

# PEDOMORPHIC FORMS AND PEDOMORPHIC SURFACES

J. DAN AND D. H. YAALON

*The Volcani Institute of Agricultural Research, Rehovot, and  
The Hebrew University, Jerusalem, Israel*

## INTRODUCTION

The considerable variation in climatic and geomorphic conditions over a small area in Israel enabled us to study and to interpret the interrelations between landscape features, catenary sequences and the soil profile characteristics on the various segments of the soil landscape. A landscape in which soils and relief are genetically and evolutionarily interdependent was termed *pedomorphic surface*. Young, mature, depositional and erosional, relic or polygenetic surfaces can be recognized. They may have a gentle, undulating, steep or hilly relief. Generally the various catenary members of a pedomorphic surface are characterized by soil profiles with a definite horizon sequence or *pedomorphic form*, which reflects their maturity and especially the nature of the erosion and sedimentation processes shaping the surface.

In this paper the pedomorphic forms recognized and defined in Israel will be discussed (Dan 1965).

## PEDOMORPHIC FORMS

1. *Mature, well drained cumulative upland pedomorphic form*. Included are deep mature upland soils with an *ABBb* horizon sequence or, in the case of grumusols, also *AC* soils. These soils were formed by slow accumulation of aeolian dust, that covered the underlying rocks and residual soils. Underneath the present soil several paleosols may be recognized (Figure 1), which usually merge into each other. The natural erosion is negligible.

2. *Mature erosional upland pedomorphic form*. Included are deep mature soils with an *ABC* horizon sequence (Figure 2). The soils were formed mainly from the underlying rock or sediments, although some admixture of fine aeolian material may have occurred. In Israel this aeolian imbedding affects most of the soils of this pedomorphic form. Natural erosion is weak or even negligible.

3. *Mature, poorly drained upland pedomorphic form*. These soils have an *ABgC*, *ABgBb* or, in case of grumusols, an *AC* horizon sequence. They are found on old flat to slightly sloping upland areas in humid or semi-humid regions. Natural erosion is negligible. Cumulative and erosional (or residual) phases are recognized.

4. *Moderately deep, mature sloping pedomorphic form, with some lithic discontinuity*. These soils have an *ABR* horizon sequence (Figure 3).

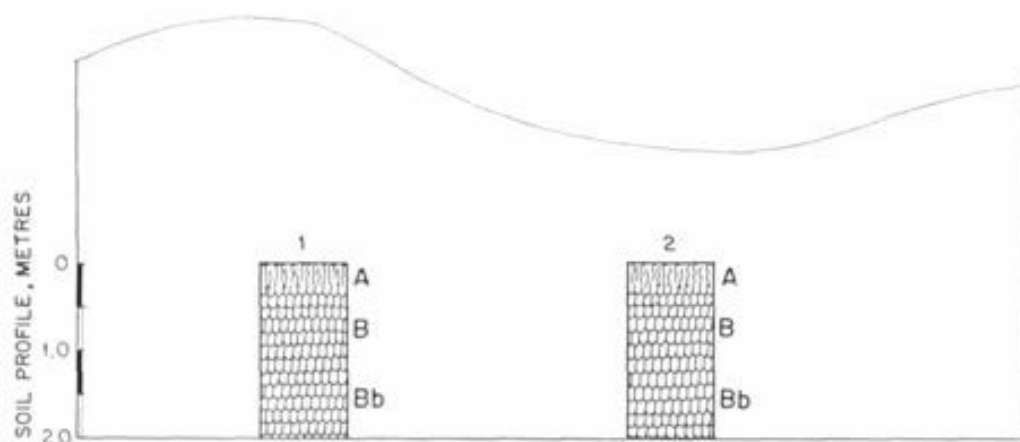


Fig. 1.—Pedomorphic forms of a mature, cumulative pedomorphic surface.

