartz veins. The visible basement is about 4-5 m deep. The following horizons can be distinguished:

Ap (0-0'3 m). As in the previous cases, the clasts of quartzite with a dark red rind appear within a sandy matrix of a dominant yellow orange colour (10 YR 7/2). But here the centile of the coarse fraction is bigger than those observed in the other two profiles.

Btg 1 (0'3-1'5 m). Cobbles and pebbles of quartzite are abundant, encompassed within a sandy-clayey mass of reddish hues (2'5 YR 5/4) which, downward, becomes orange (5 YR 7/6). The structure of this horizon changes from blocky upward to massive downward.

Btg 2 (1'5-3 m). Drastic changes in colour affecting both the clasts and the sandy clayey matrix, ranging from very red (10 R 4/6) to grey (7'5 Y 8/2). The coarse fraction shows different degrees of disintegration.

2 Bw/Cg (3-5 m). Weathered schists and slates, the degree of weathering being controlled by the structure and mineralogy of the parent rock. Here also white colours appear related to fissures and cracks. Upward, the quatz veins are progressively fractured and diverted from their original tracks, the fragments being integrated within the general mass of the horizon.

2 C (5- 7 m). Folded Ordovician schists and slates.

Table I: Semiquantitative mineralogical composition (% wt. between samples). Navahermosa profile. Ph = phyllosilicates; Q = quartz; F = feldspars; C = calcite; G = goethite; H = hematite; S = smectites; I = illite; K = kaolinite; t = traces; — = not detected

	Sample	Ph	Q	F	C	G	H	Phyllosilicates S	I	K
Fraction < 2 mm	NH6	69	25	—	—	5	1	25	12	32
	NH5	63	34	—	—	4	—	41	5	16
	NH4	61	30	—	7	2	—	50	3	8
	NH3	68	27	5	—	—	—	65	2	t
	NH2	60	31	9	—	—	—	28	31	t
	NH1	48	33	19	—	—	—	30	17	t
Fraction < 2 µm	NH6	95	—	—	—	5	—	33	29	33
	NH5	96	—	—	—	4	—	62	12	22
	NH4	95	—	—	2	3	—	81	7	7
	NH3	100	—	—	—	—	—	99	t	t
	NH2	100	—	—	—	—	—	85	7	8
	NH1	100	—	—	—	—	—	66	28	6

Analytical Methods

Samples were air dried and passed through a 2 mm mesh sieve before analysis. Also, the clay fraction (< 2 µm) was separated. Analytical studies have been performed on both fractions: < 2mm and <2µm. Mineralogical studies have been carried out by X-ray diffraction (XRD) with a Philips PW1130 diffractometer (Graphite monochromated Cu-Kα1 radiation).

XRD patterns were obtained from random powder and the following oriented aggregates: a) air dried, b) ethylene glycol solvated, c) glycerine solvated, d) heated to 300° C for 3 hours and e) heated to 500° C for 3 hours.

Semiquantitative estimations of quartz, feldspars, goethite, hematite, calcite and total phyllosilicates were obtained from the XRD random powder patterns integrating the area of the peaks at 4.26, 3.25, 4.17, 2.69, 3.03 and 4.4 Å, respectively, and using the intensity factors given by Schultz (1964) and Biscaye (1965). Kaolinite, Illite and 14 Å minerals were estimated in a similar way, using the oriented aggregate patterns (peak areas at 7.2 Å for kaolinite, 10.0 Å for illite, 14.0 Å for vermiculite, 29.1 Å. for interstratified chlorite-smectite, 16.9 Å for smectite in ethylene glycol solvated aggregates and 14.0 Å for chlorite in oriented aggregate heated to 500° C).

Quantitative determinations of elements were carried out by X-ray fluorescence spectroscopy on pressed-powder pellets, using international rock standards for calibration. The Kα lines were measured on a Siemens SRS 300 sequential spectrometer (Rh end window tube) equipped with a PDP 11/23 microcomputer.

Discussion of the results.

In the analytical methodology we only studied the < 2 mm fraction (coarse fraction) and the < 2 µm fraction (fine fraction).

The mineralogy of the < 2 mm fraction of the weathered granite in the Navahermosa profile (Table I) indicates a progressive decrease in the feldspar content upward (samples NH1, NH2 and NH3). Smectite is the dominant phyllosilicate, and is especially abundant near the contact with the Raña cover (sample NH3). Carbonate is accumulated at the base of the Raña (sample NH4) in the form of calcite. As expected, a small amount of kaolinite was detected in this smectite-rich environment.

