CATENA vol. 18, p. 345–354 Cremlingen 1991

STUDY OF PALEOWEATHERING ON THE SPANISH HERCYNIAN BASEMENT MONTES DE TOLEDO (CENTRAL SPAIN)

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Summary

The Hercynian basement of the Iberian Peninsula consists of a series of late Hercynian blocks that were unleveled by the Alpine orogeny. The "Montes de Toledo" range is found in one of the elevated blocks of the central zone and shows ancient alterations affecting different rocks which are fossilized by sediments of different ages.

Two of these weathering profiles, under the Plio-Pleistocene sediments of "Raña" formations are studied. One is developed on granodiorite with some intercalated metamorphic rocks and the other on a slaty series. In both profiles smectite is formed in a first weathering process. A second weathering process, yielding kaolinite and affecting "Raña" sediments is superimposed on older one. Both processes seem to be widely spread in the western part of the Iberian Peninsula.

1 Introduction

The Iberian Hercynian Massif (SOLE & LLOPIS 1952) is the oldest geological formation of the Iberian Peninsula. It occupies the western half of this Peninsula and consists of granitic rocks, micaschists, slates, quartzites and limestones (fig. 1).

At the end of the Hercynian orogeny this basement was fractured and divided into a series of blocks which were later uplifted or sunk by the Alpine orogeny. In the center of the Peninsula two great horsts, the Central System ("Sistema Central") and the Mountains of Toledo ("Montes de Toledo"), and a tectonic graben (the Tajus river trench) between them, were formed.

On this Hercynian basement old weathering profiles which in some cases exceed 30 m in depth, are found. These alterations may be covered by sedimentary series of different ages, from the Permian to the "Raña" formations of Plio-Pleistocene age, or appear at the surface (DAVEAU 1969, RIEDEL 1973, VIRGILI et al. 1974, ESPEJO 1978, GEHRENKEMPER 1978, MOLINA & BLANCO 1980). The best preserved and most developed weathering profiles are those that occur fossilized under the continental series attributed to the Cretaceous-Tertiary transition (MARTIN SERRANO 1985, MOLINA et al. 1989). This suggests that a intensive alteration occurred in the Mesozoic al-

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ISSN 0341–8162

W-3302 Cremlingen-Destedt, Germany
0341–8162/91/5011851/US$ 2.00 + 0.25

though no definite proof can, at present, be offered.

In the Tertiary two major alterations took place: one in the Paleogene-Neogene transition causing intense reddening (GEHRENKEMPER 1978, MARTIN-SERRANO 1985) and other in the Middle-Upper Pliocene, yielding kaolinite (ESPEJO 1978).

In the "Montes de Toledo" area we may distinguish two morphologically distinct features:

- A pediment situated to the North, at an altitude of 700–800 m, developed on granitic rocks and migmatites (APARICIO 1971) with inselbergs formed by quartzites and slates.
- The Mountains of Toledo sensu stricto whose summits descend smoothly from the West (at more than 1400 m) to the East, where they become submerged below the Tertiary of La Mancha area. The folded series, extending from the Pre-Cambrian to the Devonian, appear in these mountains (I.G.M.E. 1970).

In both zones, the remnants of important alterations which exceed 20 m in depth are found; they are covered by deposits attributed to the Upper Tertiary ("Raña" formations).

In this work we study two weathering profiles, one developed at the head of the pediment, on granodiorites, and the other in the interior of the "Montes de Toledo", on a basement of cambrian slates. Both profiles appear fossilized by the "Raña" formation.

2 Description of the profiles

2.1 Valleálamos profile

The profile is close to road 401 between the villages of Navahermosa to the East and Los Navalmorales to the West (fig. 1.1). It is located in the West side of the valley of Valleálamos creek and has 50 m.

