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Red palaeosols sequence in a semiarid Mediterranean environment region

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Abstract In this work we study one of the most palaeopedological sequence formed in Central Spain, which is located on the Pliocene–Pleistocene erosional surface in the Madrid Basin. We also analyse its relationship to erosive and sedimentary Pleistocene events in order to obtain new data for a correct interpretation of the origin and evolution of forms at the top of tabular lands in this site. The geomorphic features and the properties of a sequence of very red palaeosols that developed on this old surface can help us in the understanding of the palaeoclimatic evolution of Central Spain in a Mediterranean climate. They were examined to identify pedologic and climatic changes during the Quaternary. The soil sequence comprises intercalated palaeoargillic and palaeopetrocalcic horizons. The clay minerals are mainly illite, kaolinite, smectite and sepiolite. The alternation of argillic and calcic horizons, limestone debris (cryoclastic colluvions) and aeolian sands suggests succeeding periods of phytostability and phytoinstability (biostasis/rhexistasis). Argillation, rubification and calcium carbonate accumulation were repeated throughout the Pleistocene and it is hypothesised that climatic conditions during numerous stages of this period were not very different from the present conditions.

Keywords Palaeosols · Palaeoclimate · Pleistocene · Mediterranean · Red soils · Central Spain

Introduction

There is a growing interest in palaeosols, especially those formed in areas undergoing active erosion (Valentine and Dalrymple 1976; Retallack 1994). Information on the genesis and development of soils formed during past periods is an indispensable input to the palaeoenvironmental reconstruction of the landscape and to the understanding of climatic changes.

Red soils, which developed on a wide range of rock types, are among the most representative soils of Mediterranean regions. One remarkable feature is the shiny red colour, especially in argillic horizons. Argillation and rubification after decarbonation, which took place when parent materials are rich in calcium carbonate, were the main soil-forming processes (Yaalon 1997). Due to their patchy distribution on the landscape and frequent truncation, red soils are often considered as relicts or palaeosols (Retallack 1981, 1997).

The region studied has undergone a broadly consistent morphoclimatic history over the last two million years. Geomorphologic context of the top of this tabular land (700–1,000 m) has been interpreted in different ways. Old studies (1900–1960) performed by different authors have assimilated the flat topped of tabular relieves to a structural surface related to the calcareous outcrops of the last sedimentary episode of Neogene basins (Mio-Pliocene). The materials of this depositional lacustrine surface would be near horizontal like other Miocene sediments of the region.

Other research carried out by several geomorphologists and geologists (Vaudour 1979; Pérez González 1982; García del Cura et al. 1991) has shown that is an erosioned surface. This took place during Pliocene and their smooth folds are truncated by a planation surface. The general flat shaping was finished at the beginning of Quaternary, when the existing base level was very high.

During the Pleistocene, the high surface trenching was produced either by base level movements or by complex climatic changes. Today, the tops of the Neogene plateau are deeply dissected (> 200 m) and drained by the Tajo river and its tributaries. On the surface, palaeosols have been identified at a wide range of occurrences; but in the majority of cases the evidences are fragmentary, profiles are disrupted and truncated, and the stratigraphic resolution is crude.

However, near the town of Colmenar de Oreja, about 60 km Southeast of Madrid, at 3°22′50″W and 40°07′40″N, we recognised a good succession of different palaeosols. The sequence is extremely important to the past history of the landscape and the reconstruction of the Pleistocene environments and shows some data from stable isotopes on the Quaternary palaeosols from this area.

Here, the tablelands that crown the limestone plateaux in this region at 700–750 m a.s.l. belong to a vast Pliocene erosional surface ("páramo surface") that planned the lacustrine sediments of the Neogene age. This region was subjected to a small tectonic deformation during the Pliocene and to karstification during the Late Pliocene (Villafranchian). The resultant is the development of "terra rossa" soils, mainly Chromic Luvisols (Vaudour 1979) and calcareous clastic crusts (Pérez González 1982). Surface drainage is poorly organised and the present topography is slightly undulating, with some small hills of 10–20 m relative elevation (anticlines) and frequent structural depressions, which coincide with synclines. Also, some palaeokarst collapse features have developed on this surface (Fig. 1). Such a depression is filled with a slope of detrital materials and buried red soils. A west–east geomorphological cross section (Fig. 2) in the profile site shows the top unit with Neogene limestone, and the associated quarries and the site with palaeosols.

The persistence of the red palaeosols together with the more recently formed Cambisols, Leptosols and Regosols suggest that soil diversification with time was more a process of adding new kinds of soils than replacing pre-existing ones (Retallack 1997).

