T. de Meester

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Büyük Konya Havzasındaki Yüksek kireçli Laküstrin Topraklar

pudoc

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Abstract

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The Great Konya Basin is in Central Anatolia, Turkey. In the centre is the Lacustrine Plain, the bottom of a Pleistocene lake. The Plain has 5 divisions with highly calcareous clay bottoms and sandy shorelines. The lake presumably dried up in Postpluvial I (ca 16000 BC). Later, during Subpluvial I (ca 9000 BC), there were five smaller lakes.

The soils of the Lacustrine Plain vary in composition and morphology. They are classified into Steppe Marl Soils, Marsh Marl Soils and Playa Marl Soils. Their distribution has been mapped and explained.

Soil peels (preserved soil profiles) of representative soils are used for studies on morphology and are described by Brewer's system of 'pedography'. Interpretation is based on studies in the field and on soil peels and thin sections, whose results link up satisfactorily.

Grain-size distribution is estimated before and after removal of carbonates and texture is silty clay and clay, respectively. The carbonate part (about 60%) consists of chemically precipitated calcite, shell fragments, alluvial debris and dust. In the non-carbonate part, smectites are the commonest clay minerals.

The productivity of Steppe Marl Soils is assessed from the results of the studies on soil peels and from data on moisture and soil fertility, by comparison with ideal conditions. The soils are mostly classified as 'restricted' under dry-farming and under irrigation but under sophisticated management will probably be 'fair'.

This is the last publication in a series of studies on the soils of the Great Konya Basin.
The complete series, published by Pudoc (Wageningen), consists of the following publications.

1. Driessen, P. M. and T. de Meester: Soils of the Çumra Area, Turkey (1969).
2. Meester, T. de (Ed.): Soils of the Great Konya Basin, Turkey (1970).
3. Driessen, P. M.: Soil salinity and alkalinity in the Great Konya Basin, Turkey (1970).
4. Janssen, B. H.: Soil fertility in the Great Konya Basin, Turkey (1970).
5. Meester, T. de: Highly calcareous lacustrine soils of the Great Konya Basin, Turkey (this publication).

Contents

1 Introduction

1.1 The subject

The Great Konya Basin is situated about 300 km south of Ankara at an altitude of 1000-1050 m.

Staff and students of the Department of Tropical Soil Science of the Agricultural University in Wageningen have studied its soils and made a reconnaissance survey of the whole Basin and semidetailed surveys of certain parts, with the assistance of Turkish soil scientists. Results have been published by Groneman (1968), Driessen & de Meester (1969) and de Meester (1970). Driessen (1970) studied soil salinity and alkalinity and Janssen (1970c) soil fertility. The present work covers the highly calcareous lacustrine soils in the central part of the Basin, the Lacustrine Plain, mainly consisting of clayey Marl Soils.

Because of its complicated history as an ancient lake floor, and its soil formation, soil physics and agriculture, this Lacustrine Plain seems the most interesting part of the Great Konya Basin.

Much of the work has been on the detailed morphology of preserved soil profiles called 'soil peels'. The information from these laboratory studies have allowed much better interpretations about soil formation and suitability than field studies alone.

Suitability under three management systems, including irrigation, has been assessed by comparing the properties of the soils with those of an ideal soil. This assessment has gained special relevance since the Turkish government has a plan to irrigate large tracts of the Lacustrine Plain.

Lacustrine soils with similar geogenesis, topography and soil formation are rare, and where they occur the soils are usually poor and salt-affected. Published studies are mainly on carbonate mineralogy as in Australia (Alderman & Skinner, 1957) or geomorphology as at Lake Bonneville in the United States (Gilbert, 1890; Graf *et al.*, 1961). There is little opportunity for comparison of the soils with others elsewhere.

As to the agricultural value of highly calcareous soils, the only useful information is on Lisan marls in Israel (Dan *et al.*, 1962), and Perrine marls in Florida (Smith *et al.*, 1967), but for several reasons these marls are only partially comparable with those in the Basin.

1.2 Terminology and definitions for highly calcareous soils

Soils containing considerable quantities of calcium carbonate and magnesium carbonate are common. They have been haphazardly called, for instance, marls, calcareous soils and lime soils. So it seems useful to define current terms to be used in this publication.

Lime, according to Webster's Third New International Dictionary is '(a) a caustic, highly infusible solid that consists of calcium oxide often together with magnesia and is obtained by calcining limestone shells and other forms of calcium carbonate, (b) hydrated lime, and (c) calcium.' The term 'lime' is in common use in geology ('limestone') and soil chemistry ('liming a field'). In soil science secondary carbonates are often referred to as secondary lime nodules etc.

In this study the use of the word 'lime' will hereafter be avoided.

Calcareous, according to Webster, is '(a) resembling calcite or calcium carbonate especially in hardness, (b) consisting of or containing calcium carbonate, also containing calcium.'

The term 'calcareous soil' is in common use in soil science. It refers to the presence of calcium and magnesium carbonates in the soil.

The term calcareous will be used only in a general way, as in the title of this publication and in field descriptions. In the field the following differentation may be made on the basis of effervescence with 10% hydrochloric acid:

audible, not visible: slightly calcareous (3-10% $CaCO_3$ equivalent)
clearly visible : moderately calcareous (10-30%)
almost explosive : highly calcareous (> 30%)

The term calcareous will also be used to indicate secondary carbonate seggregations, such as calcareous nodules or calcareous concretions.

Carbonates Webster defines a carbonate as 'a salt or ester of carbonic acid' (H_2CO_3) and carbonic as 'relating to or derived from carbon, carbonic acid or carbondioxides'.

The word is widely used in physical chemistry of soils. Handbook 60 (Diagnosis, 1954) states: 'the alkaline earth carbonates that occur in significant amount in soils consist of calcite, dolomite and possibly magnesite'. The 7th Approximation (Soil Classification 1960) applies the expression 'fine earth carbonates' in the same sense. The term refers to qualitative and quantitative analysis and not to field estimations.

The usual way to express the alkaline earth carbonates of the soil is by determining the calcium carbonate equivalent by the methods of Scheibler (Diagnosis, 1954), which are based on the production of CO_2 with acid. But this may cause errors up to about 16% if carbonates of magnesium are present.

In this study the term 'carbonate equivalent' will be used where the calcium or magnesium carbonate content of a soil can be better specified than with the words slightly, moderately or highly calcareous mentioned above.

Carbonatic has been introduced in the 1967 Supplement to the 7th Approximation (Soil Classification, 1960) to indicate a soil mineral group as a family characteristic of highly calcareous soils. The term is used as follows:

sandy, silty and loamy soils are carbonatic when they contain over 40% (w/w) carbonates (as $CaCO_3$) and gypsum, and when carbonates make up more than 65% of the sum of carbonates plus gypsum

loamy, silty and clayey soils are fine-carbonatic when more than a third of the fraction $< 2\ \mu m$ consists of carbonates and the apparent texture of the soil is fine-loamy, fine-silty or clayey. Particle-size classes are not mentioned; the soil is referred to as just fine carbonatic.

Hereafter term 'carbonatic' will be adopted for the highly calcareous soils of the Basin. But instead of solely mentioning 'fine carbonatic soil' the texture class will always be added as in 'carbonatic clay-loam' and 'carbonatic clay'.

The term 'carbonatic' will mainly be used in descriptions and discussions of well analysed highly calcareous soils.

Marl, *chalk* and *tufa* indicate geogenetic differences between highly calcareous sediments.

According to Webster, *marl* is a 'loose and crumbly deposit (as of sand, silt or clay) that contains a substantial amount of calcium carbonate'. The term is used mainly in geology and the cement industry for a mixture of fine-grained lime and fine terragenous material.

Pettijohn (1957) indicates marls as 'certain friable earths accumulated in recent or present-day freshwater lakes.'

According to a petrographic classification, marl should contain 35-65% carbonate. Other mixtures are indicated with terms as 'limey marl' (65-75% carbonate) and 'clayey marl' (25-35% carbonate).

In soils, marl often coincides with peat. Brady (1965) states that 'in many cases peat soils are underlain at varying depths by a soft impure calcium carbonate, called boglime or marl.' The Soil Survey Manual (1951) mentions that marl (defined as by Webster) is usually formed in lakes and ponds and that the calcium carbonate may have originated from the calcareous remains of the alga *Chara* (Chara marl), from mollusc shells (shell marls) or from simple precipitation from solution.

As in Kellogg (1956) the term 'marl' will be used hereafter as defined by Webster as a convenient name for the highly calcareous, lacustrine clay soils of the ancient lake floor, which indeed contain 30-70% calcium or magnesium carbonate.

The word is also used to indicate soil associations or soil series, as in 'Marl Soils'.

Webster defines *chalk* as 'a soft white gray, or buff limestone chiefly composed of the shells of Foraminifera.'

Pettijohn (1957) refers to chalk as a porous fine-textured somewhat friable material which is normally white and consists almost wholly of calcium carbonate as calcite and formed mainly by accumulation of the remains of planktonic calcareous microorganisms. But he adds that the term 'chalk' is used in geology for a wide variety of carbonate deposits. Other authors call chalk any limestone that is soft.

In this study the term chalk is used in 'Chalk Soils' as a substitute for the soil association 'Soft Lime Soils' (de Meester, 1970), a soft sediment which contains up to about 98% calcium carbonate equivalent.

According to Webster *tufa* is 'a porous rock formed as a deposit from springs and streams.'

Pettijohn (1957) calls calcareous tufa a purely chemical precipitate from super saturated solutions, being the product of local precipitation in springs, lakes and in the soil profile. It may be deposited on plant stems and has a high porosity and a spongy character. It is weak and semi-friable, and restricted to recent or Quarternary deposits.

The term tufa will be used in 'Tufa Soils', to replace the term 'Marsh Soils' used for the soil association in the Aslım swamps, where the calcium carbonate equivalent reaches 90%.

In genetic systems highly calcareous soils have been called by various names, such as Pedocals (Marbut, 1935), terra calxis (Kubiëna 1953), calcimorphic soils, calci or calcitic soils (in: Bunting, 1967). These terms will be ignored here, as it seemed prudent to adhere in this study to the soil classification of the 1967 edition of the 7th Approximation (Soil Classification, 1960). In this classification *calcic horizon* is used of a diagnostic horizon that 'includes horizons of secondary carbonate enrichment that are more than 15 cm thick, have a calcium carbonate equivalent content of more than 15 percent, and have at least 5 percent more calcium carbonate equivalent than the C horizon. If no C horizon is present, and the calcic horizon is not indurated, it is more than 15 cm thick, has a calcium carbonate equivalent content of more than 15 percent and contains more than 5 percent, by volume, of identifiable secondary carbonates in concretions or soft powdery forms.'

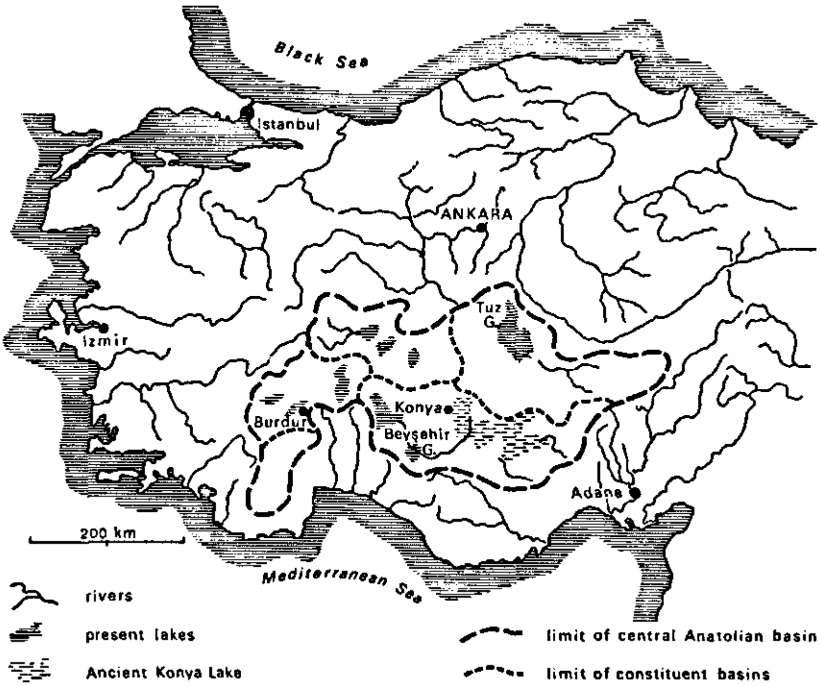
1.3 The Great Konya Basin

1.3.1 General data

The Great Konya Basin is one of several drainless areas on the Central Anatolian Plateau, which is itself also a closed basin (Fig. 1). Several rivers flow into it from all sides (except the north) giving rise to marshes and several lakes in its central part. Their catchment area is a belt of mountains surrounding the Basin but in the southeast the River Çarşamba extends its catchment area far into the mountains, including the large Beyşehir Lake. This river begins in the lake's only outlet and is fairly well regulated by dams; its yearly discharge is about 400×10^6 m^3.

The *climate* is semi-arid with hot dry summers and cold moist winters. The annual precipitation is about 300 mm, mainly falling from November to April. Total evaporation exceeds precipitation by 1000 to 1500 mm. Northern winds prevail, but westerly

Fig. 1. Position of the Central Anatolian Basin and its constituent basins.



Şekil 1. Orta Anadolu Çukurluğunun ve alt bölümlerinin yerleri.

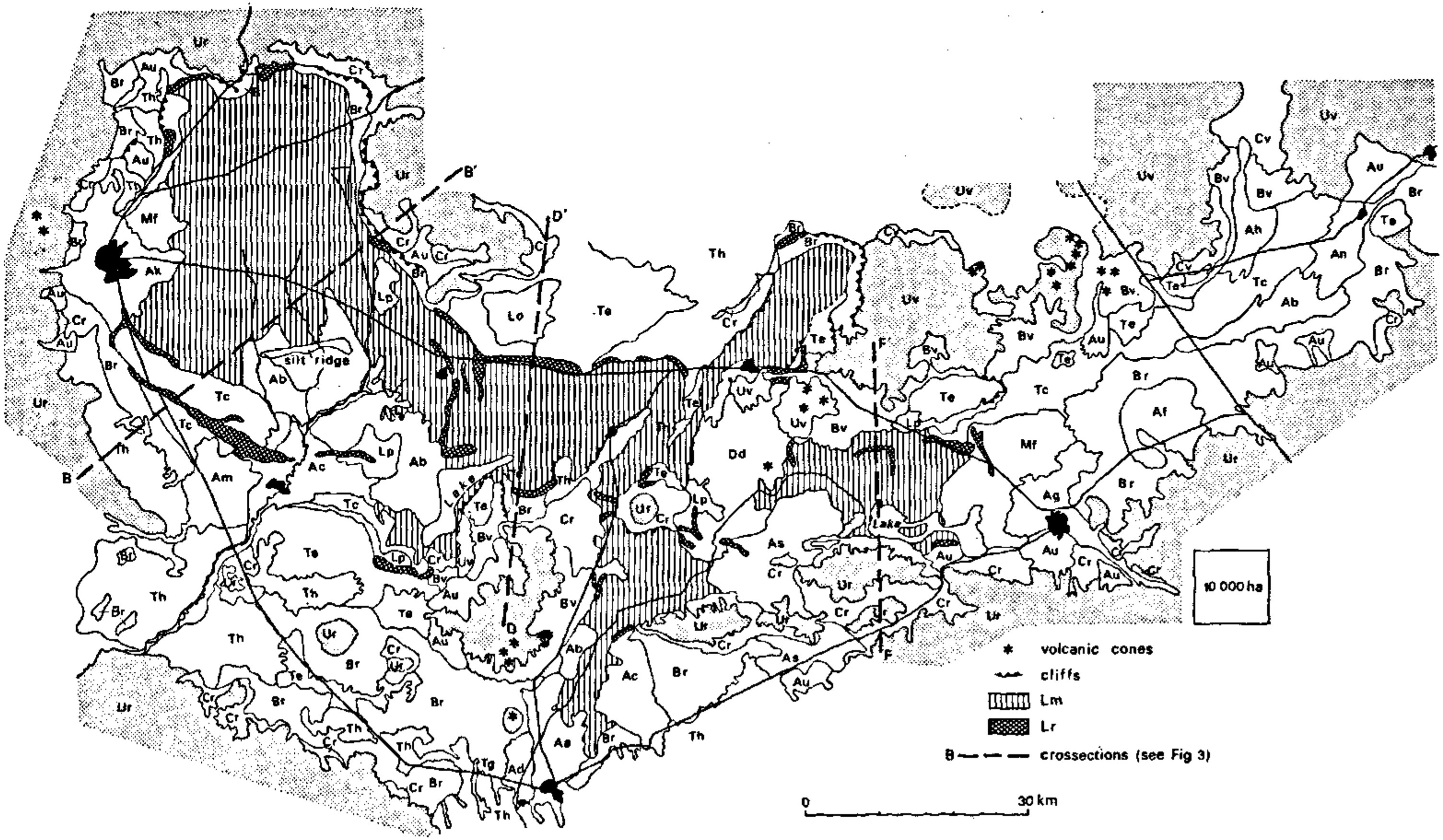
storms occur in winter, southerly storms in summer. The frost-free season is about 165 days.

As to the *geology*, according to de Ridder (1965), the Great Konya Basin is structural and is in the south bordered by the complicated group of Devonian and Permo-Carboniferous limestones, schists and Cretaceous limestones of the Toros Range. Tromp (1947) mentions serpentine intrusions, one of which borders the Basin southeast of Konya. In the north and east the borderline is formed by the Anatolides, a mountain chain chiefly consisting of Palaeozoic sediments, schists and igneous rocks, and covered by Mesozoic limestones.

During the Tertiary uplifting the Anatolian dome broke and subsided with respect to the flanks, giving rise to large depressions filling with water during much of the Tertiary and Pleistocene periods. In this water alternating layers of clay and freshwater limestone were deposited during the Neogene, at present cropping out at several places along the Basin fringes and also present in the Basin at various depths due to faulting and folding (Ketin, 1966).

There is evidence that a large, shallow lake existed in the late Pleistocene, which is hereafter referred to as the Ancient Konya Lake. The Quarternary history of this

Fig. 2. Soil association map of the Great Konya Basin (after de Meester, 1970). For cross-sections, see Figure 3.



Şekil 2. Büyük Konya Havzası'nın toprak birlikleri haritası (de Meester 1970'e göre). Kesitler için şekil 3'e bakınız.

Fig. 2. Legend
Lejant

Ur Limestone Upland Soils
Ur Kalkerli yüksek arazi toprakları
Uv Volkanic Upland Soils
Uv Volkanik yüksek arazi toprakları
Cr Limestone Colluvial Soils
Cr Kolloviyal topraklar (Kalker kökenli)
Cv Volcanic Colluvial Soils
Cv Kolloviyal topraklar (Volkanik kökenli)
Te Flat Terrace Soils
Te Düz teras toprakları
Th Undulating Terrace Soils
Th Ondüleli ve bölünmüş teras toprakları
Tc Soft Lime Soils
Tc Yumuşak kireçli topraklar
Br Limestone Bajada Soils
Br Bajada toprakları (Kalker orijinli)
Bv Volcanic Bajada Soils
Bv Bajada toprakları (Volkanik menşeli)
Aa Çamurluk Fan Soils
Aa Çamurluk nehri yelpazesi toprakları
Ab Former Backswamp Soils
Ab Eski bataklık ardı toprakları
Ac Çarşamba Fan Soils
Ac Çarsamba nehri yelpazesi toprakları
Ad Deli Fan Soils
Ad Deli nehri yelpazesi toprakları
Ae Selereki Fan Soils
Ae Selereki nehri yelpazesi toprakları

Af Çakmak Fan Soils
Af Çakmak nehri yelpazesi toprakları
Ag Zanopa Fan Soils
Ag Zanopa nehri yelpazesi toprakları
Ah Bor Fan Soils
Ah Bor nehri yelpazesi toprakları
Ak Meram and Sille Fan Soils
Ak Meram ve sille nehri yelpazesi toprakları
Am May Fan Soils
Am May nehri yelpazesi toprakları
An Bayat Fan Soils
An Bayat nehri yelpazesi toprakları
As Ayran Fan soils
As Ayrançı nehri yelpazesi toprakları
Au Soils of Medium Sized Fans
Au Orta büyüklükte nehri yelpazesi toprakları
Lm Marl Soils
Lm Marn toprakları
Lr Sandridge Soils
Lr Göl kenarı toprakları
Lp Sandplain and Beach Soils
Lp Kum düzlükleri ve plaj toprakları
Lo Old Sandplain Sils
Lo Eski kum düzlüğü toprakları
Mf Marsh Soils
Mf Bataklık toprakları
Dd Sand Dunes
Dd Hareketli ve sabit kumul'lar

lake will be discussed in Chapter 2.

During the Miocene period, after the uplift had stopped, volcanic activity started, presumably first near Konya (Westerveld, 1957). This resulted in a zone with several volcanoes around the eastern part of the Basin with widespread andesite, dacite, basalt and tuff.

Information about the substrata is available from a few core-drillings, mainly in the western part. The deepest were 400 metres and did not reach the bottom of the sediments but ended in heavy clays, probably of Eocene-Oligocene age. The sediments include clastics (clay, marl, sand, gravel and conglomerates) as well as hard and cavernous freshwater limestones intercalated in many places by beds of soft chalk. They must have been formed by chemical and biochemical precipitation from lake water during the Neogene and possibly also during the Pleistocene although there is no evidence for this (de Ridder, 1965).

1.3.2 Soils of the Great Konya Basin

Soil associations The soil associations were distinguished mainly by physiography. A simplification of the soil map of de Meester (1970; Fig. 2) shows the broad soil associations only. The schematic cross-sections of Fig. 3 illustrate the topography along three traverses.

The very flat plains with Marl Soils (Lm) in the central part of the Basin are the dried-up floor of the Ancient Konya Lake. This floor is covered along its southern and western limits by alluvial sediments (A, alluvial fans). The River Çarşamba Fan (Ac) is by far the biggest and is a former delta rather than a fan.

Elsewhere along the fringe narrow belts of hillwash were deposited in the form of steep Colluvial Slopes (C), but also as gently sloping piedmont plains or Bajadas (B). C and B together will be referred to as the Piedmont Zone (de Meester *et al.*, 1966).

Remnants of Neogene Structural Terraces (T) occur locally. The terraces have different but indistinct levels. The highest levels (Th), however, are undulating and incised by erosion whilst the lower are relatively flat. The lowest, Tc, is close to the ancient lake level.

The former shoreline of the ancient lake is still marked by Sandridges (Lr), which have locally been levelled off into Sandplains and Beaches (Lp).

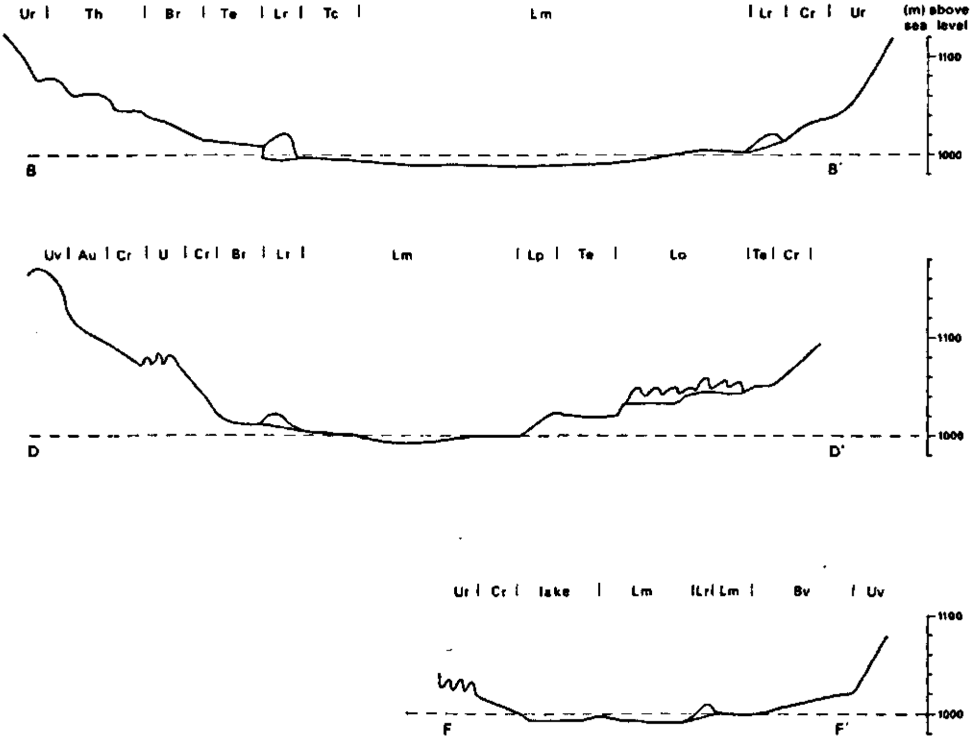
Where the Basin narrows, near Karapınar, a large body of sand was deposited which has become an area of Sand dunes (Dd) and there is also an area with sand dunes of much older origin (Do).

Several poorly drained areas, in depressions or at the springline of alluvial fans or the piedmont zone, are marshy or flooded. Uplands consist mainly of limestone, but volcanic rock occurs near Konya and in the eastern part.

General characteristics The soils of the soil associations differ, in particular in profile development.

The recent soils, such as the Alluvial Fan Soils, the Sandridge Soils and the Marsh

Fig. 3. Three schematic cross-sections through the Basin and the Lacustrine Plain. For position, see Figure 2.



Şekil 3. Havza ve lakustrin düzlük boyunca şematik kesitler. Yerler için şekil 2'ye bakınız.

Soils, have weakly developed A and B horizons. Secondary carbonate seggregation occurs as pseudomycelium and faint white spots, and is not enough to meet the conditions for a calcic horizon (Soil Classification, 1960).

Most of the Marl and the Sandplain Soils, the Bajada and the Colluvial Slope Soils, which are about Pleistocene in age, have in general a well developed structural B horizon and a pronounced calcic horizon. Some soils in volcanic material have duripans.

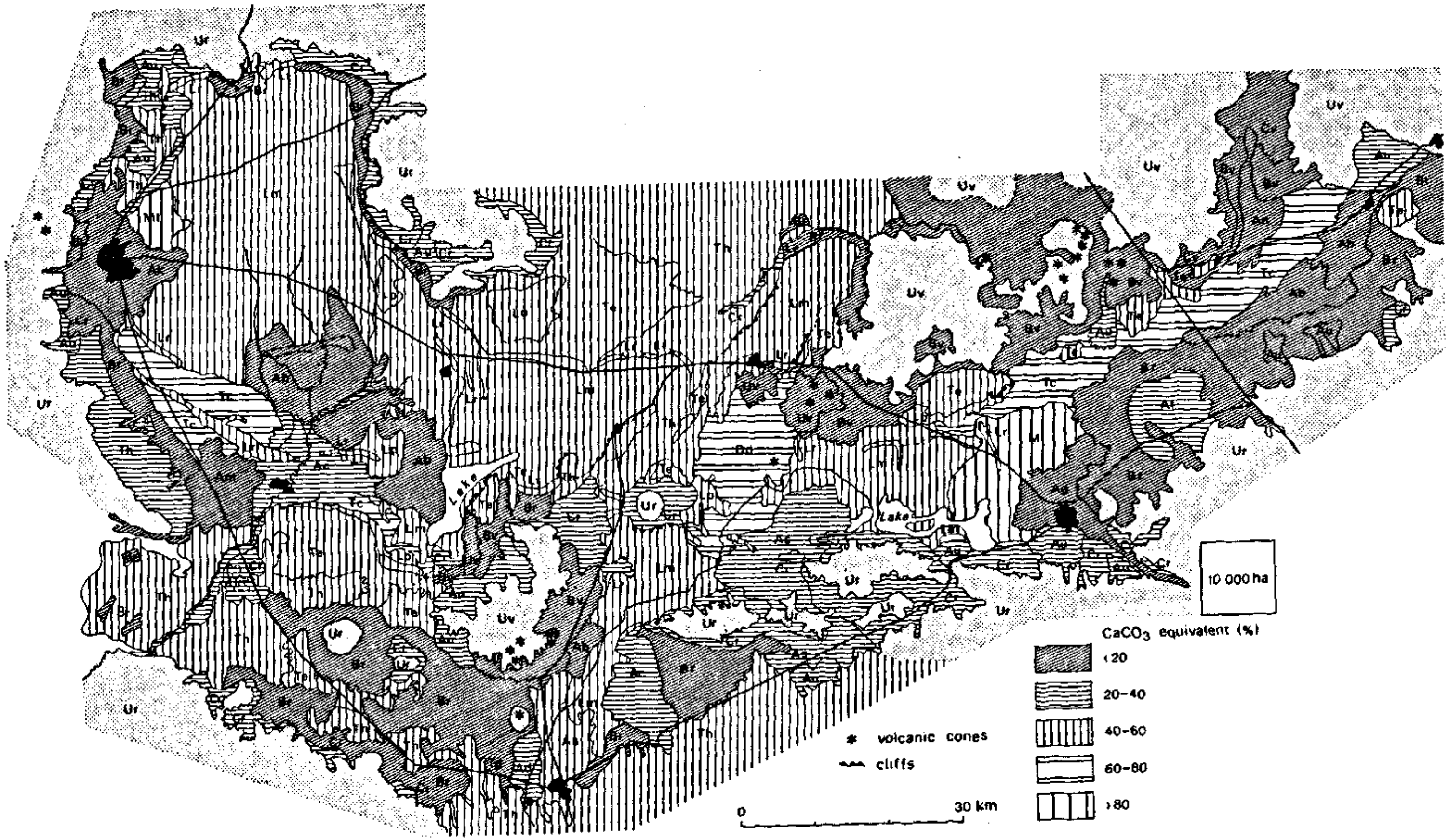
The Terrace Soils, which are Tertiary (Neogene), have also pronounced A and B horizons and well developed calcic horizons, locally even petrocalcic.

Soil texture is mainly clay or loam, but the Sandridges, the Sandplains and the Dunes are sandy and the colluvial slopes are cobbly. The former Backswamp Soils are very heavy clay.

Soil structure is in general granular or subangular-blocky in the surface soil, but becomes angular and prismatic with increasing depth.

Soil salinity is widespread and increases from the fringes inwards. The soils of the Basin are in general internal solonchaks except in depressions and spring zones, where external solonchaks occur (Driessen *et al.*, 1970). The soil salinity in August

Fig. 4. Distribution and percentage of calcium carbonate equivalent in the soils of the Basin.



Şekil 4. Büyük Konya Havzası'nın daki topraklarda kalsiyum karbonat dağılışları, ve miktarları.

1967 is shown on the map in Appendix 3. Non-saline alkali soils do not exist, but alkalinity increases with increasing salinity (van Beek & Driessen, 1970; Driessen, 1970).

Carbonate content All soils of the Basin have a high percentage of fine earth carbonates in common. This is mainly caused by the calcareous nature of the parent material, which is derived from the surrounding limestone uplands. Due to the semi-arid climate no part of the soil is entirely decalcified, the pH is never less than 7. Secondary carbonate enrichment is common, causing the formation of calcic horizons at a depth of about 50 cm. Secondary carbonates may also accumulate as result of lateral or upward transport of bicarbonate-rich groundwater. In the piedmont zone, the formation of pendants on stones in the profile is common. In the centre of the Basin, highly calcareous sediments have been deposited in the former lake.

A general map of calcium carbonate equivalent has been prepared (Fig. 4), showing the approximate carbonate content for each soil association.

1.3.3 Soils of the Lacustrine Plain

The Lacustrine Plain reaches the limits of the Ancient Konya Lake, and is composed of 3 physiographic units, each of which represents a soil association. Their distribution is shown on the map (Appendix 3). They are: the ancient lake floor with Marl Soils (Lm), the former shores with Sandridge Soils (Lr), and the former sandplains and beaches with Sandplain and Beach Soils (Lp) and Sand Dunes (Dd).

It also includes those parts of other physiographic units that are within the former coastline and therefore formed or modified by lacustrine action: the Terraces with Chalk Soils (Tc), and the Marshes with Tufa Soils (Mf).

Marl Soils have developed in the uniform highly calcareous clay on the ancient lake floor, which occupied most of the Lacustrine plain. Due to differences in soil-forming factors, they differ considerably in profile morphology and have therefore here been separated into three groups: Steppe Marls, Marsh Marls and Playa Marls. They are classified mainly as Aquic Calciorthids, Salic Calciorthids and Salorthids (Soil Classification, 1960, addition 1967).

Sandridge, Sandplain and Beach Soils have formed on the sandy and gravelly well drained shore deposits of the Ancient Lake. They are mainly Calcixerolls.

Sand Dunes have formed from lacustrine sand, reworked by wind.

Chalk Soils have formed on soft Neogene limestone, which was abraded by former wave action. They are mainly Aquic Xerorthents.

Tufa Soils have been formed recently in marshes as result of precipitation of carbonates. They are mainly Typic Haplaquents.

2 The Lacustrine Plain

2.1 Physiography

The Lacustrine Plain of the centre of the Great Konya Basin is entirely flat and level (Fig. 5). Its borders are at about 1017 m altitude (Louis, 1938), but to avoid topographic errors and level changes due to sedimentation or tectonics, the borderline can better be traced by connecting the outer shorelines still clearly visible on steeper margins but obscured in alluvial fans and on gentle slopes.

The soil pattern of this plain shows five divisions, separated by elevations consisting of sandridges, alluvial deposits or low hills. These five areas are:

Fig. 5. Characteristic scenery of the Lacustrine Plain. The fields are cultivated Steppe Marl Soils. Fallow field on left and ancient dwelling mound (hüyük) on horizon.

Şekil 5. Lakustrin ovanın karakteristik görünüşü. Tarlalar kültüre alınmış step marn topraklarından kuruludur. Solda nadas arazi ve ufukta bir hüyük.

1. the Yarma Plain, north of Yarma
2. the Hotamış Plain, around Hotamış
3. the Karaman Plain, north of Karaman
4. the Karapınar Plain, north of Karapınar
5. the Ak Göl Plain, north of Ak Göl

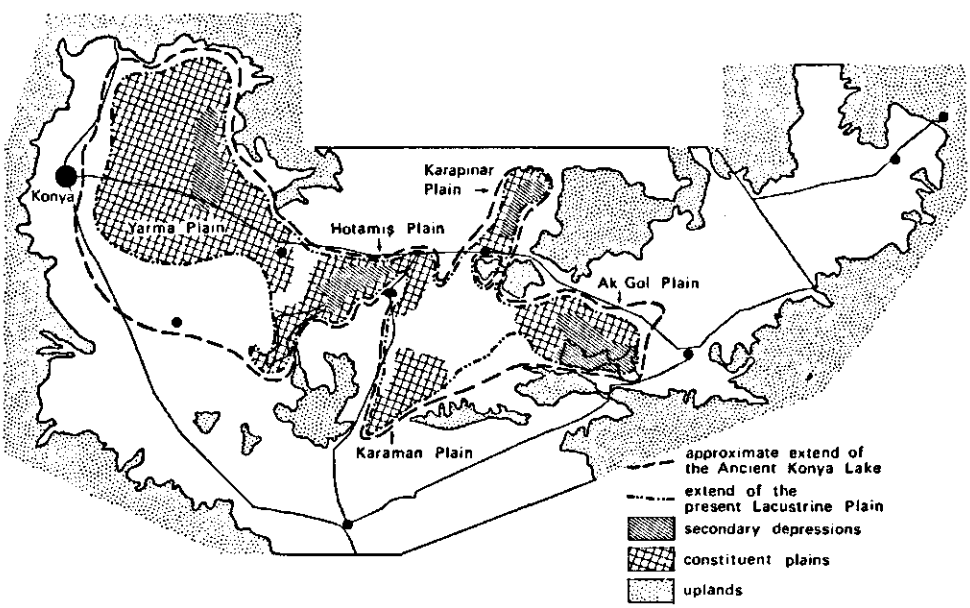
There is a low area (Secondary Depression) in four of the five above mentioned plains (Fig. 6).

The Secondary Depression near Yarma is 995 m, near Hotamış 997.5 m, near Ak Göl 997.5 m and the depression in the Karapınar Plain is 985 m, which is the lowest of all. The ancient lake floor narrows between Karapınar and the Kara Dağ Massif, separating the western Yarma and Hotamış plains from the eastern Karapınar and Ak Göl plains and the southern Karaman plain. A large mass of sand accentuates this separation. As will be shown later (Chapter 3), the soils on each side of the separation are entirely different.

All Secondary Depressions have been small isolated lakes (hereafter called Recent Lakes) since they have had their own shorelines.

Mainly before and during the existence of the Ancient Konya Lake, but also afterwards, alluvial and colluvial sediments have been deposited over the marls. Some as river fans or deltas (like of the River Çarşamba), others as basin deposits, as at the

Fig. 6. Extent of the Lacustrine Plain in the Basin, of the constituent plains and of the depressions in them.



Şekil 6. Lakustrin ovanın, alt ovaların ve içerisindeki çukur kısımların havzada yayılışı.

very bottom of the Çarşamba Delta where heavy dark-gray smectite-type clay occurs under semi-lacustrine conditions in the 'backswamps' (van der Plas & Schoorl, 1970).

Several marshes and lakes are not found in the depressions, as would be expected: they occur on their fringes as a result of seepage and are always rich in carbonate. North-east of Konya and north-west of Ereğli, their soils consist of thick deposits of calcareous tufa, containing up to 90% calcium carbonate equivalent (Driessen & de Meester, 1969).

The sandridges are fossil shorelines of the Pleistocene lake and of the Recent Lakes. Several authors have studied them: first Chaput (1936) who considered them to be of alluvial origin; later Louis (1938) who gave detailed descriptions; de Ridder (1965), and Cohen & Erol (1969) who both examined those west and north of the Yarma Plain. Nota & van Beek (1970) also mention them. They are striking features in the monotonous landscape.

2.2 Geogenesis

The description of the geological history of the Great Konya Basin in Section 1.3.1 has rather abruptly ended with the statement that it contained a large Pleistocene lake which dried up. On its Holocene history the information is restricted to some casual remarks about archaeology and geomorphology (Mellaart, 1961, 1963; Cohen & Erol, 1969; French, 1970).

Our present knowledge of palaeozoology, palaeobotany, Pleistocene climatology and archaeology justifies an attempt to reconstruct the geogenesis of the Lacustrine Plain in more recent times. The most important questions to be answered are:

1. When did the Ancient Konya Lake exist and which were the environmental conditions during its existence and thereafter?
2. When were the Recent Lakes formed, and how?

2.2.1 Pleistocene and Holocene climatology

The Pleistocene and postglacial climate of Anatolia has received considerable attention (Louis, 1938; Bobek, 1954; Wright, 1960; Cohen & Erol, 1969). In 1958, Butzer reviewed the then existing literature and compiled a climatic chronology for the Near East, which we adopted as a basis for discussion (Table 1). Since Butzer's review, much new climatological information has been published by palynologists (van der Hammen *et al.*, 1965; Beug, 1966, 1967). Wijmstra (1969) compiled an uninterrupted chronology of the late Pleistocene and the Holocene entirely based on pollen data from a peat core in northern Greece. His deductions about changes in aridity and humidity seem to agree roughly with Butzer's in the periods which were important in the formation of the Lacustrine Plain. It should be realized, however, that the use of any chronology from outside Central Anatolia is speculative because topography and altitude must have had considerable influence on local precipitation and temperature.

Table 1. Climatic chronology of the Near East (after Butzer, 1958).

1	Riss Pluvials I and II Colder, moister and longer than Würm Pluvial.
2	Last Interpluvial (Riss/Würm Interglacial) Rainfall lower than now and pronounced aeolian denudation.
3	Würm Pluvial I (Early Würm) The most typical Pluvial. Warmer than Würm Pluvial II.
4	Würm Interpluvial Probably as rainy as now. Temperatures unknown.
5	Würm Pluvial II (Main Würm), 23000-16000 B.C. Maximum extension of montane glaciers in Anatolia. Not particularly rainy. Temperatures about 4° C less than now.
6	Postpluvial I, 16000-about 10000 B.C. Still cooler and less rainy than now, probably with a minimum in the 12th millenium. At least one moister interval.
7	Subpluvial I, about 10000-9000 B.C. Cooler and temporarily moderately rainy. Last advance of Würm glaciers.
8	Postpluvials II a + b, 8500 (or 8000)-2400 B.C. Warmer. Beginning of typical postpluvial aridity. In IIa slightly less rainy than now but in IIb as rainy as now.
9	Subpluvial II, 5000-2400 B.C. Rainier than now and perhaps warmer (and hence higher evaporation). Temporarily less rain soon after 3600 and again about 2800 B.C.
10	Postpluvial III, 2400-850 B.C. Period of fluctuating aridity, probably warmer. Slightly less rain than now but at least one moist interval about 1200 B.C.
11	Postpluvial IVa, 850 B.C.-700 A.D. After short moist interval rainfall similar to the present but slightly fluctuating. Especially arid between 590 and 645 A.D.
12	Postpluvial IVb, 700 A.D.-present After 650 A.D. increasingly cold winters; since 1900 A.D. decrease of 1 to 15% in rainfall.

Tablo 1. Butzer 1958'e göre yakın doğuda iklim kronolojisi özeti.

Lake levels Because of the climatic changes during the Pleistocene and later, several Anatolian lake basins show ancient shorelines at various levels. In Lake Burdur they occur even about 40 and 90 m above the present level, the highest at levels with an overflow (Louis, 1938). The former shores in the Great Konya Basin, first described by Louis, occur mainly at about 1017 m. He and de Ridder (1965) surmise the presence of an underground outlet through the pervious limestone substrata. Deep drainage can indeed be noticed in several areas (Driessen & van der Linden, 1970). Moreover there is the much disputed sinkhole Düden Göl, together with the much larger Ak Göl, mentioned already by Hamilton (1843) as a possible outflow which kept the lake level constant. This cannot be confirmed, but Hamilton notes that its level was in 1800 some 20 m lower than the present plain, and according to our observations from 1960-8 its level was always several meters lower. Turkish hydrologists have recognized its function by leading three very large and long drainage channels to Ak-Göl and by making an overflow from this lake to Düden Göl.

A feature indicating the presence of other lake levels is the occurrence of terraces at about 1020 and 1050 m along the valleys of the Sille, from which de Ridder (1965) concludes that the Ancient Konya Lake must have had levels above 1017 m. As the lowest pass to the Tuz Gölü basin in the north is at about 1050 m this may be true, but it seems disputable whether this can be ascribed to a former late Pleistocene lake, because nowhere else around the basin are traces of shorelines at these levels: they may be early Pleistocene or older.

The present surveys have revealed that the sandridges and cliffs of the shoreline around Ancient Konya Lake are between 1012 and 1020 m, and those around the Secondary Depressions between 1000 and 1006 m.

In the western part of the Basin, Erol (see Cohen & Erol, 1969) has observed shorelines at 1017, 1010, 1006, 1002, 1000 and 996 m. He thinks (personal comm., 1969) that these levels represent six recessional phases of the ancient lake which must have occurred in a period starting before 23000 BC (Würm Pluvial II) and ending at about 850 BC (Postpluvial IVa). Erol gained his information from topographic maps 1 : 20000 and from aerial photographs. His datings are partly the result of geomorphological considerations in relation to Butzer's climate chronology, partly from archaeological evidence.

Erol's results seem rather disputable, even though he has thoroughly verified the photo-interpretation and the rather crude contour lines of the map. Firstly because the observed variation in the shorelines can be explained by changes of short duration due to the wind force and wind direction (Section 2.3), and secondly because there are two groups of ridges, containing semi-fossil shells differing in age (see below).

Soils The morphological investigations on Marl Soils (Chap. 5-8) show that the substratum, to a depth of about 150 cm, almost everywhere consists of collapsed pellets, presumably wormcasts. This means that, during the last stages of sedimentation, the area of Ancient Konya Lake was only occasionally flooded and that its floor was not or only slightly salt-affected, a situation not much different from the present (outside the Secondary Depressions).

Many Marl Soils show a clear or vague discontinuity in sedimentation and soil formation at about 100 cm depth, often accentuated by an old buried A1 horizon or by thin layers of organic soil. Such discontinuities are especially abrupt in the Secondary Depressions, where dark-gray marl occurs on top of white carbonatic clay, indicating a sudden change of sedimentation. Of particular interest is that the transition contains dark tongues, presumably cracks in the white subsoil filled with organic mud formed in an alkali environment (Section 3.2.3).

Shells During the soil survey, it was observed that the white carbonatic clay in the subsoil of the ancient lake floor, in the surface soil outside the Secondary Depressions, and in all associated sandridges and beaches, contained mainly fractured shells almost exclusively of *Dreissena.* The dark surface soils in the Secondary Depressions, however, and the few remains of associated sandridges below 1002 m contained exclusively shells of *Planorbis, Lymnaea* and *Viviparus.* All mentioned molluscs still occur in the Anatolian lakes (Lahn, 1946), so their indentification was no evidence for dating. However, six shell samples from the above mentioned deposits (mainly from the western half of the Lacustrine Plain) were used for ^{14}C-dating by Dr W. G. Mook. The results in Table 2 show that three samples from the subsoil and the soils and sandridges outside the secondary depressions were from about 20000 BC, whilst those from the soils and ridge of the Konya depression were from about 9000 BC.

The species themselves clearly indicate the environment they lived in. *Dreissena* lives in medium-sized bodies of water with turbulent water, whilst *Planorbis, Lymnaea* and *Viviparus* prefer shallow stagnant water (de Ridder, 1965). All species are fresh-water molluscs, although there is some uncertainty about the determination of *Dreissena* which seems a transitional form to *Congeria,* which lives in slightly salty water (de Ridder, pers. comm.).

Pollen Several profiles in the Lacustrine Plain were sampled between 100 and 200 cm for a pollen analysis, carried out by Dr. B. Polak (13 were scanned and 4 counted). Except for one, their picture was rather uniform. Table 3 gives two representative examples (white carbonatic clay subsoils from Profile G 1.1, Yarma Plain, and from

Table 2. Approximate ages of six lacustrine deposits, determined on fossil shells by ^{14}C method.

No	Site	Sample No (Groningen)	Shell species	Deposit	Age in years
1	Karapınar (E 2.1)	GrN 5728	*Dreissena*	white marl of Basin	21800 ± 455
2	Hotamış (65-15)	GrN 5729	*Dreissena*	white marl of Basin	20700 ± 450
3	Çumra	GrN 6014	*Dreissena*	sand and gravel of primary shoreline	21370 ± 215
4	Merdiven	GrN 6015	*Dreissena*	sand and gravel of primary shoreline	32350 ± 410
5	Ortakonak	GrN 5841	*Lymnaea*	dark marl of secondary depression	10950 ± 65
6	Yarma	GrN 6016	*Lymnaea*	sand of secondary shoreline	12010 ± 65

Tablo 2. Lakustrin depozitlerin C-14 metoduyla yarı-fosil kabuklarından faydalanılarak tayin edilmiş, takribi yaşı.

Table 3. Pollen and algae analysis of two samples: G 1.1 in the Yarma Plain and MD 3 in the Hotamış Plain (200 grains counted).

	G 1.1		MD 3	
Pollen				
Abies or *Cedrus*	0.5		0.5	
Pinus	8.1		10	
Quercus	2.0		2.5	
Total trees		10.6		13.0
Gramineae		2.8		10.0
Cyperaceae		3.8		4.0
Caryophyllaceae				14.0
Chenopodiaceae		41.0		41.0
Compositae		4.8		13.0
Thyphaceae		5.0		5.0
Artemisia spp.		2.0		0.0
Tamaricaceae		30.0		0.0
Algae (as percentage of total pollen)				
Pediastrum spp.		179.0		107.0
Botryococcus spp.		5.0		8.0

Tablo 3. 200 cm derinlikte Lakustrin ovada (profil G 1.1 ve MD 3) karbonatlı iki kil örneğinde polen analizleri.

Site MD 3, Hotamış Plain). The data indicate a sedimentation under water (*Pediastrum* and *Botryococcus* are algae). A periodic drying-out is evidenced by the high percentage of damaged and oxidized pollen. Less resistant pollen, e.g. those of trees, may have disappeared entirely. The flora indicates a saline steppe (many *Chenopodiaceae* and *Tamaricaceae*).

Ancient settlement From 1961 till 1966 Mellaart (1961, 1963, 1966) excavated part of the Çatal Hüyük, an ancient habitation mount near Küçükköy, some 15 km north of Çumra. He reports on Neolithic settlement as early as 6000, and possibly even 8000 BC, and he found evidence of a rich fauna of wild cattle, wild asses and red deer, all animals of open grassland. At present the mount lies in an area of alluvial levee soil of the River Çarşamba, and very close to a vast area of Former Backswamp Soils presumably deposited in a semilacustrine environment (de Meester, 1970). Because at about 6000 BC the river levees will have been under forest, the grassland must have been where the Backswamps and the Lacustrine Plains now are. This means that no lake was then present, but that in depressions the soil was sufficiently moist or marshy to supply the vegetation necessary for feeding the animals.

The settlements on the ancient lake floor are considerably younger; they date mainly from 3000 BC, or they are more recent. In the depressions below 1000 m, no hüyüks have been found, or those found could not be dated (Mellaart, 1961, 1963; French, 1970).

Cohen (Cohen & Erol, 1969) used the data on hüyük age to support the dating of their presumed recessional phases, but French (1970) points out that they by no means give evidence for that. The more recent civilizations tend to move away from the centre of the Basin in search of better farmland on the piedmont slopes.

Information on the condition of the Lacustrine Plain after 1000 BC is from Cicero's letters to Atticus (50 BC), St. Luke, (Acts, Chapter 14 and 16), and from Hamilton (1843). They all describe a vast and marshy plain, locally with tall grasses or covered with the yellow stubble of reeds and rushes. They report that the Plain is entirely flooded in winter. Saline conditions are not mentioned.

