The soils of the Trabzon catena north east Turkey

David Leslie Dent

THE SOILS OF THE TRABZON CATENA

NORTH EAST TURKEY

David Leslie Dent

M.Sc. Thesis
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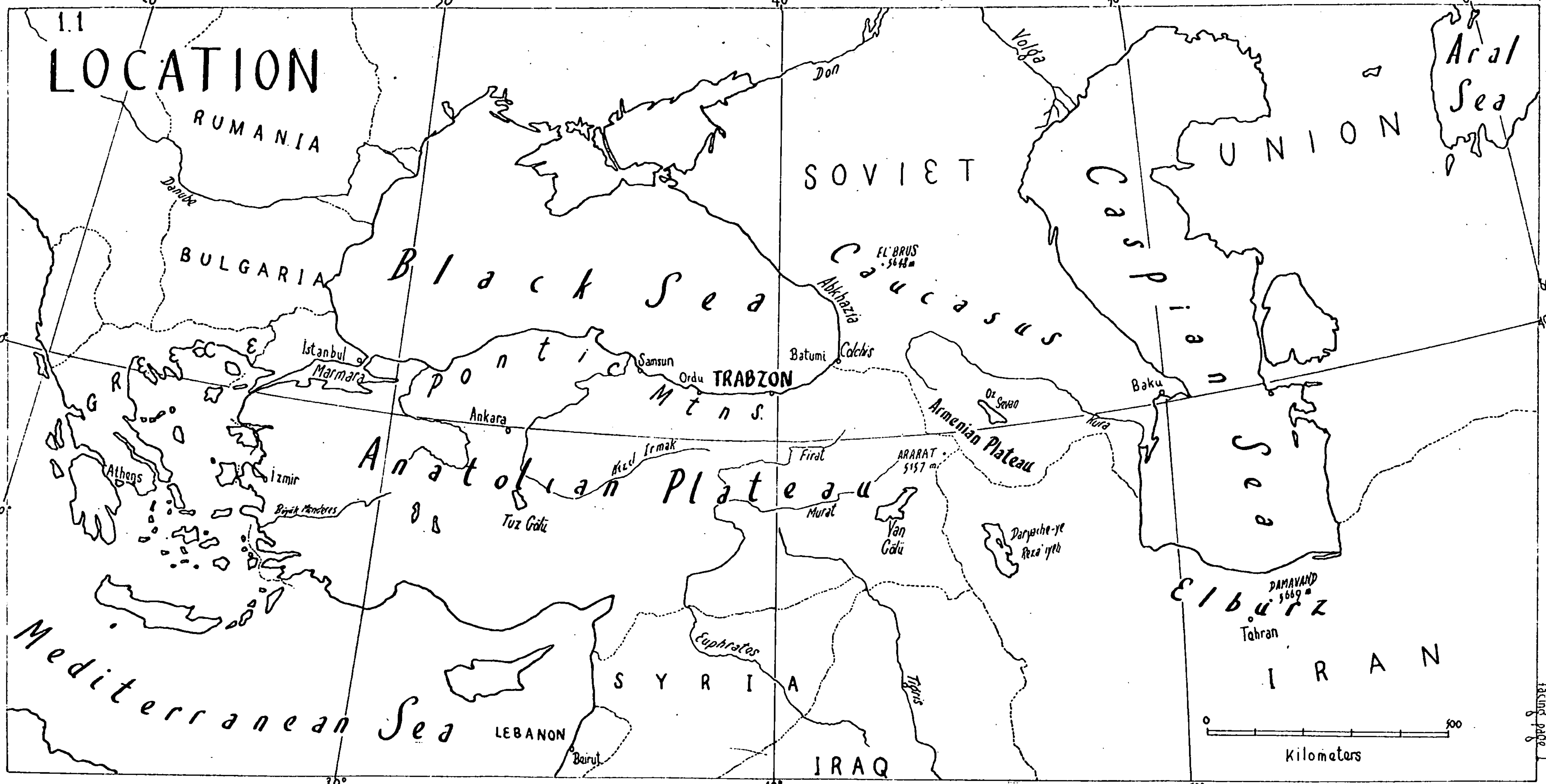
CONTENTS

Volume 1

Maps and Diagrams

Photographs


1.1
LOCATION
RUMANIA
BULGARIA
GREECE
Black Sea
SOVIET UNION
Caspian Sea
Aral Sea
Caucasus
Pontic Mtns.
Anatolian Plateau
Armenian Plateau
Mediterranean Sea
Elburz
IRAN
IRAQ
SYRIA
LEBANON
Danube
Don
Volga
Istanbul
Marmara
Samsun
Ordu
TRABZON
Batumi
Colchis
Abkhazia
EL'BRUS 5648 m
Baku
Kura
Oz. Sevan
Ankara
Kızıl Irmak
Fırat
ARARAT 5157 m
Van Gölü
Murat
Daryache-ye Reza'iyeh
Tuz Gölü
Izmir
Büyük Menderes
Athens
Euphrates
Tigris
Bairut
DAMAVAND 5669 m
Tahran
Kilometers
0
500
20°
30°
40°
50°
60°

Chapter 1

INTRODUCTION

Turkey is basically an agricultural country and its most assured future lies in the scientific development of its agricultural resources. At present the extensive continental interior provides staple cereal crops and animal products, whilst the climatically-favoured coastal regions produce the high value industrial and export crops for which the country is noted, viz: cotton, tobacco and a variety of fruit and nuts (1,2,3). Personal experience leads to the conclusion that improvement in the quality of agricultural production in the coastlands promises a greater economic return than more ambitious projects in the harsh interior.

The Eastern Black Sea Region extends eastwards from Ordu to the Soviet frontier in a narrow strip between the Black Sea and the crest of the bordering Pontic Mountains (figure 1.1). With its humid sub-tropical climate and a long history of intensive agriculture, this region offers a wide scope for field investigations as a basis for rational economic development, in spite of the fact that it has received little attention, even within Turkey.

This study is concerned primarily with the soils. Pedologists have traditionally studied the soil as an expression of many natural processes, conveniently summarised as the soil-forming factors - Parent Material, Climate, Topography, Time and Man (4). The subject has evolved from an appreciation of the landscape in toto and its mode of formation; and with this in mind Part 1 of this work reviews some relevant factors of the physical environment which have influenced the development of the soils.

A review of available references shows that little field work has been carried out on the soils of the Eastern Black Sea Region. In his important reconnaissance survey of Turkey, Harvey Oakes (5) contented himself with the designation of the region as "Rough

Mountainous Land (in Red and Grey-Brown Podsolic Soil Zone)". A more detailed soil conservation survey of Turkey is at present being carried out by TOPRAKSU at a scale of 1:25,000. (I had the advantage of working with the TOPRAKSU team in the Giresun area in May 1966).

The present work has been carried out on selected soil profiles representative of a restricted part of the region, in the vicinity of Trabzon, as a first step in the production of a detailed picture of the soils of the region. The compilation of a soil map of the Değirmendere basin was originally envisaged but aerial photographs and 1:25,000 topographic maps proved to be unavailable for security reasons, and enlarged 1:200,000 maps proved inadequate for soil survey. This study has therefore been confined to the recognition and characterisation of the major soil groups and to the problem of placing them in their regional genetic context.

During three months spent in the field in the Trabzon area in 1966 a transect was made across the grain of the country between Zafanos and the valley of the Sera Dere (figure 2.5). The major land-scape units were identified, and observations of the variations in soil morphology enabled a nuclear concept of each major soil group to be established. Twenty profiles were studied in detail, and of these fifteen were later subjected to physical and chemical analysis. Two monoliths representative of the major soil groups were collected and subjected to more detailed micromophological, physical and chemical investigations. Plant collections were made at representative sites and later identified by Dr. P.H. Davis of the Department of Botany at Edinburgh University. Laboratory investigations have been carried out at the Macaulay Institute for Soils Research in Aberdeen and I am indebted to Dr. R. Glentworth, Head of the Soil Survey of Scotland, through whose good offices laboratory facilities were made available to me. I have also consulted many senior colleagues at the Macaulay Institute. In particular I wish to thank Mr. J. Logan (techniques of specialised analysis), Mr. L. Robertson (preparation of thin sections),

Mr. A. Thomson (X-ray investigations), Mr. B.D. Mitchell and Mr. A. Bernie (differential thermal analysis), Mr. D. Duthie (mineralogy), Mr. J.C. Romans and Mr. J. Muir (pedology). Information on the morphology and infra-red spectrum of kaolin minerals was provided by Mr. J. Russell and Dr. W.J. McHardy of the Macaulay Institute. Dr. R.W. Gloyne of the Meteorological Office, Edinburgh assisted with climatic information. In addition, the advice and experience of Dr. S.G. Willimott of Reading University and Dr. A. d'Endredy of F.A.O. are greatly appreciated.

Note: Selected profile descriptions with standard analytical data are bound in a separate volume for ease of reference.

Chapter 2

STRUCTURE, GEOLOGY and RELIEF

Structure

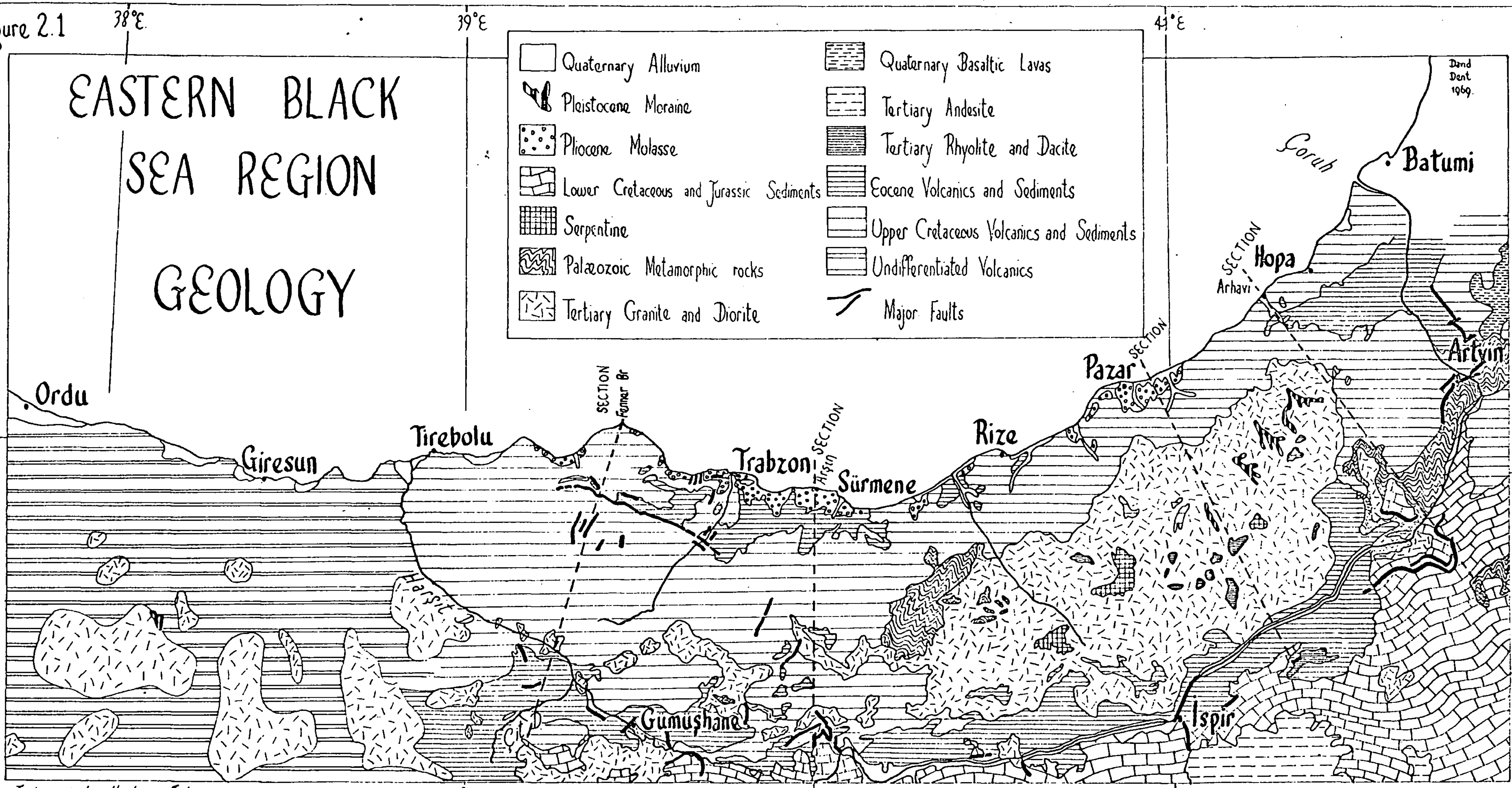
The Pontic Mountains (Pontids) form the northern rampart of Anatolia, rising steeply from the Black Sea, and extending for over 1200 km. from the valley of the Rioni, south of the Caucasus, almost to the Bosphorus. In the Eastern Black Sea Region the mountains form an inclined block, sloping from south to north. Major step faults are found running more or less parallel to the coastline (figure 2.1); notable examples can be seen in the fault region south of Trabzon. Smaller transverse faults run perpendicular to these. In the south the Pontids are delimited by another major fault system along the Çoruh depression and the upper Gümüşane - Harşit valley and continuing beyond this in a southwesterly direction. (9)

Geological History

Intensely-folded metamorphic rocks (schists, greywackes, quartzites and marbles) form the Palaeozoic basal series of the Eastern Pontid Block, overlain by extensive Upper Cretaceous and Eocene volcanic masses and intruded by various, mainly acid, plutonic rocks, (figure 2.2).

Cretaceous volcanic activity began with the extrusion of basaltic lavas, followed by dacites and andesites along with tuffs and agglomerates. In the hinterland between Pazar and Sürmene basaltic extrusions are not of great significance, but andesites and dacites with tuffs and agglomerates are found. The Cretaceous lavas attain their greatest thickness in the Trabzon-Gümüşane region where they reach up to 1000m. They contain lenticular intercalations, up to 200m. thick, of crystalline, and sometimes dolomitic limestones interbedded with marls and flysch beds, together with occasional reef limestones. Following the initial uplift of the Pontids at the end of the Cretaceous there was a short interruption of sedimentation.

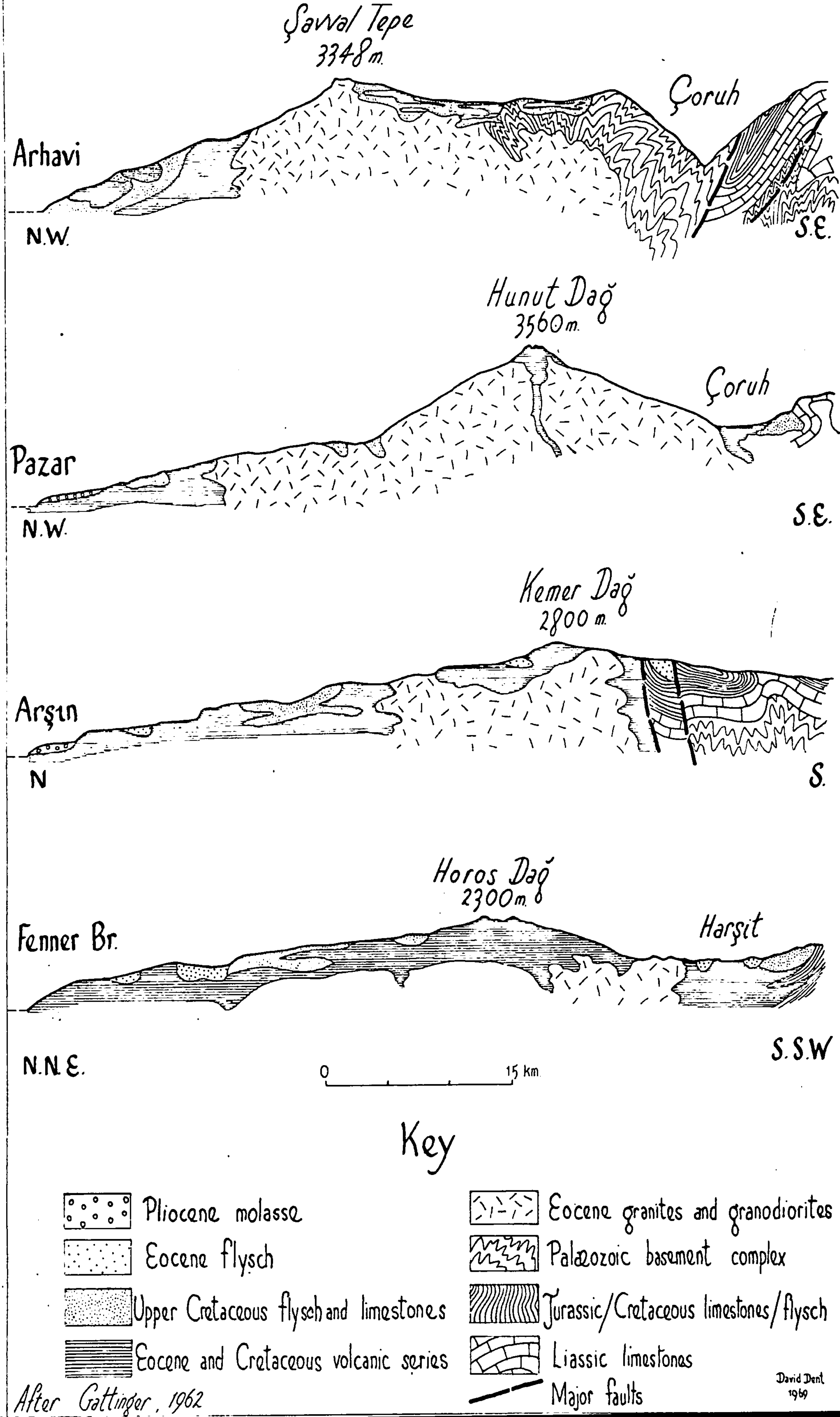
figure 2.1



Source: Türkiye Jeoloji Haritası, Trabzon 1:500 000
no reliable information for area west of longitude 39°E.

figure 2.2

GEOLOGICAL SECTIONS



There was a further volcanic episode during the Eocene. The rocks of this period consist mainly of andesites, porphyries and porphyrites, except in the eastern region where andesites were followed by trachyte and basalt lavas towards the end of the Eocene and probably during the Oligocene. Once again, there are intercalations of flysch elements - sandstones, conglomerates, shales, marls and occasionally limestones. The thickness of the whole series is about 1000m., while the thickness of the intercalated sediments ranges up to 300m.

There are isolated outcrops of acid to intermediate plutonic rocks of late Eocene and Oligocene age in the west, and a single extensive mass in the east. Coarse-grained granites form the greater part of the central axis of the eastern mass extending from Savval Tepe to the Soğanlıdağları, the central zone of granite being surrounded by acid diorites. The smaller, isolated intrusive bodies in the west are of similar composition. Metamorphic rocks, formed by contact metamorphism of Cretaceous and Eocene flysch sediments, are associated with the plutonic mass and fix the date of intrusive activity. Basic and acid intrusions around Trabzon and Maçka may be of somewhat later Tertiary age.

Some of the highest peaks, including Kaçkar and Hunut Dağ, are lava cones superimposed on the main eastern plutonic mass.

Throughout the Oligocene period the Pontids retained a stable continental position, but the northern edge was once more submerged during the Miocene, enabling the accumulation of molasse derived from the Pontic hinterland from Miocene to upper Pliocene times. These deposits, which include sands, clays and marls, are found along the slopes of the Black Sea coast, particularly behind Trabzon and Pazar.

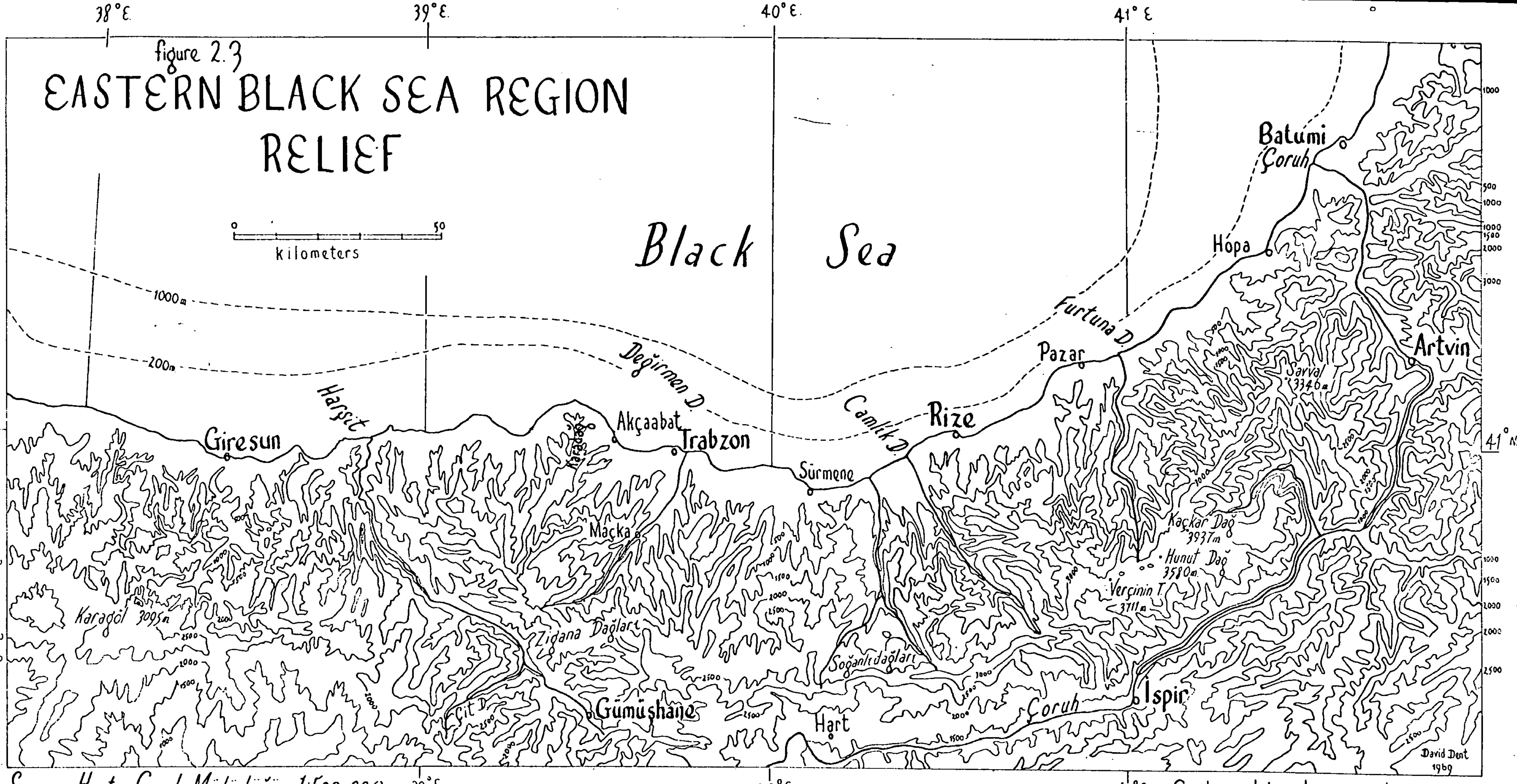
The Pontids began to acquire their present high mountain character as a result of vertical movements during Upper Pliocene times, and the fault zones are still subject to frequent, sometimes catastrophic earthquakes. The crest line of the Eastern Pontids forms an arc from south of Kutaisi to the Yeşil Irmak, breached only by the gorges of the Çoruh and the Harşit. Highest and most dissected in the east, the summit region reaches 3937m. in Kaçkar Dağ, and broadens westwards into a smoothly-sloping plateau - known in Turkish as yayla (photographs 1 and 2). Short, rapid streams flowing directly to the Black Sea cut the plateau into narrow ridges lying at 90^{o} to the strike of the mountains, producing rugged foothill country (photograph 3) with the land rising to over 2000m. within 15 to 20km. of the coast. Alluvial sands and gravels are found only in narrow strips along the lower reaches of streams and the coastline, excepting the larger deltas of the Harşit and Çoruh.