1. Mature, well drained cumulative upland pedomorphic form (No. 1).

2. Mature, well drained cumulative lowland pedomorphic form (No. 9).

#### LEGEND



Figs. 1 to 4.—Legend to the signs used in the figures. A, B, C, and R represent soil horizons and underlying bedrock; Bb is a B horizon which has become gradually buried by younger soil sediments.

They cover hard rocks, mainly limestone or dolomite and characterize slightly sloping areas. They are usually formed on uplands, but they might be detected also on pediments that are not covered by pedisements. Natural erosion is usually very small or even negligible.

5. *Shallow, mature pedomorphic form with lithic discontinuity.* These soils have an AR horizon sequence (Figure 3). They usually cover hard rocks on steep slopes. In cracks B horizon material may be found. Natural

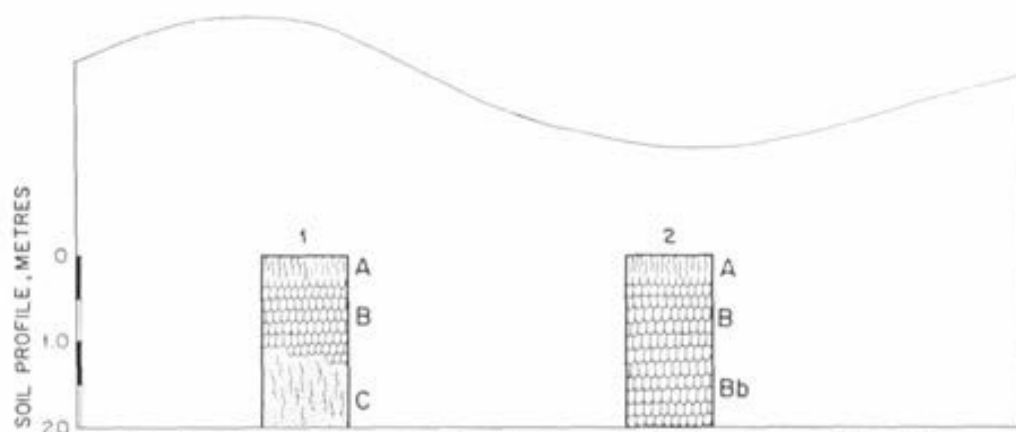


Fig. 2.—Pedomorphic forms of a mature erosional pedomorphic surface.

1. Mature erosional upland pedomorphic form (No. 2).

2. Mature, well drained cumulative lowland pedomorphic form (No. 9).

For legend, see Fig. 1.

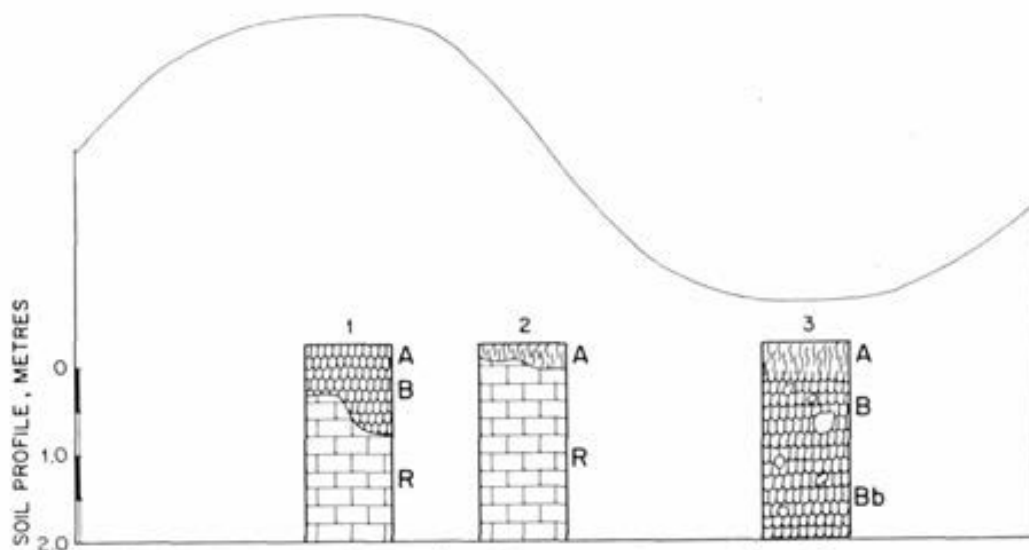


Fig. 3.—Pedomorphic forms of a stable steep pedomorphic surface.