2.2.2 Chronology in lake formation

From the above information, the following chronology is suggested:

- Before the Würm Pluvial I (Early Würm) and presumably in the Neogene, the level of the Ancient Konya Lake was above 1020 m.
- The Ancient Konya Lake existed during the Würm Pluvials I and II, and its level was between 1012 and 1020 m.
- This lake was a large, slightly brackish waterbody with strong currents and moderately turbulent water (Section 2.3). Shorelines were formed mainly at 1017 m, but also at lower levels due to variations in force and direction of winds of short duration.
- The lake fell quickly in level at the beginning of Postpluvial I (about 16000 BC) and ultimately dried up. Its upper sediment was a white carbonatic clay. During the last stages of sedimentation, conditions were alternatingly dry and wet.
- After the lake had dried, its floor became salt-affected; the upper parts until the present time, the lower parts only temporarily.
- In Subpluvial I (about 10000-9000 BC), the four secondary depressions filled with water and became small shallow stagnant freshwater lakes: the Recent Lakes. Their level varied between 1000 and 1006 m. In the Yarma and Hotamış depressions, the lakes had marshy stages during which dark carbonatic clay was formed, but in the Karapınar and Ak Göl depressions this did not happen. In all five lakes shorelines were formed, of which few still exist.
- In Postpluvial IIa (about 8000 BC) the Recent Lakes gradually retreated and entirely disappeared at about 3000 BC, except for the lower parts, which remained either marshy or became a playa (as in the Karapınar and Ak Göl depressions).
- The ultimate situation, since 8000 BC, is an area covered with tall grass steppe alternating with marshland. Since Byzantine times, overgrazing has changed the original steppe vegetation into a degraded steppe with much wind erosion. Irrigation, especially since 1920, has caused widespread salinity.

2.3 Limnology of the Ancient Konya Lake

2.3.1 Past environmental conditions

Ancient Konya Lake had an area of about 500000 ha, but due to its irregular shape the SD index (Shore Development index = ratio of shoreline length and circumference of circle enclosing the same area as the lake) was high (about 1.76). It was about 130 km long and between 10 and 40 km wide. Because of much recent sedimentation, it is difficult to estimate its original volume, but the maximum depth was about 35 m in the Karapınar depression, about 25 m in the other depressions. Most of it was about 10 m deep. Before littoral erosion and aggregation steep cliffs, gently sloping alluvial fans, bajadas and low Neogene terraces bordered the lake.

It was relatively small, so that there were no tides and only the wind may have altered its level, especially when blowing from one direction for longer periods and thus generating currents. So some information on the force, the frequency and the direction of the prevailing winds during the late Pleistocene would be useful to explain the formation of the shore features and lacustrine sand deposits.

According to Butzer (1957) the normally prevailing westerlies in the upper atmosphere were weaker in the Würm Pluvials I and II than earlier and the extensive upper air troughs extended far further towards the equator, thus introducing polar air masses into the tropics. In the lower atmosphere, the zone of maximum frontal activity was likewise shifted southwards and the subtropical high pressure cells were weaker. The result may have been an intensification of the Mediterranean westerly circulation. In summer the prevalent wind may have been a steady breeze from the north or north-west and in winter the dominant winds were gales from the west. Whether the occasional hot southerly summer storms, as now, occurred during the Würm Pluvials cannot be decided.

Erol (see Cohen & Erol, 1969) remarks that at several places the spits from the higher lake levels have obviously resulted from northerly winds, as suggested by the above evidence, but that the spits of his 1006 m level seem to have formed by the action of southerly winds. He concludes that this observation, and similar ones, are evidence for a climatic change of long duration.

But such phenomena (if they occur) can fully be explained as the result of opposite or cross currents due to reflexion, diffraction and variations in wind direction and force of short duration. The cuspate spit in the small Lake of Süleyman Hacı is a fine example of what may occur in this way today.

In a large sea a prevalent but weak wind may build up a shore and a strong wind may destroy it. But this cannot have occurred on the borders of Ancient Konya Lake, as its size and irregular shape would have caused much wave reflexion and diffraction, resulting in almost equal wave action on all coasts, though locally conditions for accretion have been favourable.

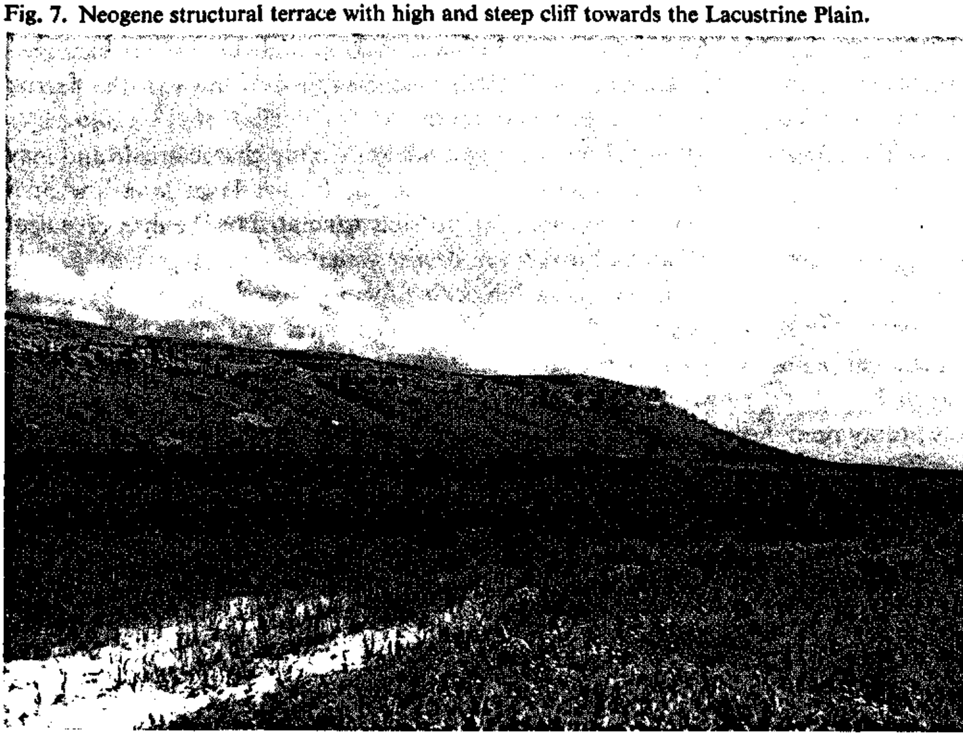
Sand and pebbles for the beaches have been derived from material carried into the lake by the rivers, and from cliff erosion of soft rock as found north of Konya where old consolidated debris cones were cut away by the waves. The Neogene limestone formations with their alternating layers of hard and soft limestone also contributed. Where cliffs were cut in the hard Mesozoic limestone, not much debris could be expected. In the eastern part of the Basin, near Karapınar, volcanic ash was available to build up the beaches. It was eroded from the volcanic bajadas and colluvial slopes in this area.

2.3.2 Present coastal features

The coastal formations of the past are still visible at present around the Lacustrine Plain. I have mapped them all by photo-interpretation and by fieldwork during the soil survey (Appendix 3). They may be reviewed as follows (terminology according to Shepard, 1963; King, 1959; Thornbury, 1965).

Cliffs occur mainly north and east of the Yarma Plain, east of the Karapınar Plain and around protruding rocks or in isolated volcanic cones (Fig. 7). Locally niches and benches have been cut into them, clearly marking the old water levels (Louis, 1938). At their foot narrow benches were formed, at present covered by colluvial material and therefore mapped as Colluvial Slopes (de Meester, 1970).

Fig. 7. Neogene structural terrace with high and steep cliff towards the Lacustrine Plain.



Şekil 7. Lakustrin ovaya doğru uzanan yüksek ve oldukça yüksek eğimlere sahip klifleri ile strüktürel neojen teras.

Beaches occur mainly along the structural terrace rims as between Okçu and Arikören, east and west of Merdiven and near Kayacik. In all sites the material consists of sand and gravel layers, clearly shaped as a stormbeach with a high ridge. The beach near Kayacik, formed at the foot of a low hill, is about 20 m thick and consists mainly of gravel from the conglomerates north of it. At several sites, bayhead beaches have formed by refraction of waves in bays where conditions have been favourable for accretion.

Barriers are found mainly where the original coast has been gently sloping as on low structural terraces and near former deltas. A characteristic formation in tideless seas is the pattern of barriers in the southern and south-western part of the Yarma Plain. Here two almost parallel beach barriers occur, attached to the piedmont zone south of Konya. The northern one, of Pireli Kas, is relatively short but may have been formerly attached to the siltridge which presumably has a sandy interior. The southern one is about 40 km long and 5 km wide, as near Fethiye, where it consists of several ridges. North of Çumra, the barrier is now interrupted by the channel of the River Çarşamba. It ends in a sandplain which apparently has extended eastward and has been connected with the sandbars near Demirkent. The barrier near Fethiye features a cuspate spit.

Both barriers have been built up by currents along the shore bringing sand and gravel from the conglomerates and from the sediments of the rivers Meram, Sille, May and Çarşamba. The same current has also pushed the Çarşamba delta eastward, first bringing sand to the beaches of Okçu and Arikören and then to the bars near Demirkent. Possibly by blocking itself, the stream has broken through the barrier and so has formed the northern part of its delta.

Parallel barriers on a gently rising coast in a tideless sea are characteristic and may be explained by assuming two kinds of waves in the former lake: long low ones breaking in the shallow water near the coast, possibly generated by the then prevalent winds, and steeper storm waves breaking in deeper water.

Bay barriers are found in several sites blocking former bays. Of a special type are the barriers or bars which were formed in the former narrow passages between two constituent plains as near Işlik between the Hotamış and the Karaman Plain, and as east of Karapınar, between the Karapınar and the Ak Göl plains and also, although less pronounced, near Demirkent, between the Yarma and the Hotamış Plains where a system of low bars locally forms an undulating sandplain.

The *sandplains* south of Karapınar are the largest; locally they consist of dunes. The sand contains about 70% calcium carbonate, partly as shell fragments. Much smaller sandplains occur north and south-west of Demirkent.

This sand almost everywhere covers carbonatic clay and the dunes migrate over this old lake floor, which is still exposed here and there in the dune valleys. In the Marl Soils of this area more fine-sandy layers, with shell fragments, occur than elsewhere in the Lacustrine Plain (except near Demirkent where there is another sandplain).

Several authors have attempted to explain, mainly in a general way, the Karapınar sandplains (Louis, 1938; Groneman, 1968). The following reconstruction of their origin seems adequate.

In general the material has been accumulated by waves and currents, and erosion has never been strong. However, a large source of sand must have been available and presumably the very large, old sand deposits, north of Merdiven, of unknown origin (de Meester, 1970) have contributed. The sand was first eroded and then carried eastwards by waves and currents caused by strong winds. Where the lake narrowed, as south of Karapınar, the waves deposited their load.

Volcanic outbursts during the lake stage may have helped to reduce or close the passage to other parts of the lake with ash and debris. After the lake fell dry, the sand was blown into low dunes which soon became covered by vegetation. The high shifting sand dunes of today are caused by recent wind erosion after the destruction of the plant cover by overgrazing (Groneman, op. cit.).

The much smaller plains of sand and sandy marl near Demirkent can also be explained by accumulation of lacustrine sand by waves, but here the River Çarşamba has presumably supplied the necessary material. East of Göçu, where dunes also occur, consolidated conglomerates forming the piedmont zone have been the source of the material.

These interpretations are mainly based on terrain morphology, thorough knowledge of the soils and their distribution, and some basic knowledge of shore formation. Mineralogical data are needed to support the assumptions made here, but this was beyond the scope of this study. As to the currents and the barrier formation in the western part of the Lacustrine Plain, mineralogical data and conclusions from shell types by de Ridder (1965) confirm the interpretations.

3 Soils of the Lacustrine Plain

Since the Lacustrine Plain dried up, its sediments have been the parent material for soil formation. This material has a uniform composition and consists mainly of carbonatic clay. But very different profiles have developed as a result of various combinations of soil-forming factors.

The main differences are between the plains east, west and south of the sands near Karapınar. The western plains have mainly dark-gray surface soils over yellow mottled white marl in their depressions and brown surface soils with a calcic horizon in the higher parts. In the southern plain (that of Karaman) all soils are as in higher parts. The eastern plains consist mainly of salt-affected white marl, in their depressions covered with a salt crust. But interesting deviations of this general type occur locally.

The Tufa Soils of the Aslım Marsh, north-east of Konya, and the Chalk Soils of the Neogene terraces of Ürünlü and Kaşınhanı, will also be described here.

The profiles of the Marl Soils (by far the most important in the area) were studied in some 50 pits and in several hundred borings to a depth of 120 to 200 cm. For a more comprehensive study, some representative profiles were selected.

In the field, soils have been described in detail, in particular their structure. The descriptions have been adapted into an easily consultable form in tables and in structural diagrams according to the Jongerius system (1957). The terminology used for the description of horizons, boundaries, texture, consistency and mottling is in accordance with the Soil Survey Manual (1951).

The analytical data in the tables were obtained mainly by methods described in Handbook 60 (Diagnosis 1954).

For the description of field structure, the Jongerius system offers advantages over the simpler system of the Soil Survey Manual; most of his terms agree with those of the Soil Survey Manual but several of his definitions are slightly different. There was no consistent English translation of the terminology, though several authors using this system had made translations for figure captions, keys or terms occurring in their text (Jongerius, 1957; van der Kloes, 1965; Slager, 1966).

Appendix 2 supplies an English translation of the Jongerius system for description of soil structure in the field. It has been prepared in consultation with Dr Jongerius of Stiboka and Mr Rigg of Pudoc.

3.1 Marl Soil map units

In the report on the reconnaissance survey (de Meester, 1970), six map units were distinguished in the Marl Soils of the Lacustrine Plain. These units roughly represent soil series, and are described as follows:

Clayey Marl Soils with shell fragments (LmA) Deep olive-gray (2.5Y 6/2) carbonatic clays, containing small shell fragments. Subangular-blocky surface soil and fine prismatic subsoil. They have a clear A1, a structural B, a calcic and often a gypsic horizon. The subsoil may contain layers of whole shells or their fragments. Yellow mottling is characteristic. The soils are moderately well drained and locally moderately internally salt-affected. Relief is flat and level. The unit is uniform, varying only locally in depth of A1 horizon and in salinity. East of Hotamış, they have a very thin A1. They are partly used for the dry cultivation of wheat, partly as rangeland. In several areas water is pumped up for irrigation.

Stratified loamy Marl Soils with shell fragments (LmB) Very deep, dark grayish-brown (2.5Y 4/2) mainly subangular-blocky medium-textured soils with a weak calcic and sometimes a gypsic horizon. They are well drained, salt-free or slightly salt-affected, flat and nearly level. The unit is complex with many sandy layers, a feature changing over short distances. They often have a dark slightly organic layer at 50-100 cm. The largest area is around Demirkent between the Yarma and Hotamış plains, where low sandy ridges (ancient bars) cross the unit. They are mainly used for dry farming of wheat.

Clayey Marl Soils with shell fragments, shallow dark-gray humic surface soil (LmC) In the LmC soils, the subsoil is similar to that in LmA, but the upper 0-30 or 50 cm is dark-gray (10Y 4/1) because of dispersed humus, resulting from former marshy conditions. Recently reclaimed soils contain root residues throughout the profile. This soil type lies in the lowest and poorest drained parts of the plains and are usually moderately salt-affected, unless irrigated. They are uniform, except in salinity and in depth of the dark surface soil, which varies between 30 and 60 cm. They occur mainly in the centre of the Yarma and Hotamış plains. Locally they merge into Former Backswamp Soils. They are used for dry farming or, if salt-affected, for cattle ranging. A large area between Yarma and Karakaya is irrigated and seems to yield well.

Predominantly salt-affected pale clayey soils (LmD) Deep olive-gray (2.5Y 6/1), angular-blocky or prismatic, carbonatic clay without distinct horizons except a salic one. Poorly drained, strongly salt-affected with patches of external solonchaks; flat and level.

The vegetation is halophytic; the land is either barren or very poor rangeland.

Strongly salt-affected clayey soils of a periodically flooded playa (LmE) Deep white (2.5Y 6/0) moist carbonatic clay with a reduced hydromorphic surface soil, entirely covered with a salt crust. Poorly drained in summer, flooded for at least six months. Flat and level. The soil surface is cracked, hard, fluffy or puffed.

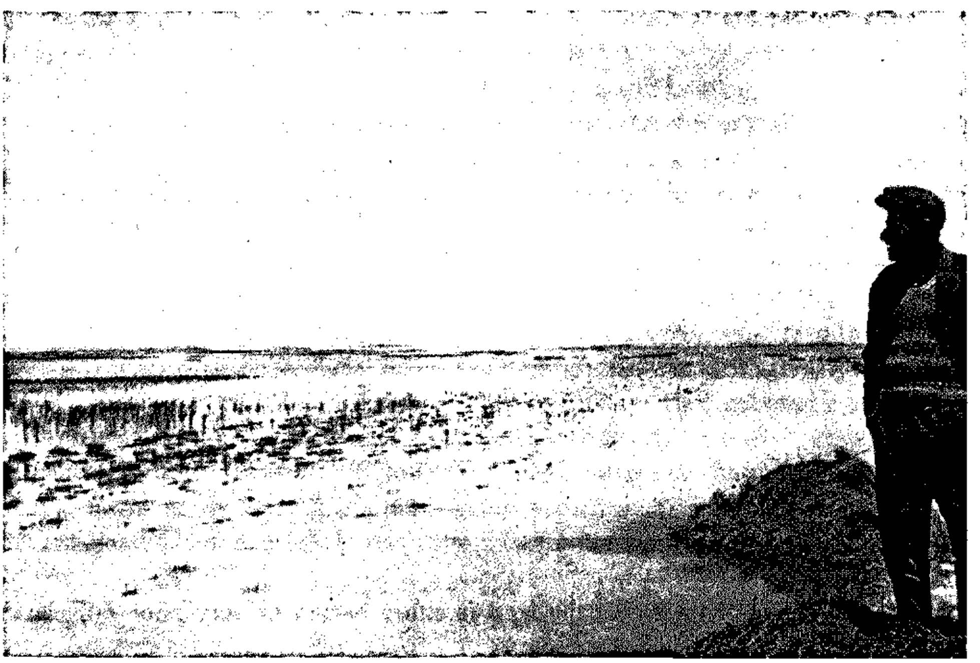
The land is barren or has only isolated tufts of vegetation.

Hydromorphic, locally gypsiferous and cemented clayey soil (LmF) Deep olive-gray (2.5Y 6/2) hydromorphic clays with reduction colours and many salt and gypsum crystals, cemented layers and layers of loose shells. They are moderately to strongly salt-affected, flat and level. They occur south-east of Lake Hotamış and have only recently dried up.

In the following sections only LmA, LmC, LmD and LmE will be further discussed. LmB soils have developed in loamy material and not in clay. LmF soils cover only a small area.

LmA will be called *Steppe Marl Soils*, LmC *Marsh Marl Soils* and LmD and LmE together *Playa Marl Soils*. A very heavy variant of the Marsh Marl Soils occurs here and there in depressions. They are called *Basin Marsh Marl Soils* (not on the map Appendix 3). A particular granular variant of the Playa Marl Soils will be indicated as *Granular Playa Marl Soil*; it is on the map as a hatched part of LmE.

Fig. 8. Flooded Marsh Marl Soil in Yarma Depression (May 1967).



Şekil 8. Yarma yakınlarında ikincil çukurda Baskına Uğramış Bataklık Marn Toprak (Mayis 1967).

3.2 Marl Soils of the Yarma and Hotamış plains

3.2.1 Regional aspects

The Yarma Plain and the Hotamış Plain are separated by an area with sandy marl and low sandridges (former bars) near Demirkent. They are flat and level, except for a 5 to 7 m deep depression. The Hotamış Depression is still associated with the present Lake Hotamış south-west of it.

The hydrology of the plains is under the influence of the River Çarşamba and the irrigation system which drains its tail water into their lower parts. The Yarma Plain also receives water from the Meram and Sille Rivers, near Konya.

In wet years (such as 1967-70) the lower parts are flooded (Fig. 8). As apparent from the remnants of marsh vegetation still found in many places near the village of Hotamış, much larger areas were flooded before the hydraulic works were built some 15 years ago. In the past the people of Hotamış lived by fishing.

A meandering creek, dry at present, connects Lake Hotamış, with the Yarma Depression. It runs from Karahüyük to Yarma.

Of particular interest is a low sandridge, at 1000 m altitude, east of the main irrigation canal near Yarma. It consists of loamy sand with remnants of *Lymnaea* and *Planorbis* shells, and represents a beach formed in a Recent Lake in the Yarma Depression.

Since most of the Yarma Plain and the Hotamış Plain is occupied by Steppe Marl Soils and Marsh Marl Soils, they will be fully discussed in this Section. Playa Marl Soils occupy small areas only here and will therefore be described in Section 3.3.

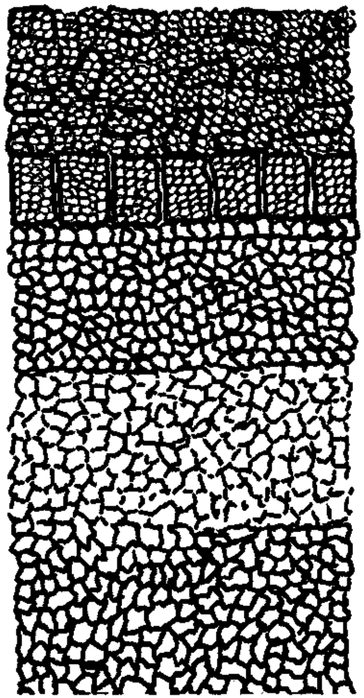
3.2.2 Steppe Marl Soils

Characteristic profiles Though the profiles of Steppe Marl Soils have many common features, they differ because of use and salinity. Four examples have been selected to demonstrate those differences: C 3.1 (Fig. 9) of a dry never cultivated soil, C 3.2 (Fig. 10) of a dry cultivated soil, G 1.1 (Fig. 11) of an irrigated soil, and D 3.1 (Fig. 12) of a dry cultivated slightly saline-alkali soil. For the sites, see Appendix 3; for the explanation of the schematic structural diagrams and formulas, see Appendix 2.

The soil surface is always light-olive-gray to grayish and olive-brown, with an organic carbon content of 0.5-1.7%. The subsoil is invariably pale-olive with clear or faint iron oxide mottles and no organic carbon at all. Very characteristic is the crumblike structure of the surface soils, resulting from intense biological activity as will be explained in Chapter 5 and 6.

The profiles from the dry cultivated sites (C 3.2 and D 3.1) show a very clear plough bottom (Ap). The subsoil has a characteristic, fine prismatic structure consisting of very fine angular-blocky elements. As regards D 3.1 the EC_e data indicate that the soil is slightly salt-affected between 0 and 50 cm, and according to its ESP (> 15, pH about 8.3) saline-alkali below 50 cm.

STRUCTURAL DIAGRAM
C 3.2



Horizon	Depth (cm)	Structure (Jongerius)	Colour (Munsell)	Field texture	Consistency wet/dry	Remarks	$CaCO_3$ eq.(%)	pH H_2O	pH $CaCl_2$	Org. C (%)	ECe mmho/cm	ESP (measured)	CEC meq/100 g
Ap1	0-20	A4b1V1½ / A3a1II2½	10YR 4/3	silt-loam	sticky & plastic, soft	ploughed with clods	31.4	8.20	7.50	1.23	0.96	0.5	20.3
											0.62	0.6	20.4
Ap2	20-30	B2.2IV3 / A3a2II2½	10YR 4/3	clay-loam	sticky & plastic, hard	few coccoons	32.0	7.85	7.45	1.21	0.54	0.5	19.4
A1	30-50	A4a1(III+IV)2½	10YR 4/3	clay-loam	slightly sticky & slightly plastic, soft	few coccoons	41.6	7.70	7.50	0.98	0.35	0.9	19.6
											0.58		
B1ca	50-72	(A4b+A5b)3 IV1½c	5Y6/3	silty clay	slightly sticky & slightly plastic, hard	many, clear medium calcareous concretions	57.0	7.30	7.20	0.0	1.16	2.7	18.0
											3.22		
B2ca	72->90	(A4b+A5b)3 V2½c	5Y6/3	silty clay	sticky & plastic, slightly hard	common, clear fine rust mottles (2,5 Y 6/6), few shell fragments	54.2	7.70	7.60	0.0	3.08		
											3.74	5.6	17.7

Fig. 10. Field description and analytical data of Profile C 3.2.
Şekil 10. Profil C 3.2, bakir Step Marn'a (LmA) ait profil izahı ve analiz kayıtları.

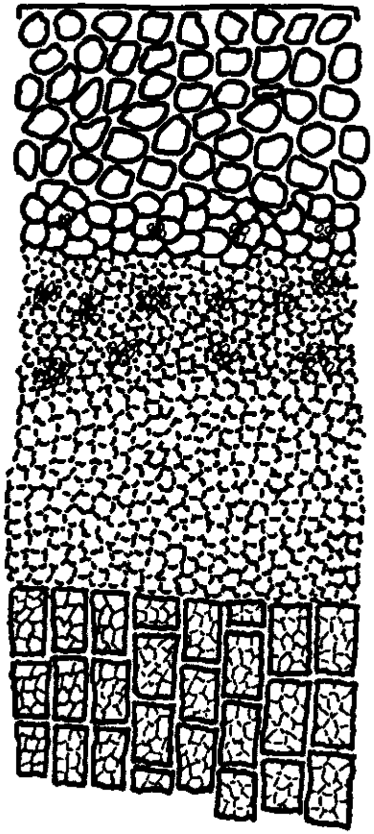
Great Konya Basin, Hotamış Area
Described by T. de Meester and A. L. J. van den Eelaart (16-8-1966); see Chapter 6.

Diagnostic horizons:	Ochric epipedon	approximate depth	0- 50 cm
	Cambic horizon		50-> 90 cm
	Calcic horizon		50- 72 cm
Classification (1967):	Carbonatic Mollic Calciorthid		

Mechanical analysis (with $CaCO_3$).

depth (cm)	sand (%)	silt (%)	clay (%)
0-20	18.5	49.8	31.8
20-30	18.2	45.0	37.6
30-50	14.6	41.4	43.9
50-72	5.9	42.9	52.7
72-90	4.6	46.9	48.2

STRUCTURAL DIAGRAM
G 1.1



Depth scale (cm)	Hori-zon	Depth (cm)	Structure (Jongerius)	colour (Munsell)	field texture	Consistency wet/dry	Remarks	$CaCO_3$ eq. (%)	pH H_2O	pH $CaCl_2$	Org. C (%)	ECe mmho/cm	ESP (meas-ured)	CEC meq./100 g
0		0-1	E1a											
10, 20	Ap1	0-25	A4b1VI-VIII3	5Y 5/1	clay-loam	sticky & plastic, hard	many roots	50.4	7.30	6.85	1.7	0.55 0.62	0.5 0.7	19.5 18.9
30	Ap2	25-33	A4b3V2½ locally A2a	5Y 5/2	loam to clay	sticky & plastic, sl. hard	common to few roots	53.8	7.65	7.10	0.7	0.54 0.42		
40, 50	A3	33-55	A1+A2a +A3III1½	5Y 5/2	clay	sticky & plastic, friable (moist)	many biopores, few humus cutans	57.6	7.85	7.40	0.6	0.39	1.0	14.5
60, 70	B2ca	55-80	A4b3III-IV 1½a2	5Y 6/3	clay	sticky & plastic, friable (moist)	common biopores, few krotovinas	61.0	8.05	7.65		0.41 0.41 0.35	 0.8	 19.5
80, 90, 100, 110	B3	80->115	B3aIII3a2 / A5a3III-IV1½	5Y 6/3	clay		common biopores humus illuviation cutans, many medium rustmottles (10YR 6/6)	56.9	8.05	7.70		0.40 0.45	 1.3	 19.0

Fig. 11. Field description and analytical data of Profile G 1.1.
Şekil 11. Profil G 1.1 sulanmış Step Marn'a (LmA) ait profil izahı ve analiz kayıtları.

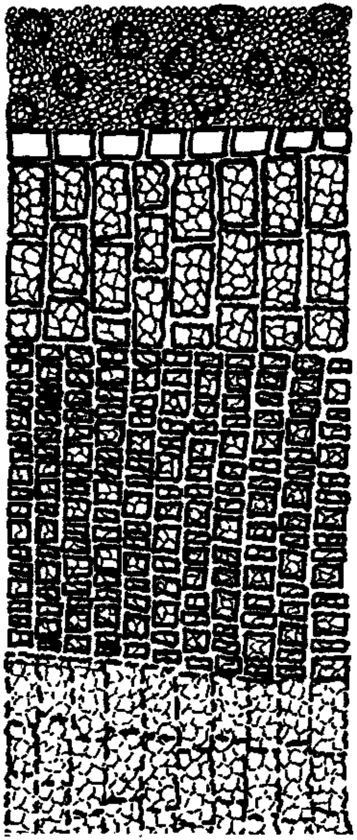
Great Konya Basin, Yarma Area
Described by T. de Meester and A. L. J. van den Eelaart (22-8-1966); see Chapter 6.

Diagnostic horizons:	Ochric epipedon	approximate depth	0- 55 cm
	Cambic horizon		55-> 115 cm
	Calcic horizon		55- 80 cm
Classification (1967):	Carbonatic Mollic Calciorthid		

Mechanical analysis (with $CaCO_3$).

depth (cm)	sand (%)	silt (%)	clay (%)
0- 25	10.8	45.9	40.3
25- 33	15.8	43.0	41.8
33- 55	11.6	41.1	47.0
55- 80	5.1	43.6	49.6
80-115	1.2	43.6	54.6

STRUCTURAL DIAGRAM
D 3.1



Horizon	Depth (cm)	Structure (Jongerius)	Colour (Munsell)	Field texture	Consistency wet/dry	Remarks	$CaCO_3$ eq. (%)	pH H_2O	Org. C (%)	ECe mmho/cm	ESP (measured)	Na meq/l	CEC meq/100g	Gypsum (%)
Ap1	0-17	A3aII3	2½Y 4½/2	clay-loam	sticky & plastic, soft		36.8	7.6	1.3	0.92	1.78	5.6	20.2	0.4
							46.2	7.7		0.98	5.04	7.3	18.8	
Ap2	17-21	C4b2V3	2½Y 4½/2	clay-loam	hard	plough bottom			1.1					0.4
B21ca	21-45	B3a3III 3a2 / (A4a+A5)3IV2½	5Y 6/3	clay	sticky & plastic, slightly hard	rootprints & cutans	59.1	8.1	1.5	1.50		10.8		0.5
B22	45-90	B4a3II 3a2 / A5a3IV2½a2	5Y 6/3	clay	sticky & plastic, slightly hard	rootprints cutans, many coarse rust mottles (10YR 6/8)	60.4	8.4	0.2	2.60	30.6	22.0	15.0	0.7
							60.1	8.3		3.04		26.6		
C1cs	90->140	B3a3III1 / A4a3IV1½	5Y 6/3	clay	sticky & plastic, slightly hard	abundant gypsum veins, few coarse rustmottles	58.2	7.9	0.1	10.0	24.0	92.0	15.8	2.5

Fig. 12. Field description and analytical data of Profile D 3.1.
Şekil 12. Profil D 3.1, tuz etkisinda kalmış Step Marn'a (LmA) ait profil izahı ve analiz kayıtları.

Great Konya Basin, Yarma Area
Described by T. de Meester and A. L. J. van den Eelaart (20-8-1966); see Chapter 6.

Diagnostic horizons:	*Ochric epipedon*	approximate depth	0- 20 cm
	Cambic horizon		20-> 100 cm

Classification (1967): Carbonatic Mollic Camborthid

Mechanical analysis (with $CaCO_3$).

depth (cm)	sand (%)	silt (%)	clay (%)
0- 17	17.8	56.1	26.1
17- 21	15.7	58.0	26.3
21- 45	2.0	42.9	55.1
45- 90	0.3	47.0	52.7
90-140	4.1	45.4	50.5

For all soils the calcium carbonate equivalent ranges from 30 to 60%, as usually in Marl Soils. The surface soil is often less calcareous than the subsoil, presumably because of leaching. In all three profiles a calcic horizon occurs at about 50 cm; it represents secondary lime accumulation, as normal in soils of semi-arid regions. The often faint and brownish-yellow (10YR 6/8) rust mottles cannot be explained as a result of recent oxido-reduction because, in spite of annual flooding, the substrata of both lacustrine plains are too dry and permeable, as shown in the moisture studies by Janssen (1970b) and by permeability tests (Section 10.3.3). Presumably the widespread yellow mottling has been formed during the last stage when the ancient lake was drying up (Postpluvial II) by fluctuations in watertable near the surface. Thus the mottles are fossil.

The saline-alkali Profile D 3.1 has clear coatings (cutans) in the subsurface horizon (Chapter 5), resulting from migration of clay-humus compounds mobilized under the slightly alkali conditions presumably existing at the end of the dry season (Driessen, 1970). The first heavy rainshowers wash down some of the surface material, which settles on the peds in the subsurface layer.

The Steppe Marl Soils are irrigated here and there. G 1.1 is a profile from a field that was irrigated for some eight years. The data show that salts have been entirely removed to give a less prismatic subsoil. Due to puddling, however, the structure of the surface soil became subangular-blocky, thus detiorating as compared with the original crumblike structures of the nearby dry Steppe Marls, but the subsoil shows biological activity to a greater depth.

Deviant profiles As indicated on the map the Marl Soils are locally salt-affected due to a high watertable. Salinity occurs mainly in the Yarma Plain by seepage from riverfans and from irrigation canals. The profile, as discussed above for the characteristic slightly saline-alkali Marl Soils (D 3.1), differs only in the surface soil, which is predominantly angular. There are more soluble salts in the upper part of the profile and there is often an accumulation of gypsum occurring with increasing depth as veins, crystal clusters and large single crystals.

Such accumulations are closely correlated with the depth of the groundwater. The subsoil structure of the gypsiferous soils is, despite the high salinity, less prismatic, less angular and more porous and permeable than of the typical Steppe Marl Soils, presumably because of alternating crystallization and solution of gypsum crystals. Gypsum veins and crystals have also been recorded, although much less, in the Steppe Marl Soils of the Hotamış Plain, mainly at the fringe because of increased seepage there.

Where sandy, silty or loamy Steppe Marl Soil occur, the profiles deviate only from the characteristic ones by a weaker structural grade throughout the profile. The profiles are less salt-affected in the subsoil, more permeable and better rooted. Such marls are mainly found in unit LmB.

3.2.3 Marsh Marl Soils

Characteristic profiles Three examples have been chosen to represent the Marsh Marl Soils. Profile C 2.1 (Fig. 13) is from the Hotamış depression, an area which was marshy until some 15 years ago and is now dry cultivated. Profiles G 1.3 (Fig. 14) and G 3.1A (Fig. 15) are from the Yarma Plain; the first is in the depression near Karakaya and is under irrigation, whilst G 1.3A is from an area which stayed marshy until recently because of seepage from the Çarşamba irrigation system. This soil is under primitive irrigation by occasional flooding.

In all these profiles the colour of the surface soil is dark-gray or dark-gray-brown. As the organic carbon content is between 2 and 3%, this dark colour is due to disperse humus and very fine carbon particles, as can be observed in the thin sections (Chapter 7). The subsoil colours are like those of the Steppe Marl (light olive-gray), but mottling is more abundant and distinct. The structure of the surface soil is subangular-blocky and often compound, that of the subsoil is coarse angular-blocky or weak compound prismatic. This structure is the result of wetting during annual flooding. The drying and a temporary moderate salinity normally gives extreme angular or prismatic elements, but this process is presumably counteracted by the stabilizing influence of organic carbon and by biological activity during the wet and moist periods.

Presumably alkali conditions have prevailed during the formation of the Marsh Marl Soils in their marshy phase.

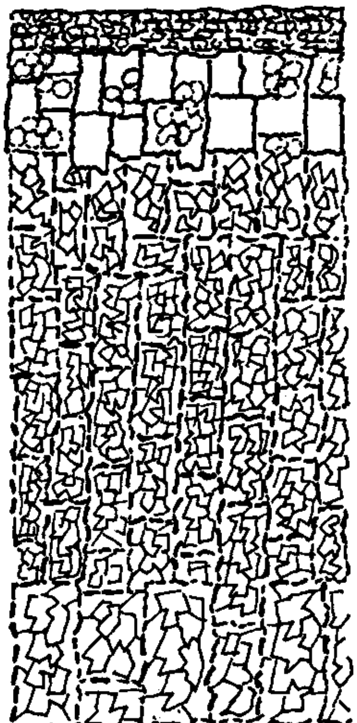
Calcium carbonate equivalent is between 40 and 70%, which is more than in Steppe Marl Soils, but a calcic horizon is lacking. The relatively high percentages of carbonate in the surface soil can be ascribed to a more calcareous parent material and limited leaching.

The increased and more distinct yellow iron oxide mottling (as compared with the Steppe Marl Soils) may be explained by a longer and more recent period of fluctuating watertable in the depressions.

A common and striking feature in all Marsh Marl Soils is the tongued horizon boundary between the dark surface soil and the whitish subsoil. Profile C 2.1 shows an extremely large dark tongue protruding deeply into the subsoil. Usually these tongues are smaller, darker and more irregular. The intrusions form vertical planes or sheets (Fig. 16) and the planes form no regular hexagonal pattern (as viewed from above).

Similar features are observed in depressions where backswamp clay covers white clay (de Meester, 1970; map unit AbC). According to Maarleveld (pers. comm., 1970) the most probable explanation is that they are droughtcracks formed in summer during the initial marsh phase. The cracks filled up with organic mud. Such a mobilization of organic carbon must have resulted from alkali conditions, as described and explained by Driessen (1970). The grayish transitional zone between surface and subsoil of Marsh Marls, as shown in Profile G 1.3, is also the result of former alkalininity.

STRUCTURAL DIAGRAM
C 2.1



Hori-zon	Depth (cm)	Structure (Jongerius)	Colour (Munsell)	Field texture	Consistency wet/dry	Remarks	$CaCO_3$ eq.(%)	pH H_2O	pH $CaCl_2$	Org.C (%)	ECe mmho/cm	CEC meq/100 g
A1	0-5	C21V½ / A3b2II2½	5Y 4/1	silty clay	sl.sticky non plastic, soft	many old roots	47.9	7.45	7.10	1.5	0.88	14.1
B1	5-20	B4bIII2½+ A4a3V1½	5Y 4/1	silty clay	sticky & non plastic, slightly hard	many old roots from marsh plants	55.2	7.95	7.50	0.8		14.8
B11	20-50	B3a3III1½C / A5a3V2½C	5Y 4½/1	silty clay	slightly sticky & plastic, slightly hard	many old roots, few fine rustmottles (5YR 5/8)	61.2	8.35	7.75	0.4	2.20	12.4
B21	50-80	B3a3III1½C / A5a3V2½C	5Y 6½/2	clay	sticky & plastic, hard	many medium rustmottles (5YR 5/8), many shells	58.2	8.70	7.95	0.1	5.40	11.9
B22	80->100	B3a3IV1½C / A5a3III2½C	5Y 6½/2	clay	sticky & plastic, hard	many medium rustmottles, many shells					5.10	

Fig. 13. Field description and analytical data of Profile C 2.1.
Şekil 13. Profil C 2.1, Bataklık Marn'a (LmC) ait profil izahı ve analiz kayıtları.

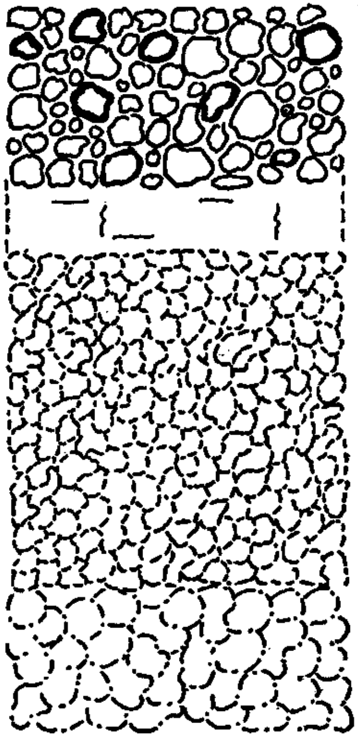
Great Konya Basin, Hotamış Area
Described by T. de Meester (August 1966); see Chapter 7.

Diagnostic horizons:	Ochric epipedon	approximate depth	0- 5 cm
	Cambic horizon		5-> 110 cm
Classification (1967):	Carbonatic Typic Haplaquept		

Mechanical analysis (with $CaCO_3$).

depth (cm)	sand (%)	silt (%)	clay (%)
0- 8	15.7	49.4	34.9
8- 20	7.2	47.3	45.5
20- 55	6.6	52.2	41.2
55-120	3.1	49.5	47.4

STRUCTURAL DIAGRAM
G 1.3



Hori-zon	Depth (cm)	Structure (Jongerius)	Colour (Munsell)	Field texture	Consistency wet/dry	Remarks	$CaCO_3$ eq. (%)	pH H_2O	pH $CaCl_2$	Org. C (%)	ECe mmho/cm	ESP esti-mated	CEC meq/100g
Ap1	0-25	A4b2(III+IX+V+VI)3	2½Y 3/2	clay	sticky & plastic, soft	many small marsh shells loose ploughed layer	62.1	7.80	7.60	2.3	1.90	5.5	10.4
Ap2	25-35	no peds	2½Y 3/2	clay	sticky & plastic, hard	dense plough bottom	64.6	8.00	7.55	2.0	1.70	2.5	10.1
A11	35-80	A4a3VI½	2½Y 4/2	clay	sticky & plastic slightly, hard	many large biopores, small shells	65.0	8.15	7.60	0.8	0.58	>1.0	11.1
A12	80->110	A4a3VI½	2½Y 5/2	clay	sticky & plastic, hard	many large biopores and large shells, below are cracks filled with dark material, many clear iron mottles (2.5Y 5/6)	71.1	8.50	7.70	0.6	0.58; 0.68	>1.0; 4.0	10.9

Fig. 14. Field description and analytical data of Profile G 1.3.
Şekil 14. Profil G 1.3, Bataklık Marn'a (LmC) ait profil izahı ve analiz kayıtları.

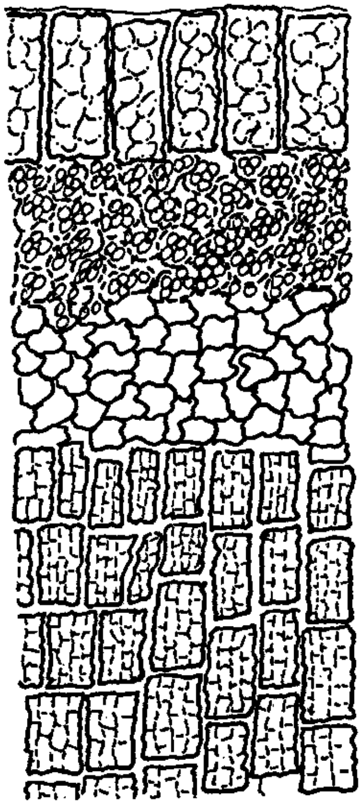
Great Konya Basin, Yarma Area
Described by T. de Meester and N. P. Christen (18-8-1967); see Chapter 7.

Diagnostic horizons: Ochric epipedon approximate depth 0- 25 cm
Cambic horizon 25-> 100 cm
Classification (1967): Carbonatic Mollic Xerochrept

Mechanical analysis (with $CaCO_3$).

depth (cm)	sand (%)	silt (%)	clay (%)
0- 25	10.1	42.1	47.8
25- 35	12.1	42.2	45.7
35- 80	5.5	49.3	45.2
80-120	10.5	45.8	43.7
120-150	1.2	46.0	52.8

STRUCTURAL DIAGRAM
G 3.1A



Depth scale (cm)	Horizon	Depth (cm)	Structure (Jongerius)	Colour (Munsell)	Field texture	Consistency wet/dry	Remarks	$CaCO_3$ eq. (%)	pH H_2O	pH $CaCl_2$	Org. C (%)	ECe mmho/cm	ESP estimated	CEC meq/100g
0–20	Ap1	0-20	B3a1V3 / A4b1VI½	2½Y 3/2	clay	sticky & plastic, soft		54.2	7.65	7.50	2.3	5.6†	<1.0	16.7 / 18.5
20–40	A11	20-40	A4a3VI1½ / A3b4III2½	2½Y 3/2	clay	sticky & plastic, soft	Lymnea shells	52.1	7.70	7.60	2.2	11.0	<1.0	12.2
40–60	A12cs	40-60	A4a3VI2	5Y 4/1	clay	sticky & plastic, soft	Lymnea shells, common gypsum veins	55.1	7.95	7.35	1.7	13.6	<1.0	
60–110	B21ca	60-108	B3a3III3ς / B5a3I1½ς	2½Y 6/2	clay	sticky & plastic, hard		71.4	8.20	8.00	0.7	13.6	<1.0	11.2
110–	B22g	108->160	B3a3II2½ς / B5a3IV1½ς			sticky & plastic, hard	many coarse rust mottles (10YR 8/8), black filled cracks							

Fig. 15. Field description and analytical data of Profile G 3.1A.
Şekil 15. Arada bir sulanan Profil G 3.1A, Bataklık Marn'a (LmC) ait profil izahı ve analiz kayıtları.

Great Konya Basin, Yarma Area
Described by T. de Meester and N. P. Christen (18-8-1967); see Chapter 7.

Diagnostic horizons: Mollic epipedon approximate depth 0- 40 cm
Cambic horizon 60-> 110 cm
Classification (1967): Carbonatic Typic Haplaquoll

Mechanical analysis (with $CaCO_3$).

depth (cm)	sand (%)	silt (%)	clay (%)
0- 20	1.2	53.4	45.4
20- 40	1.0	49.9	49.9
40- 60	3.1	44.2	52.7
60-108	3.0	48.1	48.9
108-160	1.0	45.8	53.2

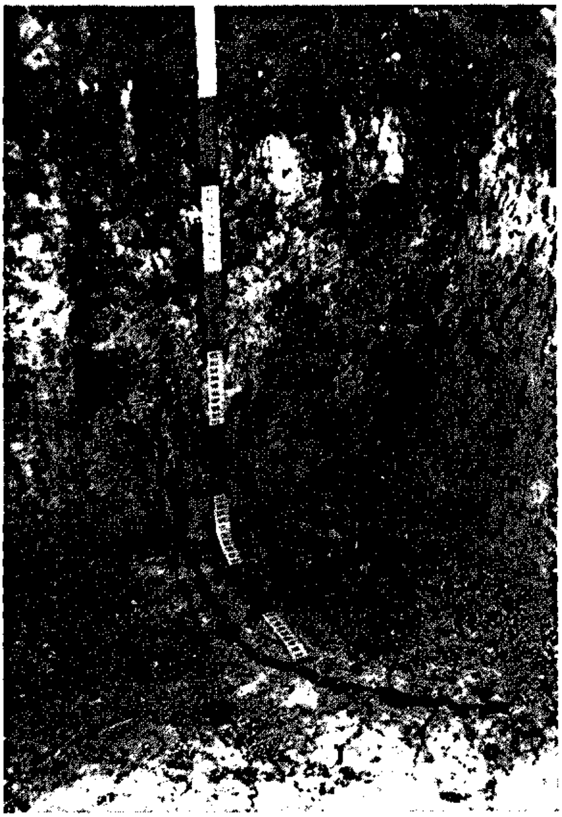


Fig. 16. Fossil crack filled with black clay in the subsoil of a Marsh Marl Soil (Profile G 3.1A)

Şekil 16. Bataklık Marn (LmC) toprağının alt katında siyah kil ile dolu fosil don çatlağı (frost crack). (Profil G 3.1A).

Deviant profiles Major deviations from the discussed characteristic Marsh Marl Soils include transitions to Steppe Marl Soils and to Former Backswamp Soils. They occur on both plains.

The deviants towards Steppe Marl Soils possess all properties of Marsh Marl Soils except that they are gray-brown. Marsh shells such as *Lymnaea stagnalis* are frequently found, so are the remnants of reed roots. In the surface soil, darker-gray and lighter-brown layers often alternate, due to drier periods with a steppe vegetation.

The deviants towards Backswamp Soils also occur in some small isolated old channels south of Sazlıpınar (Profile C 2.3, Figs. 17 and 18). There the percentages of organic carbon and smectite clay are higher, so that dark-gray or black very coarse and strong prismatic peds occur. We called them Basin Marl Soils.

3.2.4 Pattern of distribution in sample areas

Field observations and an experiment with undisturbed soil cores (Chapt. 10, Fig. 66) have shown that in all Marl Soils root development is limited to the A horizon because the white marl subsoil is unfavourable. Thus Steppe Marl Soils and Marsh Marl Soils have both been subdivided according to the depth of the A horizon. the

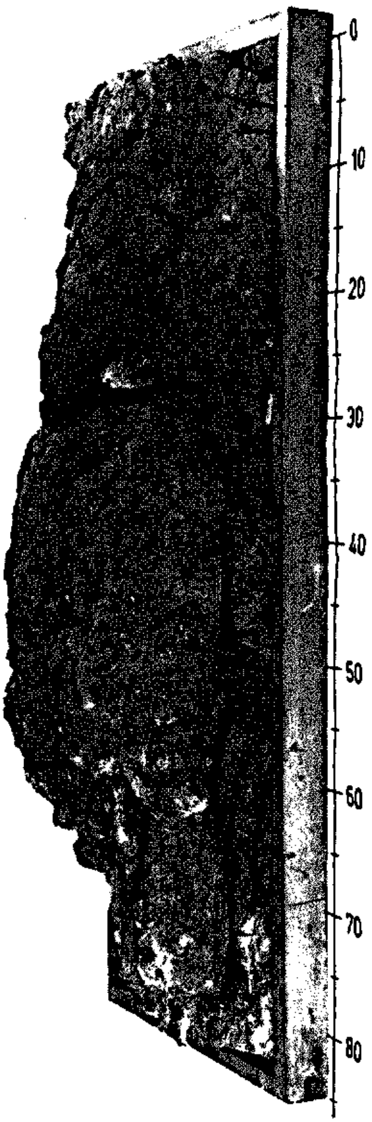


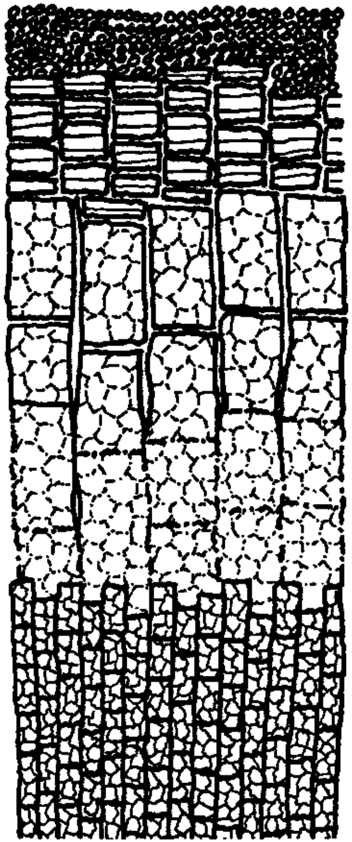
Fig. 17. Oblique view of a soil peel from a Basin Marsh Marl Soil (Profile C 2.3).