Pleistocene and Recent History

Above 2500m. corries, scree aprons, "U"-shaped valleys and extensive moraines are evidence of glaciation, particularly to the north of the main crest. Only traces of a single major glaciation have been reported and have been correlated with the Würm. Erinç (10) observed that the position of the Pleistocene snowline in the Eastern Pontids lies 200 to 300m. higher than in Western Pontids, and suggested that this might indicate continued uplift subsequent to the last major glaciation.

Small glaciers are found today north of the main crest on Kaçkar Dağ (three), Hunut Dağ and Verçilin Dağ. They are heavily loaded with ablation moraine and are clearly in retreat at the present time. From an examination of the recent and Pleistocene moraines Erinç (11) concludes that following a general shrinkage after the Würm there was a readvance - recent moraines partly covering glacial outwash deposits - but that the present glaciers are not direct survivors of the Pleistocene. The present glaciers were probably regenerated during a more humid, cooler stage of the Post-glacial epoch, and in historical times there has been a general decline, interrupted by various stages of re-expansion.

figure 2.3



Source: Harta Genel Müdürlüğü 1:500,000 — Contour Interval 500 metres

The Trabzon Platform (figures 2.3 and 2.4)

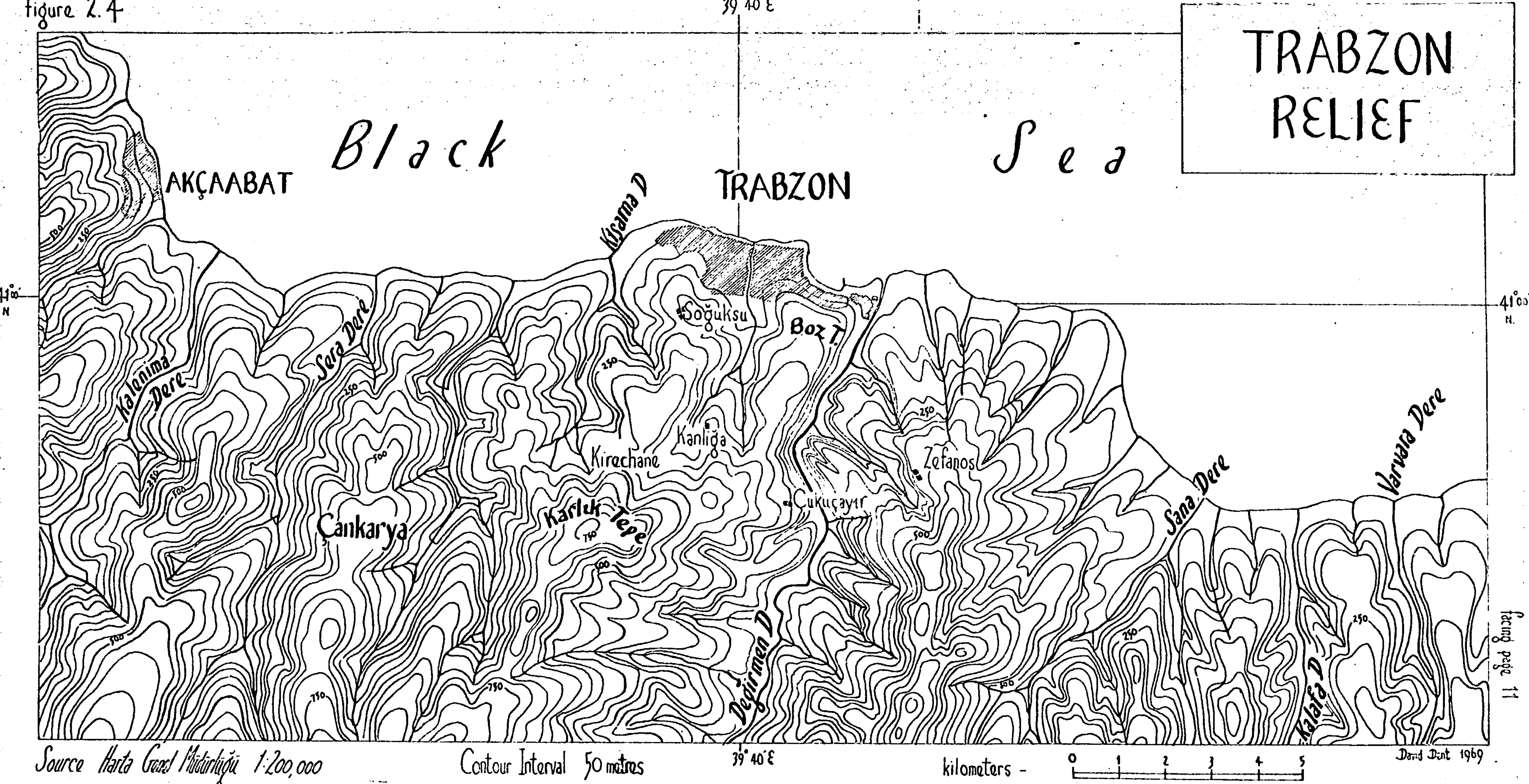
The Trabzon Platform extends from Sürmene to Akçaabat, a distance of 20 km. It has a maximum width of 8 km. and slopes gently northwards from an elevation of about 450m. to the coast where it is abruptly terminated by faulting at an elevation of 50 to 100m. Immediately south of Trabzon it is further interrupted by faults parallel to the coastline.

Closely-spaced gorges have carved the platform into a series of long, broad, smooth topped ridges (known as sirtes) at 90^{o} to the coastline. Also observed were younger marine terraces at 110-120m., 15-20m. and 6-8m., as reported by Ardel (12). They are inclined gently towards the coast. Caves associated with the highest, and best-developed terrace may be seen on valley sides up to 3 km. inland.

The ridge tops usually retain a heterogeneous cover of Miocene and Pliocene molasse sediment, which lies unconformably over the basal volcanic formations (olivine and augite basalts, dacites and andesites, along with tuffs and agglomerates). The volcanic basement is exposed in the gorges and occasionally on those ridges which have been completely stripped of their sedimentary cover. In the vicinity of Kireçhane and Kısarna, Upper Cretaceous flysch beds are exposed: these include dark grey sandstones and light-coloured marls.

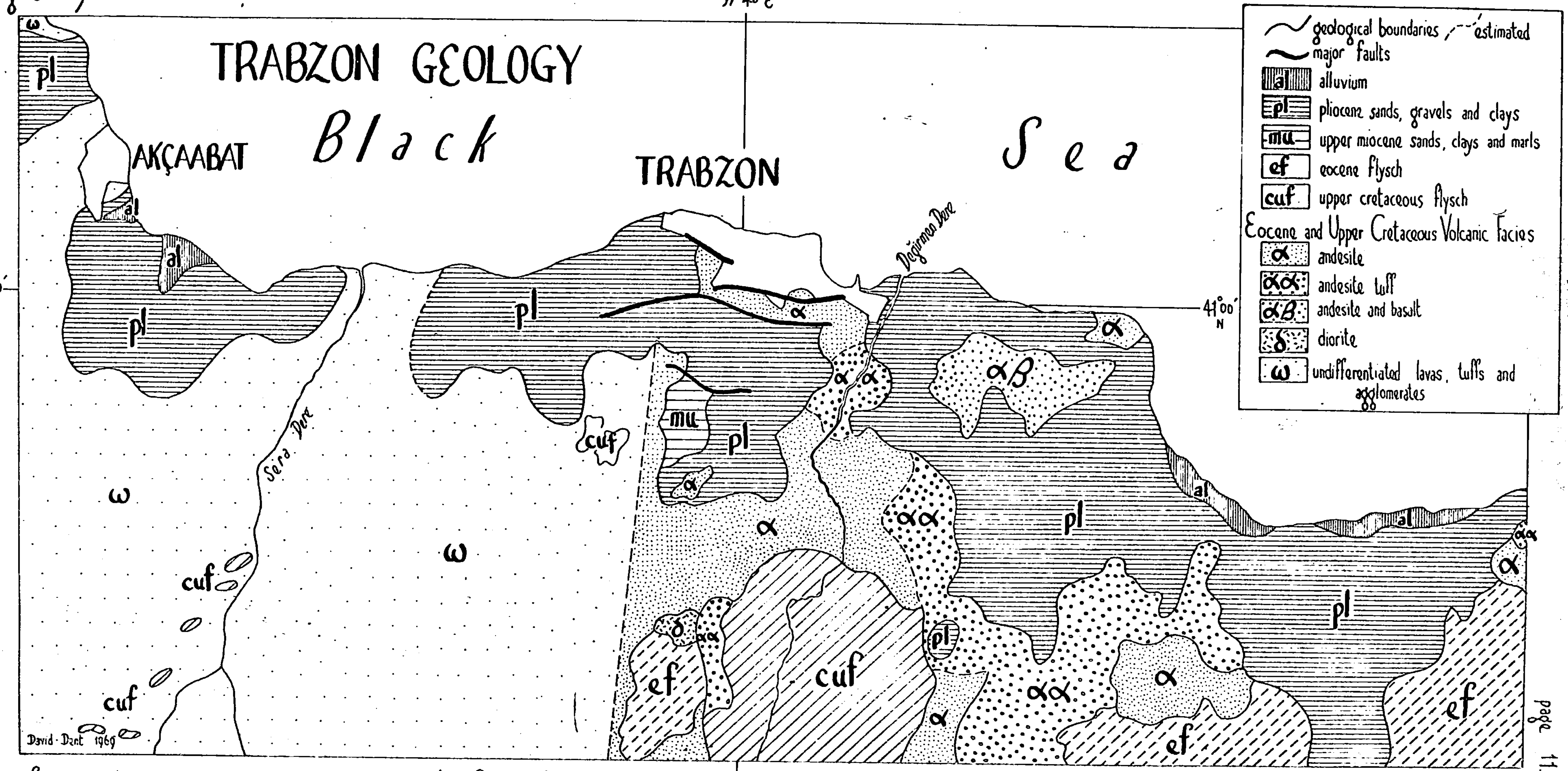
Slopes vary between 0^{o} and 12^{o} (usually less than 6^{o}) on the broad, convex ridge tops; and between 25^{o} and 40^{o} on the sides of the dissecting gorges. An intermediate slope, straight to convex, between 10^{o} and $22{\cdot}5^{o}$, frequently forms a shoulder on the ridges and is cut into the molasse sediments. Where volcanic materials are exposed in gorges or on ridge tops they give rise to a characteristically rugged, rocky topography.

figure 2.4



Source Harta Genel Müdürlüğü 1:200,000 Contour Interval 50 metres

figure 2.5



Source : unpublished manuscript maps a 1:100,000 . Maden Tetkik ve Arama Enstitüsü , Ankara

The Soil Forming Factors of Parent Material, Topography and Time in the Eastern Black Sea Region

Parent materials are predominantly lavas and tuffs of basic to intermediate composition, with granitic rocks in some of the highest mountains, particularly in the east. Sedimentary rocks occupy only a small proportion of the total area, but are important in the coastal zone. The sediments are predominantly calcareous, comprising the limestones and flysch intercalated within the volcanic series, the Miocene-Pliocene molasse of the coastal zone, and pockets of recent alluvium.

The region is geomorphologically young; slopes are generally steep and processes of natural erosion tend to limit the maturity of soil profile development, and to maintain a close relationship between soil and parent material. However, the absence of Pleistocene glacial and periglacial activity in the coastal zone has permitted the development of mature soils on stable sites. In the region as a whole such sites are rare, but locally - on the Trabzon platform - they form a significant proportion of the total area.

Chapter 3

CLIMATE

The Eastern Black Sea Region

The narrow strip between the crest of the Eastern Pontids and the Black Sea forms a distinctive climatic region. In the coastal zone mean maximum temperatures in summer reach 22-23°C., while in interior Anatolia over 30°C. is recorded. The contrast between the coastal zone and the Anatolian plateau is even more marked in winter with mean January temperatures of 7°C. and absolute minima of -7°C. on the coast, and mean temperatures of -3°C. or less and absolute minima of -30 to -43°C. in the continental interior.

In the Eastern Black Sea Region maximum monthly temperatures occur in August and minimum monthly temperatures are delayed until February; annual and diurnal ranges of temperatures are the lowest in Turkey (13).

Table 3.1 Mean Air Temperatures (°C.) in the Eastern Black Sea Region and in Continental Eastern Anatolia

Region	Station	Altitude (m)	August mean max.	August avge.	February avge.	February mean min.
Eastern Black Sea	Giresun	34	22•6	21•9	6•8	4•0
	Trabzon	37	26•3	23•2	6•9	4•1
	Rize	4	25•8	22•6	6•9	3•7
					January	
N.E. Anatolia	Erzincan	1214	32•0	24•3	-3•6	-8
	Kars	1750	25•9	17•5	-12•0	-17•9

There is an equally sharp contrast in rainfall between the coastal zone and the interior. The Eastern Black Sea Region has the most abundant, reliable and evenly distributed rainfall in Turkey (15a), while the Interior is a region of summer drought. The heaviest rainfall occurs below about 2000m. on the northern slopes of the Pontids, with a consequent intense rain shadow in the lee.

Table 3.2 Rainfall (mm.) in the Eastern Black Sea Region and in Continental Eastern Anatolia

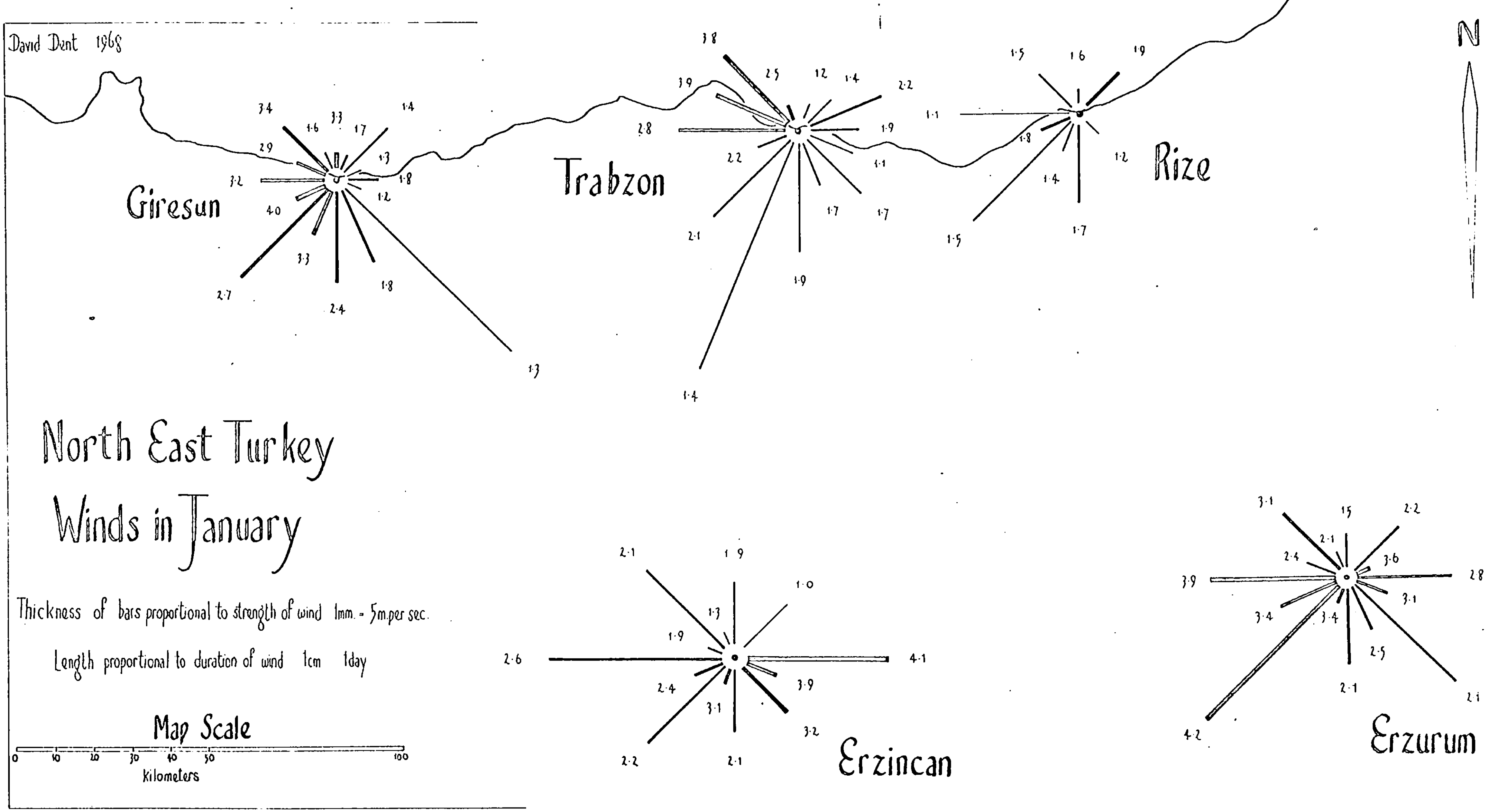
	Giresun	Trabzon	Rize	Batumi	Erzincan
Mean Annual Rainfall	1319	837	2441	2465	364
Mean Rainfall, May-September	459	268	859	957	111

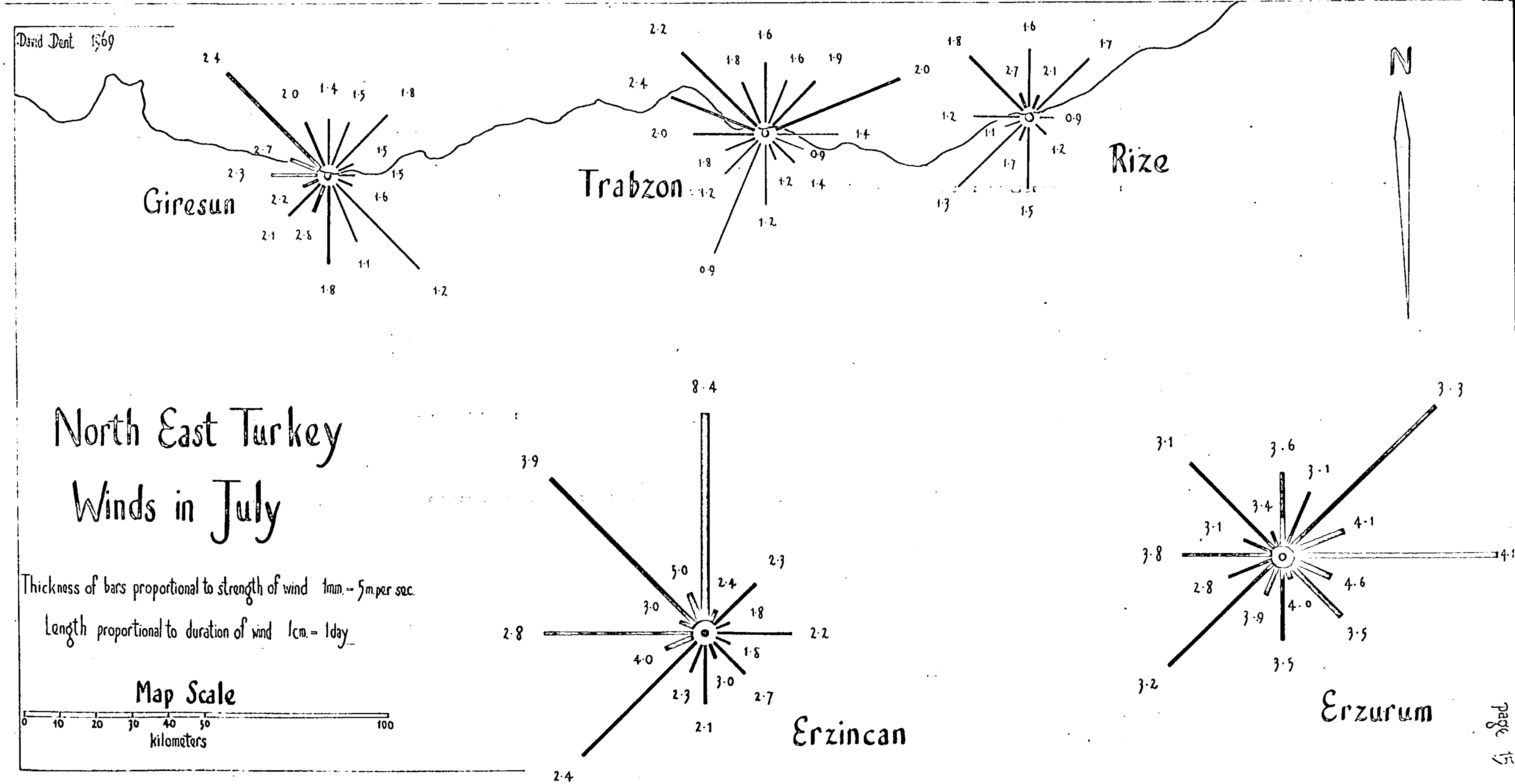
Although snowfalls are comparatively infrequent in the Eastern Black Sea Region, the heaviest recorded snowfalls in Turkey have occurred here - maximum depths at Rize 187cm., Giresun 125cm., Trabzon 115cm. However, the snow is of short duration; mean duration 8 to 17 days at coastal stations compared with 41 days at Erzincan in the Interior.