Materials and methods

The study area is located in the Central region of the Iberian Peninsula. The Neogene plateau of the Madrid Basin (Central Spain) constitutes an excellent example of tabular landscape and can be regarded as the unified geographical region "Alcarria" (Madrid, Guadalajara and Cuenca provinces).

The present climate is semiarid continental Mediterranean, with 540 mm of annual rainfall and 13.5°C mean annual temperature. The hummed index is between 0.30 and 0.70 due to the high values for evapotranspiration in summer. The potential climax vegetation is a *Quercus ilex* forest.

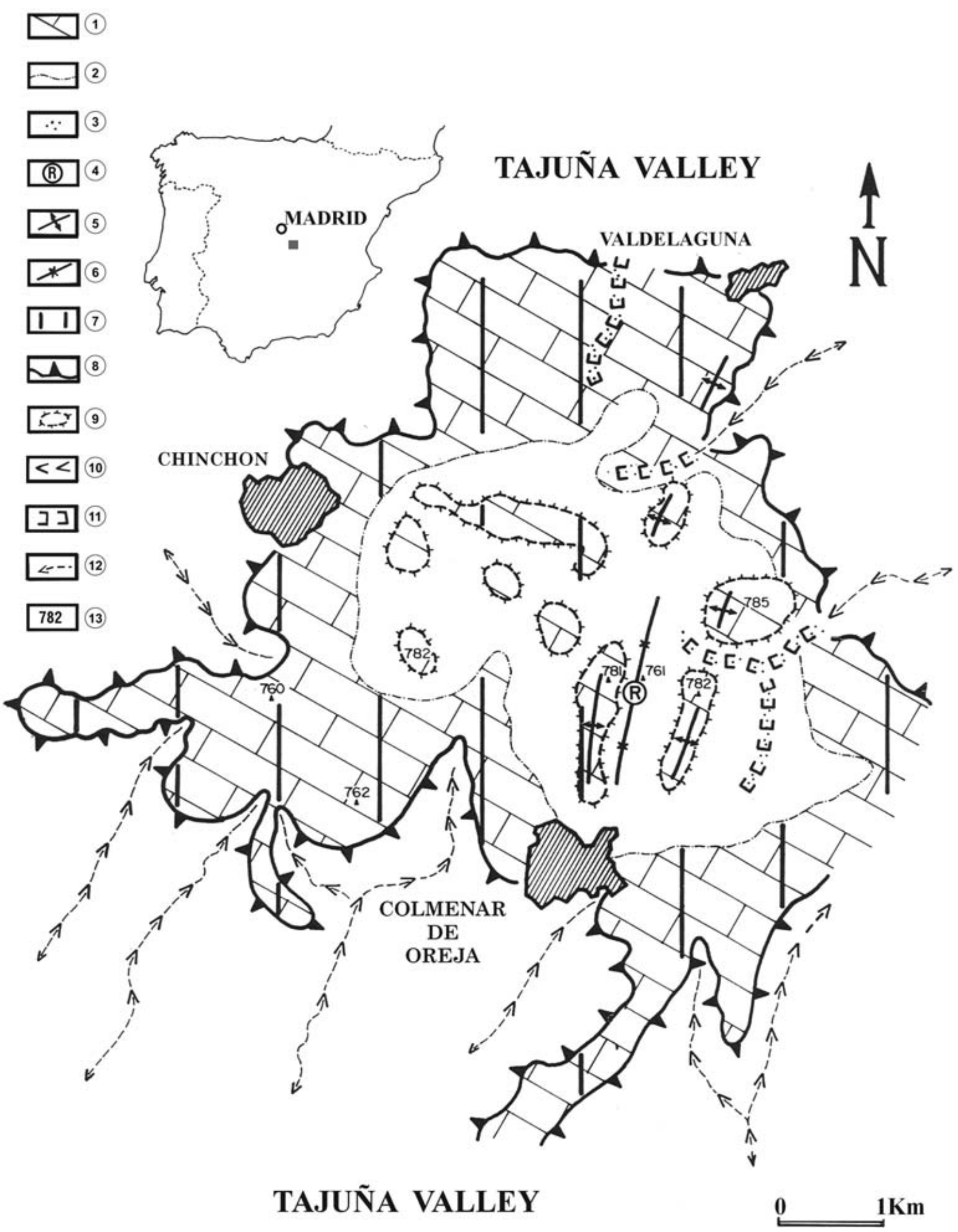
This paper studies a complex composed by multiple palaeoargillic horizons and others placed on the erosioned surface over the landscape from the Madrid Basin. We also analysed the mineralogical composition and the isotopic data of the soil sequence from the Colmenar de Oreja (Madrid).