Şekil 17. Bir havza Marn Toprağı'ndan alınan monolite eğik bakış.

limit for the first being fixed at about 40 cm, for the latter at about 60 cm. As yellow iron mottles start where the A horizon ends, this characteristic has been used as an additional criterion.

According to the Soil Maps of Sample Areas (de Meester, 1970, App. 2) the depth of the A horizon in the Yarma Sample Area shows a regular alternation of these subdivisions for both soil types. In the Steppe Marls this is, probably, mainly caused by removal or accretion of surface material as observed in the field and even on the aerial photograph. In the Marsh Marls, the variation in soil depth is due to slight differences in hydrological conditions.

STRUCTURAL DIAGRAM
C 2.3



Depth scale (cm)	Hori-zon	Depth (cm)	Stucture (Jongerius)	Colour (Munsell)	Field texture	Consistency wet/dry	Remarks	$CaCO_3$ eq.(%)	pH H_2O	pH $CaCl_2$	Org. C (%)	ECe mmho/cm	ESP (meas-ured)	CEC meq/100g
0–10	Ap1	0–10	A3a+b2III3	5Y 3/1	silty clay	sticky & plastic, loose	loose clods	47.9	7.25	6.90	2.9	1.36		24.4
10–20	Ap2	10–25	B4a3IV3ζ / C4a3V2½ζ	5Y 4/1	silty clay	sticky & plastic, very hard		43.4	7.25	7.05	2.5	0.98	0.8	23.4
30–50	A1.1	25–55	B3a3V3ζ / A4b3VI1½ζ	5Y 3/1	clay	sticky & plastic, hard		44.7	7.40	7.30	1.6	0.84 1.12 1.90	1.1	22.5
60–70	A1.2ca	55–80	B3a3V½ζ / A4b3VI½ζ	5Y2/1 (black)	clay	sticky & plastic, hard	many small calcareous concretions boundary tongued	47.7	7.75	7.55	1.1	1.60 1.90		22.8
80–110	B1ca	80– >110	B3a3III2½ζ / A5a3IV2½ζ	5Y6/2	clay	sticky & plastic, slightly hard	common small soft calcareous spots, common fine rust mottles (10YR7/6), abundant shell fragments	60.5	8.00	7.80	0.4	1.16 0.92		18.1

Fig. 18. Field description and analytical data of Profile C 2.3.
Şekil 18. Profil C 2.3, Bataklık Marn'a (LmC) ait profil izahı ve analiz kayıtları.

Great Konya Basin, Hotamış Area
Described by T. de Meester and A. L. J. van den Eelaart (August 1966); see Chapter 7.

Diagnostic horizons:	Mollic epipedon	approximate depth	0- 80 cm
	Cambic horizon		80-> 110 cm

Classification (1967): Carbonatic Cumulic Haplaquoll

Mechanical analysis (with $CaCO_3$).

depth (cm)	sand (%)	silt (%)	clay (%)
0- 10	1.5	46.5	50.2
10- 25	5.5	42.8	49.3
25- 55	5.0	40.1	54.4
55- 80	7.5	37.8	53.4
80-120	4.8	49.6	45.1

The soil pattern of the Hotamış Sample Area is more regular. There the A horizon of the Steppe Marl is almost uniform in depth and that of the Marsh Marl increases in depth towards the centre of the depressions. In the eastern part of the Hotamış Plain, Steppe Marl Soils occur with very shallow or hardly any A1 horizon because of wind erosion.

Small areas of moderately salt-affected Steppe Marls with shallow surface soils occur in the Karapınar and Ak Göl Plains. The Karaman Plain is entirely occupied by Steppe Marls. They have been only superficially studied (de Meester, 1970).

3.2.5 Land use and reclamation

At present about 51 and 15% of the Steppe Marl Soils and 58 and 17% of the Marsh Marl Soils of the Yarma and Hotamış Plains are, respectively, dry cultivated and irrigated.

In the Yarma Plain, Marsh Marls are irrigated with surface water once or twice in spring and usually remain dry for the rest of the year. In wet years, however, they may be inundated all summer, as in 1968, 1969 and 1970. On both soils small plots are irrigated with groundwater pumps, mainly around Tömek and Ortakonak in the Yarma Plain, and around Sazlıpınar and Hotamış in the Hotamış Plain.

No fertilizers are used either in dry or irrigated farming, but attempts have been made to introduce them. A fallow every other year is regular practice under both systems. The land is generally ploughed in spring to minimize evaporation (Janssen, 1970c). Wheat is by far the most important crop, both on dry and irrigated fields, but sugarbeet and lucerne are increasingly cultivated on irrigated Marl Soils.

Irrigated farming on Marsh Marl Soils started in the Yarma Plain after the Çumra Irrigation Project was established in 1915. Çarşamba irrigation water enters the Yarma Plain by three main channels, one near Yarma and two near Sakyatan and is carried northward as far as Divanlar. Irrigation control has always been poor in this area and natural drainage is slow.

As far as information is available from local agricultural sources (mainly Teknik Ziraat, Konya Office), in the past both marl plains were (with the exception of the above irrigation area) never cultivated, apart from some small allotments around village wells. The land was covered by a degraded steppe vegetation or by reeds or halophytes (Walter, 1956; H. A. de Wit, internal report, 1970) and used almost entirely for sheep and cattle ranging. Cultivation of cereals and other crops was confined to the irrigated or moist less salt-affected alluvial fans and piedmont zones of the Basin.

Reclamation of the marl plains started in 1945 with the introduction of mechanized farm equipment like tractors and disk ploughs, encouraged by government policy and foreign aid. On the topographic map and on aerial photographs, the newly occupied areas can be distinguished from the old arable lands by their shape; the first are large and rectangular, the old plots are small and irregular.

Encouraged by the fair yields on virgin Steppe Marls and because profits from cattle ranging decrease as nomads disappear, more *mera* (uncultivated steppe) has been (and still is) turned into *tarla* (cultivated fields) than is economically justified. There is also danger of increasing duststorms and decreasing yields as result of detioration of soil structure. So belts should be preserved with the original steppe vegetation.

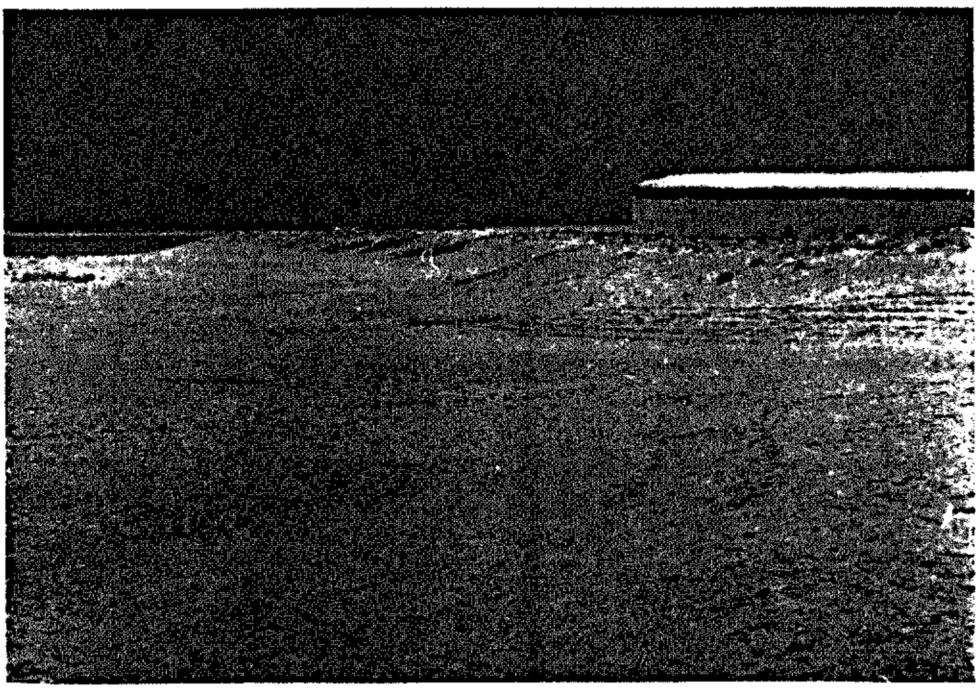
3.3 Marl soils of the Karapınar and Ak Göl plains

3.3.1 Regional aspects

The Karapınar and Ak Göl Plains form the saline counterparts of the western plains discussed in Section 3.2. The accumulation of salts is due to a high watertable all the year round, and prolonged flooding in winter and spring. Apart from some scattered halophytes no vegetation is present. The plains have a flat and level surface; each has a slight depression in its centre: in the Karapınar Plain it is some 10 to 15 m below average plain level (1000 m), in the Ak Göl Plain some 5 to 10 m. The plains are now separated by an area of lacustrine and volcanic sand and by sandridges (ancient bars and barriers).

The Karapınar Plain receives its surface water mainly as run-off from the Uplands

Fig. 19. Salt-affected Secondary Depression (playa) with low cliff, near Ak Göl.



Şekil 19. Akgöl yakınlarında, alçak klif'e sahip tuz etkisinde kalmış ikincil çukur saha(playa).

and from some springs along the eastern border and near Karapınar which means black spring. In the absence of drainage it disappears only by evaporation (Driessen & van der Linden, 1970).

The Ak Göl Plain receives its water mainly as run-off from the eastern part of the Basin including the Zanopa River of Ereğlı. The Ayrancı River contributes little because most of its water is used for irrigation. An important means of drainage is the presumed karstic substratum of Ak Göl and Düden Göl, which is a doline. Long drainage canals from the Hortu Marshes in the east and the Karapınar Marshes in the south-west tail out into them. The lowest area of the Ak Göl Plain is not connected with the karstic lakes and groundwater therefore remains high there.

Due to the past and present floods, recent (secondary) shorelines have formed at many sites, mainly as low escarpments or cliffs (Fig. 19) but also as sandy beaches as in the Ak-Göl depression. Striking features are a few isolated oval or circular depressions which at first sight seem to be formed as blow-outs (Groneman, 1968).

In both plains wind may have helped to deepen the larger depressions, but the clear-cut cliffs in the small and large depressions are due to wave action. When dry, the floors of the depressions are covered with a salt crust, which classifies them geomorphologically as 'playas' (Thornbury, 1965). Since the Karapınar Plain and the Ak Göl Plain are mainly occupied by Playa Marl Soils, they will be discussed here. The Steppe Marl Soils which occur only in small areas have been described in Section 3.2.2.

3.3.2 Playa Marl Soils

Characteristic profiles Characteristic for the Playa Marl Soils, as defined in Section 3.1, are the Profiles E 1.1 and P 115 (Fig. 20; Table 4A + B). Both have a thin platy surface soil and an extremely angular-blocky or strong and coarse prismatic layer generally extending into the subsoil if not disturbed by layers of shells or sand.

Profile E 1.1 is from a low spot in the playa and its platy surface layer is due to former periodic sedimentation of carbonatic clay. Its salt content is relatively low, because of strong leaching. However, profile P 115 represents a strongly affected saline-alkali soil with a high concentration of soluble salts in the surface layer.

Driessen (1970) has studied the salinity and alkalinity of Playa Soils in the Konya Basin. The characteristic strong coarse and smooth prisms (Fig. 52) can be ascribed to the saline-alkali conditions, to the absence of organic carbon and to the annual fluctuations of the watertable. Although at present vegetation is almost absent, the common occurrence of rootprints on the ped surfaces indicates its former occurrence.

Deviant profiles In the western part of the Ak Göl Plain the surface of the playa is covered with 20 to 40 cm sand; it is hummocky and carries a tufted vegetation. Under the alkali conditions the composed organic material has become mobile and has covered the prismatic peds of the subsurface soil with distinct coatings 0.1 to 0.5 mm thick.

Table 4A. Field description of Profile P 115: LmE, Playa Marl, Great Konya Basin, Karapınar Area (by A. F. Groneman, June 1965).

Horizon	Depth in cm	Structure (Soil Survey Manual)	Colour (Munsell)	Field texture	Consistency wet	Consistency dry	Remarks
A1	0- 3	very strong medium angular-blocky	5Y 6/2	clay	very plastic, very sticky	extremely hard	salt and soil crust
A2	3-20	strong very fine angular-blocky	10YR 6/2	clay	very plastic, very sticky	very hard	many macropores and mesopores
C1	20-70	strong very fine angular-blocky	5YR 6/1	clay	very plastic, very sticky	very firm (moist)	many macropores and mesopores
C2	70-80	strong very fine angular-blocky	10YR 6.5/2	clay	very plastic, very sticky	very firm (moist)	many macropores and mesopores; water table at 78 cm

Tablo 4. A. Profil P 115'e ait izahlar: LmE, Playa Marn, Büyük Konya Havzası, Karapınar bölgesi (Haziran 1965'de A. F. Groneman).

Table 4B. Analytical data from Profile P 115.

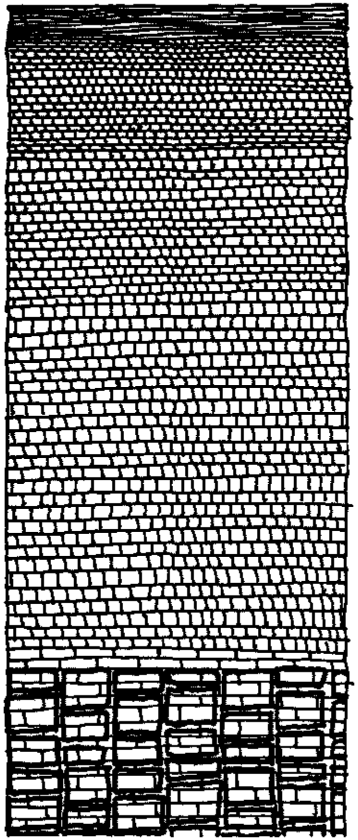
Depth in cm	EC_e in mmho/cm	SAR	ESP % (calculated)	pH of saturated extract
0-10	70	215	> 40	8.48
10-20	53	143	> 40	8.50
20-30	54	132	> 40	8.50
30-40	52	123	> 40	8.49
40-50	53	122	> 40	8.56
50-60	51	111	> 40	8.38
60-70	52	105	> 40	8.30

Tablo 4. B. Profil P 115'e ait analitik kayıtlar.

Near the saline-alkali Playa Marls with strong prismatic structures, equally salt-affected marls occur entirely composed of friable, loosely packed carbonatic clay granules. These soils are related to the Playa Marls; Profile E 1.3 (Fig. 21) is a well developed example. We called them Granular Playa Marl Soils.

Except for the upper 20 cm, which is subangular-blocky, the entire profile down to at least 170 cm has a granular structure. After drying out, the soils may show very coarse weak secondary prisms. The granules are spheric and vary in size between 0.05 and 3 mm. Detailed studies have revealed that such soils only locally occur but

STRUCTURAL DIAGRAM
E 1.1



Hori-zon	Depth (cm)	Structure (Jongerius)	Colour (Munsell)	Field texture	Consistency wet/dry	Remarks	$CaCO_3$ eq. (%)	pH H_2O	Org. C (%)	ECe mmho/cm	ESP (measured)	CEC meq/100g
A1	0-5	E1b33	5Y 6/2	silt	sticky & plastic hard		66.3	9.80	0.0	53.3		
B	5-18	C23III3ζ / C1b3III3ζ	5Y 6/2	silt	slightly sticky & slightly plastic, slightly hard		58.8			20.0	59.0	16.4
IIB11	18-42	C23III3ζ / A5a3IV3ζ	5Y 6/2	silty-clay	slightly sticky & slightly plastic slightly hard	rootprints on peds	53.2	9.25	0.0	16.4 14.0	27.5	
IIB1.2	42-90	C23IV1a2 / A5a3V3a2	5Y 6/2	clay	sticky & plastic, friable (moist)	rootprints and humus illuviation cutans on peds	56.5	8.90 8.52 8.80		15.4 22.2 31.4 19.8 10.0		
IIB2	90->160	B4c4IV3a2 / C4a4V3a2	5Y 6/2	clay	sticky & plastic, very friable (moist)	rootprints and humus illuviation cutans on peds	63.7	8.00	0.0	7.20 9.80	34 35	17.8

Fig. 20. Field description and analytical data of Profile E 1.1.
Şekil 20. Profil E 1.1, Playa Marn'a (LmE) ait profil izahı ve analiz kayıtları.

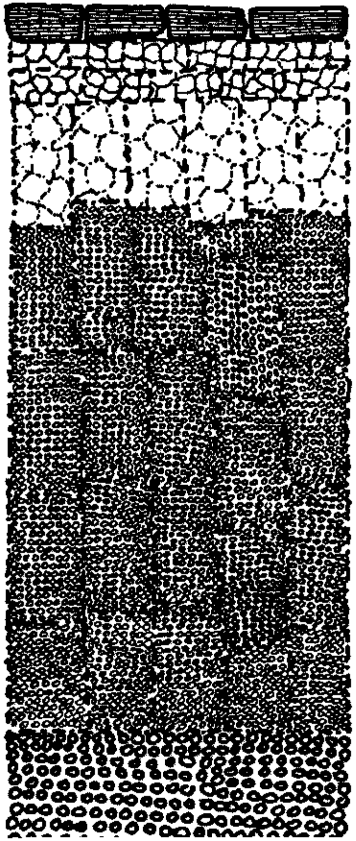
Great Konya Basin, Ak Göl Area.
Described by T. de Meester and A. L. J van den Eelaart (26-7-1966); see Chapter 8.

Diagnostic horizons:	Ochric epipedon	approximate depth	0- 5 cm
	Cambic horizon		5-> 110 cm
Classification (1967):	Carbonatic Typic Halaquept		

Mechanical analysis

before removal of $CaCO_3$				after removal of $CaCO_3$			
depth (cm)	sand (%)	silt (%)	clay (%)	depth (cm)	sand (%)	silt (%)	clay (%)
0- 5	6.2	64.0	29.8	0- 5	5.0	43.4	51.6
5- 18	9.1	40.8	30.1	5- 18	2.4	48.0	49.6
18- 42	6.3	65.6	28.1	18- 42	6.9	40.3	52.8
42- 90	1.3	62.1	36.6	42- 90	0.8	38.9	60.3
90-160	3.2	58.7	38.1	90-160	9.5	32.0	58.5

STRUCTURAL DIAGRAM
E 1.3



Hori-zon	Depth (cm)	Structure (Jongerius)	Colour (Munsell)	Field texture	Consistency wet/dry	Remarks	$CaCO_3$ eq. (%)	pH H_2O	pH $CaCl_2$	Org. C (%)	CEC meq/100g
A11	0-5	C21V3/C4a2I3	2,5Y 5/4	silt	as A12	abundant small roots	62.4	7.45	7.20	1.4	11.8
A12	5-15	C21V1½ / A4b1III2½	2,5Y 5/4	silty clay	sl.sticky & sl.plastic, sl.hard	common roots	60.8	7.85	7.55	0.5	12.1
AC	15-30	B3a1V½ / A4b1VIII½	2,5Y 5/4	silty clay	sticky & plastic, friable (moist)	few krotovinas	61.0	8.50	8.25	0.4	9.8
C1sa	30-100	B21VI½ / A3b2I3	2,5Y 6/4	silty clay	sticky & plastic, very friable (moist)	pseudo coarse sand	61.1	8.75	8.45	0.0	13.1
C2sa	100->110	A3a4II3	2,5Y 6/4	silty clay	sticky & plastic, very friable (moist)	pseudo coarse sand	60.6	9.60	8.80	0.0	14.4

ECe mmho/cm	ESP estimated
2.10	17
13.0	
13.0	39
24.2	
27.0	55
32.6	80
37.4	
31.6	77
36.2	
39.8	78
33.6	

cm: 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110

Granular Playa Marl Soil (LmE, hatched)

Fig. 21. Field description and analytical data of Profile E 1.3.
Şekil 21. Profil E 1.3, Step Marn'a (LmE) ait profil izahı ve analiz kayıtları.

Great Konya Basin, Ak Göl Area
Described by T. de Meester and A. L. J. van den Eelaart (26-7-1966); see Chapter 8.

Diagnostic horizons: Ochric epipedon approximate depth 0-15 cm
Salic horizon 60-110 cm
Classification (1967): Carbonatic Typic Salorthid

Mechanical analysis (with $CaCO_3$).

depth (cm)	sand (%)	silt (%)	clay (%)
0- 5	29.6	51.9	16.2
5- 15	33.8	47.9	17.8
15- 30	17.2	40.6	41.1
30-100	13.5	50.7	35.9
100-130	10.1	53.2	39.3

then always within a few metres of strong prismatic ones. The map (App. 3) shows that the areas with granular marl are situated in belts directly bordering the north-eastern fringe of the main playa in the Ak Göl Plain. The microrelief of these areas is undulating because of small dunes.

3.3.3 Pattern of distribution in sample areas

There was no need to study sample areas, as the Ak Göl Playa Marls had already been mapped in more detail than usual during reconnaissance (de Meester, 1970, soil map). They are extremely complex. The peculiar pattern of isolated circular or oval depressions and their possible genesis has been discussed, whilst the genesis and local detioration of Granular Playa Marl Soils will be dealt with in Chapter 8.

3.3.4 Land use and reclamation

The playa marls have no agricultural value. The plains of Karapınar and Ak Göl are barren, except for parts under poor grazing and for the vicinity of Ak Göl, which is marshy.

3.4 Other highly calcareous soils

In the Great Konya Basin, soils occur which are more calcareous than the Marl Soils but have not developed in lacustrine carbonatic clay. Their genesis is different, though they have all formed under lacustrine conditions.

They occur in the Lacustrine Plain and will receive only passing mention.

3.4.1 Sandplain Soils and Dunes

In Chapter 2, the formation of sandplains was explained by wave action and by an abundant supply of sand in the Ancient Konya Lake. The dunes were formed when this lake had dried up.

A large area with sandplains and dunes occurs south of Karapınar. Its soils and shifting sands have been studied mainly by Groneman (1968) and de Meester (1970). Profile 65-3 (Fig. 22) is a characteristic example of a recent dune. It shows that the sand is mainly fine and that it contains about 78% calcium carbonate equivalent. Fragments of shells and limestone are an important component.

The stratification of the profile is typical for an aeolian deposit.

Where the sands have been stabilized by vegetation cover and the relief is flat or slightly undulating, a thin A1 horizon and a weakly developed calcic horizon at about 50 cm is normal. Due to varying admixtures of dark volcanic sandgrains from nearby volcanoes, the colour of the sand varies from place to place.

The land is grazed, but overgrazing must be avoided to prevent blow-outs and the formation of shifting dunes.

3.4.2 Calcareous Tufa Soils

Calcareous tufa (defined in Chapter 1) occurs in the Aslım Marshes, north-east of Konya. Seepage of water rich in bicarbonate from the nearby Limestone Uplands is abundant there (de Meester, 1970), locally rising as springs. Carbonates of calcium and magnesium are precipitated around the roots of the marsh vegetation (mainly *Juncus maritimus*) and as mixed grains resembling oolites. The calcium carbonate equivalent of the soils is about 90%. Figure 23 (Profile 64-9) is a characteristic example.

The absence of soluble salts in the soil, except in the surface layer, is remarkable; it is caused by non-saline groundwater. Silt-loaded surface run-off, entering the marshes through numerous creeks, has enriched the tufa with non-calcareous clay. The Calcareous Tufa Soils of Aslım are extremely poorly drained and the watertable is usually near the surface.

Though experiments have shown that with permanent drainage field crops on these soils are feasible, reclamation is very expensive. But the land can also be considerably improved by a limited drainage and flood prevention so that it becomes suitable for better grazing. Further investigations on this subject are being carried out by the Turkish Ministry of Agriculture, and recently large drainage canals have been dug for the purpose (Çuhadaroğlu, 1966; Ziba, 1967).

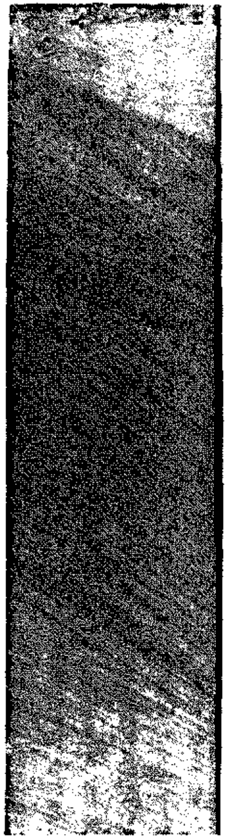
3.4.3 Chalk Soils

Between Abditolu and Kaşınhanı and around Ürünlü are areas with deep soils of almost pure soft calcium and magnesium carbonate. They have been called Soft Lime Soils (de Meester, 1970) but the name Chalk Soils is now preferred (for definition, see Chapter 1). They occupy parts of the lowest structural Neogene terraces which have been flooded by the Ancient Konya Lake. Their surface has been flattened by abrasion and locally they are covered with a soft limestone sediment, formed by precipitation in bicarbonate-rich seepage water from the karstic Limestone Uplands. Where the watertable is at about 1.20 m, the Chalk Soils are, apart from some stratification, deep and uniform (Ürünlü Series, Driessen & de Meester, 1969). In sites where the watertable is nearer the surface the carbonates have been redistributed and form hard concretions or pans in the upper 100 cm (Kaşınhanı Series). The solum is shallow The brownish A1 horizon is not residual but contains loam and gravel washed in from the adjoining piedmont zone. The chalk subsoil contains about 80% calcium carbonate equivalent. Only the surface soil is salt-affected. Limestone is below 150 cm.

North of Kaşınhanı, an area of Chalk Soils with impeded drainage occurs, with a vegetation consisting mainly of *Juncus maritimus*. Here soils have developed with a very dark-gray A1 horizon, classified as a Typic Haplaquoll (Fig. 24, Profile 64-15).

The Chalk Soils are mainly used for cattle ranging. Where the A1 horizon is deep enough cereals can be cultivated, but yields are low. Near Kaşınhanı several fields are irrigated from wells and cultivated with sugarbeet. Fertilizers are used, but success has been limited.

PROFILE PHOTO
65-3.



Hori-zon	Depth (cm)	Structure (Jongerius)	Colour (Munsell)	Field texture	Consistency wet/dry	Remarks	$CaCO_3$ eq.(%)	pH H_2O	ECe mmho/cm	CEC meq/100g
C1	0-2	J2	10YR 6/2	coarse sand		abundant shell fragments	76,5	7,8	0,45	2
C2	2-70	J2	10YR 6/2	fine sand	non sticky & non plastic, loose	highly calcareous, many shell fragments	77,7	7,6	0,50	3
C3	70->110	J2	10YR 6/2	fine sand	Non sticky & non plastic, loose	highly calcareous, many shell fragments	78,3	7,8	0,51	3

Depth scale (cm): 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110

Fig. 22. Field description and analytical data of Profile 65-3.
Şekil 22. Profil 65-3, Kalkerli Kumullar'a (Dd) ait profil izahı ve analiz kayıtları.

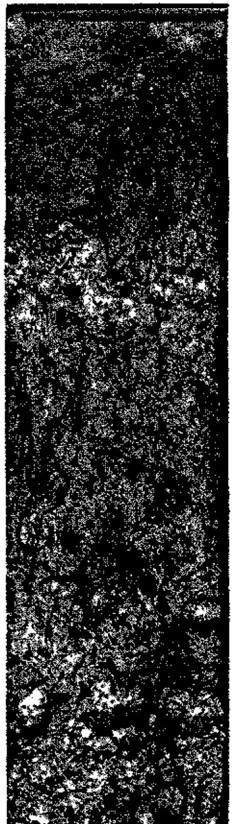
Great Konya Basin, Karapınar Area
Described by A. F. Groneman (15-5-1965).

Classification: material of shifting sand dunes is not considered soil and cannot be classified by the USDA System.

Mechanical analysis.

before removal of $CaCO_3$				after removal of $CaCO_3$			
depth (cm)	sand (%)	silt (%)	clay (%)	depth (cm)	sand (%)	silt (%)	clay (%)
0- 50	89.8	5.5	4.7	0- 50	83.8	8.5	5.7
50- 70	89.5	3.7	6.8	50- 70	65.9	9.7	24.4
70-110	91.2	3.6	5.2	70-100	70.2	9.6	20.2

PROFILE PHOTO
64-9



Hori-zon	Depth (cm)	Structure (Jongerius)	Colour (Munsell)	Field texture	Consistency wet/dry	Remarks
A11	0-19	A4a2V½	10YR 4/1½	loam	non sticky & non plastic, soft	abundant roots calcareous concretions
A12	19-29	A4a2V½	10YR 4/1½	loam	non sticky & non plastic, soft	slightly lighter coloured
C1	29-96	J2	10YR 5/2	pseudo sand	non sticky non plastic, slightly hard	soft calcareous tufa with common roots, hard, calcareous concretions
C2	96->110	G see remarks	10YR 6/3½	see remarks	non sticky & non plastic slightly hard	porous calcareous tufa with pieces of hard caliche

$CaCO_3$ eq. (%)	pH H_2O	ECe mmho/cm	ESP esti-mated
82	8.01	3.51	3.2
87	8.43	2.42	
88	8.31	1.84	1.2
90	8.15	2.51	
93	7.81	2.10	1.1
93	8.10	1.93	0.8
89	8.00	2.14	

Fig. 23. Field description and analytical data of Profile 64-9.
Şekil 23. Profil 64-9, Kalkerli Tufa Toprağı'na (Mf) ait profil izahı ve analiz kayıtları.

Great Konya Basin, Yarma Area
Described by T. de Meester and P. van Blom (21-8-1964).

Diagnostic horizon: Ochric epipedon approximate depth 0-30 cm
Classification (1967): Carbonatic Typic Haplaquent

Mechanical analysis (with $CaCO_3$).

depth (cm)	sand (%)	silt (%)	clay (%)
50-60	72.2	20.3	6.5

PROFILE PHOTO
64-15

Depth scale (cm)	Hori-zon	Depth (cm)	Structure (Jongerius)	Colour (Munsell)	Field texture	Consistency wet/dry	Remarks	CaCO$_3$ eq.(%)	pH H$_2$O	Org. C (%)	ECe mmho/cm	CEC meq/100g
0–20	A11	0-19	A3a+A4a2V1½	10YR 2½/3	loam	sticky & plastic, slightly hard	abundant roots	24.1	8.59	3.2	3.11	32.0
20–40	A12	19-37	B5a2□V3	10YR 4½/2	loam	sticky & plastic, hard	many roots	32.3	9.00	1.6	8.54	25.4
40–50	ACca	37-51	B5a2□V3	10YR 5/2	see remarks	sticky & plastic, slightly hard	chalk with krotovinas	63.1	8.63	3.7	0.95	18.9
50–110	Cca	51-110	H2	2½Y 8/1	see remarks	very sticky & plastic, very hard	chalk with few hard calcareous concretions, few roots					
60–70								76.2	8.38	0.0	0.53	
80–90								71.4	8.25	0.0	0.58	17.8
100–110								65.2	8.28	0.0	0.45	

Fig. 24. Field description and analytical data of Profile 64-15.
Şekil 24. Profil 64-15, Tebeşir Toprağı'na (Tc) ait profil izahları ve analiz kayıtları.

Great Konya Basin, Yarma Area
Described by T. de Meester and P. van Blom (22-8-1964).

Diagnostic horizons: Mollic epipedon approximate depth 0-20 cm
Cambic horizon 20-51 cm
Classification (1967): Carbonatic Typic Haplaquoll

Mechanical analysis (with $CaCO_3$).

depth (cm)	sand (%)	silt (%)	clay (%)
20-30	17.1	34.7	48.2
70-80	7.9	24.1	68.0

4 Soil-peel description

4.1 Levels of description

Some profiles, typical of the Marl Soils described in the previous chapter, have been selected for morphological study in more detail than possible by conventional profile studies in soil pits. Micromorphological studies, as introduced by Kubiena (1938), Jongerius (1957), Brewer (1964), Slager (1966) and others, reveal features scarcely detectable by the naked eye or with a handlens. Thin sections can be examined by microscope at magnification of 50 to 800. Preparations can even be examined by electron-micrography.

Micromorphology has rendered important contributions to soil science, but it has the disadvantage of being elaborate and needing an expensive technical outfit to obtain good thin sections. A wide gap still exists between the information it supplies and the features observed in the field.

Brewer (1964) has devised a comprehensive and fairly consistent system for drawing up both the resulting very detailed morphological descriptions, which he calls 'Pedography': 'the systematic description of soils based on observations in the field, on hand-specimen and thin-sections and on data from other techniques on the size, shape, arrangement and identification of the constituents.'

The study of hand-specimen is an effort to fill the gap mentioned above and Brewer recommends the use of crated soil columns, called monoliths. Blokhuis *et al.* (1968) add that, among other advantages of this procedure, the stereomicroscopic study of peds and their fragments provides a link and allows the establishment of correlations between field types and thin sections.

Our soil studies in the Great Konya Basin have shown that soil peels, if properly prepared, are preferable to (small) hand-specimens and (heavy) soil monoliths, because they combine the advantages of both without their disadvantages: they are easy to handle and present the entire profile.

The following levels of description can be distinguished:

	Purpose	Terminology	
Field description	characterization of mapping units and profile properties	Soil Survey Manual, Jongerius (1957)	Chapter 3
Peel description	futher characterization of profile properties	Brewer (1964), with additions	Chapters 5-8
Thin section description	supplement to peel description	Brewer (1964), with additions	Chapters 5-8

4.2 Preparation and use of soil peels

Soil peels are as much as possible undisturbed vertical sections of profiles, glued on a board and framed for transport. They should be at least as long as the solum is deep, they must be wide enough to show horizontal variations in the pedon and must contain whole peds.

Those of moist sandy and clayey soils are easy to make (Jager & van der Voort, 1966). In arid regions, however, especially when the soil is highly calcareous and contains dry and hard peds, peels can best be prepared by a procedure I have developed (de Meester & Bouma, 1967).

Soil peels are useful for demonstrations and for scrutiny by microscope, under much better conditions than in the field. They can reveal many new details, and allow careful selection of samples for thin sections.

To examine a soil peel it is put on a working table under good light and scanned with a binocular or handlens at a magnification of 10 to 50. A general comparison between field studies and peel studies of some 60 sites indicates that the latter are especially useful for the study of intrapedal voids and pedological features. Such a study is best carried out as a systematic analysis, almost like that for aerial photographs. It has the following stages: (1) the profile features are recognized and identified; (2) the features are classified into uniform groups and the boundaries of these groups are deliniated on the peel surface; (3) the resulting peel map or 'pedograph' and its pattern is used to interpret how the soil formed and what it is suitable for. The uniform zones are tentatively delimited as peel units with coloured woollen threads. Within these units, smaller sections or strips across the peel are studied in detail and described by Brewer's terminology (Section 4.3.1). If necessary, the unit boundaries are revised. A legend is then made about elementary peel structure, i.e. the most characteristic or prevailing pedological features and voids and, finally, the unit boundaries are copied onto a photograph or a sheet of paper.

Generally peel units are complexes of various pedological features and voids, and they often coincide with genetic soil horizons found in the field or by other laboratory analysis. But as they may differ from or overlap between genetic horizons, there is justification for a distinct terminology of the uniform layers or zones as peel units, e.g. krotovinas may be genetically part of a C horiozn but are a separate peel unit.

The soil-peel analysis does not deal with the soil matrix, for which thin sections are necessary. Samples for a thin section should be selected from the soil peel and their exact position recorded so that later their analysis will form a valuable addition to the peel description.

Laboratory examination does not supersede field data from the pits themselves. Artificial cracks may alter the peds and interpedal voids. Horizons, colours, textures and data on consistency can be better described from fresh profile walls. So the best procedure is to make the general profile description in the field and to select a suitable profile for preservation as a peel.

Information from soil peels can, with little more effort than field survey alone, provide a much firmer basis for statements about soil formation and suitability for agriculture.

Marl Soils are more suitable for the suggested approach than other soils in the Konya Basin, because they have more pedological features to show.

4.3 Terminology in soil-peel descriptions

In the field descriptions of Chapter 3, the traditional terminology of the Soil Survey Manual (1951) and the designations proposed by Jongerius (1957) have been used. But neither is suited for the description of soil peels and thin sections, for which Brewer's terminology (1964) has been used. As it is not widely known, most terms used in descriptions will be explained or elaborated.

4.3.1 Selection from Brewer's terminology

Soil material 'is the unit of study; it is that unit in which the characteristics being studied are relatively constant, and it will vary in size with the kind and extend of development of those characteristics.' Soil materials are the elements from which 'soil' or 'soil profile' are built up; they must be studied before considering how they are integrated into the whole soil, e.g. as skeleton grains and plasma (see below).

Skeleton grains of a soil material are 'individual grains which are relatively stable and not readily translocated, concentrated or reorganized by soil-forming processes; they include mineral grains and resistant siliceous and organic bodies larger than colloidal size.'

Plasma of a soil material is 'that part which is capable of being or has been moved, reorganized and/or concentrated by processes of soil formation. It includes all the material, mineral or organic, of colloidal size and relatively soluble material, which is not bound up in skeleton grains.'

Soil fabric is 'the physical constitution of a soil material as expressed by the spatial arrangement of the solid particles and associated voids.' Fabric is also concerned with the spatial arrangement of compound particles and the voids between them.

Soil structure is a wider term than soil fabric being defined as 'the physical constitution of soil material as expressed by size, shape, and arrangement of the solid particles and voids, including both the primary particles to form compound particles and the compound particles themselves; fabric is the element of structure which deals with arrangement.' In the Soil Survey Manual soil structure is defined as 'the aggregation of primary soil particles into compound particles, or clusters of primary particles, which are separated from adjoining aggregates by surfaces of weakness.' In Chapter 3, however, field descriptions include the scheme for description of soil structure devised by Jongerius (1957) who, like Brewer, includes in it the arrangement of particles and of voids.

Pedality is 'the physical constitution of a soil material as expressed by the size, shape and arrangements of peds.' So Brewer's 'pedality' is close to Soil Survey

Manual's 'structure'. Hereafter pedality will be used exclusively, in particular because Brewer and Soil Survey Manual attach almost the same meaning to ped.

A *ped* in Brewer's sense is 'an individual natural soil aggregate consisting of a cluster of primary particles, and separated from adjoining peds by surfaces of weakness which are recognizable as natural voids or by the occurrence of cutans.' The Soil Survey Manual does not define ped but implies that peds are compound particles, or clusters of primary particles, which are separated from adjoining aggregates by surfaces of weakness. Ped is distinguished from artificial aggregates such as clods and fragments.

Jongerius calls a ped a 'structural element'.

Lines on the structural diagrams in Chapter 3 are surfaces of weakness and not necessarily natural voids. Jongerius determines the grade of structure by applying a force to the soil and estimating the elements (peds) which remain whole after a spadeful is dropped from 50 cm. If the force turns a soil mass into a collection of units of similar shape and size, the material is, according to Brewer, 'pedal', if not it is 'apedal'.

Pedological features are 'recognizable units within a soil material which are distinguishable from the enclosing material for any reason, such as origin (deposition as an entity), differences in concentration of some fraction of the plasma, or differences in arrangement of the constituents (fabric).' 'This definition is not intended to include peds, but does include features inherited from the parent rock or formed by the processes of deposition of transported parent material.' Pedological features include, for instance, cutans, pedotubules, glaebules, crystallaria, subcutanic features and fecal pellets, which will all be defined later.

Voids as such are not defined by Brewer. They are classified as packing voids, vughs, vesicles, channels, chambers and planes, which will be discussed in Section 4.4. For size classes see below:

Voids have different names for different sizes:

cryptovoids	$<$ 0.1 μm		
ultramicrovoids	$<$ 5 μm		
microvoids	5-30 μm		
mesovoids	30-75 μm		
macrovoids	$>$ 75 μm ($>$ 0.075 mm)	very fine macrovoids	0.075-1 mm
		fine macrovoids	1 -2 mm
		medium macrovoids	2 -5 mm
		coarse macrovoids	$>$ 5 mm

In the Jongerius terminology (Chapter 3) micropores, mesopores and macropores are $<$ 30, 30-100 and $>$ 100 μm, respectively.

The *s-matrix* of a soil material is 'the material within the simplest (primary) peds, or composing apedal soil materials, in which the pedological features occur, it consists of the plasma, skeleton grains, and voids that do not occur in pedological features other than plasma separations.'

Brewer considers s-matrix as the basic (i.e. initial) material of soil and primary peds as the convenient simplest units for pedographic descriptions of pedal soil material. Therefore he distinguishes plasmic, basic, elementary, primary, secondary and tertiary levels of structure, some of which are defined below.

The *Basic structure* is 'the structure of the s-matrix, that is, the size, shape, and arrangement of simple grains (plasma and skeleton grains) and voids in primary peds or apedal soil material, excluding pedological features other than plasma separations.'

The organization of the plasma of the s-matrix can be referred to as:

Plasmic structure: 'The structure of the plasma of the s-matrix, that is the size, shape, and arrangement of the plasma grains and associated simple packing voids.'

Primary structure is 'the structure within an apedal soil material or within the primary peds in a pedal soil material; it is an integration of the size, shape, and arrangement of all the pedological features, enclosed in the s-matrix and the basic structure, or structure of the s-matrix.'

Elementary structure has proved a useful term, defined 'a simplified level of primary structure; it is an integration of a characteristic size, shape, and arrangement of pedological features and the basic structure, or structure of the s-matrix.' The term Elementary structure has mainly been used in micromorphology on thin sections. I found it equally useful to express characteristic pedological features and voids in soil peels and this concept has been distinguished, where necessary, as *Elementary peel structure.* The term has still been used where pedological features are absent in order to mention the voids.

Size classes The following classes are used to mention size of features other than voids (i.e. pedological features and grains):

extremely fine	< 0.005 mm (< 5 μm)		medium	0.1- 0.5 mm
very fine	0.005-0.02 mm (5- 20 μm)		coarse	0.5- 2 mm
fine	0.02 -0.1 mm (20-100 μm)		very coarse	2 -10 mm
			extremely coarse	> 10 mm

N.B. The size classes for peds (Chapter 3) from the Soil Survey Manual are different. See Appendix 2.

4.3.2 Additions to Brewer's terminology

Brewer's terminology does not include terms for enumeration of features. Because they are needed for the interpretation of descriptions, the following may be here added.

Fecal pellets Brewer recognized two types: single and welded. For Marl Soils, I distinguish four types: single, welded, strongly welded and collapsed (Fig. 25).

Size of crystic primary grains is important for a full description of Marl Soils, as their fabrics are mostly crystic. A division is introduced here into 'fine crystic' (cristals

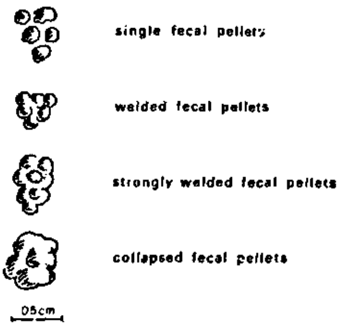


Fig. 25. Key to 4 types of welded fecal pellets.

Şekil 25. Ayrı dört tip parçalanmış hayvan dışkılarını işaret etmek için anahtar.

mostly < 2 μm) and 'coarse crystic' (crystals mostly 2-5 μm). A mixture of fine and coarse is called 'mixed crystic'. The density of the grains may be indicated as 'dense' (few ultramicrovoids) or 'open' (common ultramicrovoids).

The *abundance classification* of the Soil Survey Manual has been adapted and put also into adverbial form to allow description of the abundance of pedological features, such as fecal pellets and voids:

0- 2%	few or little	(hardly)
2- 20%	common	(commonly)
20- 70%	many or much	(mainly)
70-100%	abundant	(abundantly)

The terms, of course, can be used only roughly. Because of the wide range of meaning, a soil with few welded, common small and common large fecal pellets could be either commonly or mainly fecal. The scale is even more for rough assessment only in the description of voids; it gives no indication of the percentage of soil volume occupied by vughs, chambers, tubules, and planes.

4.4 General information on interpretation

A soil peel analysis provides morphological data that have to be used in describing differences between units within one peel, and differences between two or more peels.

It is normal that changes occur in a soil profile with depth. Slager (1966) calls them trends.

Differences between two peels, or between two profiles of one soil unit, may be due to differences in soil management. They can only be interpreted if field descriptions are available.

Peds and associated voids which are the result of granulation and fragmentation form a pedogenic structure (according to Jongerius, 1957), whereas geogenic structures are caused by sedimentation or pressure, results of the geological past. Granulation is mainly by biological activity, whilst fragmentation is the result of such processes as shrinking and swelling. In accordance with Slager (1966) the term biogenic will be used hereafter for structures resulting from biological activity, and physicogenic for those caused by physical processes. Geogenic is retained as above explained.

The study of soil structure as a result of biogenic and physicogenic forces will be the main topic of the next chapters, not only because they are of great interest for pedogenesis but also, as will be explained in Chapter 10, to estimate the suitability of the soil for plant growth (a biogenic structure is 'better' than a physicogenic one). Pedological features and intrapedal voids, besides pedality and interpedal voids, are important indicators.

Fecal pellets are excrements of the soil fauna. Separate ones are entirely biogenic, but they may be welded together by physical forces, thus become partly physicogenic. Collapsed fecal pellets may degenerate into almost physicogenic angular-blocky peds. Size and shape of single fecal pellets may indicate the kind of organism that has produced them and, through this, the environmental conditions. But little is yet known about this subject. In 1969, Dr Schweizer from Vienna kindly looked at our fecal material from Marl Soils and concluded, mainly on Turkish experience, that they were all from earthworms, the coarse ones from *Octolasium* spp., the medium ones from *Allolobora* spp.

Pedotubules are animal burrows and are common in soils. Brewer (1964) classifies them in detail on shape and contents. They vary from burrows made by animals the size of a rat to those of tiny gastropods. When more or less spherical, they are old resting places (chambers) of soil organisms in diapause. The relatively fresh ones contain single or slightly welded fecal pellets (aggrotubules) and thus are biogenic. The older ones may be void or filled with sand grains (granotubules) or with skeleton grains and plasma (isotubules). When filled with compact material, the 'chambers' stand out in the profile as peds, called 'clay balls' or 'clay sausages'. The later development of these features is mainly physicogenic.

Other pedological features like cutans, glaebules and crystallaria are mainly the result of chemical and physical processes. They may be formed by clay and humus migration, solution and subsequent precipitation of carbonates, gypsum and more soluble salts.

Interpedal voids are spaces in shape and size dependent on the neighbouring peds and the structural grade. They usually have the form of three-dimensional planes and are best described in the field because in peels many are unnatural as result of drying. But peels provide good opportunity for study of *intrapedal voids*. Their type, size and abundance is connected with biogenic and physicogenic structure, which provides important additional information. Brewer (1964) has drawn up a detailed classification of voids and we have added terms for abundance.

Vughs, chambers and channels are predominant in biogenic structures and planes in physicogenic and geogenic.

5 Completely elaborated analysis and interpretation of a Virgin Steppe Marl Soil

As mentioned in the Introduction one Marl Soil (Profile C 3.1, a Mollic Calciorthid) has been selected as illustrative of a completely elaborated analysis by the methods described in Chapter 4. The other Marl Soils will be treated in a more condensed form (Chapters 6-8), mainly by presenting the elementary structure instead of full descriptions of soil peels and thin sections. Their full descriptions are in Appendix 1.

5.1 Description

The structural diagram and the field description of this profile are given in Figure 9. Figure 26 shows its peel map, with the legend in terms of elementary structure. The full description of all pedological features and intrapedal voids is presented in Table 5. The components of the Peel Units 1 + 2, 3 and 5 in the sample sections are presented in the figures 27, 28 and 29. The stereopair in Figure 30 is a typical aggrochamber.

The descriptions of the thin sections which follow in Tabel 6 refer to Peel Units 1, 2, 3 and 5. The photographs in Figures 31, 32 and 33 present information on the s-matrix; they are direct enlargements of thin sections from Peel Units, 2, 3 and 5.

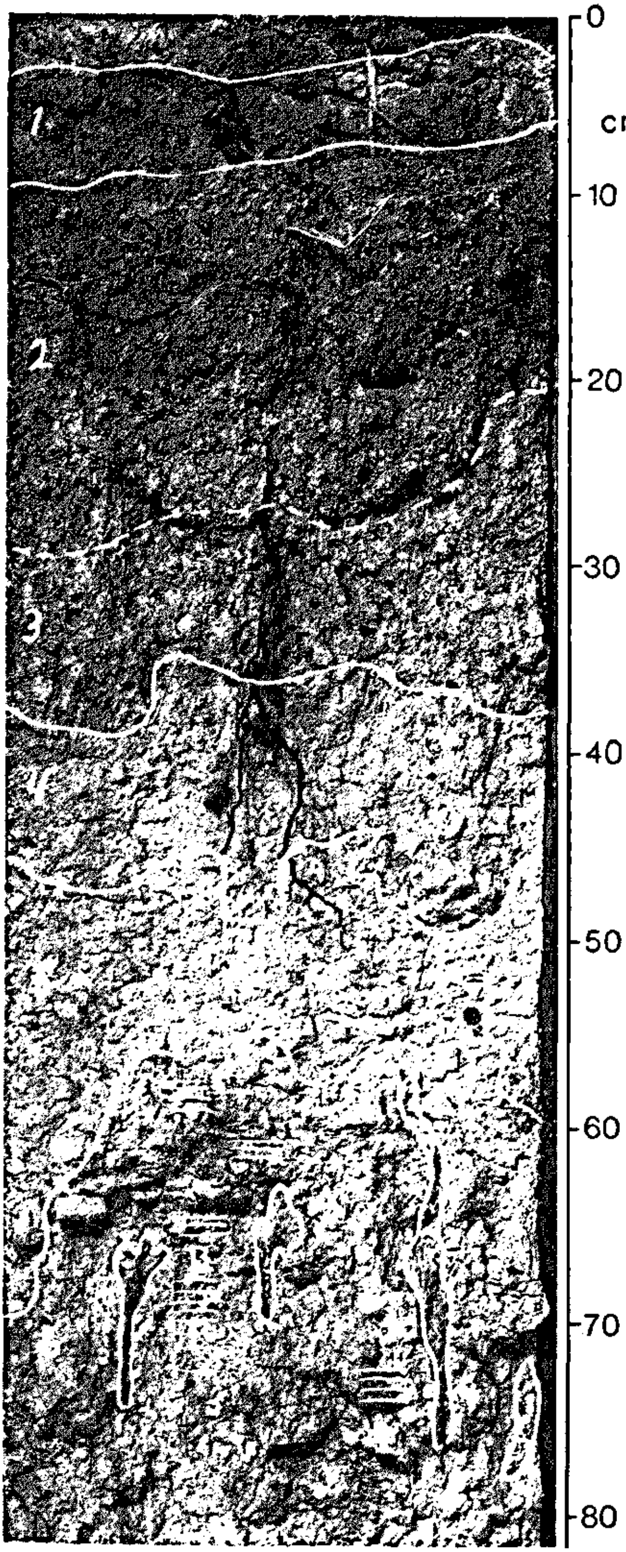
Figure 34 is a photomicrograph of Unit 2, showing its porphyroskelic basic structure. Here the individual grains of the crystic fabric are hardly distinguishable because of their small size (mainly $< 2 \mu m$), but a scanning electron micrograph reveals their nature (Fig. 35).