Air Masses (14)

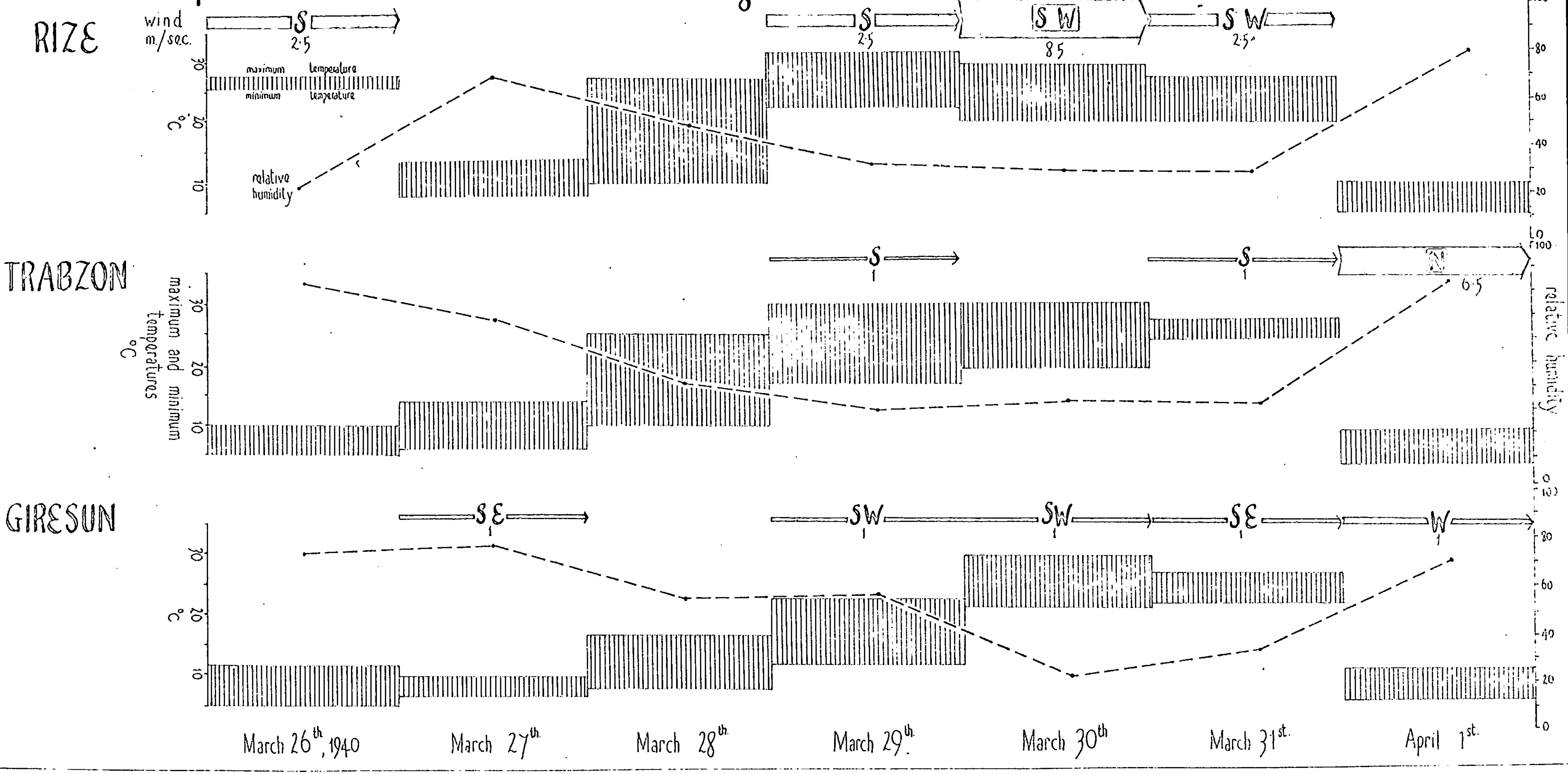
From late-May to mid-September maritime tropical and maritime polar air masses move across Turkey from the sub-tropical Azores High in the N.W. towards the Intertropical Convergence to the S.E. These air masses are diverted by the Pontid barrier eastwards along the Black Sea coast. In the Eastern Black Sea Region they are finally forced to surmount the mountain barrier and bring orographic rains, heaviest in the east and on slopes exposed to the northwest (figure 3.2).

In winter the region is subject to maritime polar warm (mPW) air masses in depressions moving eastwards across the Black Sea Basin, and continental polar cold (cPK) air masses descending from the plateaux of Anatolia and Armenia to a line of convergence along the axis of the East Black Sea basin (figure 3.1). Föhn conditions are a frequent feature of the winter: polar continental air masses must rise over the Pontids then descend two to three thousand metres to the Black Sea coast when their temperature rises considerably as a result of


David Dent 1968
N
Giresun
Trabzon
Rize
Erzincan
Erzurum
North East Turkey
Winds in January
Thickness of bars proportional to strength of wind 1mm. = 5m.per sec.
Length proportional to duration of wind 1cm 1day
Map Scale
0 10 20 30 40 50 100
Kilometers


David Dent 1969
N
Giresun
Trabzon
Rize
Erzincan
Erzurum
North East Turkey
Winds in July
Thickness of bars proportional to strength of wind 1mm. = 5m.per sec.
Length proportional to duration of wind 1cm. = 1day
Map Scale
0 10 20 30 40 50 100
kilometers

A föhn period in the Eastern Black Sea coastal region



adiabatic processes. During föhn periods temperatures of over 30°C. and relative humidities of less than 10 percent have been recorded, and a prolonged föhn period may cause severe damage to vegetation, particularly to tea and citrus plantations. A typical föhn condition is illustrated by figure 3.3 which has been constructed from the data of Erinç (14). His analysis of daily weather records from 1940 to 1960 shows that the number of föhn days per year varied from 2 to 24, and that the average duration of the föhn period was 2•4 days.

Table 3.3 Average Monthly Distribution of Föhn Days

Nov.	Dec.	Jan.	Feb.	Mar.	Apl.
2•3	2•5	3•3	3	4	3•8

The high mean winter temperatures of the region may be attributed more to the effects of the föhn than to the moderating effects of the Black Sea.

Temperature

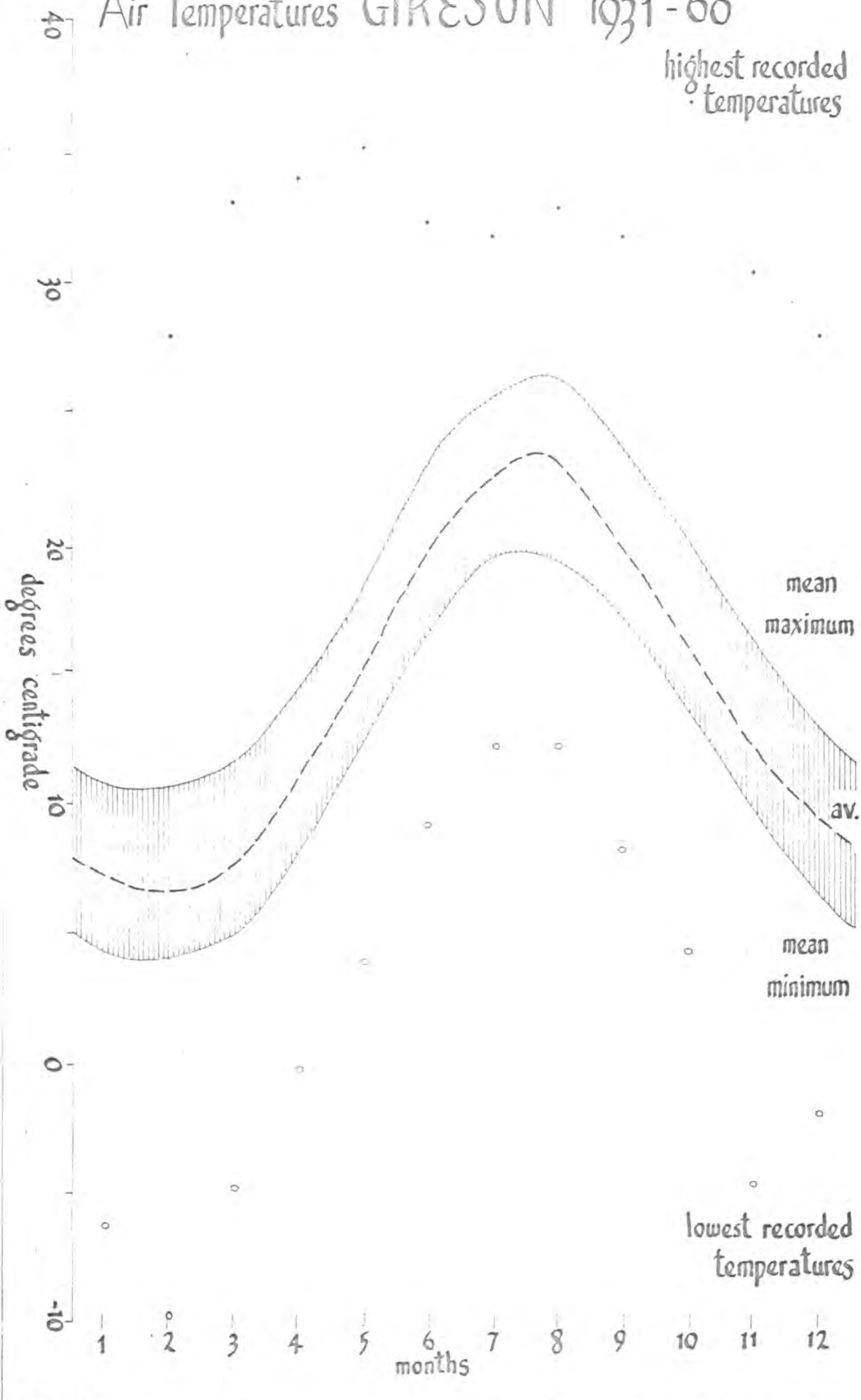
Comparison of the annual march of air temperatures within the region shows a general similarity - figures 3.4, 3.5 and 3.6. The salient features are:

1. The delay of annual minimum temperatures until February and of maxima until August - a characteristic feature of maritime climates.
2. High winter temperatures as a result of the föhn effect, the moderating effect of the Black Sea, and shelter from outbursts of Siberian cPK air by the Caucasus.

The growing season (average number of days per year with mean air temperature greater than 5°C.) is 337 days at Trabzon and 327 days at Giresun and Rize. The progress of soil temperature (figure 3.7) shows a delay of maxima and minima and, as usual, a gradual lessening of seasonal differences with depth. Frosts are rare. At Trabzon the

facing page 17

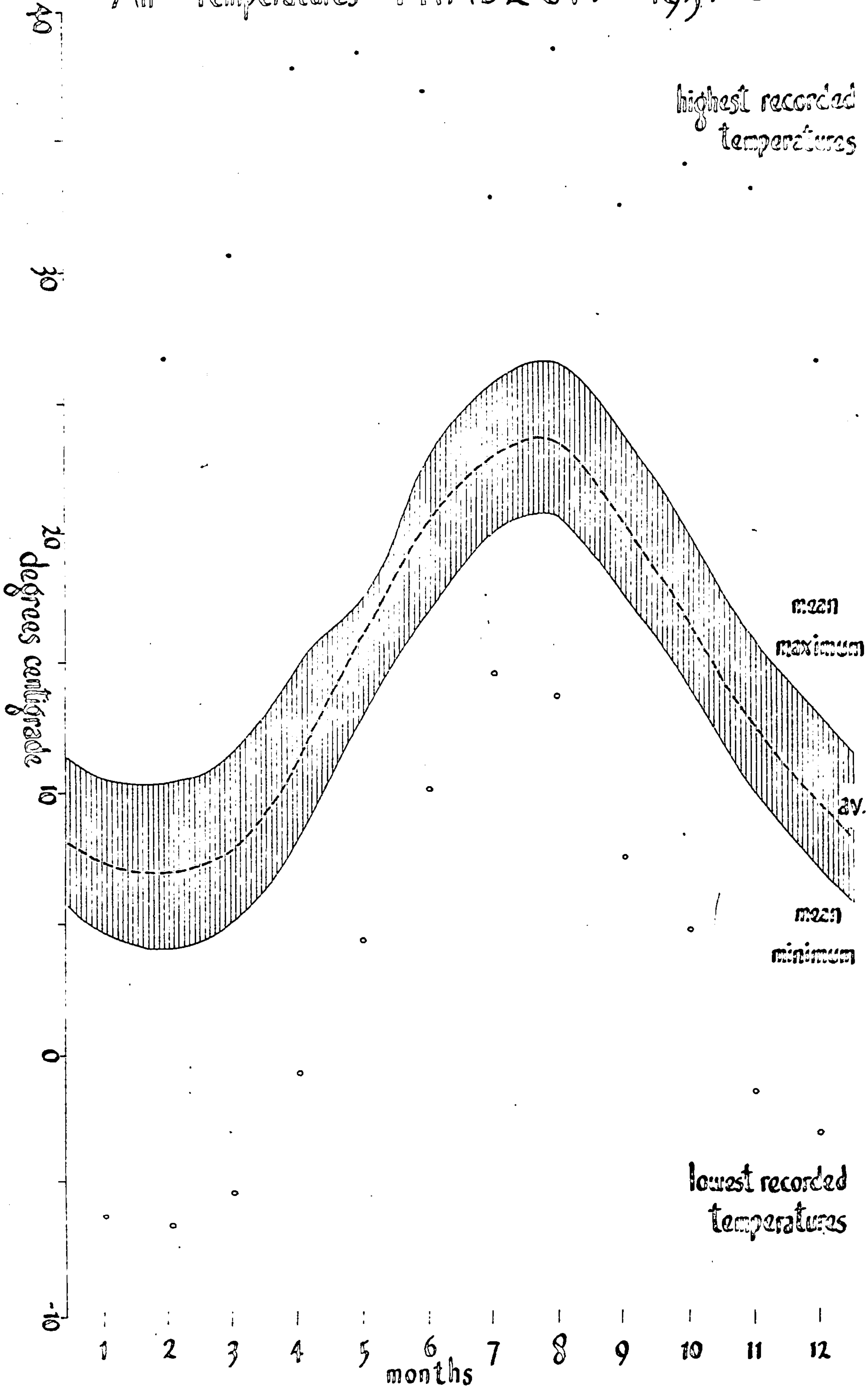
Air Temperatures GIRESUN 1931-'60



	1	2	3	4	5	6	7	8	9	10	11	12
highest	24·9	28·0	33·3	34·1	35·4	32·2	[illegible]	32·0	31·7	37·3	30·3	27·8
mean max	10·6	10·7	11·4	14·5	18·5	23·0	25·5	26·2	23·3	20·0	16·3	12·9
average	7·1	6·8	7·6	10·8	15·2	19·0	22·3	22·6	19·6	16·0	12·5	9·1
mean min	4·3	4·0	4·8	8·0	12·4	15·4	19·2	19·2	16·8	13·4	9·8	6·3
lowest	-6·2	-9·8	-4·8	-0·2	4·0	9·1	12·1	12·1	8·1	4·2	-4·7	-2·0

David Dent 1968

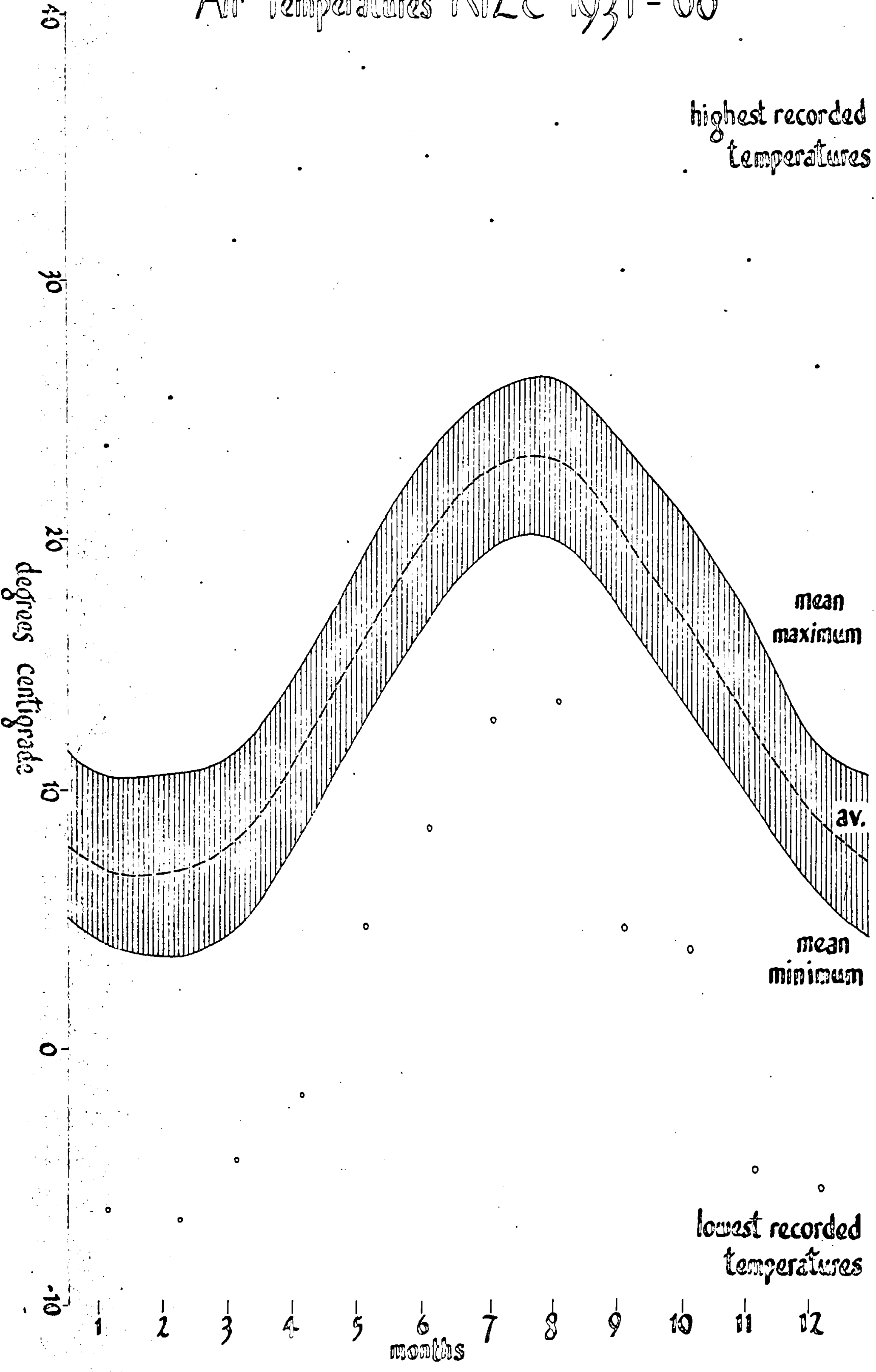
Air Temperatures TRABZON 1931-'60



	1	2	3	4	5	6	7	8	9	10	11	12
highest	25·9	26·6	31·1	37·6	38·2	36·6	32·6	38·2	32·2	33·8	32·8	26·1
mean max.	10·5	10·3	11·2	14·8	17·1	22·6	23·3	26·3	23·3	20·0	16·4	12·7
average	7·2	6·9	7·7	11·2	15·6	19·9	20·1	23·2	20·1	16·6	12·9	9·3
mean min.	4·6	4·1	4·8	8·2	12·7	16·9	17·5	20·5	17·5	13·9	10·4	6·7
lowest	-7·0	-7·4	-5·8	-0·8	4·2	10·0	7·3	13·5	7·3	4·5	-1·6	-3·3

David Dent 1968

Air Temperatures RIZE 1931 – '60



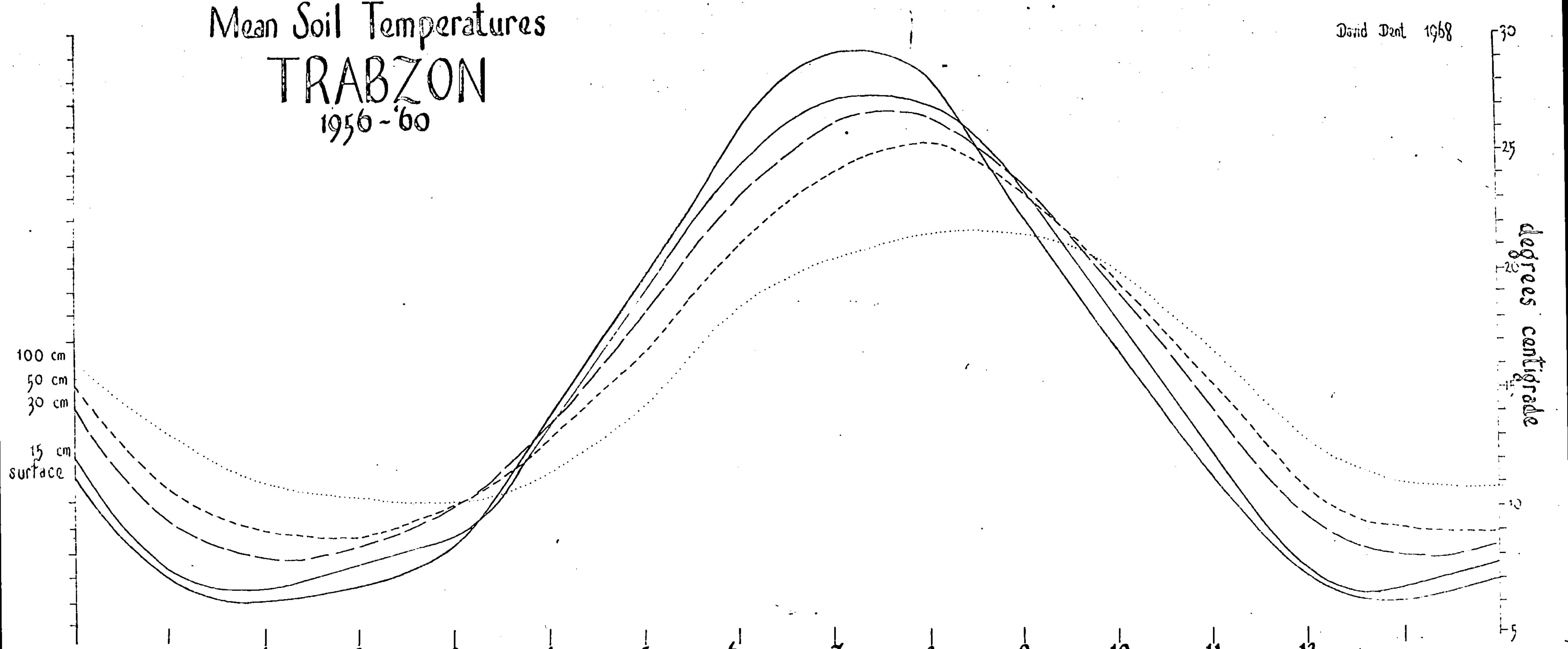
	1	2	3	4	5	6	7	8	9	10	11	12
highest	23·4	25·2	31·3	34·0	37·9	34·5	32·0	35·6	30·0	33·8	30·4	26·2
mean max	10·5	10·6	11·4	14·7	18·8	22·9	25·2	25·8	23·3	20·1	16·4	12·7
average	6·9	6·9	7·8	11·4	15·7	19·8	22·4	22·6	19·7	16·3	11·9	8·9
mean min	4·0	3·7	4·6	8·2	12·6	16·5	19·3	19·6	16·8	13·0	9·6	5·9
lowest	-6·5	-6·6	-4·1	-1·6	4·6	8·5	12·6	13·4	4·6	3·9	-4·8	-5·4

David Dent 1968

Mean Soil Temperatures

TRABZON

1956 ~ '60



temperature at soil	1	2	3	4	5	6	7	8	9	10	11	12
surface	6·3	7·0	8·6	14·1	19·8	26·0	29·1	28·4	22·2	16·6	11·4	7·2
at 15 cm.	6·7	7·7	8·8	13·4	19·0	24·3	27·1	27·0	23·6	17·9	12·3	7·5
at 30 cm.	8·2	8·8	9·9	13·5	18·2	23·1	26·2	26·6	23·7	19·2	14·3	9·6
at 50 cm.	9·2	8·9	9·9	13·0	16·5	21·0	24·1	25·3	23·2	19·6	15·3	10·9
† 100 cm	11·1	10·4	10·2	11·0	14·2	18·4	20·5	21·5	21·7	20·0	16·0	12·6

† estimated from 1963-'5

minimum daily temperature drops below 0^{o}C. on an average of 9•8 days per year: corresponding figures for Giresun and Rize are 8•9 and 12•1 days. The earliest frost occurs about the end of November, and the latest in mid-April.