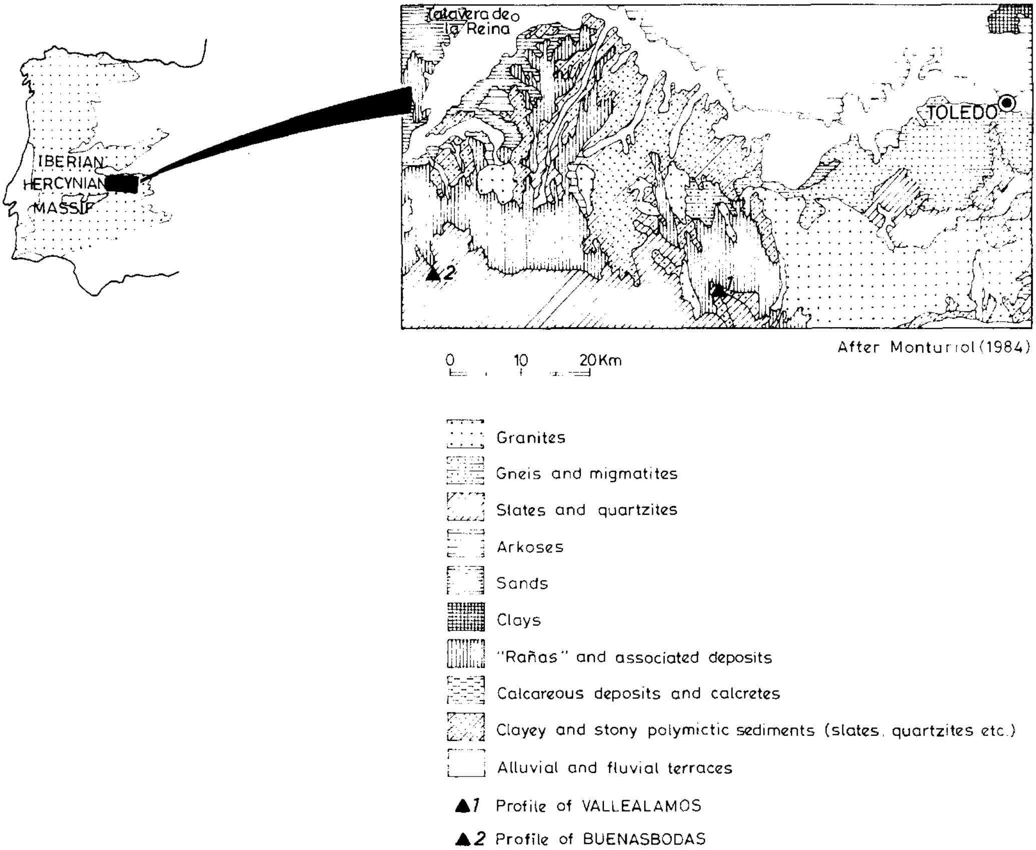
This profile has a granodiorite basement which shows intercalations of slate nodules with strong contact-metamorphism features (fig. 2); it is covered by a "Raña" formation less than 3 m thick, which is constituted by pebbles of quartzite, sandstone and quartz in a sandy-clayey matrix of reddish (7.5R 4/8) and ochre (2.5Y 6/6) hues.

The granodiorite appears disaggregated and with clay pseudomorphs; with depth the alteration is restricted to the neighbourhood of planes that define irregular polyhedra.

In the strongly altered material, the plagioclases have been converted into a white clay; microclines have become strongly fissured. The alteration has been centripetal, directed from the old planes between the polyedre toward the interior. The origin of these planes and fissures affecting the granodiorite is not clear although they probably have several origins: pressure relief, lamination of tectonic origin, etc. (TWIDALE 1982).

2.2 The Buenasbodas profile

This profile is also found next to the county road 401 between the villages of Buenasbodas and La Nava de Ricomalillo, some 43 km westward the former profile (fig. 1.2). It is placed on the valley of La Garganta creek at some 650 m in altitude.



After Monturiol (1984)

Fig. 1: *Geological scheme of the study area.*

The weathering profile is developed over a series of slates and graywackes of Pre-Ordovician age and is covered, as in the preceding case, by a "Raña" deposit.