1. Moderately deep, mature sloping pedomorphic form with some lithic discontinuity (No. 4).
  2. Shallow, mature pedomorphic form with lithic discontinuity (No. 5).
  3. Mature, well drained cumulative lowland pedomorphic form (No. 9).
- For legend, see Fig. 1.

erosion is constrained by the occurrence of rock outcrops. Soil formation on hard rocks is slow or very slow, and as a result the slopes, although steep, are quite stable.

6. *Immature (young) erosional pedomorphic form*. Included are soils with an AC or ACR horizon sequence (Figure 4). They characterize steep

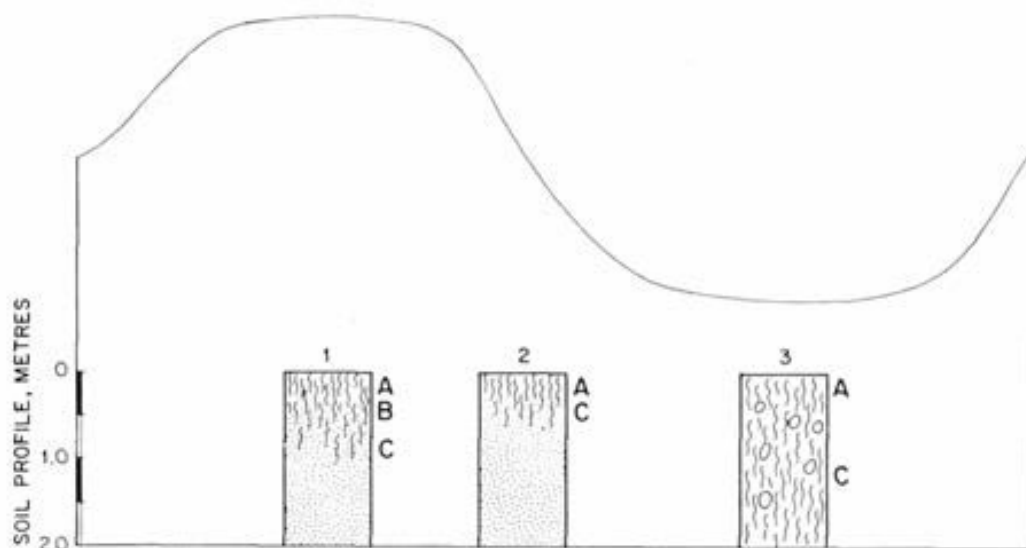


Fig. 4.—Pedomorphic forms of a steep unstable pedomorphic surface.

1. Shallow, moderately mature erosional soils (No. 7).
  2. Immature (young) erosional pedomorphic forms (No. 6).
  3. Immature, well drained cumulative lowland pedomorphic form (No. 10).
- For legend, see Fig. 1.

unstable slopes on soft rocks or unconsolidated sediments. The soils may be quite deep, but they do not differ much in their chemical composition from the underlying sediments. Erosion is severe, but the physical breakdown of the soft parent material is also quite rapid, so that a dynamic equilibrium exists between soil formation and erosion.

7. *Shallow, moderately mature erosional pedomorphic forms.* Included are soils with some profile differentiation, mainly with an *ABR*, *ABCR*, or in arid areas also *ACcaR* horizon sequences (Figure 4). The *B* horizon has a cambic nature. These soils are found on comparatively stable slopes on soft rocks or on stable segments of complex slopes. Complex slopes are found where soft rocks intergrade with hard ones and as a consequence they exhibit segments of different stability. Erosion is quite pronounced, but not so severe as in the previous pedomorphic form; weak development of *B* or *ca* horizon is thus recognizable.

