A SOIL SEQUENCE IN THE NATURAL AND RECLAIMED MARSHES OF THE GUADALQUIVIR RIVER, SEVILLE (SPAIN)

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SUMMARY

Five soil profiles from a saline zone in the province of Seville ("Marismas del Guadalquivir", SW. Spain) and one from an adjacent non-saline zone, have been analyzed in order to determine their physical and chemical properties and their classification.

All of these soils are recent and of fine texture. Hydraulic conductivity, except in top layers, as well as aeration porosity, is always low; non-available water holding capacity and linear extensibility, high. Differences are however found between those located near the river channel and those at the limit of Marismas in contact with vertisols, due to parent material, situation and use. Particularly noticeable is the progressive increment of their vertic character.

1. INTRODUCTION

Some 2000 km² of Seville province (SW.Spain) is occupied by saline soils. They represent 14% of its total area.

These soils have developed after the infilling of an ancient lake (*Lacus ligustinus*), which was connected to the open sea during Roman times. According to the work of LEYVA (1976), the materials forming the Guadalquivir "Marisma" (marsh) are typical of sediments deposited at different levels. The oldest sediments have a thickness between 7 and 25 m and are mainly formed by very fine earths (silt and clay) in various proportions. These materials correspond to the old fluvial network of the Guadalquivir river, the morphology being typical of a river bed near to its mouth. Upon this section, lies another, partially discordant, thinner one (20 cm to 5 m), its lithology being similar to that of the underlying section in this lower part (argiolites and/or clayey limolites). This section occupies the largest part of the Marisma.

The recent sediments have been deposited on the lower parts, with altitudes between 0 and 2 m, in depressions where there is stagnation of flood or run-off water from rainfall, enriched with salts as a consequence of evaporation.

The variety of soils found in this zone is important. In most cases, they contain predominantly clay of a non-expandible type (GONZALEZ GARCIA et al. 1956, MORENO et al. 1980) and the water surrounding the adsorbed cations is responsible for some of the soil properties, particularly the very high coefficient of linear extensibility.

The soils of this zone in the Marisma present an obvious handicap when used for agriculture, as their salt content is much too high for this purpose. To overcome this problem a series of reclamation projects were put into operation, the results of which can be found in GRANDE COVIAN (1967 and 1976). On the other hand certain areas have supported rice

cultivation for more than 20 years in some cases. These facts pose the question about what may happen to these soil after several years of leaching by drainage or rice cultivation and what could be the physical, physico-chemical and chemical properties developed under these conditions due to either their situation within the Marisma or their cultivation. It is important also to consider the problems involved in the classification of these soils, particularly those devoted to rice cultivation as shown by KYUMA & KAWAGUCHI (1967).

The aim of this work is to present and discuss the physical, physico-chemical and chemical properties derived from laboratory determinations on samples corresponding to profiles representative of various zones in the Guadalquivir Marisma and adjacent areas. The profiles studied belong to soils of various classes, from those still under natural conditions, to those under reclamation schemes or cultivated with rice. These different situations allow a comparison of their peculiar soil properties to be made. Finally, a classification of these soils, according to the Soil Taxonomy (U.S.D.A.), is proposed. Some aspects have already been dealt with in previous works by AYERS et al. (1960), GIRALDEZ & CRUZ (1975), MARTIN et al. (1978), and MORENO et al. (1978, 1979).

1.1. CLIMATE AND VEGETATION

The climate is typically Mediterranean, with moderate humid winters and hot dry summers.

Mean temperature varies from 10.0°C (January) to 25.5°C (August). Maximum temperature, during summer period, frequently reaches 40°C and above.

Annual total rainfall varies from 350 to 1100 mm, with an average of 550 mm. Most of the precipitation falls from November to March. There is practically no rainfall during July and August.

The halophytic plant community of these saline soils belongs to the Order Thero-Salicornetalia within the Class Salicornifera. The most characteristic communities contain Chenopodiaceae, like: *Beta vulgaris* subsp. *maritima*, *Arthrocnemum perenne*, *A. glaucum*, *Salicornia ramosissima*, *Suaeda vera*, *S. splendens*, *Salsola soda*, together with other species, mainly: *Spergularia salina*, *Melilotus indica*, *M. segetalis*, *Trifolium resupinatum*, *Frankenia laevis*, *Cressa cretica*, *Plantago coronopus* var. *maritima*, *Thrinicia hispida*, *Sphenopus gouani*, *Aeluropus littoralis*, *Hordeum maritimum*, *Monerma cylindrica*, *Polypogon maritimus*, *Crypsis aculeata*. Where flooding is persistent, Phragmiteteae, with *Scirpus*, *Eleocharis*, and *Cyperus*, are present.

2. MATERIAL AND METHODS

2.1. SOILS

The general area considered in this study is represented in fig. 1. Profiles have been chosen for each of the six subzones included in the scheme.

Profile 1 is representative of the most natural, undisturbed soil today. Profiles 1 and 4 represent the most saline parts in the area. Profile 6 is given as a contrasting example from a border situation and it is a typical vertisol. Profiles 2 and 3 are cultivated with wheat and rice, respectively; the latter under almost permanent flooding. Profiles 4 and 5 are situated in marginal zones; profile 4 without cultivation, profile 5 recently under wheat (see photo 1).

Fig. 1: Situation of profiles.

2.2. SAMPLING

In each profile samples have been taken at 20 cm intervals, except for the first layer, in which samples have been taken at 10 cm intervals. Stainless steel cylinders (8.0 cm diameter by 4.0 and 2.0 cm high) with sharp edges have been employed. Samples, hermetically covered with plastic lids, were transported to the laboratory for analysis.

Profile 1

Profile 2

Profile 3

Profile 4

Profile 5

Profile 6

2.3. METHODS

The following analyses have been done:

In undisturbed samples:

- Hydraulic conductivity in saturated status in constant water head permeameter, following the technique of FLANNERY & KIRKHAM (1964) in an apparatus designed by MARTIN ARANDA (1973).
- Bulk density (D_b) (from weight/volume ratio of core samples).
- Coefficient of linear extensibility (COLE) (from volume difference in sample cores, from field capacity to air dry).

In undisturbed subsamples:

- pF values (0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.7 and 4.2). The range 0-1.5 by suction in fritted glass plates following a technique similar to that of VOMOCIL (1965) and 2.0-4.2 by pressure in ceramic plates, in Richards chambers (RICHARDS 1948).