Three zones may be distinguished in the weathered materials:

1. A lower zone, at 40 m of depth, where the slate shows no alteration.
2. An intermediate zone, beginning at 18 m depth, in which the structure of the slate is preserved. A progressive, upward argillization and fragmentation is observed. The color of the weathered slate changes from greenish-ochre (10YR 4/2) in the lower part to red (10R 4/6) toward upper part.
3. An upper zone, beginning at 6 m depth in which the original rock structure has not been preserved. This level shows a vertical color segregation associated to strong changes in the hydric regime of the material; the predominant colors are white (10YR 8/1), red (10R 4/7), and ochre (10YR 6/8).

The covering of "Raña" formation is something more than 3 m in thickness.

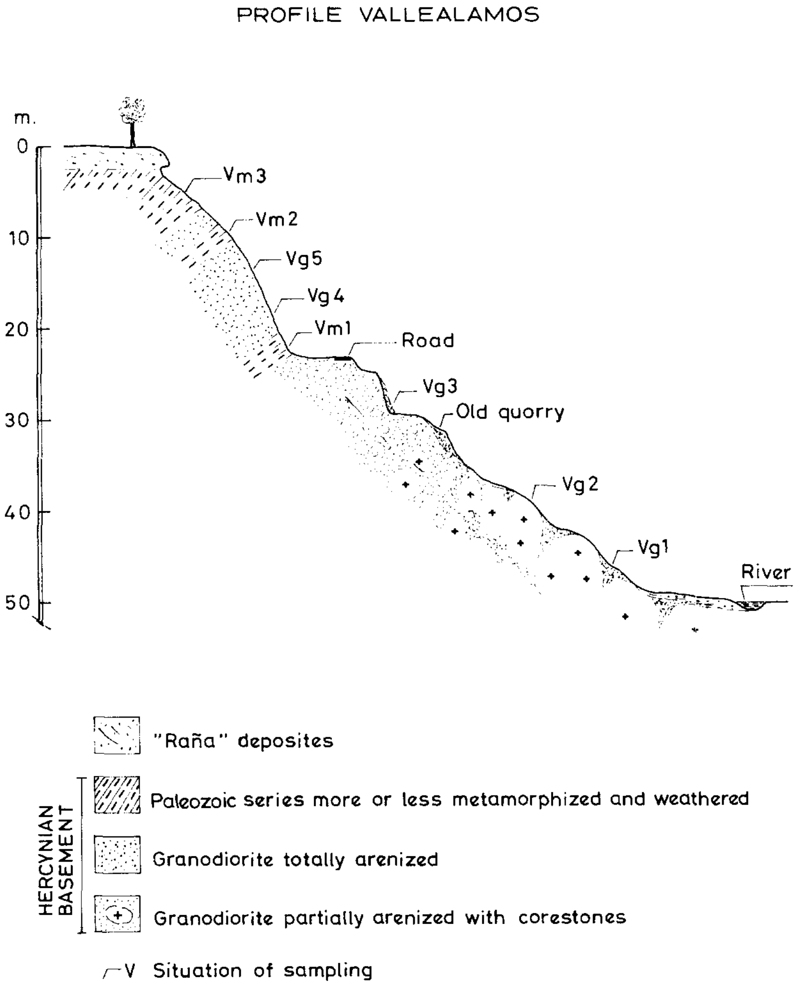


Fig. 2: *Schematic weathering profile of Valleálamos.*

3 Experimental methods

The samples were air dried and passed through a 2 mm mesh sieve before analysis. The (≤ 2 mm) fraction was studied. In several cases the clay fraction (≤ 2 μm) was also studied. In the clay fraction the mineralogical study was performed by X-ray diffraction and IR spectroscopy. In the (≤ 2 mm) fraction only X-ray diffraction was used. XRD patterns were obtained with a Philips PW 1130 diffractometer (Graphite monochromated Cu-K_α radiation). The IR spectra were obtained from KBr pressed discs and the Fluorolube paste method was used to study the OH region.

