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Chemical and micromorphological study of the humification in several analogous soils in Spain

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INTRODUCTION

Considering the soil as the result of the action of biological and climatological factors on the parent rock, the climate and the vegetation are added thereto as active factors taking part in the development of the soil whilst the parent rock is called "passive factor".

This criterion of a passive influence attributed to the parent rock leads to the danger of sometimes darkening the rather complex interactions established between the soil and the vegetation and of despising the influence possibly exercised by the nature of the geological material on superficial horizons the extent of which is unknown.

Admitting as valid the ample concept of "zonality" created by Sibircev, i.e. the notion of the zonal climatical soil, although Duchaufour [4] pointed out the difficulty of adopting same in France owing to the complexity of local climates, slight variations of the general climate and above all the anthropic action through which the original vegetation has been considerably modified, the difficulties are still greater on the Iberian Peninsula because of the scarce more or less intact vegetations remains as a consequence of the transformation of the original vegetation into cultivated fields, pasture grounds, scrubs or artificial woods throughout the centuries.

Taking into account the above mentioned considerations the present paper has the object of examining how far the climax soils formed as a consequence of a similar vegetal association on different parent rocks have humic horizons of identical morphology and properties or, on the other hand, the same as deep mineral horizons, show different qualities reflecting the diversification of the humification process caused by the variation of the chemical composition of the original geological material.

For that purpose we chose three profiles of analogous soils covered with *Quercus ilex* L. and two profiles of analogous soils covered with *Pinus pinaster* Sol., all of them proceeding from the center of Spain.

There do not exist any metereological stations in the neighbourhood of the woods selected. According to the Klimatdiagramm Weltatlas by Walter and Lieth]13] (scales 1:3,000,000) and the atlas published by Andrade (1966) at a more reduced scale of 1:1,000,000, soil profiles are roughly traced on the phytoclimate IV_{7c} characterized by the presence of sclerophill-evergreen *Quercus* accompanied by *Juniperus,* etc. The prevailing vegetation is arborescent or shrubby, evergreen, of hard leaves, resistant to strong climatical variations. This subzone is also characterized through the existence of some really cold annual period (average of the coldest month lower than 6°C) and rather irregularly distributed yearly rainfalls of about 400 mm mainly during Autumn, Winter and Spring; average temperature of monthly minima of the coldest month 0.9°C and absolute minimum temperature −13°C; average maximum temperature of the hottest month 35.5°C and absolute maximum temperature 42.3°C, with dried periods from June to September and seven months of frost (October to April).

Quercus ilex L. constitutes the most widely spread arborescent species in Spain which with 3 million ha of evergreen oak groves, is the first country as to the territorial extension of *Q. ilex* in spite of destructions and transformations in cultivated soils to which our woods have been exposed. Quite apart from the nature of the soil it is also outstanding on account of its resistance to most adverse climatic conditions.

The choice of analogous soils covered with *Pinus pinaster* results very representative for Spain, it being the most widely spred pine species of the country (1 million ha of old pine groves and 300,000 ha of reforestations according to Ceballos [3]. The two profiles of our paper belong to *P. pinaster* ssp. *mediterranea* wodds (= *P. mesoogensis* Fies. Gaus) which from a climatical and edaphological point of view are less exacting than the *atlantic* ssp., this being the consequence of the roughness of the continental climate of the lower Castilian Plateau, and of the calcareous plugs where there are sometimes really splendid pine-groves of this sub-species, thanks to its tolerance of the calcium, which have also been represented in our paper.

TECHNIQUES

The thin section of soils and rocks was carried out in accordance with conventional techniques. The methods of determining the pH [6], organic matter [11], total nitrogen [7], exchange capacity and exchange cations [10], absorption of light and resistance to electrolytes of the humate solutions [8], as well as the techniques of withdrawing and breaking-up humic compounds [5], have already been described.

MATERIAL STUDIED

Profile 1

0 — 1 cm: A_L
1 — 3 cm: A_0
3 — +23 cm: A_1

Location: 82.3 km from National Highway II (Guadalajara); height: 1,000 m; topography: flat. Geological material: pontiense limestone. Type of soil: mull rendzina. Vegetation: *Quercus ilex, Cistus laurifolius, Juniperus communis, Lavandula latifolia,* graminae, etc.