In disturbed samples:

- Granulometric analyses, by chain hydrometer (DE LEENHEER et al. 1965).
- CaCO_3 content, in Bernard's calcimeter (HIDALGO & CANDELA 1958).
- Salinity (following the U.S. Salinity Lab. Methods, RICHARDS 1954).
- Organic matter content, following Walkley and Black method, modified (PIPER 1950).
- Particle density (D_p) (by the use of a helium-air pycnometer, Micromeritics, mod. 1302).

3. RESULTS AND DISCUSSION

3.1. PROFILE DESCRIPTIONS

PROFILE 1

Classification: Fluvaquent

Location: Lebrija (Sevilla). Farm "La Señuela". Section III of Marismas.

Longitude: 6°10'25"W.; Latitude: 36°56'30"N.

Altitude: 2 m; Topography: Alluvial plain; Slope: 1%.

Parent material: Colluvial clayey deposits.

Vegetation and use: Natural pasture (hallophytes).

A ₁	0-10 cm	Dark gray brown (10 YR 4/2) moist, light gray (10 YR 7/2) dry; clayey; medium to large moderate to well developed, subangular blocky structure, tending to prismatic; very plastic and adhesive wet, firm moist, very hard dry; calcareous; salt efflorescence on dry aggregates surfaces; sharp smooth boundary.
B _{11g}	10-37 cm	Dark gray brown (10 YR 4/2) moist; clayey; slightly developed, massive structure with tendency to blocky-prismatic; very plastic and adhesive wet, firm moist; diffuse red-brown mottling increasing with depth; abundant radicular saline micelium partially hardened; calcareous; gradual smooth boundary.
B _{12g}	37-56 cm	Diffuse dominant variegate colour, dark gray (5 Y 4/1) with dark brown mottles (7.5 YR 4/4); clayey; massive structure with a tendency to weakly developed blocky-prismatic; very plastic and adhesive wet, firm moist; calcareous; abundant anastomosed tubular, salt micelium; gradual smooth boundary.
Cg	56-110 cm	Dark brown variegate colour (7.5 YR 4/4) moist and dark gray (5 Y 4/1) moist; clayey; large blocky structure; plastic and adhesive wet, firm moist; calcareous; abundant white salt micelium with gray mottles.

PROFILE 2

Classification: Haplaquept.

Location: Lebrija (Sevilla). Subsection B, Section III of Marismas.

Longitude: 6°44'0" W.; Latitude: 36°57'50" N.

Altitude: 5 m; Topography: Alluvial plain; Slope: 2%.

Parent material: Colluvial clayey deposits.

Vegetation and use: Wheat (after drainage).

Ap	0-20 cm	Gray to gray brown (10 YR 5.5/2) dry, dark gray brown (10 YR 4/2) moist; clayey; large columnar prismatic blocky structure, strongly developed in the top 10 cm, with large subangular blocky substructure, subconcoideous corrugated surface fracture; plastic and adhesive wet, firm and friable moist, very hard dry; strongly calcareous; frequent small gypsum concretions; slightly wavy boundary.
Bg	20-40 cm	Diffuse variegated colour, finely mottled, brown (10 YR 5/3) matrix moist; clayey; massive structure breaking up into prismatic columnar blocks, a little smaller than in previous horizon; plastic and adhesive wet, firm to friable moist, hard dry; strongly calcareous; gypsum micelium and concretions concentrated in a layer between 25 and 35 cm depth, diffuse boundary.
C _{1g}	40-80 cm	More defined variegated colour, on brown (10 YR 5/3) matrix, moist; with gray-dark gray (5 Y 3.5/1) and dark gray brown (10 YR 4/2) streaks moist; clayey; massive structure which breaks up into prismatic-columnar or subangular-prismatic blocks; plastic and adhesive wet, very firm moist; frequent gypsum micelium, concentrated at the horizon base, forming a more diffuse layer than before; more frequent, larger and more defined ferruginous mottles and concretions with depth; gray streaks along channels and galleries; strongly calcareous; gradual boundary.
C _{2g}	80-220 cm	variegated colour, with more defined and larger mottles than in previous horizon, gray (5 Y 6/1), brown-dark brown (7.5 YR 4/4) and brown (7.5 YR 5/4); clayey; massive structure with tendency to medium blocky; very plastic and adhesive wet, very firm moist; frequent ferruginous concretions; calcareous; gradual boundary.
IIC ₁	220-350 cm	Dark gray (10 YR 4/1) moist; clayey to clay loam; massive structure; very plastic and adhesive wet, very firm moist; compact; calcareous; diffuse boundary.
IIC ₂	350- cm	Same characteristics as before, but with the presence of abundant fragments of fine shells.

PROFILE 3

Classification: Haplaquept.

Location: Las Cabezas de San Juan (Sevilla). Farm "Quevedo – COTEMSA".

Longitude: 6°0'0" W.; Latitude: 37°4'10" N.

Altitude: 10 m; Topography: Alluvial plain; Slope: 1%.

Parent material: Colluvial clayey deposits.

Vegetation and use: Rice (20 years).

Ap ₁	0-5 cm	Dark gray brown (2.5 Y 4.5/2) moist, with fine diffuse yellowish brown streaks (10 YR 5/4), coincident with fine radicular ferruginous channels, small black mottles or concretions; clayey; weakly developed, medium crumbly structure; plastic and adhesive moist; calcareous; abrupt broken boundary.
Ap ₂	5-20 cm	dark to very dark gray (7.5 YR 3.5/0) moist; clayey; massive, without visible aggregates; very plastic and adhesive; calcareous; abrupt somewhat wavy boundary
Bg	20-30 cm	Brown to dark brown (10 YR 4/3) moist, with fine isolated gray streaks (5 Y 5/1) and abundant very diffuse yellowish brown mottles (10 YR 5/4) and some very small black mottles or concretions; clayey; massive; very plastic and adhesive; very compact; very firm moist; calcareous; gradual boundary.
C _{1g}	30-55 cm	Diffuse variegated colour, on brown to dark brown matrix (10 YR 4/3) moist, with fine and medium long gray streaks (2.5 Y 5/0) and diffuse brown to dark brown mottles (7.5 YR 4/4), parallel to gray streaks; clayey; weakly developed subangular blocky structure tending to massive; very plastic and adhesive wet; very firm moist; frequent small concretions; compact; calcareous; gradual boundary.