Rainfall

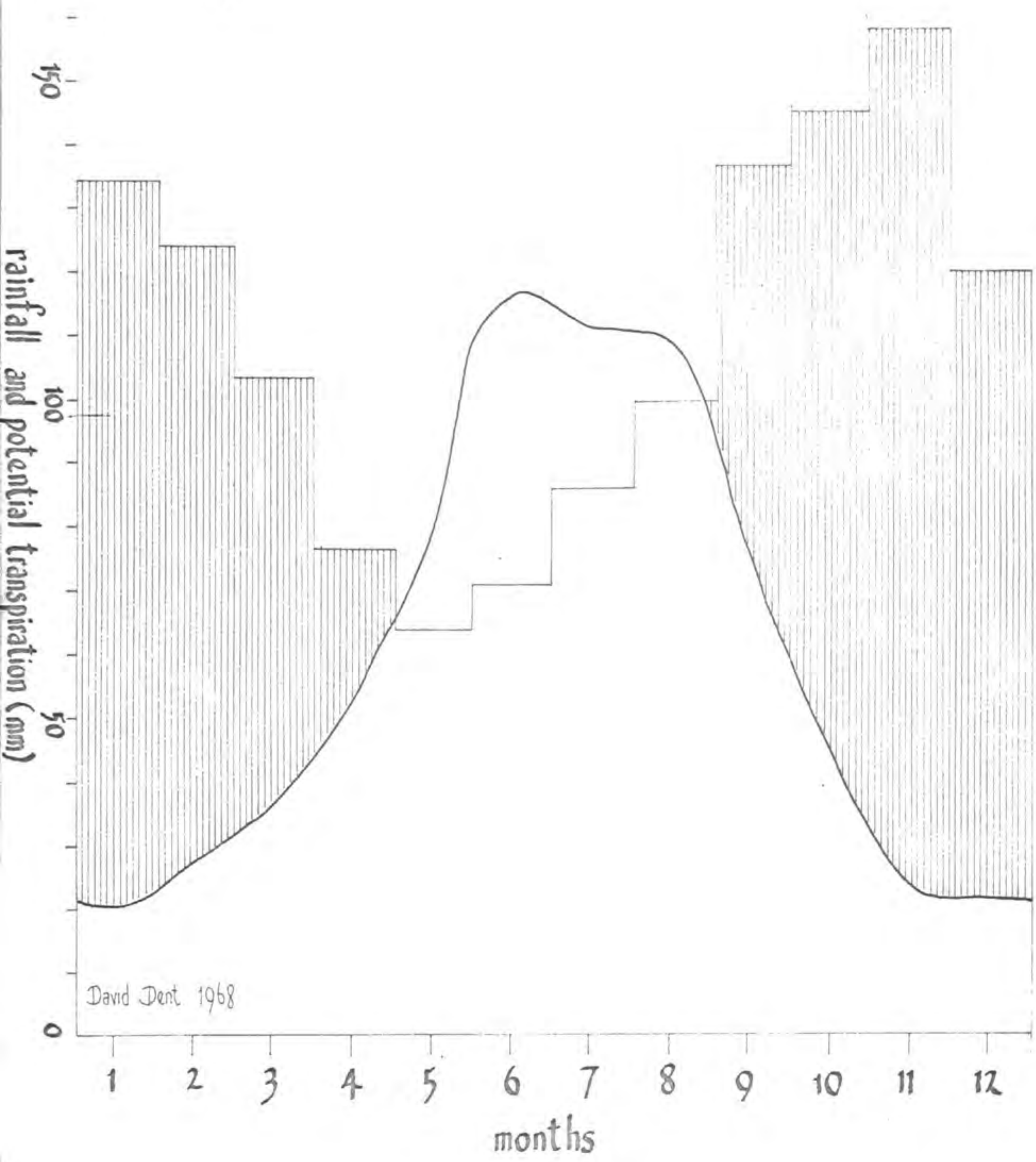
The Eastern Black Sea Region as a whole is characterised by an abundant and evenly-distributed rainfall (table 3.2) but in the Trabzon area rainfall is significantly lower in all seasons, especially from June to August (figures 3.8, 3.9 and 3.10). This may be explained by shelter from the rain-bearing northwesterlies afforded to the Trabzon area by the high Karadağ peninsula. Rainfall frequency and intensity are roughly proportional to total rainfall (15a,b):

Table 3.4 Rainfall Frequency and Intensity in the Eastern Black Sea Region

	Giresun	Trabzon	Rize
Mean no. of rain days (> 1mm.) per year	155	134	168
Max. no. equalled or exceeded in any 10 years	174	161	188
Min. no. equalled or exceeded in any 10 years	136	108	148
Max. daily precipitation (mm.) with a recurrence interval of 2 years	69	49	112
Max. daily precipitation (mm.) with a recurrence interval of 10 years	110	73	176

Rainfall and Potential Transpiration

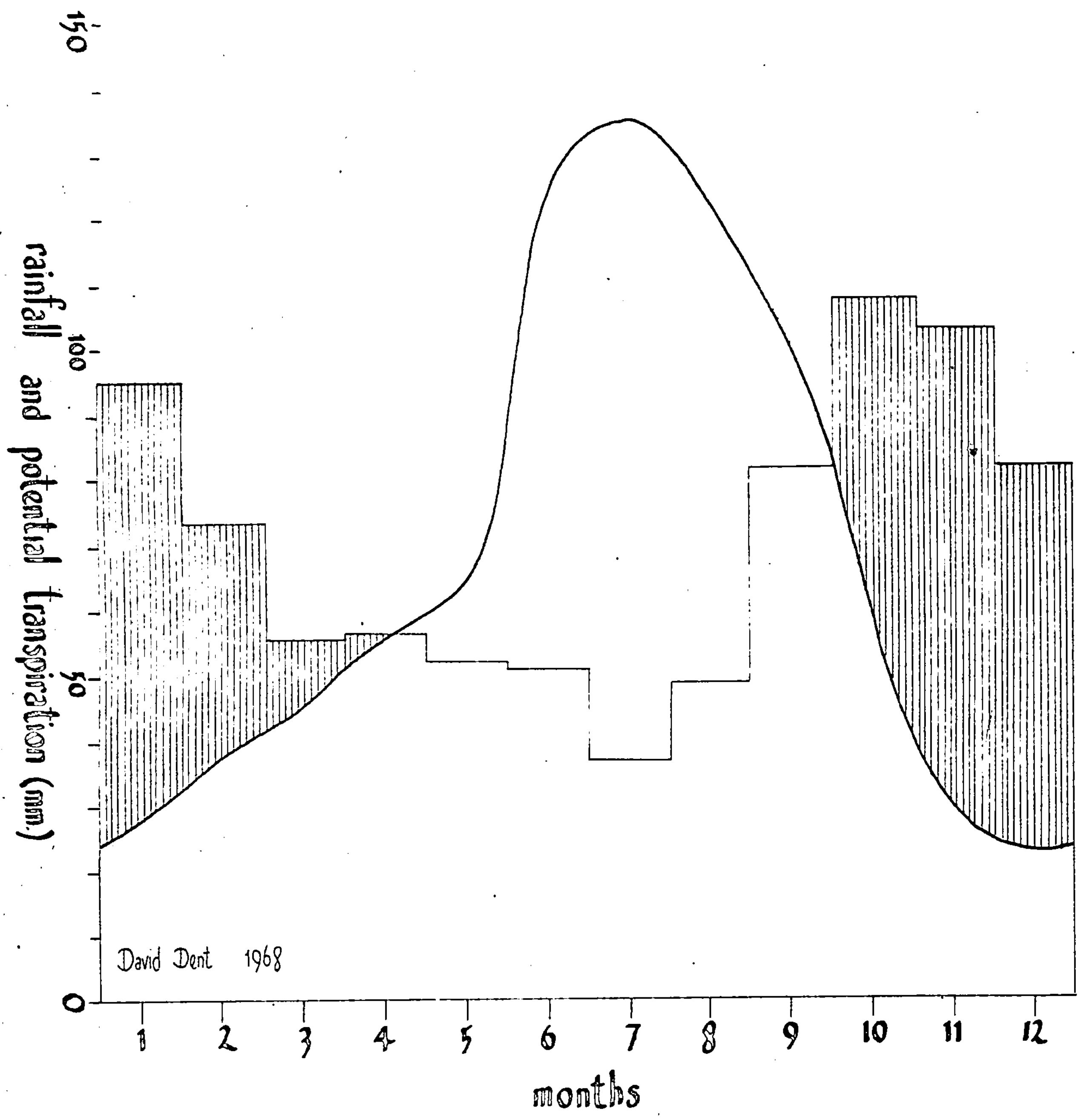
GIRESUN



	1	2	3	4	5	6	7	8	9	10	11	12	Annual Total
Rainfall (mm)	134·2	122·8	103·5	76·5	63·8	71·7	86·3	99·3	137·8	145·3	158·4	119·5	1319·1
Potential Transpiration (mm.)	20·5	27·2	37·0	53·6	78·0	119·9	111·6	109·6	73·5	45·7	23·2	22·7	722·5

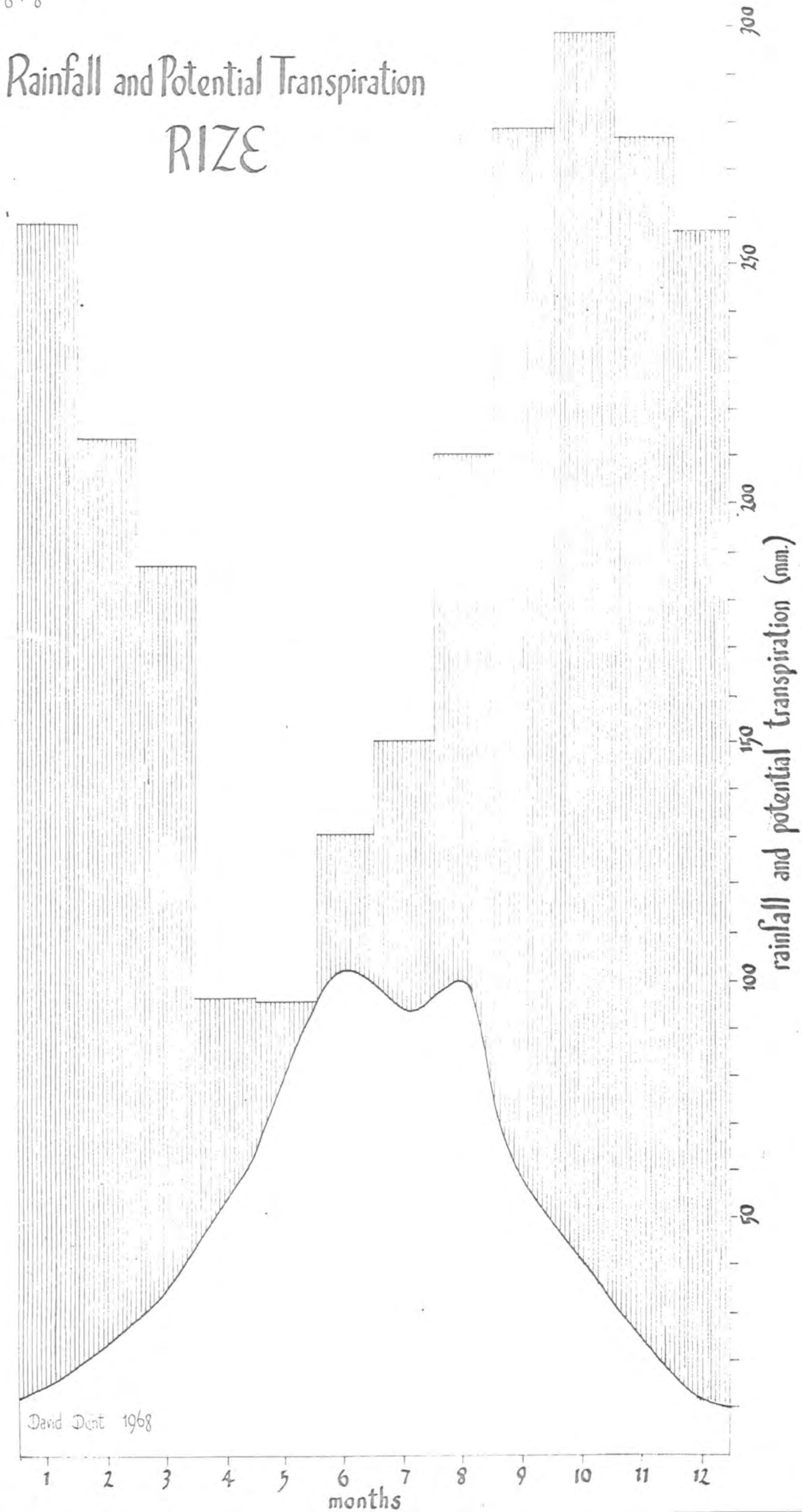
Rainfall and Potential Transpiration

TRABZON



	1	2	3	4	5	6	7	8	9	10	11	12	Annual Total
Rainfall (mm.)	93·6	72·8	56·8	56·9	51·7	50·3	37·1	48·3	80·8	106·4	101·6	80·2	836·5
Potential Transpiration (mm.)	29·4	36·2	42·0	56·4	63·2	119·0	134·0	119·8	98·2	57·3	27·4	22·4	851·3

facing page 21



Rainfall and Potential Transpiration, RIZE

month	1	2	3	4	5	6	7	8	9	10	11	12
mean rainfall (mm.)	259	214	187	97·4	96·7	131	150	211	270	299	278	246
potential trans-piration	15·8	24·7	36·4	52·9	81·7	103·1	94·9	100·6	59·8	41·8	25·5	11·9

Potential Transpiration

From the point of view of soil formation, the most important feature of the climate is the relationship between rainfall and loss of water through transpiration. At Trabzon the period of maximum potential transpiration, calculated according to Penman's formula (Appendix I), corresponds with the period of lowest rainfall (figure 3.9). The results is a deficit of rainfall compared with potential transpiration of 266 mm. for the period May to September. Maximum potential transpiration occurs in July at Trabzon, whereas at Giresun and Rize potential transpiration in July is reduced by relatively low sunshine figures (figures 3.8 and 3.10). At Giresun there is a small rainfall deficit of 98 mm. from May to August; at Rize there is no month in which potential transpiration exceeds rainfall.

Climatic Changes since Pliocene Times

Paleobotanical evidence from Europe indicates accelerating climatic deterioration from mid-Tertiary to Pleistocene times, with temperate and herbaceous species invading the tropical forest floras. In Pliocene times the geographical range of many tropical species was still wider than at present, indicating a somewhat warmer climate (16).

At the glacial maximum the exposure pattern of the Pontid glaciers was similar to the present, but the snow line was about 1000m. lower. Assuming a lapse rate of 5·4°C. per 1000m., mean temperatures in the Eastern Black Sea coastal zone may be estimated, by extrapolation of present day figures, as 17•2° to 17•8°C. in August and 3•4° to 3•5°C. in February. The eastern Euxine area is thought to have served as a refuge for the relatively thermophyllic Tertiary flora during the Pleistocene (Chapter 4). As the absence of severe frosts, rather than high average temperatures, is the critical factor in the survival of most tropical species, winter temperatures may have been somewhat higher than the calculated figure. It is also the author's view that increased snowfall would be more effective in lowering the snow line in the Pontids than would a general lowering of temperature.

From an extensive review of the relevant literature on geomorphology, soils and vegetation, Erinç (17) has concluded that in the southern part of the Black Sea basin glacial periods were more humid, and interglacials dryer than today, whereas in the Balkans and S. Russia glacial periods were characterised by colder, dryer conditions and interglacials by warm, more humid climates. Büdel (18a, b) also considers that during glacial periods the sub-tropical regions were more humid but only moderately cooler than today.

The fluctuations of the Caucasian and Pontic glaciers are evidence of climatic changes in recent times, and it is reasonable to assume that the Eastern Black Sea Region has experienced climatic variations analagous to those revealed by pollen studies in N. Europe. In the Trabzon area the establishment of an enclave of Mediterranean vegetation (Chapter 4), and the development of soils with carbonate horizons alongside ancient leached soils, indicate a relatively recent period of greater aridity which might have resulted from a slight change in the direction of the prevailing winds.

Evidence for significant climatic change during the historical period is ambiguous. De Planhol (19) and Wilson (20) have discussed the significance of changes in the distribution of olives, but these may well be attributed to human diligence and neglect as much as to climatic change. (See Appendix II).

Climate and Soil Formation in the Eastern Black Sea Region

A relatively warm, humid climate brings about rapid chemical and biological weathering of soil parent materials. Over many thousands of years deep weathering crusts, tens of metres thick, may develop. Thick tropical weathering crusts have been described in various parts of Georgia (34,35) and have been found buried by Quaternary lavas (36). This highly weathered material frequently forms the parent material of modern soils on stable sites.

An excess of precipitation over transpiration leads to the illuviation of soluble constituents from freely-drained sites, but where soil drainage is impeded the illuvial sequence is interrupted:

Table 3.5 Soil Constituents in Order of Illuviation[1]

1. Soluble Salts (halides, sulphates)
2. Less-Soluble Salts (carbonates)
3. Clay
4. Silica, from relatively easily-weathered minerals
5. Sesquioxides.

Where potential transpiration is in excess or in balance with precipitation, as in the Trabzon area, soluble constituents may accumulate at some depth in the soil profile.

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[1] J.W. Muir, personal communication

Chapter 4

NATURAL VEGETATION

The warm, humid climate of the Black Sea Region is reflected in a predominantly mesophytic vegetation of deciduous and mixed forest remarkable for its luxuriance and profusion of species. Within the Eastern Black Sea Region of Turkey and adjacent Colchis and Abkhazia occur a large number of endemic species. Many of these are considered relics of a flora widespread during the Tertiary period, which was able to survive the Pleistocene by reason of the mild, moist climate of the region. Amongst the Tertiary forest relics, the following species are particularly isolated taxonomically, and may well date back to mid-Tertiary times: Betula medwedewii, Epigaea gaultheroides, Lauroceracus officinalis, Pachyphragma macrophylla, Phyllerea decora, Pterocarya fraxinifolia.[1]

Conifers, represented chiefly by spruce and fir, predominate at higher altitudes, and the tree line is reached at 1500m. to 2100m. when the forest is succeeded by the Alpine communities of the high plateau (yayla), again rich in species. On the drier inland slopes of the Pontids pine forest descends to about 1600m., and appears again on the highest ranges of Inner Anatolia as islands within the steppe of the Anatolian plateau (photograph 4).

A Mediterranean element, characterised by the evergreen and thorny shrubs of maquis vegetation, occurs in enclaves along the Black Sea coast which can be correlated with areas of summer moisture deficit.

The Euxine Forest

Davis, who has made the most detailed study of the flora of Turkey (21), assigns the flora of the northern slopes of the Pontids to a Euxine Province of the Euro-Siberian phytogeographical region. The following trees and shrubs may be considered characteristic.

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[1] Dr. P.H. Davis, personal communication

Abies nordmannia fir

Acer campestre plane

A. trautvetteri

Alnus glutinosa alder

Buxus sempervirens box

Carpinus betulus hornbeam

C. orientalis

Castanea sativa chestnut

Cornus australis

Corylus avellana hazel

C. colurna

Crataegus microphylla hawthorn

Daphne pontica

Fagus orientalis beech

Fraxinus excelsior ash

Hedera colchica ivy

Hypericum androsaemum

Laurocerasus officinalis cherry laurel

Mespilus germanica

Ostrya carpinifolia

Pinus sylvestris pine

P. nigra subsp. pallasiana

Quercus dschorocensis oak

Q. hartwissiana

Q. pendunculiflora

Rhododendron luteum

R. ponticum

Smilax excelsa

Sorbus torminalis

Staphylea pinnata

Tilia rubra lime

The wetter eastern part of the Euxine Province, which corresponds with the Eastern Black Sea Region, is delimited by the range of the spruce Picea orientalis, frequently the dominant tree. Other species of trees and shrubs found only in the Eastern Black Sea Region are:

Acer Cappadocicum plane

Alnus glutinosa subsp. barbata alder

Betula medwedewii birch

Daphne glomerata

D. mezerum

Phillyrea decora

Quercus pontica oak

Rhamnus imeritanus

Rhododendron caucasium

R. smirnovii

R. ungernii

Sorbus subfusca

Diospyros lotus, a species of persimmon known locally as kara yemiş, is also confined to the Eastern Black Sea Region where it is cultivated as a tree crop.

The forests of the region are the fastest-growing and most productive in Turkey. A particular feature is the abundance of epiphytes and evergreen shrubs, which benefit from a growing season extending almost throughout the year at low altitudes. *Daphne ponticum* is evergreen below 150m. to 200m. but also occurs as a deciduous form up to 2300m. More important are the various species of *Rhododendron* which rapidly colonise cleared areas and may prevent the regeneration of forest trees. The impenetrability of the Euxine forest may have played a crucial role in the survival of Hellenic civilization in the Eastern Black Sea Region when Asia Minor was overrun by Turkish pastoralists. Although there was a slow infiltration at high levels, no pastoral tribe appears to have penetrated to the coastal zone (22).

In the climax forest of the coastal zone the several species of *Quercus* predominate with a great variety of associated species including *Alnus glutinosa*, *Buxus sempervirens*, *Carpinus* spp., *Castanea sativa*, *Corylus* spp., and *Fagus orientalis*. *Fagus* becomes the dominant tree in the foothills and is found in mixed forest up to about 1500m. *Buxus sempervirens* often forms a distinct zone between 1100m. and 1400m. *Picea orientalis* occurs from sea level to the tree line; it is associated with *Fagus* in the mixed forest zone and becomes dominant at higher altitude. The beech, box and spruce are valuable for economic timber production. In the Değirmendere valley *Picea* gives way to *Pinus sylvestris* and *P. nigra* at about 1300m. These two species continue almost to the Zigana col at 2000m., and reappear on the southern slope.