8. *Deep, moderately mature pedomorphic forms on sloping areas, foot-slopes and alluvial plains.* Included are mainly *ABC* soils with a cambic *B* horizon. In arid areas they may include also soils with an *ABcaC* horizon sequence. The soils were formed from unconsolidated parent material. This pedomorphic form is found on different surfaces, and is therefore subdivided into several phases. *An erosional phase*, on moderately steep slopes where erosion is quite severe; *an aeolian cumulative phase*, on sloping areas where aeolian accumulation of sand or loess is quite pronounced; *an alluvial cumulative phase*, on footslopes and alluvial plains where alluvial deposition is quite pronounced but is not fast enough to prevent the formation of some diagnostic soil horizons; *a young surface phase*, on recent depositional surfaces where the accumulation of the parent material has terminated, either due to change of base level (e.g., in old alluvial plains), or due to interruption of aeolian deposition (in dunes).

The soils of all the four phases of these pedomorphic forms are similar in their profile characteristics. They are all well drained, comparatively young soils and developed from unconsolidated parent material. Eventually, the same soil type may develop on several, or even all of these phases.

9. *Mature, well drained, cumulative lowland pedomorphic form.* These soils usually have an *ABBb* horizon sequence or grumusolic *AC* profiles. The soils are found on footslopes and lowland flats where the deposition of alluvial material is very slow (Figures 1, 2 and 3). These soils resemble cumulative upland soils; they differ from them mainly in their position and origin of the parent material. Cyclic accumulation of the parent material is more widespread, so that it is often possible to distinguish various paleosols.

10. *Immature, well drained cumulative lowland pedomorphic form.* These soils have an *AC* horizon sequence (Figure 4). Several buried *A* horizons, or sometimes even well developed paleosols might be found in deeper layers. The soils cover well drained footslopes, floodplains and depressions where the accumulation of alluvial material is fast.

11. *Mature, poorly drained depressional pedomorphic form.* These soils have an *ABgBb* or *AC* (of grumusols) horizon sequence. They are

found at footslopes and depressions where impeded drainage conditions prevail. The ground water table is usually found at a depth exceeding 1½-2 m at the end of the dry season. However some or all of the horizons are water saturated during most of the rainy season. The accumulation of the alluvial parent material is slow.

12. *Immature, poorly drained depressional pedomorphic forms.* These soils have an AC horizon sequence; cs or sa horizons may also occur, especially near the surface. The deposition of the alluvial parent material is usually fast. These soils cover areas where the ground water table is less than 3 m below the surface most of the year.

13. *Boggy and marshy pedomorphic forms.* These soils have usually an AC, AgCg, AgG, OC OCg or similar horizon sequence. The soils are found in places where the ground water table is near the surface, or the whole area is covered by water. The accumulation rate of the parent material is quite considerable both mineral and organic.

14. *Young, aeolian pedomorphic forms.* Included are AC and C soils or sediments which originated in recent aeolian accumulation. No diagnostic horizons except of an A or ca horizon may be recognized. These soils and sediments occupy shifting sand dunes and stabilized dunes.

#### PEDOMORPHIC SURFACES

In every landscape several pedomorphic forms that are genetically and evolutionarily interdependent can be recognized. On the other hand, a certain pedomorphic form usually covers most of a certain landscape and it characterizes the area. In karstic mountainous lands, for instance, shallow mature soils with lithic discontinuity cover most of the area; the same holds true for mountainous areas dominated by hard silicate rocks. On the other hand, chalky areas and badlands are characterized by immature erosional soils. It is therefore suggested that the term pedomorphic surface should be applied to such landscapes.

The term is in part equivalent to the ground surfaces of Butler (1959), but we wish to emphasize more the relation with soil profile characteristics. Mature cumulative or mature erosional upland surfaces (Figures 1 and 2), steep stable or steep unstable pedomorphic surfaces (for areas characterized by shallow mature erosional soils and immature erosional soils respectively (Figures 3 and 4)), immature or mature well drained pedomorphic surfaces, etc may be defined. In addition, young pedomorphic surfaces are defined for areas covered recently by thick aeolian sediments on the one hand, or for dissected recent alluvial areas on the other hand. The same may hold true for very old or senile soils covering peneplained or pediplained areas, which may be designated as old or ancient pedomorphic surfaces.