C _{2g}	55-100 cm	Very diffuse variegate colour on brown matrix (7.5 YR 5/4) moist, with ferruginous very dark medium-size mottles or concretions, and frequent hard and fragile crystalline gypsum micelium or tubulum, filling 2-3 mm diameter root voids; clayey; massive; very plastic and adhesive; calcareous; diffuse boundary.
C _{3g}	100- cm	Variegate brown (10 YR 5/3) and strong brown (7.5 YR 5/6) colour moist, with fine gray streaks, following the small radicular channels, bordered by strong brown mottles (7.5 YR 5/6) moist. Same general characteristics as before. Micelium forms a polygonal interlocking network; frequent ferruginous dark nodules.

PROFILE 4

Classification: Chromoxerert.

Location: Lebrija (Sevilla), Lake "Val de Ojo".

Longitude: 6°3'30" W.; Latitude: 36°57'5" N.

Altitude: 8 m; Topography: Alluvial plain; Slope: 2%.

Parent material: Marly-saline alluvial deposits.

Vegetation and use: Natural pasture (hallophytes).

A ₁₁	0-10 cm	Dark brown (7.5 YR 5/2) moist, brown (7.5 YR 5/2) dry, clayey; medium to large granular structure, strongly developed in the surface and moderately in the base of horizon; plastic and adhesive wet, friable moist, very hard dry; calcareous; sharp, smooth boundary.
A ₁₂	10-20 cm	Brown to dark brown (7.5 YR 4/2) moist; clayey; medium to fine moderately developed, subangular blocky structure; plastic and adhesive wet, friable to firm moist, hard dry; calcareous; gradual, smooth boundary. Cracks each 20 cm are appreciated.
B	20-34 cm	Brown to dark brown (7.5 YR 4/3) moist, dark brown (7.5 YR 5/3) dry; clayey large blocky-prismatic peds structure, with corrugated faces and salt efflorescence; plastic and adhesive wet, very firm moist, very hard dry; aggregates show tendency to conchoideous fracture; calcareous, with some small lime nodules, and also very isolated medium ones; gradual boundary. Cracks are observed.
BC	34-50 cm	Same colour and texture as above, strongly developed large blocky structure tending to prismatic; somewhat conchoideous fracture and shiny faces; plastic and adhesive wet, very firm moist, very hard dry; calcareous, with abundant calcosaline concretions; gradual boundary. Appreciable cracks.
C ₁	50-80 cm	Brown to dark brown (7.5 YR 4/3) with diffuse gray mottles (7.5 YR 5/1) and small strong brown still more diffuse mottles (7.5 YR 4/4) moist; clayey; massive; very plastic and adhesive wet, very firm moist; compact; frequent calcosaline concretions or micelium; gradual boundary.
C ₂	80-105 cm	Same general characteristics as above; tendency to blocky structure with shiny face aggregates; more plastic; calcosaline concretions; diffuse boundary.
C ₃	105-145 cm	Dark brown (7.5 YR 4/2) moist, with frequent very small white calcosaline concretions, uniformly distributed in the soil; clayey; massive structure tending to blocky with shiny faces; plastic and adhesive wet, firm moist; compact; calcareous; sharp boundary.
C ₄	145-200 cm	Brown (7.5 YR 4.5/2) moist; less frequent calcosaline concretions; clayey; massive; very plastic and adhesive wet, firm to very firm moist; compact; calcareous.

PROFILE 5

Classification: Pelloxerert-Haplaquept.

Location: Sevilla. Farm "Micones".

Longitude: 6°5'2" W.; Latitude: 36°52'2" N.

Altitude: 2m; Topography: Alluvial plain; Slope: 2%.

Parent material: Colluvial clayey deposits.

Vegetation and use: Wheat and barley (5 years).

Ap ₁	0-7 cm	Gray (10 YR 6/1) dry; gray (10 YR 5/1) moist; clayey; medium to fine well developed subangular blocky structure; large cracks 20 cm long, 2-3 cm width, each 10-15 cm, configuring large prismatic-columnar blocks; very plastic and adhesive wet, very firm moist, extremely hard dry; lime reaction; sharp smooth boundary.
Ap ₂	7-21 cm	Dark gray (10 YR 4/1) dry, gray (10 YR 5/1) moist; clayey; fine to medium moderate to well developed subangular blocky structure; plastic and adhesive wet, firm moist, very hard dry; no concretions; diffuse mottles; abrupt and smooth boundary.
B	21-50 cm	Gray (10 YR 5/1) moist; clayey; massive; moderately vertic with shiny conchoideous fractures; plastic and adhesive wet, firm moist; slickensides; no concretions; gradual boundary.
BC	50-70 cm	Gray brown matrix (10 YR 5/2) moist, with diffuse mottles, brown (10 YR 4/3) to gray brown (2.5 Y 5/2) streaks; clayey; plastic and adhesive wet; friable to firm moist; compact; shiny surfaces; conchoideous fractures; gradual to diffuse boundary.
Cg ₁	70-130 cm	Dark brown matrix (10 YR 4/3), dominant brown (7.5 YR 4/2) or brown (10 YR 5/3) streaks; clayey; massive; weakly developed large blocky structure shiny conchoideous fracture; abundant saline tubular streaks increasing with depth; slight discontinuous diffuse dark 2 mm mottling; plastic and adhesive wet; compact; lime reaction; diffuse boundary.
Cg ₂	130- cm	Brown matrix (10 YR 5/3) moist; with isolated yellowish brown (10 YR 5/8) mottles; other characteristics as above.

PROFILE 6

Classification: Pelloxerert.

Location: Utrera (Sevilla). Farm "Torre Marismas".

Longitude: 5°53'40" W.; Latitude: 37°2'35" N.

Altitude: 10 m; Topography: Plain; Slope: 2%.

Parent material: Calcareous marl deposits.

Vegetation and use: Wheat and sunflower.