Within the Raña sediments kaolinites are common

	Sample	SiO2	Al2O3	Fe2O3	MgO	CaO	K2O	P2O5	TiO2	MnO	Na2O
Fraction < 2 mm	NH6	48.54	15.95	12.36	0.90	0.83	1.10	0.14	0.66	0.10	0.36
	NH5	52.47	15.18	7.92	1.30	1.02	0.72	0.05	0.61	0.01	0.35
	NH4	47.86	12.68	7.38	2.45	9.06	0.92	0.03	0.48	0.03	0.34
	NH3	57.38	13.09	4.61	3.54	1.57	2.16	0.03	0.50	0.01	0.99
	NH2	60.19	12.84	3.21	1.94	0.97	3.94	0.07	0.49	0.02	1.77
	NH1	60.18	12.58	4.11	1.91	1.12	4.11	0.21	0.48	0.03	1.76
Fraction < 2 µm	NH6	49.21	30.78	11.55	1.22	1.11	1.37	0.61	0.86	0.02	0.83
	NH5	52.24	28.10	11.52	1.70	1.41	0.83	0.52	0.69	0.01	0.79
	NH4	56.49	22.55	9.73	3.53	2.66	0.97	0.79	0.52	0.03	0.85
	NH3	62.69	21.29	7.60	4.69	2.01	0.70	0.27	0.34	0.01	0.70
	NH2	59.06	23.96	5.88	3.77	1.76	0.59	1.45	0.20	0.01	1.11
	NH1	56.92	25.88	6.77	3.23	1.30	0.99	1.11	0.51	0.05	0.96

Table II: Analytical results (% wt.) from the Navahermosa profle.

minerals and smectites have been strongly leached (< 2 µm fraction). The absence of feldspars in this cover (< 2 mm fraction) can be explained in two ways: 1) the source of these sediments had already been affected by a strong pre-Raña weathering, or 2) once these sediments had been deposited, they underwent post sedimentary weathering processes. In support of this second hypothesis is the fact that the Raña shows clasts of resistant components (quartzite and quartz), although there are large amount of slates in the source areas. Moreover, pebbles of weathered schists and slates can be found in some Rañas. These clasts disappear upward in the profile. The content in oxi-hydroxides is also related to the cover, increasing upward and with hematite appearing only at the top.

On comparing the data from Tables I and II it is clear that a certain amount of iron oxides in the weathered basement was not detected by the XRD. This same fact is also observed in the upper horizon of the Raña, although it does have hematite and goethite. This is because some oxi-hydroxides are present in a more or less amorphous form.

The decrease in potassium upward in the weathered basement (Table II, < 2 mm fraction) is in agreement with the decrease in feldspar contents (Table I, < 2 mm fraction).

The mineralogical data of the coarse fraction (< 2 mm fraction) of the Sangrera profile (Table III) clearly point to the two different parts of the profile: the slaty basement (samples RS1 to RS4) and the Raña cover (samples RS5 and RS6). In the basement, there is a high proportion of phyllosilicates, mainly illite and smectite and an interstratified chlorite-smectite. In the clay fraction (< 2µm fraction) the high proportion of smectite in the lower parts (samples RS1, RS2 and RS3) is related to a low content in illite and kaolinite. Sample RS4 differs in its high content in kaolinite and a decrease in smectite, near the base of the Raña. Goethite was the only oxide detected, its presence probably being related to hydromorphic conditions.

The so called "fresh" parent rock, located 25 m beneath the general platform of the piedmont, is also weathered, and has a strong smectite content. It represents the remains of old palaeoweathering processes, similar to

	Sample	Ph	Q	F	G	Phyllosilicates Ch	In	S	I	K
Fraction < 2 mm	RS6	21	76	1	2	—	—	—	14	7
	RS5	65	27	—	8	—	—	11	9	45
	RS4	60	33	3	4	—	t	19	30	10
	RS3	66	30	4	—	—	t	20	36	9
	RS2	64	32	4	—	—	4	16	30	14
	RS1	67	30	3	—	—	7	18	32	10
	F.R.	40	43	17	—	11	—	9	17	3
Fraction < 2 µm	RS6	81	13	—	6	—	—	—	40	41
	RS5	95	—	—	5	—	—	23	27	45
	RS4	88	—	—	12	—	—	41	16	31
	RS3	81	10	8	1	—	—	70	8	3
	RS2	79	11	8	2	—	—	63	9	7
	RS1	76	10	10	4	—	—	56	14	6
	F.R.	85	9	6	t	—	—	67	6	12

Table III: Semiquantitative mineralogical composition (% wt. between samples). Sangrera profile. Ph = phyllosilicates; Q = quartz; F = feldspars; G = goethite; Ch = chlorite; In = Interstr. smectite-chlorite; S = smectites; I = illite; K = kaolinite; t = traces; — = not detected; F.R. = "fresh" rock.

