Spain C II

SOIL SURVEY AND PHOTO-INTERPRETATION IN THE GUADIANA VALLEY, SPAIN

Doeko Goosen

INTRODUCTION

The soil surveys carried out by the Spanish National Institute of Edaphology and Agrobiology (Guerra and Monturiol, 1959, 1968, Hernando Fernandez et al., 1962), had revealed a soil pattern in the lower Guadiana Valley not consistent with that of a typical alluvial area. In a relatively high position on the north side of the river, Vertisols occur, while farther down, towards the river, Red and Brown Meditteranean Soils, comparable to Alfisols, are found. The recent deposits along the river are mainly Entisols. See fig. 2. It is uncommon to find Vertisols in a higher position than Alfisols within an alluvial area.

The aerial photographs of this area date from 1956. They show an intensive parcelling, as a result of the Badajoz Plan for irrigation. Levelling of fields had been done already, and the development of the irrigation scheme continued, so that by the time the students of the Soils Section of the ITC started in 1966 their exercise soil surveys in the area, much of the natural small relief features had disappeared.

In this respect intensive land use puts an obscuring veil over the "natural" soil surface, through which it is difficult, also on aerial photographs, to distinguish subtle differences in the physiography of the soil pattern. It is one of the objectives of the ITC courses in soil survey, to train the students in recognizing the relationships between physiography and soils. In the following certain hypotheses will be discussed about the landscape development of the Guadiana valley, and their validity will be checked with a number of soil properties.

ALLUVIAL TERRACES

During the first years of the ITC soil survey it was thought, that the Vertisols corresponded to a high river terrace, the Alfisols to a medium terrace, and the Entisols to a low terrace.

This hypothesis was not in direct contradiction with the studies on the geology of the area. See Hernández-Pacheco (1949, 1956). According to these studies the Guadiana river is continuously eroding since the Pliocene, and is now cutting down into Oligocene formations. The mantle of Pleistocene-Holocene valley deposits has a thickness of several metres. Near Montijo the Oligocene was found at two sites to be at resp. 4 and 10 metres depth. (Roso de Luna & Hernández-Pacheco, 1954). Through slight oscillations in the erosional behaviour of the river very easily terraces could have been formed. This would correspond with the situation schematically outlined in fig. 2.

The hypothesis concerning the existence of river terraces was supported by the fact, that in several places the slope gradient of the terrain is slightly greater than the average slope of the valley floor. These ~~greater~~ steeper slopes were thought to represent faint remnants of terrace escarpments. The subdued relief in general, and the intensive levelling in particular, made it difficult to trace these escarpments over a long distance.

However, a more essential problem remained unexplained. If the three zones of soils represent river terraces, as caused by erosion of the river into its own deposits, then the highest terrace should have the oldest soils, and each lower terrace should have more recent soils. The location of the Entisols conforms to this normal pattern, but the Vertisols (Entic Pelloxererts and Chromoxererts), should not occur on the highest terrace. Vertisols form typically in depressional positions in river plains, where leaching is less intensive. If Vertisols are found in high position, then it is frequently the character of the parent material (rich in expandible clay, calcium and magnesium), which causes the occurrence of them. In this respect it is important to note, that in the deposits of calcareous Miocene clays of the uplands North and South of the Guadiana Valley, Vertisols (Typic Chromoxererts) are typical members of the soil associations there. It seemed therefore logical, to assume a certain connection between the Vertisols in the valley, and those of the uplands.

Furthermore, the parent material of the Vertisols in the valley does not show any resemblance to the recent alluvial deposits of the Guadiana river. The latter are characterized by a high amount of gravel and sand, and a conspicuous absence of calcium carbonates. The parent material of the Vertisols in the valley has a high clay content, and in the lower soil horizons calcium carbonate is present in two forms: a) regularly distributed through the soil matrix; b) randomly distributed gravelsized concretions.
Consequently, the hypothesis of alluvial terraces was abandoned.