A geomorphological map of the area (Fig. 1) was prepared using photo interpretation and field survey. The soil profiles were described according to the FAO guidelines (FAO-UNESCO 1977, 1990). The physical–chemical properties have been analysed following the methods of the Soil Survey Staff (1992). The Munsell soil colour chart was used to describe the soil colours. Particle size distribution was determined by the pipette method after the removal of organic matter with H_2O_2 and dispersion by shaking with sodium hexametaphosphate (Loveland and Whalley 1991). The pH was measured potentiometrically in a 1:2.5 soil/water suspension and also the conductimetry. The organic carbon content was determined using the method of Tyurin. Total iron oxides was extracted with citrate-dithionite and the amorphous forms. Iron in the extract was measured by atomic absorption spectroscopy.

The mineralogical analysis was studied by X-ray diffraction (XRD) and scanning electron microscopy (SEM) using a PHILIPS XL30 electron microscope equipped with energy dispersive X-ray analyser (EDX). Characterisation by XRD was carried out using the random powder method for the bulk sample and the oriented slides method for the < 2 μm fraction (Moore and Reynolds 1997). The X-ray diffractometer is a SIEMENS D-5000 with a Cu anode, operated at 30 mA and 40 kV using divergence and reception slits of 2 and 0.6 mm, respectively. To quantify the components in the bulk sample, the procedure proposed by Schultz (1964) was used. The XRD profiles were measured in 0.04 2θ goniometer steps for 3 s. For the clay fraction (< 2 μm), oriented aggregates were air dried, glycolated with ethylene-glycol and heated at 550°C for 2 h. Semiquantitative mineralogical analysis was based on the diffraction peaks (Kisch 1990).

On the other hand, systematic observations were done using an SEM–EDX device (PHILIPS XL30, W source, DX4i analyser and Si/Li detector). The analyser was previously calibrated with a multimineral sample: the USGS standard ADV-1 (Govindaraju 1994).

Fig. 1 Geomorphological sketch of surrounding palaeosols zone. *1* Neogene limestones, *2* detritic materials—clays, silts, etc. (Quaternary), *3* detritic Holocene accumulations (valley bottoms), *4* location of palaeosols, *5* anticline, *6* syncline, *7* erosional surface, 8 associated scarps, *9* minor relief features, *10* V-shaped valleys, *11* valleys with flat bottom, *12* intermittent water flows, *13* altitude elevation (in m. a.s.l.)



Pedogenic carbonate samples were analysed for carbon and oxygen stable isotope composition. They were reacted with 103% phosphoric acid at 90°C under IRMS, VG PRIMS-2 system to liberate CO_2 gas in VG-ISOCARB.

The soil sequence had three levels (Figs. 3, 4):

(1) The lowest part of the profile (10R–11R). The bedrock is the Neogene lacustrine limestones (11R) crossed by a system of fissures more or less filled with red clay (“terra rossa”). It was formed by the karstic corrosion that occurred during the Pliocene times. It is capped by a calcareous breccial (10R calcrete). At its top, the calcrete is partially disintegrated. On the other hand, a water table is perched on the impermeable Neogene layers.

(2) The middle part of the profile contains a buried palaeosol sequence (Ck_1 to $9Ck_8$). It overlies calcretes with sharp contacts. Successive palaeohorizons of similar kind were recognised in 14 m of the stratigraphic section. The soil horizons are concordant, but not parallel to the present land surface. Their lateral continuity of thickness is similar and there are no variations to backslap to footsteps near the bottom depression. The top of the palaeosol

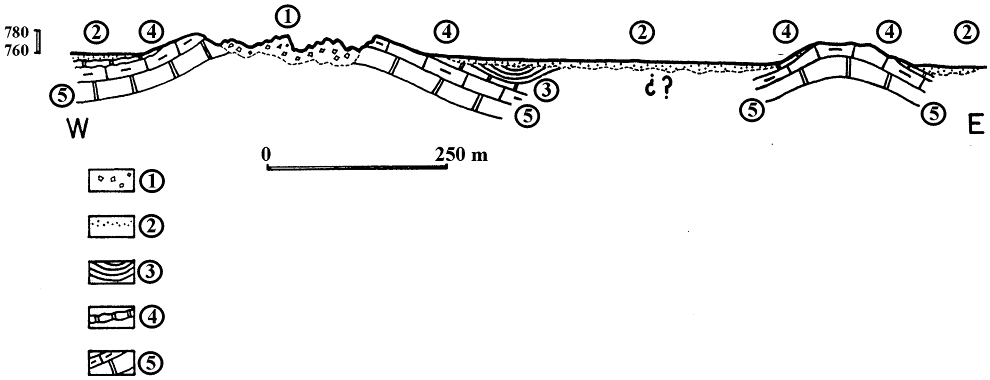


Fig. 2 West–east geomorphological cross-sectional outline in the profile site. *1* Limestones quarries, *2* soils and recent sediments, *3* site with palaeosols, *4* Fini-Neogene (Villafranchian) lacustrine calcrete, *5* Neogene limestone stratum