	Sample	SiO2	Al2O3	Fe2O3	MgO	CaO	K2O	P2O5	TiO2	MnO	Na2O
Fraction < 2 mm	RS6	66.75	8.69	6.89	0.43	0.26	0.98	0.15	0.67	0.03	0.43
	RS5	45.69	19.01	13.41	0.59	0.34	1.65	0.07	0.62	0.00	0.34
	RS4	60.45	18.06	7.20	1.14	0.41	2.66	0.04	0.70	0.01	0.14
	RS3	57.69	19.91	7.35	1.66	0.45	3.58	0.12	0.80	0.06	0.19
	RS2	57.30	19.26	7.68	1.78	0.35	3.69	0.13	0.80	0.08	0.20
	RS1	57.16	19.36	7.44	1.93	0.45	3.61	0.12	0.79	0.04	0.32
Fraction < 2 µm	RS6	47.11	29.37	13.34	1.00	0.59	2.09	0.80	1.18	0.06	0.91
	RS5	50.56	35.63	6.48	0.79	0.37	1.76	0.16	0.77	0.00	0.70
	RS4	43.66	25.74	9.13	1.44	0.88	1.53	1.70	0.33	0.01	0.65
	RS3	46.89	20.77	6.42	3.35	1.04	1.38	2.33	0.14	0.04	1.44
	RS2	44.59	22.01	7.65	3.16	1.05	1.81	4.00	0.19	0.04	1.47
	RS1	44.36	21.50	6.90	2.84	1.05	1.42	4.33	0.15	0.03	1.50

Table IV: Analytical results (%wt.) from the Sangrera profile.

Sample		Ph	Q	F	G	H	Phyllosilicates V	S	I	K
PT4	pebbles	8	81	t	—	10	—	—	8	—
	matrix (< 2mm)	12	85	3	—	—	—	—	12	—
PT3	pebbles	33	55	t	4	7	—	—	24	9
	matrix (< 2mm)	40	54	t	5	—	—	—	28	12
PT2 (< 2 mm)		67	23	3	5	2	—	—	58	9
PT1 (< 2mm)	red	52	31	3	5	9	—	—	43	9
	ochre	53	39	3	5	—	—	—	49	4
PT4 (< 2 µm)		71	22	2	5	—	4	—	38	29
PT3 (< 2 µm)		75	12	2	11	—	—	t	38	36
PT2 (< 2 µm)		75	15	3	7	—	—	—	53	22

Table V: Semiquantitative mineralogical composition (% wt. between samples). Torre de Abraham profile. Ph = phyllosilicates; Q = quartz; F = feldspars; G = goethite; H = hematite; V = vermiculite; S= sectites; I = illite; K = kaolinite; t = traces; — = not detected

those found on the basement of the foregoing profile.

On comparing the data from Tables III and IV, the presence of amorphous iron is clear in both the weathered basement and the matrix of the Raña.

A noteworthy feature of Table IV is the increase in TiO_2 in the fine fraction (< 2 µm fraction) at the top of the Raña and the progressive reduction in P_2O_5 upward. Both data point to the existence of important weathering and leaching processes after deposition of the Raña cover.

In the case of the Torre de Abraham profile, Table V indicates that here the basement is not weathered as deeply as in the previous cases. In the deepest visible weathering level there are domains of red and yellowish hues, depending on the predominance of hematites or goethite, respectively. The proportion of kaolinite present in all the samples is striking, being 22 % at the top of the weathered basement (< 2 µm fraction).

Samples PT3 and PT4 show that hematite is concentrated in the coarse fraction and goethite is not present in the upper level. As in the foregoing cases, at the top of the Raña the fine fraction is leached downward and concentrated in the lower level.

Comparative study of the mineralogical and geochemical data (Tables V and VI) reveals that in the Raña deposits the iron is concentrated in the clasts. Additionally, there is a certain amount of amorphous iron that seems to be concentrated in the surface horizon of the profile. In Table VI it is also interesting to note: a) the high content in Fe_2O_3 in sample PT1 (red), with high proportions of goethite and hematite (Table V), b) the TiO_2 content which is concentrated in the fine fraction of the Raña and c) the drastic change in the K_2O content between the Raña cover and the basement.