Remarks: very good structure, earthworms in A_1 horizon.

Profile 2

0 — 0.5 cm: A_L
0.5 — 1 cm: A_0
1 — 3.5 cm: A_1
3.5 — +20 cm: (B)

Location: 111 km from National Highway to Guadalajara; height: 1,000 m; topography: flat. Geological material: cretaceous limestones. Type of soil: Terra rossa. Vegetation: *Quercus ilex,* graminae, etc.

Remarks: the soil is more compact than of profile 1. There are more spiders than earthworms.

Profile 3

0 — 0.5 cm: A_L
0.5 — 1.5 cm: A_0
1.5 — 8 cm: A_1
8 — +20 cm: (B)

Location: Hoyo de Manzanares (Madrid); height: 981 m; topography: flat. Geological material: granite with two micas. Type of soil: Meridional braunerde. Vegetation: *Quercus ilex, Juniperus oxycedrus, Cistus ladaniferus, Daphne gnidium, Lavandula pedunculata,* etc.

Profile 4

0 — 0.5 cm: A_L
0.5 — 2 cm: $A_0 + A_1$
2 — +20 cm: A_1

Location: Cuéllar (Segovia); height: 1,000 m; topography: flat. Geological material: Pontiense limestones below diluvial sands. Type of soil: rendsina. Vegetation: *Pinus pinaster* Sol. ssp. *mediterránea* = (*P. mesoogensis* Fies), graminae, mosses, lichens.

Remarks: earthworms; there appear limestone pebbles on the surface.

Profile 5

0 — 0.5 cm: A_L
0.5 — 1 cm: A_0
1 — 5 cm: A_1
5 — +25 cm: (B)

Location: road from Robledo de Chavela to Hoyo de Pinares (Madrid); height: 900 m; topography: almost flat. Geological material: granite. Vegetation: *Pinus pinaster, Cistus ladaniferus, Thymus mastichina,* graminae, papelionaceae, lichens. Type of soil: Meridional braunerde.

Remarks: arachnids and fungi hyphae.

MICROMORPHOLOGICAL STUDY

Profile 1. The original material is a microcrystalline limestone with scarce quartz crystals. Fragments of this material are remarkable at all samples taken; they are sometimes 1.5 cm length (sample of 4-8 cm depth).

The contexture is not compact, the aggregates contain porphyroskelic fabric [2]. The plasma is brown coloured, no separations thereof are recognized.

The humus is *mull* with the typical spongy structure and the cavities are of rounded contours (Fig. 1); it contains scarce but little disintegrated plant remains. A_0 horizon consists of predominant but little humified plant remains, fungi hyphae and droppings of small animals.

Profile 2. The original material is also microcrystalline limestone. The remaining profile does not contain any calcium carbonate; a calcareous nodule of secondary origin has only been identified in A horizon.