Some surfaces are defined as polygenetic, e.g., when some of the soils are remnants of older surfaces or when they are buried at shallow depth and affect plant growth. They can be subdivided into polyerosional pedomorphic surfaces that resulted from a lowering of the base level or from change in climatic conditions, and polydepositional surfaces where areas with well developed soils were covered by young alluvial or aeolian deposits.



## DISCUSSION

The relationship between soil profile characteristics, soil maturity, relief and natural erosion was noted by Marbut (1928) who defined several profile types. Milne (1936) considered this relationship to be one of the most important features of a soil catena. Bushnell (1943) divided the soil catena into several sections, each characterized by a definite type of soil profile that resulted from certain erosional or hydrological conditions. These types of profiles he designated as major profiles. Bushnell stressed the role of the drainage conditions and grouped all the well drained soils into two major profiles. This system might be quite satisfactory for temperate humid climates where the drainage conditions play a most important role in soil formation. However, in arid, semi-arid and even sub-tropical areas, soil profiles on well drained areas are much more diversified. Well drained soils may be found also on lowland areas and many of them may show the accumulative type of profile. The rate of erosion and deposition can also be interpreted from the profile characteristic in these regions. Our definition of pedomorphie forms thus extends and broadens Bushnell's definition of major profiles.

The relationship between soil profile characteristics, soil distribution and landscape features have been studied intensively during the last decades. Ruhe (1956), Butler (1959), Jessup (1961) and other scientists stressed the importance of periodic covers of aeolian and alluvial material on the one hand and of erosional cycles on the other. This cyclic development of soil and landscape does not necessarily modify the whole landscape; it may result in the erosion of a soil layer or in the deposition of a restricted sheet of alluvial or aeolian material. Butler thus suggested the term ground surface for the soil landscape in contrast with the term land surface which is related to the general landforms features. The definition of the pedomorphie surface that is presented here is thus a further development of the term ground surface. The modification is proposed in order to stress the connection with the soil-forming processes that are responsible for the shaping of the soil landscape.

## REFERENCES

- Bushnell, T. M. (1943)—Some aspects of the soil catena concept. *Proc. Soil Sci. Soc. Am.* **7**, 466-476.
- Butler, B. (1959)—Periodic phenomena in landscape as a basis for soil studies. CSIRO Aust. Soil Publ. No. 14.
- Dan, J. (1965)—The effect of relief on soil formation and distribution in Israel. Ph.D. Thesis, Hebrew University, Jerusalem, Pamphlet No. 100, Volcani Institute of Agricultural Research (Hebrew, with English summary).
- Jessup, R. W. (1961)—A Tertiary-Quaternary chronology for the south-eastern portion of the Australian arid zone. *J. Soil Sci.* **12**, 199-213.
- Marbut, C. F. (1928)—A scheme for soil classification. *Proc. 1st Congr. Int. Soil Sci. Soc.* **4**, 11-31.
- Milne, G. (1936)—Normal erosion as a factor in soil profile development. *Nature, Lond.* **138**, 548.
- Ruhe, R. V. (1956)—Geomorphie surfaces and the nature of soils. *Soil Sci.* **82**, 441-445.

## SUMMARY

The processes of erosion-sedimentation and soil development have been found to be intimately interrelated in all climatic regions of Israel. Based on the analysis of soil profile characteristics on the various segments of the catenary slope sequence and on the relative rates of erosion and deposition, which shape the soil landscape, the concept of the interrelation between pedomorphic forms and pedomorphic surfaces was developed.

Soil profiles exhibiting a characteristic soil horizon sequence were termed *pedomorphic forms*. The concept is an extension of Bushnell's six major drainage profiles, but recognizes in addition the effect of erosion and deposition in shaping the soil. The various pedomorphic forms recognized in Israel have been described.