SOIL FORMATION ON EROSIONAL SLOPES

The geological maps of the valley area, where the Vertisols occur, have as mapping units Oligocene and Miocene (Roso de Luna & Hernández-Pacheco, 1950, 1954). Based on this, the possibility was considered, that the Vertisols had developed "in situ" from these formations, which presumably had become exposed at the surface through river erosion. However, Roso de Luna & Hernández-Pacheco (1954) had found already that the clayey surface deposits were locally separated from the Oligocene by a layer of gravelly alluvium. In our detailed surveys of the last years this layer proved to be continuous and abruptly underlying the Vertisols. Locally these gravelly layers emerge at the surface. Therefore it was apparent, that the Vertisols had developed in material younger than this river deposit, which in its turn must be more recent than the Pliocene epoch.

Based on this, the idea that the soils might have formed on erosional slopes, was rejected.

Through renewed photo-interpretation, fieldwork and especially the fruitful discussion with our Spanish colleagues Guerra, Monturiol, Badorrey and Gallardo, another feature was studied. It was known already, that in the area of the Vertisols very sandy surface horizons occur of variable thickness. The soils with such a sandy layer did not have the characteristic features of Vertisols and were classified as Alfisols, or even Psamments if the layer of sand was sufficiently thick. Originally it was thought that this sand corresponded to the normal variations in alluvial sediments. The renewed study of the last years revealed however, that the sand occurred in irregularly rounded patches. One location was found where no levelling for irrigation purpose had been done, and here the sand formed a rounded mound of a few hectares, up to two metres above the level of the area around it. The uniform grainsize of the sand and its physiography appeared not very consistent with alluvial sedimentation. Tentatively an aeolian origin was postulated. In this respect it was significant, that Guerra and Monturiol (1968) had surveyed an extensive area of aeolian sand within the Guadiana Valley some 50 km unstream. See also Badorrey et al. (1967).

With this in mind the zone of the Alfisols was reconsidered. Here almost all the soils have a rather sandy surface horizon. Frequently the contrast with the more clayey subsoil is sufficiently great to classify the soils as Palexeralfs. This is however, an unsatisfactory classification, because it suggests an advanced stage of eluvation, which is difficult to explain under the circumstances of time and climate (semi-arid, attenuated by Atlantic influence). Further fieldwork in the Alfisol area revealed a highly important fact:
In a few soil profiles, starting at a depth of about 50 cm, the clayey subsoil showed fossile vertical cracks filled with sand.

From the foregoing it was concluded, that aeolian activity had played a role in the Guadiana valley. The sandy cover is less extensive in the area where the Vertisols occur, then in the Alfisol area. This might be due to differences in intensity of aeolian sedimentation, proportionally to the distance of the source. It also could be possible, that the Alfisol area had been subjected to aeolian sedimentation for a longer time than the Vertisol area.
Anyhow, the fossile cracks in the subsoil of the Alfisol suggested the existence of a buried soil profile with characteristics of Vertisols.

RELATIONSHIPS BETWEEN THE ALFISOLS AND THE VERTISOLS

The possible relation between the Vertisols and the subsoil of the Alfisols was further confirmed by the discovery in a deeper augering of an Alfisol, that below 120 cm small concretions of calcium carbonate are present.

A more or less systematic search was carried out to see whether the calcium carbonate concretions were common. Systematic augering was inconvenient because the concretions occurred deeper than the usual augering depth of 120 cm. Therefore by photo-interpretation sites were marked where the levelling operations had removed the original topsoil to a considerable depth, or where canals and ditches provided easier access to the deeper subsoil. These sites were visited, and it appeared that hardly without any exception, the calcium carbonate concretions are present everywhere in the zone of the Alfisols. Their distribution is random throughout the subsoil, and their number and size increase with depth.
The random distribution means that the concretions do not occur in horizontal layers, such as would form if pedogenetic processes of leaching and precipitation were responsible. The random occurrence suggests much more, that the concretions form an inherited part of the parent material. Naturally they partake in pedogenetic processes. If they occur in Vertisols, then the mechanical churning and the dissolution will make them disappear from the upper soil horizons at a rather rapid rate. Deeper in the profile, and also in the Alfisols, chemical solution will make them smaller and more rounded with time. The concretions found in the deeper subsoil of the Alfisols, did indeed show rounded forms, analogous to the concretions found at shallower depths in the Vertisols.