The tree line in the Pontids has been lowered by reckless felling and grazing over a long period. From my own observations in the Karagöl and Zigana areas, the steep valley slopes are normally occupied by dense stands of spruce, pine and fir, while the gentle slopes of the high plateau are clothed in alpine meadow or a dense secondary growth of *Rhododendron*. The upper boundary of the forest in these areas is often sharp, and coincides with the break of slope.

The Mediterranean Vegetation

The Trabzon area constitutes the eastern most enclave of Mediterranean flora on the Black Sea Coast.[1] Mediterranean species are found particularly in habitats sheltered from the rain-bearing north-westerlies, with maximum insolation and thin soils. They find their purest expression in the sheltered valley of the Kalenima Dere on slopes facing south and south-east, up to 25 km. from the coast and up to 300-500m. in altitude. Handel-Mazzetti (23) described *Pinus pinea* woodland with a dense undergrowth including *Cistus creticus*, *Pistacia terebinthus* subsp. *palaestina*, and *Juniperus oxycedrus* extending from 100m. to 500m. on southeast-facing slopes of the Kalenima Dere valley. Other characteristic Mediterranean shrubs found in the enclave include *Arbutus andrachne*, *Cistus salviifolium*, *Erica arboris* and *Myrtus communis*. The Mediterranean species generally form a subsidiary element in thickets of scrub vegetation dominated by Euxine species such as *Carpinus Orientalis*, *Corylus* spp., *Castanea sativa*, *Quercus* spp., and *Smilax excelsa*. Even within the Mediterranean enclave, fine stands of *Picea orientalis*, *Quercus* spp., and *Pinus sylvestris* are found, and above 350m., the dominant vegetation is a mixed stand of *Fagus orientalis* and *Picea orientalis*.

Davis observed that the Mediterranean element within the Euxine province is atypical, impoverished and almost entirely lacking in endemic species, indicating a relatively recent establishment in the region. (The Trabzon area lacks even some species characteristic of the more westerly enclaves on the Black Sea coast, notably *Arbutus unedo*, *Quercus ilex*, and *Vitex agnis-castus*). On the other hand, Czeczott (24) suggested that the Mediterranean species may originally have formed the undergrowth of the Euxine forest. In the present author's view, it is probable that high Euxine forest has clothed the

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[1] A Mediterranean element including *Pinus pinea*, *Arbutus andrachne*, *Cistus salviifolius* and *Juniperus oxycedrus* occurs further east inland in the Çoruh gorge below Artvin. It is found on south facing slopes between 150m. and 600m. altitude, (23).

greater part of the Eastern Black Sea Region from mid-Tertiary times. Mediterranean vegetation in the Trabzon area may date from a relatively dry period of the Post Glacial, or even from the era of forest clearance by man, when the relatively dry climate of the enclave hindered the re-establishment of Euxine forest and favoured the invasion of Mediterranean species.

Vegetation and Soils in the Eastern Black Sea Region

Vegetation, soils and climate are always closely interrelated. The influence of soil characteristics on vegetation type is illustrated by the relationship between Mediterranean vegetation and thin, excessively-drained soils in the Trabzon area. However, the climax vegetation of the region is forest and the predominant soils are forest soils with characteristic leached surface layers. A notable feature of the forest soils of the coastal zone is the virtual absence of surface organic horizons because of the vigorous microorganic activity which is promoted by the mild, wet winters. Raw humus accumulation does take place under coniferous forest and under mixed forest at higher altitude, where winters are more severe, and here podsolisation is more evident. Under the montane pastures of the yayla typical humose alpine soils are found.

Chapter 5

LAND USE

For a long time the coastal zone of the Eastern Black Sea Region has carried the densest rural population in Asia Minor, while the hinterland of the city of Trabzon has been intensively utilized for the past 2,700 years. The present city grew up on the site of ancient Trapezus, founded in 756/5 B.C. by Greek colonists (20). This first settlement, which was probably a base camp for tunny fishing, soon grew into a small trading station; later it became a colony of Sinop. The native inhabitants of the area lived by hunting, fishing and gathering nuts and honey. One native tribe, however, the Chalybes, were iron workers and the forests provided charcoal for smelting.

Xenophon records that oxen, barley meal and wine were provided by Trapezus for the remnants of the Army of Ten Thousand in 400 B.C. From ancient accounts it appears that a wide variety of crops was produced in the region wherever suitable land was available:- cereals, fruits, chestnuts, hazel nuts, wine and olives. The region was apparently notorious for its poisons and its honey. The honey is harmless in small quantities, and is still prescribed by local doctors for certain conditions, but noxious if immoderately consumed; its remarkable properties derive from the nectar of _Rhododendron luteum_.

The influence of the Greek colony was limited to a coastal strip no more than twenty kilometers in width, extending eastwards to somewhere between Sursurmene (Sürmene) and Rhizaeum (Rize) and bordering in the west the smaller colony of Pharnaceia (Giresun), which was founded about 180 B.C. (20).

In 1204 A.D. Trapezus became the capital of the Byzantine empire of Trebizond and its influence quickly spread over most of the Black Sea Region. It fell to the Ottoman Turks in 1461, surviving the fall of Constantinople by eight years. Despite the Turkish conquest, the social and agricultural pattern remained unchanged: in contrast to the Mediterranean and Aegean coastal plains, the Eastern Black Sea Region was not devastated or subjected to the catastrophe of invasion by pastoral tribes. De Planhol (22) reasonably attributes the high density of population in the region partly to this continuity of civilization.

Cuinet (25) furnished an invaluable account of the region in late Ottoman times - 1890. The major crops were maize, hazelnuts, tobacco, haricot beans, fruits and vegetables. Boxwood was exploited particularly inland in the region of Hopa, Pazar, Sürmene, Görele and Giresun. Fishing was important; the porpoise was caught for oil from Rize, Sürmene and Trabzon; anchovies were landed in great numbers, exported in quantity and even used as fertilizer in times of glut. At this time the Eastern Black Sea Region was remarkable in Turkey as an importer of grain. With a population of over 600,000 a demographic problem was developing, and in the most densely populated parts of the region the change from subsistence to commercial agriculture was already in progress. Maize was the staple crop of the rural population (figure 5.1), having replaced less familiar cereals such as spelt and sorghum, by the beginning of the 17th century (26). It remains the principal grain crop, widely cultivated up to about 1300m., but has declined to less than one sixth of the area occupied in 1890 (figure 5.2 and Appendix II.2), giving way to cash crops, particularly hazelnuts.

Although known in the region from ancient times, hazelnuts were a minor crop until the early 19th century. A wide range of tree crops is possible in the region and cherries were perhaps the principal orchard crop until the early 19th century.[1] But for external trade,

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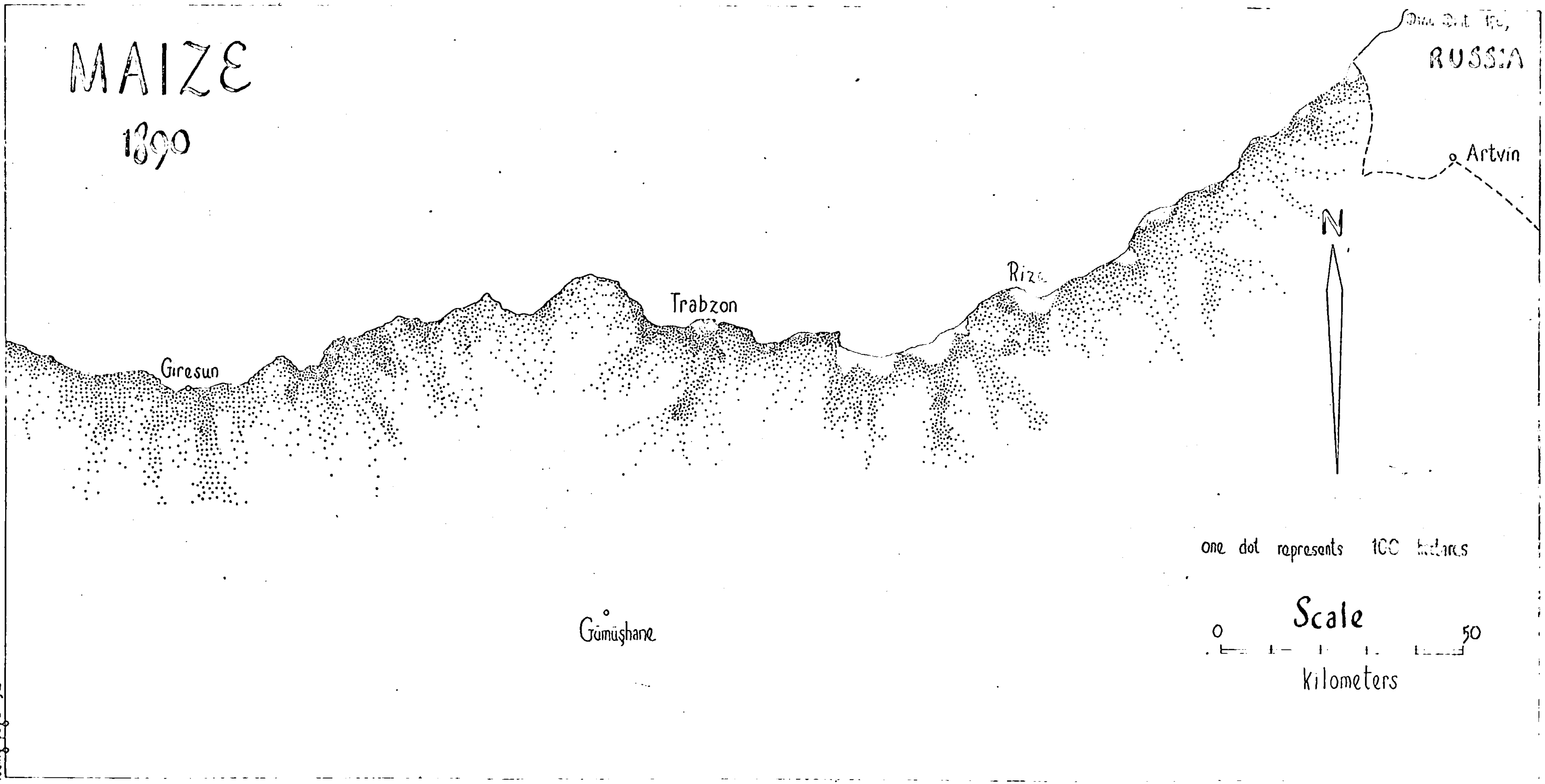
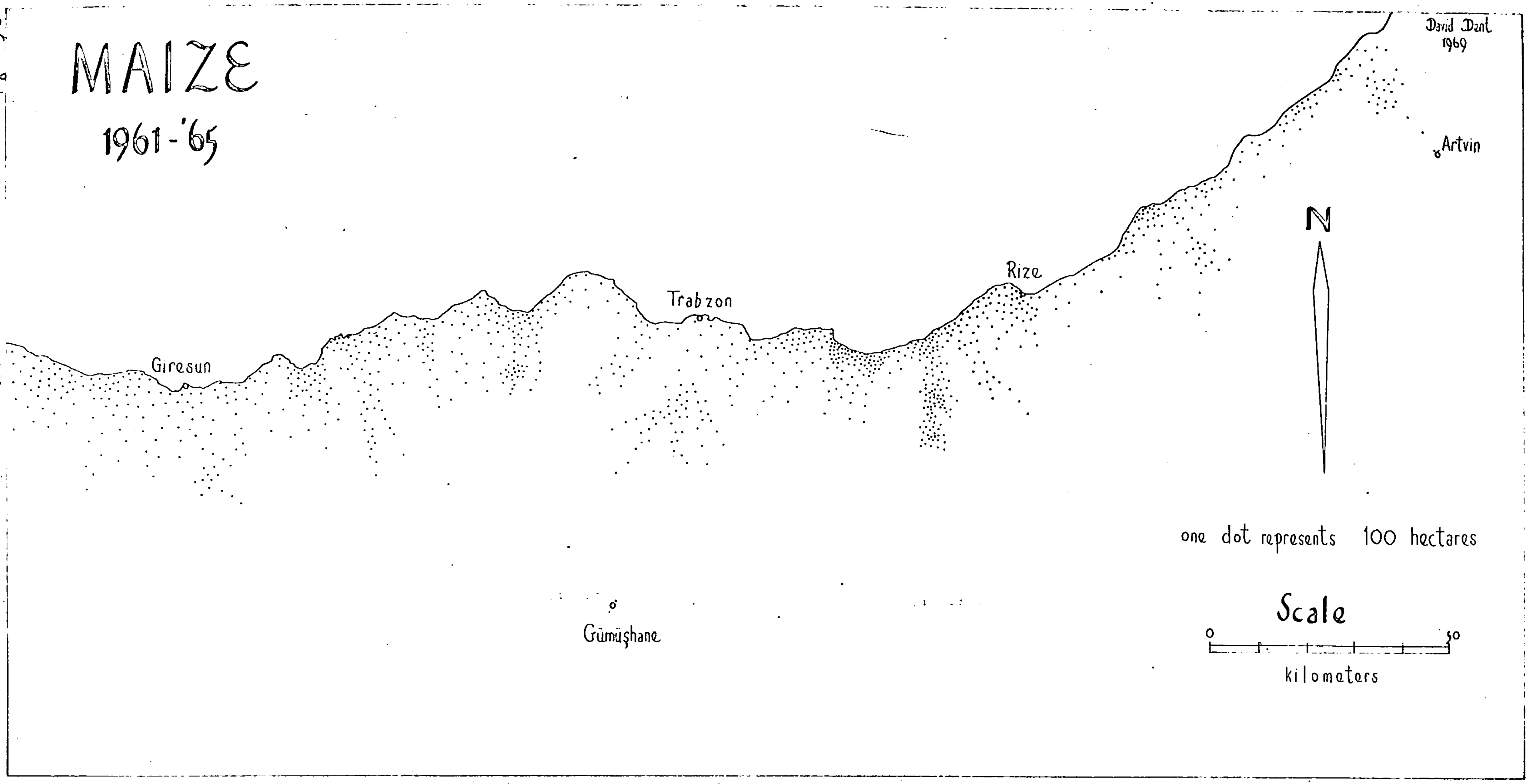
[1] The name Giresun (Kérassunde in Cuinet) is thought to be derived from the cherry.

facing page 32




MAIZE
1961-'65
Giresun
Trabzon
Rize
Artvin
Gümüşhane
N
one dot represents 100 hectares
Scale
0
50
kilometers
David Dahl
1969

a crop with good-keeping qualities was needed, especially since the humid climate makes open-air drying impractical, in contrast with the Mediterranean and Aegean coastlands. Cuinet reported a rapid increase in the area under hazelnuts, particularly around Giresun. The crop was exported to Europe, especially to Russia. The area now under hazelnuts continues to increase; around Giresun up to 90 per cent of the cultivated area is under hazelnuts (figure 5.3 and Appendix III). Most plantations are found below 700m., but wild hazels are common up to 1600-1800m., and hazelnuts are becoming increasingly the mainstay of mountain villages. Once established, the bushes provide excellent protection against soil erosion and have the particular attraction of demanding little attention (cf. Willimott, 27).

Tobacco (Nicotiana rustica) is a traditional Turkish crop. Cuinet records tobacco cultivation in Trabzon, Akçaabat, Tirebolu and Giresun, though Samsun was, and still is, the major tobacco-producing area on the Black Sea Coast. Up till 1950 tobacco was widely grown in the Eastern Black Sea Region and Pazar attained some importance as a producer of fine cigar tobacco. In recent years production has concentrated around Akçaabat and Trabzon (figure 5.4) but the area under the crop in the region as a whole has declined.[1]

Citrus cultivation is of long standing in the Eastern part of the region. Cuinet described the tangerine orchards of Rize as the outstanding agricultural enterprise of Lazistan (the region east of Sürmene). The Rize district remains the principal citrus-growing area; tangerines are by far the most important citrus crop, with a much smaller production of oranges and lemons.[2] The lemon is particularly

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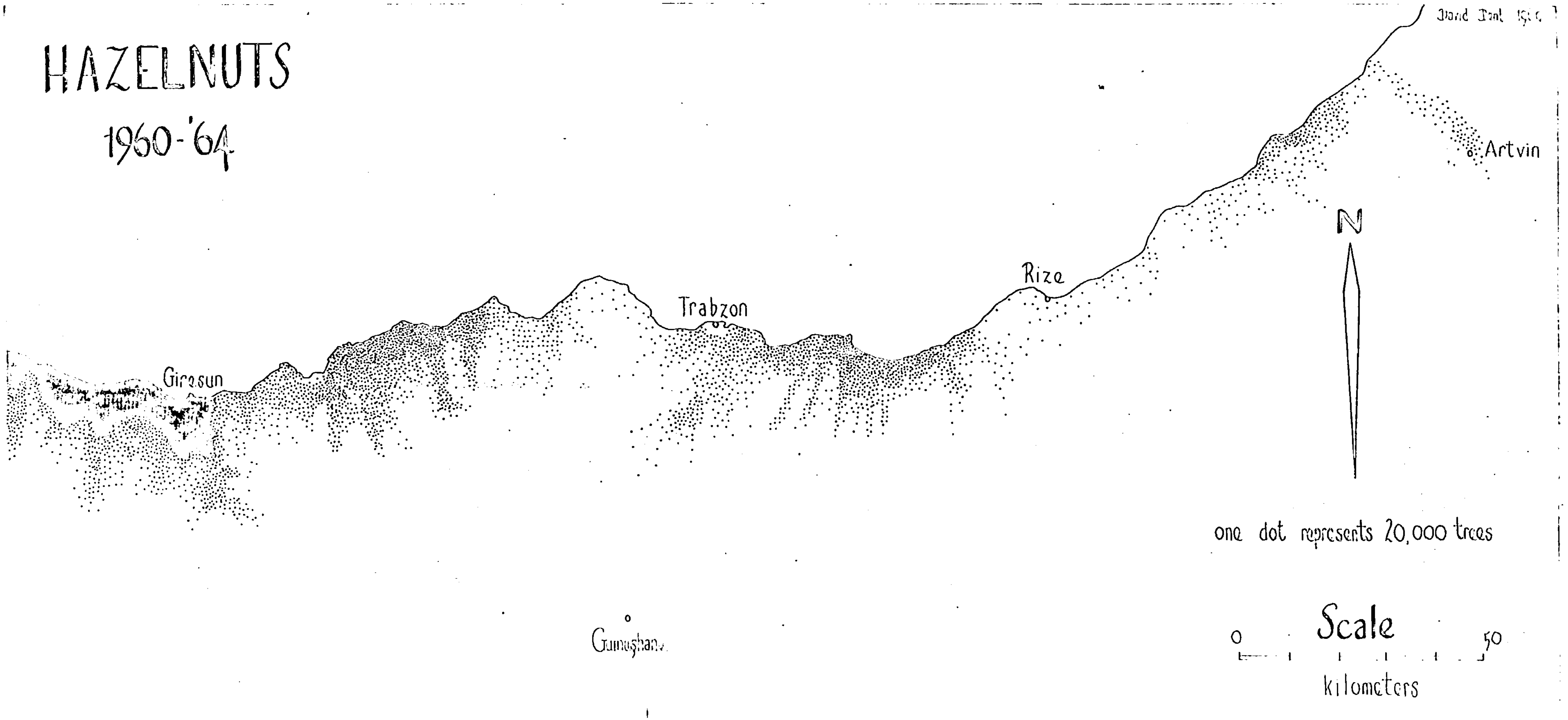
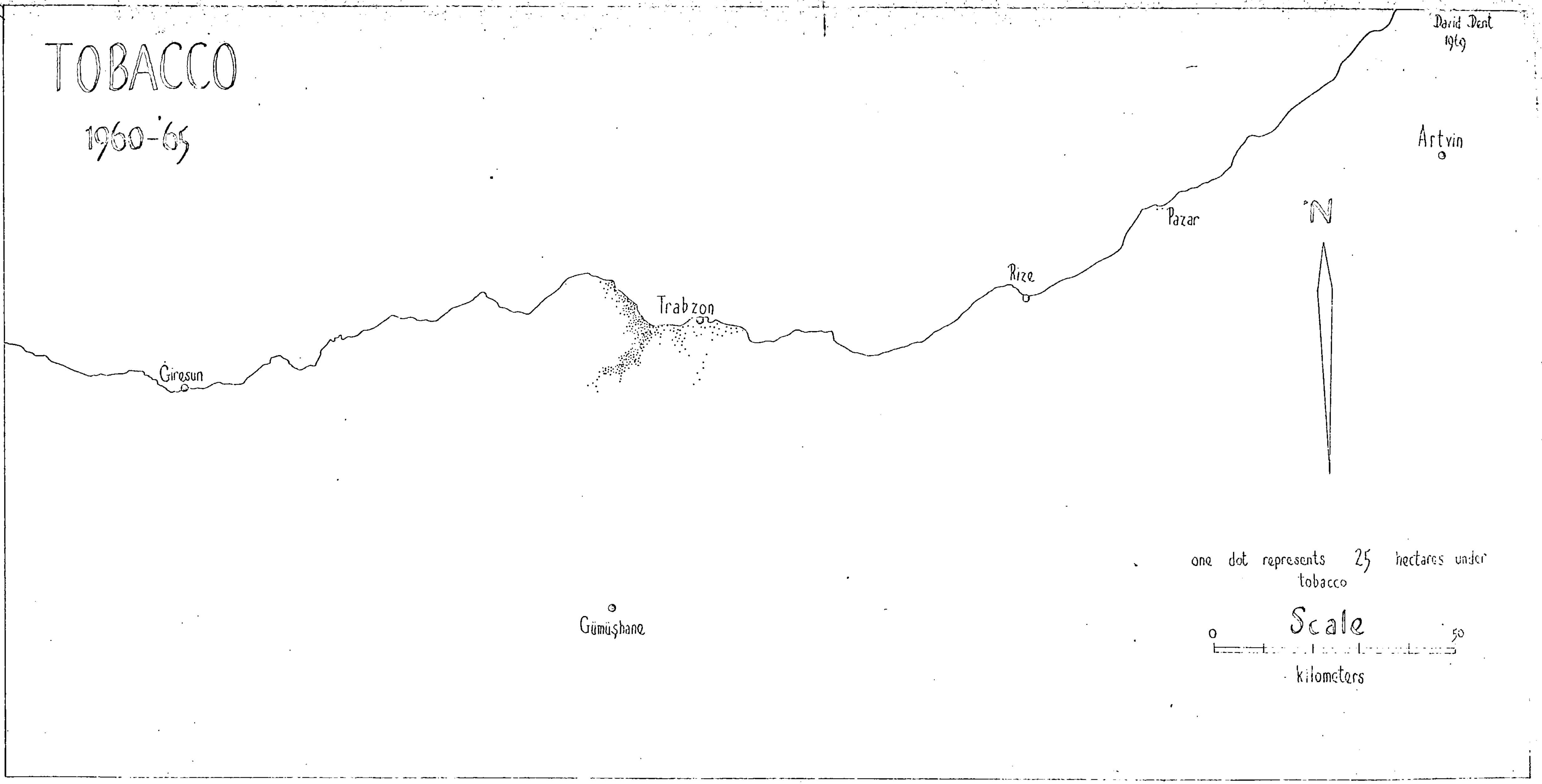
[1] Area under tobacco in the Eastern Black Sea Region