Several indices have been proposed to quantify the degree of weathering of a rock. Some of them are based on the assumption that certain chemical components, namely Al_2O_3, Fe_2O_3 and TiO_2, are "stable components" whereas others such as SiO_2, MgO, Na_2O, etc. are "movible components". Thus, one approach to knowing the degree of weathering is the relationship between the stable and movible elements. However, in certain weathering processes (eg. podsolization, hydromorphism) this working hypotesis is not valid

Owing to that in silicates the movible ions Na^+, K^+, Mg^{++}, and Ca^{++} are bonded by $O^=$, A. Parker (1970) established an index of weathering for these minerals in which the energies of these bonds were taken into account. Parker's index of weathering (Iw) is defined as: Iw = [(Na)/0'35 + (Mg)/0'90 + (K)/0'25 + (Ca)/ 0'70] x 100

In this equation (Na), (Mg), (K) and (Ca) are the concentrations of the elements in percentage related to their atomic weights.

For a single profile developed from a silicated parent rock, the values of the Iw index increase downward, the rate depending of many factors (eg. climate, mineralogy, age of the profile, etc.). Unweathered basic parent rocks normally have an Iw > 100; unweathered granitoids have an Iw = 60-90, whereas for more or less acid schists Iw < 60 (Macías Vázquez, 1991; Taboada Rodríguez, 1992).

Sample		SiO2	Al2O3	Fe2O3	MgO	CaO	K2O	P2O5	TiO2	MnO	Na2O
PT4	pebbles	68.09	5.63	15.20	0.10	0.15	0.45	0.21	0.48	0.03	0.62
	matrix (< 2mm)	86.55	5.52	2.24	0.20	0.16	0.90	0.05	1.11	0.01	0.68
PT3	pebbles	59.16	14.78	9.32	0.28	0.24	1.79	0.07	0.83	0.00	0.69
	matrix (< 2mm)	58.03	17.22	8.25	0.36	0.38	1.83	0.05	1.05	0.00	0.68
PT2 (< 2 mm)		52.14	22.77	9.40	0.47	0.35	4.31	0.10	1.02	0.00	0.99
PT1 (< 2mm)	red	50.70	19.95	17.51	0.28	0.18	4.13	0.09	0.96	0.00	1.01
	ochre	56.61	19.75	8.33	0.31	0.16	4.17	0.12	0.97	0.01	1.01
PT4 (< 2 µm)		51.74	22.39	7.00	0.72	0.40	2.91	0.11	2.26	0.06	0.81
PT3 (< 2 µm)		41.77	25.38	13.77	0.53	0.48	2.60	0.06	1.06	0.00	0.73
PT2 (< 2 µm)		44.20	23.71	10.06	0.55	0.40	3.73	0.08	0.82	0.00	0.82

Table VI: Analytical results (% wt.) from the Torre de Abraham profile.

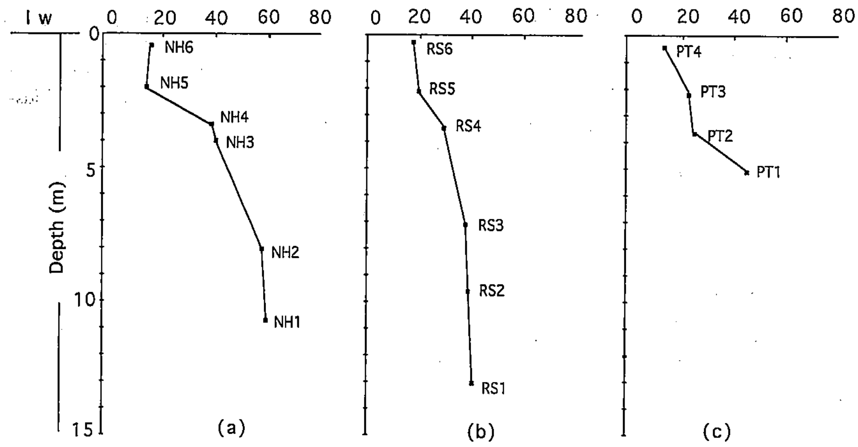

Figura 6.- Vertical changes of the Parker index (Iw) in the profiles studied: (a) Navahermosa profile; (b) Sangrera profile; (c) Torre de Abraham profile.

