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Capillary rise in a Paleosol from Vinga Plain

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Abstract: To obtain a good insight into the hydrology of the subsoil, data are sometimes required up to depths of dozens of meters. Soil profile irregularities occur very often, causing abnormal root development. Such a situation is in the case of Paleosol, which is a soil formed totally or partially on a landscape of past geological times, and having in its profile at least one horizon of Pleistocene age or older. Three features of paleosols in particular aid their identification: root traces, soil horizons, and soil structure. Most Paleosols are red to reddish brown from iron oxide, or yellowish brown from goethite. Vinga Plain, a region situated in the western part of Romania is covered mostly by loess and loesslike deposits, in which several buried soils, situated under Chernozems, can be identified. From the description of profiles, as well as from the analytical data of samples, substantial differences result between the soil layers and loess layers, on the one hand, and between the paleopedological formations developed under different bioclimatic conditions on the other one. The section represents a quaternary deposit – Superior Pleistocene-Middle Pleistocene, which contents actual sol (the first 70 cm from the surface), and 5 Paleosols with red or yellow-reddish colour and 2 layers of loess. Data on particle size distribution show an increasingly finer texture from loess (L_1, L_2) to Chernozemic soils and up to argillic B horizons and red clays. Consequently, the hydraulic conductivity (K) presents a certain vertical variation. Chernozems are usually well drained, but in case of a compacted argic horizon (as in the Paleosol) internal permeability may be low so that water stagnates on the bB_2, bB_3, bB_4 horizons, and so is created a temporary groundwater layer. So that, the real capillary rise is only 0.8-1m (mm /day) for sandy soil, 1.3m for clayey soil, and 2-2.5m for loamy soil.

Keywords: capillary rise, waterflow, Pleistocene, Paleosol.

1. INTRODUCTION

In a normal routine soil survey, the observation depth of the profile is generally limited to approximately 1.50 - 2.00m. This corresponds with the root depth of most crops and as such is sufficient to give an insight into the possibilities of crop rotation but it is inadequate when it concerns drainage problems. To obtain a good insight into the hydrology of the subsoil, data are sometimes required up to depths of dozens of meters. The required soil data have to be of physical and chemical nature to relate to the hydrological problems, but they must also allow interpretation in agronomical terms in connection with the increased yields that can be expected after drainage improvements, have been made. [1]

For a drainage plan, the following soil data will be required [2]:

- gley phenomena;
- permeability of the soil profile for water (vertical permeability, horizontal permeability, transmissibility);
- available moisture;
- capillary rise;
- salinity and alkali problems.

Soil profile irregularities occur very often, causing abnormal root development; such irregularities are also of importance in drainage, because they influence the permeability. Such a situation is in the case of Paleosol, which is a soil formed totally or partially on a landscape of past geological times, and having in its profile at least one horizon of Pleistocene age or older. Paleosols or fossil sols are commonly divided into buries, relict and exhumed Paleosols. Three features of paleosols in particular aid their identification root traces, soil horizons, and soil structure [6].

Both fossilized roots and root traces show the downward tapering and branching of roots. Paleosol horizon are seldom more than a meter thick and tend to follow one of a few set patterns. Subsurface layers enriched in clay are called Bt horizons.

Soil structure replaces sedimentary structures such as bedding planes and ripple marks, metamorphic structures such as schistosity and igneous structures such as crystal outlines and columnar jointing. Paleosols are commonly described as massive, hackly or jointed. The technical term for a natural soil clod is a ped, which can be crumb granular, blocky, or columnar, among other shapes. Paleosols, like sediments, can be altered: cementation with carbonate, haematite or silica; compaction due to pressure or overburden, etc. Most paleosols are red to reddish brown from iron oxide, or yellowish brown from goethite. Burial gleization is suspected when the lower parts of the profile are highly oxidized and have deeply penetrating roots, and when is no pronounced clayey layer that would perch a water table within the soil [2]

Climatic interferences also can be made from ice deformation features, concretions, clay mineral compositions, bioturbation and chemical analyses of

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paleosols.

Paleosols formed below the water table include peats and are grey with chemically reduced minerals such as pyrite. From the times for paleosols formation and the thickness of rock for successive paleosols it is possible to calculate rates of sediment accumulation.

A soil survey carries out to assess the drainage problems in certain regions aims at providing the planning engineers with the soil data required to draw up a justified plan, and enables them to arrive at accost – and – benefit comparison with possible alternatives. The factor soil will have to be integrated with all the other factors, influencing the economic results of the plan.