5.2 Interpretation of pedological features

5.2.1 Occurrence of fecal pellets

The peel analysis and the description of intrapedal features and voids (from the thin sections) reveal that the soil consists almost entirely of fecal pellets from earthworms, mainly single in the upper units, increasingly welded with depth and collapsed in the subsoil. In other words: the soil structure is entirely biogenic in the surface soil and becomes increasingly physicogenic with depth. This is characteristic for all Steppe Marl Soils, but very unusual for most other soils in the Great Konya Basin (de Meester, 1970).

The abundantly single fecal units of C 3.1 are in the field described as microporous compacted crumblike peds. Where the pellets become more and more welded as a



Virgin Steppe Marl Soil

Fig. 26. Peel map of Profile C 3.1.

Elementary peel structure of the peel units:

1. abundantly fecal and vughy
2. abundantly welded fecal; vughy and channelled
3. mainly single and welded fecal; vughy and channelled
4. abundantly welded fecal; vughy and channelled
5. moderately welded fecal; glaebular; vughy, channelled and fractured
6. mainly collapsed fecal; pedotubulic; channelled, fractured and jointed

Note: in Unit 6 undisturbed stratified soil material (B) alternates with biogenic pockets (A).

Şekil 26. Profil C 3.1, Bakir Step Marn'a ait monolit haritası.

Table 5. Description of pedological features and intrapedal voids of Profile C 3.1.

Pedological features	Voids
Unit 1	
abundant single medium fecal pellets common welded coarse fecal pellets few very coarse aggrochambers with collapsed fecal pellets	common interconnected irregular fine macrovughs few fine macrochannels
Unit 2	
many single medium fecal pellets many welded coarse fecal pellets common very coarse aggrochambers with collapsed fecal pellets	common irregular very fine macrovughs common irregular fine macrovughs common fine macrochannels
Unit 3	
common single and welded medium fecal pellets many welded coarse fecal pellets common very coarse subrounded bodies of collapsed coarse fecal pellets few very coarse aggrotubules with welded fecal pellets	many irregular very fine macrovughs few fine macrochannels common very fine macro-craze-planes
Unit 4	
abundant welded and strongly welded fine and medium fecal pellets common coarse and very coarse subrounded glaebules of collapsed fecal pellets few similar glaebules with welded fecal pellets	very many mesovughs common fine macrochannels few macro-craze-planes
Unit 5	
common strongly welded medium fecal pellets few strongly welded coarse fecal pellets few aggrotubules common white extremely coarse subrounded calcareous nodules	common fine macrovughs in fecal zones common fine macro-craze-planes and macro-joint-planes common medium macrochannels
Unit 6	
many strongly welded and collapsed fecal pellets common very coarse aggrotubes with strongly welded medium and coarse fecal pellets few coarse aggrotubules with organic pellets few very coarse diffuse yellow sesquioxidic nodules (mottles) and calcareous nodules	common clustered very fine macrovughs many medium macrochannels very many micro- and meso-skew-planes many meso and fine macro-joint-planes

Tablo 5. Profil C 3.1'de pedolojik görünümlerin ve interpedal ve voidlerin izahları.

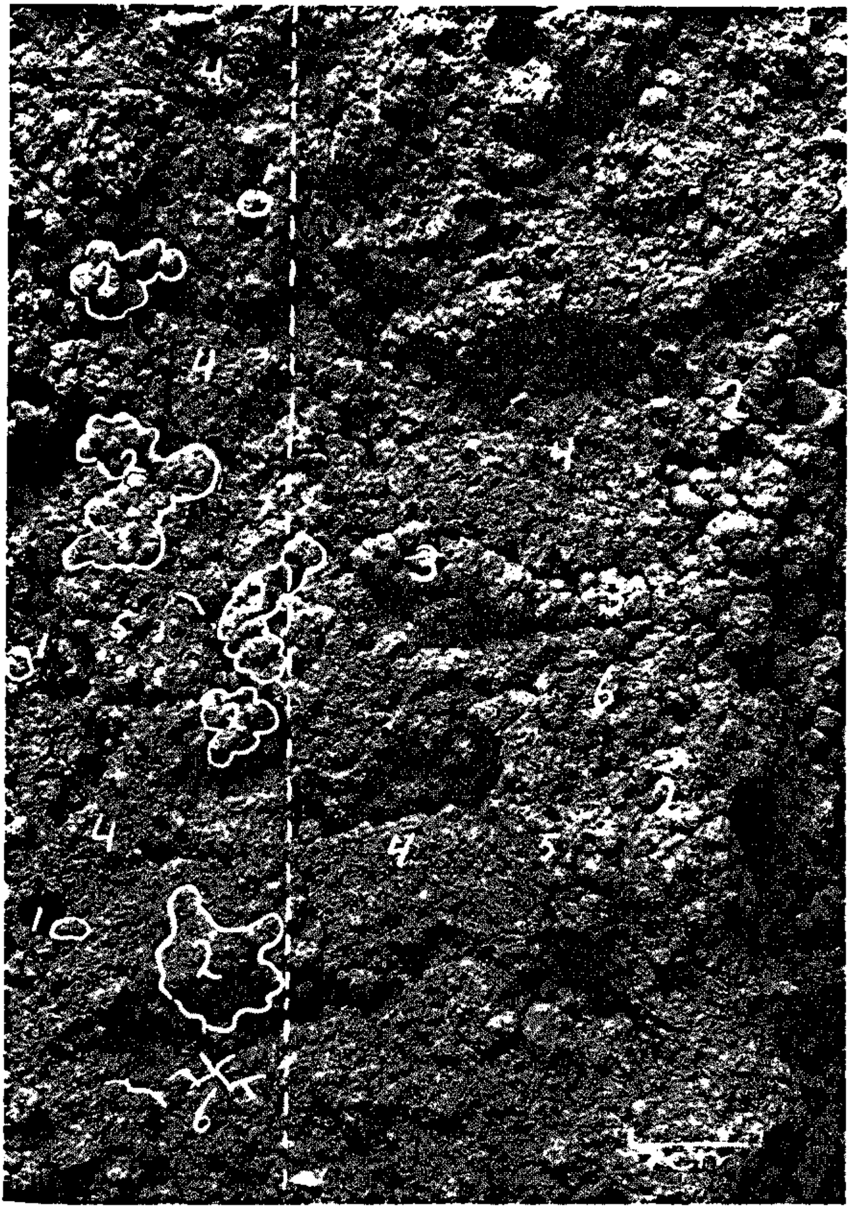
Fig. 27. Sample of Peel Units 1 and 2 from Profile C 3.1.

Şekil 27. Monolit ünitesi 1 ve 2 ye ait örnekler, profil C 3.1 'den.

Pedological and other features

1. mixture of single medium and single coarse fecal pellets with common interconnected irregular fine macrovughs
2. welded coarse fecal pellets
3. fine-macro channels
4. isochambers with collapsed fecal pellets

Fig. 28. Sample of Peel Unit 3 from Profile C 3.1.

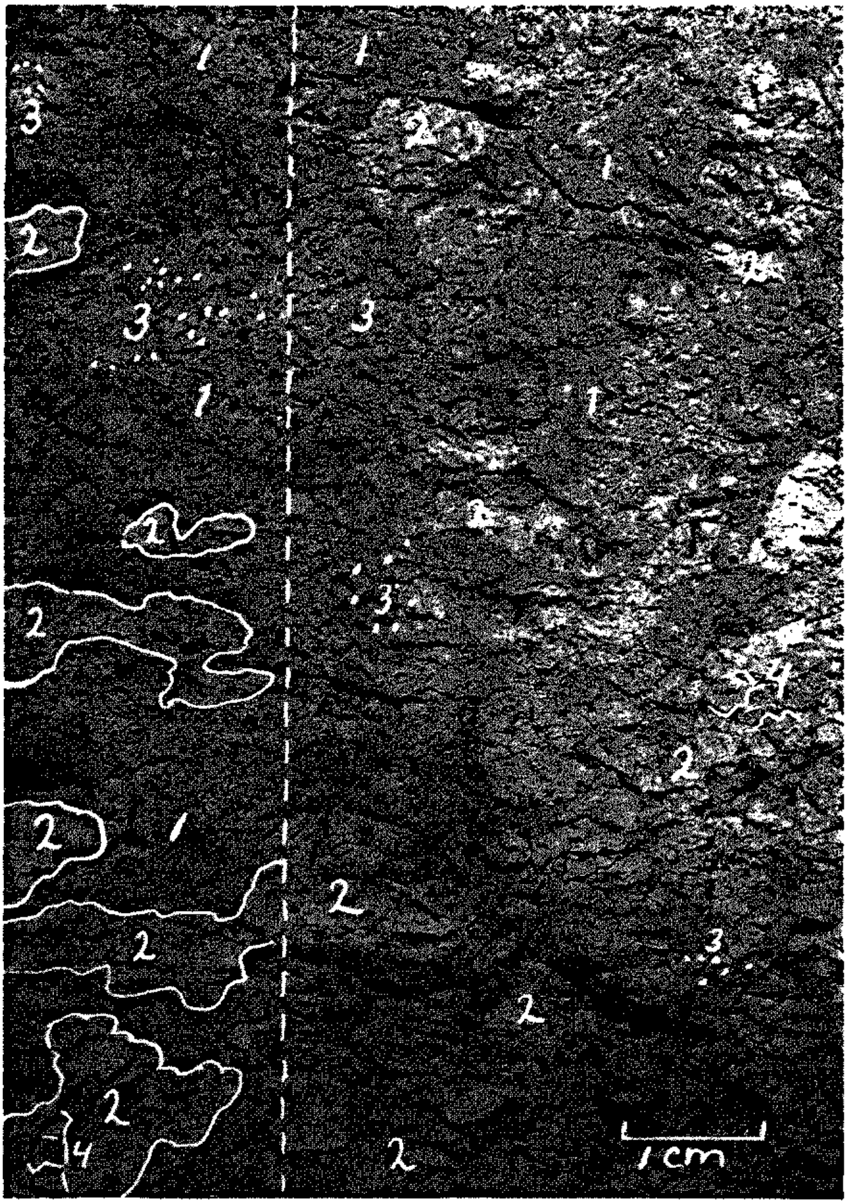


Şekil 28. 3 numaralı monolit ünitesi örneği, profil C 3.1'den.

Pedological and other features:

1. single coarse fecal pellets
2. welded coarse fecal pellets
3. aggrotubules with welded coarse fecal pellets
4. mainly single, medium fecal pellets with irregular fine macrovughs in between
5. fine macrochannels
6. very fine macro-craze-planes

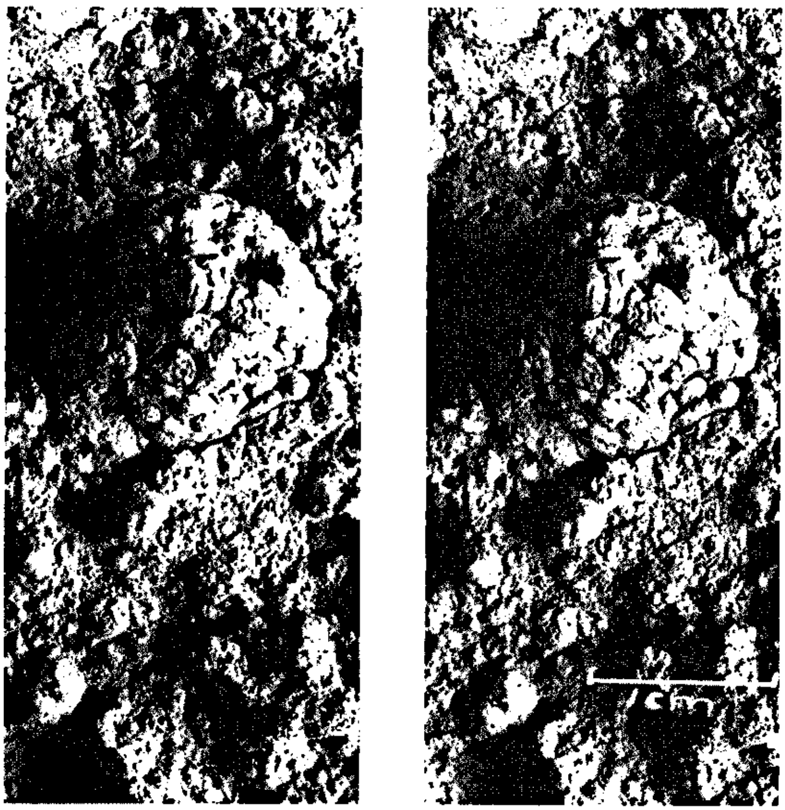
Fig. 29. Sample of Peel Unit 5 from Profile C 3.1.



Şekil 29. 5 numaralı monolit ünitesi örneği, profil 3 C.1'den.

Pedological and other features:
1. strongly welded, fine fecal pellets with fine macrovughs
2 and 4. fine macro-craze (2) and macro-joint-planes (4)
3. medium macro channels

Fig. 30. Stereo pair of a macrochamber filled with welded fecal pellets. Bottom left is an empty chamber. From Peel Unit 2, Profile C 3.1.



Şekil 30. Parçalanmış hayvan dışkıları ile dolmuş makro-çember stereo çifti. Sol alt tarafta boş çember, monolit ünitesi 2, profil C 3.1'den.

result of deterioration, the field structure changes from often compound, subangular-blocky to angular-blocky. The white marl subsoil was described in the field as 'mainly smooth very fine and fine angular-blocky' (Fig. 9), but the peel description reveals that these peds are in fact collapsed fecal pellets, hence their unusually small size. Similar features, but still more pronounced, have been observed in almost all Steppe Marls. In saline-alkali soils the welded fecal pellets form fine prismatic peds.

The enormous activity of the soil fauna is characteristic of soils, such as Chernozems and Pararenzinas (Kubiëna, 1953).

That the subsoil of the white marl consists also almost entirely of (now collapsed) fecal pellets can be explained by assuming that the soil remained moist for long periods after the lake had disappeared. This conclusion has already been mentioned in Chapter 2. Part of this type of feature could also be explained by soil ripening.

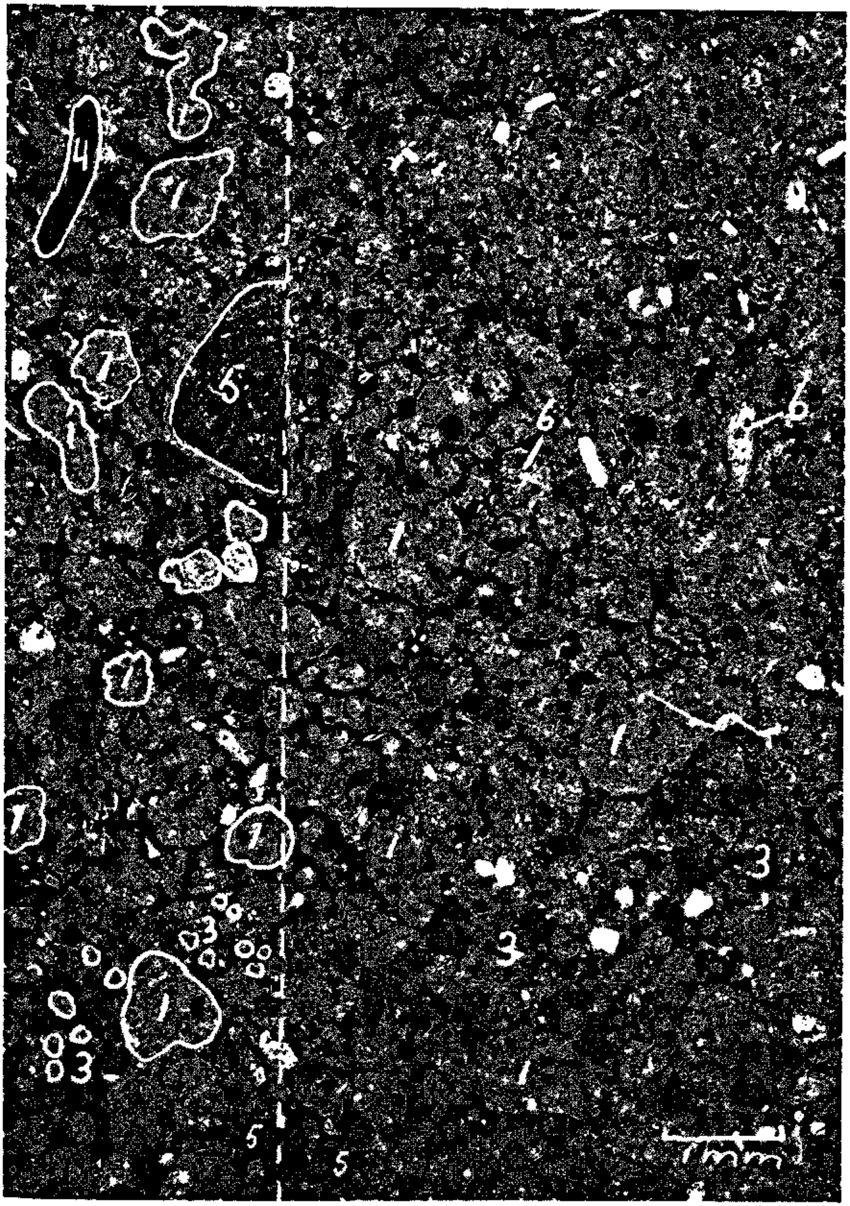
Aggrochambers, cavities filled with fecal pellets, are found mainly in the surface soil. Aggrotubules, burrows filled with pellets, occur mainly in the subsoil. The

Table 6. Description of four thin sections from peel units of Profile C 3.1.

Peel unit	Plasmic fabric	Basic structure	Elementary structure	Primary structure
1	mixed loose crystic	porphyroskelic *voids:* mainly microvughs, abundant irregular inter-connected mesovughs and macrovughs; few macro-channels *skeleton grains:* many fine and medium rounded and subrounded grains	fecal vughy loose crystic (abundant welded and many single, matric fecal pellets)	*glaebules:* many fine sharp fine-crystic nodules *cutans:* common matrans around skeleton grains *biorelicts:* common course mainly rounded shell fragments; root fragments
2	mixed loose crystic	porphyroskelic *voids:* many irregular mesovughs and macro-vughs; common macro-channels *skeleton grains:* many fine and medium rounded and subangular mineral grains	fecal vughy loose crystic (abundant welded and many single matric fecal pellets)	*glaebules:* many sharp fine crystic nodules *cutans:* common matrans around skeleton grains *biorelicts:* common rounded coarse shell fragments; common root remnants
3	fine loose crystic	porphyroskelic *voids:* few fine to medium irregular clustered vughs; common medium craze planes; common medium channels *skeleton grains:* common fine mainly rounded and few subrounded grains	cutanic and pedotubulic, fractured and channelled loose crystic (fine crystic-vugh and channel calcitans; common coarse sharp aggrotubules)	*glaebules:* few rather sharp fine-crystic nodules *biorelicts:* few shell fragments and few root remnants
5	fine loose crystic	porphyroskelic *voids:* common micro-vughs, few irregular macrovughs, many very fine to fine skew and joint planes *skeleton grains.* few fine grains, mainly in banded pattern or in clusters	pedotubulic, microvughy fractured and jointed loose crystic (few rather sharp granotubules)	*glaebules:* few diffuse coarse yellow sequioxydic nodules *biorelicts:* few fine rounded shell fragments

Tablo 6. Profil C 3.1'e ait 4 monolit ünitesinin izahı.

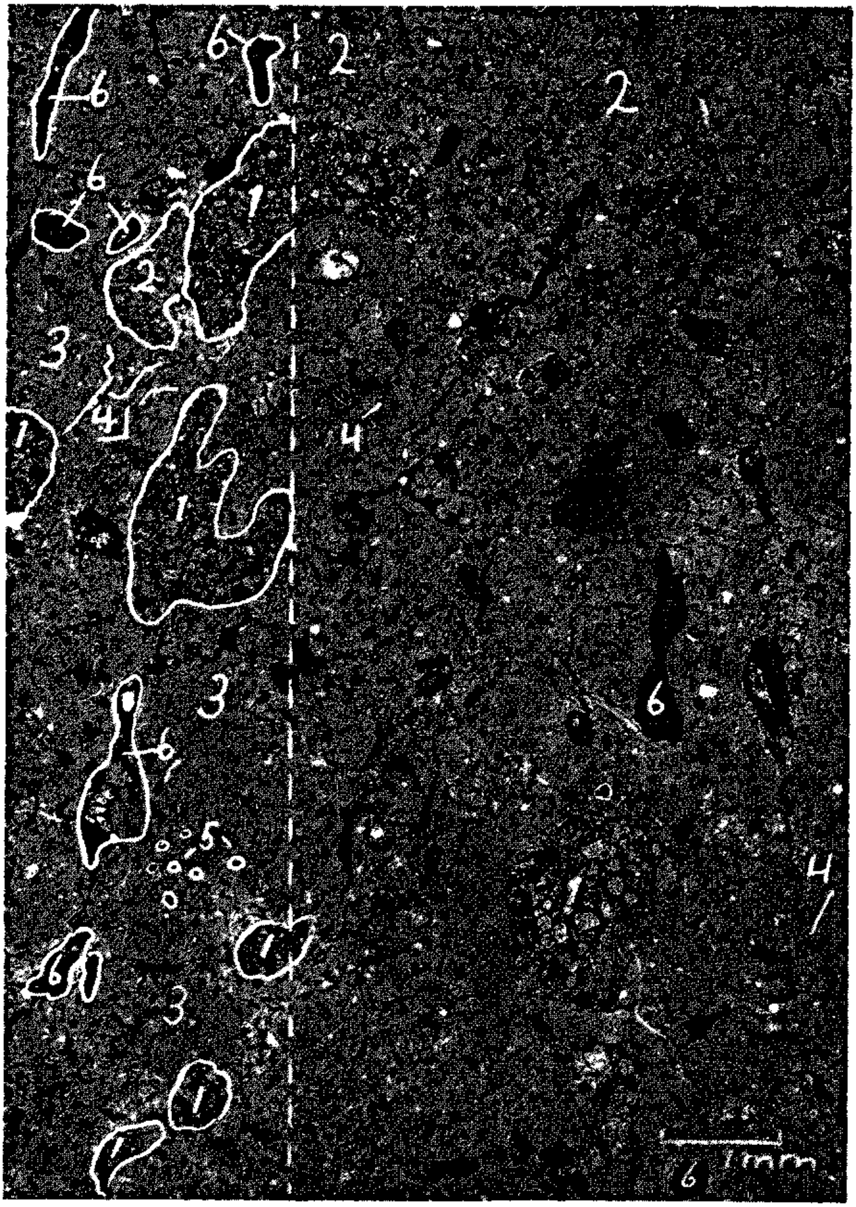
Fig. 31. Thin section of Peel Unit 2 from Profile C 3.1.



Şekil 31. Profil C 3.1'e ait monolit ünitesi 2'nin ince kesiti.

Pedological and other features:
1 and 2. coarse, single and welded fecal pellets with a porous crystic fabric
3. medium fecal pellets
4. channels
5. skeleton grains with matrans
6. biorelicts (mainly shell fragments)

Fig. 32. Thin section of Peel Unit 3 from Profile C 3.1.

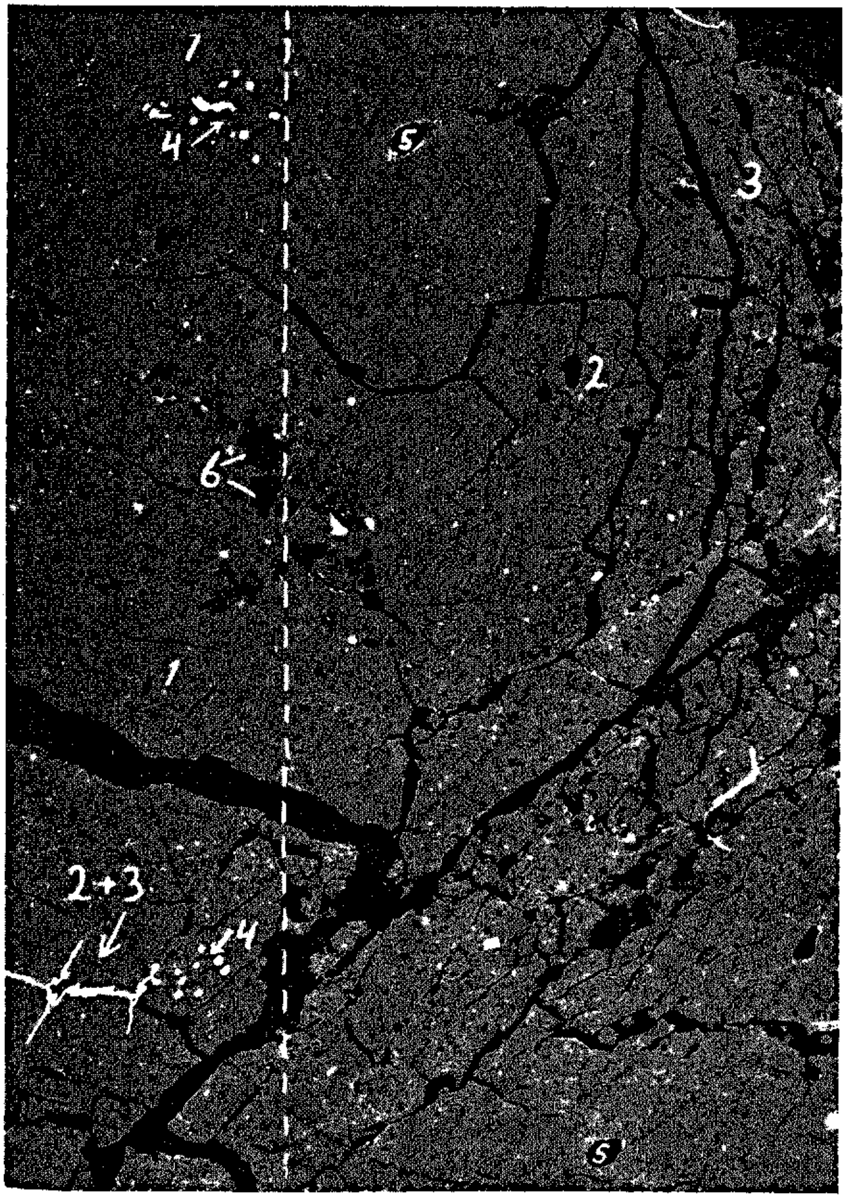


Şekil 32. Profil C 3.1'e ait monolit ünitesi 3'ün ince kesiti.

Pedological and other features:

1. pedotubules with single medium fecal pellets
2. welded fecal pellets with mesovughs and macrovughs
3. mixed porous crystic fabric
4. meso-craze-planes
5. rounded mesovughs
6. channels

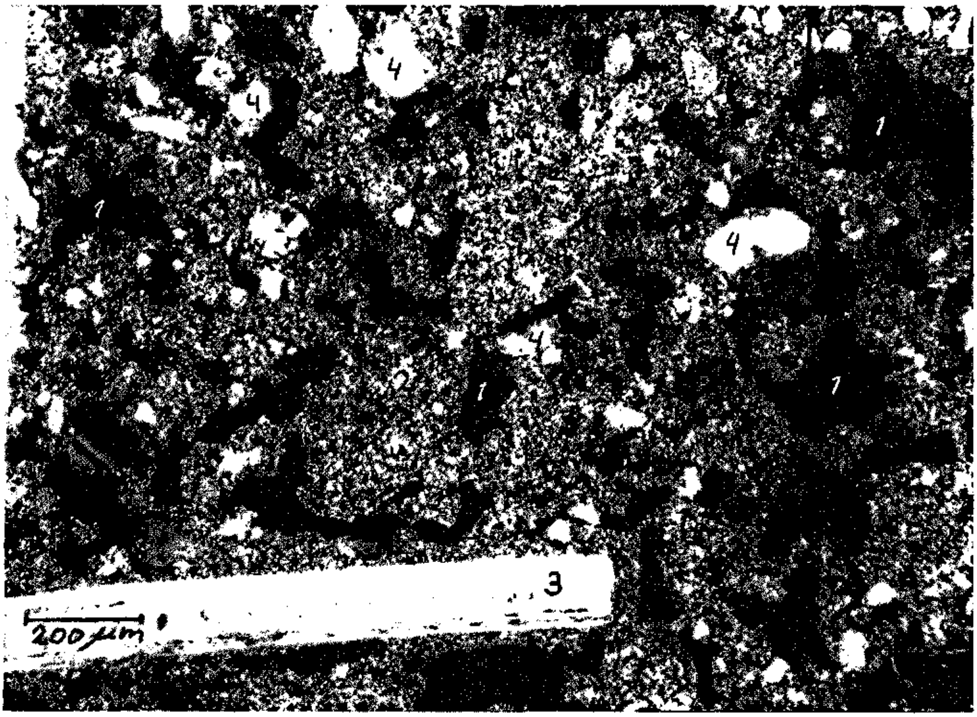
Fig. 33. Thin section like one of Peel Unit 5 from Profile C 3.1.



Şekil 33. Profil C 3.1'e ait monolit ünitesi 5'in ince kesiti.

Pedological and other features:
1. dense crystic fabric
2. and 3. very fine to medium skew (2) and joint (3) planes
4. mesovughs and macrovughs
5. macrochannels
6. skeleton grains

Fig. 34. Photomicrograph of a thin section of Peel Unit 2 from Profile C 3.1. (1) vughs, (2) mixed loose crystic fabric, (3) shell fragment and (4) skeleton grains. Photographed with polarized light.

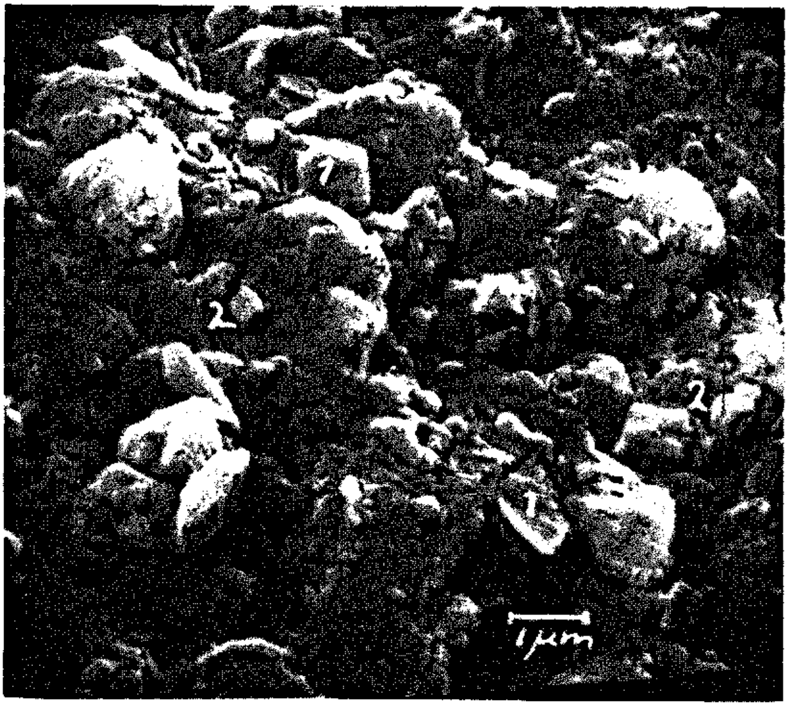


Şekil 34. Profil C 3.1'e ait monolit ünitesi 2'in ince kesit fotomikrografı.

material of both is generally welded or collapsed pellets. Here and there are hard round bodies, formed in the cast of a cavity. They consist of matric soil material and may have originated from collapsed pellets or may have been washed in and dried hard; they are called glaebules. Other kinds of glaebules will be discussed later. In addition there are burrows filled with mainly skeleton grains which have been washed in from the surface soil; they are granotubules. Thin sections of the various zones show that the s-matrix of the fecal pellets is the same as between the pellets, except for some dark pellets of recent origin.

The thin sections and the peels both show an increase in pedotubules with depth. In thin sections the contents of these pedotubules can be seen as fine and medium, mostly single, fecal pellets of recent origin. The size of these pellets suggests that worms now active are small in size. This is supported by the observation that in the surface soil of peels the medium pellets are less welded than the coarse ones. Furthermore the smaller pellets occur mostly in vertical zones along cracks or channels, through which the organisms seem to have penetrated the deeper soil layers (Fig. 44). All this strongly suggests that a decrease of the larger-sized worms and an increase in smaller ones has occurred during the degradation of the steppe vegetation.

Fig. 35. Scanning electron micrograph of a fragment surface from 105 cm deep in Profile E 3.1. The dense plasmic fabric consists of clay micelles (1) and very fine carbonate crystals (2). (Photograph by courtesy of Mr S. Henstra with JSM 2)



Şekil 35. Profil E 3.1'de yüzeyden 105 cm derinlikteki bir toprak parçasının elektron mikroskop mikrografları. Kati plasmık yapi kıl minerallerinden (1) ve çok ince karbonat kristallerinden (2) ibarettir (fotoğraf JSM 2 ile S. Henstra tarafından alınmıştır).

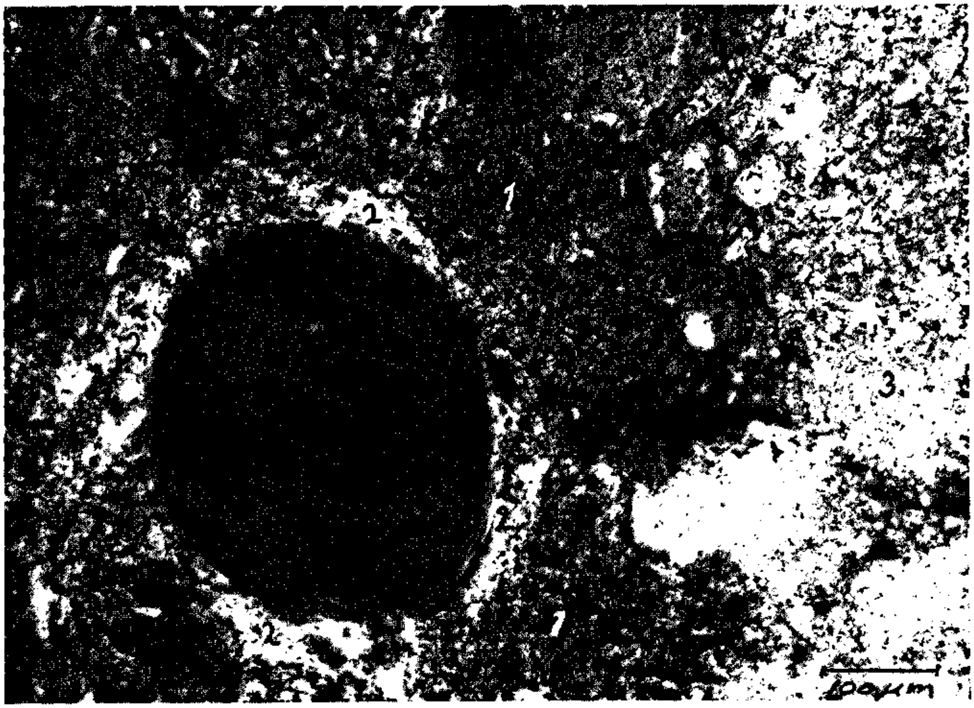
5.2.2 The occurrence of cutans

The peel description of Profile C 3.1 does not mention cutans. The thin sections, however, show various types.

In the samples of peel units 1 and 2, many skeleton grains are covered with matrans, which are cutans of soil material identical with the s-matrix. Their presence in the surface soil may perhaps be explained by mud, formed from puddled soil after rain or floods, adhering as a film to the grains. Deeper in the soil, as in Peel Unit 5 taken from the calcic horizon, clear fine crystic calcitans lining vugh and channel walls occur, but they are nowhere thick enough to make the zone impermeable. The size and shape of the calcite crystals in the calcitans indicate that calcium carbonate enrichment is there secondary (Blokhuis *et al.*, 1968).

The thin sections of C 3.1 have no traces of decalcification, but because decalcification is common in Steppe Marls it should be discussed here. The decalcified zones

Fig. 36. Decalcified zones (1) and argillans (2) in Marl Soil. Thin section of Peel Unit 2 from Profile C 3.1. (3) is mixed loose crystic fabric.



Şekil 36. Marn toprağında kireci yıkanmış bölge (1) ve argillanlar (2). Profil (3).

have been detected in comparison with artificially decalcified thin sections of Marl Soils. Figure 36 shows such a decalcified zone. Moreover, in decalcified zones, artificial or not, argillans (zones of oriented clay particles) have been observed. Thus argillans otherwise obscure in Marl Soils can be made visible by decalcification. Even in highly calcareous soils clay is sometimes mobile.

5.2.3 Occurrence of nodules

Beside the matric glaebules mentioned earlier, the soil peel of Profile C 3.1 shows common extremely coarse calcareous nodules in Peel Unit 5 and a few in Unit 6. They are the result of secondary calcium carbonate seggregation. They cause the structure to become increasingly physicogenic, as witnessed by a sudden increase of craze and joint planes. In other words: the elementary peel structure becomes fractured.

In the white carbonatic parent material of Unit 6, there are a few very coarse diffuse yellow iron oxide mottles, sesquioxidic nodules that have resulted from fluctuations in groundwater; they are presumably fossil (Chapter 3).

The thin sections show common fine crystic nodules in peel units 1 and 2 and a few in 5. It is not likely that they are the result of a redistribution of calcium carbonate, and they may have been formed by biological activity or by slaking. Their plasmic fabric is similar to the s-matrix but dense crystic rather than open. They decrease in abundance with depth. They are common in all Marl Soils.

5.3 Interpretation of voids

The units with mainly single fecal pellets in Profile C 3.1 have common interconnected irregular vughs which are, in fact, packing voids. The number of vughs and their size decrease with depth; soil structure gradually becomes less biogenic, more physicogenic.

The fine macrochannels above Peel Unit 5 (the calcic horizon) are mainly recent burrows of small animals increasing in number with depth.

Peel Unit 5 has no visible fine macrochannels, because they are either filled with secondary calcium carbonate or have never been formed because the unit is too hard. Medium macrochannels, however, are abundant in Peel Unit 6, the white carbonatic subsoil. All Marl Soils contain many macrochannels in the parent material which is thereby less physicogenic in structure than expected from other features. These channels are from fossil roots, presumably of luxurious marsh vegetation in the last stage of the Ancient Konya Lake.

The number of planes is an important indication of physicogenic structure. As expected, their number increases with depth in peel units 1, 2 and 3, but in 4 it is low because of high gypsum content in this horizon. In peel units 5 and 6, the planes become many. Interesting is the large number of micro and meso skew planes, which is associated with the collapsed fecal structure in these units. The surfaces of weakness between the compacted pellets have become small cracks by drying.

For the smaller voids, thin sections add nothing to the picture.

In summary, Virgin Steppe Marl Soils are characterized by:

- an abundantly fecal solum, single pellets near the surface soil and increasingly welded at depth
- aggrotubules in the subsoil
- thin calcitans in the calcic horizon
- argillans, visible only in decalcified zones
- calcareous and sesquioxidic nodules in the subsoil
- many fossil macrochannels in the subsoil.

6 Analysis and interpretation of the other Steppe Marl Soils

After the extensive discussion of the example of a Virgin Steppe Marl Soil in Chapter 5, only the elementary structure of the other Steppe Marl Soils will be described. The full descriptions are in Appendix 1.

6.1 Cultivated Steppe Marl Soil

6.1.1 Description

Cultivated Steppe Marl Soils were originally Virgin Steppe Marl Soils. After repeated tillage with a disk plough to clear the soil of weeds, to prepare the seedbed, and to conserve moisture, wheat is grown. A cropping year always alternates with a fallow year. In general, no chemical fertilizers or dung are used.

Profile C 3.2, a Mollic Calciorthid, situated only 50 m from that discussed in Chapter 5, is illustrative. Its soil has been 15 years under cultivation. For the peel map, see Figure 37, its legend is in terms of elementary structure.

The components of Peel units 2 and 6 are illustrated by the sample sections in Figure 38 and 39. Descriptions have been made of thin sections from Peel Units 2, 3 and 4. The elementary structures are:

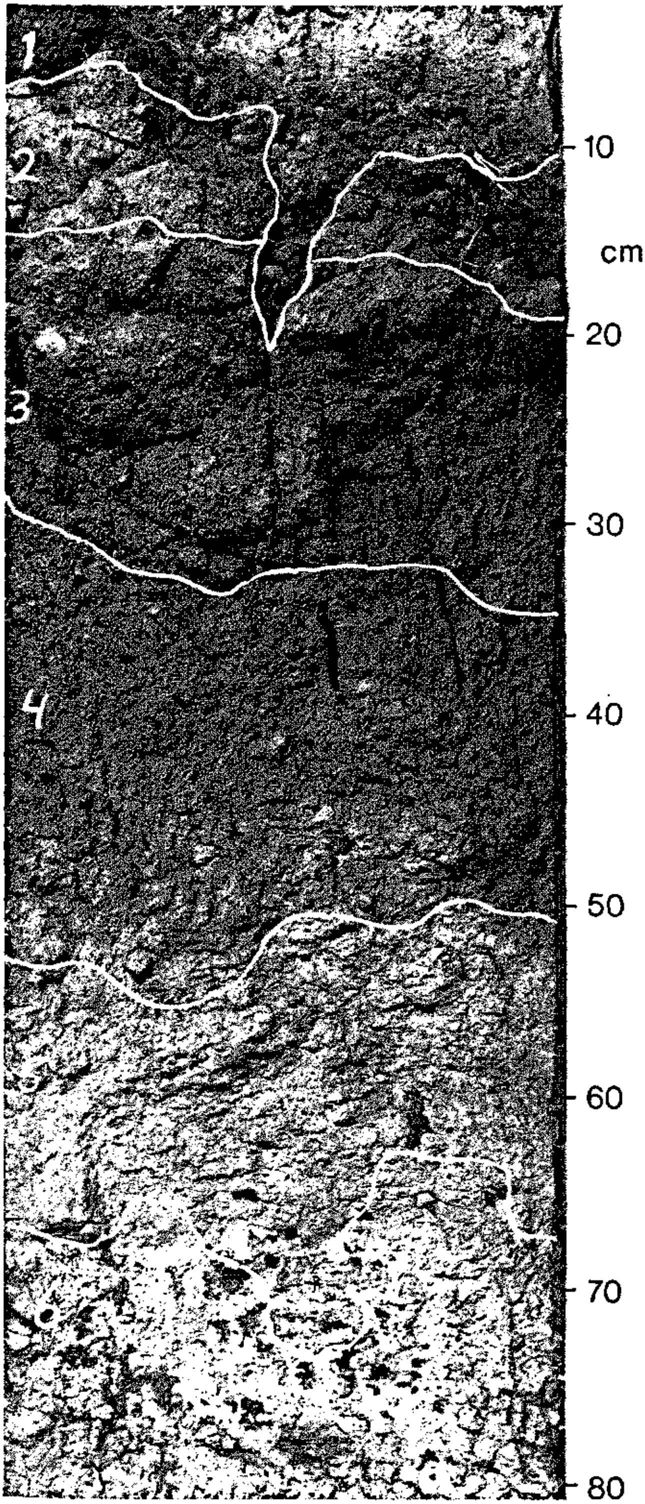
Peel Unit 2: fecal, vughy and loose crystic (many welded and common single matric fecal pellets)

Peel Unit 3: fecal, vughy and loose crystic (many welded and common single matric fecal pellets)

Peel Unit 4: cutanic, vughy and crazed loose crystic (common fine, fine crystic vugh calcitans and channel calcitans).

6.1.2 Interpretation of Profile C 3.2

The structural diagram made in the field (Fig. 10) shows that, as a result of cultivation, the originally crumblike 50 cm of the Virgin Steppe Marl Soil has been replaced by three horizons: a loose ploughed layer of some 20 cm of subangular-blocky clods composed of granular peds, underlain by a compacted prismatic plough bottom from 20-30 cm, whereas the layer between 30 and 50 cm, although untouched by the plough, has become irregular subangular-blocky. Below 50 cm (the calcic horizon and below it), there were no differences from the virgin soil, as observable in the field, but there were in the peel.



Cultivated Steppe Marl Soil

Fig. 37. Peel map of Profile C 3.2.

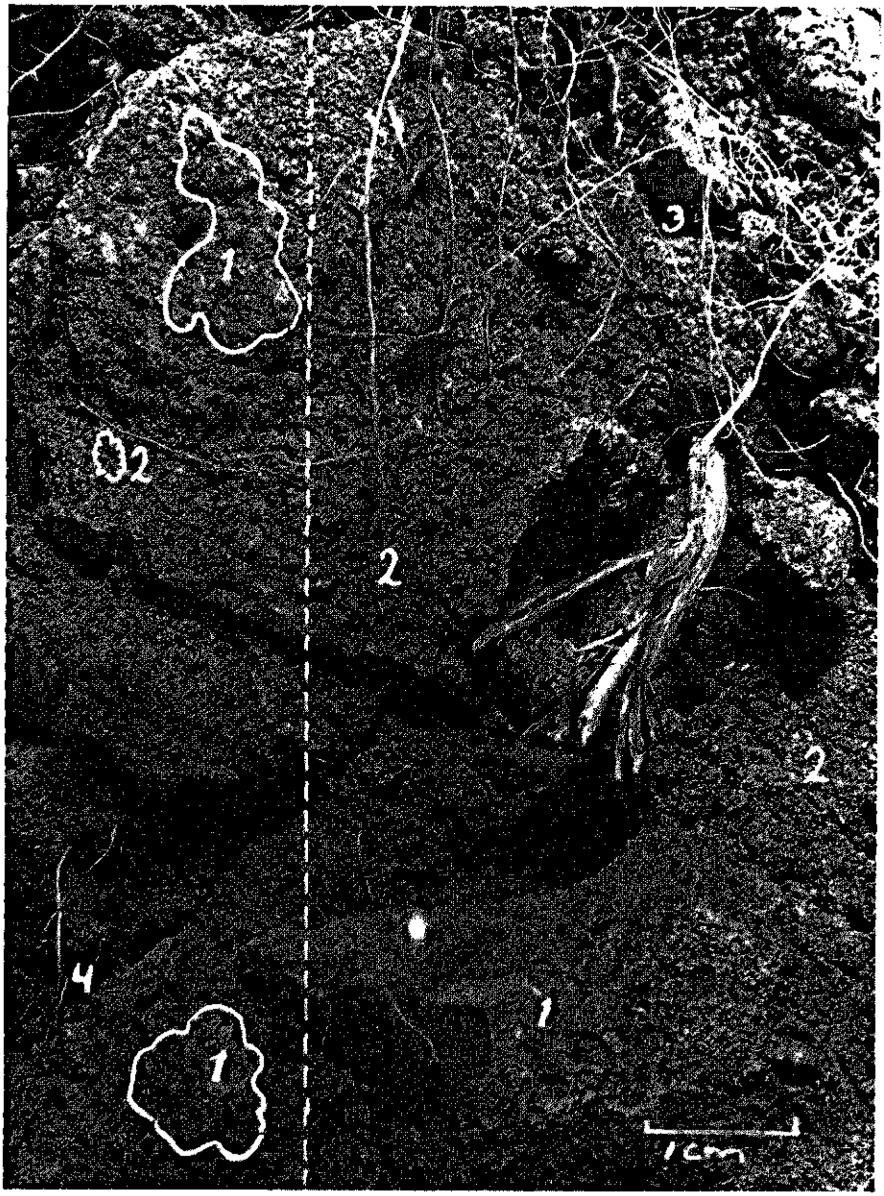
Şekil 37. Kültüre Alınmış Step Marn Toprağı'na ait profil 3 C.2'nin monolit haritası.

Elementary structure of the peel units:

1. abundantly single and welded fecal; vughy
2. mainly collapsed fecal; partly vughy
3. mainly welded fecal; fractured
4. hardly fecal; channelled
5. moderately welded fecal; channelled and jointed
6. hardly fecal, pedotubulic, channelled and jointed

N.B. The dark patches in units 5 and 6 are holes in the peel.

Fig. 38. Sample of Peel Unit 2 from Profile C 3.2.

