

14 AVRIL '972

Reprinted from:
Paleopedology—Origin, Nature and Dating of Paleosols
Ed. D. H. Yaalon, 1971
Published by Intl. Soc. Soil Sci. and Israel Universities Press
P.O.B. 7145, Jerusalem, Israel

THE HISTORY OF SOILS: SOME PROBLEMS OF DEFINITION AND INTERPRETATION

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ABSTRACT

According to the agreement or disagreement which seems to exist at present between the soil and its environment, one can distinguish three types of soils whose pasts are different.

In the soils whose characteristics seem in balance with the present environment, there is no proof of a past evolution different from the present one. Among such soils, there are, on the one hand, those whose main characteristics are rapidly formed and whose total differentiation does not undergo further modification over a long period of time; and on the other hand, those whose formation is very slow, but always in the same direction.

Numerous soils have relict features, indicating past pedological conditions different from the present ones. These relict features can be very young and should not be solely attributed to paleoclimate. Tectonic movements, progressive differentiation of the soils and the utilization of soils by man can also modify the direction of soil evolution, certain characteristics of which become, in consequence, relict.

The third type includes the buried soils. The study of these soils poses numerous problems concerning the determination of the upper limit of the buried soil, the distinction between allochthony and reworking, and the processes which modify the soils both during and after burial.

RESUME

(L'histoire des sols: quelques problemes de definition et d'interpretation)

D'après l'accord ou le désaccord qui semble exister actuellement entre le milieu pédologique et son environnement, on distingue trois types de sols dont les passés sont différents.

Dans les sols dont tous les caractères paraissent en accord avec l'environnement actuel, rien ne témoigne d'une évolution passée différente de l'évolution actuelle. Il y a parmi ces sols, soit des sols dont les caractères principaux se différencient rapidement puis sont en différenciation globale ne se modifie

O. R. S. E. U. M. Fonds Documentaire

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plus en fonction du temps, soit des sols qui se différencient lentement en fonction du temps, toujours dans le même sens.

De nombreux sols ont des caractères reliques qui témoignent de conditions pédogénétiques passées différentes des conditions actuelles. Ces caractères reliques sont souvent très jeunes et la paléoclimat n'en est pas la seule signification possible; les mouvements tectoniques, la différenciation des sols et l'utilisation des sols par l'homme, modifient aussi le sens de l'évolution des sols dont certains caractères deviennent alors reliques.

Le 3ème type est celui des sols enterrés. L'étude de ces sols pose de nombreux problèmes concernant la reconnaissance de la limite supérieure du sol enterré, la distinction à faire entre allochtonie et remaniement, la nature des mécanismes modifiant les sols pendant et après l'enfouissement.

INTRODUCTION

Soils have a fairly long and complicated history. One of the pedologist's objectives is the reconstruction of this history. Are the soils young or old? What were the principal stages of their formation? Are the present-day environments and landscapes different from those in which the soils evolved? These are the main historical questions posed by pedologists.

In attempting to answer these queries, the pedologist can rely on but few proven facts. Principally, he must interpret these facts in the light of his knowledge and his suppositions about the relationship between the characteristics of the soil itself and the elements of its present environment.

According to the agreement or disagreement which seems to exist at present between the soil and its environment, one can distinguish various types of soils which probably have undergone very different historical development. Reflection on this subject theoretically obliges one to recognize that there are in fact three large categories of soils, as follows:

- 1) Soils whose characteristics are in balance with the present environment. These soils show no evidence that their historical evolution differed from that at present.
- 2) Soils which contain certain features, so-called relics, indicating past pedological conditions different from the contemporary ones.
- 3) Buried soils, which are, in fact, a particular case of the previous group.

In the following pages, I shall try to define and delimit the theoretical contents of these groups, and to state the principal problems relating to their local identification, study and historical interpretation. I shall corroborate my thesis with examples found mainly in Morocco.

SOILS IN ENVIRONMENTAL BALANCE

I define as soils in environmental balance those which have constantly evolved in accordance with the present unchanged environment, or, at least, which furnish no evidence of lasting characteristics indicating a different past environment.