XRD patterns were obtained from random powder, and the following orientated aggregates:

a) air dried,

b) ethylene glycol solvated,

c) glycerine solvated,

d) heated to 300°C for 3 h,

e) heated to 500°C for 3 h.

Semi-quantitative estimations of quartz, feldspars, goethite, calcite and total phyllosilicates were obtained from the XRD random powder patterns, integrating the area of the peaks at 4.26, 3.25, 3.03 and 4.44 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 orientated aggregate patterns (peak areas at 7.2 Å for kaolinite, 10.0 Å for illite, 12.0 Å for interstratified illite-chlorite, 16.9 Å for smectite in ethylene glycol solvated aggregates and 14.0 Å for chlorite in oriented aggregate heated to 500°C).

Data of particle size distribution were obtained by the method of KILMER & ALEXANDER (1949).

4 Results and discussion

4.1 Valleálamos profile

The mineralogical study of the weathering affecting to granodiorite and metamorphic materials was carried out by a set of samples taken between the creek level and the base of the Raña formation (fig. 2). Samples Vg 1 to Vg 5 refer to granodiorite and Vm 1 to Vm 3 to metamorphic materials.

According to the degree of weathering of the granodiorite, two zones were distinguished:

- The lower one (samples Vg 1 to Vg 3), in which corestones are found and arenization-argillization is controled by fissures and joints.
- The upper one (samples Vg 4 and Vg 5) consisting of a true saprolite.

In the lower zone, data of mineralogy of whole fraction (tab. 1, fraction ≤2 mm) show that samples belonging to arenized granodiorite (Vg 1 and Vg 3) have nearly four times more phyllosilicates and the half of the feldspars than samples of corestones (Vg 2). In the clay fraction (≤2 μm) samples Vg 1 and Vg 3 show a predominance of smectite and kaolinite.

In the upper zone, the semiquantitative proportions of minerals present in the total fraction (≤2 mm) of the weathered granodiorite (samples Vg 4 and Vg 5 in tab. 1) remain nearly constant respect to the arenized material of the lower zone. The clay fraction (≤2 μm) shows an increase in the kaolinite content respect to smectite towards the "Raña" contact (the sample Vg 5 was taken 7 m above the Vg 4 and closer to "Raña" formation). These mineral changes coincide with the first hydromorphic features in the profile which increase toward the upper part and are dominant just beneath the "Raña" cover.

In the samples of metamorphic rocks (Vm 1 to Vm 3) the general interpretation is more difficult since all metamorphized sediments may have a different initial mineralogical composition in function of sedimentation and metamorphism. Nevertheless, we observe a decrease in feldspars content towards the "Raña" contact (tab. 1, fraction ≤2 mm).

Tab. 3 shows that in the weathered granodiorite clay content increases and silt content decreases towards the "Raña" contact.

Fraction	Sample	Ph	Q	F	G	C	K	I	S	In
≤2 mm	Vm 3	15	82	tr	3	—	3	12	—	—
	Vm 2	64	34	2	tr	—	10	54	—	—
	Vg 5	39	40	21	—	—	17	23	tr	—
	Vg 4	38	35	27	—	—	10	16	12	—
	Vm 1	40	55	5	tr	—	3	32	—	5
	Vg 3	36	43	21	—	—	17	16	3	—
	Vg 2	9	49	42	—	—	—	9	—	—
	Vg 1	40	45	15	—	—	8	28	3	—
≤2 μm	Vm 2	82	8	tr	5	3	31	35	16	—
	Vg 5	99	—	tr	—	tr	58	13	28	—
	Vg 4	92	—	tr	—	7	14	13	65	—
	Vg 3	97	—	3	tr	—	41	11	45	—

Ph = phyllosilicates, Q = quartz, F = feldspars, G = goethite
C = calcite, K = kaolinite, I = illite, S = smectite
In = interstratified illite-chlorite, — = not detected, tr = traces