sequence has been substantially eroded and buried. These facts suggest that the palaeosol is located in a synpedogenic karstic depression. The palaeosol shows relatively uniform profiles and characteristics. The A horizons are absent because of erosion.

The sequence consists of superimposed soils, which overlap through vertical accretion and have poligenic features (Fig. 3). High densities of vertical root traces with deep penetrating are present in several horizons. Large root traces are an obvious indicator of former forest vegetation and well-drained conditions. The root traces were replaced by calcium carbonate. The depth of calcic horizons below the surface reflects the depth of wetting of the soil by available waters.

(3) Upper level of profile. After the formation of palaeosols and karstic subsidence, an erosional event and a weathering phase started in dry conditions. At the top of the profile, there are new horizons that show drastic changes in disposition and colour. An exposed unconformity separates the middle set of palaeosols from an upper horizontal soil from the recent Pleistocene; in this case the soil forming is an Inceptisol with Bw horizon of grey or very dark greyish brown colour (see Table 1).

The main morphological properties are reported in Table 1. Eroded calcrete tops are common, so that boundaries between horizons are generally clear. The zoned crust at the case of the sequence is breccial, including angular fragments, and originated by multiple repetition of sedimentary-pedogenic cyclothems at centimetre scale. Calcic concretions vary from a few millimetres to several centimetres. They are frequently prismatic and show a systematic vertical elongation. Locally, they fuse into each other. Their disposition suggest that they formed in response to disruptive horizontal compressive stress. The 8Ck horizon, in the middle of profile, shows an aeolian deposition (García et al. 1998). The study of the quartz grains by SEM reveals superficial impacts with triangular morphology due to the transport by wind (Fig. 5) and on the surface

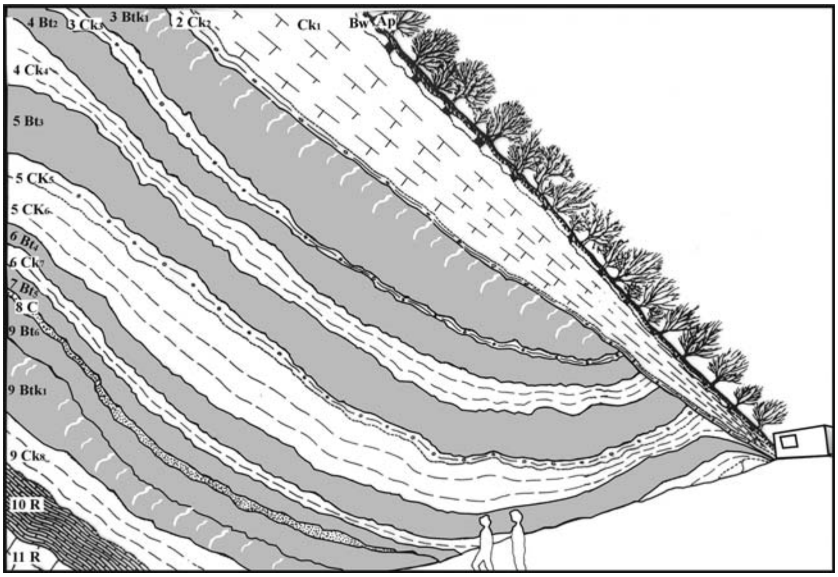


Fig. 3 Schematic palaeosol sequence from Colmenar de Oreja

Fig. 4 General view of the palaeosol sequence with their three levels

show calcium carbonate and calcium silicate concretions. After formation, the soils were exposed to physical compaction and desiccation.

Results and discussion

The palaeosurface of the soil profile was just a result of the ongoing karstification during the Pliocene, in humid conditions. Durn et al. (1999) observed differences in particle size, mineralogy and geochemistry between "terra rossa" and the insoluble residue of limestones. They indicate that the addition of external materials might have diminished the influence of the insoluble residue of limestones as the primary parent material. The relationship of this type of soils to underlying carbonates has been interpreted in different ways. For some authors, "terra rossa" has developed from the insoluble residue of carbonate rocks (Bronger et al. 1983; Moseri and Mongelli 1988). Other authors have emphasised that "terra rossa" could not have been formed exclusively from the insoluble residue of carbonate rocks (Rapp 1984; Durn et al. 1999). We prove the polygenetic nature of "terra rossa": the erosion-deposition processes have been induced both by climatic changes and tectonic movements.