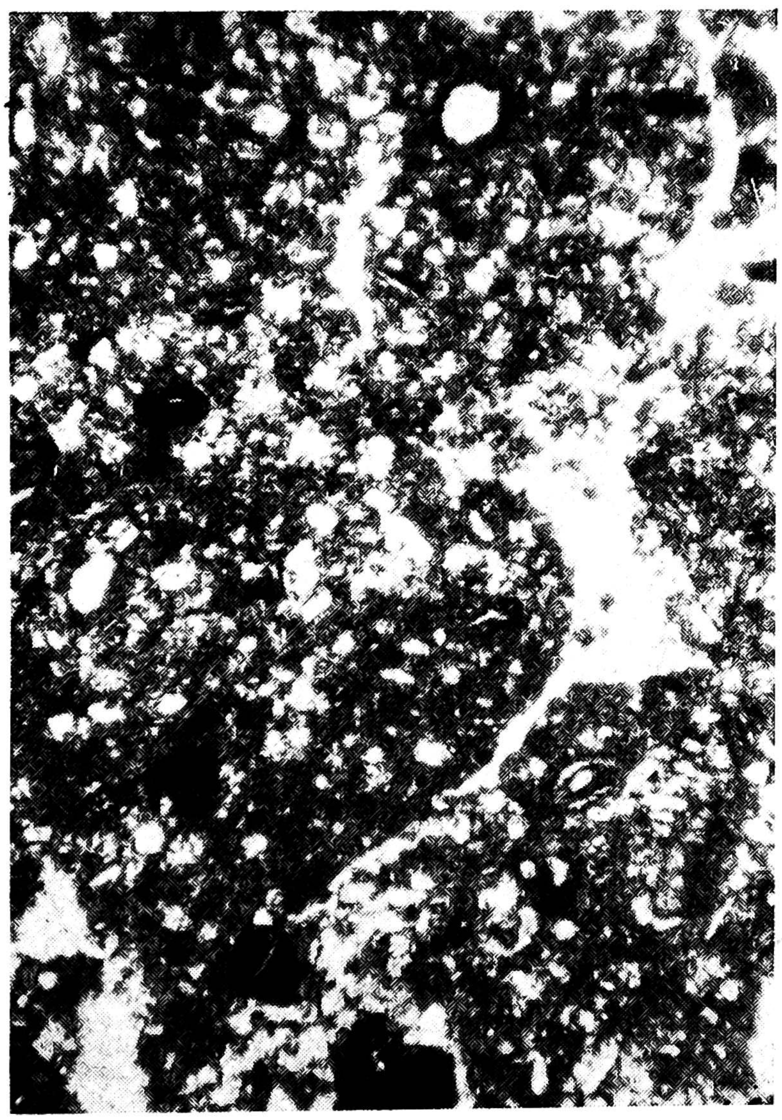

Fig. 1. Rendzina mull, profile 1, 5-9 cm depth. Thin section, × 50.

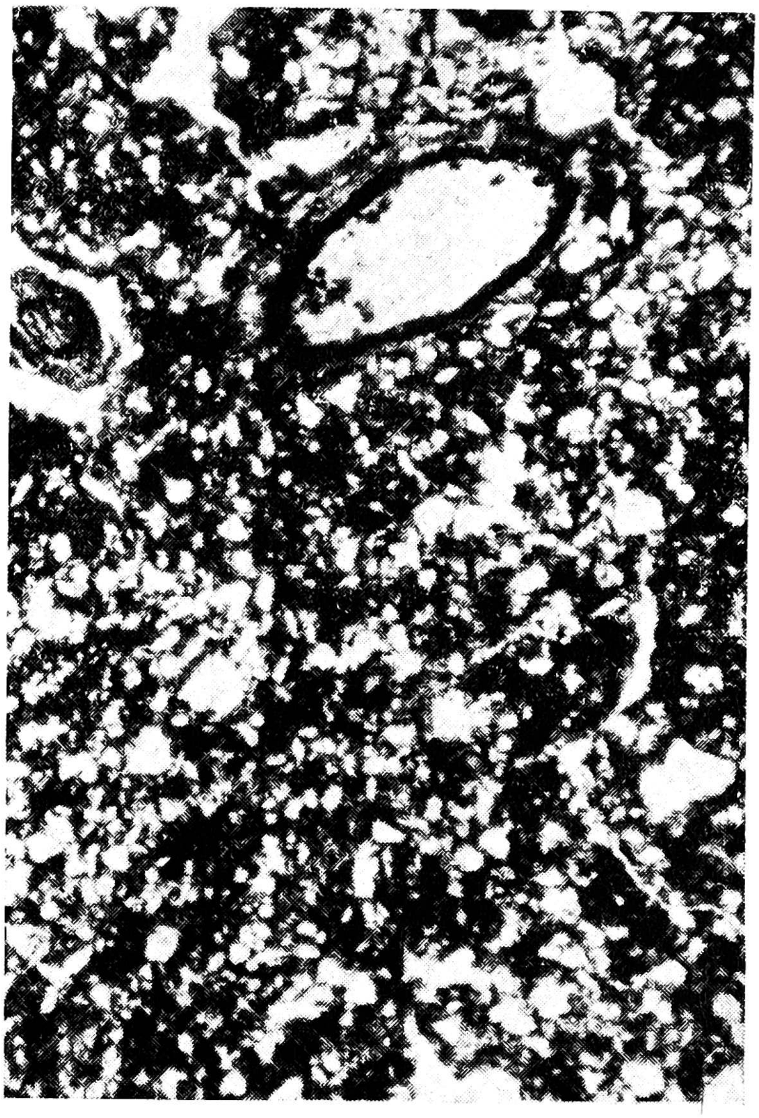

Fig. 2. Terra rossa, profile 2, 4-8 cm depth. Plant remains with droppings of *Oribatides* are shown. Thin section, × 50.