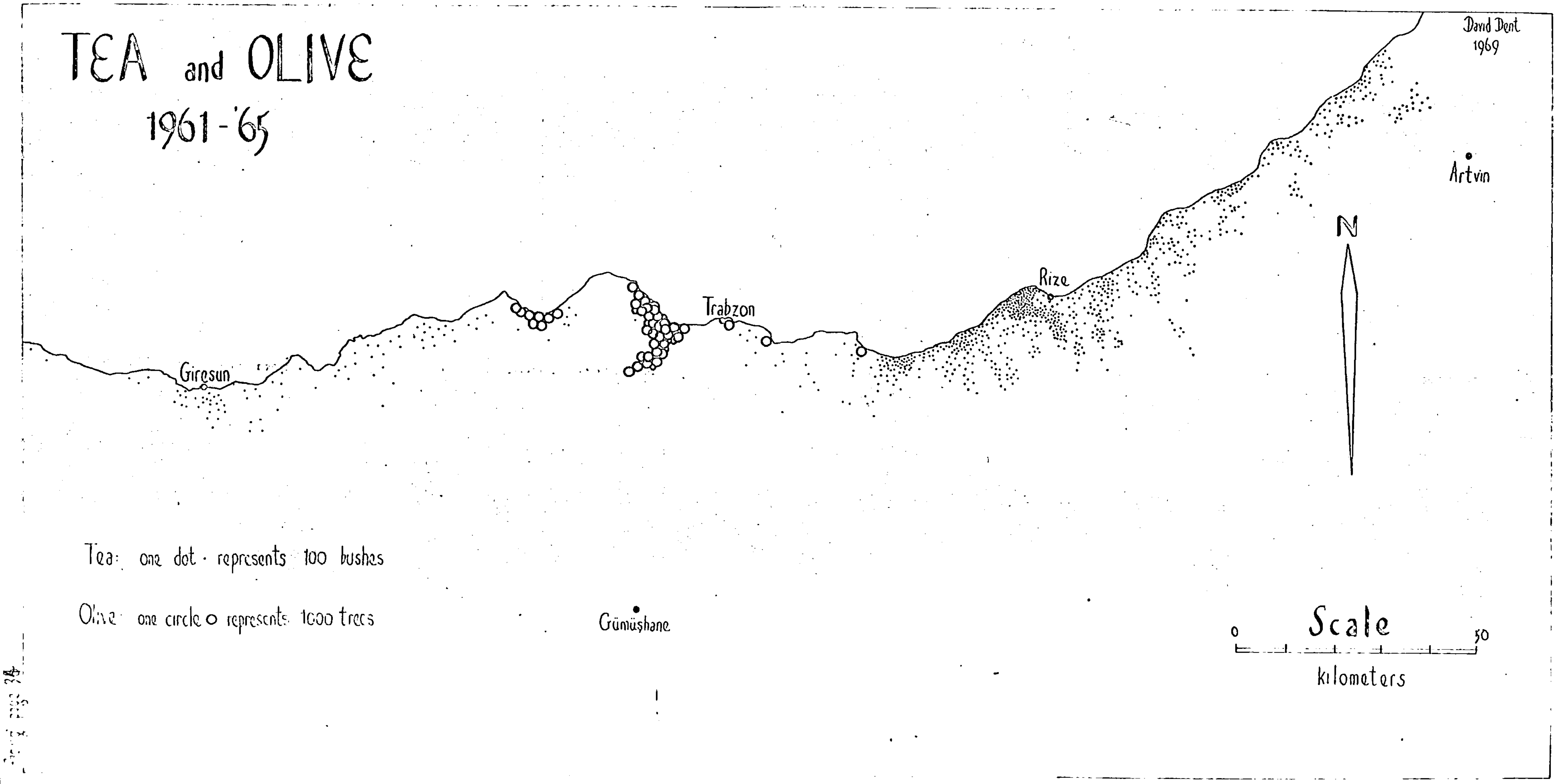
1958	11,986 hectares
1965	3,860 hectares

[2] Average number of citrus trees in the E.B.S.R. 1960-'64

Tangerine	294,000
Orange	76,000
Lemon	15,000


HAZELNUTS
1960-'64
Giresun
Trabzon
Rize
Artvin
Gumushane
N
one dot represents 20,000 trees
Scale
0
50
kilometers


TOBACCO
1960-'65
Giresun
Trabzon
Rize
Pazar
Artvin
Gümüşhane
N
one dot represents 25 hectares under tobacco
Scale
0
50
kilometers
David Dent
1969


TEA and OLIVE
1961-'65
David Dent
1969
Artvin
N
Rize
Trabzon
Giresun
Tea: one dot · represents 100 bushes
Olive: one circle o represents 1000 trees
Gümüşhane
Scale
0
50
kilometers

sensitive to frosts and is confined to the Rize, Ardeşen and Trabzon districts. In 1949-'50 frosts reduced the number of lemon trees in the Rize district from 6,000 to 300.

The role of the principal cash crop in the eastern part of the region has been taken over by tea. An abortive attempt to establish the crop in the Rize area was made in 1892 (28), but a State plantation initiated in 1924 laid the foundations for a remarkable expansion to almost 2,000 hectares in 1964. The region now satisfies over half of the increasing national demand for tea. Although the bush will withstand temperatures as low as $-12^{o}C.$, most tea is grown below 600m. to ensure a picking season of at least six months. The quality of the leaf is impaired by low humidity, and the crop is concentrated in the most humid parts of the region (figure 5.5).

A wide range of temperate fruits is grown, notably apples, pears and cherries (Appendix III), also peach, quince, plum, morello and melon. On the other hand, apricot and almond are not of economic importance. Amongst characteristically Mediterranean crops the fig and vine are widely distributed in the coastal zone, but the olive is grown only between Of and Vakfikebir and is strongly localised in the Akçaabat district.[1]

Field crops in the region include potatoes, beans and onions. Soya beans are grown around Ordu in the western part of the region. Rice and hemp are mostly grown in the east, but only on a small scale.

The modern expansion of commercial agriculture in a region dominated by many small, self-sufficient peasant proprietors has been greatly facilitated by the availability of cheap grain (wheat) through government agencies. The increasing specialisation in the coastal zone has been accompanied by a decline in the practice of transhumance,

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[1] The only other centre of olive production on the Black Sea Coast is Sinop. In 1965 there were 47,730 olive trees in the vilayet of Trabzon and 10,000 in Sinop, compared with over 10 million in Izmir and 13 million in Aydın - major olive-producing areas.

another traditional aspect of the land use in the region. Formerly 60 to 80 per cent of the population of the coastal zone migrated to the summer pastures of the yayla in May, and returned at the end of September. Now, in the Giresun area where commercial agriculture is most developed, only 3 to 5 per cent of the population go to the yayla, and return in early August for the nut harvest (22).

Scarcity of cultivable land is a distinctive feature of the Eastern Black Sea Region. Apart from the Pliocene platforms of Trabzon and Pazar, level lowland is confined to small patches of alluvium. Remarkably steep slopes, sometimes exceeding 25-30^{o}, have been brought into cultivation, but somewhat surprisingly in a long-settled and densely-populated region, terracing is rarely used. This provides a notable difference in the agricultural system from traditional practice in comparable environments, e.g. many Mediterranean countries and the Inca system in the Andes. Normal geological erosion is very active; soil creep is widely prevalent, and land slips occasionally occur on steep valley sides under cultivation, but the spectacular soil erosion characteristic of most drier parts of Turkey is not evident. Soil erosion in the Eastern Black Sea Region is checked by the luxuriance of the vegetation and the minute scale of cultivation where only small, isolated plots are left bare at any one time. For the most part, difficult terrain and pressure on the land dictate hand cultivation by mattock and hoe. Oxen and buffalo, the principal plough animals, have declined in numbers along with the drop in maize cultivation and in the practice of transhumance, which assured their winter and summer feed.

There is a tradition of permanent and seasonal migration by the male population of the region, formerly to the Caucasian countries, now to other parts of Turkey and abroad, leaving the womenfolk to do most of the routine work in the fields. In the eastern part of the region the development of tea cultivation has stemmed this migration and even draws workers from Trabzon, Giresun, Ordu and Samsun at the height of the picking season in May.

Land Use in the Trabzon Area

The Trabzon area embraces the greatest concentration of cultivable land in the Eastern Black Sea Region, and supports the highest density of population (Appendix III). The gentle slopes of the ridge tops and raised beaches are intensively cultivated; hazel plantations[1] occupy slopes uo to 25-30°; only the steepest, rockiest slopes and most sterile soils are given over to scrub and woodland (photographs 8-12). Individual holdings are small and unspecialised, and all the characteristic crops of the region, except tea, are widely cultivated.

A typical village on the Trabzon platform consists of a loose cluster of houses, each separated by fruit trees and fences of brushwood. Usually the villages are built on the ridge tops; in many cases they lie a kilometer or more from the nearest motor track and are approached by paved pack-horse tracks. An individual house is characteristically stone-built, with tiled roof and shuttered windows. Close by is a barn of open wooden construction with two sides covered by tarred, flattened oil cans - a popular weatherproofing material; here maize and hazel nuts are dried and stored. Around the house is a small hay field, frequently cut like a lawn, and a vegetable plot producing egg-plant, onions, garlic, tomatoes, potatoes and Cucurbitae. Beyond are field crops and hazel bahçes. Maize is the principal field crop, sown in April, usually planted in holes 8 to 10 cm. deep, six seeds to a hole planted in a circle (rarely the seeds may be broadcast). After emergence the plants are thinned to three per hole. Beans, and frequently cabbages also, are interplanted with the maize. Interculture is also a feature of newly-established hazel bahçes, maize and beans being planted between the individual bushes. The sward beneath mature bahçes is cut for hay, or grazed by cattle which are sometimes tethered. Fruit trees are scattered within the fields and hazel bahçes, or may be planted in small orchards.[2]

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[1] Fındık bahçesi. Bahçe = Turkish, garden - rather more appropriate to the small-scale intensive husbandry of the region than plantation.

[2] Yemiş bahçesi, literally fruit garden.

Interculture is particularly valuable in reducing the amount of bare ground, so reducing the risk of soil erosion. Tobacco is grown without intercultivation; the plots are clean-weeded throughout the growing season leaving the soil virtually unprotected during the early stages of the crop's growth, hence soil erosion is a problem and is often severe. Artificial fertilizers are not used, but all available manure and compost is applied and worked into the soil. No specific soil conservation measures are normally taken although TOPRAKSU[1] have constructed demonstration terraces in the Değirmendere valley towards Maçka. There can be no doubt that summer irrigation would greatly increase the yields of many crops, particularly of vegetables for the urban market, but on the Trabzon platform the streams run in narrow valleys below the level of most cultivable land. One small scheme, again constructed by TOPRAKSU, is in operation on a pocket of alluvium just east of the mouth of the Değirmendere.[2]

All possible responses to a scarcity of cultivable land are seen in the Eastern Black Sea Region, namely permanent and seasonal migration, intensive cultivation of available land, and the production of commercial crops of relatively high value. Further development of the agriculture of the region may result from further emphasis on commercial crops, wider application of artificial fertilizers, and the adoption of some kind of contour terracing - especially for crops which leave the soil unprotected for any length of time.

Man as a Soil Forming Factor

In the coastal zone, replacement of the natural forest by cultivated land began over 2,500 years ago, and in densely-populated areas pristine forest soils are rare. Under a humid climate and

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[1] TOPRAKSU - the Soil and Water Conservation Service, under the Ministry of Village Affairs.

[2] In this instance the extra water could be used for the production of fresh vegetables which fetch a good price in Trabzon, but instead it is used mainly in hazel bahçes.

intensive management the soils have resisted the catastrophic erosion which devastated much less-steeply sloping land in the drier parts of Anatolia (cf. Oakes (5)). However, cultivation of steeply-sloping land in the region without resort to terracing can, and does, lead to considerable loss of soil by sheet erosion. On the other hand, in long-settled areas, deep surface horizons have been developed by long-continued cultivation and manuring, and these soils are stable and highly productive.

6 **Trabzon,** The old harbour. The andesite mass of Boztepe rises along a fault line behind the city.

7 **Trabzon**. Part of the walled citadel.

8 **The Trabzon Platform**. A view westwards from Boz Tepe showing the succession of parallel ridges.

9 **The Trabzon Platform**. A view eastwards across the Değirmen D. towards Zafanos. Intensive hazel, maize and tobacco cultivation.

10 **The Trabzon Platform**. A ridge-top farm on Red Clay and Lithosol soils

11 **The Trabzon Platform**. A farm on Brown Calcareous soils. Red Clays occur on the sparsely-wooded ridge top in the background.

PART TWO

SOILS

Previous Investigations in the Eastern Black Sea Region

Although there has been little pedological investigation in the Eastern Black Sea Region of Turkey, the sub-tropical soils of neighbouring Georgia have been the subject of some notable research by Russian scientists. With characteristic insight, V.V. Dokuchaiev, in 1900 (29), placed the zonal soils of the region amongst the laterites. Zakharov, in 1935 (30), classified them as krasnozems (red earths) and zheltozems (yellow earths) by virtue of the large amounts of iron oxides and hydroxides present in the clayey weathering crust. Polynov (31) distinguished between the thick red weathering crust, and the soil layers themselves - "formed under the influence of acid soil-forming processes". This work was followed by Romashkevich (32a,b) and Gerassimov (33) who drew attention to the translocation of clay and iron hydroxides within the soil profile.

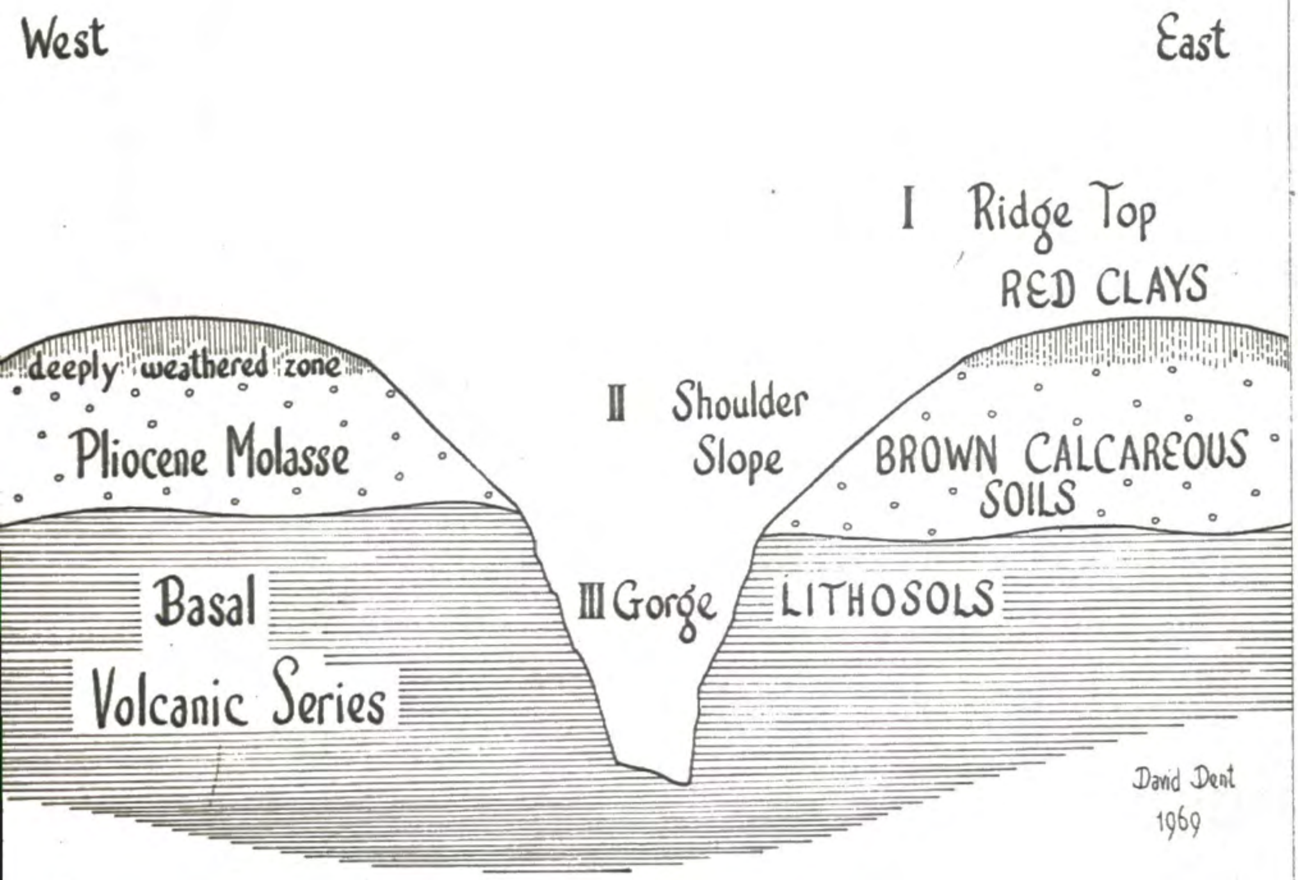
The predominant clay minerals of the krasnozems and the red weathering crust are kaolinite and halloysite, but Yakovleva (34) and Lisitsina (35) have found considerable amounts of gibbsite, which emphasises the lateritic or, more precisely, ferrallitic nature of these soils. Work on soils from the Rize district in the Turkish section of the Eastern Black Sea Region by Mitchell and Irmak (36) and Gülcur (37) has established the predominance of kaolinite/ halloysite and illite in krasnozem and brown forest soils below about 600 m.; and illite, vermiculite and mixed layer minerals in somewhat podsolised brown forest soils at higher altitudes.

The present work is concerned with field and laboratory studies on soils in the Trabzon area. Terminology follows the F.A.O. "Guidelines for Soil Description" (38). Selected profile descriptions, and results are given in volume 2.

facing page 40

6.1 THE TRABZON CATENA

Idealised Section



A view southwestwards across the Catena, showing the typical pattern of land use with hazel and fruit bahçes. Most villages, and also occasional stands of woodland, are on the ridge tops.

THE SOILS OF THE TRABZON PLATFORM

The pattern of soils found on the Trabzon Platform, developed on the regular sequence of ridge and valley, may be described as catenary (39) figure 6.1. The units of the catena are outlined below:-

I. On the broad, gently-sloping ridge tops (the remnants of the Pliocene surface) there are RED CLAY SOILS developed on Pliocene molasse sediments.

II. On the younger erosion surfaces of the shoulders of the ridges, developed on the same parent material, there are BROWN CALCAREOUS SOILS.

III. On the steep gorge sides and on ridges stripped of their sedimentary cover the volcanic basement rocks outcrop and give rise to LITHOSOLS.

These groups of soils were encountered in a rhythmic succession in a transect across the grain of the country between Zafanos and the valley of the Sera Dere. In small patches around settlements another group of soils has developed, distinguished by particularly deep, dark-coloured A horizons. These are analagous to the Plaggenboden of north-west Europe. The deep "plaggen" horizon is the product of incorporation of compost and domestic refuse over a long period, and most are found on long-settled ridge sites. Each profile is thus highly individual; some have developed from Red Clays, some from Brown Calcareous or colluvial soils.

Other soils of minor importance in the area are developed on alluvium - principally on the delta of the Değirmendere - recent marine terraces, and colluvial materials of mixed origin.

Chapter 6

THE RED CLAYS

These soils usually occur on the ridge tops on slopes of 0^{o} to 12^{o}, at elevations between 200m. and 350m., although transported and redeposited red clay material may be found on steeper slopes below. The outstanding properties of the Red Clays are a high degree of weathering (frequently to a great depth) and high clay content. Only the most resistant minerals, such as quartz, zircon and garnet, remain in the coarser fractions, while the clay fraction is dominated by minerals of the kaolin group along with iron oxides. The striking red colour is a feature of the upper part of the profile and is most marked under cultivation; pale gley colours are always dominant at depth in the natural profile.

MORPHOLOGY

Profile 1 represents the nuclear concept of the Red Clay soils. Under mixed forest the horizons present are as follows:

Horizon number in profile description	
1, 2	Thin surface organic and A_1 horizons incorporating mor humus.
3	A pale-coloured A_2 horizon of heavy texture but lacking a clearly-developed macro-structure. This could be described as an "Albic" horizon in terms of the 7th Approximation.[1]
4	An argillic (Bt) horizon enriched in fine clay and sesquioxides; stronger in colour and structure than the A horizons. Translocated clay is often visible as pore fillings and cappings on pebbles.

[1] The traditional A, B, C horizon nomenclature and the more recent connotative terminology are used as defined in the American 7th Approximation (40a,b).

5, 6 The profile becomes increasingly gleyed with depth because of the heavy texture. The Bt merges through a mottled zone with small manganese nodules to a pale, gleyed Cg horizon marbled with veins of iron oxides. The clay content of the Cg horizon may be as high, or higher than that of the Bt.

The Trabzon Platform has a very long history of human occupation and intensive agriculture; consequently profiles with natural or semi-natural A horizons are rare. However, most soils in the Red Clay group may be considered derivatives of the basic type through various degrees of erosion - both normal (geological) erosion, and accelerated (soil) erosion following forest clearance and cultivation. The broad, gently-sloping ridge tops are the remains of the late-Tertiary marine platform subsequently uplifted. They have provided stable, weakly regressive (41) sites for soil formation, and may carry very deep, mature soils. But as normal erosion of the ancient surface has proceeded from the sides of the dissecting gorges, less-weathered material, which retains the structure of the parent rock, is brought close to the surface. The parent rock is a molasse of rounded lava, tuff and agglomerate stones and boulders embedded in a fine-grained matrix. In profiles 2, 3 and 13 the original outline of the stones and even the crystal structure of the lavas is clearly visible in the field, but the whole mass has been replaced by clay minerals and can be cut through with a spade. This type of material is referred to as "saprolite" in the 7th Approximation. In general, the steeper the slope, the nearer to the surface can identifiable parent rock be seen, and on the steep shoulders of the ridges deeply-weathered material has been completely removed leaving the slightly calcareous molasse as the parent material of the Brown Calcareous Soils.

Normal erosion is accelerated by forest clearance and cultivation. The surface organic and A_1 horizons, maintained by the forest vegetation (profiles 1 and 2), are lost when the natural vegetation is destroyed. Loss of organic matter is very rapid under cultivation,[1] and this loss of organic matter leads to a deterioration of soil structure, which is naturally weak in the albic horizon. Percolation of water through the clayey soil is slow, and during heavy rains the unprotected soil is subject to sheet erosion. Following erosion, the B horizon may be encountered at or near the surface (profiles 3 and 4). When the sesquioxide-rich B horizon material is exposed at the surface, water-stable granules which are relatively resistant to sheet erosion are formed, but percolation through the profile remains so slow that the surface layer quickly becomes saturated and may be subject to solifluction.