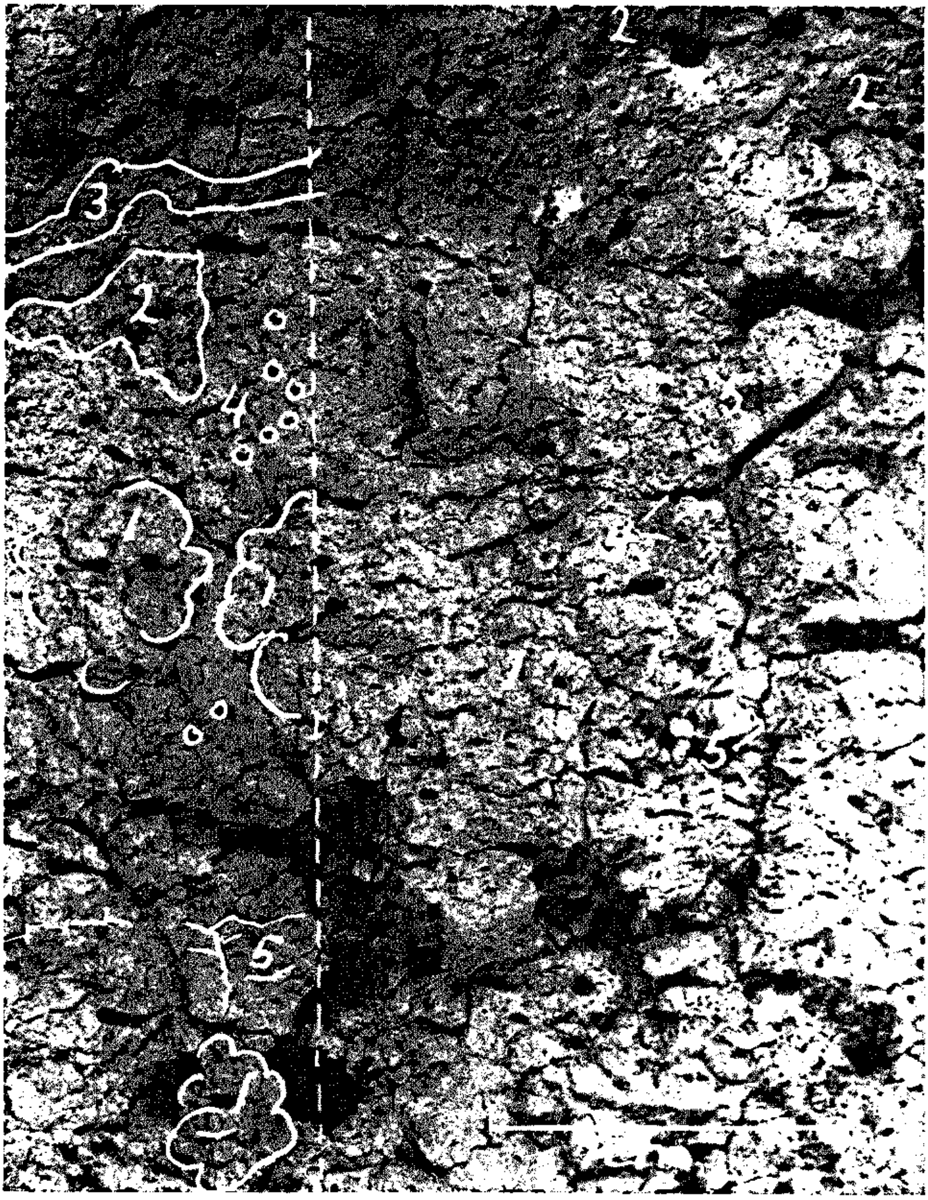


Şekil 38. Monolit ünitesi 2'nin örneği, profil C 3.2'den.

Pedological and other features:
1. collapsed coarse fecal pellets
2. welded and strongly welded medium fecal pellets with irregular fine macrovughs

Note broken peds of compacted plough bottom with abundant wheat roots in top right corner (3) and few in bottom left corner (4).

Fig. 39. Sample of Peel Unit 6 from Profile C 3.2.



Şekil 39. Monolit ünitesi 6'in örneği, profil C 3.2'den.

Pedological and other features:
1. entirely collapsed fecal pellets
2. welded fine fecal pellets
3. aggrotubules with strongly welded fine fecal pellets
4. macrochannels
5. very fine macro-joint-planes

The same structural trend as observed in the field was seen in the peel. Even in the surface layer (Peel Unit 1) many fecal pellets were welded and the elementary structure of the plough bottom (Peel Unit 2) is mainly collapsed fecal.

Field and peel structure indicate that cultivation has made the originally biogenic structure more physicogenic.

Peel units 3 and 5 are also more welded fecal than in the Virgin Steppe Marl Soil (Profile C 3.1) at comparable depths. The calcic horizon (Peel Unit 4) is hardly fecal. Its fecal origin has been obscured; the soil material is entirely s-matrix. The white carbonatic subsoil (Peel Unit 6) is a fine example of compound fine prismatic peds consisting of compacted collapsed fecal pellets with joint planes and fossil channels.

The distribution of pedotubules, mainly aggrotubules, shows the same trend as the virgin soil, but they are more frequent because in an uncompact soil worms can move about between particles without forming burrows.

The thin sections show the same trend as the peel. Remarkable is the occurrence of Lublinite crystals and decalcified zones along channels in Unit 4 (the calcic horizon).

In summary, the main structural characteristics of a Cultivated Steppe Marl Soil are:
- a surface soil with horizons of collapsed fecal pellets, including a compacted plough bottom
- a subangular-blocky layer between 30-50 cm
- a compacted hardly fecal calcic horizon
- many aggrotubules in the subsoil.

6.2 Irrigated Steppe Marl Soil

6.2.1 Description

In the Lacustrine Plain, small plots of Steppe Marl Soil are irrigated, mainly from wells (as near Tömek, Ortakonak and Hotamış), but near Yarma also from a canal fed from the River Çarşamba. Usually the fields are flooded every two to three weeks from May to July. The customary fallow, as in dry farming, is commonly maintained, presumably to restore soil fertility and structure.

Lucerne, wheat and sugar-beet are the main crops. Fertilizers are hardly applied.

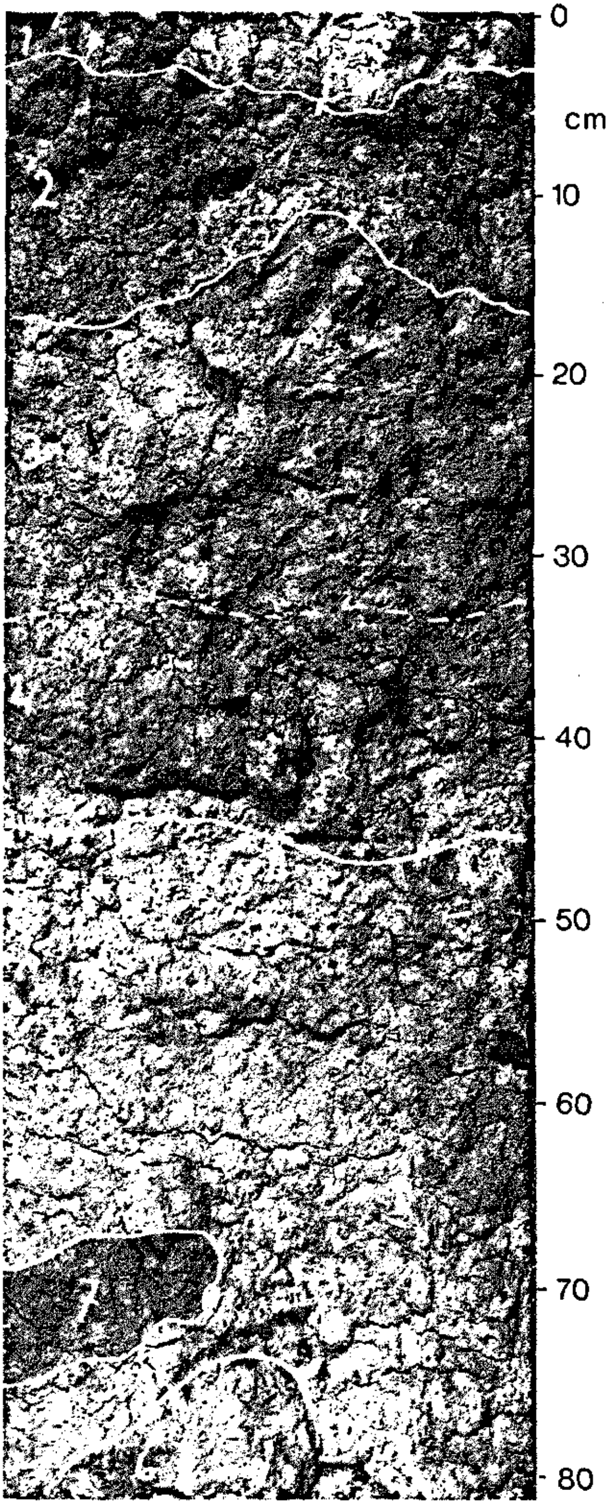
Profile G 1.1, a Mollic Calciorthid gives a representative example from a site irrigated for some eight years and cultivated with wheat or lucerne.

Figure 40 is the peel map; its legend is in terms of elementary structure. No sample sections are included, because there are no distinctive features.

Descriptions of thin sections have been made from the peel units 2, 3, 4 and 5, with elementary structures as follow:

Peel Unit 2: vughy and channelled, dense crystic (locally common welded matric fecal pellets and few organic fecal pellets)

Peel Unit 3: fecal, vughy and channelled, loose crystic (many welded and single fecal pellets)



Irrigated Steppe Marl Soil

Fig. 40. Peel map of Profile G 1.1.

Şekil 40. Sulanmış Marn Toprağı'na ait profil G 1.1'in monolit haritası.

Elementary structure of the peel units:

1. non fecal; jointed (surface crust)
2. abundantly welded fecal
3. mainly collapsed fecal; vughy and channelled
4. abundantly welded fecal, pedotubulic; vughy and channelled
5. mainly welded fecal; vughy and channelled
6. commonly collapsed fecal; fractured
7. (krotovina) abundantly welded fecal; vughy

Peel Unit 4: fecal, microvughy, loose crystic (many single and abundant welded fecal pellets)
Peel Unit 5: cutanic, fractured, dense crystic (many very fine plane, vugh and channel calcitans).

6.2.2 Interpretation of Profile G 1.1

The field structure (Fig. 11) in the upper 80 cm is subangular-blocky with granular areas; deeper it is compound prismatic angular-blocky. Remarkable are the surface crust and the weak structural grade.

The peel analysis and the descriptions show that the upper 5 cm of surface crust is entirely non-fecal, which means that it has been puddled beyond recognition of original pellets. There are even no vughs left, only joint planes, indicating that the structure has become completely physicogenic.

The peel units 2 (the ploughed layer), 3 and 4 are welded or collapsed fecal but there is no trend of increasing deterioration with depth, nor is there a compacted plough bottom as in the dry Cultivated Steppe Marl Soil (Profile C 3.2). The zone of recent faunal burrows, with the aggrotubules, has moved to deeper layers (Peel Unit 4), presumably because of irrigation.

Peel Unit 5 is the calcic horizon. Its structure is partly biogenic. Irrigation has not caused significant changes in the white marl subsoil (Peel Unit 6).

In the thin sections, the absence of crystic nodules in the surface soil (Peel Unit 2) is remarkable. They seem to have dissolved away. Crystallaria do not occur in any of the samples. The section in Peel Unit 5 (calcic horizon) shows many calcitans in planes, vughs and channels. The section shows the dense, fine-crystic plasmic fabric. Both features are results of intensive redistribution of calcium carbonate.

The section also contains irregular dark organic bodies, which have formed by migration of material, presumably from decaying roots. They do not occur in Virgin Steppe Marl Soils, but are abundant in Marsh Marl Soils.

The above observations and deductions indicate that irrigation of Virgin Steppe Marl Soils results in structural deterioration by compaction and slaking.

In summary, the structure of an Irrigated Steppe Marl Soil is characterized by:
- a puddled surface crust
- a strongly welded fecal solum
- an uncompacted plough bottom
- a loose partly fecal calcic horizon.

6.3 Alkali-affected Steppe Marl Soils

6.3.1 Description

Saline-alkali Steppe Marl Soils occur in much of the Lacustrine Plain. Though they are mainly internally affected, they are often under dry-farmed wheat, because there is little soluble salt and sodium in the rooting zone.

Profile D 3.1, a Mollic Camborthid, is typical. Its peel map is Figure 41, whose legend is in terms of elementary structure. Peel units 1, 2b and 5 are given in more detail by sample section in Figure 42, and 43 and 44.

Descriptions of thin sections have been made for peel units 2 and 3. Their elementary structures are:

Peel Unit 2b: fecal, mammilated vughy loose crystic (many single and welded matric fecal pellets; few organic pellets)

Peel Unit 3: vughy crazed crystic (no characteristic pedological features).

6.3.2 Interpretation of Profile D 3.1

In the structural diagram (Fig. 12), pedality is seen to be prismatic below the plough layer. The peel description, however, reveals that, despite collapse, the soil material is almost all clearly fecal. The plough layer still has single and welded pellets. But in Peel Unit 2 they are strongly welded and in Peel Units 3, 4, 5 and 7 they have collapsed, so that craze and joint planes are frequent. Peel unit 6 contains vughs and no planes. From the field description, the explanation of this difference is clear: it is caused by the higher gypsum content of Peel Unit 6. A similar correlation was observed in the gypsiferous Steppe Marls near Tömek, north of Konya, because of replacement of Na^{+} by Ca^{2+} on the soil complex, which encourages aggregation. The alternating growth and solution of gypsum crystals in these spots makes the soil porous. The number of pedotubules increase with depth, as usual.

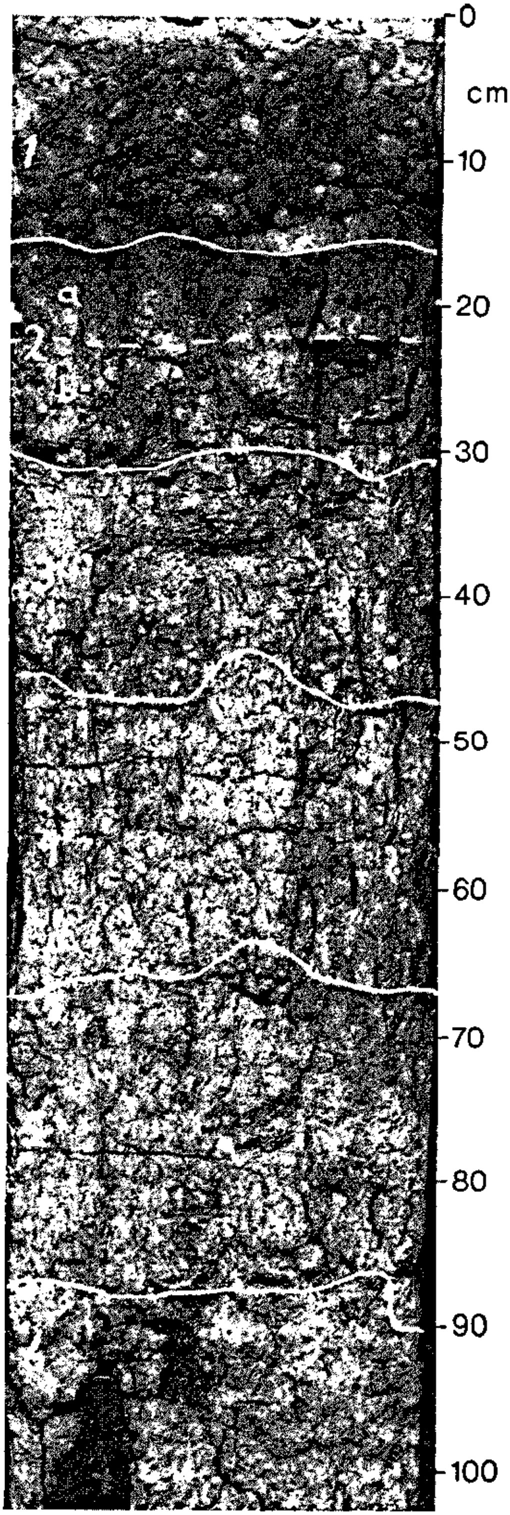
The sample section in Peel Unit 5 illustrates that the fine prismatic peds in the subsoil consist entirely of collapsed fecal pellets. Fossil channels can be seen and pedotubules with fresh single medium fecal pellets occur along rootholes and in planes between peds.

Other remarkable features in this alkali-affected soil are very clear organans in Peel Unit 2, the cutans of dispersed humus which cover ped surfaces. Humus compounds from the surface soil turn mobile in a saline-alkali environment (Driessen, 1970). The thickness and size of the organans suggest that they have formed under a steppe vegetation more luxurious than now. Organic carbon in the surface soil is now only 1.3‰.

The thin sections, like the peel, show that in Peel Unit 2b the elementary structure is welded fecal but show further abundant mesovughs and many macrovughs.

In the sample of Peel Unit 3, structural deterioration can be deducted from the non-fecality. There are craze or skew planes, as in the peel, but also mesovughs and macrovughs. Interesting is the observation, supported by similar phenomena in other marl profiles, that, if structural collapse is obvious in the field and on the peel, the crystic fabric is dense, which means that the plasmic structure has also collapsed.

There are decalcified zones in the thin section from Peel Unit 3 and calcium carbonate is seen not to have accumulated anywhere in this profile. These features were not visible in the field or in the peels.



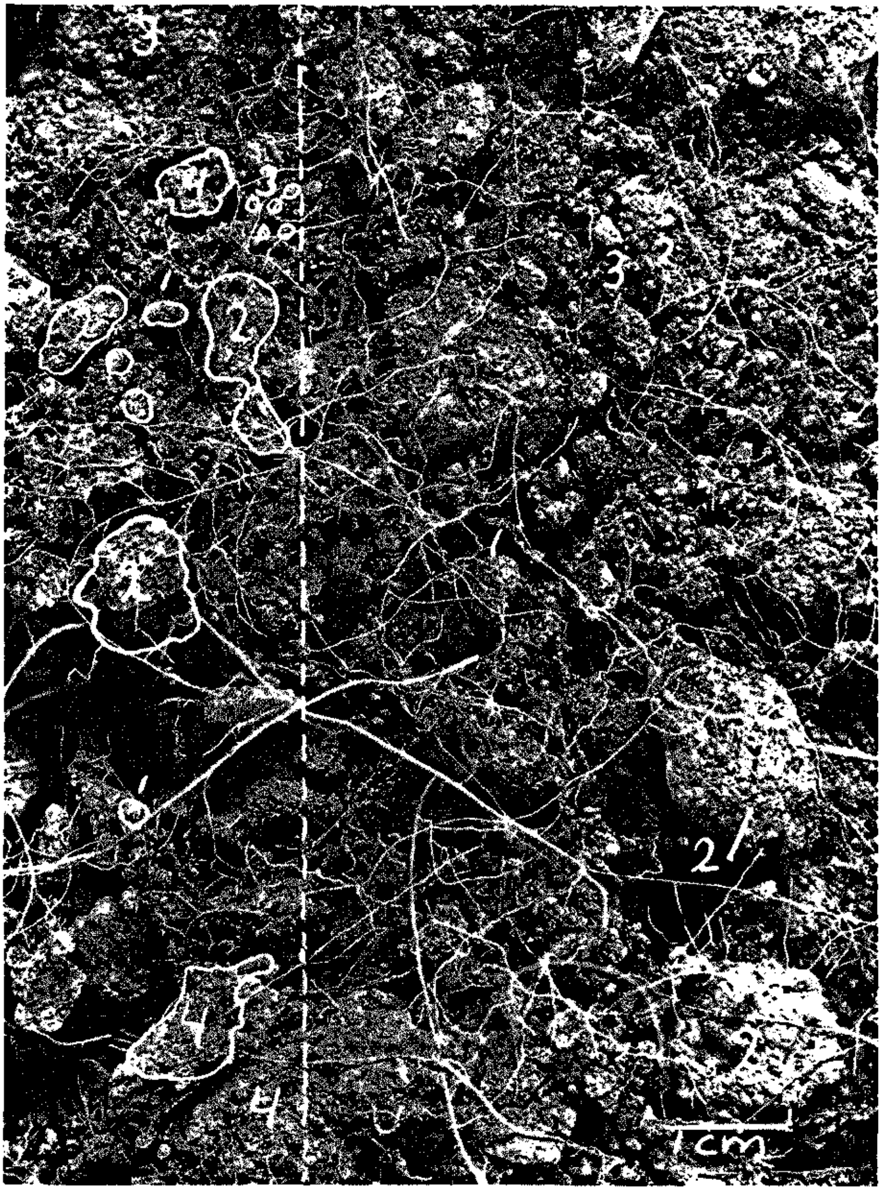
Alkali-affected Steppe Marl Soil

Fig. 41. Peel map of Profile D 3.1.
Şekil 41. Profil D 3.1'e ait monolit haritası, ünite kültüre alınmış Step Marn'ın tuz etkisinde kalmış

Elementary structure of the peel units:

1. abundantly fecal; vughy
2. abundantly collapsed (a) and welded (b) fecal, cutanic; fractured
3. abundantly collapsed fecal; channelled and fractured
4. abundantly collapsed fecal, glaebular; fractured
5. abundantly collapsed fecal, pedotubulic; channelled and fractured
6. pedotubulic, crystallaric; channelled and fractured

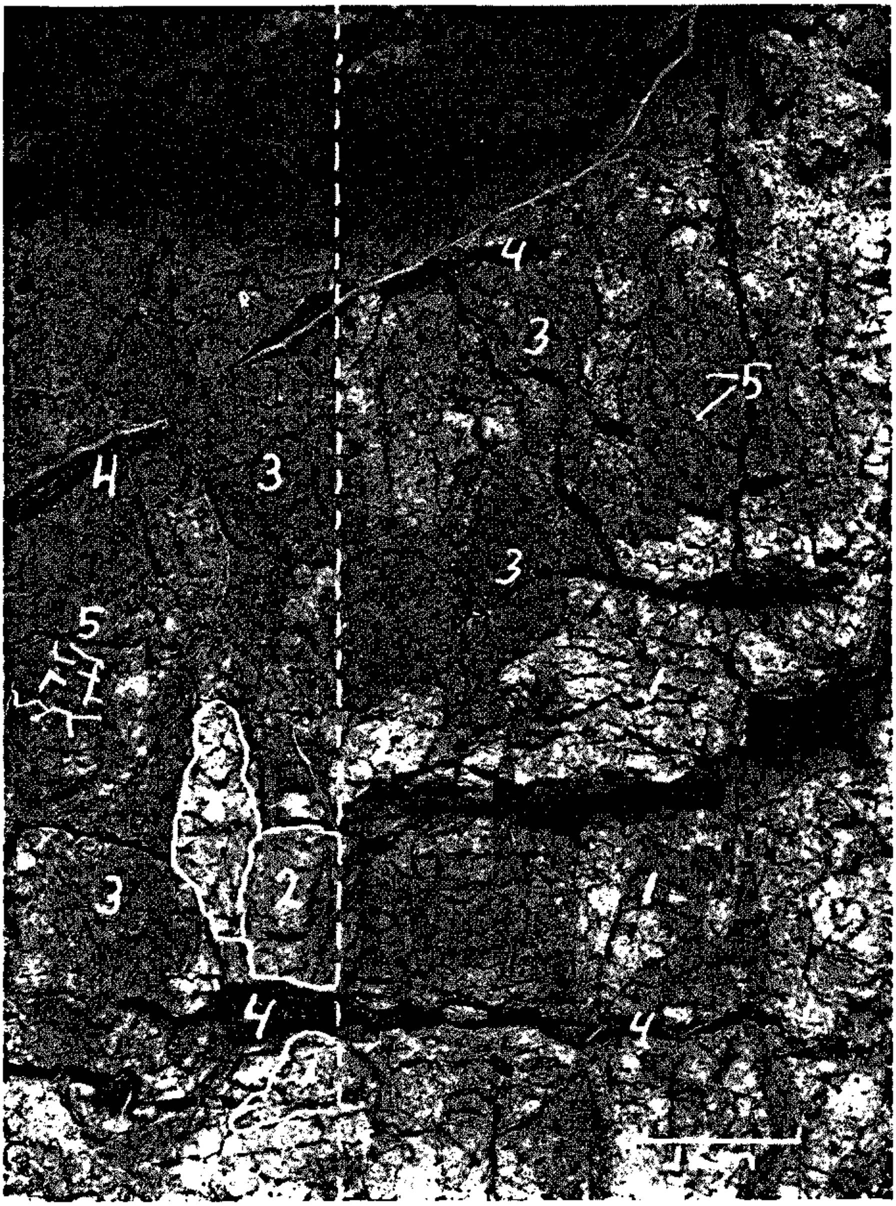
Fig. 42. Sample of Peel Unit 1 from Profile D 3.1.



Şekıl 42. Monolit ünitesi 1'in örneği, profil D 3.1'den.

Pedological and other features:
1 and 2. single (1) and welded (2) coarse fecal pellets with irregular interconnected fine macrovughs
3 and 4. single (3) and welded (4) medium fecal pellets with irregular interconnected very fine macrovughs
Note the abundant roots.

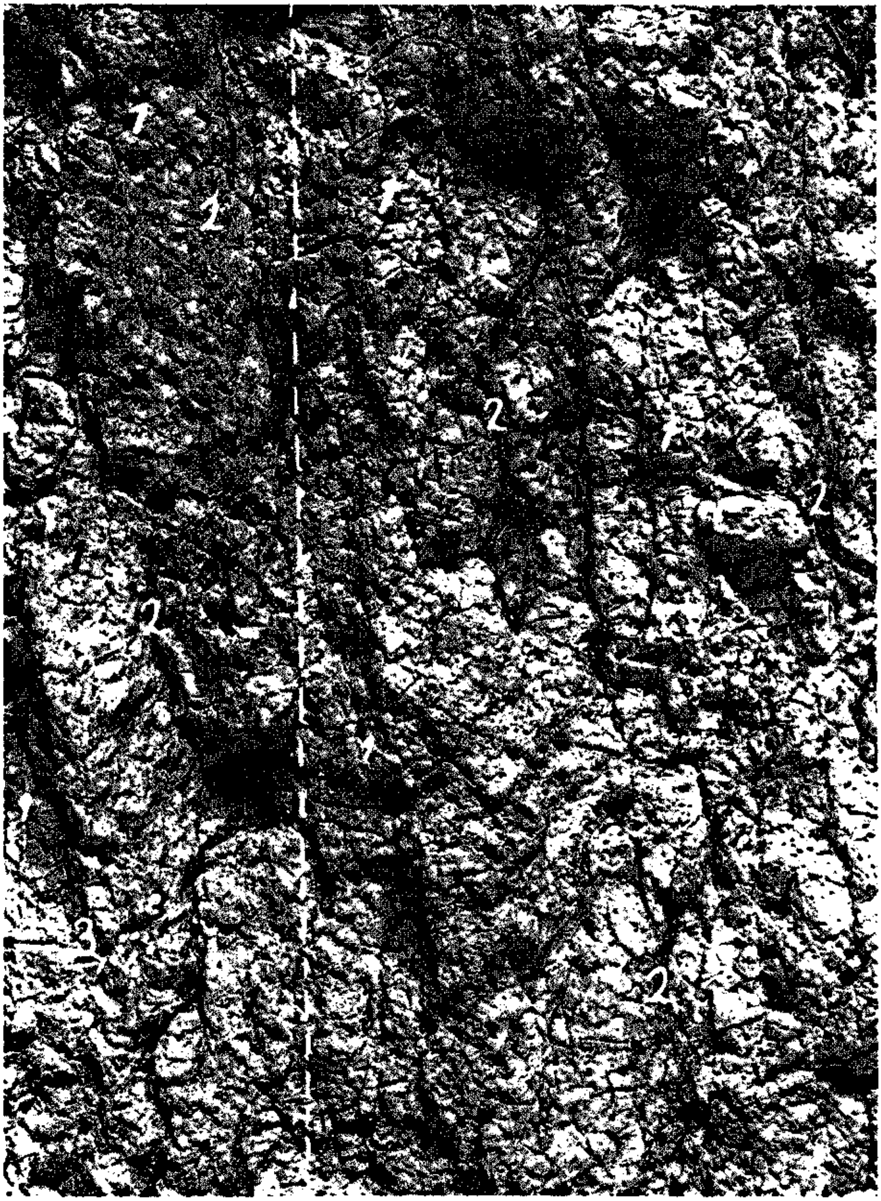
Fig. 43. Sample of Peel Unit 2b from Profile D 3.1.



Şekil 43. Monolit ünitesi 2b'in örneği, profil D 3.1'den.

Pedological and other features:
1. strongly welded coarse fecal pellets
2. collapsed fecal pellets
3. organic ped cutanss (organans)
4. old transpedal root channels, some used for new roots
5. craze planes

Fig. 44. Sample of Peel Unit 5 from Profile D 3.1.



Şekil 44. Monolit ünitesi 3'in örneği, profil D 3.1'den.

Pedological and other features:

1. entirely collapsed fecal pellets forming the primary peds of fine compound prisms
2. fresh aggrotubules of medium fecal pellets along roots
3. macrochannels

The collapse of structure in saline-alkali Steppe Marl Soils is mainly due to a high exchangeable sodium percentage (ESP) which makes clay particles mobile. Biogenic structure tends to become entirely physicogenic with increasing ESP.

In summary, a cultivated internally saline-alkali Steppe Marl Soil is characterized by:

- a collapse of structure without complete loss of its fecality except in the surface soil (ploughed layer)
- a compacted collapsed fecal plough bottom
- a strong fine compound prismatic pedality in all horizons except the surface
- organic cutans on ped faces below the surface soil.

7 Analysis and interpretation of Marsh Marl Soils

Chapters 2 and 3 have explained how Marsh Marl Soils have formed in the lowest areas of the Lacustrine Plain. A high watertable throughout the year, much seepage, and a luxurious marsh vegetation were the important conditions.

The resulting soils have a dark gray surface layer, richer in organic carbon than the Steppe Marl Soils, over white gleyed lacustrine carbonatic clay. Most are slightly salt-affected, but where sufficient water is available for irrigation, they can be cultivated.

7.1 Recently reclaimed Marsh Marl Soils

7.1.1 Description

Until the drop in groundwater due to the control of the River Çarşamba, some 15 years ago, the Marsh Marls in the Hotamış Area could not be reclaimed. A typical profile of the resulting soils in this area is Profile C 2.1, a Typic Haplaquept.

The land is still occasionally flooded. Small parts have been now and then ploughed, and used for the cultivation of wheat.

Figure 45 is the peel map; its legend is in terms of elementary structure. Figure 46, 47 and 48 are more detailed illustrations of peel units 1, 3 and 5 and 6.

Thin sections have been described for peel units 2, 3 and 5. The elementary structures are:

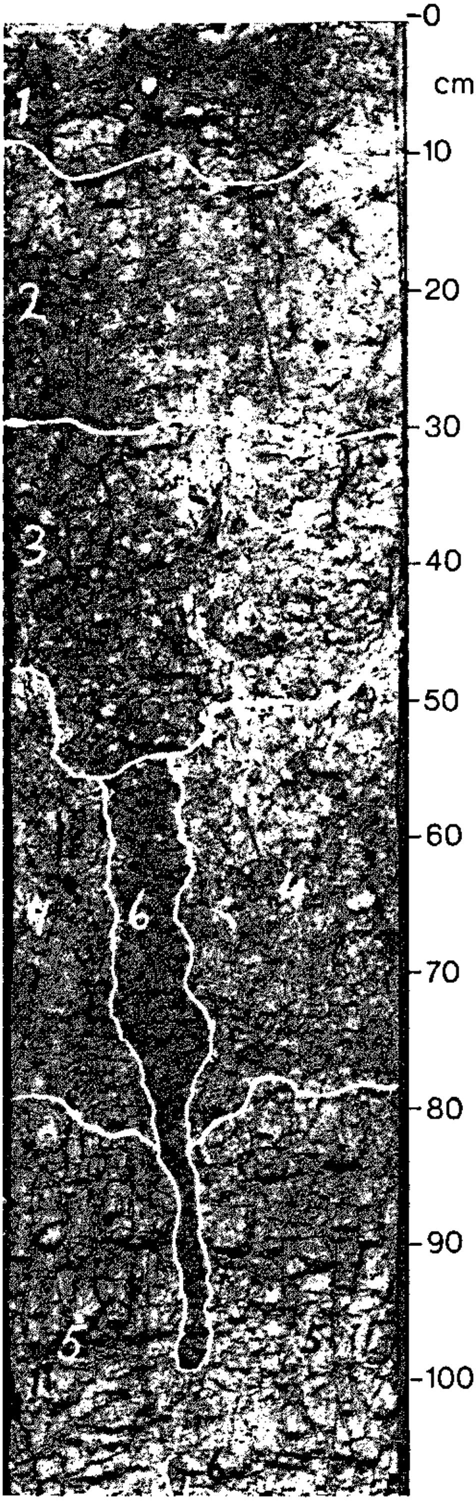
Peel Unit 2: fecal mammilated vughy microfractured loose crystic (common mainly welded medium matric fecal pellets and few fine organic fecal pellets)

Peel Unit 3: pedotubulic vughy crazed crystic loose (few aggrotubules; partly filled with single fecal pellets)

Peel Unit 5: glaebular (humus and iron nodules) crazed crystic dense (few discrete, and common diffuse, dark nodules with small skew planes, filled with crystic fabric and few yellow rather diffuse iron and humus nodules with skew planes filled with crystic fabric).

7.1.2 Interpretation of Profile C 2.1

The field description of Profile C 2.1 (Fig. 13), the peel and the thin sections show that, even in this little disturbed profile, the pellets are all strongly welded or collapsed and part of the soil material is not fecal. Vughs are absent and there are many planes:



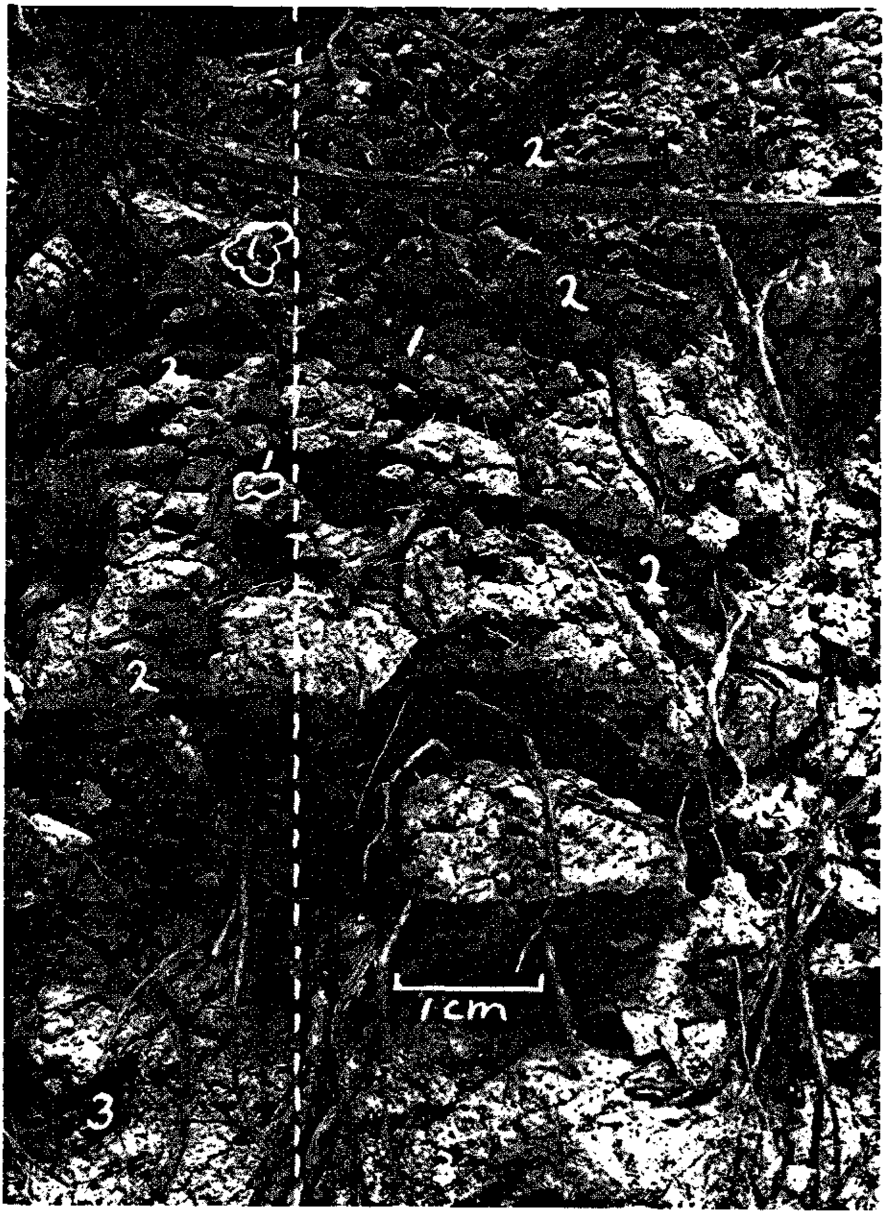
Marsh Marl Soil

Fig. 45. Peel map of Profile C 2.1.
Şekil 45. Profil C 2.1'e ait monolit haritası, ünite Bataklık Marn'dır.

Elementary structure of the peel units:

1. hardly fecal, channelled and jointed
2. mainly welded fecal, glaebular, channelled and skewed
3. mainly collapsed fecal, channelled and skewed
4. mainly collapsed fecal, glaebular
5. non fecal, glaebular, channelled and jointed
6. commonly welded fecal, vughy and channelled

Fig. 46. Sample of Peel Unit 1 from Profile C 2.1.



Şekil 46. Monolit ünitesi 1'in örneği, profil C 2.1'den.

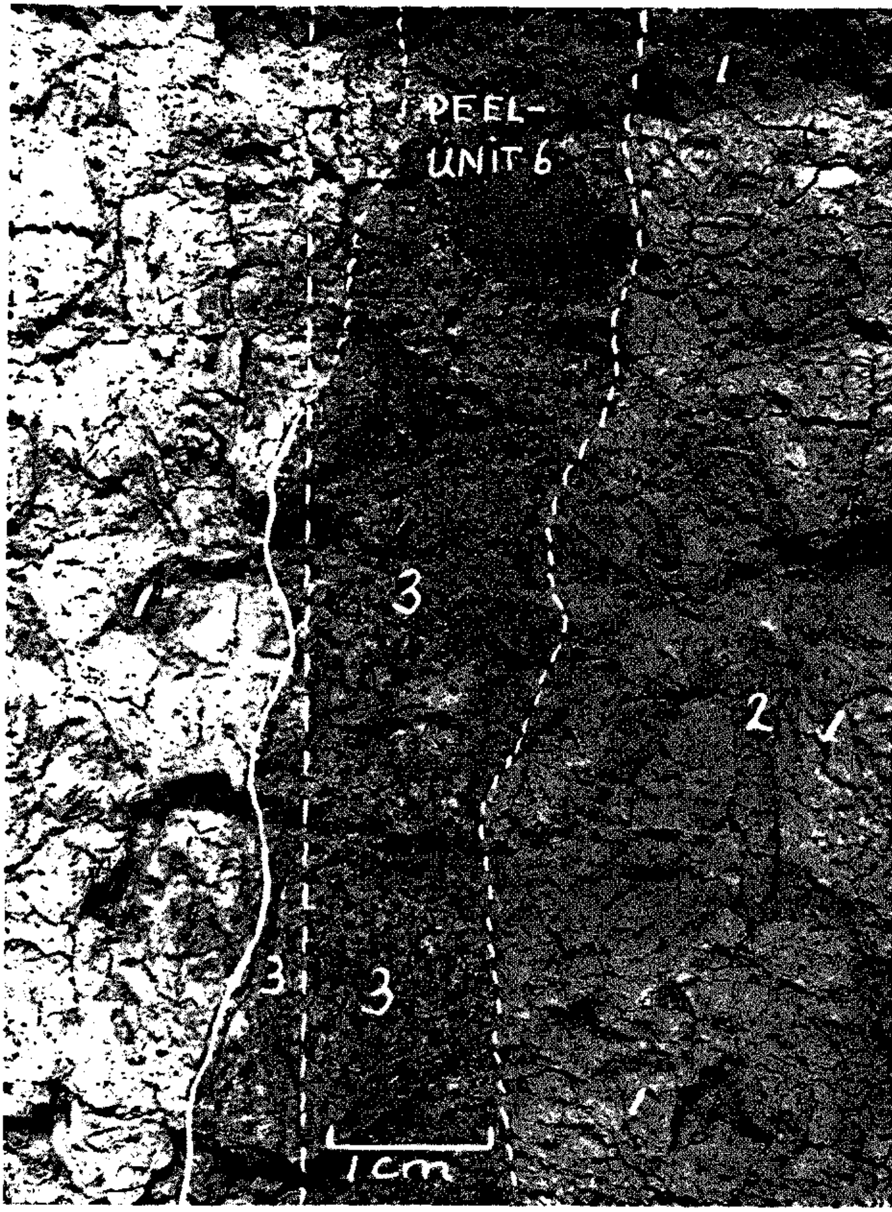
Pedological and other features:
1. welded coarse fecal pellets
2. non-fecal soil material with fine macro-joint-planes
3. welded and strongly welded medium fecal pellets (transition to Peel Unit 2)
Note stratification, and abundance of reed roots.

Fig. 47. Sample of Peel Unit 3 from Profile C 2.1.

Şekil 47. Monolit ünitesi 3'ün örneği, profil C 2.1'den.

1 and 3. collapsed fecal pellets with skew planes (1) and fine macrochannels (3)
2. isochambers (spherical cavities filled with soil material)

Fig. 48. Sample of peel units 5 and 6 from Profile C 2.1.



Şekil 48. Monolit ünitesi 5 ve 6 'in örneği, profil C 2.1'den.

Unit 5:

1. non-fecal soil material with joint and skew planes and fine macrochannels
2. pedotubule with welded fecal pellets
3. welded and strongly welded medium fecal pellets with fine macrovughs and fine macrochannels

the structure is mainly physicogenic, unlike the Virgin Steppe Marl Soils.

Medium fecal pellets are absent or few: therefore earthworms seem now to be little in evidence, perhaps because of annual floods. The absence of pedotubules also indicates little recent worm activity.

Remarkable is the commonness of isochambers in the peel units 2 and 3 .They form part of the primary subangular peds of medium prisms and were presumably formed by animals or plants before reclamation.

Another striking feature in the profile is a large vertical crack, probably a drought-crack, filled with welded fecal pellets (Peel Unit 6) and darkened by organic material Such cracks in the subsoil are distinctive for Marsh Marl Soils, as explained in Chapter 3. The fill of the cracks is derived from the surface and is more biogenic than the surrounding soil. In the subsoil (Peel Unit 4), there are many glaebules in the form of very coarse diffuse iron mottles (nodules). Even in Peel Unit 5 they are common. They formed by oxidation and reduction of free iron when the groundwater used to fluctuate (Chapter 3).

The thin sections confirm the trend in type and number of fecal features and voids observed in the peel, but brings out also a few aggrotubules in Peel Units 2 and 3. Peel Unit 5 contains a few granotubules but they may have once been more numerous, if the clustered skeleton grains of the basic structure, observed in this unit, are the remnants of old granotubules. Such clusters of skeleton grains were occasionally observed in the subsoil of other Marsh Marl Soils.

The channel-calcitans in Peel Unit 3 and the crystal planes (craze planes filled with calcite crystals) in Peel Unit 5 indicate a redistribution of calcium carbonate, although there is no calcic horizon.

Remarkable is the general occurrence of extremely fine dark-gray organic particles in a fine crystic fabric. Dispersed humus causes the colour in this profile, though it has an organic carbon content of about 1%. This dispersed humus is seen also in the thin sections of Peel Unit 5 as diffuse dark fractured nodules with a dappled or streaky appearance.

In summary, Profile C 2.1 is characterized by:
- mainly welded or collapsed fecal pellets
- structure increasingly physicogenic with depth
- few pedotubules
- many isotubules in subsurface soil
- tongues of dark surface soil extending deep into the subsoil (filled cracks)
- very fine dispersed humus particles.

7.2 Irrigated Marsh Marl Soils

7.2.1 Description

West of Karakaya, near the lowest point in the Yarma Depression, lies a large area of Irrigated Marsh Marl Soils. The fields are flood-irrigated once or twice in spring for wheat, lucerne or sugarbeet, and at intervals of three to five years the area is inundated in winter and spring by melting of snow from the mountains. The area has been farmed for over twenty years.

Profile G 1.3, a Mollic Xerochrept, is typical with a deep dark surface soil. The legend of the peel map (Fig. 49) is in terms of elementary structure.

Peel Unit 4 has been selected as a sample section to illustrate details (Fig. 50). The elementary structure, as seen in thin section, is: pedotubulic, vughy, loose crystic fabric (few, very coarse, rather sharp aggrotubules, partly filled with welded fecal pellets and organic material).

7.2.2 Interpretation of Profile G 1.3

The field description and analysis (Fig. 14) indicate an almost salt-free soil with predominantly subangular-blocky peds and an organic carbon content of over 2% in the upper 40 cm.

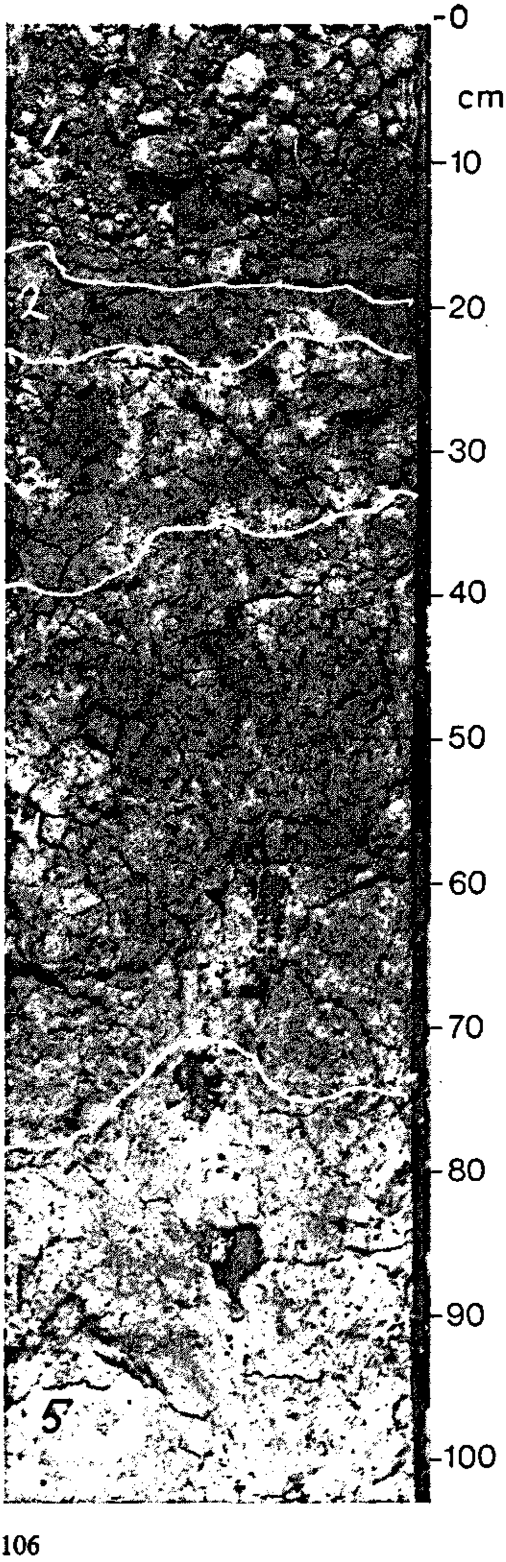
The peel consists almost entirely of welded fecal pellets with a loose plough layer and a compacted collapsed fecal plough bottom. Unlike the Irrigated Steppe Marl Soil of Profile G 1.1, this profile is mainly biogenic. Irrigation has probably encouraged biological activity by washing out soluble salts, and by increasing moisture content. The soil is quite rich in organic carbon, medium fecal pellets are numerous (especially in Peel Units 2 to 5) and aggrotubules are present (as seen in Peel Unit 4). Much of the soil seems to have been reworked from former collapsed coarse fecal pellets into medium fecal, which have welded.

As usual, the subsoil contains diffuse iron nodules.

The pattern and type of voids follows the same trend. Vughs and channels are common or many in almost all peel units. The skew planes (cracks) are all fine macro. In the field more long macroplanes (big cracks) and less short mesoplanes have been observed than in the Steppe Marl Soils, possibly because of a higher content of swelling (smectite-type) clay minerals (van der Plas & Schoorl, 1970).

The thin section of Peel Unit 4 confirms the picture. There is a loose crystic fabric with very fine dark particles of dispersed humus, a feature of the Marsh Marl Soils. The coarse crystic calcite nodules indicate redistribution of calcium carbonates but there is no calcic horizon.

In summary, Profile G 1.3 is characterized by:
- a thick loose plough layer

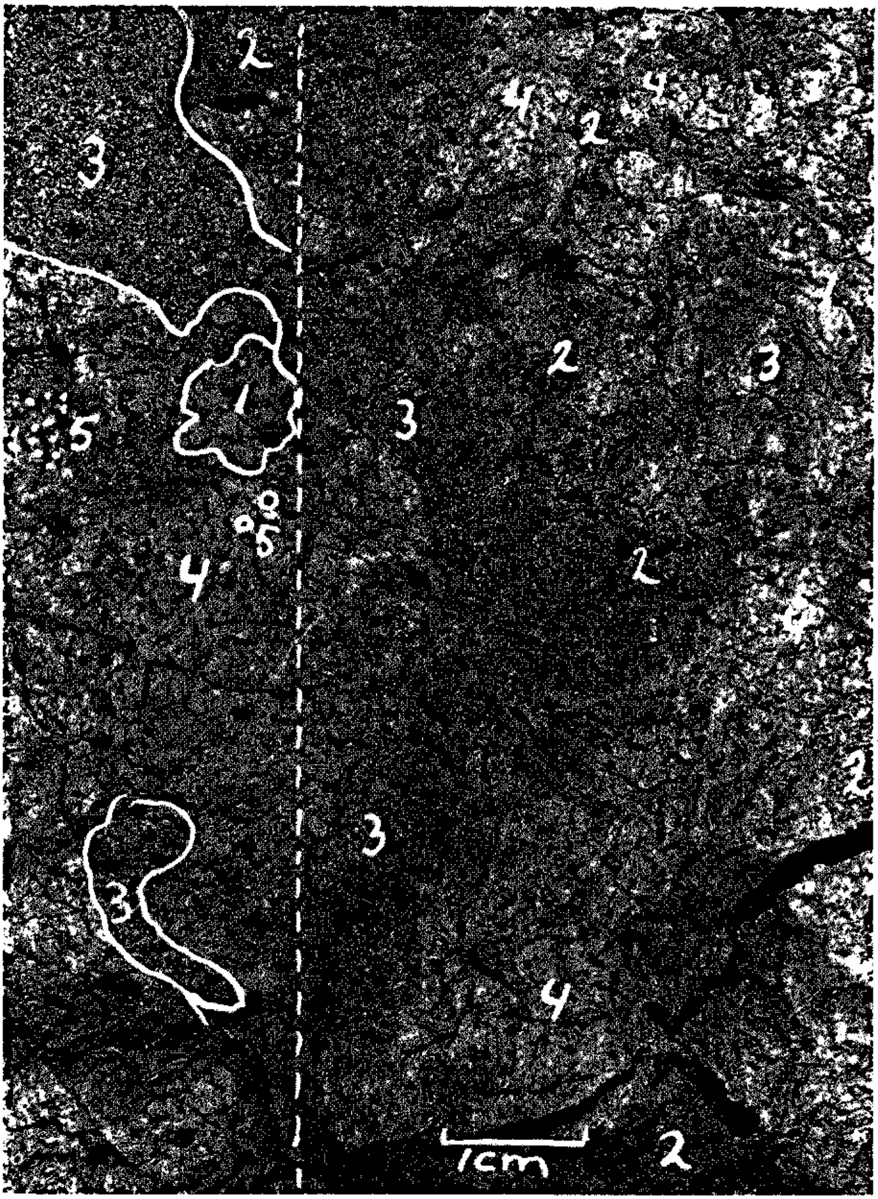


Irrigated Marsh Marl Soil

Fig. 49. Peel Map of Profile G 1.3.
Şekil 49. Profil G 1.3'e ait monolit haritası, ünite sulanmış Bataklık Marn'dır.