(B) horizon contains porphyroskelic fabric; the contexture is more compact than in the case of profile 1. The plasma is yellowish red-coloured, separations thereof are visible. The skeleton grains are mostly angular quartz crystals of the size of fine sand; the presence of feldspars is noticeable. Cavities are predominant over cracks; plant remains are frequent, sometimes with small animal droppings inside (Fig. 2). As can be seen from the shape, size and arrangement of excreta inside plant remains they come from various species of mites belonging to the group of Oribatides, according Selga [1]. Fungi hyphae are also noticeable.

The humus is *mull* but it can be seen that humification is not so good as in case of profile 1 (Fig. 3).

Profile 3. It is a soil with prevailing skeleton grains, isolated, of a very heterogeneous size, consisting of fragments of the original material, sometimes longer than 9 mm in (B) horizon and isolated crystals thereof; quartz, feldspars and micas. There are also more or less desintegrated plant remains.

The plasma, of a yellowish brown colour, very scarce, can generally

[1] Dr. D. Selga, Instituto Español de Entomología, C.S.I.C., Madrid.

be found as a fine coating surrounding the skeleton grains but in an uneven way. Cavities are mostly intergranular spaces.

The humus is *mull* with a worse degree of humification than in the case of profile 2, to be found in smaller quantities.

Profile 4. A soil has been formed on limestones, the skeleton grains consist of diluvial sands (coarse and fine grains). These diluvial sands probably come from a river basin prior to the present one and, of course, with different direction and origin of materials from the nearest river basin of the Duero River.

Fig. 3. Mull-formation, Terra rossa, 0-4 cm. Thin section, × 50.

Crystals are rounded up, their size oscillating between 1.02 and 0.06 mm; quartz is predominant followed by feldspars. Some microcrystalline calcite nodules are noticeable partly of secondary origin as well as very small calcite crystals distributed over the basal mass imparting an intense birefringence throughout.

The brown-coloured plasma is very scarce, it surrounds the crystals and fills the packing voids in some zones (Fig. 4). Very little disintegrated plant remains are frequent. Fungi hyphae can be found. The humus is *Rendsina moder* (chalk moder).

Fig. 4. Profile 4, 0-4 cm depth. Rounded sand grains are predominant. Thin section, under crossed nicols, × 50.

Profile 5. The original material consists of granite containing biotite, between the micas, and andalucite. Fragments of the original material can be found throughout the profile, on (B) horizon they are longer than 9 mm. Quartz crystals, feldspars and biotites are abundant, but also phytoliths are present.

There are plant remains which are very little disintegrated and fungi hyphae. The yellowish brown coloured plasma is very scare and, as a rule, surrounds the mineral grains which are loosely arranged. The humus is *coarse moder.*

ANALYTICAL STUDY OF SOILS AND DISCUSSION OF RESULTS

Comparing the results of Tables 1 and 3 it can be seen that the richness in part of the parent rock has a clear influence on the pH, exchange acidity and degree of saturation not only on deep horizons but also on the horizon of humification in the three analogous soils covered with *Q. ilex,* and that the degree of saturation is gradually diminishing as the carbonate contents of the respective parent rock is getting more and more reduced whilst, on the other hand, the actual acidity and the exchange acidity gradually increase.