Tab. 1: *Semi-quantitative mineralogical composition (wt% relative between samples) in the Valleálamos profile.*

Fraction	Sample	Ph	Q	F	G	K	I	S	Ch	In
≤ 2 mm	Bv 1	52	45	tr	2	19	33	—	—	—
	Bv 2	45	51	tr	2	23	22	tr	—	—
	Bv 3	61	35	2	3	8	36	8	—	9
	Bv 4	68	29	tr	2	8	44	5	—	12
	Bv 5	67	30	2	tr	tr	31	11	—	24
	Bv 6	62	36	tr	tr	6	29	8	—	20
	Bv 7	61	27	10	tr	tr	44	—	17	—
≤ 2 μm	Bv 1	77	15	tr	8	38	39	—	—	—
	Bv 2	67	25	2	6	35	30	2	—	—
	Bv 5	75	23	2	tr	3	16	42	—	13

Ph = phyllosilicates, Q = quartz, F = feldspars, G = Goethite
K = kaolinite, I = illite, S = smectite, Ch = chlorite
In = interstratified illite-chlorite, — = not detected, tr = traces

Tab. 2: *Semi-quantitative mineralogical composition (wt% relative between samples) in the Buenasbodas profile.*

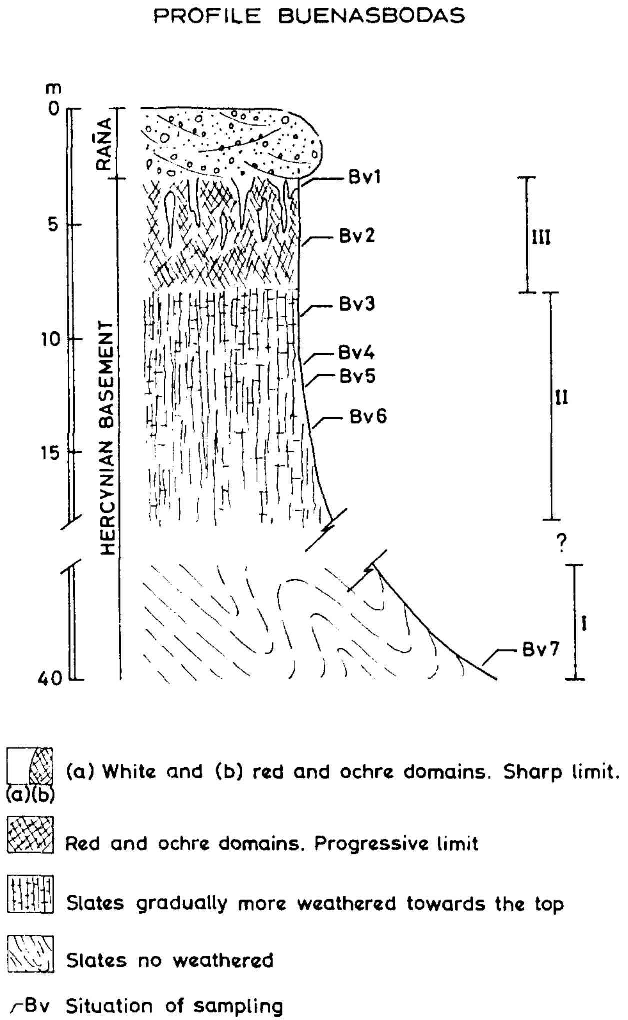


Fig. 3: *Schematic weathering profile of Buenasbodas.*

Profile	Sample	Coarse sand 2–0.2 mm	Fine sand 0.2–0.02 mm	Silt 0.02–0.002 mm	Clay ≤2 μm
		%			
Valleálamos	Vg 5	36	10	8	46
	Vg 3	47	16	11	26
	Vg 1	50	22	15	13
Buenasbodas	Bv 2	2	12	28	58
	Bv 3	1	15	49	35
	Bv 6	3	22	60	15

Tab. 3: *Particle size distribution in selected samples of Valleálamos and Buenasbodas profiles.*

4.2 Buenasbodas profile

In this profile we studied samples corresponding to the weathered basement formed by folded series of slates and graywackes.