Ap ₁	0-20 cm	Dark gray (10 YR 4/1), very dark gray (10 YR 3/1) moist; clayey; medium subangular blocky structure, strongly developed on the surface, when dry, with tendency to crumbly moist; conchoideous fracture aggregates; plastic and adhesive wet, firm moist, hard dry; abundant very small calcareous concretions gradual boundary.
Ap ₂	20-40 cm	Dark gray (10 YR 4/1) moist; clayey; weakly developed medium to fine crumbly structure, tending to massive; shiny conchoideous fracture aggregates; plastic and adhesive wet, firm moist, hard dry; frequent very small calcareous concretions; gradual boundary.
B ₁₁	40-60 cm	Dark gray (10 YR 4/1) moist; clayey; massive structure, with a tendency to form small and medium shiny-surface blocky aggregates; plastic and adhesive wet, firm moist, very hard dry; scarce very small calcareous concretions; gradual boundary.
B ₁₂	60-80 cm	Dark gray (10 YR 4/1) moist; clayey; weakly developed blocky structure; massive in fresh cuts; plastic and adhesive wet, firm moist, very hard dry; very scarce, very small, calcareous concretions; gradual smooth boundary.
B ₂	80-120 cm	Dark to very dark gray (10 YR 3/1) moist; clayey; structure formed by large blocky peds with slickensides; massive in fresh cuts; plastic and adhesive wet, very firm moist, very hard dry; very small isolated calcareous concretions; gradual boundary.
BC	120- cm	Dark gray brown (10 YR 4/2), with diffuse dark greyish streaks (10 YR 4/1) and brown (10 YR 5/3) moist; clayey; massive; without visible aggregates in fresh cuts; plastic and adhesive wet, firm moist; compact; lime reaction stronger than in previous horizons.

Tab. 1: GENERAL PHYSICAL PROPERTIES

Profile	Depth cm	Particle size (mm, %)				Dp g/cm ³	Db g/cm ³	K cm/h	COLE x 10 ²
		> 0.2	0.2-0.02	0.02-0.002	< 0.002				
1	0-10	0.5	1.0	27.5	71.0	2.70	1.43	0.5	7.0
	10-20	0.5	1.5	35.0	62.5	2.70	1.44	0.2	7.8
	20-30	0.5	1.5	29.0	69.0	2.73	1.44	0.1	7.1
	30-50	0.5	1.5	25.0	73.0	2.74	1.39	0.1	9.4
	50-70	1.0	2.5	33.5	63.0	2.74	1.43	0.1	6.7
	70-90	0.5	2.5	62.5	34.5	2.77	1.45	0.5	7.9
	90-110	1.0	3.5	42.0	53.0	2.77	1.30	0.1	11.3
2	0-10	0.5	1.5	28.0	70.0	2.72	1.30	0.2	12.8
	10-20	0.5	2.5	29.0	68.0	2.74	1.37	< 0.1	11.1
	20-30	0.5	2.5	29.0	68.0	2.75	1.26	< 0.1	11.6
	30-50	0.5	0.5	36.0	63.0	2.75	1.16	1.5	8.0
	50-70	0.5	0.5	29.0	70.0	2.78	1.26	< 0.1	11.4
	70-90	0.5	0.5	34.0	65.0	2.79	1.31	< 0.1	10.6
	90-110	0.5	1.0	33.5	65.0	2.79	1.27	< 0.1	10.0
3	0-10	0.5	1.5	28.0	69.5	2.72	0.96	0.3	17.1
	10-20	0.5	1.5	28.0	70.0	2.70	1.01	< 0.1	18.8
	20-30	0.5	1.5	31.0	67.0	2.75	1.27	0.3	13.0
	30-50	0.5	2.0	27.0	70.5	2.80	1.31	< 0.1	8.8
	50-70	0.5	2.0	30.5	67.0	2.79	1.20	< 0.1	11.5
	70-90	0.5	2.0	32.0	65.5	2.80	1.10	< 0.1	14.0
	90-110	1.0	2.0	30.0	67.0	2.80	1.10	< 0.1	13.8
4	0-10	1.0	3.0	39.0	56.5	2.70	1.39	0.1	9.7
	10-20	0.5	2.5	32.0	65.0	2.71	1.32	0.1	8.6
	20-30	0.5	2.5	28.0	69.0	2.74	1.40	< 0.1	7.8
	30-50	0.5	2.0	39.0	58.5	2.76	1.33	< 0.1	10.0
	50-70	0.5	1.5	33.0	65.0	2.77	1.35	0.1	7.7
	70-90	0.5	1.5	31.5	67.5	2.79	1.37	0.1	7.8
	90-110	0.5	2.5	34.5	62.5	2.78	1.32	< 0.1	9.7
5	0-10	0.5	2.5	39.5	57.0	2.66	1.16	3.8	14.2
	10-25	0.5	2.5	41.0	56.0	2.70	1.13	2.7	14.7
	25-35	0.5	0.5	41.0	58.0	2.70	1.23	0.3	14.7
	35-50	0.5	1.0	39.0	59.5	2.71	1.27	0.3	12.4
	50-80	0.5	1.5	41.0	57.0	2.72	1.23	0.2	9.7
	90-110	0.5	1.0	39.5	58.5	2.74	1.26	0.3	13.5
6	0-10	2.0	15.5	23.0	59.0	2.75	1.15	6.5	14.3
	10-20	2.5	15.0	23.0	59.0	2.72	1.33	0.1	12.6
	20-30	2.0	16.0	22.5	59.0	2.74	1.25	0.1	13.0
	30-50	2.0	16.5	22.5	58.5	2.78	1.23	0.1	13.0
	50-70	3.5	16.5	21.0	59.0	2.79	1.29	0.1	12.8
	70-90	3.0	16.0	22.5	58.5	2.73	1.30	1.5	12.4
	90-110	3.0	12.0	20.0	65.0	2.76	1.31	0.1	12.4

3.2. GENERAL PHYSICAL PROPERTIES

Particle-size range percentages, particle density (D_p), bulk density (D_b), hydraulic conductivity (K) and coefficient of linear extensibility (COLE) for the different profiles are given in table 1.