The following table summarizes some characteristics of the parent material and of the soils in the three zones.

ENTISOLS	ALFISOLS	VERTISOLS
gravelly	no gravel	no gravel.
no uniform grainsize of sand	almost totally covered with sand of uniform grainsize	local patches of sand of uniform grain-size
no cracks	fossile cracks in the subsoil	cracks
no $CaCO_3$ concr.	$CaCO_3$ concr. at 120 cm or deeper	$CaCO_3$ concr. at 70 cm or deeper
--------	random distribution of concretions	ditto
gravelly subsoil without abrupt transition	underlain by gravel with abrupt transition	ditto

Table 1. Comparison of some characteristics of parent material and soils in the three "soil zones" of the Guadiana Valley near Montijo.

From this table it emerges that the Alfisols have many features in common with Vertisols. An analogous origin is suggested.

MASS MOVEMENTS

The common origin of the parent material of Alfisols and Vertisols is thought to be related to the Miocene clays of the uplands. Fieldwork in those areas during 1971 and 1972 had revealed that in the Miocene clays extensive mass movements of the past are responsible for much of the surface configuration of the landscape. In forthcoming publications details will be presented. These mass movements have occurred as multiple rotational slips, as blockglides, and as mudflows. The marly character of the Miocene clays makes them susceptible to mass movements in general (Casgrande, 1948, Ferzaghi and Peck, 1967). Liquefaction of calcareous clays is under certain circumstances highly probable (Van Schuylenborgh, 1972, Goosen, 1972). The Miocene clays are originally layered, as an alternation of more or less calciumcarbonate-rich layers. Therefore, liquefaction will differ according to the characteristics of such layers. Compact clay layers devoid of calcium carbonate, or cemented calcium carbonate layers may not liquefy, but will become broken up in fragments during the turbulent flow of the liquefied soil mass. After redeposition the compact clay fragments and the calcium carbonate concretions are randomly distributed throughout the soil mass. The clay fragments become rounded and form "clay balls", very common in the Miocene uplands. Bisdom (1973) of the Netherlands Soil Survey Institute discovered in thin sections under the microscope, that very small clay fragments, still with angular forms, also are present in the deeper subsoil, and are surrounded by cutans which for 70% appear to have formed from clay dissociated from the fragments themselves.

If mass movements have taken place extensively in the uplands, it seems logical to assume that in particular the mudflows have advanced into the Guadiana valley. Considering fig. 2, mudflows originating in the uplands of Miocene clays north of the valley, are thought to have advanced over a wide front into the Guadiana valley, sweeping across the valley floor over the gravelly veneer of alluvium. The mudflows crossed over the lower Silurian/Cambrian ridges, locally covered with remnants of the Pliocene gravel terrace. In a deep pit on top of one of these remnants near La Garrovilla it was found that the upper metre of gravel is highly disturbed and includes lumps and curved zones of clay with calcium carbonate concretions. Because Pliocene deposits have been affected, the mudflows are of Pleistocene age or younger. Mirajkar (1973) and Fadul (1973) under the direction of Dr. M. Knibbe have studied in detail some of these aspects during their study at the ITC.

At present the ridges, including the Pliocene remnants, are higher than the upland Miocene clays in the immediate vicinity (fig. 2). This is because the Miocene clays erode more easily than the ridges. Through gaps in the ridges the eroded material is removed in a normal fashion. Jungerius (1965) describes an analogous "inversion of relief" in Eastern Nigeria.