The examination of the relationships between different horizons provides evidence of several episodes of the pedogenesis within the same profile (Fedoroff 1997). This is the characteristic of "Composite palaeosols" (Morrison 1978). During warm and humid stages of Quaternary, the smaller relieves related to anticlines were efficiently protected by vegetation and the development of weathering and pedogenesis processes. But when climatic conditions turned more arid and/or colder, the vegetation cover was minimal and soil mantle and unconsolidated deposits were easily removed. Subsequently, wash erosion intensified and colluvium movement began. So the soil was eroded and deposition of new material occurred on this truncated soil. A lot of anticlines began to be levelled and the resultant erosive products were deposited in the synclines or in small valleys. Therefore, a younger soil formed in the overlying material and developed in the remains of the older soil and the colluvial deposits. The new surface soil that formed was similar to the fossil soil.

Therefore, buried palaeosols are preserved only in the syncline depressions and adjacent structural slopes, in karstic depressions or in the flat-floored small valleys on the top of the tabular land. Their thickness is the result of the initial palaeosurface related to slight topographic relief and does not exceed 3–4 m. However, the 14-m thick palaeosol section in the Colmenar de Oreja profile (Madrid province) provides the palaeopedological record on the "Páramo plateau" in Central Spain.

The age of palaeosols is imprecise because they are too old for radiocarbon dating and too poorly fossiliferous to establish their chronology. Beside, dating of these relict soils is difficult and presents considerable problems. They are related to diagenetic changes in buried soils, which have introduced some isotopic pollution from the vertical migration of recent carbonates, in the forms of concretions or nodules. Similar problems are possible in the $^{13}C/^{12}C$ and $^{18}O/^{16}O$ values. However, we studied these values in specific stratigraphic sampling sites where root contamination is absent or becomes minimal.

The paleosols do not contain any organic material, paleontological or prehistorical remains that would facilitate their dating by the classical methods. The dating of calcareous concretions by carbon 14 is not advisable because of the risks for too old ages (due to the possible occurrence of "dead carbon" in the calcareous particles) or too young ages (due to younger carbonates from water infiltration). Thermoluminescence method is not good by the same water circulation in the profile.

Stable isotopes $^{13}C/^{12}C$ and $^{18}O/^{16}O$ $\delta‰$ values are shown in Table 1 (with standard deviation ± 0.1 $\delta^{13}C$ and ± 0.2 $\delta^{18}O$). $^{13}C/^{12}C$ range is from −9.80 to −7.54 and for $^{18}O/^{16}O$ $\delta‰$ values the range is from −5.98 to −4.62. These values corroborate the pedological origin of these materials. ^{13}C fluctuating between −10 and −7‰ makes it possible to clearly separate these carbonates from those belonging to marine sediments (−2 to +2‰ ^{13}C) and that could originate from the Mesozoic calcareous material of a similar area (Coudé-Gaussen et al. 1987). Many potentially significant factors complicate the interpretation of the isotopic composition of pedogenic carbonates, among these are the variations in O isotope values of meteoric and soil water on the O isotopic values of pedogenic carbonate and the magnitude of inheritance of C and O isotope values from carbonate present in the soil parent materials (McFadden et al.

Table 1 Main macromorphological features, isotopic data and mineralogical total composition of the soil sequence