Elementary structure of the peel units:
1. abundantly welded fecal; vughy
2. abundantly welded fecal; vughy and fractured
3. commonly collapsed and welded fecal; vughy and fractured
4. commonly collapsed and welded fecal; pedotubulic, vughy, channelled and fractured
5. abundantly welded fecal; vughy, channelled and fractured
6. commonly collapsed fecal; channelled and fractured

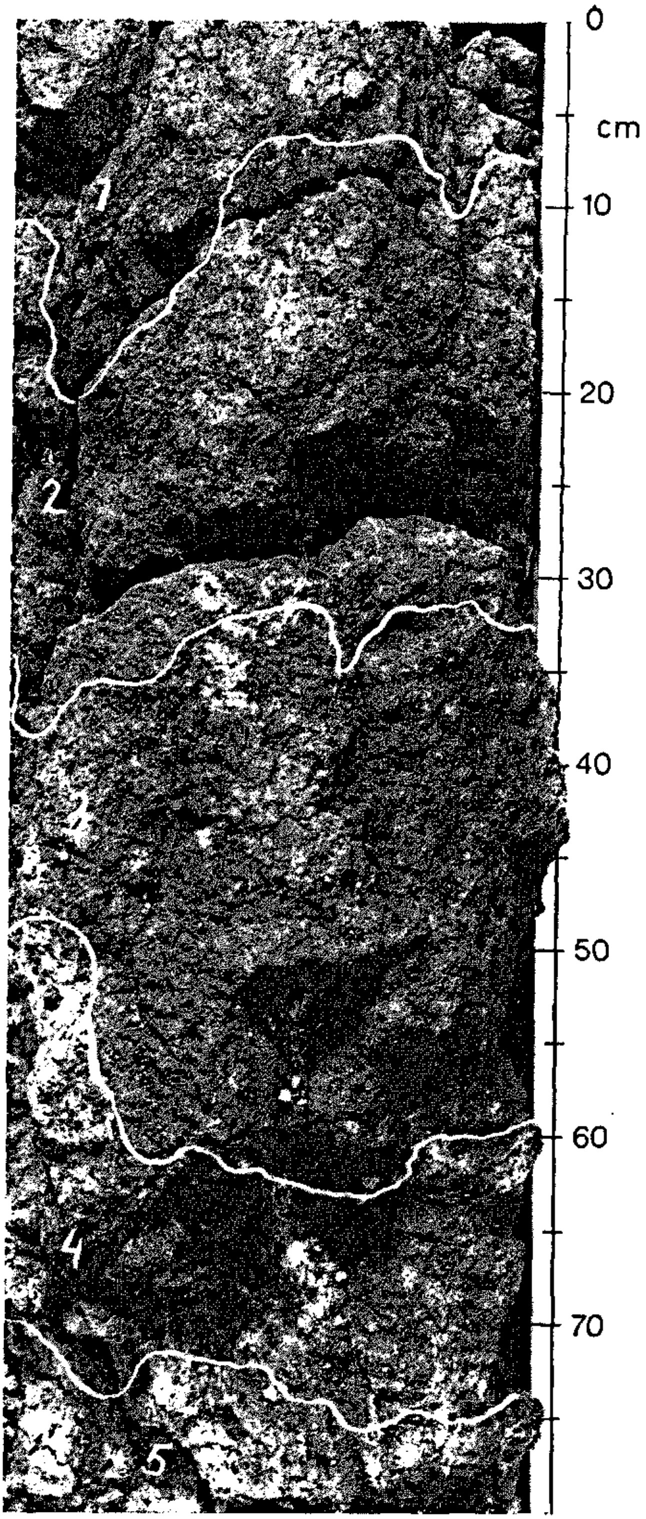
Fig. 50. Sample of Peel Unit 4 from Profile G 1.3.



Şekil 50. Monolit ünitesi 4'ün örneği, Profil G 1.3'den.

Pedological and other features:

1. collapsed coarse fecal pellets
2. welded medium fecal pellets with many fine macrovughs
3. coarse aggrotubules with single and welded medium fecal pellets
4. fine macrochannels
5. medium macrochannals



Basin Marsh Marl Soil

Fig. 51. Peel map of Profile C 2.3.

Şekil 51. Profil C 2.3'e ait monolit haritası, ünite Çukur Bataklık Marn'dır.

Elementary structure of the peel units:

1. mainly welded and collapsed coarse fecal, channelled
2. mainly welded coarse fecal, channelled and crazed
3. mainly collapsed coarse fecal, channelled and crazed
4. channelled and crazed
5. channelled

- a slightly compacted plough bottom
- a predominantly biogenic structure due to reworking by worms
- numerous aggrotubules in the subsurface soil and subsoil
- a coarser pattern of cracks than in Steppe Marl Soils.

7.3 Basin Marsh Marl Soils

7.3.1 Description

A small part of the Hotamış Area and the Yarma Area form transitions between the Marsh Marl Soils and Backswamp Soils. They have deep black soils quite rich in smectite-type clay. They are often flooded and are permanently affected by sodium salts, so that they have very coarse prismatic peds and a loose fine angular-blocky surface soil. The structure of the white carbonatic clay subsoil is normal for Marsh Marl Soils. They are used for irrigated or dry-farmed wheat.

Profile C 2.3, a Cumulic Haplaquoll, is typical. The peel-analysis is in Fig. 51. The elementary structure of thin sections from surface and subsoil is:
Peel Unit 2: channelled dense crystic fabric
Peel Unit 3: channelled and crazed loose crystic fabric.

7.3.2 Interpretation of Profile C 2.3

In the field (Fig. 18) very coarse prismatic peds and wide cracks were seen and the thin sections indicate an entirely collapsed and non-fecal soil material in the surface soil. This entirely physicogenic structure is a result of smectite-type clay in the dark upper 70 cm, which makes the soil swell and shrink with changes in moisture content. There are, however, no slickensides.

In summary, the structure of Profile C 2.3 is characterized by:
- a compacted and non-fecal surface soil
- coarse prismatic peds
- wide cracks in the surface soil
- a collapsed fecal subsoil

8 Analysis and interpretation of Playa Marl Soils

East and North of the sand dunes of Karapınar the depressions have extremely salt-affected Marl Soils, called Playa Marls. Most are the result of sedimentation of local wash and recent precipitation from solution (Chap. 9).

Two entirely different soils, situated close together, have been selected for discussion: one normal and one granular.

8.1 Playa Marl Soils

8.1.1 Description

The normal Playa Marl Soils occur on the floor of a saline depression and carry no vegetation. The upper part of the profile consists of thin layers of carbonatic clay, often becoming flaky after drying before new sediment covers them. They are flooded in winter and spring, and then are often non-saline, but they soon dry and become covered with a salt crust.

Profile E 1.1, a Typic Halaquept, is typical, although it was only moderately salt-affected in the subsoil when sampled.

Soil conditions prevented the preparation of a soil peel, but hand specimens have revealed that the soil material was entirely non-fecal with no other pedological features and no intrapedal voids.

Figure 52 shows a smooth strong compound platy prismatic ped from the subsoil.

Thin sections at depth of 8 cm and 90 cm have been described.

In the surface soil the basic structure is granular; the abundant skeleton grains are mixed with crystic nodules and have a banded distribution. In the subsoil the elementary structure is pedotubulic, crazed and channelled dense crystic fabric.

8.1.2 Interpretation of Profile E 1.1

Strong saline-alkali conditions for most of the year, alternating erosion and sedimentation and the absence of vegetation make the soil extremely compact. The surface soil consists of thin layers (Fig. 21), and layers differ in compactness rather than in grainsize. Remarkable is the number of fine crystic nodules, which presumably are from crushed clayflakes. The channels and rootprints on the smooth prismatic peds are not recent.

Fig. 52. Smooth single prism from a Playa Marl Soil (100 cm deep in Profile E 1.1). Compare with pedality of the nearby E 1.3 in Figure 64.

Şekil 52. Playa Marn'a ait düz tek prizma elementi, Profil E 1.1'den (100 cm derinlikte). Yanındaki E 1.3 profili ile pedaliteyi mukayese ediniz.

In summary, the structure of Profile E 1.1 is characterized by:
- a thinly layered surface soil
- a compacted subsoil with strong smooth single prismatic peds.

8.2 Granular Playa Marl Soils

8.2.1 Description

North of the central playa of the Ak Göl Depression deep granular Marl Soils and prismatic Marl Soils occur in an intricate pattern correlated with microrelief.

Both are strongly saline-alkali affected.

Although such soils are rare in the Lacustrine Plain, their morphology and genesis are interesting and are therefore described in full. Profile E 1.3, an Typic Salorthid, is typical.

Its peel map is in Figure 53; its legend is in terms of elementary structure. For reasons below, the granules are here of geogenic origin and the elementary structure of a pellet-rich unit is therefore 'pseudofecal'. A sample section (Fig. 54) illustrates Peel Unit 6.

Descriptions have been made of thin sections from Peel Units 3 and 6. The elementary structure of unit 3 is vughy and crazed dense crystic. Unit 6 consists of single pellets with a crazed and dense crystic elementary structure (Fig. 55). Several pellets have ped-neostrians (orientation of the crystic fabric at the surface of the pellets).

8.2.2 Interpretation of Profile E 1.3

In the field, Profile E 1.3 was angular-blocky and prismatic in the surface soil, granular in the subsoil (Fig. 23).

Units 1, 2 and 3 of the peel (to a depth of about 25 cm) are similar in pedological features and voids to a saline-alkali Steppe Marl Soil: there are welded and collapsed fecal pellets and, in unit 2, aggrotubules. Thus worms are active.

Units 4, 5 and 6, however, are peculiar: the soil material consists entirely of pellets, mostly single but locally some welded rounded and subrounded medium and coarse pellets. Superficially they look like the fecal pellets of the Steppe Marl Soils, but they are not of faunal origin, because

a. unlike those in Steppe Marl Soils, they become less welded with depth (Peel Unit 6 contains only single pellets)

b. there are no signs of worms, such as pellet clusters, aggrotubules or aggrochambers

c. medium and coarse pellets are mixed at random and do not occur in vertical tongues as often observed in other Marl Soils

d. many coarse pellets have a compact crust (fecal pellets never have).

In summary, Profile E 1.3 is characterized by:

- a prismatic hardly fecal surface soil
- a subsoil entirely of geogenic single pellets of all sizes between 3000 and 50 μm.

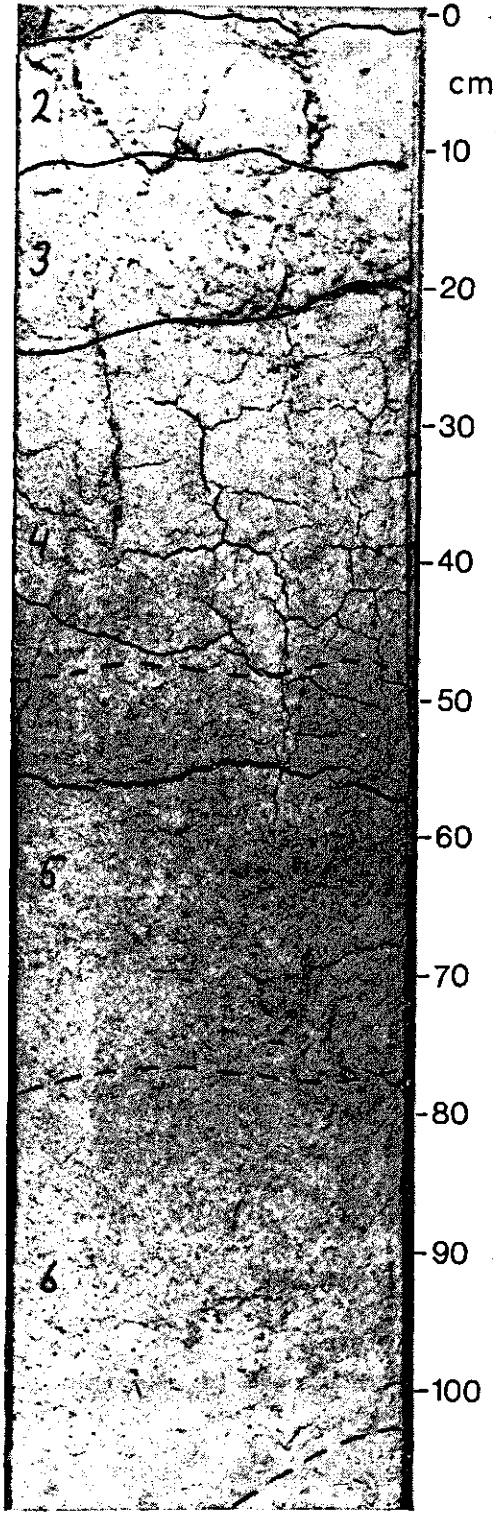
8.2.3 Soil formation

The Granular Playa Marl soil may have formed from windblown salty carbonatic clay grains, derived from flakes left on the surface of playas when the water has dried up. This supposition is supported by the following facts:

a. the area with Granular Marl Soils is north of the Ak Göl Depression and the shifting sands near Karapınar also move north.

b. the size distribution of the pellets is characteristic of a windblown deposit (*Fig. 56*).

c. many pellets have a compact surface, which could have formed during transport.

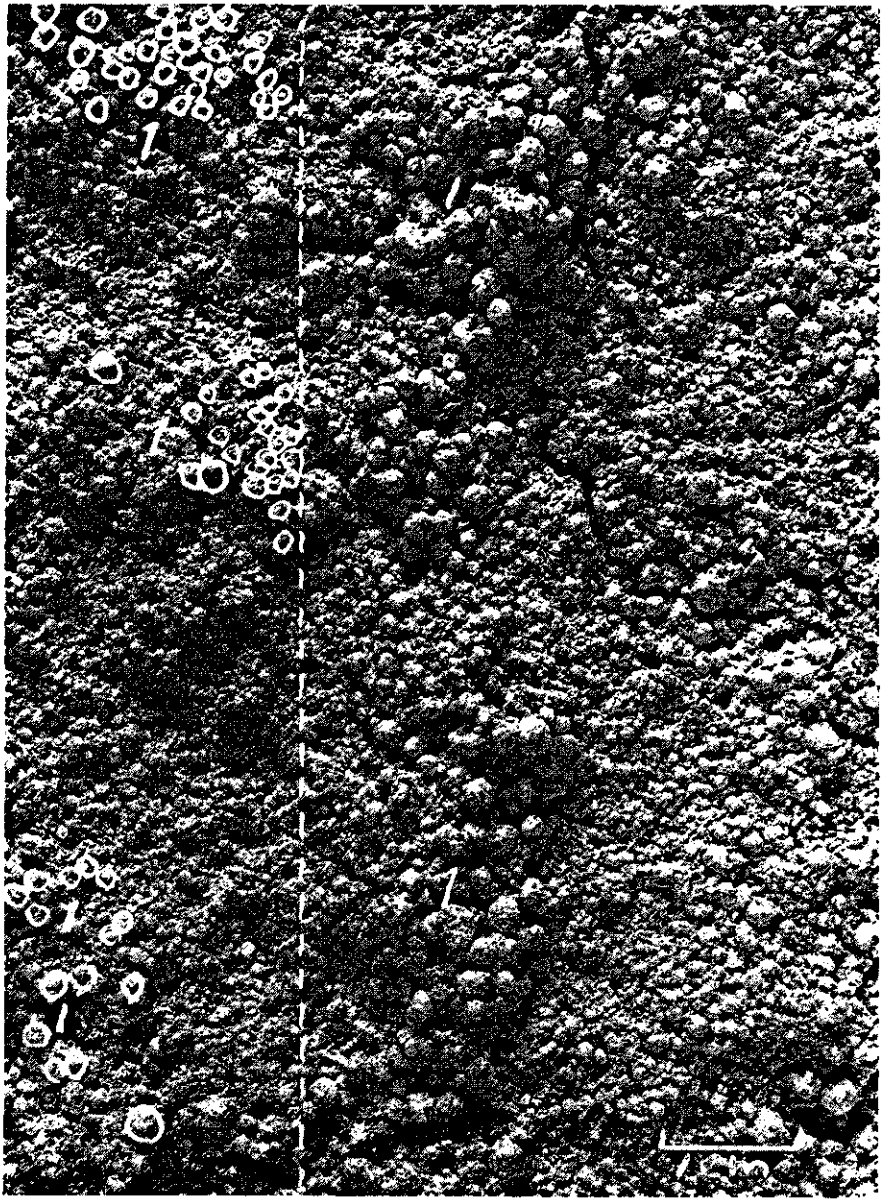


Granular Steppe Marl Soil

Fig. 53. Peel Map of Profile E 1.3.
Şekil 53. Profil E 1.3'e ait monolit haritası, ünite Granüler Step Marn'dır.

Elementary structure of the peel units:
1. commonly collapsed and welded fecal; jointed
2. mainly collapsed fecal: channelled
3. mainly welded fecal; vughy
4. abundantly single pseudofecal; vughy
5. abundantly single pseudofecal; vughy and fractured
6 and 7. entirely single pseudofecal and vughy

Fig. 54. Sample of Peel Unit 6 from Profile E 1.3.

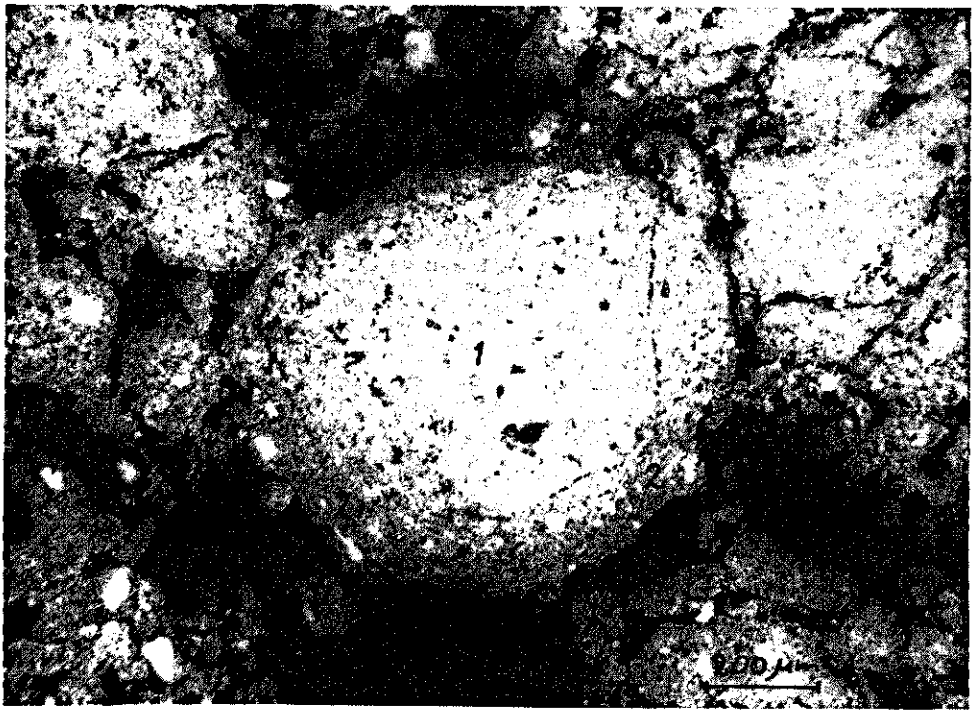


Şekil 54. Monolit ünitesi 7'nin örneği, profil E 1.3'den.

Pedological and other features:

1. single, medium and coarse subrounded pseudofecal pellets with irregular fine macrovughs

Fig. 55. Thin section of Peel Unit 6 from Profile E 1.3. Pellet (1) with ped neostrian (2). (3) is void. Photographed with polarized light.



Şekil 55. Profil E 1.3'e ait monolit ünitesi 6'nın ince kesiti.

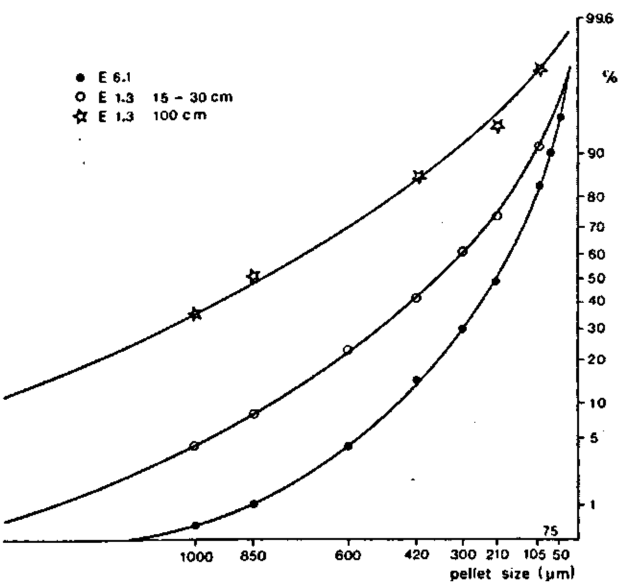


Fig. 56. Size distribution of pseudofecal pellets from some Granular Marl Soils.

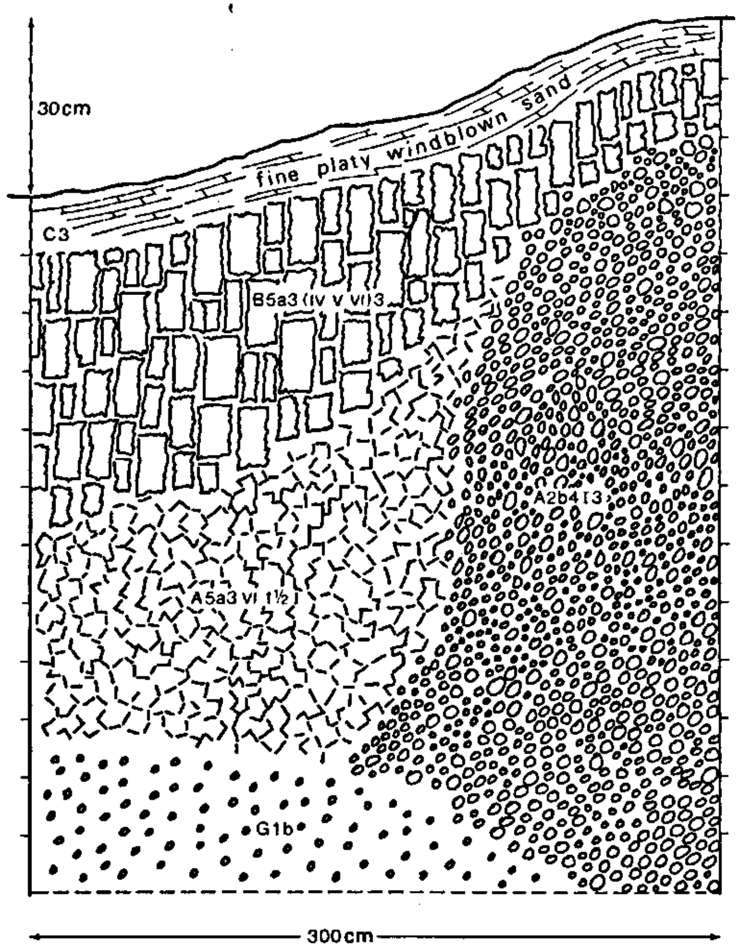
Şekil 56. Yalancı hayvan artiklarının parça büyüklüğü dağılımı.

8.2.4 Soil pattern

The Granular Marl Soils alternate with the Prismatic Marl Soils in a regular pattern, obviously related to microrelief. To study this peculiar phenomenon, a trench was dug at site E 6.1 across an elevation and adjacent depression. A continuous structural diagram of this transect has been drawn (Fig. 57). The sudden change, within three metres, from deep almost entirely granular soil to deep almost entirely prismatic soil can be explained as follows:

The pseudosand was deposited, not long ago, during a drier period. Since then its

Fig. 57. Structural diagram of a section between a depression and an elevation at site E 6.1.



Şekil 57. E. 6.1 numara ile işaretedilmiş yer de çukur ve tümsek arasında şematik olarak gösterilen struktur diyagramı.

Table 7. Some chemical data on Granular Playa Marl Soils from slight elevations (A) and in slight depressions (B).

	Depth (cm)	EC_e (mmho/cm)		pH paste		% $CaCO_3$ equiv.	
		A	B	A	B	A	B
Site E 6.1	0- 10	21.0	1.72	8.2	8.2	50	55
	20- 30	42.8	1.51	8.4	8.4	57	61
	50- 60	58.0	6.81	8.4	8.6	59	54
	80- 90	64.0	24.8	8.4	8.7	57	60
	110-120	56.2	31.8	8.5	8.6	60	60
Site E 1B	20- 30	29.6	1.80				
	80- 90	46.6	26.6				
Site E 1C	20- 30	31.8	0.43				
	80- 90	44.6	8.21				
Site E 6D	20- 30	41.8	0.72				
	80- 90	62.0	16.6				
Site E 6E	20- 30	36.0	1.22				
	80- 90	68.0	3.70				
Site E 6F	20- 30	46.2	11.8				
	80- 90	66.0	1.14				

Tablo 7. Mikrorölief'le (A tümsekler, B çukurlar) ilgili olarak Marn Topraklara ait analiz kayıtları.

microrelief has been stabilized by an increase in precipitation, presumably causing a surface crust to form and some vegetation to grow. The rain, not exceeding the present annual 200 to 300 mm, collected in depressions but wetted the elevations only superficially. Thus partly because of their salinity, the granular structure of hillocks was preserved. In depressions, soluble salts were leached out and the pellets collapsed into prismatic peds.

To check this view, salinity was estimated on ten nearby sites. The results (Table 7) confirm the hypothesis.

9 Mechanical and mineralogical composition of Marl Soils

Before the Chapter on suitability of Marl Soils for agriculture (Chap. 10) their mechanical and mineralogical composition must be described to explain how they have been deposited.

9.1 Mechanical analysis

The plasmic structure of the Marl Soils, as described in chapters 6 to 8, is mainly porphyroskelic with a fine or very fine crystic plasmic fabric. Skeleton grains are few, at random in the plasma. Hard calcareous nodules and many shell fragments of all sizes are also present. The calcium carbonate equivalent ranges between 30 and 70%.

A mechanical analysis of such soil material can be made of the whole soil or of the non-calcareous part only. The choice depends on the purpose of the analysis, but both present some difficulties.

In mechanical analysis, dispersion of the primary soil particles may be hindered by organic matter (which can be removed by oxidation with H_2O_2) and by calcareous cementation. If the carbonates are not to be removed, Deb (internal FAO-report 1963) recommends for calcareous soils the use of sodium tripolyphosphate, $(NaPO_3)_6$, even for salt-affected soils. Van Baren en Van Schuylenborgh (pers. comm.) use sodium pyrophosphate, $Na_2P_2O_3$, for this purpose with good results. For Marl Soils I have found that simple stirring is as effective as 30 minutes in a 500 Watt ultrasonic generator (Table 8), provided that sodium phosphate is added before or afterwards to keep the particles dispersed for several days. Gypsiferous samples have first to be washed with water of about 40° C to remove all calcium sulphate.

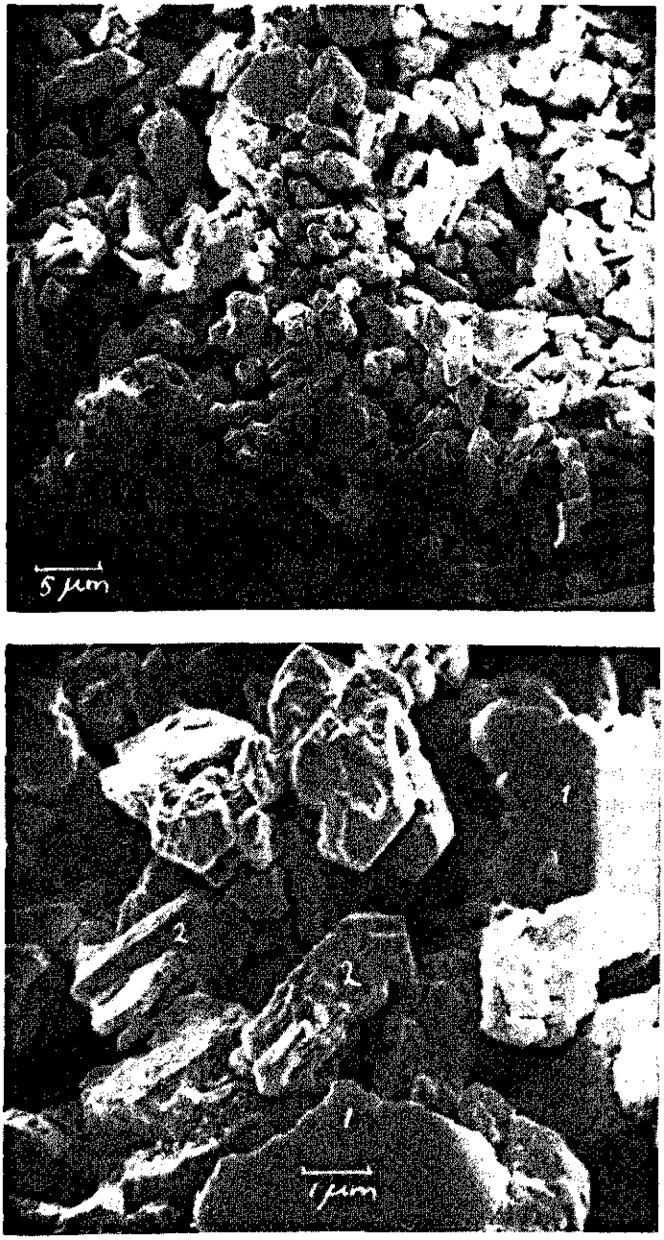
The separation of the fractions by sieving or settling introduces a serious error

Table 8. Grain-size distributions in percentage of total sample of a Steppe Marl Soil (Profile A 1.1, layer 58-102 cm) after dispersion by different treatments ($CaCO_3$ equivalent 64.7%).

	50-2000 μm	32-50 μm	16-32 μm	8-16 μm	2-8 μm	< 2 μm
Stirring 2 h	0.9	0.8	3.3	6.1	34.1	54.8
Ultrasonic vibration 3 min	1.0	4.6	4.1	1.8	33.9	54.6
Ultrasonic vibration 30 min	0.8	3.1	2.6	7.1	30.6	55.8

Tablo 8. Bir Step Marn Toprak örneğinde, (profil A 1.1, 58-102 cm) dispersiyon için çeşitli muamelelerden sonra, tane büyüklükleri dağılımı. $CaCO_3$ ekivalanı % 64.7'dir.

Fig. 58. Scanning electron micrographs of the size fraction 2-8 μm from 105 cm deep in Profile E 3.1. The material consists of clay micelles (1) and carbonate crystals (2). (Photographs by courtesy of Mr S. Henstra with JSM 2.)



Şekil 58. Marn Toprağı'nın 2-8 mu çapındaki tanelerinin elektron mikroskop fotoğrafı. Materyal kil miselleri (1) ve karbonat kristallerindan (2) ibarettir (Fotograf JSM 2 ile 1969 yılında Paris'te S. Henstra tarafından alınmıştır).

because carbonate grains and non-carbonate grains differ widely in shape and density: the sand fraction contains elongated shell fragments and rounded material, the clay and silt fractions contain carbonate crystals and clay micelles (Fig. 58).

For mechanical analysis of the non-calcareous part of a soil, the carbonates are usually removed with cold diluted hydrochloric acid (Diagnosis, 1954). This treatment is insufficient to get rid of hard calcareous nodules, especially those of dolomite, but heating causes serious damage to the minerals (Ruellan, 1970).

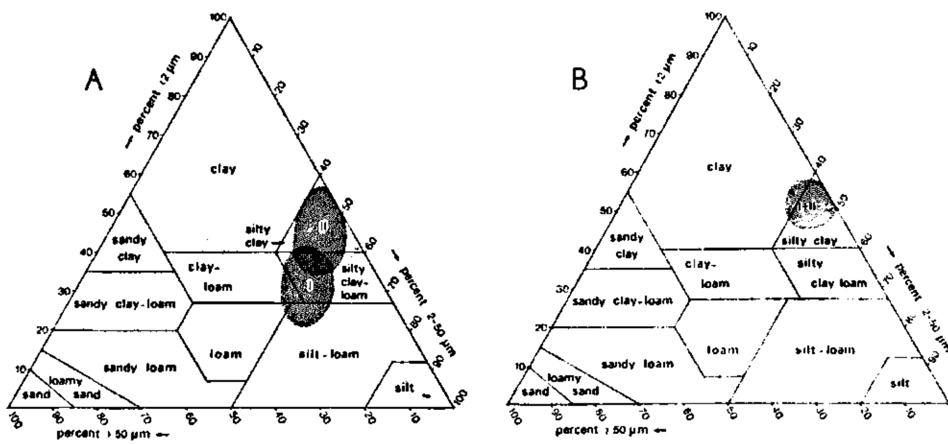
All this leads inevitably to errors, so that a grain-size analysis of Marl Soils as such is difficult to interprete.

9.2 Grain-size distributions

The grain-size distribution in surface soil and subsoil was determined in some 70 Steppe Marl and Marsh Marl samples. Figures 59A and B show that the texture without removal of carbonate is mainly silty clay, which confirms the field assessment. The results also show that the texture in the surface of Steppe Marl Soils is slightly coarser than in the subsoil, which is explained by removal of the clay and silt fractions by wind. There is hardly any difference between surface and subsoil in Marsh Marl Soils, because they are mostly moist.

The difference in texture of Marl Soils before and after removal of carbonates is given in Figure 60. There was an average increase of about 25 percentage units in clay and a decrease of about 20 percentage units in silt and a decrease of 5 percentage units in the sand fraction.

Fig. 59. Texture of surface soil (I) and subsoil (II)
A – Steppe Marl Soils (50 samples from 12 profiles)
B – Marsh Marl Soils (20 samples from 4 profiles).



Şekil 59. Marn Toprakların yüzey (I) ve alt (II) topraklarında toprak teksturu.
A-Step Marn Toprakları (12 profilden 50 örnek).
B-Bataklık Marn Toprakları (4 profilden 20 örnek).

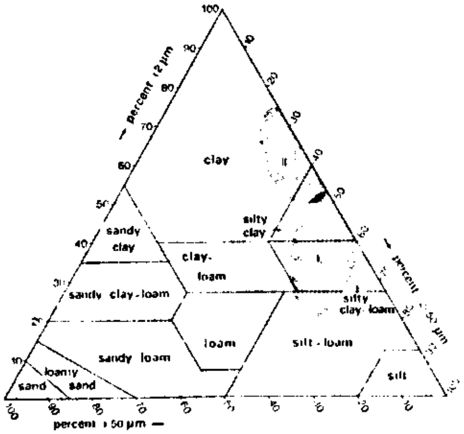
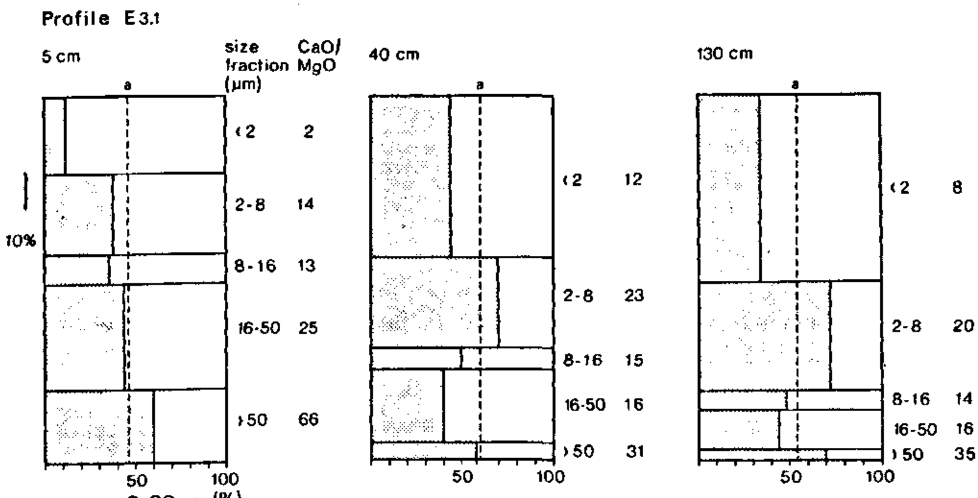


Fig. 60. Texture of Marl Soils before (I) and after (II) removal of carbonates (30 samples).

Şekil 60. Karbonatları giderilmeden (I) ve giderildikten sonra (II) Marn Topraklarda tekstur (30 örnek).



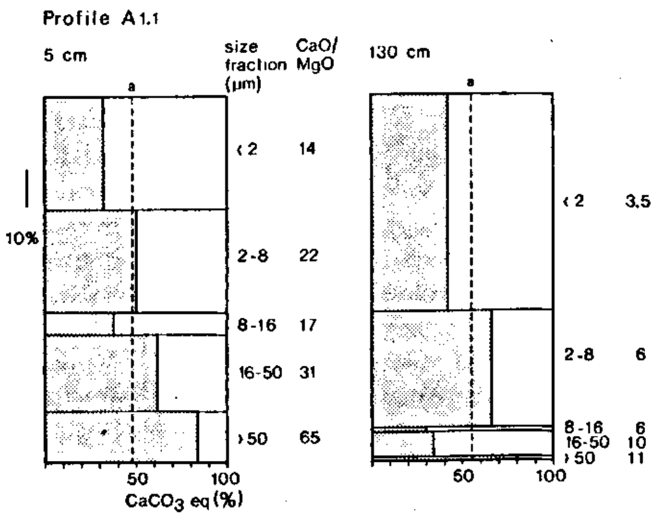


Fig. 61. Percentage of calcium carbonate equivalent per size fraction in 5 samples from 2 Marl Soils. Dotted line (a) is percentage calcium carbonate equivalent in whole sample.

Şekil 61. 8 Marn Toprağı örneğinde beher tane büyüklüğüne düşen kalsiyum karbonat ekivalan yüzdeleri. Noktalı çizgi (a) bütün örneğin kalsiyum karbonat yüzdesidir.

Table 9. Non-carbonate components in Marl Soil fractions (Profile E 3.1).

Depth (cm)	Particle size in Marl Soil fraction	Percentage particle-size distribution in non-carbonate fraction		
		8-50 μm	2-8 μm	< 2 μm
0- 5	2- 8	–	58.5	41.5
105-170	2- 8	–	86.1	13.9
0- 5	16-50	100.0	0.0	0.0
105-170	16-50	84.0	2.7	13.3

Tablo 9. Marn Toprağın da, kireçsiz büyüklük dağılımı (profil E 3.1).

The distribution of the carbonates over various grain-size fractions by Atterberg's method is shown in more detail in Figure 61; a rectangle represents a full sample. The percentages are expressed in calcium carbonate equivalent. The CaO/MgO relation has been added for each fraction for further information on the composition of the carbonates. The data show that the carbonate content in the clay fraction ranges from 12 to 43%, in the silt fraction from 26 to 70% (with more than average in the fraction 2-8 μm) and in the sand fraction from 24 to 76%. The calcium carbonate equivalent of the soil is not the calculated average of all fractions, but has been determined on the full sample. Differences are within the experimental error.

The carbonate parts of the fractions may contain grains with smaller non-calcareous particles which should be added to the non-carbonate fractions. Table 9 shows, however, that the amounts vary considerably. Because the samples have been too small to obtain very accurate data, no corrections have been made in the totals per fraction.

9.3 Carbonate minerals

In the previous chapter, the carbonate part of the Marl Soils, consisting of calcium and magnesium carbonates, has been expressed in calcium carbonate equivalent. The CaO/MgO relation in Figure 61 shows that calcium carbonate predominates.

In addition, X-ray diffractograms have been made of 18 samples from six representative Marl Soils (Chapter 3) to obtain some semiquantitative information on calcite, dolomite and aragonite in the carbonate minerals. Table 10 shows that almost all samples contain at least 85% calcite; the rest is dolomite. The calcite-dolomite relation as assessed by X-ray diffractograms seems higher than as estimated by chemical analysis. This could be caused by the presence of magnesium calcite or even Huntite, of which indications are found in the X-ray analysis of several samples (van der Plas, pers. comm.). A few samples have less calcite and some aragonite, apparently from aragonite-bearing shells of *Dreissena*.

In the clay, silt and sand fractions separately, no carbonate minerals have been

Table 10. Carbonate minerals in the carbonate part of Marl Soils derived from Guinier de Wolff diffractograms. The relation CaO/MgO is added for comparison.

Sample No	Profile	Depth (cm)	Calcite (%)	Dolomite (%)	Aragonite (%)	CaO/MgO	$CaCO_3$ equiv. (%)
1	A 11	20- 32	about 90	about 10		6.5	67.5
2		40- 58	about 90	about 10		6.2	74.7
3		102-148	80-90	10-20			59.4
4	E 31	0- 5	> 95	< 5		10.8	45.9
5		30- 52	> 95	< 5		11.3	59.0
6		105-170	> 95	< 5		12.4	44.6
7	D 31	0-17	> 95	< 5		13.8	38.2
8		21- 45	> 95	< 5		10.0	48.5
9		90-140	> 95	< 5		11.0	42.3
10	G 1.3	0- 25	> 95	< 5		12.9	59.0
11		35- 80	> 95	< 5		12.1	50.0
12		80-120	> 95	< 5		10.5	75.8
13	C 2.3	0- 10	> 95	< 5		6.2	41.2
14		55- 80	> 95	< 5		10.0	37.8
15		80-120	about 95	about 5		20.0	54.3
16	E 1.3	0- 5	about 85	about 10	< 5	7.8	61.8
17		15- 30	about 75	10-20	< 5	4.6	59.6
18		30-100	about 75	10-20	< 5	4.2	57.7

Tablo 10. Tahmini olarak ve Guinier-De Wolf difraktogramlarından türetilen, Marn Toprakların karbonatlı kısımlarında karbonat mineralleri. CaO/MgO oranları mukayese için ilave edilmiştir.

estimated. But differences may be expected, as morphological studies have revealed that the silt and sand fractions contain more shell fragments than the clay, whilst the clay and fine silt fractions mainly consist of chemically precipitated carbonate crystals (Section 9.5).

9.4 Non-carbonate minerals

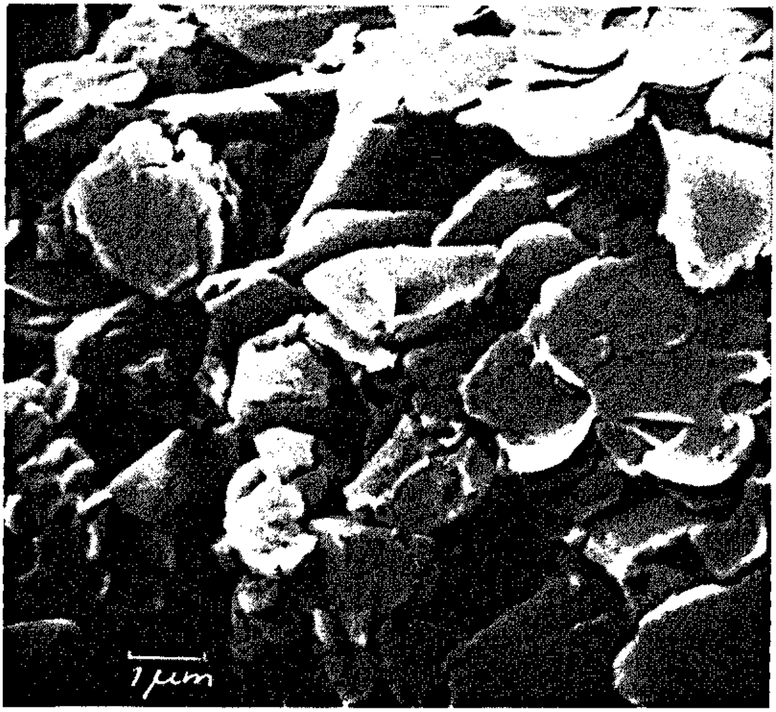
9.4.1 Clay minerals

The clay fraction of the non-calcareous part of the 18 samples mentioned above was obtained in two ways:
Series B: by separating the clay fraction and then treating it with acid,
Series C: by treating the whole soil with acid and then separating the clay fraction.

Series B contained clay minerals brought in by dust and water or formed *in situ* (Fig. 62) whereas series C also contained clays incorporated in limestone debris.

A semiquantitative analysis of both series by Guinier de Wolf X-ray diffractograms showed little variation in composition between samples and between series (for averages, see Table 11). Smectite minerals were commonest, as could also be con-

Fig. 62. Scanning electron micrograph of the size fraction < 2 μm from 105 cm deep in Profile E 3.1 after treatment to remove carbonates. Material consists almost entirely of clay micelles. (Photograph by courtesy of Mr S. Henstra with JSM 2.)



Şekil 62. Bir marn toprağında < 2 mμ çaplarında (profil E 3.1, 105 cm) karbonatları giderildikten sonra tanelerin elektron mikroskop fotografi. Materyal hemen tamamen kil minerallerindan ibarettir. (Fotograf JSM 2 ile 1969 yılında, Paris'te S. Henstra tarafından alınmıştır).

cluded from the CEC, which ranged between 40 and 65 meq per 100 g clay for both series.

Even so Series B contained more quartz, kaolinite and feldspars, as confirmed by the slightly lower CEC in almost all samples (average difference 5.3 meq per 100 g clay). This means that part of the smectite, chlorite, vermiculite and palygorskite moved in with limestone debris.

Important are the quantities of palygorskite in the samples (Figure 63 shows an electron-micrograph of this mineral). It may be of sedimentary origin, as it is sometimes found in lagoonal deposits (Caillère & Hénin, 1961). Such lagoons existed during the last stages of the Ancient Konya Lake and presumably also during the formation of the Neogene freshwater limestones, from which part of the debris originates. Large quantities of palygorskite have also been found in the Jordan Valley in lacustrine marl deposits formed in the Middle Pleistocene Period (Wiersma, 1970).

Table 11. Mineralogical composition of clay samples of series B and C in percentages (w/w) of the total non-carbonate part.

Smectite, chlorite and vermiculite	Mica	Kaolinite	Palygorskite	Quarz	Feldspar
20-40	20-30	20-30	10-20	about 10	about 5

Tablo 11. Seri A ve C'nin kil örneklerinde yüzde olarak (w/w) toplam kireçsiz kısımda mineralojik bileşim.

Fig. 63. Electron micrograph of a suspension of the carbonate-free size fraction $< 2\,\mu m$ from 105 cm deep in Profile E 3.1. The predominant clay mineral is palygorskite (needles). (Photograph by Techcal and Physical Engineering Research Service, Wageningen with Philips EM 300).

Şekil 63. Bir Marn Toprağı'nın taneleri < 2 mu (profil E 3.1, 105 cm) olan kireçsiz süspensiyonunun elektron mikroskop fotografı. Esas kil minerali Palygorskittir (iğne şeklinde). (Fotoğraf Philips EM 300 ile TFDL tile Wageningen'de alınmıştır.)

9.4.2 Heavy minerals in the sand fraction

The non-calcareous part of Marl Soils contains up to 5% sand (1 to 2% of the entire soil). Van Beek (Internal report, 1968) observed that in the Lacustrine Plain this percentage decreases from the fringes to the centre and from the soil surface downwards. Analysis of 44 samples from 20 Marl Soil profiles, scattered over the area, has shown that the percentage heavy minerals of the non-calcareous fraction 50-420 μm ranges between 0.3 and 14% (average about 3.7%). Only surface soil from sites near the Volcanic Uplands, mainly in the eastern plains, contain much more than average.

In 12 samples from 5 selected profiles, there were mainly amphiboles (green, brown and basaltic hornblend) and much pyroxenes (augite and hypersthene) (*Table 12*). These minerals must have been carried into the basin by rivers or wind. At Site MB 3, in the Ak Göl plain, volcanic pyroxenes and epidote are commonest, whereas amphiboles predominate in the central and the western part of the Lacustrine Plain.

9.4.3 Light minerals in the sand fraction

Table 13 gives the percentages of light minerals in the light fraction from the samples. Potassium feldspars are present in equal quantities, but plagioclazes are slightly commoner in the eastern and central plains. At site MD 10, in the middle of the Hotamış Depression, both minerals are rare. The residue, 49 to 84% of the fractions, was mainly quartz.

9.5 Formation of Marl Soils

Several of the Guinier de Wolf X-ray diffractograms of Marl Soil samples show sharp lines for calcite and for dolomite, which indicate that these minerals occur in a well crystallized form. Together with observations on thin sections (Fig. 34) and with the electron scanning microscope (Fig. 58), this strongly suggests that the carbonate clay fraction of Marl Soils is mainly formed by chemical precipitation, presumably in the shallow parts of the Ancient Konya Lake. A high pH, saline-alkali conditions, and water rich in bicarbonates of Ca^{2+} and Mg^{2+} may promote this. Withdrawal of CO_2, partly during photosynthesis, eventually in combination with diarnal changes in water temperature, easily result in precipitation of calcium carbonates, and of dolomite which is less soluble (Alderman & Skinner, 1957; Alderman, 1959; Skinner, 1963).

Carbonates are still precipitated on a small scale in the Lacustrine Plain, as observed in July 1967 in a shallow saline temporary lake in the Karapınar Depression where ooze of almost pure crystalline calcite formed almost 3 cm thick. The area soon dried up. In day time the pH of the ooze was 8.8 (CO_3^{2-} and HCO_3^- were not measured).