Table 1

Profile	Horizon	Vegetation	% CaO parent rock	pH	Exchange complex (m. e. q./100 gr. soil)							
					H^+	Ca^{++}	Mg^{++}	K^+	Na^+	S	T	V
1	A_0	*Q. ilex*	50.88	7.65	—	53.0	5.05	1.27	0.52	59.84	59.84	sat.
,,	A_1	,, ,,	5.00	7.75	—	33.0	2.79	0.51	0.52	36.82	36.82	sat.
2	A_1	,, ,,	33.60	7.25	7.81	42.0	6.62	1.27	0.47	50.36	58.17	86.57
,,	(B)	,, ,,	,,	6.35	6.73	11.0	3.65	0.25	0.52	15.42	22.15	69.62
3	A_1	*Q. ilex*	1.26	6.15	9.00	6.0	1.65	0.38	0.52	8.55	17.55	48.71
,,	(B)	,, ,,	,,	6.25	5.6	5.0	1.65	0.25	0.61	7.51	13.11	57.28
4	A_0+A_1	*P. pinast.*	50.20	7.35	1.60	16.0	4.18	0.25	0.55	20.99	22.59	92.92
5	A_1	,, ,,	1.30	5.35	24.0	6.0	3.48	0.25	0.52	10.25	34.25	29.92
,,	(B)	,, ,,	,,	6.20	6.0	1.0	1.04	0.25	0.43	2.72	8.72	31.19

It may be that of the replacement of exchange cations had been effected at pH 7 the A_1 horizon of the Terra rossa (profile 2) would also be saturated in spite of showing a decalcification. However by applying the Mehlich method with the substituting solution at a pH 8.1 the medium passes to alcaline conditions, so that not only the H of the carboxylic groups of humic acids but also that of the hydroxydophenolic groups takes part in exchange reactions.

The influence on exchange Ca^{++}, sum of bases (S) and exchange capacity (T) is rather difficult to be estimated because these values depend not only upon the degree of humification of the organic matter, but also on the clay content of the mineral fraction and the mineralogical composition of the clay. The date referring to Ca^{++}, S and T of the mineral fraction would be required after the destruction of the organic matter so as to know those exclusively pertaining to the organic fraction on account of the existing difference. Nevertheless, in view of the loose texture of the Meridional Braunerde (profile 3) as well as the organic matter content it can be said in advance that the carbonate content in the substratum does not have any influence on the ratios of Ca^{++}/M.O. and T/M.O.

The C/N ratio shows a slight influence exercised by the parent rock in the sense of getting slightly increased as the $CaCO_3$ content diminishes.

Taking into account the properties already considered as well as the other circumstances leading to the formation of humus studied, and based on a succinct criterion about the humus classification, we can consider the humus of *mull rendzina* as *calcic mull* and the humus obtained respectively from the Terra rossa and the Meridional braunerde (profile 3) as *eutrophic* and *mesotrophic forestal mull.*

Table 2. Optical density (D) of humic acids from P. pinaster analogous soils

Profile	Horizon	Vegetation	Values for optical density wavelength mμ						
			726	665	619	571	533	496	465
4	A_0+A_1	*P. pinaster*	0.036	0.062	0.094	0.142	0.207	0.295	0.440
5	A_1	,,	0.039	0.055	0.080	0.127	0.184	0.262	0.372

Although the rendzina humus shows a better biological synthesis of very polymerized humic acids closely connected to the clay than the two remaining soils as well as a greater ratio between the aromatic structure and the aliphatic one (Table 4), there does not exist any relation between the $CaCO_3$ content of the parent rock of the Terra rossa and the Meridional braunerde and the synthetizing activity of the organic fraction and hydrophobic qualities of the humic acid molecule; hence there may intervene other factors which have not been taken into account here and which

Table 3. Content and composition of humus from analogous soils

Profile	Horizon	C	N	C/N	A_f	A_{hp}	A_{hg}	% A_f	% A_{hp}	% A_{hg}	$\frac{C(A_f+A_h)}{C_t}$	$A_{hg}/A_h \cdot 100$
1	A_0	11.31	0.65	17.40	1.72	0.81	0.35	15.20	7.16	3.09	25.46	30.17
1	A_1	4.80	0.31	15.48	1.11	0.38	0.27	23.12	7.91	5.62	36.66	41.53
2	A_1	12.36	0.77	16.05	1.55	0.69	0.32	12.54	5.58	2.58	20.71	31.68
2	(B)	1.90	0.15	12.67	0.52	0.21	0.09	27.37	11.05	4.73	43.15	30.00
3	A_1	3.67	0.21	17.48	0.49	0.31	0.18	13.35	8.44	4.90	26.70	36.73
4	A_0+A_1	5.37	0.19	28.26	0.63	0.23	0.24	11.73	4.28	4.46	20.48	51.06
5	A_1	13.05	0.34	38.38	0.90	0.70	0.48	8.96	5.36	3.68	15.94	40.67

unfavourably activate the Terra rossa in spite of the higher $CaCO_3$ content of the substratum.