Horizon	Depth (cm)	Colour (in dry)	Structure	Clay coating	Carbonate coating	Gaebules of carbonates	Others features	δ^{13} $C_{V\text{-}PDB}$	δ^{18} $O_{V\text{-}PDB}$	Calcite (%)	Quartz (%)	Feldp (%)	Phyl (%)	Gyps (%)
Ap	0–25	10R 6/10	Strong, subangular blocky coarse	No	No	No	Plonghed, firm, abundant-roots, fragments—20%	–	–	30	50	10	2	5
Bw	25–100	10R 3/2	Subangular blocky coarse	No	Yes	No	Fragments—10%; many pores	−7.54	−5.98	10	45	9	36	–
Ck$_1$	100–210	5YR 8/2	Platy/blocky coarse	No	No	No	Nodular calcrete; colluvion	−8.61	−5.20	90	–	–	10	–
2Ck$_2$	210–240	5YR 8/3	Platy/blocky coarse	No	No	No	–	−8.78	−5.10	95	–	–	5	–
3Bt$_1$	240–355	5YR 6/2	Angular blocky coarse	Yes	Yes	Yes	Few mottles; fragments—40%	−9.80	−5.20	30	50	–	20	–
3Ck$_3$	355–420	2.5YR 6/8	Platy/blocky coarse	No	No	No	–	−9.00	−5.01	40	10	30	20	–
4Bt$_2$	420–500	2.5YR 5/8	Subangular blocky coarse	Yes	Yes	Yes	–	−9.56	−4.81	20	52	–	28	–
4Ck$_4$	500–590	2.5YR 5/8	Subangular blocky coarse	No	No	No	–	−8.91	−5.01	36	41	–	23	–
5Bt$_3$	590–660	2.5YR 5/6	Subangular blocky coarse	Yes	Yes	Yes	–	−9.30	−4.81	40	5	–	55	–
5Ck$_5$	660–720	5YR 7/6	Subangular blocky coarse	No	No	No	–	−8.99	−5.10	60	12	8	28	–
5Ck$_6$	720–830	5YR 6/8	Platy/blocky coarse	No	No	No	–	−8.75	−5.10	30	48	7	25	–
6Bt$_4$	830–920	5YR 4/3	Subangular blocky coarse	Yes	Yes	Yes	–	−8.45	−4.71	8	22	3	65	2
6Ck$_7$	920–990	2.5YT 5/6	Subangular blocky coarse	No	No	No	–	−8.79	−5.20	26	50	10	11	3
7Bt$_5$	990—1,000	2.5YR 4/6	Subangular blocky coarse	Yes	Yes	Yes	–	−9.40	−4.91	70	8	2	16	4
8C	1,000–1,040	10R 4/6	Massive	No	No	No	Sometimes; cemented	−8.59	−4.81	2	68	2	24	4
9Bt$_6$	1,040–1,170	2.5YR 4/8	Subangular blocky coarse	Yes	Yes	No	–	−9.06	−4.71	12	60	4	20	–
9Btk$_1$	1,070–1,250	7.5YR 4/4	Subangular blocky coarse	Yes	Yes	No	–	−8.71	−4.62	20	55	3	22	–
9Ck$_8$	1,250–1,380	5YR 7/6	Angular blocky coarse	No	No	No	–	−8.82	−5.10	98	–	2	–	–
10R	1,380–1,490	7.5YR 8/4	–	–	–	–	Breccial; calcrete	−8.69	−5.01	100	–	–	–	–
11R	> 1,490	–	–	–	–	–	Limestone	–	–	100	–	–	–	–

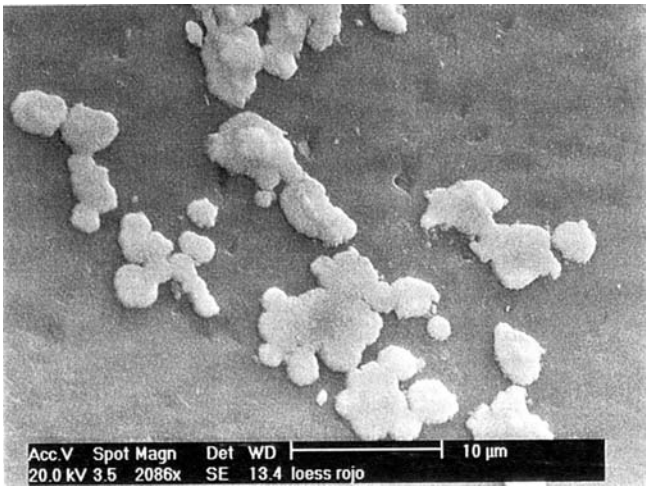


Fig. 5 Photo of the quartz grains with triangular impacts. Upper calcium carbonate and silicate calcium concretions by SEM

1991). The contents are good climatic indicators because they show little change in the isotopic composition indicating a specified pedogenetic period. We suggest that the carbonates were formed in an environment with more available moisture (Kadeami and Mermut 1999). The migration of carbonates and their accumulation in the Ca horizons generally in the form of concretions are the principal arguments for a pedogenesis. This conclusion is confirmed by the study of the stable isotopes (Coudé-Gaussen et al. 1983), which indicate the probable occurrence of a steppe vegetation.