Among this type of soils, whose characteristics are in balance with the present environment, it is theoretically possible to distinguish two principal subgroups:

1) Soils whose main characteristics are rapidly formed, and whose total differentiation does not undergo further modification over a long period of time. These soils continue to evolve normally, but, apart from seasonal changes, the differentiation of their principal characteristics does not increase with time, because, in fact, these characteristics are continually reconstituted. For example, in Morocco this is the case with certain Vertisols, or certain Red Mediterranean soils, non-leached and non-calcareous, on compact limestone. Solely on the basis of the pedological characteristics, it is not possible to determine whether these soils are young or, on the contrary, very old. Such soils can be very old despite the fact that most of their pedological characteristics are young, or rather reconstituted.

2) Soils whose main characteristics have been formed and which continue to differentiate slowly and progressively with time, fairly rapidly under varying climatic conditions, but without having undergone any apparent modification in their evolutionary trend in the past. The study of the pedological characteristics of these soils in relationship to the present environment provides one with an idea of their age, which can be quite considerable. As examples we may cite some calcareous soils in Morocco: in certain situations it is possible to estimate the age of soils with a differentiated calcareous profile from the development of the B_{ca} -horizons (Ruellan, 1970b).

We thus find that these soils in environmental balance have varying ages. More precisely, in each soil there are characteristics of different ages. In Morocco, such is the case with soils showing a differentiated calcareous profile: one can show, by a study of the soils on surfaces of varying ages (Ruellan, 1970b), that whereas the B_{ca} -horizon of carbonate accumulation can be very old, on the contrary, the partition of the organic matter, the structure of the surface horizon, and its more or less dark colour are, it seems, always young characteristics, or features that are continually reconstituted.

We are confronted with two questions. Must certain types of soils and characteristics which are very old be considered paleosols and paleocharacteristics? Does the study of the Quaternary development stages of these old soils constitute one of the subjects of paleopedology?

The answer to the first question depends on the exact meaning given to the term "paleo". I agree with several authors who have corresponded with me recently

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in connection with this subject (J. Bennema, J. F. Dormaar, E. Fotakiewa, J. Fink, H. S. Gibbs, and D. H. Yaalon) that one must not confuse "paleo" with "old". An old soil is not a paleosol if all its characteristics are the result of an evolution which took place in the same environment as that which presently exists.

However, the study of the Quaternary development stages of these old soils is nevertheless, in my opinion, a subject for paleopedology, as it is a question of trying to elucidate the stage of differentiation reached by these soils in each phase of the Quaternary Period, and also if the differentiation of the characteristics was a continuous and invariable phenomenon, or if, on the contrary, it was more or less rapid and discontinuous, thus proving environmental variations.

RELICT SOILS

In addition to the soils whose characteristics are in environmental balance, at present there exists a second, probably greater group of soils possessing certain (in some cases virtually all) characteristics which are the outcome of a former pedological evolution different from the present one. These are relict soils, and I here wish to emphasize the very precise significance which I attach to the term "relict", a significance which excludes, in particular, any notion of great age. A relict characteristic can be very young provided that the pedological evolutionary change is very recent.

The study and interpretation of this type of soils present several types of problems which principally concern the identification of relict characteristics on the one hand, and, on the other, the historical interpretation of these characteristics.

1) Positive local identification of a pedological relict characteristic has proved to be an impossible task up to now. The identification is always an interpretation supported by certain facts to which each pedologist, according to his personal convictions, attributes particular significance. Frequently, what is considered a relict characteristic by one pedologist is not recognized as such by another, all the more so as each individual often gives his own interpretation of the word "relict". In North Africa, for example, there are two principal tendencies among pedologists, which also exist in many other countries.

On the one hand, there are those who enlarge the group of relict characteristics and consider that the main features of well-differentiated soils were acquired in the past, under different climatic conditions which were, in general, more humid than those of the present. At the same time, they agree that the present evolution of these soils is not basically different from that of the past, but is proceeding at a far slower rate. In particular, they consider the following characteristics to be almost invariably relict: red colour of the soils, well-formed B₁-horizons, hardened

horizons (calcareous incrustations and crusts, iron pans, silica pans), kaolinic C-horizons of several metres thickness.