Thick crusts of precipitated carbonates on waterplants were observed also in July 1967 in a small shallow saline pool near Kaşınhanı (*Fig. 64*). At 10.00 h the pH was

Table 12. Numbers of heavy mineral particles in percentages of total opaque-free heavy fraction (50-420 μm). At least 100 grains counted.

Sample No	Site	Depth (cm)	pyroxene (augite and hypersthene)	amphibole (green, brown and basic hornblende)	epidote	aggregate	garnet	tourmaline	zircon	titan mineral	mica	residue	opaque mineral (percentage of total sample)
284	MB 3	30	55	27	9	3						6	20
285		100	42	20	18	5	1	1				13	
286		200	26	28	27	8				2		9	12
301	MD 3	30	20	71	2		1	2		1		3	10
302		100	15	81			2			1		1	2
304		150	5	87	2	1	2					3	2
317	MD 10	30	4	89	1			1		2		3	7
318		100	6	91						1		2	6
324	ME 2	30	13	77	4	4	1		1				5
325		100	9	80	4	2				1	3	1	20
354	MG 8	30	42	40	6	3			2	1	1	5	9
355		100	41	40	7	1			2	2	3	4	16

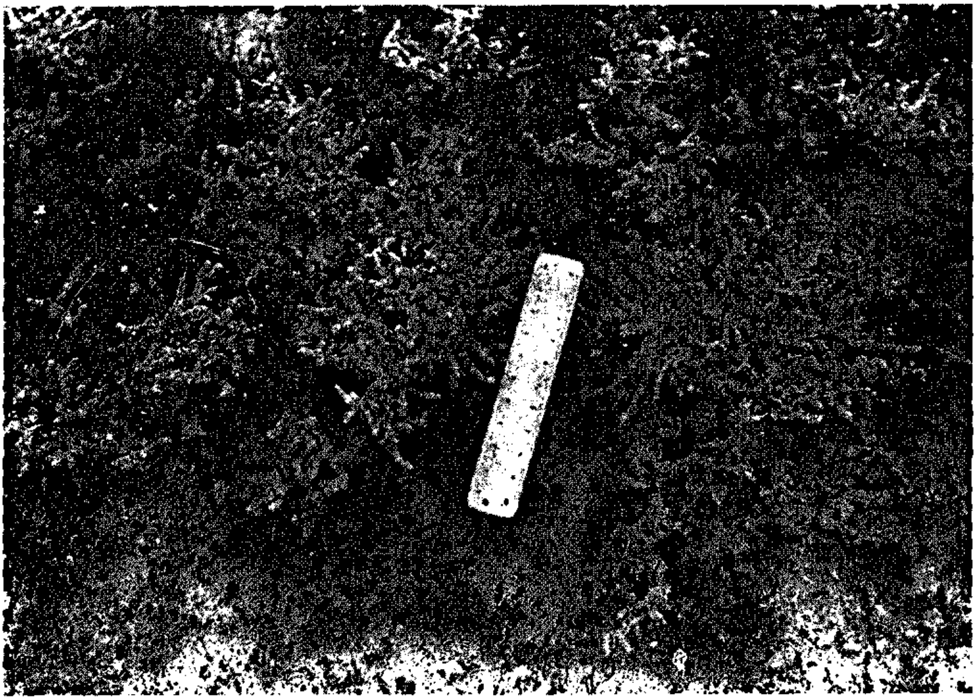
Tablo 12. Toplam olarak ağır fraksiyon içinde (50-420 μm), ağır mineraller yüzdesi. En azından 100 tane sayılmıştır.

Table 13. Numbers of light mineral particles in total light fraction (50-420 μm). Separation with bromoform followed by staining; 3 × 100 grains counted.

Sample No	Site	Depth (cm)	Potassium feldspars	Plagioclaze	Residue
67/284	MB 3	30	9	22	69
67/285		100	10	26	64
67/286		200	9	13	78
67/301	MD 3	30	15	38	47
67/302		100	15	36	49
67/304		150	9	25	66
67/317	MD 10	30	11	2	87
67/318		100	8	8	84
67/324	ME 2	30	17	19	74
67/325		100	12	29	59
67/354	MG 8	30	23	8	69
67/355		100	13	27	60

Tablo 13. Toplam hafif fraksiyon içinde (50-420 μm) hafif minerallerin yüzdesi. Ayıklama bromoformu takiben boyalanmak suretiyle olmuştur. 3 × 100 tane sayılmıştır.

Fig. 64. View from above of a shallow pool with plants and algae covered with carbonates (near Kaşınhanı, June 1967). Scale is 10 cm.



Şekil 64. Düşey olarak sığ bir gölcükte bitki ve alglerin karbonatlarla kaplanmış halinin görünüşü. (Kaşınhanı yakınları, Haziran 1967.)

about 10 in the middle and 7.5 near the shore; concentration of CO_3^{2-} and HCO_3^- were 2.75 and 6.38 meq/l, respectively. There was little change in pH at night, so that vegetation did not seem the direct cause. The extreme pH in both sites suggests the presence of sodium carbonate, which could certainly cause precipitation of calcium carbonate. X-ray diffractograms of these precipitates show mainly calcite, with less than 5% dolomite. The electron scanning micrograph shows typical carbonate crystals in ooze and crusts (Fig. 65).

After drying up, the precipitated carbonate sediment was on both sites about 0.4 cm thick. Already in the muddy stage, numerous organisms had started working the material. A few weeks later, the crust of precipitate had completely disappeared from the surface by the activity of organisms and by cracking after drying. The material was mixed with parts of the surface soil.

Presumably Marl Soils in the Lacustrine Plain initially formed in this way.

Insummary, it seems that the carbonate clay and fine silt fractions in the Marl Soils mainly originate from precipitation and that the non-carbonate clay component has been blown and washed in or has been formed *in situ*. The coarser carbonate

Fig. 65. Scanning electron micrographs of different types of carbonate crystals (presumably calcite) in a crust of dried calcareous ooze from a lake near Karapınar.
Note solution pits in the crystals on the upper plate. The crystal type on the plate below was also observed in the crusts on the plants in Figure 75. (Photograph by courtesy of Mr S. Henstra, Paris 1969.)

Şekil 65. Karapınar yakınlarındaki bir gölden, kurumuş kalkerli, çeşitli tip karbonat kristallerinin (tahminen kalsit) elektron mikroskop fotoğrafı. Fotoğraf A'da, kristaller içinde ceplerdeki çözeltiye dikkat ediniz. Fotoğraf B'de ki kristal tipi şekil 75 deki bitkilerin kabuğunda tesbit edilmiştir. (Fotoğraf 1969 yılında, Paris'te, S. Henstra tarafından alınmıştır.)

fractions are crushed shell fragments, limestone debris from coastal erosion, and secondary aggregates. The coarser non-calcareous components are carried in by rivers and wind.

Finally the resulting highly calcareous soil material is homogenized by organisms.

10 Agricultural suitability of Marl Soils

The preceding chapters on the highly calcareous soils of the Lacustrine Plain mainly concern morphology and genesis. The agricultural aspects, the improvement of the soil, the reclamation of more land for crops and cattle, have up to now been ignored. These subjects will be treated in this chapter.

The Chalk and Tufa Soils consist almost entirely of carbonates, and the Marsh and Playa Marls, although mainly cultivated, are either often flooded (continuously so in 1968, 1969 and 1970) or, if dry, salt-affected because they occur in depressions, so that the Steppe Marl Soils are the most promising of all Marl Soils for future extension and intensification of agriculture. Hence the Steppe Marls are dealt with below. The study of their suitability will be based mainly on the previous chapters, supplemented by some data on soil moisture and fertility. Additional data have been borrowed from the work of Janssen (1970 a, b, c) and from research on highly calcareous soils in Israel and Florida, as referred to in Section 10.6. I have already devised a suitability classification for all soils of the Great Konya Basın, including the Marl Soils, in the frame of the reconnaissance survey (de Meester, 1970) based on general information. The procedure to be followed here will be the same. It is adopted from the work of Beek *et al.* (1965) in Brazil, but my procedure lays more emphasis on soil structure, expecially the analysis of soil peels and thin sections.

10.1 Classification procedure

The classification procedure so successfully applied in Brazil and in the Great Konya Basin (though still under revision) comprises the following five working stages.

1. *An inventory of soil properties pertinent to the agricultural use of the soil*, which has to include everything affecting the cultivation of crops. These properties will be referred to in the discussions to avoid repetition.
2. *The analysis of a number of 'agricultural soil conditions'*, defined as complexes of the soil properties pertinent to the agricultural use of the soil.

Beek *et al.* (1965) have selected as such: natural fertility, moisture condition, oxygen condition, erosion and the use of implements. Van der Kloes (1965), who has examined the suitability of soils for horticultural crops in the Netherlands, bases his judgements on soil texture, soil structure, soil moisture and root development. Most are agricultural conditions in the above sense.

As there is little or no erosion in the Steppe Marl Soils of the Great Konya Basin, and as use of implements is nowhere hampered, the discussion of Steppe Marls can be limited to soil structure, soil moisture and soil fertility. The last two, although certainly important, will be discussed more briefly than the first.

3. *Comparison with a hypothetical soil in which the agricultural conditions are optimum*, for each particular soil after being examined for the properties mentioned above. The differences between the 'reference soil' and the actual indicate a deviation in some respect, expressed as zero, slightly, moderately, strongly and very strongly deficient.

4. *The study of the deficiencies to assess the feasibility for improvement*, and to decide whether this improvement will be partly of fully realizable. This can be expressed as easily feasible, feasible, perhaps feasible (after special measures) and not feasible.

A technically feasible improvement may be hampered by social and economic circumstances. This means that it can only be realized under certain conditions, under a well-defined management system. For the Marl Soils three such management systems can be distinguished:

Management System A: the land is dry-farmed with a fallow every other year, hardly any fertilizer is used, technical skill is limited, capital input is zero, crops (mainly cereals) are not weeded. This system is common in the area.

Management System B: dry-farmed as A, but with fertilizers, either superficially or by deep placement; farmers are more skilled, machinery is widely used; capital is invested on fertilizers, weed control, maintenance and transport; cereals are the main crop. This system hardly exists in the area, but it could be widely introduced.

Management System C: involves irrigation, sometimes with a fallow period every second year. Farmers are well skilled, use of capital, credit and fertilizers; the work is mechanized. Main crops are cereals and sugar-beet, with some melons, oilseeds and fruit (apples, pears, plums, apricots). This system occurs in all irrigated areas, but not in the sophisticated form suggested here.

5. *The assessment of the suitability of a soil for each of the three management systems*, based on feasibility and degree of improvement of deficiencies in the combined agricultural soil conditions.

The final step is essential and, in fact, the aim of all agricultural soil surveys. However, in the present study, it remains tentative for lack of adequate checks. But the various stages clearly bring out, in a systematic way, the important aspects of agriculture on the Steppe Marl Soils, both when dry-farmed and when irrigated. Much more research will be necessary for a final evaluation and classification of their capabilities.

Some remarks have to be added on the 'reference soil' mentioned under 3 and introduced under the name 'ideal agricultural soil' (Beek *et al.*, 1965). According to Beek, this soil 'has the largest scale of possibilities for the highest organized forms of plant associations' and 'it should not be deficient in any of the recognized agricultural soil conditions.'

Even apart from crops which need special soil conditions (such as rice, cotton and tobacco) which are here ignored, such an ideal soil is difficult to define. Its nature varies between regions. Nevertheless general experience supplies sufficient knowledge about the structure, moisture conditions and optimum fertility of such an ideal soil.

The same problem arises in measuring or estimating the deficiencies of a certain soil as compared with the reference soil. Frequently exact terms and figures are lacking because of the intricate complex of often interrelated properties. In addition, an area with a primitive agriculture and with dry soils offers few ways of checking as experimental data are scarce, yields vary strongly from year to year and from place to place even within one unit, and information from farmers is often biased.

Nevertheless I tried to draw up a reasonably reliable concept of the ideal soil conditions in Central Anatolia. In the next sections it will be given first, and then it will be compared with the prevailing agricultural conditions in the Steppe Marl soils.

10.2 Soil structure of Steppe Marls

10.2.1 The structure of the ideal soil

Several authors have dealt with the evaluation of soil structure from an agricultural viewpoint, amongst them van Lieshout (1960), Edelman *et al.* (1963), van der Kloes (1965) and Slager (1966). They all consider the roots of a crop a good indicator for the structural conditions of the soil. Though a well developed root system does not always guarantee a good yield, it reduces risks to a minimum.

As long as moisture, aeration and fertility conditions do not disturb the growth, the soil should present the least possible mechanical resistance. Van der Kloes states that for Dutch soils a good biogenic structure (see Chapter 4) favours rooting, and that rooting becomes better with increasing porosity, decreasing ped size and decreasing structural grades. According to Hoeksema (1953) a fully heterogeneous pore system (a soil containing pores of all sizes) is best. Plant roots do not easily penetrate pores smaller than 20 μm (Wiersum, 1957); the larger ones ($> 30\ \mu$m), are important for transport and the smaller ($< 30\ \mu$m) for storage of moisture and air and thus for the supply of nutrients.

Both van der Kloes and Slager emphasize that biological phenomena decrease with depth. Thus the model of the ideal soil should also show this trend, and in stratified sediments the soil has to be homogenized to a depth of at least 60 cm.

Another aspect of an ideal structural condition is a high stability preventing slaking and collapse due to cultivation or irrigation.

To allow comparison between the structure of the model soil, and that of a Steppe Marl, the assumed ideal field structure and the ideal elementary peel and matrix structure have to be presented for both the solum, i.e. the upper part of the soil profile above the undisturbed parent material (here about 0-60 cm) and the substratum below. They should be as follows:

1. the field structure of the solum has to be crumb (A1 or A2) or granular (A3), which also means that the soil material must contain a heterogeneous pore system; with increasing depth the pedality may become subangular-blocky but should remain heterogeneous porous, without cutans;
2. the elementary structure (on soil peels) of the solum has to be abundantly

fecal, mainly pedotubulic and mainly vughy or channeled; with increasing depth the soil may become less fecal but still pedotubulic and mainly vughy or channeled;
3. the elementary structure (in thin sections) should be fecal, vughy and porous, in the surface soil with increasing depth. It may change to pedotubulic, but the fabric should remain vughy and porous, and not become cutanic.

10.2.2 Deficiencies in structure

Chapters 3, 5 and 6 have discussed the profile morphology of Steppe Marl Soils in a virgin state (steppe, used as rangeland), in a dry cultivated state, and under irrigation.

Only the cultivated type should be considered here, but the behaviour of structure in virgin state and under irrigation are better discussed also to assess the feasibility for improvement. After the study of all Steppe Marls under various managements it seems more practical to treat them together.

Virgin Steppe Marl (profile C 3.1) The descriptions in Chapter 3 (Fig. 9) and Chapter 5 (Fig. 26) show that the structure of the solum of the Virgin Steppe Marl is close to ideal. Field structure is mesoporous and microporous false crumb to nearly 50 cm. The peel and thin section descriptions indicate an abundantly fecal and vughy material. The few centimetres of the surface are compound, flattened, subangular blocks, as a result of dessication, but they consist also of fecal pellets. The solum is therefore slightly deficient in structure.

As regards the substratum, a weak subangular calcic horizon with decreasing porosity merges at 70 cm into a strong but very fine and fine angular-blocky pedality with macroporous peds. The peel and thin sections show that fecal pellets become increasingly welded and that the soil material becomes gradually less vughy but more channeled. Deficiency is assessed as moderate.

Rooting of wheat in a similar soil was tested in an undisturbed core of 30 cm diametre and 100 cm length. Moisture, temperature and pest control were optimum during growth. Figure 66 shows the roots in a soil slice 2 cm thick through the centre of the core after harvest: roots are abundant down to the calcic horizon at about 35 cm.

Cultivated Steppe Marl Soil (Profile C 3.2) The field structure description and the peel description are given in Chapters 3 and 6 (Figs. 10 and 37).

In the solum, deficiencies are obvious: pedality in the upper 20 cm is angular-blocky, with granular primary peds. Directly below is an irregular subangular-blocky layer. Porosity of the loose topsoil layer is heterogeneous, but the blocky layer (plough bottom) is only microporous. The elementary structure of peel and fabric shows welded fecal pellets, except for the upper few centimetres, and a partly vughy soil material becoming mainly channelled between 30 and 40 cm. This structure is assessed as moderately deficient.

The subtratum is identical with that of the Virgin Steppe Marl and therefore also moderately deficient.

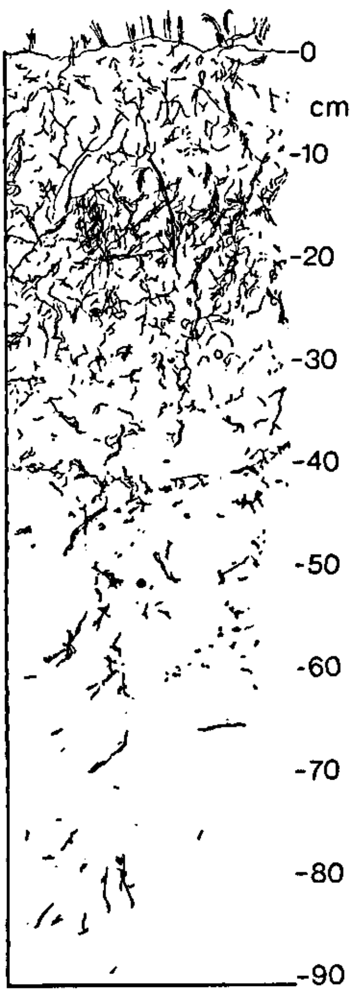


Fig. 66. Root distribution in a soil slice 2 cm thick from an undisturbed soil core in which wheat had been grown. The core was from Site E 3.1.

Şekil 66. Profil E 3.1 boyunca 2 cm kalınlığında, buğday ekildikten sonraki durumda bozulmamış toprak keseğinde kök dağılışı.

Irrigated Steppe Marl Soil (Profile G 1.1) For the field description and the peel analysis, see Chapters 3 and 6 (Figs. 11 and 40).

The ploughed layer of the solum is subangular-blocky and macroporous, but below this zone pedality is crumb and false crumb as in Virgin Steppe Marl. Elementary structure in the peel and in the thin sections is mainly welded fecal and vughy in the ploughed layer, partly collapsed fecal, partly tubulic and mainly channelled in the zone below. Porosity is low. There is a surface crust and the structural grade is weak.

The decline in structure of the surface layer increases its deficiency as compared with the dry Cultivated Steppe Marl, but moisture makes the structural grade weak, which is favourable because it causes less mechanical resistance to roots.

So it may be concluded that the structural deficiency of the solum must be classified as moderate.

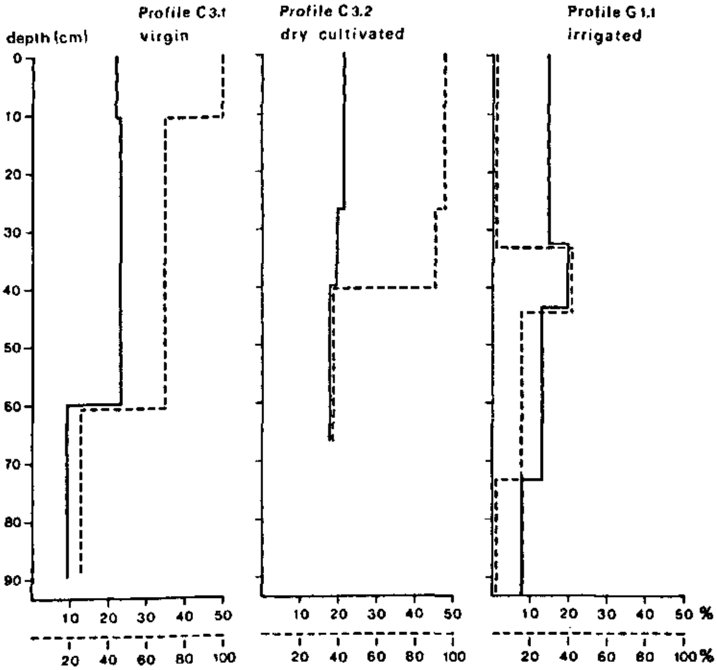
The subtratum has a moderate compound-prismatic pedality with moderate weak very fine angular primary peds. The elementary structure of peels and thin sections is mainly collapsed fecal, mainly vughy and channelled and becomes increasingly cutanic and fractured with depth. This structure of the subtratum is strongly deficient as compared with the reference soil.

10.2.3 Deficiencies in structural stability

An ideal soil has a high resistance to disturbing forces such as compaction, ploughing, irrigation, rain, desiccation and frost. The increased structural deficiency observed between Virgin, dry Cultivated and Irrigated Steppe Marls suggests a low stability. Some experiments have been carried out to obtain more information on this subject.

The distribution of open biogenic fabrics and of pores larger than 30 μm has been determined by point counting on thin sections of Profiles C 3.1, C 3.2 and G 1.1. The

Fig. 67. Trend of open biogenic fabrics and pores counted in thin sections of peds from profiles C 3.1, C 3.2 and G 1.1 (Steppe Marl Soils) estimated by point counting.
Solid lines: percentages of voids > 30 μm diameter.
Broken lines: percentages of open biogenic fabric.



Şekil 67. Profil C 3.1, C 3.2 ve G 1.1 (Step Marn Toprakları) de pedlerin ince kesitinde nokta sayımı ile tahmin edilen açık biyojenik yapının ve porların dağılışı
katı çizgi: > 30 μ çaptaki viodlerin yüzdesi
noktali çizgi: açık biyojenik yapı yüzdeleri

results in Figure 67, although their reliability is not high, show a drop in biogenic fabric, whereas the porosity in the counted class appears to be little affected.

To simulate the effect of repeated irrigation, a similar soil core as mentioned above (Section 10.2.2) 30 cm in diameter and a length of 100 cm was taken from a Virgin Steppe Marl Profile E 3.1. It was cut lengthwise into two halves. One half was wetted some fifteen times to field capacity and dried in an air current, the other half was left as it was. Afterwards thin sections were made of each halves. Table 14 gives their elementary structures; the wetted half shows a moderate structural detioration above 60 cm.

To estimate the stability of the aggregates, surface samples of the three profiles were put on a sieve and suddenly immersed in water to simulate border irrigation, whereas others were slowly moistened for 24 hours on a sandplate with 3 cm water tension. Figure 68 shows the results. The steepness of the curves are a measure for the resistance to air-explosion after sudden immersion and the forces of the water currents in the sieves.

The results show that the surface-soil aggregates of the Irrigated Steppe Marl are more resistant to explosion than those of the dry Steppe Marls, but this may be due to a different texture and carbonate content. With slow moistening, there is little difference in destruction between profiles.

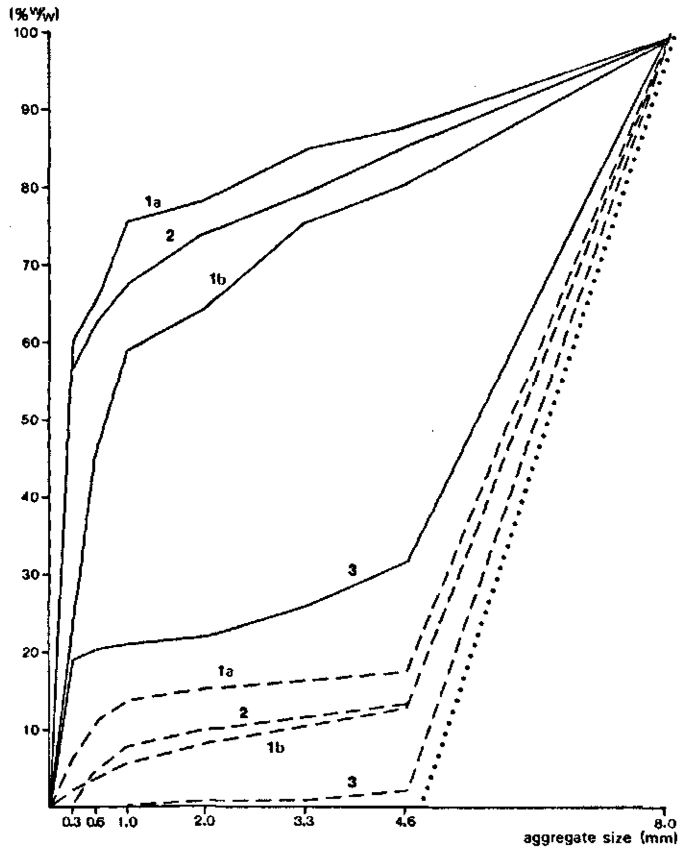
The general conclusion is that Steppe Marl Soils have a low aggregate stability, especially after sudden moistening; their deficiency in this respect is strong. This is

Table 14. Comparison between elementary structure of a Steppe Marl Profile (E 3.1) before and after repeated soaking and drying.

Before treatment	Depth (cm)	*After treatment*
Fecal and vughy, channelled loose crystic (common single medium and abundant welded coarse fecal pellets)	8-24	Fecal and vughy, channelled loose crystic (common welded medium and common collapsed coarse fecal pellets)
Fecal, vughy and channelled loose crystic (common welded medium and collapsed coarse fecal pellets)	25-40	Glaebular, vughy and channelled loose crystic (common, strongly welded and collapsed fine and coarse fecal pellets)
Pedotubulic, channelled dense crystic fabric (common aggrotubules with welded medium fecal pellets)	43-60	Pedotubulic, vughy, channelled and crazed dense crystic (few aggrotubules with strongly welded fecal pellets)
Pedotubulic channelled and crazed dense crystic (common granotubules and few aggrotubules with welded fecal pellets)	65-90	Pedotubulic, vughy and channelled dense crystic (common granotubules, and common aggrotubules with welded fecal pellets)

Tablo 14. Kuru ve sulanmış marn toprağından yapılan ince kesitte elementer yapı.

Fig. 68. Additive curves of size distribution of Steppe Marl aggregates after a wet sieving analysis.
Dotted line: before moistening.
Solid lines: with air-explosion after rapid moistening.
Broken lines: after slow moistening.
1. Profile C 3.1 (Virgin Steppe Marl Soil) 0-8 cm deep (a) and 8-45 cm deep (b).
2. Profile C 3.2 (Cultivated Steppe Marl Soil) 0-22 cm deep.
3. Profile G 1.1 (Irrigated Steppe Marl Soil) 0-25 cm deep.



Şekil 68. Islak eleme yoluyla yapılan analizlere göre Step Marn toprağında agregatların kümilâtif büyüklük dağılımı.
katı çizgi: hava kabarcıkları ile süratli ıslatmadan sonra
kırık çizgi: yavaş ıslatmadan sonra dağılışı
noktalı çizgi: ıslatmadan önce dağılışı

1. Profil C 3.1 (Bakir Step Marn toprağı) 0-8 cm derinlikte (a) ve 8-45 cm derinlikte (b)
2. Profil C 3.2 (Kültüre Alınmış Step Marn toprağı) 0-22 cm derinlikte
3. Profil G 1.1 (Sulanmış Step Marn toprağı) 0-25 cm derinlikte.

supported by observations on similar soils (Lisan Marls) in Israel (Ravikovitch, *et al.*, 1958).

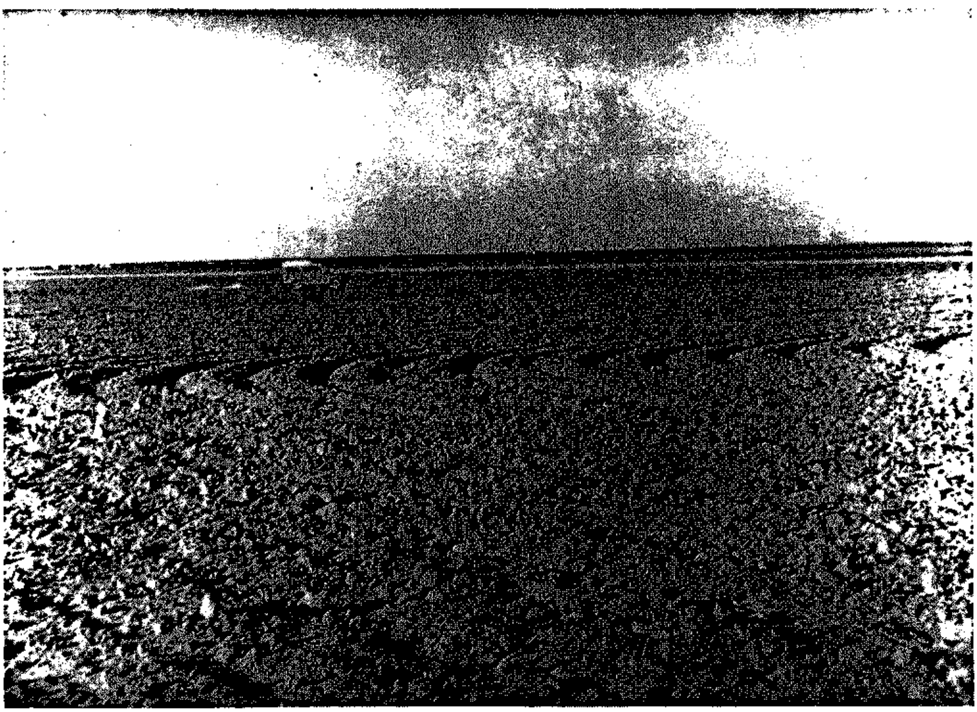
The sensivity of the soil for compaction and slaking after tillage and in relation to moisture is discussed in Section 10.3.

10.2.4 Ways of improving structure

Management System A offers no possibility of improvement, which means that improvement of the soil is not feasible.

Management System B offers more prospects because it includes more skill. Formation of dense plough bottoms and structure detioration in the plough layer itself as observed in Profile C 3.2 can be avoided by using better methods of tillage. At present trailed disk ploughs are used which start their work along the borders of the field and gradually proceed in a spiral towards the centre, which means that they have to be turned 90° on the diagonals (Fig. 69). Along these diagonals not all the soil is moved, which the farmer corrects by going up and down them to finish the job. As a result the surface structure of the diagonal strips, about 10 m wide, is much more deteriorated than the rest of the field. This could be clearly observed in the

Fig. 69. A freshly ploughed field with a clear 'plough diagonal' where the plough turned sharply through 90°.



Şekil 69. Yeni sürülmüş bir tarlada, aşikar olarak pulluğun 90° döndüğü yerde 'pulluk diyagonali'.

summer of 1967 after a few days of heavy rain (surface crusts were stronger there). In a small field of, say, 100 × 50 m (2 Konya dönum) such diagonals occupy about 40% of the surface; in a field of 300 × 100 m (12 Konya dönum) this percentage is about 20. This custom should therefore be dropped.

Other measures to reduce structural decline are adding organic manure and a management in which the soil is tilled less frequently and when moisture conditions are most favourable.

The conclusion is that improvement of structure under System B is partly feasible.

Management System C, which involves irrigation, needs a skilled farmer and the use of fertilizers, machinery and capital. Here contradictory tendencies make the estimation of feasibility difficult.

As observed for Profile G 1.1, and in the tests described in Section 10.3, irrigation and moistening rapidly result in collapse of the soil structure. However porosity remains fair and the structural grade is low.

Undeı this system, aggregate stability can be improved and crust formation lessened by the application of organic manure. It seems that good results have been obtained on the Marl Soil at the Topraksu Wind Erosion Control Camp near Karapınar with 25 tons dung per hectare.

From irrigation studies on highly calcareous soils elsewhere, it is however known that an almost irreversible detioration of soil structure can often result from irrigation (Rawitz *et al.*, 1964).

Improvement of soil structure seems not feasible and, unless highly sophisticated, irrigation management may even increase the deficiency.

10.3 Soil moisture of Steppe Marls

10.3.1 The ideal moisture situation

Beek *et al.* (1965) simply state that the reference soil should not be deficient in moisture. Although this sounds quite obvious, any approach to a more detailed concept leads into the complicated field of soil-moisture relationships, the treatment of which is beyond the scope of this chapter. But it is also possible to start from the fact that under ideal moisture conditions a soil can supply a well developed root system with sufficient water (and oxygen!), even when evapotranspiration is high, as in arid regions. Under such circumstances the moisture content of the entire profile is permanently at field capacity or a little below it, with about 25% (v/v) moisture and 25% (v/v) air (Russell, 1961; Brady, 1965), irrespective of the origin of the water (from a high watertable, from rain, from irrigation, or from some combination).

An ideal situation for soil moisture refers not only to the amount of moisture in the soil, but also to a regular supply.

The initial intake rate may fluctuate between about 15 and 25 cm per hour, but the permeability of the subsoil should not be less than moderate (2-6 cm/hour). In such a soil internal drainage is sufficient ('medium', according to the Soil Survey

Manual, 1951) so that salinization and lack of aeration are avoided.

The amount available to the plants depends on soil-moisture relationships, which correlate with soil texture, soil structure and content of organic matter (mainly because organic matter improves structure). 'Available moisture' is the difference between the amount stored at field capacity (pF about 2.5) and that at permanent wilting point (pF 4.2). In irrigated soil it seems better to take pF 3 as the lower limit, because much damage is already done to a crop if the soil has dried to permanent wilting point. Brady (1965) mentions that silt-loam has the highest amount of available moisture; in combination with a favourable (a heterogeneous porous) structure, he considers about 15% (v/v) optimum for the rooting zone.

Soil moisture also affects the liability of a soil to compact and slake, which is very important for tillage, especially in irrigated areas where farming is mechanized. In an ideal soil the moisture percentage at the lower plastic limit must not be too much below that at field capacity to guarantee tillage without compaction, whereas the upper plastic limit should be well above field capacity to be safeguarded against slaking (Boekel, 1963).

Soil moisture causes linear swelling (expansion), which is important in irrigated areas and with heavy rains. In expansive soils the voids between primary peds close after wetting, resulting in impeded drainage. So an ideal soil should have a low linear swelling percentage. For this property the type of clay mineral, and its amount, are decisive, but limits for an ideal soil are not available.

10.3.2 *Estimation of soil moisture in undisturbed samples*

For an easy assessment of the moisture in a soil, the usual percentages by weight of moisture must be converted into percentages by volume. For this, the bulk density (which is almost equal to the volume-weight) of the undisturbed sample should be estimated but in arid areas such samples cannot be taken in the usual way with steel rings because the soil is too hard. Instead we used natural peds or clods of about 100 cm^3 and coated them in the field with Saran resin by the method of Brasher *et al.* (1966). This protects the clod during transport. The covering is permeable to vapour but not to water; it stands heat to 105° C and can stretch with swelling of the sample. According to Brasher and to van den Eelaart (pers. comm.), who have both assessed its reliability and reproductivity, bulk density and soil-moisture relationships in the lower tension ranges estimated on coated clods correlate well with those obtained by traditional methods, and the method even has some advantages due to the properties of the coating. The data of the phase diagrams, shown in the next section are all obtained from Saran coated clods.

Nevertheless, both ring samples and peds or clods are only small portions of relatively undisturbed soil; the bigger interpedal voids are discounted.

In an effort to obtain information from more natural but still undisturbed material, a core 30 cm in diameter and 100 cm in length with undisturbed Steppe Marl Soil of Profile E 3.1 (also referred to in Section 10.2 and 10.3.3) was used to estimate bulk

Fig. 70. Completed soil core before removal from the field.

Şekil 70. Tarladan alınmadan önce aşınmak için hazırlanmış bozulmamış toprak özü.

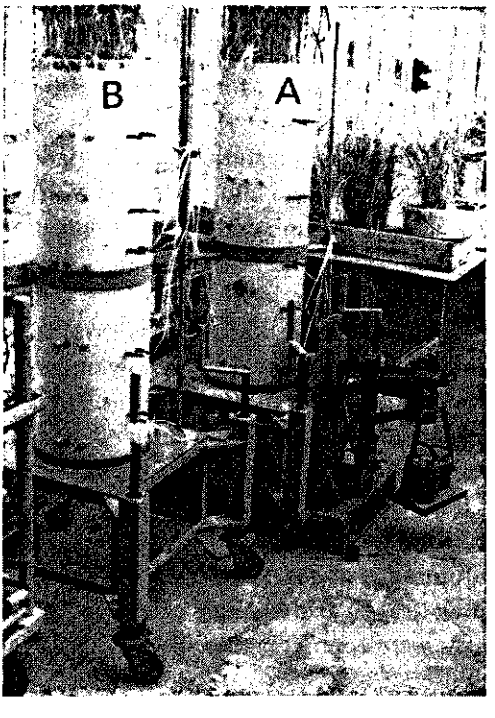


Fig. 71. Two soil cores in experiments.

Şekil 71. Deneyler için kullanılan iki bozulmamış toprak özü. Elektrotlara, nem örnekleri için deliklere ve basitçe tartım için yapılan alet'e dikkat ediniz.

density, field capacity, permanent wilting percentage, infiltration rate and permeability of the entire profile. Field capacity was estimated 48 hours after saturating the core. The permanent wilting point was estimated after a well rooted wheat crop was left to wilt before moisture were taken with a little core auger through holes in the wall at various depths.

Figures 70 and 71 show several aspects of the described methods. Results will be mentioned in the next Section.

10.3.3 Deficiencies of soil moisture

In *dry Steppe Marls* with a deep watertable, moisture storage and availability entirely depend on precipitation. Figure 72 shows the phase-distribution diagrams for the sites A 1 (Yarma Plain) and C 3 (Hotamış Plain) in cultivated fields under fallow and under wheat in May, July and August 1967.

The diagrams for the fallow sites show that there is still considerable loss of moisture. This is partly due to weeds. The diagrams of the wheat sites indicate that evapotranspiration is mostly from moisture in the upper 80 cm and, as evaporation is from the upper 20 cm (Janssen, 1970b), the plants live mainly on the moisture between about 20 to 80 cm (and on precipitation during growth). The moisture data at different moisture tensions are from estimates on clods. They have been plotted in the diagrams to show the amount of moisture used by the crop between May (beginning of stem extension) and July (harvest) which is between 70 to 90 mm for the upper 20-80 cm (rooting zone).

It seems that in July the entire solum has dried out to a level below the wilting point, in places even to pF 5.6.

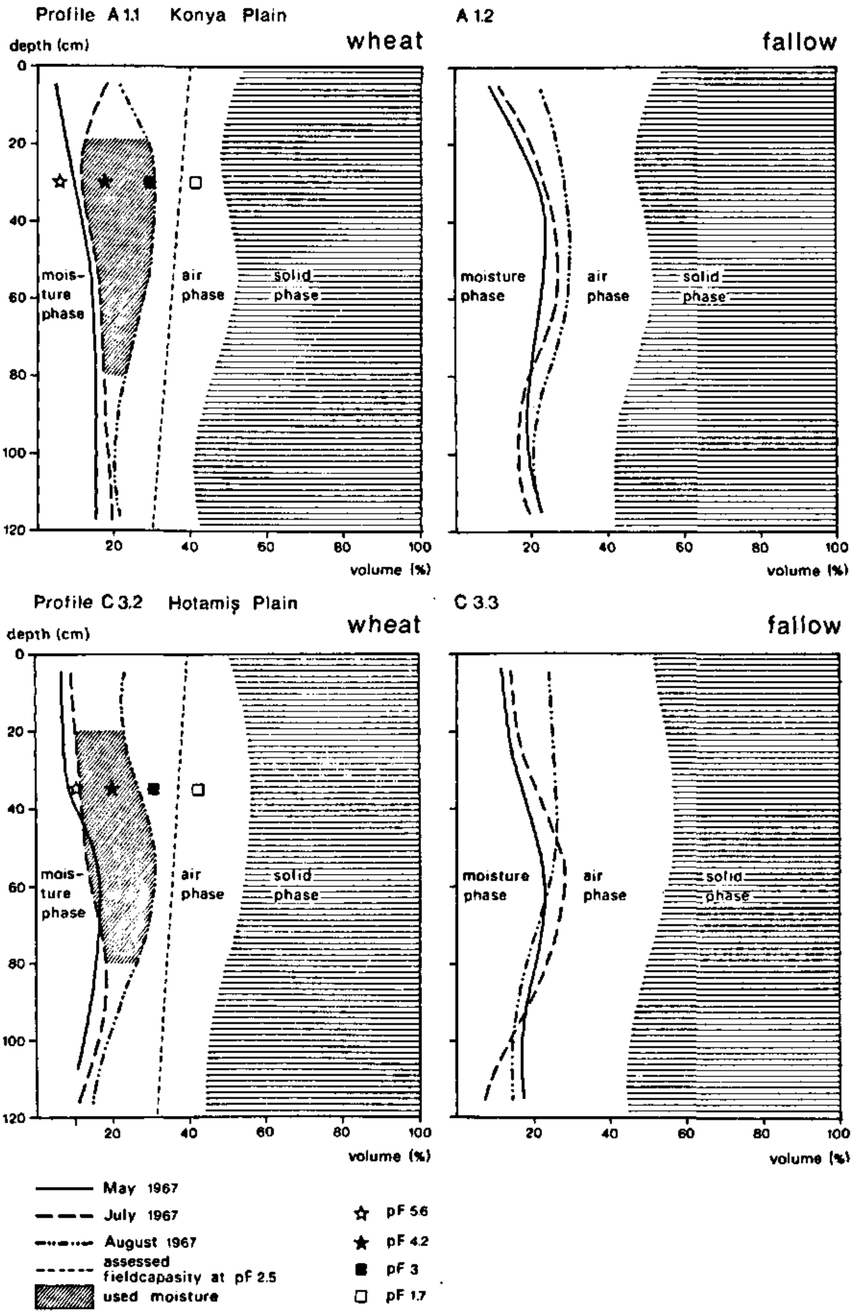
All this means that the moisture conditions in dry Steppe Marl Soils are strongly deficient.

For *Irrigated Steppe Marls*, the soil is hardly deficient of moisture. But the suitability of the soil for irrigation ('irrigability') will also be considered and compared with the irrigability of an ideal soil. Most important factors for moisture are the infiltration rate, total availability, liability to compact and to slake, and swelling.

Intake rates have been measured in triplicate on Steppe Marl Soils in the Yarma Plain (near site A 1.1) and the Hotamış Plain (site E 3.1) with ring infiltrometers. Values would be higher than those in a flooded field because water can flow outwards as well as downwards. Infiltration rates have therefore been measured in the soil core of Profile E 3.1. The solid line in Fig. 73 represents the infiltration rates of the core after one hour had elapsed. Its slope is representative. It is constant for the soil under different moisture conditions. The broken line represents the amount of water infiltrated (cumulative infiltration). It is derived from the solid line by integration.

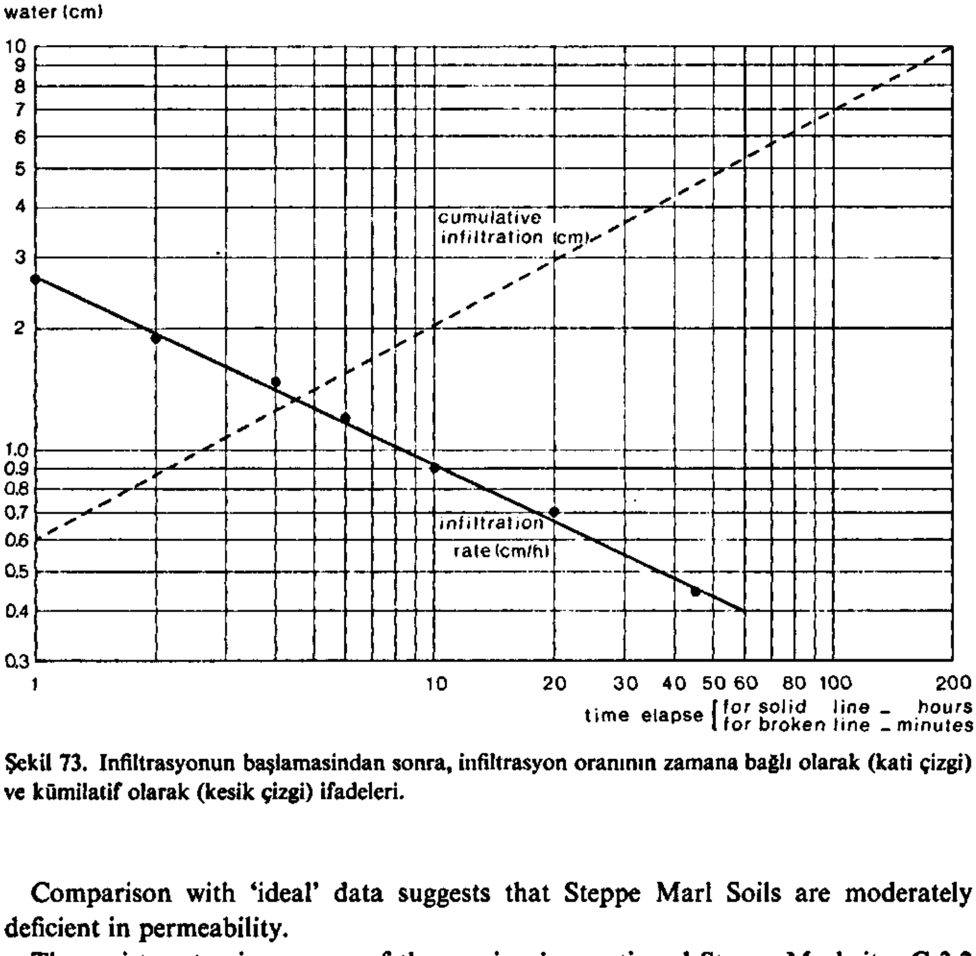
The data in Fig. 73 show that initial infiltration is about 36 cm/h, which confirms the field measurements. Infiltration rates after 1, 5, 10 and 40 hours are 2.7, 1.3, 0.92 and 0.48 cm/h respectively. Alle measurements were approximations because of errors due to cracks, voids, slaking and swelling.

Fig. 72. Phase distribution in profiles at sites A1 and C3 on Steppe Marl Soils under fallow and cultivation in May, July and August 1967.



Şekil 72. A 1 ve C 3 ile işaretli yerlerdeki Step Marn topraklarındaki profillerde faz dağılımı ve tahmin edilen tarla kapasiteleri.

Fig. 73. Infiltration expressed as a rate (solid line) and as a cumulative total (broken line), against time elapsed since start of infiltration.



Şekil 73. Infiltrasyonun başlamasindan sonra, infiltrasyon oranının zamana bağlı olarak (kati çizgi) ve kümilatif olarak (kesik çizgi) ifadeleri.

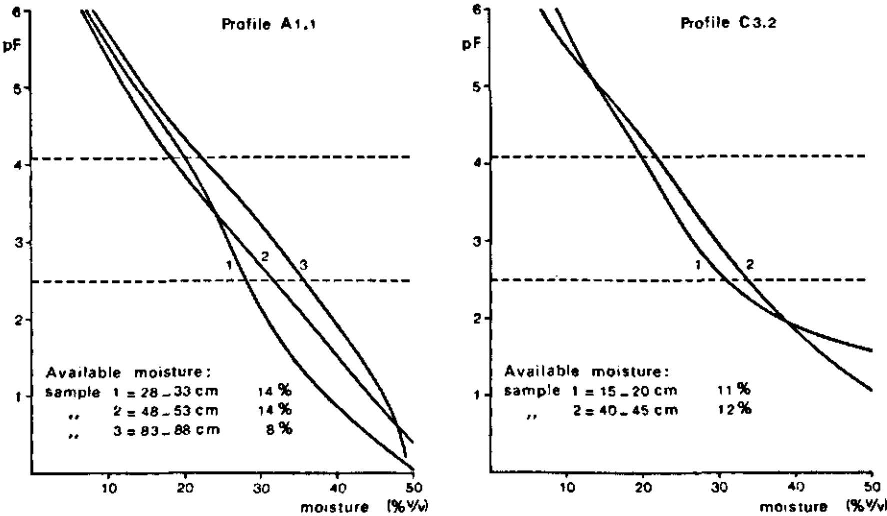
Comparison with 'ideal' data suggests that Steppe Marl Soils are moderately deficient in permeability.

The moisture-tension curves of the previously mentioned Steppe Marl sites C 3.2 and A 1.1 are given in Figure 74. Total available moisture (between pF 2.5 and 4.2) is between about 11 and 14% v/v for the solum (0-50 cm). Available moisture was also experimentally estimated on the soilcore of Profile E 3.1. Field capacity has been measured 36 hours after the permeability test was stopped. Wilting point was measured after a wheat crop, grown on the core until its heading stage, had wilted. Used moisture at 5 cm, 25 cm, 55 cm, 80 cm and 95 cm was respectively 20.1%, 18.9%, 27.0%, 13,6% and 11.8% by volume

In conclusion moisture seems only slightly deficient, but if the soil by over-irrigation is kept for too long at or near field capacity, air may become limiting. See phase diagrams, Fig. 72.

Steppe Marls are locally salt-affected (Driessen, 1970; de Meester, 1970), which reduces the availability of moisture by osmotic tension ('physiological drought'). Irrigated soils, however, are in general not or only slightly salt-affected in the surface

Fig. 74. Graphs of moisture tension (pF) and moisture content of 2 Steppe Marl Soils at sites A1 and C3.



Şekil 74. A 1 ve C 3 ile işaretli yerlerde iki step marn toprağında nem başınç eğrileri (pF) ve ı em miktarları.

soil, but they easily may become so under poor management.

The upper plastic limit ranges between about 40 and 50% (v/v), the lower plastic limit between about 33 and 40% (v/v). The field capacity (pF 2.5) of these soils is about 33% (v/v) so there seems to be no danger of either compaction or slaking during tillage at that field capacity. However after heavy rain or flood-irrigation and especially when the watertable is high, moisture in the surface soil may remain close to pF 2 (about 40% v/v) for some time. If so, there is much danger of compaction if tilled. Liability to slake seems less than expected from my observations on structural stability (Section 10.2.3).

Linear swelling of Marl Soils was estimated on clods treated with Saran resin at about 3% in the surface and 4-6% in the subsoil, which is normal for clayey soils.

The Steppe Marl is assessed as moderately deficient in irrigability, if the soils are not or slightly salt-affected, becoming strongly deficient with increased salinity.

10.3.4 Improvement of moisture condition

On *dry Steppe Marls*, despite the yearly moisture deficit of about 400 mm, rainfall in the Great Konya Basin is sufficient to produce wheat if the land is left fallow every second year. The fallow efficiency (i.e. proportion of precipitation in the fallow year conserved in the soil), was estimated by Janssen (1970c) at 15-30%.