During the Quaternary, an important system of alluvial terraces was formed in the valleys of the Tajo river and its tributaries. This stepped landscape included successively older surfaces at higher levels and these in turn have progressively better developed soils (Vaudour 1979). The youngest terrace with a similar red evidence is $T + 30$ m and its age is Riss-Würm interglacial (number 5, Oxygen Isotopic Stage). So, palaeosols are possibly older than the Riss-Würm interglacial. Moreover, in Central Spain, some investigations based upon detailed mapping and sedimentological methods indicated a palaeoclimatic evolution reflected by stratified slope deposits (González et al. 2000), loess mantles (García et al. 1998; García 2004) and a lot of tufa deposits (Pedley et al. 1996; García del Cura et al. 1997; Ordoñez et al. 2005) formed during the humid and warm Oxygen Isotopic Stages (1, 3, 5 and 7).

Depth functions of the principal parameters are displayed in Fig. 6. Soil reaction is moderately alkaline and towards alkaline in some horizons, see 9Ck$_8$ (8.9) and 6Bt$_4$ (8.7). Exceptionally, pH values are below or above 9 in contact with the bedrock and the electric conductivity values are higher. Organic matter is present in the samples of level 6 (Bt$_4$, Ck$_7$) and the surface. Total iron can be higher than 15% near the bedrock (levels 6, 7, 8 and 9). During the weathering phases, iron was released and produced red soil colours. The ratio of free iron shows moderate values, original higher ratio values decreased after horizon formation.

Calcite contents vary from 0 to 98%, according to the horizon type (Table 1). Dolomite and gypsum appear in small quantities in some horizons. Likewise, feldspars are scarce in general and potassium feldspars are present only in two horizons (3Ck$_3$ and 6Ck$_7$), resulting from the scarcity or even total absence of feldspars in the limestone substrata.

Phyllosilicates vary inversely to calcite. In some horizons, there is no calcic; the variations are caused by the intrusion of allochthnous sediments. Phyllosilicates include illite, kaolinite, smectite and sepiolite (Table 2). Locally, some of these minerals are absent. Sepiolite is in the top horizon and illite at the bottom of the sequence. The Kubler index (Kubler 1968) for illite in the samples is $<0.20\ 2\theta$ (fairly crystalline). This values shown a process of neoformation. Illite and kaolinite follow an opposite trend. Composition variations result from the combined effects of differential sedimentation (inheritance) and neoformation. Calcium carbonate can mask the significance of this balance. Quartz is present everywhere, with a maximum (68%) in a eolian sands lenticular stratum at 1,000–1,040 cm depth (Table 1, sample 8C).

Sepiolite is a common mineral in arid and semiarid regions (Jiménez Ballesta et al. 1985; Ortiz et al. 2002). The presence of sepiolite and smectite together suggests a sepiolite formation from the partial weathering of smectite in confined conditions. This process is favoured by the enrichment of the soil solution in H_4SiO_4 and the provision of Ca and Mg ions, possibly from the weathering of other minerals (Williams et al. 1985). This hypothesis supports a trend towards aridity throughout the Quaternary, and shows the formation of calcium silicate above the quartz grains by EDAX (Fig. 5).

Aridity also favours calcium carbonate accumulation (Bronger and Bruhn-Lobin 1997). Braithwaite (1983) has shown that such accumulations are common in arid and semiarid climates, while Retallack et al. (1987) correlated them with a warm, seasonally dry climate. The presence of wide and abundant cracks in the deeper horizons promoted the circulation and accumulation of calcium carbonate, while the collapse setting favoured its concentration. Calcite accretion was independent of rubification, argilation and carbonate dissolution (Fedoroff and Courty 1993).

Conclusions

In Central Spain, the assumptions that the erosional “páramo” surface history began and finished between Pliocene and Lower Pleistocene by karstic corrosion