MICROMORPHOLOGY

A detailed examination was made of a monolith from profile 2 which displayed all the characteristic horizons of the semi-natural Red Clay Soil, including saprolite, within 120 cm. Continuous undisturbed samples were impregnated with "Bakelite" resin and thin sections prepared from each horizon. Thin sections were also prepared from the Bt and Btg horizons of profile 5, a cultivated Red Clay.

Albic Horizon A_2

Profile 2, 10-14 cm - photograph 13

Earthworm casts comprise three-quarters of the soil material; individual pellets range from 100μ to 250μ in diameter. The remaining soil fabric has a dense, welded appearance, reminiscent of an old cultivated horizon and the worm burrows are often sharply delineated. The overall colour in reflected light is 10YR 5/2.

There are abundant angular and subangular grit fragments, 100μ to 500μ in diameter, which are only slightly weathered, and frequent

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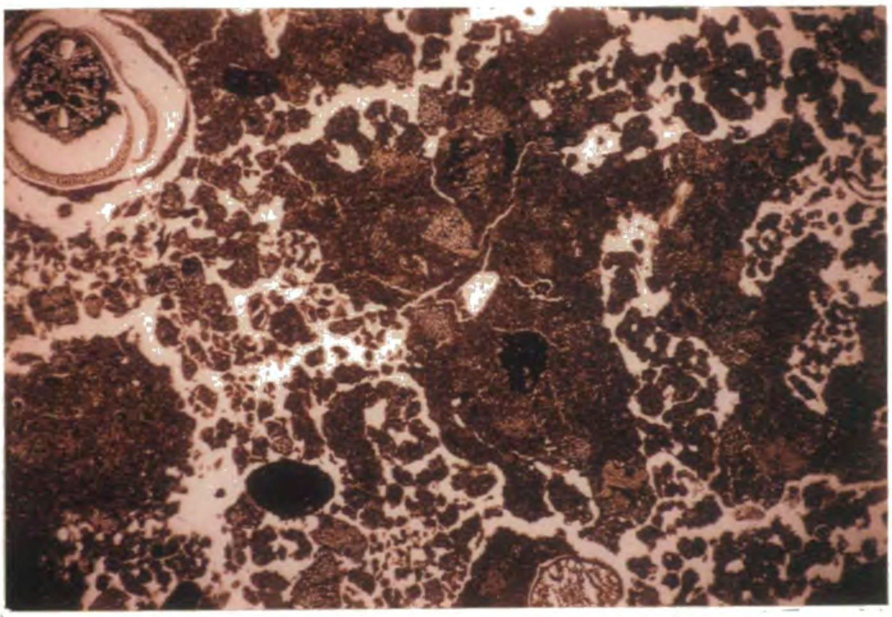
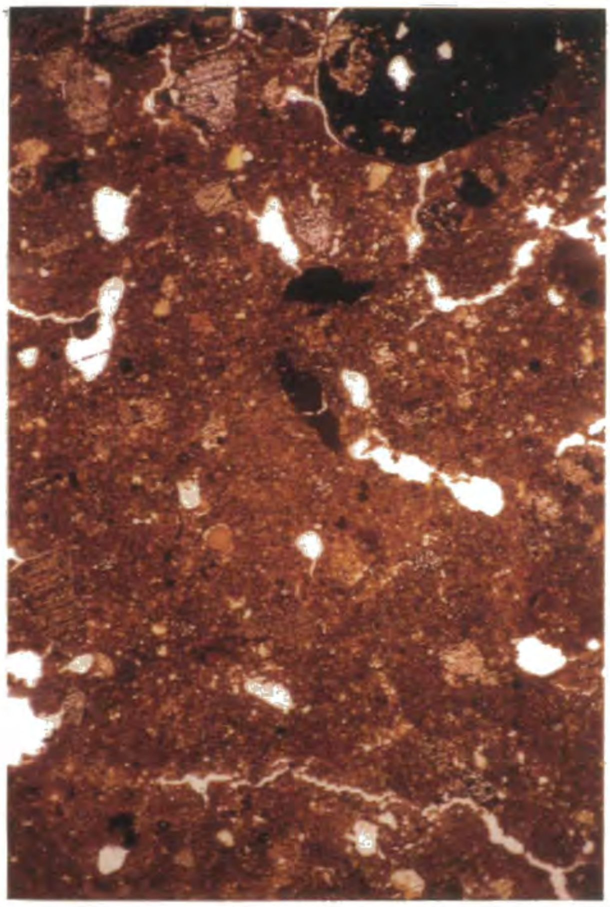
[1] In profile 12 the Ap horizon of the present cultivated soil has little more than half the organic content of the underlying $A_{1.2}$ horizon, and little more than one third the organic content of the A_1 horizon of an adjacent profile under scrub vegetation.



13 Albic Horizon, profile 2. 10-14 cm. x 8

Dense, welded fabric with sharply-defined earthworm burrows and faecal pellets. The fabric contains black manganese-iron concretions and angular grit fragments.



14 Argillic Horizon, profile 2, 40-46 cm. x 8

Reconstituted fabric with abundant grit and large, rounded iron-manganese concretions giving way to less-disturbed material with only small manganese nodules at the bottom of the photograph.

photographs by L. Robertson and D.L. Dent

dark-coloured, opaque iron-manganese ("ironstone") concretions up to 5mm. diameter, rounded and sub-rounded, and probably transported. The horizon contains abundant fresh woody roots and occasional translucent resin droplets. There is no evidence of clay orientation.

Argillic Horizon Bt

Profile 2, 40-46 cm. - photograph 14

In profile 2 there is a discontinuity in the soil fabric at about 41 cm. Above 41 cm. the fabric has a dense reconstituted appearance, with numerous fresh grit particles up to 6mm. long and frequent iron-manganese concretions up to 4mm. in diameter. The largest concretions are rounded and probably transported; the distribution pattern of quartz grains, which are relatively stable soil constituents, is similar in the concretions to that in the matrix but not continuous with it. There are also frequent small, irregular manganese concretions, up to 250µ in diameter, superimposed on the soil fabric and developed in situ. The overall soil colour above 41 cm. is 5YR 5/4.

Below 41 cm. the fabric is dominated by completely weathered rock agglomerate, tuff and lava - in situ, with a random pattern of black hairline manganese cutans.[1] These cutans are often multiple - up to 5µ in total thickness, and may occupy cracks inherited from the parent rock. There are rare fresh grit particles, which may have fallen down between structural faces. The overall colour below 41 cm. is 5 to 7·5 YR 5/8.

In polarised light the whole section shows a wavy vertical orientation pattern, with very weak orientation around concretions and less-weathered rock. Old root channels and pores are filled with oriented, translocated clay, but the present roots and ped faces ignore the clay-filled pores and do not have cutans of translocated clay.

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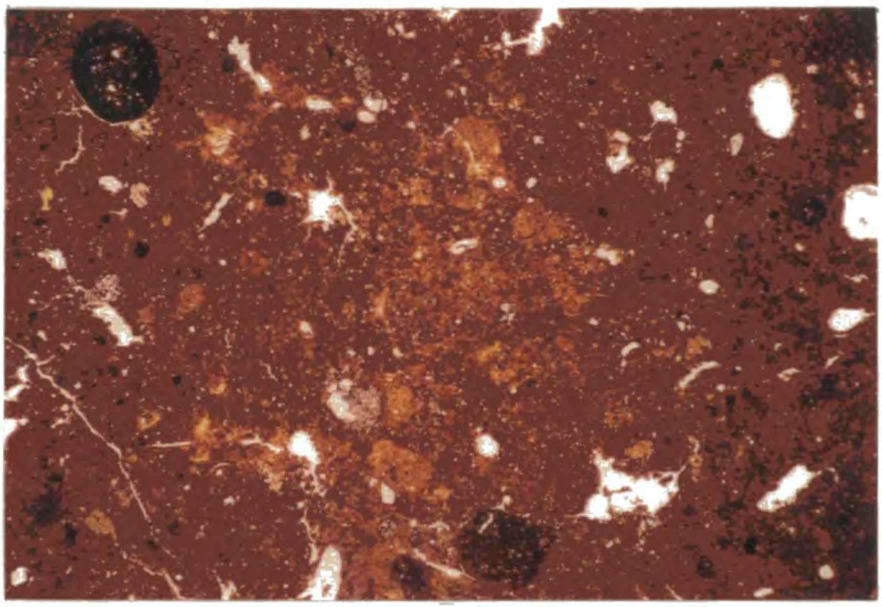
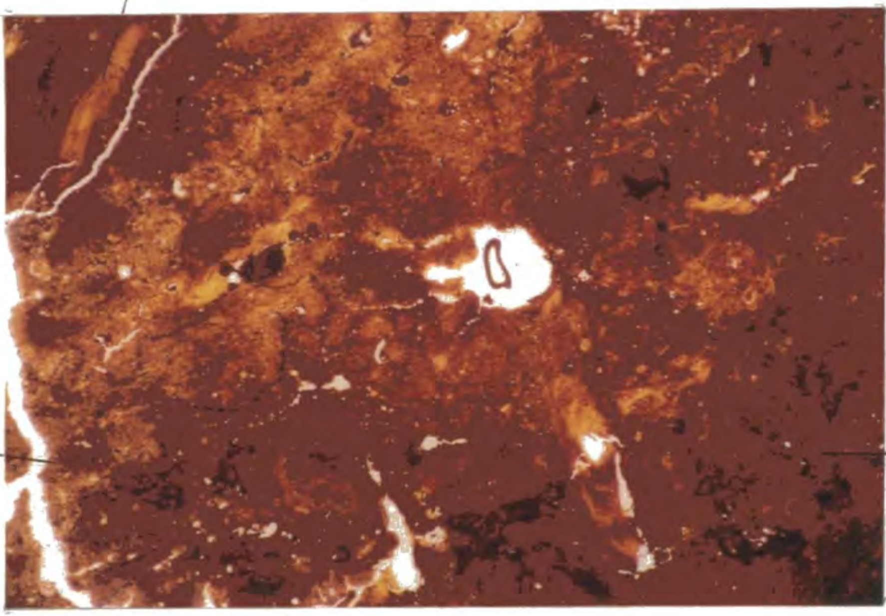
[1] Cutan, defined by Brewer (42) as a concentration of some particular constituent or in situ modification of the soil at a natural surface in the soil fabric.



15 Argillic Horizon, profile 5, 30-33 cm. x 8

Dense fabric with predominantly irregular unoriented pores. Light deposition of translocated clay and prominant iron-manganese concretions.



16 Gleyed Argillic Horizon, profile 5, 65-70 cm. x 8

Dense fabric with heavy deposition of translocated clay in an old dendritic pore system, and gleying along present ped faces.

photographs by L. Robertson and D.L. Dent

Profile 5, 30-33 cm. - photograph 15

A dense clay fabric with a random distribution of irregular pores up to 4mm. in diameter. Background colour 10R 4/4. Common iron manganese concretions 0·3mm. to 1·5mm. diameter, developed in situ and occasional identifiable fragments of highly-weathered lava. In polarised light the fabric shows weak pressure orientation and occasional thin cutans of translocated clay in pores.

Gleyed Argillic Horizon Bt (g)

Profile 5, 65-70 cm. - photographs 16, 17 and 18

A very dense clay fabric with an intense red colour, 10R 4/4, in the ped cores and clearly-defined, gleyed ped faces. At the ped faces the colour is 5YR 6/6, and the bleached zone may be up to 1 cm. thick at a major ped face. Under high magnification (photograph 17) the original crystalline structure of the parent rock can be seen.

Pores and old root channels are heavily infilled with oriented, translocated clay which has a distinct "varved" appearance, (photograph 18). The present ped faces and root channels frequently cut through the clay-filled pores, but do not themselves have cutans of oriented clay.

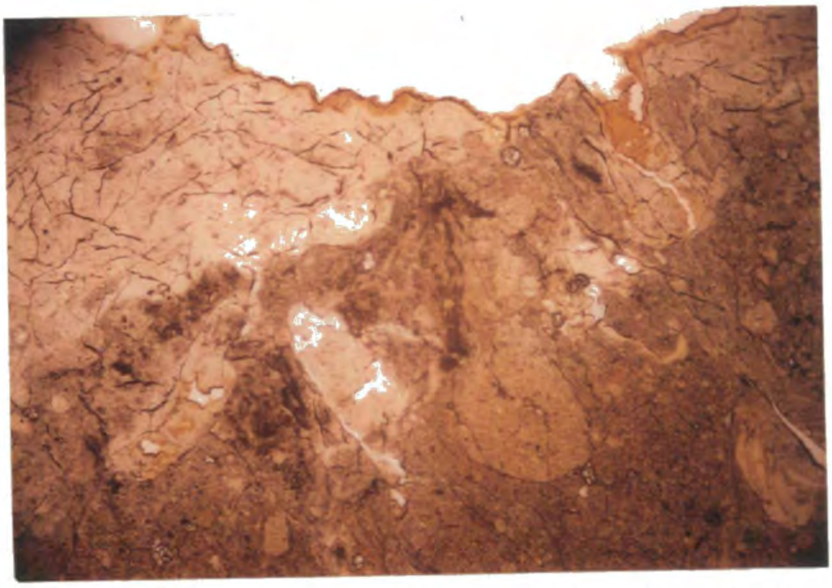
Saprolite Horizon C (g)

Profile 2, 50-54 cm.

The soil fabric is predominantly highly-weathered lava, tuff and agglomerate, with a background colour of 7·5YR 5/8. Quartz crystals up to 3mm. in diameter are common, and many retain crystal faces; the olivine crystals are completely replaced by clay minerals and brown to crimson iron oxides, but retain their crystal shape.

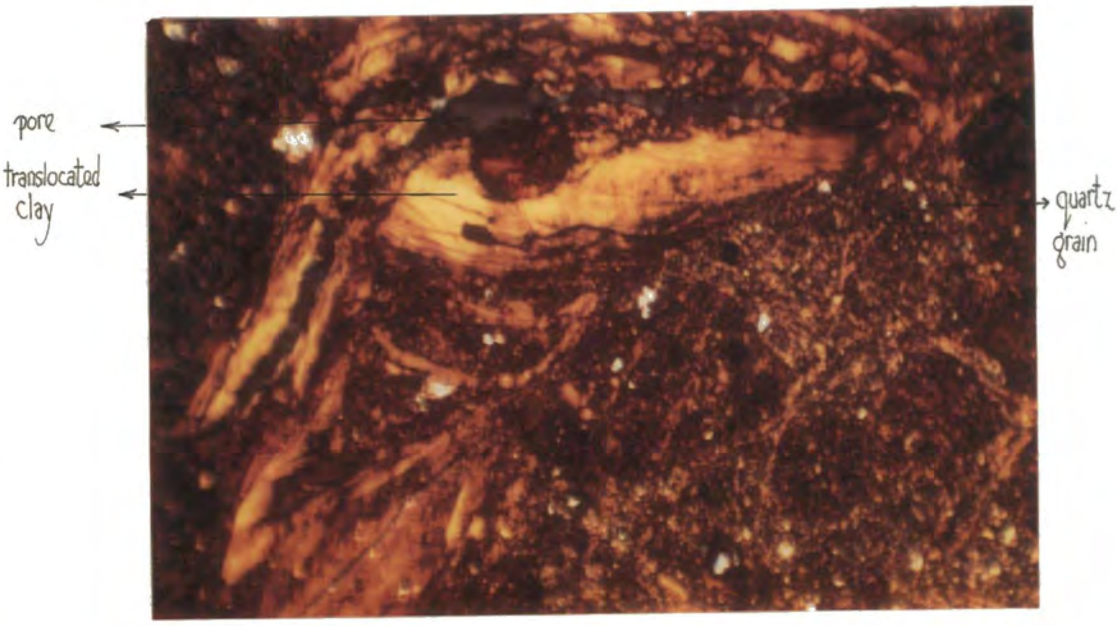
There is a random pattern of hairline manganese cutans and frequent irregular, but sharply defined, manganese concretions 200µ to 300µ in diameter.

Carbonised organic material is present. Earthworm burrows, which are up to 3mm. in diameter, are infilled with humus-stained soil. This



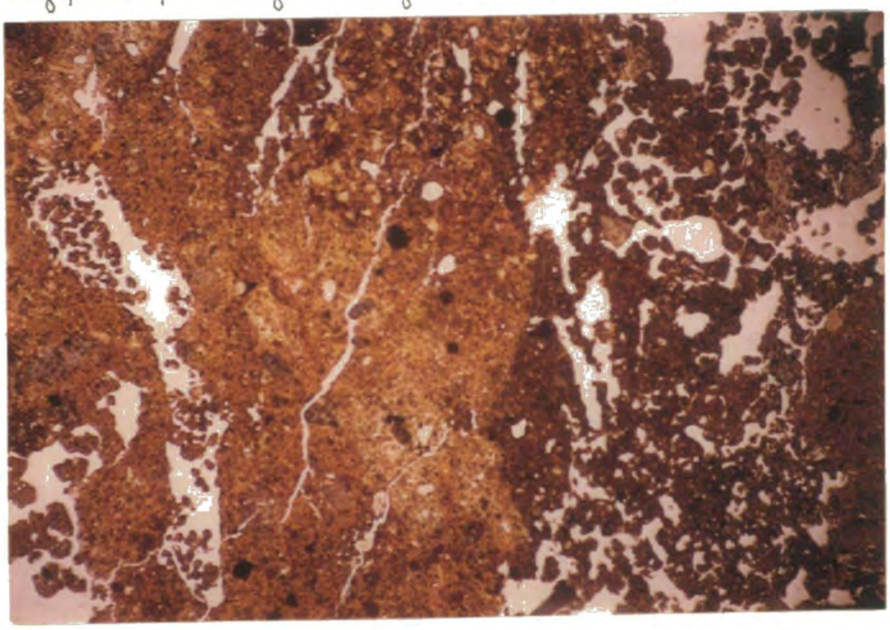
17 Gleyed Argillic Horizon, profile 5, 65-70cm. x25

Bleached ped face showing traces of original rock structure



18 Clay-filled pore, profile 5, 65-70cm. x 250

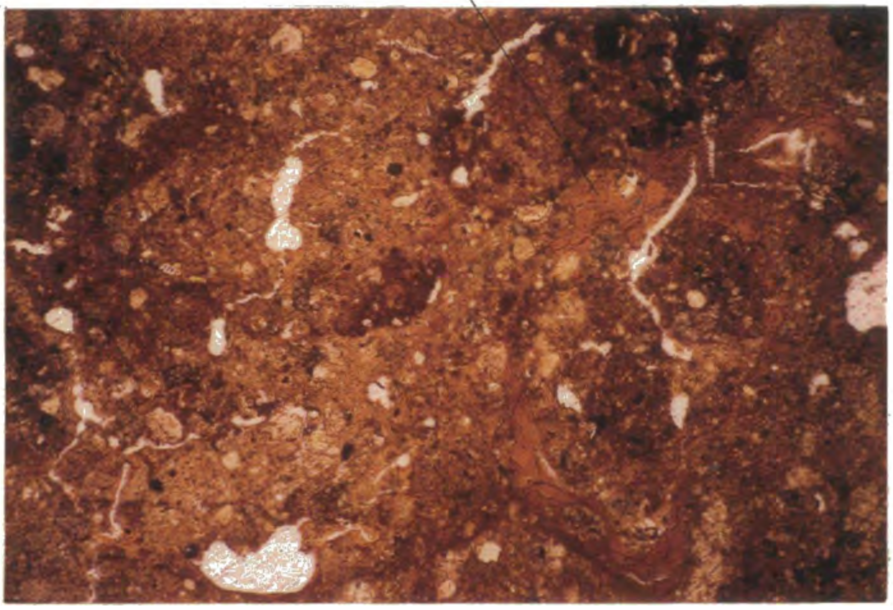
Photographed in polarised light showing "varved" translocated clay.



19 Saprolite Horizon, profile 2, 50-54 cm. x8

Saprolite with fine manganese nodules, intersected by earthworm burrows with darker soil and some fresh grit.

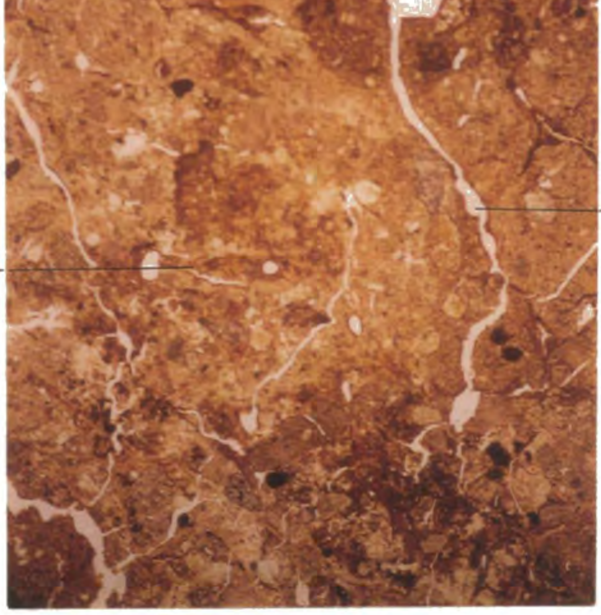
20



Saprolite Horizon, profile 2 94-99 cm.
x 8

Original structure of parent material preserved but primary minerals other than quartz replaced by clay minerals. Old dendritic pore system infilled with translocated clay which also coats weathered pebbles. Numerous fine manganese nodules.

21



photographs by L. Robertson and D.L. Dent

gives to them a darker colour (7•5YR 5/4) than the matrix (photograph 19).

Old dendritic pores are completely filled with oriented, translocated clay, and are ignored by present structural faces and root-channels, which are not themselves coated by oriented clay. In polarised light the section shows a weak pressure orientation of the clay fraction, particularly around the larger quartz grains.

Profile 2, 94-99 cm. - photographs 20 and 21

Pseudomorphically replaced parent rock. Colours in ped cores 5YR 5/8 to 7•5YR 5/7 with bleaching to 7•5YR 7/6 near ped faces. There are common irregular, but sharply delineated, manganese concretions 200μ to 300μ in diameter.

Clay-filled dendritic pores permeate the entire fabric at intervals of 125μ to 600μ, cutting indiscriminately through the saprolite. The translocated clay is distinctly varved - slightly different colours of clay and dark bands between each varve differentiate individual layers. Maximum varve thickness is up to 8μ, but is usually less than 4μ. Present voids do not have clay coatings, although they may have weak organic staining and often contain dark, hairy, spherical spores about 20μ in diameter - probably the mycorrhizal fungus associated with the roots of <u>Picea</u> <u>orientalis</u>. Earthworm burrows rarely occur.