A sensitivity analysis reveals the relative influence of the various factors involved: the permeability and thickness of the soil layers through which groundwater flow can occur, wetted perimeter of drains, depth of drains, etc.

2. MATERIALS AND METHODS

Nowadays soil maps are available for many parts of Romania. The classification of the soil units on these maps is mainly based on taxonomic soil classification principles.

The present study is based on a soil surveys which was effected on the year 2003th for the National Soil Science Conference [10].

The study presents, also, a continuation of our preoccupation for soil improvement. After all, it is not just a matter of pedological data, but also information pertinent to agriculture, arriving finally at problems of soil mechanics and civil engineering.

Vinga Plain, a region situated in the western part of Romania is covered mostly by loess and loesslike deposits, in which several buried soils, situated under Chernozems, can be identified. On the greatest part of its distribution area, the loess presents typical characteristics: unstratification, high porosity rate (52 – 55 percent), lime content (15 – 20 percent), medium textured. The clay fraction is dominantly an illitic – montmorillonitic material.

Paleosols with argillic B horizon occur all over the region.

According to the development degree of the argillic horizon in these soils the water can be stored for beneficial use. They provide storage for deep percolation from precipitation and streamflow used in overlying areas, and for water artificially placed in them.

3. RESULTS AND DISCUSSIONS

From the description of profiles, as well as from the analytical data of samples, substantial differences result between the soil layers and loess layers, on the one hand, and between the paleopedological formations developed under different bioclimatic conditions on the other one.

For a good understanding of the problems, it is necessary to present a chronology of Quaternary environmental changes, the correlation between glacial epochs and historical periods.

Table 1.Correlation between European mountainous Glaciation and Historical periods

Geological era			Time years	European glaciation	Climate	Historical period	
1			2	3	4	5	
Quaternry	Holocene		400-800 BC 800 BC 2500 BC 4000 BC 5500 BC 7000 BC 8300 BC	Post glaciation	Actual Under - Atlantic Under - Borealis Superior – Atlantic Inferior – Atlantic Borealis Ante - Borealis	Bronze Iron Neolitic Mesolithic	Homo sapiens duplex
	Pleistocene	Superior	8300-14000 BC	Tardiglacial	Unsteady: cold-arid; warm	Superior Paleolithic	Homo sapiens fossilis Cro-Magnon
			14000-25000 BP 25000-55000 BP 55000-80000 BP	Glacial 3 Würm 2 1	$-1^0C…+4^0C$		
			20000-120000	Interglacial Riss - Würm	$+8^0C$ moist	Middle Paleolithic	Homo sapiens Neanderthaliensis
		Middle	120000-250000	Glacial Riss	-3^0C, arid		
			250000-300000	Interglacial Riss -Mindel	$+10^0C$	Inferior Paleolithic	Homo erectis
		Inferior	300000-660000	Glacial Mindel	-		
			660000-700000	Interglacial Günz-Mindel	-		
		Old	700000-1200000 1200000-1600000 1600000-1800000 1800000-2000000	Glacial Günz Interglacial Donau-Günz Glacial Donau Glacial Biber	-	Archaeolithic	Homo habilis

Table 2.Anterior Quaternary Glaciation –

Geological Era	Time, Million years		Glaciations
Mesozoic	500-2000		Proterozoic Glaciation 1. 615 BP 2. 770 BP 3. 950 BP
Paleozoic	Permian Carbonifer Devonian Sillurian Ordovician Camberian	2000-2500 → 2500-3000 3000-3500 3500-4000 4000-4600 →	Huronian ~ 2300 Glaciation Ordovician ~ 4000 Glaciation

BC – Before Christ
BP – Before Present (1950)
AD – Anno Domini

Soil development is helpful in assessing geomorphic stability or the extent to which landforms have been preserved buried, or modified. Soils showing the most development are usually the oldest in a given study area and these soils are places where older archaeological deposits may be preserved. Older archaeological deposits commonly overlie or are found within diagnostic subsurface horizons such as argillic and calcic horizons.

Vinga Plain, a region situated in the south-western part of Romania between the Mureș river and the Bega river, is covered mostly by loess and loesslike deposits in which several Paleosoils can be identified. The loess and loesslike deposits can be of aeolian origin or deluvial.

The successive steps for defining the soil type have been:

- determination of the presence and kind of horizons;
- identification of specific vertical successions of horizons;
- application of the technical key to define the soil type and subtype;
- determination the morphological, physical and chemical soil properties.