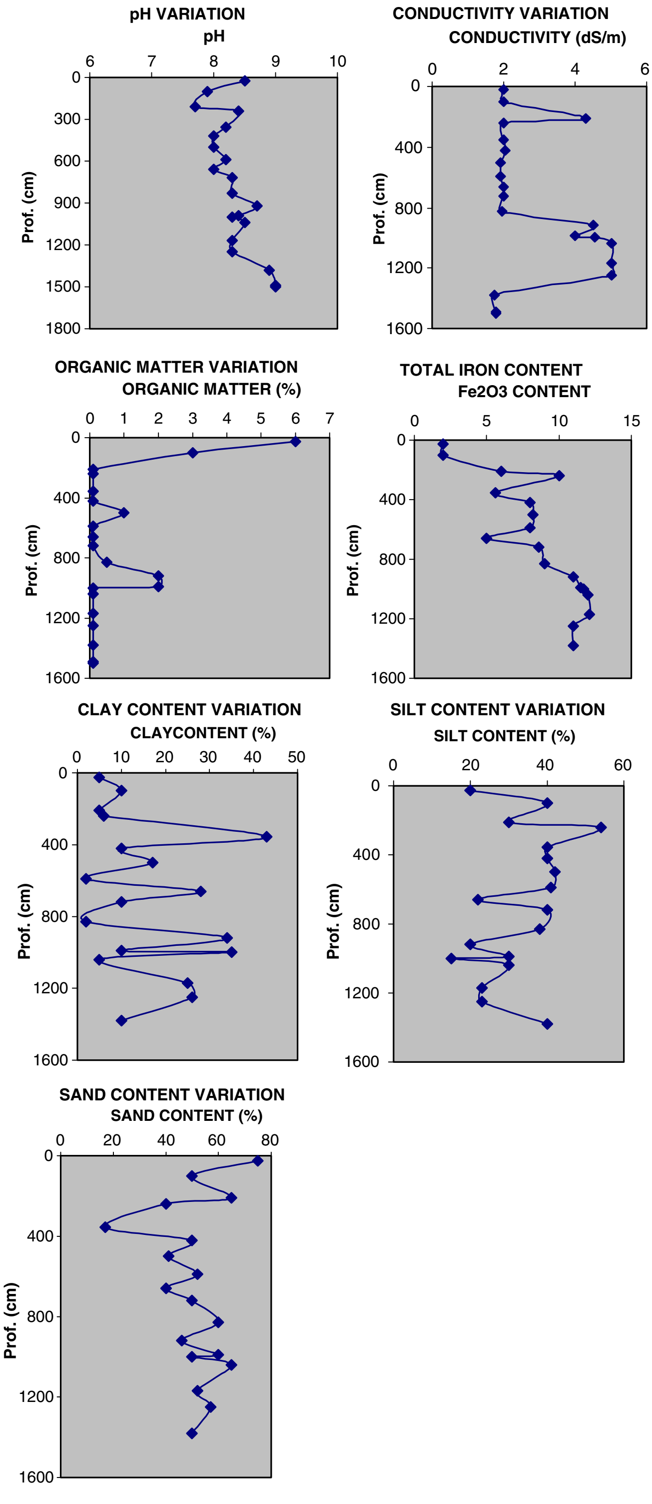


Fig. 6 Physical–chemical properties variation of the soil sequence

processes are probably too simple. Flat land surfaces are hardly ever stable very long. They are subject to episodes of erosion by colluvial processes.

Table 2 Mineralogical composition of clay fraction of some horizons

Horizon	Illite (%)	Kaolinite (%)	Smectite (%)	Sepiolite (%)
A p	37	22	41	–
Bw	70	6	1	23
3Btk$_1$	10	42	20	28
4Bt$_2$	41	8	21	30
5Bt$_3$	20	46	24	10
6Bt$_4$	66	8	20	6
9Bt$_6$	60	40	–	–
9Btk$_1$	42	58	–	–

The soil sequence examined here is associated with a complex palaeokarstic terrain. The profile consists of superimposed soils, which overlap one another through vertical accretion of palaeoargillic horizons and calcium carbonate accumulations, which differ in thickness and colour.

All the palaeosols developed from the same parent rock, a reworked material from pedological surface horizons. They are the result of the erosion and the removal of limestone crioclasts, calcrete debris and residual red clay.

These colluvial sediments were carried in several phases by transportation from the upper part of the limestones anticlines to the synclines and karstic depressions. They accumulated during short events of cold or dry conditions. In some cases, together with this complex colluvium, these are allochthonous materials (sand of quartz) from aeolian erosion of more or less remote geomorphologic units: alluvial terraces and detritic “glacis” (ramp) surfaces.

The succession of palaeosols reflects recurrent periods of stability, during which clay formation, rubification and calcium carbonate accumulation took place. It is hypothesised that this may have resulted from the persistence of a Mediterranean climate during most of the Pleistocene, interrupted by climatic oscillations towards cooler and drier conditions.

The different geomorphological deposits and soils of the Madrid region, which are studied in this paper, suggest that numerous climatic crises of short duration have occurred in this area. Some were of cool character. These coincided with cryoclastic deposits (stratified slope deposits) in the mountain areas and flat surfaces. Others were dry or very dry environments. They have calcium carbonate accumulation, dunes, loess deposits and detritic “glacis” (ramp). Finally, other periods were characterised by a more humid climate than the present one, generating tufa buildups, phytotherm barrage deposits, stromatolitic tufa, lacustrine carbonates, spring-tufa. Their formation was produced during the humid and warm Oxygen Isotopic Stages (1, 3, 5 and 7).

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