Ploughing at the right time, which means in early spring, and weeding are necessary measures to improve fallow efficiency, which are both possible under system B.

Fertilizers (Nitrogen) may worsen the situation because the larger plants require more moisture (Janssen, *op. cit.*).

The conclusion is that improvement in moisture condition of dry soils is only partly feasible under B. Under A and if the soil is more than slightly salt-affected, improvement will not be feasible.

For *Irrigated Steppe Marl Soils* (Management System C) the situation would have been favourable if unlimited water was available, and if intensive irrigation did not result in progressive salinization. The latter might be avoided by sufficient drainage, but as the Steppe Marl Soils occur mainly in relatively low areas, this is hardly possible. This means that, though improvement is theoretically easily feasible, in practice, it is only partly so.

As regards the 'irrigability' of the soil, its liability to compact, which also affects the infiltration rate, can hardly be improved but can possibly be avoided under sophisticated management. The conclusion is that improvement of irrigability is not or is only perhaps feasible.

10.4 Soil fertility of Steppe Marls

Two aspects of chemical soil fertility are important for evaluation: the natural fertility and, if this is deficient, the response to fertilizers. Both depend on an intricate pattern of factors. Though their study is outside the scope of the subject, a general discussion of the problems and the most important soil properties is necessary.

Fortunately part of the information gathered by Janssen (1970a, b, c) can be used here, together with some general data on the fertility of highly calcareous Lisan Marls in Israel and the Perrine Marls in Florida.

10.4.1 Ideal fertility condition

The natural fertility of a soil is ideal when the crop produces (when other conditions – such as water supply and structure – are optimum) a maximum yield without application of manure or chemical fertilizers. Some Chernozems in eastern Europe, where fertility is due to a high and readily available mineral reserve, intense microbial activity, good management and low salinity closely approach this ideal.

In deficient soils, response to fertilizers is optimum under conditions mentioned above for natural fertility (except mineral reserve). Most important is a high cation-exchange capacity (about 35 meq/100 g) and a pH between 6 and 7. Cation exchange is, in general, a measure for potential fertility and Marshall (see Brady, 1965) even considers it the most important factor in agriculture, after photosynthesis. Next comes pH, as it determines the availability of major and minor elements as well as the microbial activity.

Table 15. Available phosphorus and nitrogen in Steppe Marl Soils and their percentage recovery in the plant (from Janssen, 1970c).

	Phosphorus		Nitrogen	
	P-Olsen (mg P_2O_5/100 g)	recovery (%)	organic N (total %)	recovery (%)
Near Konya	2.3	1.7	0.64	18.7
Near Hotamış	2.4	1.1	0.84	10.0

Tablo 15. Step Marn Toprağı'nda bitkilere yarayışlı fosfor ve azot ve bitki bünyelerinde bulunan, bitkiler tarafından alınmış miktarın yüzdeleri (Jansen 1970'den).

10.4.2 Deficiencies in natural fertility

The natural fertility of *dry Steppe Marl Soils* shows shortcomings due to moisture deficiencies, though not sufficient to prevent wheat cultivation every other year. But chemical deficiencies also play a role.

Janssen (1970a, b) concludes that potassium is present in sufficient quantities, as mineralogical data in Table 12 suggest. Table 15 gives availability and recovery values for phosporus and nitrogen: the availability of phosporus is low, nitrogen is sufficient in the absence of leaching. Base saturation is almost 100% (mainly Ca and Mg).

In saline-alkali soils, plant nutrition is inhibited.

The conclusion is that the dry Steppe Marl Soils are slightly deficient in natural fertility if salt-free, and strongly deficient if salt-affected.

On the natural fertility of *irrigated Marl Soils* no data from trials are known, but a moderate deficiency is expected there, mainly because the availability of phosporus and nitrogen will be low.

10.4.3 Deficiencies in reponse to fertilizers

For *dry soils* the effect of fertilizers on wheat and rye in the Great Konya Basin has been investigated by Janssen (1970a, b, c) in NPK trials on unirrigated soils. His preliminary results show that on the Steppe Marls near Konya fertilizers are likely to increase yield, but not on those near Hotamış. The main cause is a difference in precipitation and, consequently, in stored moisture.

Where stored moisture is less than 50 mm, the grain yield (about 400 kg/ha) depends almost entirely on precipitation during growth. Under such circumstances the response to fertilizer is mainly a matter of moisture. It seems that no response can be expected with an annual precipitation below 250 mm.

Other properties depressing response are the same as for natural fertility and will be discussed below for irrigated soils, because they hardly play any role on dry soils.

The conclusion is that dry Steppe Marls are strongly deficient in response to fertilizers.

In *irrigated soils,* provided neither moisture nor aeration nor structure are limiting factors, the response to fertilizers depends entirely on whether the fertilizing elements N, P and K support and check each other and the other nutrients (Brady, 1960).

In Marl Soils, mainly because of their alkaline reaction and their cation-exchange capacity (CEC usually between 15 and 25 meq/100 g) disturbances easily happen.

The large amounts of calcium and magnesium carbonates in the soil may result in lime-induced iron chlorosis, in particular where the percentage of fine-textured fraction is high (Hagin, 1952), as in the Steppe Marls. In the Lisan Marls of Israel, iron chlorosis frequently occurs when, before irrigation, green manures are ploughed in. It also easily occurs after too large an application of phosporus (Russell, 1961). As to nutrients, the availability of molybdenum increases and that of zinc decreases in highly calcareous soils (Ravikovitch *et al.*, 1968), but in fine-carbonatic soils, such as Steppe Marls, they generally are not deficient (Ravikovitch, 1961). It seems that irrigated Steppe Marls are moderately deficient in response.

10.4.4 Improvement in soil fertility

The feasibility of improvement in soil fertility varies widely under different management systems, mainly because of soil moisture.

For *System A* improvement of soil fertility is not feasible.

For *System B* it is only partly feasible, depending on the amount of conserved moisture. Here good management involves deep placement of the fertilizer.

Under *System C* (irrigation) improvement seems easily feasible, but it will be only partly because the soil is highly calcareous. Success will mainly depend on good irrigation management and the use of a balanced fertilizer mixture. The CEC may be improved by adding part of the fertilizer in organic form, preferably as stable manure.

10.5 Productivity of Steppe Marl Soils

Table 16 reviews the previously discussed agricultural conditions for Steppe Marl Soils, their degree of deficiency and the assessed feasibility for improvement under the three management systems A, B and C. The final general suitability class is added. The classification scale has been fully explained in my earlier publication (1970) and can be summarized as follows:

Class I *Good:* suitable for cereals under systems A and B and for a large variety of crops under System C. Improvements easy and lasting.

Class II *Fair:* moderately suitable for cereals under A and B and for a moderate variety of crops under System C. Improvements difficult but possible.

Class III *Restricted:* very poor results with cereals under A and B and limited choice under C. Deficiencies severe and not removable or only with great effort, much depending on management class (capital and skill).

Class IV *Not suitable* for arable farming:
- IVa Ranging possible.
- IVb Ranging not possible.

Table 16. Summary of agricultural conditions, properties, deficiencies and feasibility of improvement of Steppe Marl Soils and their tentative suitability for agriculture under three management systems.

Agricultural soil conditions	Pertinent soil properties or complexes of properties	Dry or wet	Deficiency as compared with ideal conditions	General conclusion on feasibility for improvement under		
				Management system A	Management system B	Management system C
Soil structure	Pedality and porosity	dry solum	moderate			
		dry substratum	moderate	not feasible	(partly) feasible	not feasible (detioration)
	Structure stability	dry or wet	strong			
Soil moisture	Storage and availability	dry soil	strong	not feasible	(partly) feasible	(partly) easily feasible
		wet soil	slight			
	Irrigability (including infiltration rate, slaking, compaction and swell)		moderate			not or perhaps feasible
Soil fertility	Natural fertility	dry soil	slight			
		wet soil	moderate	not feasible	(partly) feasible	(partly) feasible
	Response to fertilizers	dry soil	strong			
		wet soil	moderate			
Tentative soil suitability classification				Class III or IVa, depending on precipitation	Class III	Class III, or perhaps II under sophisticated management

Tablo 16. Tarımsal durumların özeti, besin maddeleri eksiklikleri ve Step Marn toprakların (LmA) geliştirilme imkanları ve 3 şedğiik amenajman sisteim altında ziraaatetah min edilen elverişlilikleri.

Any suitability classification based on profile studies and laboratory experiments should be thoroughly checked against farm data, but in the area considered here such checks were limited to primitive random checks on yields (just before harvest), interviews with farmers and the preliminary results of Janssens' field trials (Janssen, 1970a).

Under *Management System A* (dry farming, no fertilizers), widespread on Steppe Marls, soils belong to Classes III or IVa, to the latter in areas with insufficient precipitation and in salt-affected areas. Wheat yields (every other year!) in Class III vary between 600-1000 kg grain/ha and may attain 2000 kg/ha in wet years. On dry or slightly salt-affected soils, yields are never over 500 kg/ha (when lower, the soil belongs to Class IVa). Rye may give slightly better results in dry years (Janssen, 1970b).

Management System B (dry farming, fertilizers) is nowhere applied in the area. Steppe Marls under this system would belong to Class III, according to the results with deep-placed nitrogen and phosphorus fertilizers in field trials. Yield increments of 500-700 kg grain/ha have been obtained on Steppe Marls of the Konya Area, but only 250 kg/ha in the Hotamış Area because of insufficient moisture. Such increments are too low to justify fertilization, but with rye the result may be better. Rates of 20-40 kg N/ha and 40-60 kg P_2O_5/ha seem acceptable for Steppe Marl Soils, except

Fig. 75. Market-garden on well manured and irrigated Marl Soil with a sandy surface, near Karapınar. Soil suitability under this management is class II.

Şekil 75. Karapınar yakınlarında kumlu yüzey toprağa sahip iyi gübrelenmiş ve sulanmış Marn Toprağı'nda kurulan bahçeler.
Bu amenajman sisteminde elverişlilik sınıfı II'dir.

when they are too dry.

In *Management System C* (irrigated farming, fertilizers, skill) the Steppe Marl Soils are all of Class III which allows a limited variety of crops. On the small areas under irrigation (mainly from wells), wheat yields amount on average to 3000-4000 kg grain/ha, but there management could be much improved. Many farmers keep to the traditional fallow year and fertilizers are not properly applied. A field with lucerne near Karapınar produced annually 6 cuts of 10 tons/ha fresh forage. On properly fertilized fields sugar-beet grown on contract with the Sugar Factory at Konya yields about 40 ton/ha. However, yields obtained on comparable soils, like the Lisan Marls in Israel (Amiran, 1963; Fuller & Ray, 1965) and the Perrine Marls in Florida, USA (Malcolm, 1957; Thompson *et al.*, 1964) are reported as very good for a variety of crops, if properly irrigated, drained, tilled and fertilized. My conclusion is that also Steppe Marl Soils could be Class II (fair) under a really sophisticated management system (Fig. 75).

Summary

The Great Konya Basin is in the south of the Central Anatolian Plateau in Turkey. It is a depression without outlet to the sea. The central part of the Basin is the floor of a former Pleistocene lake, the Ancient Konya Lake. This area, called the Lacustrine Plain, has highly calcareous clayey sediments and is flat and level, except for ancient shorelines which form sandy ridges and beaches. Its soils have been studied in the summers of 1964-8 as part of the Konya Project, a research and training programme of the Department of Tropical Soil Science of the Agricultural University, Wageningen. This book is the last publication about the results in a series of five.

The Quarternary history of the Lacustrine Plain, as regards sedimentation, was reconstructed with the help of existing climatic chronologies and with observations on geomorphology, soils, shells and pollen. Presumably Ancient Konya Lake, which had a constant level of about 1017 m, dried up in Postpluvial I (about 16.000 BC) and four smaller lakes or marshes existed in secondary depressions during Subpluvial I (about 9000 BC), which gradually disappeared. Their level varied between 1000 and 1006 m.

The soils of the Lacustrine Plain were mostly formed in white uniform carbonatic clay, but differ markedly in composition and morphology because of past and present differences in hydrology, topography and vegetation. The soils have been studied and mapped on a regional basis and divided into Steppe Marl Soils, Marsh Marl Soils and Playa Marl Soils. The last group occurs north and east of Karapınar and is strongly salt-affected. Profile data of some 13 representative Marl Soil profiles are presented in the form of structural diagrams and tables for easy reference.

Soil peels (preserved natural soil profiles) of the same representative soils are also used for a precise description of the pedological features and voids of the soil material, using Brewer's system of 'pedography'. Areas for more expensive thin sections could be selected more carefully. Interpretation is based on the descriptions in the field, in the soil peel and occasionally in thin section. Organisms, presumably mainly earthworms, seemed the main cause of the present structure of the solum. The effects of recent cultivation and irrigation are also demonstrated. Redistribution of carbonates, humus and iron is observed and explained.

The textural and mineralogical composition of Marl Soils was studied superficially. The soil texture without removal of carbonates is mostly clay to silty-clay and is slightly finer-textured after carbonates have been removed. The carbonates (mainly calcium carbonate as calcite) occupy about an equal proportion of the clay, silt and sand fractions. Clay minerals of the smectite group are commonest and palygorskite

is present.

The carbonatic clayey parent material of the Marl Soil is a sediment of about 60% mainly chemically precipitated calcite, debris from limestone and shells and the rest is a residue of non-calcareous clay minerals of residual and alluvial origin and sand sized mineral grains of alluvial or aeolian origin.

The productivity of Steppe Marl Soils is estimated, using results from the soil peels and data on moisture and soil fertility. The suitability for agriculture is estimated by an existing procedure, which was refined and adapted to the area. The procedure compares estimated deficiencies in soil structure, soil moisture and chemical soil fertility in comparison with ideal conditions. The feasibility for improvement is then assessed for three management systems: dry farming without fertilizers, dry farming with fertilizers and irrigated farming with fertilizers. The soil suitability in 4 classes (good, fair, restricted and unsuitable) is assessed on the basis of the above analysis. The suitability of Steppe Marl Soils for agriculture is judged as 'unsuitable' or 'restricted' under the dry-farming systems, mainly because of lack of moisture and 'restricted' under irrigation (mainly because of poor irrigability and poor response to fertilizers). It may become 'fair' under highly sophisticated irrigational management as is demonstrated on comparable soils in Israel and Florida.

Özet

Büyük Konya havzası Orta Anadolu Plâtosunun güneyinde bulunmaktadır. Burası denizle irtibatı olmayan çukur bir sahadır. Havzanın orta kısmı eski Konya Gölünün tabanıdır. Bu saha, kumlu seddeler ve plajlardan kurulu eski göl kıyıları hariç düz yüksek miktarda kireçli kil çökeltileri ihtiva eden, ve prüzsüz olan lakustrin ova olarak isimlendirilmektedir. Havza toprakları, Wageningen Ziraat Üniversitesi Tropikal Toprak Bilgisi Bölümünün araştırma ve eğitim programı içinde olan Konya projesinin bir kısmı olarak 1964-68 yaz aylarında incelenmiştir.

Lakustrin ovanın çökeltilere bağlı olarak kuaternerde geçirdiği devreler, jeomorfolojik gözlemler, topraklar, fosil kabukları ve polen üzerinde yapılan gözlemlerin de yardımıyla Butzer'in iklim kronolojisine bakılarak tesbit edilmiştir. İhtimalki sabit 1017 m seviyede bulunmakta olan Konya Gölü, postpluviyal I'de (milattan takriben 16.000 sene önce) kurumuştur ve alt Pluvial I'de (milattan takriben 9.000 sene önce ikincil çukur sahalar şeklinde 5 küçük göl veya bataklık haline gelmiş ve yavaş yavaş ortadan kalkmıştır. Seviyeler 1000 ile 1006 m arasında değişmekteyi.

Genellikle beyaz üniform karbonatlı kil'den kurulu olan lakustrin ova; hidrolohi topografya ve bitki örtüsünde eskiden ve halihazırdaki bulunan degişiklikler dolayısiyle, birbirlerinden bileşim ve morfoloji bakımından önemli bir şekilde ayrı özellikler göstermektedirler. Topraklar bölgesel esaslara göre Step Marn Toprakları, Bataklık Marn toprakları, Playa Marn Toprakları şeklinde birbirlerinden ayrılarak incelenmiştir. Son grup Karapınar'ın kuzey ve doğusunda bulunur ve fazla tuz etkisinde kalmıştır. 14 temsili marn toprağı profili hakkında elde edilen kayıtlar, struktur diyagramları ve kolay anlaşılabilir tablolar halinde takdim edilmiştir.

Bazı toprakları temsil eden tabii durumlarındaki toprak monolitleri, toprak materyalindeki pedolojik görünümler, ve porların daha detaylı izahları için Brewer pedografi sistemi kullanılarak incelenmiştir. Böylece daha pahalıya mal olan ince kesitlerin yapılması gerekli yerlerin seçimi de mümkün olmaktadır.

Yorumlamalar, genellikle tarlada yapılan izahlara ve toprak monolitlerine, bazende ince kesitlere istinaden yapılmıştır. Genellikle solucanlar, solumda, halihazırdaki strukturun başlıca sebebi olarak görünmektedir. Yeni yapılan toprak işleme ve sulamanın etkileri de gösterilmiştir. Karbonatların, humus ve demir'in profilde yeniden düzenlenmesi takip ve izah edilmiştir. Marn toprakların tekstur ve mineralojisi sathi olark incelenmiştir. Karbonatları giderilmeden toprak, genellikle kilden siltli kile kadar teksturlu ve killeri giderildikten sonra daha ince tekturludurlar. Karbonatlar (genellikle kalsit olarak kalsiyum karbonat) topraktaki kil, silt ve kum fraksiyonuna eşit miktarlarda dağılmıştır. Bu demektirki, toprakta kum'un az bulunması dolayı-

siyle karbonatlar takriben eşit miktarlarda kil ve silt fraksiyonunda bulunmaktadırlar. Kil minerallerinden smektit grubu en çok bulunanıdır ve paligorskit de ayrıca mevcuttur.

Marn toprağın karbonatlı killi ana materyali, bir çökelti (sediment) olup, takriben % 60'ı genellikle kimyasal yollarla çökelerek kalsit, kireç taşı döküntüleri ve kalkerli fosil kabukları ve resudial ve aluviyal orijinli kalkerli olmayan kil mineralleri kalıntıları ve aluviyal ve eolik kökenli kum büyüklüğündeki mineral tanelerinden kuruludur.

Marn toprakların bitki yetiştirme yeteneği, monolitlerin incelenmesinden elde edilen sonuçlar, toprak nemi ve toprak verimliliği üzerindeki elde edilen kayıtlardan tahmin edilmiştir. Ziraate elverişlilik, sahaya adaptesi mümkün bir hale getirilen, bilinen usuller yardımıyla tahmin edilmiştir. Bu tahmin toprak strukturunda, toprak neminde ve kimyasal toprak verimliliğindeki yetersizliklerin ideal şartlarla karşılaştırılması suretiyle yapılmıştır. Geliştirmeye uygunluk üç değişik amenajman sistemi için kyymetlendirilmiştir: gübrelemesiz kuru ziraat, gübrelemeli kuru ziraat ve gübrelemelı sulu ziraat. Toprak yugunlukları 4 sınıf içinde (iyi, orta, sınırlı ve uygun değil), yukarıda belirtilen analizlere dayanılarak kıymetlendirilmiştir. Step Marn Toprakların kuru ziraat sistemi altında 'ziraate uygun olmayışı' veya 'sınırlı' olarak, genellikle sulamaya uygun olmayışları ve gübrelemeye gerekli cevabı vermeyişleri dolayısıyle 'sınırlı' sınıf topraklar olarak muhakeme edilmiştir. Israil ve Florida'da gösterildiği gibi, çok ustalık ve masraflarla sulu ziraat amenajman sistemi altında bu topraklar orta dereceli bir duruma gelebilir.

Appendix 1

Soil-peel descriptions and descriptions of thin sections

Profife C 3.2

Soil-peel description

Pedological features	*Voids*
Unit 1	
few single and many strongly welded coarse fecal pellets; very many single and welded medium fecal pellets	very many irregular fine macrovughs between fecal pellets (packing voids)
Unit 2	
many collapsed coarse fecal pellets; many welded and strongly welded medium fecal pellets	few subrounded very fine macrovughs in collapsed mass; common irregular fine macrovughs between medium fecal pellets
Unit 3	
many welded and strongly welded coarse fecal pellets; few welded medium fecal pellets; few coarse aggrotubules	common irregular fine macrovughs in collapsed mass; common irregular fine macrovughs between medium fecal pellets
Unit 4	
very coarse irregular glaebules of collapsed fecal pellets and strongly welded medium fecal pellets; few aggrotubules and few aggrochambers with welded fecal pellets; few diffuse calcareous nodules	common very fine macrovughs; many very fine macrochannels; few fine macro-skew-planes
Unit 5	
many welded fine and medium fecal pellets predominantly in planes alternating with non-fecal soil material; few macrochambers with collapsed fecal pellets (isochambers)	many very fine macrochannels, many fine macro-joint-planes
Unit 6	
soil material non-fecal, mixed with collapsed fecal pellets; common pedotubules with welded fine fecal pellets	many very fine macro-joint-planes; many coarse channels

Description of thin section of Unit 2 (Sample 66172)

Plasmic structure: mixed loose crystic fabric (with common very fine organic particles)
Basic structure: porphyroskelic
voids: many irregular mesovughs and macrovughs; common macrochannels

skeleton grains: many fine to coarse rounded and subangular grains
Elementary structure: fecal vughy and loose crystic (many welded and common single matric fecal pellets)
Primary structure
glaebules: common medium sharp fine crystic nodules; common fine to medium organic nodules
biorelicts: common coarse shell fragments; common root residues

Description of thin section of Unit 3 (Sample 66173)

Plasmic structure: mixed loose crystic fabric
Basic structure: porphyroskelic
voids: many microvughs, many irregular mesovughs and macrovughs; few macrochannels
skeleton grains: common fine and medium rounded and subrounded grains
Elementary structure: fecal vughy and loose crystic (many welded and common single matric fecal pellets)
Primary structure:
glaebules: common medium and coarse sharp fine crystic nodules
biorelicts: common shell fragments, common root residues

Description of thin section of Unit 4 (Sample 66174)

Plasmic structure: mixed loose crystic fabric
Basic structure: porphyroskelic
voids: common microvughs, many irregular mesovughs and macrovughs; few rounded macrochannels
skeleton grains: common fine and medium mainly rounded grains
Elementary structure: cutanic vughy and crazed loose crystic (common fine, fine crystic vugh calcitans and channel calcitans)
Primary structure:
fecal pellets: common welded and common single matric fecal pellets
pedotubuies: few macro aggrotubules partly filled with welded and single fecal pellets
glaebules: few fine rounded sharp iron nodules; few fine sharp fine crystic nodules
crystallaria: common coarse calcareous crystal chambers (in vughs); common acicular extremely thin crystals (Lublinite) in voids
biorelicts: common coarse shell fragments

Profile G 1.1

Soil-peel description

Pedological features	*Voids*
Unit 1	
no pedological features, non-fecal	many fine macro-joint-planes
Unit 2	
common coarse strongly welded fecal pellets; abundant medium welded fecal pellets	many fine macrovughs, few fine macrochannels
Unit 3	
common collapsed coarse fecal pellets; common strongly welded medium fecal pellets	many fine macrovughs, many medium macrochannels, common very fine skew planes

Unit 4

common strongly welded and collapsed coarse fecal pellets; abundant strongly welded medium fecal pellets; common aggrotubules and aggrochambers with welded fecal pellets	many fine macrovughs, many fine macrochannels

Unit 5

common collapsed coarse fecal pellets; many welded medium fecal pellets; few isochambers	many very fine macrovoids between medium fecal pellets; many fine macrochannels, few fine macro-skew-planes

Unit 6

common collapsed coarse and medium fecal pellets	common fine macrovughs; many very fine macro-skew-planes; few fine macrochannels

Unit 7 (krotovina) ·

abundant welded medium fecal pellets; few welded coarse fecal pellets	many fine macrovughs

Description of thin section of Unit 2 (Sample 66138)

Plasmic structure: mixed dense crystic fabric
Basic structure: porphyroskelic
voids: common, irregular or mammilated clustered mesovughs and macrovughs; common macrochannels; few very fine craze planes
skeleton grains: common very fine and few fine grains
Elementary structure: vughy and channelled dense crystic (here and there common welded matric fecal pellets; few organic fecal pellets)
Primary structure:
glaebules: very few, spherical, rather sharp crystic nodules; few fine to medium iron nodules
biorelicts: common shell fragments

Description of thin section of Unit 3 (Sample 66184)

Plasmic structure: mixed loose crystic fabric
Basic structure: porphyroskelic
voids: many to abundant clustered mammilated mesovughs and macrovughs; common macrochannels
skeleton grains: common very fine and few fine rounded and subrounded grains
Elementary structure: fecal vughy and channelled loose crystic (many welded and single matric fecal pellets)
Primary structure:
cutans: few calcitans (matrans) around roots, single grains and shell fragments
glaebules: common fine spherical sharp crystic nodules
biorelicts: few organic root remnants; common very fine and few coarse shell fragments

Description of thin section of Unit 4 (Sample 67265)

Plasmic structure: fine loose crystic fabric
Basic structure: porphyroskelic (few grains)
voids: abundant mammilated mesovughs and macrovughs; many microvughs; common macrochannels; few very fine to fine craze planes

skeleton grains: few fine and medium mainly subrounded grains
Elementary structure: fecal, microvughy loose crystic (many single and abundant welded matric fecal pellets)
Primary structure:
glaebules: few fine nodules
biorelicts: common coarse shell fragments; few vegetation fragments

Description of thin section of Unit 5 (Sample 66185)

Plasmic structure: fine dense crystic fabric
Basic structure: crystic (very few grains)
voids: few clusters with many microvughs; few macrovughs; common macrochannels; many very fine to fine craze and skew planes
skeleton grains: few fine grains
Elementary structure: cutanic fractured dense crystic (many veıy fine plane calcitans, vugh, and channel calcitans)
Primary structure:
glaebules: common diffuse clusters of irregular particles (presumably disperse humus); few fine crystic nodules
fecal pellets: few single fecal pellets
biorelicts: few very fine shell fragments

Profile D 3.1

Soil-peel description

Pedological features	*Voids*
Unit 1	
abundant single and welded medium and coarse fecal pellets; common roots	very many irregular interconnected very fine and fine macrovughs
Unit 2	
(a) collapsed, coarse fecal pellets; few aggrotubules with many medium fecal pellets; many organic ped and channel cutans, (b) abundant strongly welded coarse fecal pellets	few irregular fine macrovughs, many very fine macro-craze-planes, common fine macrochannels
Unit 3	
abundant collapsed coarse fecal pellets; few medium aggrotubules; few diffuse grey nodules of dispersed humus; few organic plane cutans	few irregular fine macrovughs; many fine macrochannels; many fine macro-skew-planes
Unit 4	
abundant collapsed coarse fecal pellets; diffuse yellow sesquioxidic coarse macro nodules	many fine macrochannels, few with root remnants; many very fine macro-skew-planes
Unit 5	
abundant collapsed coarse fecal pellets, common welded and strongly welded fecal pellets; few to common aggrotubules with single and	very many very fine and fine macro-skew-planes

welded medium fecal pellets; many fine macrochannels

Unit 6

many crystic sheets (gypsum); many coarse aggrotubules with strongly welded medium fecal pellets

abundant very fine and fine macrovughs; few channels; few to common very fine macro-skew-planes

Unit 7

abundant collapsed and strongly welded fecal pellets; few aggrotubules with welded medium fecal pellets; common crystal sheets (gypsum)

many fine macrochannels, many very fine macro-skew-planes

Description of thin section of Unit 2 (Sample 66175)

Plasmic structure: mixed loose crystic fabric with common very fine dark-brown humus particles; fabric locally dense
Basic structure: porphyroskelic
voids: abundant irregular mesovughs; many interconnected mammilated macrovughs; few mesochannels; common micro-skew-planes in dense areas
skeleton grains: abundant fine and medium subrounded grains
Elementary structure: fecal mammilated vughy loose crystic (many single and welded matric fecal pellets and few organic pellets)
Primary structure:
glaebules: common rounded fine crystic nodules
biorelicts: many fine shell fragments

Description of thin section of Unit 3 (Sample 66176)

Plasmic structure: fine dense crystic fabric (common decalcified zones around vughs and channels)
Basic structure: crystic (very few skeleton grains)
voids: common irregular mesovughs and macrovughs, common macro-craze-planes, few macrochannels
skeleton grains: few clustered fine rounded grains
Elementary structure: vughy and crazed dense crystic (no characteristic pedological feature)
Primary structure:
glaebules: diffuse coarse yellow sesquioxidic nodules, locally discrete
biorelicts: shell remnants

Profile C 2.1

Soil-peel description

Pedological features	*Voids*
Unit 1	
few welded coarse fecal pellets; few coarse carbonate nodules	many fine macro-joint-planes, few fine macrochannels; common roots
Unit 2	
many strongly welded coarse fecal pellets; com-	many irregular very fine macrovughs, many

mon welded and strongly welded medium fecal pellets; common very coarse isochambers; common very coarse carbonate nodules	fine-macro-channels; many fine macro-skew planes
Unit 3	
many collapsed fecal pellets, many very coarse isochambers (weakly adhesive)	many fine macrochannels, common skew planes
Unit 4	
many collapsed coarse fecal pellets; many very coarse diffuse yellow iron nodules	many fine macro-skew-planes, common fine macrochannels
Unit 5	
common extremely coarse diffuse yellow iron nodules; few pedotubules with medium welded fecal pellets	common fine macro joint and skew planes, common fine macrochannels
Unit 6 (old filled crack)	
common welded and strongly welded medium fecal pellets	common very fine and fine macrovughs; many fine macrochannels

Description of thin section of Unit 2 (Sample 65149)

Plasmic structure: fine loose crystic fabric with common extremely fine to very fine dark organic particles, locally clustered
Basic structure: porphyroskelic
voids: many mammilated mesovughs and macrovughs; common microvughs; few macrochannels; common micro-skew-planes
skeleton grains: common fine mainly subrounded grains
Elementary structure: fecal, mammilated vughy microfractured loose crystic (common mainly welded medium matric fecal pellets and few fine organic pellets)
Primary structure:
pedotubules: few aggrotubules, partly filled with single pellets
biorelicts: common fine rounded and subrounded shell fragments; few elongated coarse shell fragments; organic root residues in channels

Description of thin section of Unit 3 (Sample 65150)

Plasmic structure: fine loose slightly clustered crystic fabric with common fine dark organic particles
Basic structure: porphyroskelic
voids: common irregular mesovughs and macrovughs; common microvesicles; few macrochannels; few craze planes
skeleton grains: common fine mainly subrounded grains
Elementary structure: pedotubulic vughy and crazed loose crystic (few aggrotubules, partly filled with single fecal pellets)
Primary structure:
glaebules: few diffuse crystic nodules
crystallaria: few clusters of crystals
cutans: fine crystic channel calcitans
biorelicts: common shell fragments

Description of thin section of Unit 5 (Sample 65151)

Plasmic structure: fine dense crystic fabric with many very fine dark organic particles
Basic structure: porphyroskelic
voids: common irregular mesovughs and macrovughs; many craze planes and few joint planes; few channels
skeleton grains: common clustered mainy rounded grains
Elementary structure: glaebular (crazed crystic few yellow discrete or rather diffuse iron and humus nodules with skew planes, filled with crystic fabric)
pedotubules: few granotubules
crystallaria: crystal planes (see glaebules)

Profile G 1.3

Soil-peel description

Pedological features	*Voids*
Unit 1	
ploughed layer with clods entirely consisting of welded fecal pellets and many fine and very fine macrovughs	
Unit 5	
abundant strongly welded medium fecal pellets	many very fine macrovughs; common fine macrovughs and skew planes
Unit 3	
common collapsed coarse fecal pellets; common welded medium fecal pellets	many fine macrovughs; many very fine macro-skew-planes; common very fine macrochannels
Unit 4	
few collapsed coarse fecal pellets; common welded medium fecal pellets; common medium coarse aggrotubules with medium fecal pellets	many fine macrovughs; common fine macro-channels; common very fine macro-skew-planes
Unit 5	
many welded medium fecal pellets	many fine macrovughs; many fine macrochannels; common fine macro-skew-planes
Unit 6	
common collapsed fecal pellets; common very coarse diffuse yellow iron nodules	common fine macro-skew-planes; common fine macrochannels

Description of thin section of Unit 4 (Sample 67311)

Plasmic structure: mixed loose crystic fabric with common very fine dark organic particles
Basic structure: porphyroskelic
voids: common irregular microvughs, mesovughs and macrovughs; few macrochannels
skeleton grains: common fine mainly rounded grains
Elementary structure: pedotubulic, vughy, loose crystic fabric (few coarse rather sharp aggrotubules,

partly filled with welded fecal pellets and organic material)
Primary structure:
glaebules: few fine coarse crystic calcitic nodules
biorelicts: common very fine shell fragments

Profile C 2.3

Soil-peel description

Pedological features	*Voids*
Unit 1	
many strongly welded and many collapsed coarse fecal pellets; few welded medium fecal pellets; root remnants and shell fragments	many medium and coarse macrochannels; few fine macro-craze-planes
Unit 2	
many strongly welded coarse fecal pellets; few welded medium fecal pellets	few medium macrochannels; many fine macrochannels; many fine macro-craze-planes
Unit 3	
many collapsed coarse fecal pellets	few fine macrochannels; many very fine macrochannels; common very fine macro-craze-planes
Unit 4	
no pedological features	few fine macrochannels; common fine macro-craze-planes
Unit 5	
no pedological features	common fine macrochannels; few fine macro-craze-planes

Description of thin section of Unit 2 (Sample 70001)

Plasmic structure: mixed dense crystic fabric with common extremely fine and very fine organic particles
Basic structure: porphyroskelic
voids: few macrochannels; few meso-craze-planes
skeleton grains: common fine and very fine subrounded grains
Elementary structure: channelled dense crystic (no pedological features)
Primary structure:
biorelicts: common fine subrounded shell fragments; few fresh organic root residues

Description of thin section of Unit 4 (Sample 70002)

Plasmic structure: fine loose crystic fabric with extremely fine and fine organic particles
Basic structure: porphyroskelic
voids: common macrochannels; common meso-craze-planes; few skew planes
skeleton grains: common fine subrounded grains

Elementary structure: channelled and crazed loose crystic (no pedological features)
Primary structure:
biorelicts: common fine subrounded shell fragments

Description of thin section from 8 cm deep (Sample 70005)

Plasmic structure: no plasma
Basic structure: granular
voids: common simple packing mesovoids
skeleton grains: abundant fine mineral grains and common fine crystic nodules in banded distribution

Description of thin section from 90 cm deep (Sample 70006)

Plasmic structure: mixed dense crystic fabric
Basic structure: porphyroskelic
voids: few meso and macro craze planes; few macrochannels
skeleton grains: few subrounded mineral grains
Elementary structure: pedotubulic, crazed and channelled dense crystic (common coarse granotubules with fine mineral grains)
Primary structure:
biorelicts: few fine subrounded shell fragments

Profile E 1.3

Soil-peel description

Pedological features	*Voids*
Unit 1	
common welded and collapsed coarse fecal pellets	few fine macrochannels; many fine macro-joint-planes
Unit 2	
common collapsed coarse fecal pellets; few coarse aggrotubules with welded medium fecal pellets	few fine macrovughs; common fine macro-channels
Unit 3	
many welded and strongly welded, medium and coarse fecal pellets	common very fine and fine macrovughs; few fine macrochannels; few fine macro-skew-planes
Unit 4	
abundant single and welded rounded and sub-rounded pellets (sedimentary relicts) 0.1-1.0 mm in diameter	very many irregular very fine and fine macro-vughs (packing voids)
Unit 5	
abundant single and locally strongly welded subrounded and angular pellets (sedimentary relicts)	very many irregular very fine and fine macro-vughs; common fine macro-skew-planes in welded areas

Unit 6

abundant single, medium and coarse subrounded pellets (sedimentary relicts) — very many irregular fine macrovughs

Unit 7

as 6, but pellets 1-3 mm in diameter

Description of thin section of Unit 3 (Sample 66179)

Plasmic structure: mixed dense crystic fabric
Basic structure: porphyroskelic
voids: many interconnected mesovughs and macrovughs; common craze planes
skeleton grains: common angular and subrounded mineral grains
Elementary structure: (pseudofecal) vughy and crazed dense crystic (no pedological features)
Primary structure:
common, coarse pseudofecal pellets
biorelicts: few fine and medium shell fragments

Description of thin section of Unit 6 (Sample 65174)

N.B. Soil material consists of loosely packed pseudofecal pellets; description is of the s-matrix of a pellet.
Plasmic structure: mixed dense crystic fabric
Basic structure: porphyroskelic
voids: common very fine and fine craze planes
skeleton grains: common subrounded very fine and fine mineral grains
Elementary structure: crazed dense crystic (no characteristic pedological features)
Primary sructure:
pedological features: several pellets have diffuse ped neostrians
biorelicts: few subrounded fine and medium shell fragments

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Appendix 2

Key to the structure symbols and formulas. An English terminology for Jongerius' classification of soil structure (developed by J. C. Rigg, A. Jongerius and T. de Meester.

Pedogenic structure

- A *Holohedral peds*
  - A1 Crumb[1]
  - A2 False crumb
    - A2a mesoporous false crumb
    - A2b microporous, densely packed false crumb
    - A2c microporous, loosely packed false crumb
  - A3 Granules[1]
    - A3a round granules
    - A3b polyhedral granules
  - A4 Subangular block
    - A4a irregularly subangular block
    - A4b regularly subangular block
  - A5 Angular block
    - A5a irregularly angular block
    - A5b regularly angular block
- B *Prismatic[2] peds*
  - B1 Column
    - B1a compact-headed column
    - B1b loose-headed column
  - B2 Granular pedestal
  - B3 Compound prism
    - B3a compound rough prism
    - B3b compound smooth prism
  - B4 Segmented prism
    - B4a segmented compound rough prism
    - B4b segmented rough prism
    - B4c segmented smooth prism
    - B4d platy segmented prism
  - B5 Single prism
    - B5a single rough prism
    - B5b rhomboid
    - B5c single smooth prism
  - B6 Comb
- C *Platy peds*
  - C1 Flattened holohedron
    - C1a flattened subangular block
    - C1b flattened angular block
  - C2 Compound plate
  - C3 Stacked plate
  - C4 Single plate
    - C4a single uniform plate
    - C4b single layered plate
  - C5 Spongy plate

Geogenic structures

- D *Geogenic peds*
  - D1 Jointed structures
  - D2 Pyramids
  - D3 Stacked uniform plates
  - D4 Compound stacked uniform plates
    - D4a platy holohedron
    - D4b platy prism
  - D5 Layered prism
    - D5a layered prism
    - D5b layered flattened polygon
    - D5c layered stacked plates

Apedal structure

- E *Collaps structure*
  - E1 No intact peds in crust
    - E1a uniform crust
    - E1b layered crust
  - E2 Heterogeneous peds in crust
- F *Macroscopic primary structure*
  - F1 Concrete or massive
  - F2 Bridge structure between sand grains
    - F2a densely packed grains
    - F2b loosely packed grains
  - F3 Cutan structure without bridges
    - F3a densely packed grains
    - F3b loosely packed grains
  - F4 Micro aggregate structure
    - F4a densely packed grains
    - F4b loosely packed grains
- G *Pore structure*
  - G1 Sponge structure
    - G1a coarsely porous sponge structure
    - G1b porous sponge structure
    - G1c finely porous sponge structure
  - G2 Bubble structure
  - G3 Tube structure
- H *Geogenic macrostructure*
  - H1 Undisturbed geogenic macrostructure
  - H2 Disturbed geogenic macrostructure
- J *Single-grain structure*
  - J1 Single grain sand
  - J2 Loosely packed sand

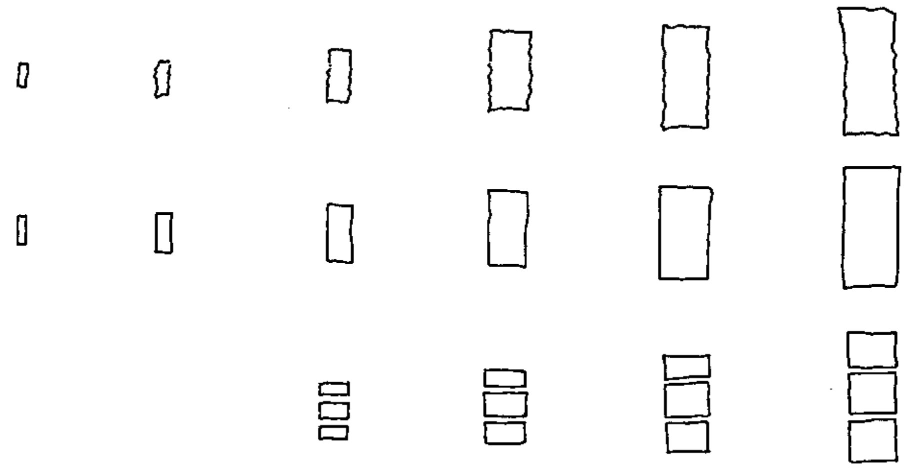
[1] Differently defined in Soil Survey Manual system.
[2] Soil Survey Manual's 'prismatic' excludes columnar.

Size and ped surface indications for structural elements (peds) in the structure diagrams and structure formulas (after Jongerius, 1957).

	I	II	III	IV	V	VI	VII
A Holohedral peds	very fine	fine	medium	coarse	very coarse		
	< 1 mm	1-2 mm	2-5 mm	5-10 mm	10-20 mm	20-50 mm	50-100 mm

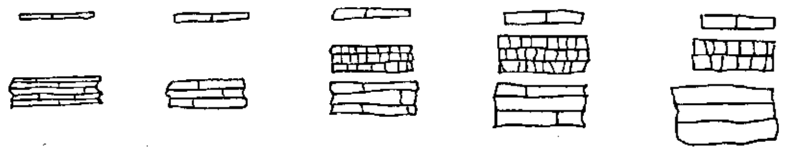
crumbs, false crumbs, granules; subangular blocks; angular blocks

B Prismatic peds	very fine	fine	medium	coarse	very coarse	
	< 10 mm	10-20 mm	20-50 mm	20-100 mm	100-200 mm	> 200 mm



rough prism; smooth prism; segmented prism (smooth)

C Platy peds	very thin	thin	medium	thick	very thick
	< 1 mm	1-2 mm	2-5 mm	5-10 mm	> 10 mm



single plate; compound plate; stacked plate

Other features

Porosity (code in formula):
1. micropores, mesopores and macropores (heterogeneous porous)
2. mostly micropores
3. no pores

diametre of soilpores: micropores <30 μm; mesopores 30-100 μm; macropores >100 μm

Structure grade					
Whole peds in percentage of total mass, after a spadefull is dropped from 30 cm.	0	< 10	10-30	30-70	> 70
peds are isolated with difficulty (code in formula)	0	¼	½	1½	2½
peds are easily isolated	0	–	1	2	3

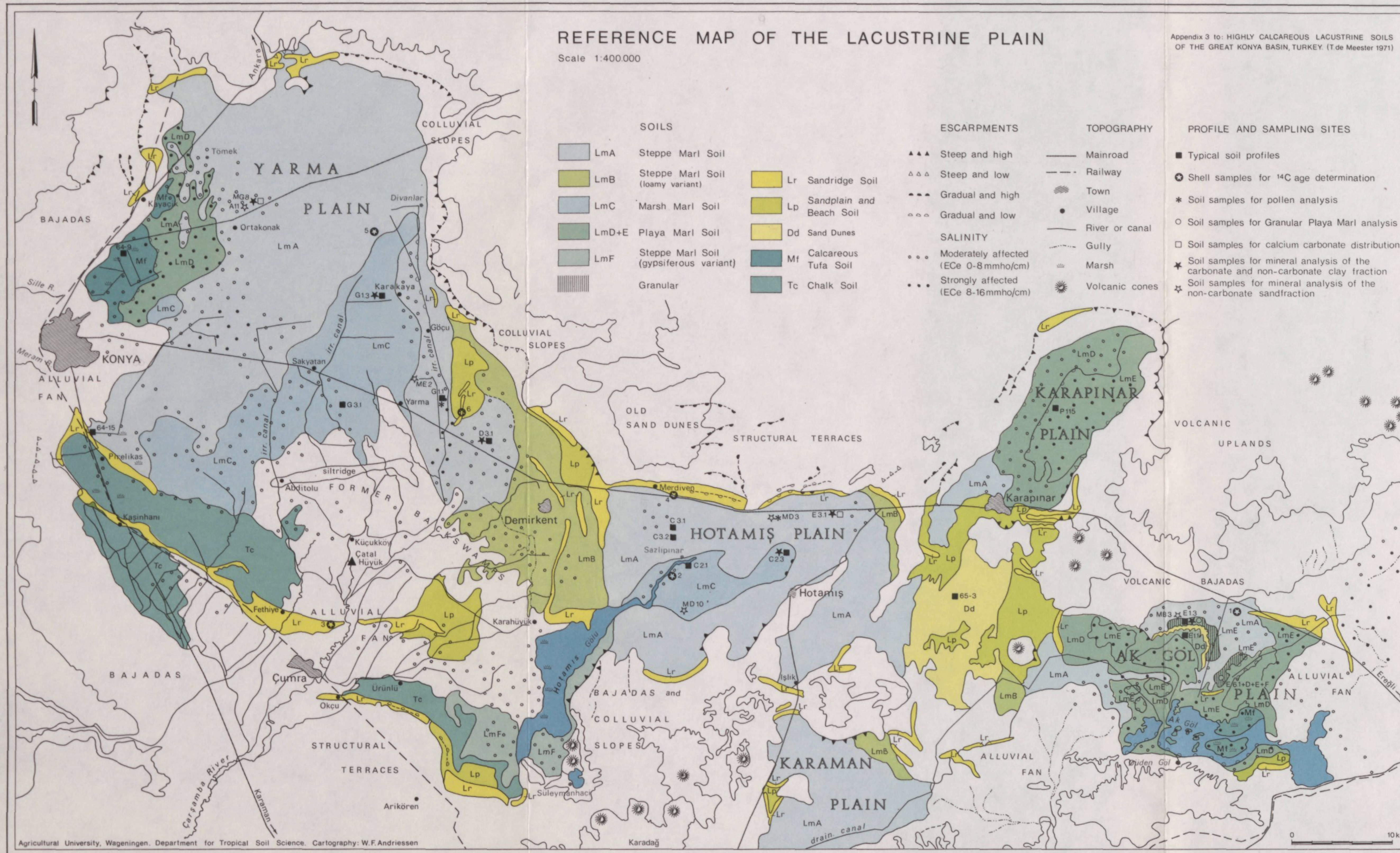
Terminology: 0 = no peds, ¼-½ = very weak, 1 = weak, 1½ = moderately weak, 2 = moderately strong, 2½ = strong, 3 = very strong

Structure grade (in the diagrams):	¼	½	1 + 1½	2 + 2½	3
primary ped surface	....	-.-.-.-.-	-------	———	═══
compound ped surface	....	-.-.-.-.-	-----	━━━	═══

Cutans and root prints (code in formula):
- α1 cutans, no rootprints on ped surface
- α2 cutans and rootprints on ped surface
- ζ rootprints, no cutans on ped surface

Example of a formula: $\frac{\text{B4a 2 III 2½ } \zeta}{\text{A4a 1 II 2}\alpha 1} = \frac{\text{compound peds}}{\text{primary peds}}$

Written in full: Segmented compound rough prism (B4a), with mostly micropores (2), peds are medium sized (III), with a strong structure grade (2½) and rootprints (ζ); consisting of irregular subangular blocky (A4a) heterogeneous porous (1), medium sized (III) peds; moderately strong (2) and with cutans (α1).


REFERENCE MAP OF THE LACUSTRINE PLAIN
Scale 1:400.000
Appendix 3 to: HIGHLY CALCAREOUS LACUSTRINE SOILS OF THE GREAT KONYA BASIN, TURKEY. (T.de Meester 1971)
SOILS
LmA Steppe Marl Soil
LmB Steppe Marl Soil (loamy variant)
LmC Marsh Marl Soil
LmD+E Playa Marl Soil
LmF Steppe Marl Soil (gypsiferous variant)
Granular
Lr Sandridge Soil
Lp Sandplain and Beach Soil
Dd Sand Dunes
Mf Calcareous Tufa Soil
Tc Chalk Soil
ESCARPMENTS
Steep and high
Steep and low
Gradual and high
Gradual and low
SALINITY
Moderately affected (ECe 0-8 mmho/cm)
Strongly affected (ECe 8-16 mmho/cm)
TOPOGRAPHY
Mainroad
Railway
Town
Village
River or canal
Gully
Marsh
Volcanic cones
PROFILE AND SAMPLING SITES
Typical soil profiles
Shell samples for 14C age determination
Soil samples for pollen analysis
Soil samples for Granular Playa Marl analysis
Soil samples for calcium carbonate distribution
Soil samples for mineral analysis of the carbonate and non-carbonate clay fraction
Soil samples for mineral analysis of the non-carbonate sandfraction
YARMA PLAIN
HOTAMIŞ PLAIN
KARAPINAR PLAIN
AK GÖL PLAIN
KARAMAN PLAIN
KONYA
Çumra
Karapınar
Demirkent
Hotamış
Ereğli
Karaman
Ankara
Sille R.
Meram R.
Çarşamba River
Hotamış Gölü
Ak Göl
Tomek
Kayacık
Ortakonak
Divanlar
Karakaya
Göçü
Sakyatan
Yarma
Merdiven
Sazlıpınar
Karahüyük
Küçükköy
Çatal Hüyük
Abditolu
Fethiye
Ürünlü
Okçu
Arıkören
Süleymanhacı
Işlık
Karadağ
Pınarlıkas
Kaşınhanı
BAJADAS
COLLUVIAL SLOPES
ALLUVIAL FAN
OLD SAND DUNES
STRUCTURAL TERRACES
FORMER BACKSWAMPS
siltridge
irr. canal
drain canal
VOLCANIC UPLANDS
VOLCANIC BAJADAS
BAJADAS and COLLUVIAL SLOPES
0 10 km
Agricultural University, Wageningen. Department for Tropical Soil Science. Cartography: W.F.Andriessen