At the base of the profile, the unweathered rock (sample Bv 7, tab. 2, fraction ≤ 2 mm) shows a high proportion of phyllosilicates (illite-mica and Fe-chlorite) and some feldspars. By sorting the data according to the mineral identity in samples from unweathered slate (Bv 7) to Raña contact (Bv 1) it is possible to distinguish also two levels of weathering above the unweathered material:

- The lower one, which ranges from sample Bv 6 to Bv 3 (fig. 3), shows an homogeneous alteration characterized by the disappearance of Fe-chlorite, a decrease in feldspars content, the presence of small amounts of kaolinite and moderate to high contents in smectite and a regular interstratified chlorite-vermiculite (tab. 2, total fraction, samples Bv 6 to Bv 3 and clay fraction (≤ 2 μm), sample Bv 4).
- The upper one (samples Bv 2 and Bv 1) which begins at 3–4 m below the contact with the "Raña" and shows a strong change in mineralogical composition (tab. 2, total and clay fractions). The most significative fact is, firstly the disappearance of the smectite and interstratified chlorite-vermiculite and, secondly, the strong increase in kaolinite content. In this level an increase in the proportion of resistant minerals like quartz is observed.

Data of particle size distribution for this profile (tab. 3) show an increase in clay and a decrease in silt contents toward the ceiling which agree with a higher weathering degree in the upper zone.

5 Conclusions

The existence of very deep weathering profiles upon the old pre-Alpine basements in West-Europe has been pointed out by different authors (KUBIENA 1954, FITZPATRICK 1963, RIEDEL 1973, HALL 1987, SMITH & McALISTER 1987). In many cases a Neogene age is attributed to those alterites. However some authors (GRANDIN & THIRY 1983) emphasize that the stages of tropical weathering in Europe finish at the beginning of the Tertiary.

The two profiles studied are part of the remnant of a weathering mantle which is fossilized here by the Raña's alluvial fans; but in other points of the interior of the Iberian Peninsula very similar profiles have been described beneath covers of different ages: Lower Tertiary (MARTIN SERRANO 1988), Paleogene and Miocene (VICENTE et al. 1987, MOLINA et al. 1990).

The analytical data from the profiles studied here show an important mineralogical variation in the clay fraction:

a) in the Valleálamos profile the change is between samples Vg 4 and Vg 5;

b) in Buenasbodas profile the change is between samples Bv 3 and Bv 2.

Both changes consist of a decay in smectites and an increase in kaolinites content. These changes can be explained by two hypotheses:

1. There is only one weathering mantle of a tropical nature which is truncated by the Raña deposits in the

level of kaolinite (upper part of the profile).

2. There was an old weathering mantle of tropical characteristics on which a new process of weathering (new kaolinization) was surimposed.

The studies by ESPEJO (1987) and VICENTE et al. (in press) about the weathering related to Raña's formation in other profiles of Montes de Toledo point to the latter hypothesis.

Hence, we can conclude:

1. The Iberian Hercynian basement in Montes de Toledo shows the remains of a very deep weathering mantle which affects all kinds of lithologies. We have studied this weathering on two types of rocks:
   a) On granodiorites, it gives rise to an arenization that has smectite minerals as a fundamental characteristic.
   b) On slates, it gives rise to the formation of smectite and interstratified chlorite-vermiculite.
2. In both cases the profiles show a kaolinization and a decay in smectites toward the top, beneath the Raña covering. The limit between smectite-rich and kaolinite-rich levels is quite sharp. This latter level has hydromorphic features.
3. The analytical data of this work point to the fact that in this zone there exists a new weathering mantle superimposed on the old one, of kaolinitic character and related to the "Raña" cover. This hypothesis is in agreement with previously published work.

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