The lower edge of the zone of Alfisols in the proposed hypothesis represents the front of the mudflow which penetrated farthest into the Guadiana valley. The zone of Vertisols represents a mudflow which advanced less far and covered a part of the older mudflow. Presumably the soil formation in the older mudflow led initially to Vertisols as well. However, aeolian sedimentation gradually arrested this process. We assume an aeolian origin of the sand cover. The source is then the riverbed, from which sand was blown over the mudflow deposit with westerly and southwesterly winds. The first layers of sand were incorporated into the Vertisols through the churning process, but gradually the sand cover became too thick and the Vertisols became "smothered". A similar process is at present still active in the Sudan (Fadul, pers. comm.).

The mudflow deposit, where nowadays the Vertisols occur, is younger in age and has been for a shorter time exposed to aeolian influence. Thus the extent of "smothered" Vertisols is less.

The micromorphological study of thin sections of the Vertisols and Alfisols is still going on. The first findings appear to confirm the hypothesis sketched above, and as yet no facts have emerged in contradiction to it. (Pers. comm.

Dr. E. Bisdom and Dr.Ir. A. Jongerius). For a summary of the hypothesis reference is made to fig. 3, where the various stages of landscape development and soil formation are shown.

In our opinion the evidence is fairly clear that at least two mudflows have occurred from North to South. There are some indications that the zone of Alfisols can be subdivided in two separate mudflows, but more detailed fieldwork is needed to establish this. The aerial photographs show very faintly and only in some places lobate forms along the supposed fronts of the mudflows. But because the erosional activity of small tributaries of the Guadiana river has influenced the zones of Vertisols and Alfisols, the actual pattern of soils is more complicated than suggested in the schematic sketch of fig. 2, and it is a time-consuming job to unravel in detail the complicated pattern.

It is interesting to compare the situation with what happened South of the river. In figure 2 the Guadiana river is sketched as running close to the southern border of the valley, with a narrow "terrace" remnant in between. In one locality the "terrace" escarpment of about 10 metres high was inspected and revealed a succession of three "Alfisols" on top of each other. Their characteristics are similar to the Alfisols North of the river. Of special significance was the fact that in the lower part of each "Alfisol" numerous concretions of calcium carbonate occur. Again, in a random distribution. Locally a big lump (up to one metre in diameter) of clay mixed with concretions was found. If our general hypothesis of mudflows is correct, then this profile shows three successive layers of mudflow deposits, in which the described processes of aeolian addition have altered the soils from Vertisols to "smothered" Vertisols. In the uplands South of the river Okagawa et. al. (1972) found in various soil profiles an irregular intermixing of Pliocene, Miocene, and even Oligocene materials, suggesting that on this surface mass movements have taken place.

The investigation of the regional occurrence of mass movements has barely begun. It is one of our expectations, that the study of the multispectral images of the ERTS-1 satellite taken from this area, will reveal some of the secrets that still lie hidden in this extremely interesting landscape of the Guadiana area. Through more detailed studies in sample areas specific aspects will be studied.

Tentative conclusions

1. During the Quarternary period several mudflows have originated in the uplands North and South of the Guadiana Valley.

2. The mudflows advanced into the Guadiana Valley over a broad front along approximately 20 km, and moved over a distance of up to 10 km.

3. The steeper slope sections parallel to the Guadiana river do not represent terrace escarpments, but mudflow fronts.

4. The mudflows may have been triggered by tectonic movements (Goosen, 1971)

5. Independent from the mudflows, aeolian activity was prominent during the Wuaternary epoch.

6. Few soils of alluvial origin exist in the Guadiana valley.

7. The taxonomic classification of the Alfisols in the Guadiana valley may have to be modified.

8. Leaching of calcium carbonate is occurring under the climatic conditions in the Guadiana valley, and there is no significant fresh accumulation of it in the subsoil.

Points of future studies

1. The correlation of mudflow activity and aeolian activity with climatic and other changes during the Quatenary.

2. The separation of individual mudflows.

3. The degradational processes which have affected the mudflow aeolian deposits in the Guadiana valley. This aspect has been mentioned briefly in the foregoing, but especiálly the erosional influence of the tributaries to the Guadiana river needs further study.

4. The consequences of the polycyclical soil development for the taxonomic soil classification.

5. The relationships between the sóil pattern and the agriculture.