<u>Vinga Plain, 1 km E of Vinga</u> [10]

Pedogenetical conditions and morphological features [10, 11]

Relief: Plain with valley; elevation about 120m; cut in the versant of about 7 m.
Parent material: loesslike deposits and Paleosol.
Drainage: well drained.
Native vegetation: steppe short grasses.
Use: cultivated field.
Climatic data: $T_m{}^0C=10.3$; $P_{mm}=593$

Table 3.Profile description

S I CZka (Calcaro-calcic chernozems)	Am_1 0-20cm; silty clay loam, very dark brown (10YR2/2), dark grayish brown (10YR3/2) when dry; moderate, fine granular structure; frequent fine roots; Am_2 20-47cm; clay loam, dark grayish brown (10YR3/2), dark grayish brown (10YR4/2) when dry; strong, medium granular structure; weak net of fine roots; gradual boundary AC 47-70cm; clay loam, dark brown (10YR4.5/3) and brown – brown pale (10YR5.5/3) when dry; invaded from white lime efflorescences; weak subangular blocky structure; very numerous channels; crotovinas weak compact; gradual boundary.
S II Würm	(bB_1ca) 70-120cm; loam, with rare rolled quartzite gravel; dark brown (10YR5/3), brown pale (10YR6/3) dry; white lime efflorescences; coarse concretions; moderate subangular blocky structure; moderate compact; fine fissure; irregular boundary (more than 25% $CaCO_3$).
L I Würm	(bC_1ca) 120-165cm; silty clay loam; light brown olive (2.5Y5.5/4), yellow light brown pale (2.5Y6.5/4) dry; chestnut tonguing from suprajacent horizon; lime concretion; massive structure fine porous; irregular boundary (bC_1ca) 120-165cm; silty clay loam
S III Würm	(bB_2ca) 165-215cm; silty clay loam with rare rolled gravel; dark yellowish brown (10YR4/4), brown (10YR5/3.5) dry; $CaCO_3$ concretions, big, white, with strong core; columnar structure; diffuse boundary (more than 25% $CaCO_3$).
S IV Riss-Würm	(bB_3ca) 215-290cm; silty clay loam with rare rolled gravel; brown (7.5YR4.5/4), brown (7.5YR5/4) dry; prismatic structure; numerous fine streak of $CaCO_3$; illuviation argillan; compact; diffuse boundary.
S V Riss	($bB_{4.1}$) 290-350cm; loamy – clayey with rare rolled gravel; brown-reddish (5YR4/4) and (5YR5/4) dry; prismatic structure wit mangan and thick clay skin; vertical wedge and hard puppet, white, rare, oblong of $CaCO_3$; slickensides, zones with platy structure, diffuse boundary. ($bB_{4.2}$)350-420cm; loamy – clayey with rare rolled gravel; dark brown-reddish (5YR3.5/4) and brown-reddish (5YR4.5/4) dry; prismatic structure; illuviation argillan and black mangan cutans; vertical, white wedge of $CaCO_3$.
S VI Mindel-Riss	(bB_5ca) 420-510cm; silty clay loam; yellowish brown (10YR5/4) structureless, compact; vertical, oblong puppets of $CaCO_3$; diffuse boundary (more than 25%$CaCO_3$).
L II Mindel?	(C_2) 510-610cm; silt loam, yellowish (2.5YR6/4) structureless, moist.

The section represents a quaternary deposit – Superior Pleistocene-Middle Pleistocene, which contents actual soil (the first 70 cm from the surface), and 5 Paleosols with red or yellow-reddish colour and 2 layers of loess (L_1, L_2).

The packets of Paleosols totalized 3.95m. Paleosols with argillic B horizon occur all over the Vinga Plain. Red clays were considered to be the most evaluated soils of this type. Their thickness varies either as a consequence of soil evolution itself or because of erosion. The upper horizons, the eluvia one included, were not preserved or cannot be identified. Manganese blackish spots and slickensides occur mostly in the lower part of the B horizons.