Tab. 2: WATER RETENTION (weight %)

Profile	Depth cm	pF							
		0	0.5	1.0	1.5	2.0	2.5	3.7	4.2
1	0-10	37.2	35.6	34.2	33.5	32.8	30.6	27.1	26.7
	10-20	36.2	34.9	33.8	33.7	33.6	31.9	29.7	28.7
	20-30	40.1	38.8	38.0	37.5	37.0	34.8	31.5	30.7
	30-50	43.4	40.6	39.3	39.0	38.7	36.3	32.4	30.8
	50-70	40.1	38.3	37.2	37.0	36.8	34.2	30.1	28.2
	70-90	39.4	38.3	37.7	37.1	36.8	35.3	31.7	30.6
	90-110	44.1	42.7	41.7	41.3	40.9	39.7	37.3	36.5
2	0-10	44.8	43.8	42.8	40.8	39.6	38.0	34.9	33.2
	10-20	44.5	43.7	42.6	40.5	39.5	38.1	34.7	33.0
	20-30	43.8	43.3	42.3	41.2	40.2	38.7	35.8	33.8
	30-50	46.8	46.6	44.6	43.8	42.7	40.8	37.0	35.9
	50-70	50.6	50.1	49.4	48.5	46.3	43.4	40.0	38.4
	70-90	47.8	47.5	46.5	45.7	43.5	41.6	38.8	36.1
	90-110	47.2	47.0	46.0	44.9	42.8	40.7	37.4	35.8
3	0-10	63.8	63.2	63.1	62.5	60.0	55.0	47.5	44.0
	10-20	62.1	60.1	59.8	59.6	57.8	52.3	46.9	44.9
	20-30	42.0	41.3	41.0	40.6	40.5	39.9	35.9	34.4
	30-50	43.5	42.3	41.9	41.1	39.3	38.2	33.3	32.2
	50-70	51.6	50.6	50.2	49.9	47.0	45.2	38.6	36.8
	70-90	60.4	60.0	59.7	58.7	55.1	53.6	46.7	45.4
	90-110	54.1	53.7	53.4	52.9	51.2	50.4	44.0	42.2
4	0-10	38.3	36.8	36.6	36.2	36.0	34.9	30.3	29.4
	10-20	32.6	31.6	31.1	30.6	30.2	29.8	26.6	26.0
	20-30	34.2	33.5	32.7	32.4	31.5	29.9	26.6	26.0
	30-50	38.0	37.5	37.0	36.8	36.0	33.9	30.0	28.6
	50-70	41.3	40.9	40.6	39.9	39.3	36.3	31.6	29.4
	70-90	44.1	43.6	42.8	42.5	41.1	38.8	34.6	32.9
	90-110	47.1	46.7	46.3	46.0	45.4	43.7	39.0	37.4
5	0-10	48.6	47.9	47.3	46.6	45.1	44.0	35.7	35.0
	10-25	47.7	47.0	46.1	45.3	44.0	40.7	34.6	34.0
	25-35	45.9	45.3	45.1	44.7	42.9	39.4	33.4	32.7
	35-50	46.1	45.5	45.2	44.3	42.9	41.0	36.2	34.8
	50-80	47.6	47.1	46.8	45.9	42.9	41.0	34.5	33.4
	90-110	48.0	47.3	47.0	46.8	45.0	42.9	36.6	35.6
6	0-10	52.6	51.2	49.8	46.4	42.4	40.1	35.7	34.9
	10-20	49.1	48.1	47.1	43.3	40.4	38.2	34.5	33.8
	20-30	52.6	51.1	49.6	44.6	42.7	38.8	34.4	33.2
	30-50	46.6	44.8	43.3	39.1	36.3	32.6	28.4	27.2
	50-70	45.9	44.8	43.3	38.6	35.8	32.6	29.3	28.2
	70-90	46.1	44.5	41.7	37.8	34.9	32.1	29.7	28.4
	90-110	44.4	43.2	41.8	38.3	35.4	32.7	29.9	28.8

Particle-size relative percentages are always typical of heavy clay soils, although certain variations are observed between profiles and also between different horizons in a given profile. In profile 1, in relation to the others, a noticeable reduction in clay content is observed, in favour of silt, between 70 and 90 cm depth, while in profiles 2, 3 and 5 there is little change. Variations within a given profile, in profiles 1 and 4, could be explained considering they are

the most natural and the nearest to the river (Guadalquivir and Salado, respectively) being therefore recent sediments. Profiles 3 and 6 (to a depth of 90 cm) are the most homogeneous; in both examples this is a consequence of the continuous agronomical use of these soils (MORENO et al. 1979): in the first case with a rice crop, in the second with winter and summer crops, usual for vertisols in the area (wheat, barley; cotton, sunflower, corn).

Bulk density (D_b) is another parameter linked to the agronomical status of soils. The highest values correspond to profiles 1 and 4 (soils maintained in natural condition), while the lowest values correspond to top layers of profiles 3, 5 and 6. Profile 2 represents an intermediate situation because of its recent use after drainage.

Hydraulic conductivity (K) (see table 1), as usual in this type of soil, is low. Only the upper 10 cm of each profile, in which the soil is looser, show higher values, due to agricultural practices or, as in natural profiles, to the annual incorporation of dry vegetal matter. It is important to note that hydraulic conductivity has not increased in the profiles under either reclamation (profile 2) or permanent agricultural use (profile 3) though the salt content has diminished considerably in top layers. This may be due to the swelling and dispersion of clay particles occluding pores responsible for water movement, if their exchangeable Na percentage (ESP), salinity level (table 3) and montmorillonite content (MORENO et al. 1980) are considered. This phenomenon has been discussed by FRENKEL & RHOADES (1978), amongst others, when studying the influence of dispersion and swelling on hydraulic conductivity of soils. On the other hand, values of this parameter in the top 25 cm of profile 5 (table 1) are higher than in other cases (3.2 cm/h against about 0.2 cm/h). This could be explained by the lower exchangeable Na content of this profile (table 3) this being a consequence of the reduction of total salt content, in relation to the others, as well as by the relative increase of Ca saturation in the exchange complex preventing the dispersion of clay. All this is undoubtedly related to the similar soil use, because of proximity (see fig. 1), of soils in contact with the Marisma, in which zone no drainage and leaching of salts have been carried out. This situation is similar to that described by TANG & CHANG (1978), in a saline region in China, in which an appropriate agricultural tillage improves hydraulic conductivity in the top horizons.

The coefficient of linear extensibility (COLE) is one of the most clearly differentiating physical parameters (see table 1). Mean values for each profile are, respectively:

8.4 - 10.5 - 13.2 - 8.8 - 12.6 - 12.8 (total profile)
and 7.4 - 12.0 - 18.0 - 9.2 - 14.5 - 13.5 (top 20 cm)

Profiles 1 and 4 show the lowest COLE, while 3, 5 and 6 show the highest. Profile 3 is subjected to a particular agronomic treatment responsible for the very high value of top layer (18.0%). In general, there is an increase for the COLE from natural saline soils to vertisol, with the exception of profile 3.