On the other hand, there are those who consider that certain of the above-cited characteristics are indeed the result of a lengthy pedological evolution, but that this does not necessarily imply different and more effective former climatic conditions. The present climatic conditions are considered to be perfectly sufficient for the formation of such characteristics. These pedologists tend to see in this evolved type of soils far more numerous old characteristics than relict ones.

2) Concerning the problems posed by the historical interpretation of these characteristics considered to be relict, one must principally emphasize that the paleoclimate should not be regarded by their sole possible explanation. In fact, I think that an important modification in the orientation and evolution of one group of pedological processes may be the consequence of four types of major environmental transformations, which will influence all the other related elements. These transformations are: a) climatic change; b) tectonic movement; c) differentiation of the soils; d) use of soils by man.

a) There is no need to discuss the well-known role of climatic change, which modifies all sorts of factors in the evolution of soils. However, one must stress that, given the fact of the existence of lateral migration in the soils, whose importance has already been emphasized many times in these last years (Maignien, 1958; Delvigne, 1965; Ruellan, 1967, 1970; Bocquier, 1968; Bocquier, Paquet and Millot, 1970), one must not interpret relict characteristics solely as a function of local climatic change, but also as a function of those changes which can affect the land upslope. This is particularly important in the case of soils found in plains situated downstream from massive mountain ranges, as is frequently the case in North Africa.

b) There is equally no need to discuss the known role of tectonic movement; however, one should not exaggerate its importance for Quaternary soils.

c) The role of pedological characteristics as factors of soil formation changing in time is still not fully understood. However, it is certain that, as a result of their differentiation, soils and pedological characteristics also progressively change, either directly or indirectly, the conditions of their own soil formation and those of pedogenesis downstream. In the course of development of a soil, certain processes bring about pedological characteristics which, as they become accentuated, progressively modify the soil medium, leading to profound changes in the moisture regime and biological activity. As a result, new processes start to develop on the one hand, and, on the other, there is a slowing down and, finally, a complete cessation of the initial process, whose characteristics become relict. One can cite two examples: 1) The plugging of an illuvial horizon, which leads to hydromorphic processes and lateral migrations, and which results in a decrease or even cessation of clay accumulation in the B-horizon (Bocquier, 1967), part of whose characteristics become

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relict. 2) The calcareous crust, which, when it is sufficiently developed, limits the penetration of water, roots and fauna: this leads to processes which start to destroy the surface of the crust and to re-enrich the A-horizon in carbonate (Ruellan, 1970).

Numerous relict characteristics can thus serve as evidence of normal stages of soil evolution. This evolution frequently provokes a transformation of the environment, especially the vegetation and microrelief, but it is not the outcome of an independent modification of this environment.

d) For several centuries and even millennia, the role played by man in the evolution of the soils, depending on the area, was considerable and should not be underestimated. Without even discussing the role of cultivation itself, destruction of the natural vegetation alone causes an upheaval of the surface horizons of many types of soils, to a depth of about one metre. This aspect is still not well known, but the first accurate studies carried out in Africa show how rapidly soils are transformed as soon as man clears the vegetation. Therefore, it is possible that: 1) On the one hand, many pedological characteristics, which appear to be incompatible with the present environment markedly changed by man, and which tend to be interpreted as evidence of old paleoclimates, are really compatible with the same environment untouched by man; 2) On the other hand, certain important structural characteristics, impoverishment of clay and, of course, also the colour of the surface horizons and organic profile, are the result of man's recent activity.

In the soils cleared by man, characteristics which have become relict as a result of this clearing are probably numerous. These are young relict characteristics, and it is important to learn how to identify them before embarking upon a detailed interpretation of the remote past.

BURIED SOILS

As in the case of relict soils, buried soils pose certain problems relating to their definition, identification in the field, and historical interpretation.