However, in the case studied here the profiles are developed on both the Raña cover and the hercynian basement; hence the interpretation becomes more complicated.

In the Navahermosa profile there is a drastic change in the Iw index for samples NH 4 and NH 3 (Fig. 6), corresponding to an accumulation of calcium carbonate and illuviated smectites rich in Mg (Tables I and II). Beneath this level, the Iw index increases downward as would be expected. By contrast in the Sangrera profile there are no drastic changes in the Iw index; only a reduction in the Raña cover (Fig. 6, samples RS6 and RS5) and a progressive increase downward is observed. In the Torre de Abraham profile, the change of this index occurs at the top of the hercynian basement, just beneath the Raña cover (Fig. 6, sample PT2). This is in agreement with the hypothesis that the weathering process affecting the Raña has also affected the upper parts of the hercynian basement. Moreover, red and ochre samples from this level show the same Iw index values, the only important difference being the Fe_2O_3 content (Table VI).

Conclusions

From the results obtained it may be inferred that in two of the profiles (Navahermosa and Sangrera) the Raña sediments lie over the remains of a deep weathering mantle affecting the hercynian basement in the northern piedmont of the Montes de Toledo. These observations indicate that this weathering mantle is a general phenomenon beneath the pediment surface, this being one of the most important factors in the development of the regional morphology. By contrast, in the Torre de Abraham profile, situated some 60-90 m below this pediment, the Raña cover rests over a basement that is not deeply weathered.

These findings show that in this region there are different levels of Raña, which means that this geological and geomorphological formation does not give an accurate chronological meaning.

The pre-Raña weathering mantle features an important smectite-rich level, or horizon, which is truncated and geochemically affected by the weathering process related to the Raña covers. The origin and nature of these smectites (s. l.) are not studied in this paper, but it should be stressed that an intermediate level several meters thick and rich in this phyllosilicate appears in palaeoweathering profiles studied in other parts of the hercynian basement (Molina *et al.*, 1990; Vicente *et al.*, 1991; Espejo Serrano *et al.*, 1992).

In the case of the Navahermosa profile, the Raña cover displays a concentration of elluviated calcium carbonate and smectites at its bottom, whereas the upper horizons are rich in kaolinites. In the Sangrera profile a post-sedimentary weathering process also affects the whole of the Raña cover and the upper part of the weathered basement. Here a mineralogical and a geochemical change occurs between the lower part (RS1, RS2, RS3) and the upper part (RS4, RS5, RS6) of the profile, essentially characterized by the content in Al_2O_3, MgO, CaO, Na_2O and TiO_2 of the clay fraction (< 2 mm). This indicates that the enrichment in kaolinite of the Raña and the upper part of the weathered hercynian basement is not only due to the illuviation of kaolinite but because of *in situ* weathering of some parent minerals. Moreover, in the three profiles studied the samples from the hercynian basement show a rather reduction in their Parker indices close to the contact with the Raña cover, in agreement with this interpretation.

It is important to note that the TiO_2 content is concentrated in the fine fraction of the Raña deposits and increases upward in the three profiles. These observations indicate that the sources of the titanium were the clasts of slates that once formed part of the original sediment of these covers.

Study of the Raña sediments reveals that the dark-red to black gravels and pebbles of the upper horizons are rich in hematite, whereas downward this mineral decreases and a certain amount of goethite appears. The matrix of the lower part contains only goethite.

Micromorphological studies performed by one of us (Molina Ballesteros, 1991) in the Rañas of Salamanca province revealed that the matrix is formed of a mixture of particles of different grain size, the clay fraction being dominant. Thin sections showed that, in many cases, contacts between coarse grains and matrix are progressive, the disintegration of pebbles and gravels of quartzite giving rise to a release of quartz grains now integrated into the general mass of the matrix. We name this process "arenización" of the quartzites, and this is common under more or less hydromorphic conditions. The process originates an *in situ* reduction in the size of clasts within the profile and an increase in their roundness by reduction of the tips and edges. Thus, the coarse fraction at the Raña surfaces is smaller and more rounded than within the sediment.

These observations show that once sedimented the Rañas were deeply weathered, their matrix being affected by important processes of redistributions and reorganization. According to Espejo Serrano (1978), these post-sedimentary processes would have caused the destruction of the sedimentary sructures and the development of a strong hydromorphism by pore plugging. All these postsedimentary weathering processes should be kept in mind in order to get an accurate interpretation of this kind of sediments.

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