Profiles 1 and 4 show a very similar COLE sequence according to depth, with a relative maximum at 30-50 cm. Profile 3, on the contrary, reaches a minimum at that depth. Differences observed in the COLE, within a profile and between profiles, have to be related to both the use of the soil and the clay fraction mineralogy. In the case of profiles 1 and 4, the most natural ones, differences observed at various depths are undoubtedly due to the montmorillonite content. Although this ranges between 5 and 25% in soils of the Marisma (MORENO et al. 1980), it is sufficient to produce a large swelling and shrinking effect, due to exchangeable Na content and to the very high clay fraction percentage (up to 70%, see table 1). It should be borne in mind that this phenomenon is also affected by the cations adsorbed on the particle surfaces of other clay minerals present in these soils (particularly illite).

Tab. 3: VALUES FOR SELECTED SOIL CHEMICAL PROPERTIES

Profile	Depth cm	O.M. (%)	CaCO ₃ pH (%) (H ₂ O)	EC mmhos/cm	Soluble salts (meq/100 g)					Ca ⁺⁺	Mg ⁺⁺	CEC	Exchange- able Na ⁺ (meq/100 g)	ESP	SAR	
					CO ₃ H ⁻ Cl ⁻	SO ₄ ²⁻	Na ⁺	K ⁺								
1	0-10	3.0	24.0	7.9	15.2	0.3	8.1	1.7	6.0	0.1	1.7	2.7	19.0	1.5	7.8	20.3
	10-37	1.5	22.5	7.8	27.1	0.2	15.7	5.2	15.0	0.2	3.4	3.0	19.4	3.6	18.5	37.0
	37-56	1.2	24.8	7.2	36.2	0.3	24.4	4.4	20.2	0.2	3.7	5.8	16.3	4.7	28.8	43.3
	56-110	0.8	26.0	7.2	50.7	0.2	34.9	5.2	29.3	0.4	3.0	8.4	17.2	5.6	32.5	55.3
	0-25	1.4	10.4	7.4	4.8	0.3	0.8	2.4	1.6	0.1	1.4	0.2	27.7	4.3	15.4	7.2
2	25-50	0.9	8.0	7.8	18.3	0.1	8.8	5.1	9.8	0.1	2.6	1.5	31.5	9.5	30.2	26.8
	50-100	0.6	20.7	7.8	28.2	<0.1	16.0	5.8	15.9	0.1	3.1	3.0	29.0	10.4	35.9	35.8
	0-10	3.3	12.8	7.8	6.9	0.2	1.9	3.3	1.5	0.1	1.7	2.2	25.3	3.3	13.0	
3	10-20	3.1	12.0	7.8	6.9	0.2	1.4	3.0	1.1	0.1	2.1	1.4	24.4	4.0	16.4	5.5
	20-30	1.3	10.0	7.9	28.1	0.2	19.1	7.9	17.2	0.3	3.7	6.3	26.2	5.0	19.0	5.0
	30-50	1.2	7.7	8.0	12.9	0.2	-	-	7.2	0.1	1.4	1.8	24.4	6.0	24.6	34.6
	50-100	0.9	4.3	7.9	23.8	0.2	17.9	4.3	14.6	0.1	3.0	5.1	27.1	10.0	36.8	32.9
	100-110	0.8	5.1	7.7	34.5	0.2	33.5	5.7	25.8	0.3	4.5	9.4	27.2	10.1	36.0	42.3
4	0-10	4.4	15.8	7.9	13.6	0.4	0.5	0.2	0.4	<0.1	0.0	0.6	25.4	2.8	11.0	2.9
	10-20	2.4	14.0	7.8	-	0.2	2.5	0.2	1.6	<0.1	0.7	0.3	22.6	3.0	13.2	8.3
	20-34	2.0	13.3	7.6	20.2	0.2	12.4	1.3	9.0	<0.1	2.6	2.0	23.5	7.0	29.8	25.7
	34-50	1.9	11.2	7.7	24.5	0.2	14.3	4.5	14.2	<0.1	3.4	1.5	24.4	9.8	40.1	39.6
	50-80	1.7	11.7	7.7	34.6	0.3	24.2	5.0	22.7	<0.1	3.0	4.0	24.4	9.3	38.1	51.4
5	80-105	1.7	11.7	7.6	42.2	0.2	31.1	4.7	28.7	0.1	3.3	4.1	28.0	11.3	40.3	62.9
	0-10	1.9	24.6	7.5	4.6	0.2	2.5	0.5	2.1	<0.1	0.4	0.6	29.9	1.7	5.6	11.0
	10-25	1.6	24.0	7.7	11.3	0.1	8.1	1.1	6.3	0.1	1.3	1.3	30.7	3.0	9.7	20.9
	25-35	1.4	23.3	7.5	19.3	0.1	12.3	3.3	10.1	0.1	2.5	2.4	31.7	5.0	15.8	24.0
	35-50	1.3	21.3	7.5	30.1	0.1	19.7	4.2	16.1	0.1	3.9	4.2	29.0	6.2	21.4	30.0
6	50-80	1.2	18.6	7.5	34.7	<0.1	28.5	3.8	20.2	0.2	5.4	6.4	25.8	8.2	31.8	30.4
	90-110	0.8	20.3	7.5	38.5	<0.1	37.2	4.1	26.3	0.2	6.5	8.5	24.4	9.4	38.9	32.9
	0-20	1.7	8.6	7.6	1.2	0.3	0.3	0.3	0.1	<0.1	0.5	-	43.0	1.2	2.8	
	20-40	1.0	9.7	7.6	1.0	0.1	0.2	0.4	0.1	<0.1	0.3	0.4	49.7	1.3	2.6	1.2
	40-60	1.0	7.8	7.4	1.0	0.1	0.3	0.4	0.2	0.0	0.4	-	47.9	1.5	3.1	
	60-80	1.2	9.1	7.4	1.3	0.1	0.3	0.4	0.3	0.0	0.4	0.1	46.1	1.9	4.1	3.2
	80-120	0.9	9.4	7.9	1.7	0.2	0.5	-	0.6	0.0	-	-	44.5	1.7	3.8	

pH, determined in saturated paste.
EC and soluble salts, in saturated paste extract.

Fig. 2: Pore-size distribution in profiles 1, 2 and 3.

Fig. 3: Pore-size distribution in profiles 4, 5 and 6.