The main problem concerning definitions is that of establishing the depth at which one can call the soil truly buried. Certain authors, such as Fotakiewa in Bulgaria (1970), claim that one can talk of a buried fossil soil only if that soil is presently found at a depth at which it is no longer subject to biological activity. In Morocco, on the contrary, as in many African countries, soils are often spoken of as buried as soon as they are considered to be covered by a few centimetres of allochthonous materials. In fact, it appears that one has to distinguish between two types of buried soils. Firstly, there are soils which are deeply buried beneath the present zone of direct biological action. They are the only true paleosols, i.e., soils whose pedological characteristics are relict. Since they have been deeply buried, their evolutionary

processes are more similar to the initial stages of diagenesis than to pedogenesis. Secondly, there are soils of shallow burial which, therefore, continue to evolve under the direct action of pedogenesis. In soils of this type there are both relict and contemporary characteristics. Thus, these soils are very similar to the relict soils mentioned above.

Up to now, deeply buried soils in Africa have been infrequently identified and studied. In Morocco, however, one can cite the following examples:

- 1) Buried Vertisols in the Recent formations of the great alluvial plains. They have been studied particularly in the Rharb Plain (Divoux and Pujos, 1960).
- 2) The isohumic buried soils, identified in Recent Quaternary formations, alluvial and colluvial, by the detailed study of organic profiles (Concaret and Mahler, 1960).
- 3) The horizons richest in carbonate, often found at varying depths, especially in Early Quaternary formations. The genetic interpretation of these horizons is yet uncertain, however, because carbonate accumulation is not necessarily a sub-surface phenomenon. Therefore, it is not possible to affirm that all the levels richer in carbonate are B_{ca} -horizons of buried soils (Durand, 1959; Wilbert, 1962; Ruellan, 1970b).
- 4) Buried soils under dune systems, either in the coastal regions, especially along the Atlantic, or in the pre-Saharan and Saharan regions. This soil type has not been studied in any detail.

In contrast to the deeply buried soils, those of shallow burial (or at least interpreted as such) have often been identified in Morocco and in the other localities in Africa. Numerous authors have long regarded the study of this type of soils as being relatively easy. At present it is possible to perceive that the problems relating to this soil type are really numerous and, in particular, that the identification of buried soils in a single soil section is rarely simple and irrefutable. There are, it seems, three essential reasons for this.

- 1) The determination of the upper limit of buried soils is often difficult and hotly disputed. In alluvial and colluvial regions in particular, the criteria which are presently used to affirm that the limit between two soil horizons is more probably sedimentary than pedological, are in general insufficient and often interpreted by authors in very different ways. Generally, two tendencies exist.

On the one hand, there are those authors who may be termed "allochthonists". They attribute great importance in soil and landscape formation to the processes of erosion and accumulation. They are inclined to exaggerate the amount of eroded and buried soils. In particular, these scientists consider that soils whose horizons are greatly differentiated or in which the limits between the horizons are very distinct and often marked by levels of coarse texture, are the result of processes of erosion and accumulation rather than of pedological processes. For example, they consider

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that calcareous crusts or very well-differentiated horizons of carbonate accumulation, located at depths of thirty to fifty centimetres, are, in general, pedological horizons buried beneath a layer of allochthonous sediment.

The opposing school are the "autochthonists", who seek to attribute the majority of existing discontinuities between horizons constituting the altered zone of the earth's crust, and the differentiation of these horizons, to pedological processes. Among these processes, the "autochthonists" include, however, reworking which might slowly modify the characteristics and thickness of the horizons and displace the horizons relative to one another.