A landscape in which pedomorphic forms and relief are genetically and evolutionarily interrelated is termed a *pedomorphic surface*. Young, mature, cumulative or erosional, relic and polygenetic surfaces have been recognized, covering a gentle, undulating, steep or hilly relief. The concept of pedomorphic surfaces is somewhat similar to Butler's ground-surface but incorporates also the nature of the processes shaping it. Giving due recognition to the spatial and vertical interrelations in landscape and soil development makes the concept of pedomorphic forms and surfaces useful in the interpretation of soil evolutionary processes.

## RÉSUMÉ

On a constaté une relation très étroite entre les processus d'érosion-sédimentation et de développement du sol dans toutes les régions climatiques d'Israël. On a formulé le concept de la corrélation entre les formes pédomorphiques et les surfaces pédomorphiques, basé sur l'analyse des caractéristiques de profil de sol sur les divers segments de la séquence de pente caténaire et sur les taux relatifs d'érosion et de déposition, qui forment le contour du sol.

On a dénommé *formes pédomorphiques*, les profils du sol qui font preuve d'une séquence d'horizon de sol caractéristique. Ce concept est une extension des six profils de drainage les plus importants, selon Bushnell, mais il reconnaît en outre le rôle de l'érosion et de la déposition dans la formation du sol. On a décrit les diverses formes pédomorphiques reconnues en Israël.

On a dénommé *surface pédomorphique* un paysage où les formes et le relief pédomorphiques font preuve d'une corrélation génétique et évolutionnaire. On a reconnu des surfaces jeunes, mûres, cumulatives ou d'érosion, relictées et polygénétiques, qui s'étendent sur un relief modéré, léger, ondulant, raide ou accidenté. Le concept des surfaces pédomorphiques ressemble quelque peu à la relation terrain-surface de Butler, mais comprend en même temps la nature des processus qui la forment. Si on reconnaît suffisamment les corrélations spatiales et verticales dans le développement du paysage et du sol, on rend utile le concept des formes et des surfaces pédomorphiques dans l'interprétation de processus évolutionnaires du sol.

## ZUSAMMENFASSUNG

Die Vorgänge der Erosionsablagerung und Bodenentwicklung wurden in allen klimatischen Regionen Israels als eng miteinander verwandt gefunden. Auf Grund der Analyse der Bodenprofilmerkmale an den verschiedenen Segmenten der Bodenabhangsreihe und an den relativen Graden der die Bodenlandschaft formenden Erosion und Ablagerung wurde der Begriff der Wechselbeziehung zwischen pedomorphischen Formen und pedomorphischen Oberflächen entwickelt.

Bodenprofile mit einer charakteristischen Aufeinanderfolge von Bodenhorizonten wurden *pedomorphische Formen* benannt. Der Begriff ist eine Erweiterung der Bushnell'schen sechs Hauptentwässerungsprofile, erkennt jedoch zusätzlich die Wirkung der Erosion und Ablagerung auf die Bodenformung an. Die in Israel anerkannten verschiedenen pedomorphischen Formen werden beschrieben.

Eine Landschaft, in welcher pedomorphische Formen und Relief genetisch und entwicklungsmässig miteinander verwandt sind, wird als *pedomorphische Oberfläche* bezeichnet. Junge, reife, kumulative oder erosionale, Relikt- und polygenetische Oberflächen, welche ein sanftes, wellenförmiges, steiles oder hügeliges Relief bedecken, wurden anerkannt. Der Begriff der pedomorphischen Oberflächen entspricht ungefähr Butler's Grundoberfläche, nimmt jedoch ebenso die Art der Formungsprozesse in sich auf. Wird den räumlichen und vertikalen Zwischenbeziehungen in Landschaft und Bodenentwicklung genügend Beachtung geschenkt, kann der Begriff der pedomorphischen Formen und Oberflächen in der Erklärung der Bodenentwicklungsvorgänge von Nutzen sein.