Soils under reclamation schemes or in agricultural use (profile 2, 3 and 5), have still higher values of COLE, and these practices have to be considered as adding their effect to that due to montmorillonite content. The effect is more noticeable in the more desalinized top horizons; in turn this should have contributed to the variation in the ESP of the exchangeable complex. This fact is important because the more the salt content decreases, a little increase of ESP may produce noticeable variations of COLE, as a consequence of the swelling of montmorillonitic material, provided ESP is within the values observed in these soils (table 3). These findings are in agreement with results shown by MACNEAL et al. (1966), when studying the effect of the composition of the solution on the swelling of clays extracted from soils. It should be taken into account that the decrease of soluble salts increases the dispersion of particles, which favours the increase in the COLE. On the other hand, the results are also in agreement with values obtained by ourselves when studying the variation of the COLE due to washing of salts from the samples. The results will be the object of a future paper.

The phenomenon is more obvious in the soils represented by profile 3 (top layers), due to the agricultural practice of incorporating the rice straw when the soil is still water saturated. In the vertisols represented by profile 6, although influenced by their use, the high montmorillonite content remains as the most important factor responsible for their high COLE.

Another similarity between certain profiles is shown by the fact that correlation between the water holding percentage at pF 2.5 and the COLE rises from $r = 0.63$, when considering all depths in all profiles, to $r = 0.78$, for only saline soils, excluding the vertisol. When the correlation is done between values for the vertisol and the top three layers of profile 3 and 5, then $r = 0.90$. It should however be noticed that the COLE, as an analytical index, may not be coincident with a vertic character (cf. profile 3), when certain unfavourable circumstances are present, as for instance when flooding is permanent.

3.3. PORE-SIZE DISTRIBUTION

Figs. 2 and 3 present the distribution of pore-size ranges corresponding to each profile. Pore-size distribution shows that the fraction greater than $9\ \mu\text{m}$ which is responsible for aeration and drainage, represents a low percentage of the total porosity which is normal considering the high content of fine particles. It is important however to analyze certain clear differences found between profiles. The largest amount of pores greater than $300\ \mu\text{m}$ (fast drainage and aeration) is found in profile 6 (fig. 3), the vertisol, in which a very considerable fraction of pores $300\text{--}30\ \mu\text{m}$ (drainage and aeration) is also present. Taken together with the fraction $30\text{--}9\ \mu\text{m}$, this represents a well balanced system, that can be explained by the fact that the vertisol in this zone shows a very good structure with very high stability (mean instability index (I_s) between 1.5 and 2.0), according to the scale given by ARRUE (1977) for the soils in this region, based on the method of HENIN et al. (1972).

Regarding pores of the fraction $9\text{--}0.2\ \mu\text{m}$ it should be noticed that the fraction $9\text{--}0.6\ \mu\text{m}$, responsible for the storage of easily available water for plants, is predominant in relation to pore fraction $0.6\text{--}0.2\ \mu\text{m}$ (strongly held available water). These two pore fractions are practically the same in all horizons, which differs from the results of ARRUE (1977) for vertisols with similar characteristics located nearby, who found fewer pores $9\text{--}0.2\ \mu\text{m}$ in the top layer than in subsoil. Although both these soils show similar structure and stability, this fact could be explained by differences in crop rotations and other agricultural practices producing a looser top layer.

In the other profiles, representative of saline soils, the fractions of pores greater than $9\ \mu\text{m}$ (figs. 2 and 3) are less abundant than in the case of the vertisol, which can be partially attributed to the larger number of fine particles. Profiles 2 and 5, which correspond respectively to soils cultivated after drainage and to a naturally well drained cultivated soil, show a good balance of the three pore fractions: greater than $300\ \mu\text{m}$, $300\text{--}30\ \mu\text{m}$ and $30\text{--}9\ \mu\text{m}$. This improvement of structure in the top layers was due to agricultural use. Profile 3, on the contrary, shows a different balance according to depth, again as a result of its particular use for rice cultivation. A minimum value is found for all fractions between 20 and 40 cm depth due to the use of mechanical implements.

The natural soils (profiles 1 and 4) have certain differences particularly in the distribution of the fractions greater than $9\ \mu\text{m}$. Differences between these two profiles, for drainage and aeration pore fraction, may be due to a different CaCO_3 content. This is lower in profile 4 (table 3) and contributes to fewer pores of this size, as the CaCO_3 is finely divided (predominant fraction smaller than $2\ \mu\text{m}$) and it probably acts as a cementing agent between particles. STAKMAN & BISHAY (1976) have observed that in loamy-clayey soils with different amounts of CaCO_3 , the aeration porosity diminished on the removal of CaCO_3 .

In all the saline profiles, pores between 9 and $0.2\ \mu\text{m}$ are less abundant than in the vertisol (profile 6), except profile 5 in which the reverse happens. This could be due both to the type of soil use and to more particles in the fraction $2\text{--}20\ \mu\text{m}$. Another fact is that in profiles 1, 2, 3 and 4 the proportion of pores with size between 0.6 and $0.2\ \mu\text{m}$, is slightly higher than in profiles 5 and 6, the meaning of which will be discussed in the following paragraph.

3.4. WATER HOLDING CAPACITY

In all the profiles studied, water holding capacities are high (see table 2) as is normal for clayey soils. However, large differences can be observed between profiles: profiles 1 and 4, as it is the case for the COLE, show the lowest values, while profile 3 shows the highest; this is practically the maximum found in all saline and heavy soils studied in the region.

Water retention at different pF levels depends on the pore-size distribution shown in figs. 2 and 3. In profiles kept under natural conditions water holding values from pF 0 to pF 4.2 are lower (10.5% in top layers of profile 4, 12.9% in profile 1) than in vertisol (20.5%); between pF 0 and 2.5 the values are 4.2, 7.8 vs. 14.6%, respectively. If water holding capacity in profiles 1 and 4 is compared with that in other profiles, clear differences exist, the values being lower in natural profiles, particularly in top layers. This fact could be related to both a different pore-size distribution (figs. 2 and 3) and a higher particle dispersion in top layers of profiles 2, 3 and 5, as a consequence of the lower salt content (table 3), previously mentioned. Dispersion is favoured by a larger water accumulation round the cations adsorbed on particle surfaces, thus increasing water holding capacity.