2) The second difficulty in the identification of buried soils stems from the very fact that the distinction which one must make between allochthony and reworking, in the interpretation of soils sections, has not generally been sufficiently defined. This is indeed a very important distinction, which, though often not easy to make in the field, is necessary, at least in order to attempt a theoretical clarification. In this context, I suggest a few definitions:

a) *Allochthonous material* is foreign material brought onto a soil by colluvial, alluvial, aeolian or volcanic transport. This material can be, in part or totally, of pedological origin.

b) *A buried soil* is one covered by a layer of entirely allochthonous material. Burial may have been preceded by erosion of the soil.

c) *A reworked horizon* is a pedological horizon whose characteristics are partially the result of mechanical movements of materials. These movements are surficial or internal, and their principal driving forces are running water, gravity, variations in the humidity of the soil, and vegetal and animal biological activity. In fact, it is probable that all soils are more or less reworked in their surface horizons, but the importance of this reworking can vary considerably—from essentially vertical churning, to lateral displacement of an entire horizon over a distance of several metres. Among these processes of reworking, one should include the lesser phenomena of erosion and surficial accumulation, linearly or in layers, which displace pedological materials without rapidly bringing to the surface a layer of entirely allochthonous materials.

d) A reworked horizon often contains allochthonous elements of colluvial, alluvial, aeolian, volcanic or anthropological origin. These have been brought to the soil surface in a slow and discontinuous process, and have gradually been integrated into the surficial soil horizons by processes of reworking. Therefore, it is assumed that there exists an entire intermediate series between the reworked horizon and the allochthonous layer, the establishment of which was rapid compared to the rate of the reworking processes.

3) The third major factor complicating the identification of a buried soil in a single soil section is that burial of the soil can be preceded and accompanied by phenomena

of erosion, and is invariably followed by an evolution which is mostly a function of the features of burial. Buried soils, as we can describe them today, are therefore always soils modified by the process of burial itself. Numerous examples have been cited by Fotakiewa (1970) in Central Europe, Gerasimov (1969) in the Soviet Union, Gibbs (1969) in New Zealand, and Ruhe (1965) in the United States.

CONCLUSIONS: THE OBJECTIVES OF PALEOPEDOLOGY

In concluding these few remarks on the history of soils, I think that although it may yet be difficult to define the word "paleosol" (Ruellan, 1970), it is easier to propose a definition for paleopedology and its principal objectives. This definition might be as follows: paleopedology is the historical branch of pedology, whose aims are: to retrace the development stages of all types of soils, principally during the course of the Quaternary Period; to research, study and interpret, in every type of soil, the relict pedological characteristics, which could be proof of all ancient pedological processes no longer taking place, irrespective of the age of these old phenomena and regardless of the reasons why the pedological processes have changed; to identify, study and interpret soils which have been buried under a layer of allochthonous materials (colluvial, alluvial, aeolian or volcanic in origin), regardless of the thickness and age of this allochthonous layer.

In order to attain these objectives a certain number of studies must be developed. These are principally:

- 1) The study of soils in toposequences, in order to reveal the relationships which might exist between different types of soil and types of horizons. This study should, for example, clarify whether fairly evolved soils are of different or similar ages. It should also result in a better distinction between "allochthonous" and "reworked". Toposequential studies have to be developed, in particular, in landscapes where there are terraced surfaces of supposedly different ages.
- 2) The detailed study of the limits separating the horizons and of the transitions between horizons, thus making possible a clearer distinction between pedological limits and sedimentary ones.
- 3) The dating of pedological elements.
- 4) The study of the contemporary evolution and dynamics of soils and toposequences, in particular in relationship to the use of soil by man. In effect, one can reconstitute the past only after having acquired a certain detailed knowledge of what is actually taking place at present.

In the Office de la Recherche Scientifique et Technique Outre-Mer, O.R.S.T.O.M. (Office of Overseas Scientific and Technical Research), the research pedologists have decided recently to devote particular attention to all these studies.