The analytical physic-chemical characteristics are present in the table 4. [10]

Table 4. Analytical data (ICPA Bucuresti)

Depth, cm of horizon	A 0-20	AC 20-47	S I, C 47-70	S II 70-120	L I 120-165	S III 165-215	S IV 215-290	S V 290-420	S VI 420-510	L II 510-610
Coarse sand, %	1.2	0.0	0.0	1.9	1.4	1.2	1.2	0.0	13.3	0.0
Fine sand, %	22.9	23.4	23.3	24.3	27.4	27.7	24.5	21.2	25.3	32.6
Silt, %	38.8	32.2	32.3	30.6	32.7	35.5	36.3	25.6	27.6	37.9
Clay, %	37.1	44.4	44.4	43.2	38.5	35.6	38.0	53.2	33.6	29.5
Humus, %	6.42	5.16	3.18	0.72	-	-				
$CaCO_3$, %	0.0	3.2	9.5	29.2	31.4	34.1	17.6	12.9	47.3	18.3
pH_{H2O}	8.08	8.1	8.17	8.29	8.44	8.44	8.50	8.61	8.92	8.92
K, mm/h	2.40	2.51	-	-	40.2	-	0.30	0.20	1.20	17.1

Data on particle size distribution show an increasingly finer texture from loess (L_1, L_2) to

Chernozemic soils and up to argillic B horizons and red clays. Consequently, the hydraulic conductivity (K) presents a certain vertical variation, depending on the layer succession: the loess strata has great values (40.2 and 17.1 mm/h) the Chernozemic soils 2.40 and 2.51 mm/h, while the B argillic horizons only 0.30-0.20-1.20 mm/h (that means a very low permeability).

Chernozems are usually well drained, but in case of a compacted argic horizon (as in the Paleosol) internal permeability may be low so that water stagnates on the B_2, B_3, B_4 horizons, and so is created a temporary groundwater layer. Water holding capacity in the argic horizon is high and ranges between 15 to 25 % of volume.

The gradient in water potential next to a root can be calculated by solving the general flow equation, in cylindrical coordinates [4]:

$$\frac{\partial\theta}{\partial t}=\frac{1}{2}\frac{\partial}{\partial r}\left(D\theta\cdot r\frac{\partial\theta}{\partial r}\right) \qquad (1)$$

where θ is the volumetric content, t is time, $D(\theta)$ the soil moisture diffusivity (depending on moisture content), and r is the radial distance from the axis of the root. This analysis suggests that soil water can move towards the root over distances of several cm until the initial soil water potential approached –15bar [6].

From the discussion it should be apparent that the amount and rate of water uptake depend on the ability of the roots to absorb water from the soil as on the presence of water in soil pores .

When water is added to the soil from below (B horizon of the Paleosol) the top soil becomes wet for a considerable distance above the water table. The movement of water upwards can be calculated from:

$$h=\frac{2\sigma\cos y}{\rho_w g r} \qquad (2)$$

where g is the acceleration of gravity, and ρ_w is the liquid density (4.5). For water at 20^0C in a glass capillary with $\gamma = 0^0$, the capillary rise will be:

- 1.5cm-15cm for r=1-0.1mm (similar with coarse sand);
- 15cm-1.5m for r=0.1-0.01mm (similar with fine sand);
- 1.5m-15m for r=0.01-0.001mm (similar with silt);
- >15m for r<0.001mm (similar with clay)

Capillarity in angular soil pores is quite different from the behavior in cylindrical pores with equivalent cross-sectional area. For example, when angular pores are drained a fraction of the wetting phase (water) remains in the pore corners and adsorbed on the walls (in the case of a clayey soils with r<2μ).

So that, the real capillary rise is only 0.8-1m (mm /day) for sandy soil, 1.3m for clayey soil, and 2-2.5m for loamy soil. This is similarly with the critical depth of salinization when the water is riched in salts [8]

For our Paleosol, with loamy layers situated between soil profile (0-70cm) and the B horizon (165-510cm) clayey, we can conclude that the water stored as water table in the B horizon, will be available for plants in the arid months.

4. CONCLUSIONS

The purpose of soil survey is to give information about soils. A study of 1:10.000for soil is not made specifically for drainage purpose, because it is only of 1 to 1.5 meter.

For hydrological calculations it is necessary to know the composition of the subsoil to depth 5 to 10m, and sometimes of 50 to 100m.

Vinga Plain is a high plain, between the rivers Mures and Bega, in which the soil cover cosnsist predominantly of Chernozems, with medium texture.

A large area under soil profile has Paleosols; for identification, three features are: root traces; soil horizons with B red to reddish brown; and soil structure. The section analyzed shows a chernozem of 70cm, two layers of loess (L_1 120-165cm and L_2 510-610 cm), and five paleohorizons B (S II-S VI). The B horizons are argillic, with low permeability. It is created a temporary water table which supplys to bottom of soil profile.

The first packet suprajacent 290 cm (S II+S III+S IV and Loess I) belong to Würm and interglacial Riss-Würm.

The second packet, subjacent (S V+S VI) – Riss and Mindel-Riss.

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