The examination of the analytical results corresponding to profiles 4 and 5 permits to appreciate the contrast existing between A_1 horizon of both soils, this being the results of the diverse nature of the parent rock, an immediate and direct consequence of the high carbonate content of C horizon in profile 4 is its basic pH, its higher exchange Ca^{++} content, sum of bases (S) and degree of saturation and its lower H^+ exchange content than in profile 5.

Moreover, we can appreciate a higher degree of humification and a greater biological synthesis of very polymerized humic acids closely connected to the clay in the rendzina humus than in the Meridional braunerde humus, at a more elevated ratio of $A_{hg}/A_h \cdot 100$, a greater density of the aromatic nucleus and a more elevated ratio between the aromatic and aliphatic structures of the humic acid molecule in the rendsina humus than in the braunerde humus, thus assuring better qualities to the humus of profile 4 to form a good structure.

Taking into account all analytical results and the micromophological observations with a succinct criterion, the rendzina humus can be classified as *calcic moder* (chalk moder) and the braunerde humus as *coarse moder*.

Although, in fact, the C/N ratio of A_0+A_1 horizon shows a high value for this kind of humus, it should be borne in mind that the blend of both horizons contributes to raise the C/N ratio when the humus is mixed with little transformed vegetal remains. The crumbs do not only contain the brown and grey humic acids (*Braunhuminsäure* and *Grauhuminsäure* ac. [12]), sensibly balanced in the rendzinas, Table 2, but also the chemically little transformed vegetal substances or intermediate compounds which influence on the elevated C/N ratio; on the other hand, the rather active nitrification of the profile stimulated by the animal activity (presence of earthworms) which helps to mix the organic matter with the mineral fraction followed by an intense period of rainfalls in the months of February, March and April of the present year which have taken away

Table 4. Threshold of coagulation of humic acids ($CaCl_2$, m.e.q. per litre humate solution)

Profile	Horizon	Vegetation	Threshold	Time
1	A_0	*Q. ilex*	20.0	2 hours
1	A_1	,,	17.5	,,
2	A_1	,,	27.5	,,
3	A_1	,,	25	,,
4	A_0+A_1	*P. pinaster*	22.5	,,
5	A_1	,,	32.5	,,

the soluble mineralization products through the profile with losses caused by percolation, may also have contributed to increase the C/N ratio. The nature of the *P. pinaster* vegetal remains constitutes an unfavourable factor partly made up by the abundance of graminae of the grove-forest; therefore far from classifying the rendzina humus as *calcic mull-moder* (Kubiëna's *mull-like rendzina moder* [9]) as it is not saturated and there is only a slight humification, it should be correctly classified as *calcic moder* and the Meridional braunerde humus, with this vegetation of resinous plants, as *coarse moder* although it is not the typical humus formation in this soil.

SUMMARY

A micromorphological and chemical study of the humification has been carried out in analogous soils proceeding from the center of Spain. In the soils covered with *Quercus ilex* it has been verified that the nature of the parent rock clearly influences some properties (such as pH, exchange acidity, degree of saturation of humus) and that certain representative indexes such as exchange Ca^{++}/organic matter and T (exchange capacity)/organic matter do not exclusively depend upon the carbonate content of the parent rock.

The C/N ratio is slightly influenced by the original geological material in the sense that it is slightly increased as the carbonate content diminishes.

The carbonate content of the parent rock influences the type and sub-type of analogous soils covered with *Q. ilex* which are converted from *calcic mull* in the mull rendzina to *eutrophic forestal mull* in the Terra rossa, and to *mesotrophic forestal mull* in the Meridional braunerde.

In the analogous soils covered with *P. pinaster* the influence of carbonate content of C horizon becomes moreover visible in the degree of humification, biological synthesis of very much polymerized humic acids closely connected to mineral colloids (grey humic acids) and the ratio between aromatic and aliphatic structures of the humic acid molecule which are the higher the richer is the carbonate content of the parent rock. The humus passes from *calcic moder* to *coarse moder* when the parent rock changes from limestone to granite.

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