Differences can also be observed between soils in relation to pF value changes with depth. Water content profiles, at pF 2.5, are given in fig. 4, so that the differences can be more easily appreciated (see also table 2). The changes under natural conditions (profiles 1, 4) are not very important and they follow a rather similar pattern. However, in profile 3 a change occurs at 20-50 cm depth, for the water content is lower. This is in agreement with both the increase of bulk density, observed at the same depth, and the fewer pores greater than $9\ \mu\text{m}$ (see table 1 and fig. 2, respectively), and is very probably due to mechanical compaction by machinery. The vertisol shows a quasi homogeneous pattern, except for the top layer in which values are higher. In the top layers of profiles 2 and 5, which are not represented in

Fig. 4: Water retention at pF 2.5 in given profiles.

fig.4, the pattern for this and other properties is similar to that of the vertisol. At deeper layers, they are similar to those of the natural saline profiles. The behaviour of top layers is related to soil use.

In profiles 1, 2, 3 and 4, the amount of useful water strongly held represents an important quantity (approx. 40%) of total useful water, this being in agreement with the porosity data. This means a greater effort by the plants to extract that water.

3.5. CHEMICAL AND PHYSICO-CHEMICAL PROPERTIES

Data corresponding to chemical and physico-chemical properties of these soils are included in table 3 and have been determined with the aim of characterizing these soils from the point of view of their salinity and also as an aid in interpreting other properties and phenomena presented in this paper.

The organic matter content is usually low, as it is the rule in cultivated soils under semi-arid climatic conditions in the Mediterranean area, except in top layers of profiles 1 and 4, which have been kept under natural conditions.

CaCO_3 content, on the contrary, is high, particularly in profiles 1 and 5. It is finely divided, about half of its quantity (in some cases up to 70%) being formed by particles smaller than $2 \mu\text{m}$.

pH corresponds to values for saline, non sodic soils; normally below 8.0. EC, excluding profile 6 (vertisol) is always high. Data from profile 1 (saline, natural), shown in table 3, are very similar to those found by AYERS et al. (1960) when analyzing samples of soil represen-

Tab. 4: GYPSUM CONTENT (%) IN PROFILES 1 AND 4

Depth	Profile 1	Profile 4
0-10	0.0	0.0
10-20	0.0	0.0
20-30	1.6	0.0
30-50	1.1	1.9
50-70	1.0	2.1
70-90	0.6	1.0
90-110	0.1	1.9

Tab. 5: SALT CONTENT OF GROUND WATER IN PROFILE 1

EC	95.0	mmhos/cm
CO ₃ H ⁻	2.2	meq/l
Cl ⁻	1420.0	meq/l
SO ₄ ⁻⁻	132.8	meq/l
Na ⁺	1086.9	meq/l
Ca ⁺⁺	84.8	meq/l
Mg ⁺⁺	349.5	meq/l

ted by this profile. Data corresponding to profile 2 (saline under reclamation and use) are much lower however. This shows the effect of reclamation and subsequent use. Table 4 shows there is no gypsic horizon, even in profile 1 and 4, in which the gypsum content is highest.

Profile 1, the most recent soil, shows no CaCO₃ mobilization; profile 2, far from the river and cultivated, has had much CaCO₃ leached. Profile 2 shows no CaCO₃ leaching and a certain salt accumulation at 20-30 cm.

In general, Na-saturation is greater than 15%. Table 5 includes values for salt content in ground water. Cl⁻, Na⁺ and Mg⁺⁺ are the main ions present.

Although it is not included in the tables, the clay mineral fraction is predominantly formed by illite, in an advanced degree of alteration. Small quantities of montmorillonite and kaolinite are present. Traces of chlorite are also found. Usually montmorillonite never accounts for more than 10% of the total mineral fraction though exceptionally it might reach 25% in certain horizons (MORENO et al. 1980).

4. CONCLUSIONS

The soils studied show differences due to situation, parent material and use. All of them, however, are recent soils of fine texture.

All these soils show high values of microporosity: 0.7-0.8 of total porosity correspond to the pore size range smaller than 0.2 μ m. On the other hand, fractions of pores greater than 9 μ m keep a good balance in profile 6 (vertisol), 2 and 5 (saline cultivated soils), although in the latter, this pore-size fraction is less abundant.

Hydraulic conductivity is very low and only in the top layers of profiles of pronounced vertic character are higher values observed, as in profile 5.

Water holding capacity is always high as is normal in clayey soils. Of greater importance is the high proportion of strongly held useful water (pores between 0.6 and 0.2 μ m), in saline soils.

The COLE, in general, increases from soils under natural conditions to vertisols. According to this and morphological observations, the vertic characteristics increase progressively from those areas near the river to the marginal zones in contact with vertisols.

From previous data it could be deduced that the existing relationship between vertisol and saline soils is due to the vertic character of the latter soils and, as a consequence, to the derived properties. Although this vertic character could be produced by reclamation and use of the soil, it should be accepted that further research is needed to find out what transfor-

mations occur in clay minerals when the soil is desalinized. We have not found, in the available references, works dealing with the relationships between saline soils and vertisols.

These soils have been classified by GIRALDEZ & CRUZ (1975) as saline-alkaline soils, according to the criteria of the U.S. Salinity Laboratory. We propose, from the results obtained in the present work and according to the U.S.D.A. (1975), the following classification for the soils:

Profile 1, the most recent one, shows a slightly developed structure. In view of its physical and physico-chemical properties, Na-saturation, EC and pH values, it should be considered as an alkali-saline soil, according to the Soil Salinity Laboratory classification. Following the U.S.D.A. it should be classified as Fluvaquent (saline phase).

Profile 2 has a more developed structure. Although still an alkali-saline soil, it could be altered into a non-saline alkali through the leaching of salts. It is a Vertic Haplaquet, with salt content increasing with depth.

Profile 3 has a slightly developed structure, due to permanent flooding, with no vertic characteristics; therefore it should be classified as Typic Haplaquet, with salt content increasing with depth.

Profile 4 shows a strong vertic character. As with profile 1 it is less expandible than the others. Na-saturation is smaller than 15%, in the first 20 cm, and increases with depth and the soil is saline (EC is greater than 4 mmhos; SAR is greater than 13 from 20 cm downwards). From these data, the soil should be considered as Entic Chromoxerert.

Profile 5 also has a strong vertic character, and with the COLE greater than 14%, it is an alkali-saline soil, with CaCO₃ content higher in the top 50 cm, as a consequence of the nearby marly-calcareous areas. It is an intergrade Entic Pelloxerert to Vertic Haplaquet.

Finally, profile 6 is a vertisol. Considering physical and chemical data (and colour "value"), it should be classified as Entic Pelloxerert.

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