REFERENCES

- Bocquier, G., 1967. "Introduction à quelques problèmes relatifs au lessivage dans les sols ferrugineux tropicaux," *Réun. Ped. ORSTOM*, Bondy, multigr., 13 pp.
- Bocquier, G., 1968. "Biogéocénoses et morphogénèse actuelle de certains pédiments du Bassin Tchadien," *9ème Congr. Int. Sci. Sol*, Adelaide, 4:605-612.
- Bocquier, G., Paquet, H. et Millot, G., 1970. "Un nouveau type d'accumulation oblique dans les paysages géochimiques: l'invasion remontante de la montmorillonite," *C.R. Ac. Sci.*, Paris, 270, D: 460-463.
- Concaret, J. et Mahler, P., 1960. "Note sur les paléosols du Haouz de Marrakech et leur importance agronomique," *Soc. Sci. Nat. Phys. Maroc, Trav. Sect. Pédol.*, 13-14:197-202.
- Delvigne, J., 1965. "Pédogénèse en zone tropicale. La formation des minéraux secondaires en milieu ferrallitique," ORSTOM, Dunod Ed., 177 pp.
- Divoux, P. et Pujos, A., 1960. "Sur l'importance fondamentale des lois tirées de l'étude du Rharb en ce qui concerne les pédogénèses récentes," *Soc. Sci. Nat. Phys. Maroc. Trav. Sect. Pédol.*, 13-14: 97-100.
- Durand, J. H., 1959. "Les sols rouges et les croûtes en Algérie," *Serv. Et. Scient.*, Alger, 188 pp.
- Fotakiewa, E., 1970. "Paleopedology: Subjects, boundaries and methods," *Eiszeitalter und Gegenwart* (in press.).
- Gerasimov, I. P., 1969. "Subject, boundaries and methods of paleopedology," Paper submitted to INQUA Congress, Paris, 10 pp., cf. present volume.
- Gibbs, H. S., 1969. "Paleopedology in New Zealand," *New Zealand Soil News*, 3: 73-82.
- Maignien, R., 1958. "Le cuirassement des sols en Guinée, Afrique Occidentale," Thèse Sciences Strasbourg, Mém. Serv. Carte Géol. Als., 16, 239 pp.
- Ruellan, A., 1967. "Individualisation et accumulation du calcaire dans les sols et les dépôts quaternaires du Marco," *Cah. ORSTOM, Sér. Pédol.*, 5: 421-462.
- Ruellan, A., 1970. "Quelques réflexions sur la paléopédologie," *Bull. Ass. Fr. Et. Quat.*, 23-24: 179-180.
- Ruellan, A., 1970b. "Contribution à la connaissance des sols des régions méditerranéennes: les sols à profil calcaire différencié des plaines de la Basse Moulouya (Maroc Oriental)," Thèse Sciences Strasbourg, multigr., 482 pp.
- Ruhe, R. V., 1965. "Quaternary paleopedology," *The Quaternary of the United States, INQUA Rev. Vol.*, Princeton Univ. Press, 755-764.
- Wilbert, J., 1962. "Croûtes et encroûtements calcaires au Maroc," *Al Awamia*, 3: 175-192.

DISCUSSION

MITCHELL suggested that characters resulting from a former stage of pedological evolution should be described as 'fossil' and not 'relict'. RUHE did not think that fossil and relict could be synonymous. Fossil (from Latin) means 'to dig'. Relict soil has never been buried, so cannot be dug up. It has properties acquired in the past, thus relict.

BAKKER remarked that, in addition to the first type of soils—in balance with their environment—there is a large group of young soils which are not yet in balance

with the environment; they are especially studied in the Netherlands. RUELLAN thought that these young soils would belong to the second subtype of soils in environmental balance but continuing to develop.

BARRIERE commented that the distinction between 'old soil in balance with the environment' and 'soil with relict characters' would often be subjective and unreliable, unless all parameters, including parent rock, are considered. RUELLAN agreed that one has to be very prudent in order to recognize and interpret relict characters. Evidently there are soils with and without relict features. Future work will have to show how this can be determined with greater certainty.

GIBBS thought that it was easier to define the subject of paleopedology than what should be considered a paleosol or paleosolic feature. VINK remarked that the speaker, in his conclusion, in fact equated paleopedology with pedogenesis. Hence there is no separate paleopedology, because the two aspects complement each other.

YAALON pointed out that pedology, like geology, is in part a historical science, one of whose aims is to attempt to elucidate and interpret the natural events and processes of the past as they happened in soils. The historical aspects of pedology cannot therefore be equated with paleopedology. Paleopedology deals with soils and soil relicts which have formed in landscapes of the past. It is a subdiscipline of pedology.