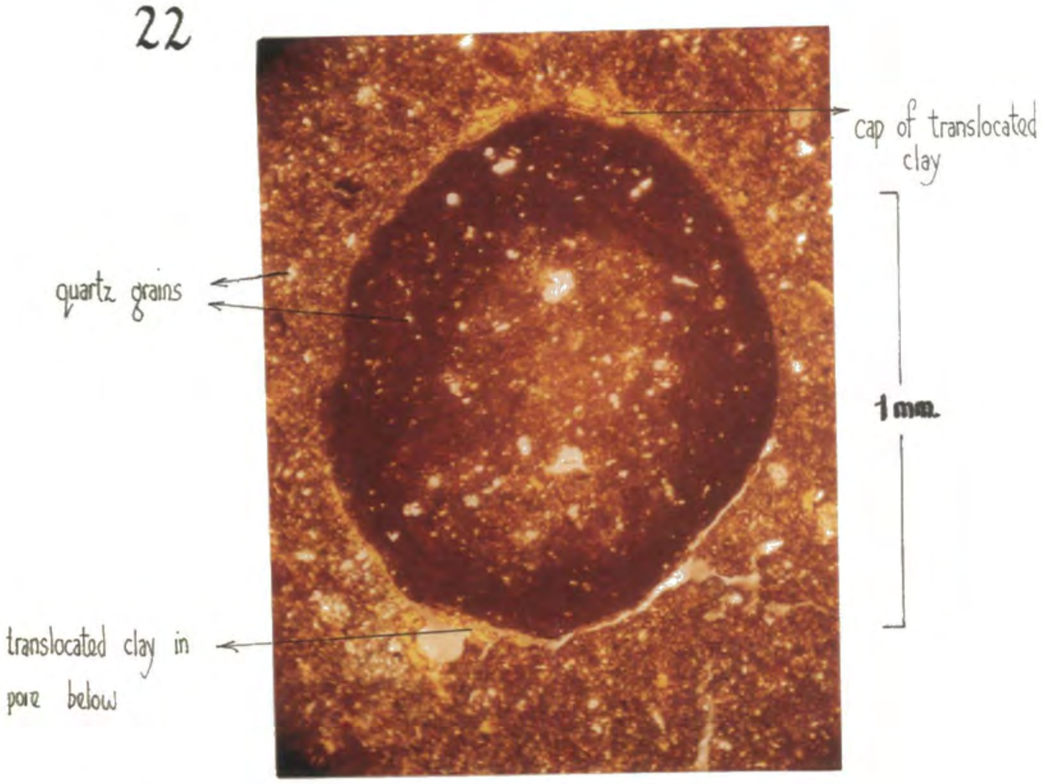
Iron-Manganese Concretions

Iron-manganese concretions of various ages are characteristic of the Red Clay Soils; they provide evidence of current soil conditions and also of past processes that helped to form the soil body.

Small, irregularly-shaped manganese oxide concretions with a sponge-like structure are seen in thin sections of the B(g) and C(g) horizons of profile 2. They are contemporary or recent pedological features representing a limited redistribution of manganese within the profile under alternating wet, anaerobic and dry, aerobic conditions related to the seasonal rainfall.

facing page 47

22



Iron-Manganese Concretion, profile 5 30-33 cm., x 60

23
Section through Iron-Manganese Concretion, profile 3

photograph by A.D. Moir

Rounded "ironstone" concretions of coarse sand and gravel size make up the greater part of the limited coarse fractions of most Red Clay profiles, notably profile 5. X-ray examination shows them to be a mixture of haematite and manganite - MnO(OH). The concretions have developed by accretionary deposition around a nucleus, frequently a cluster of quartz grains. Photograph 22 shows a concretion in situ. The pattern of stable quartz grains is continuous with that of the matrix of surrounding soil, and there is heavier deposition of sesquioxides (or a chromatographic separation of iron and manganese) in an eccentric outer zone. The concretion is of some antiquity since:-

i. It occurs at shallow depth in a now freely-drained horizon.

ii. There is a weak pressure orientation of the soil fabric around the concretion (evident in polarised light). The concretion is tearing away from the matrix above and below due to swelling and shrinkage of the clay, and release of pressure by vertical movement.

iii. The upper void is completely filled with translocated clay and the lower void partly filled. The phase of lessivage must have been a considerable time later than active concretionary growth.

The "ironstone" concretions of profile 2, seen in thin section in photographs 13 and 14, are probably transported and may be subject to dissolution under present conditions since many are pitted.

Profile 3 provides the most spectacular example of relict iron-manganese concretions (photograph 23). The concretionary zone outcrops at the surface nearby, and some concretions are the size of a rugby ball. The principal concretionary mineral is manganite which coats the quartz grains, forming a shiny black skin on the outer surfaces of core regions of kaolinite and quartz with goethite and haematite. The manganite has been deposited in concentric zones around the core areas and these zones of deposition and cementation have fused to produce large convoluted concretions. When the concretionary zone is exposed at the surface the un-cemented clay is washed out by rain to leave a cǿndery, vesicular material.

These concretions have been formed by slow diffusion of manganese-rich groundwater, probably over thousands of years, at some depth in a tropical weathering crust, and are probably the oldest concretions in the Red Clay soils. The manganese ore mined in the 19th century near Sürmene (25) may have been of similar origin.

PHYSICAL AND CHEMICAL CHARACTERISTICS

Texture

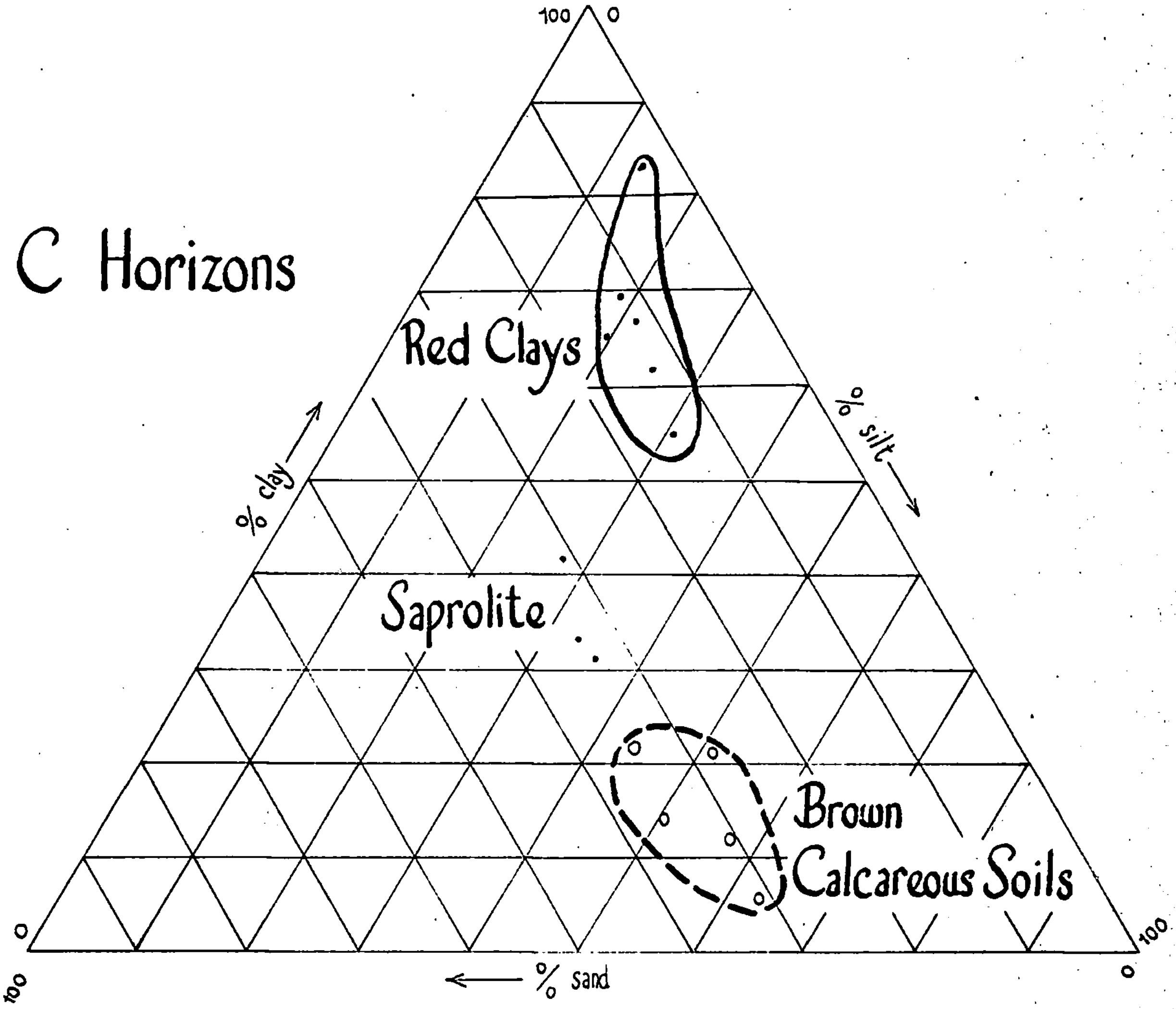
Very fine textures are an outstanding characteristic of the Red Clays. The coarsest textures are found in albic horizons under semi-natural vegetation; the two albic horizons analysed in the laboratory (profiles 1 and 2) were clay loam and silty clay, with 29•7 and 35 per cent clay respectively. Bulked samples from the top 25 cm. (the maximum depth of cultivation) were finer in texture since the argillic horizon is often close to the surface (e.g. profile 4) and may be partially incorporated in the Ap horizon - see figure 6.2.

The argillic horizons analysed contained 50 to 83 per cent clay. Compared with any overlying albic or cultivated (Ap) horizon they show absolute increases in clay content of 14 to 20 per cent. Lessivage accounts for some of the difference in clay content between the surface and argillic horizons, but surface horizons often show a significant increase in the sand fraction due to an accumulation of small residual ironstone concretions.

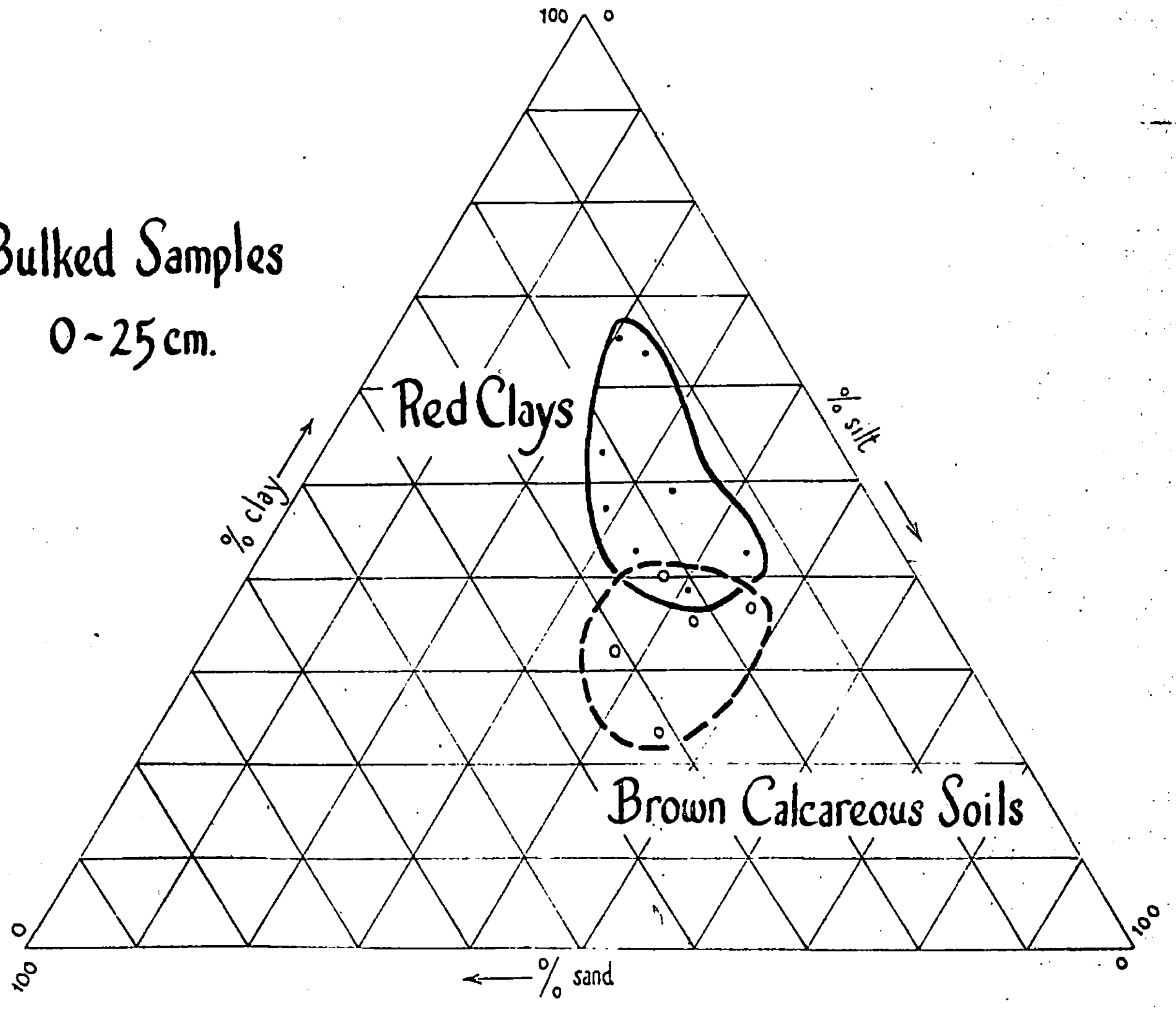
Profiles were dug to 120-150 cm., but showed little change in texture in the gleyed horizons below the argillic horizon, except where less-weathered parent material (saprolite) was encountered - as in profiles 2 and 13.

6.2 MECHANICAL ANALYSES

C Horizons



Bulked Samples
0-25 cm.



Structure

Structure is often weak in the surface horizons. Albic horizons have no macro-structure, and are loose and powdery when dry. The layer-silicate clay minerals, which are responsible for the swelling and shrinkage which generates soil structure, are disrupted, and cementing sesquioxides leached. Structure in cultivated horizons varies from weak medium crumb to small subangular blocky, according to organic content. Cultivated horizons are frequently former B horizons, rich in sesquioxides, and may break down to hard granules 1-3mm. in diameter, which are not readily dispersed. Soils abandoned after cultivation have a massive, sun-baked surface horizon.

Deeper in the profile structure is stronger. Very coarse prismatic structure develops in the B horizons due to slow, prolonged shrinkage during the summer with the formation of cracks perpendicular to the surface of drying: more rapid drying closer to the surface produces a coarse blocky structure. Individual prisms up to 60 cm. by 12 cm. may occur. In the permanently moist Cg horizons structure is poorly-developed.

Consistence

In cultivated horizons consistence, like structure, is strongly influenced by the organic content of the soil. Topsoils with a satisfactory organic content (more than 2 per cent organic carbon) may be slightly hard when dry, friable when moist, slightly sticky and slightly plastic when wet. Soils depleted of organic matter bake in summer to a hard or very hard consistence.

B and C horizons are compact, firm to very firm in the moist state, slightly sticky and plastic to very plastic when wet. In the natural state they remain moist or wet, but samples allowed to dry are hard, and material exposed in road cuttings develops a very hard, indurated crust.

Colour

Anaerobic conditions in the Cg horizon produce pale colours. Chromas of 2 or less and values of 5 or more are dominant, and a bluish hue is sometimes visible in the freshly-cut surface. The pale mass is marbled with veins of dark red, 5YR 3/3 or redder. A similar pattern may be detected in ped cores in the overlying B(g) horizon where the dominant colours are reds and reddish browns.

The strongest colours are developed in well-drained B horizons where hues are 7•5YR or redder, values 3 to 3•5, and chromas 4 to 6. Organic matter in cultivated horizons (Ap developed from B) produces slightly darker colours, still strikingly red; hence the name Red Clays. Albic horizons are pale - 10YR 6 to 6.5/2 to 3. Tongues of pale colours may penetrate the argillic horizon along ped faces to depths of 20 cm., or more.

Natural Drainage

The fine texture and close-fitting structural units of the B and C horizons impede soil drainage. All profiles examined were considered to be imperfectly to moderately well drained - class 2 or 3 - despite the annual balance of rainfall and potential transpiration, and the water-shedding tendencies of the ridge-top sites on which the Red Clays usually occur.

Colour mottling and fine soft manganese nodules indicate seasonal waterlogging in the B(g) horizons, and the pale colours of the Cg horizons indicate permanently moist conditions.

Mineralogy of the Sand Friction

The coarse sand fractions of the bottom samples (B(g) and Cg horizons) from six Red Clay profiles were examined optically. Quartz - the most resistant mineral under tropical weathering conditions - comprised the entire light fraction which made up 73 to 98 per cent of the whole coarse sand fraction.

In each sample the heavy fraction was composed mainly of ironstone

Table 6.1

Analyses of Total Silica and Sesquioxides in the Clay Fraction of Some Red Clay Soils

Profile	Horizon (sample depths in cm.)	% by weight SiO_2	% by weight Fe_2O_3	% by weight Al_2O_3	Molecular proportions SiO_2	Molecular proportions Fe_2O_3	Molecular proportions Al_2O_3	Molecular ratios $\frac{SiO_2}{R_2O_3}$	Molecular ratios $\frac{SiO_2}{Fe_2O_3}$	Molecular ratios $\frac{SiO_2}{Al_2O_3}$	Molecular ratios $\frac{Al_2O_3}{Fe_2O_3}$
5. Beştaş I Bt (g)	65 - 75	44•6	12•1	37•5	•743	•075	•368	1•68	9•93	2•02	4•91
3. Çukuçayır I Cg	100 - 110	48•7	13•1	38•1	•812	•082	•373	1•79	9•92	2•18	4•55
2. Çukuçayır II A_1	2 - 4	54•6	8•8	29•6	•909	•055	•290	2•64	16•51	3•14	5•28
A_2	14 - 16	56•9	9•2	29•6	•946	•058	•290	2•73	16•30	3•26	5•00
Bt(g)	44 - 46	49•1	12•6	36•4	•818	•079	•356	1•88	10•35	2•30	4•50
Bt(g)	72 - 74	48•4	13•4	35•9	•806	•085	•351	1•85	9•48	2•30	4•13
B/C(g)	100 - 102	49•9	13•3	35•1	•831	•083	•344	1•95	10•00	2•42	4•14
Cg	125 - 135a	48•8	13•2	33•5	•813	•082	•329	1•98	9•93	2•47	4•01
Cg	125 - 135b	50•5	11•7	33•4	•840	•073	•328	2•09	11•50	2•56	4•49

concretions. Other heavy minerals made up only a fraction of one per cent. These included the particularly resistant minerals zircon and epidote (found in all six samples), rutile (in four samples), garnet and tourmaline (in three samples), and occasional highly-weathered crystals of apatite, augite, biotite, hornblende and muscovite.

Mineralogy of the Clay Fraction

Analyses of total silica and sesquioxides were carried out on clay (< 1•6μ) samples from successive horizons of profile 2, in which the original rock structure was most evident in the lower part of the profile; and on the deepest samples from profiles 3 and 5, in which the original rock structure was less obvious in the field (Table 6.1). The silica:sesquioxide ratios of samples from profiles 3 and 5 were 1•79 and 1•68 respectively, an indication of a very high degree of weathering. The lowest ratios in profile 2 (1•88 to 1•85) are in the B(g) horizon; ratios rise to about 2 in the lower horizons in which the original rock structure is well preserved, though pseudomorphically replaced by clay minerals.

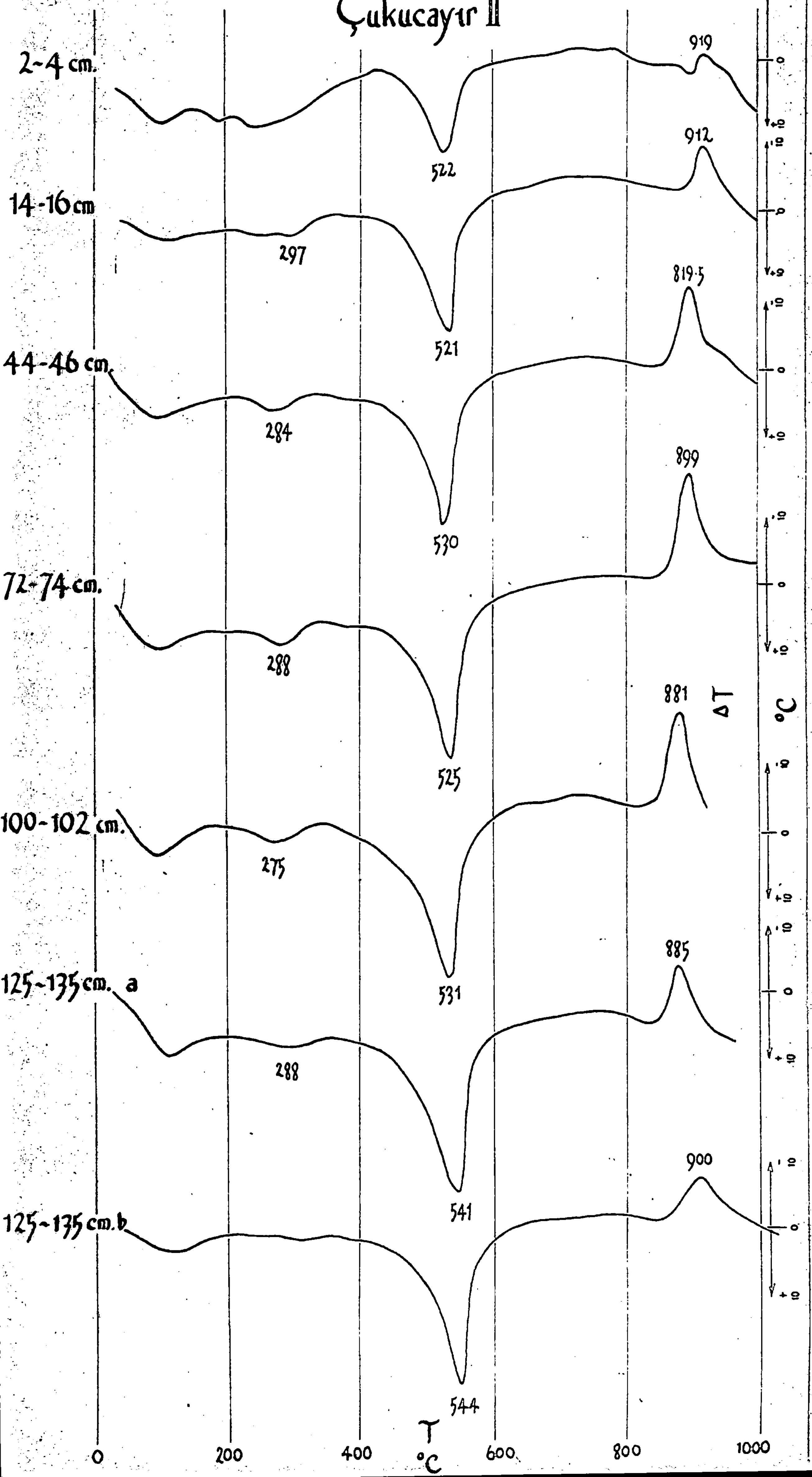
Further investigations on these profiles were carried out using differential thermal analysis and X-ray diffraction techniques.

Kaolin Minerals

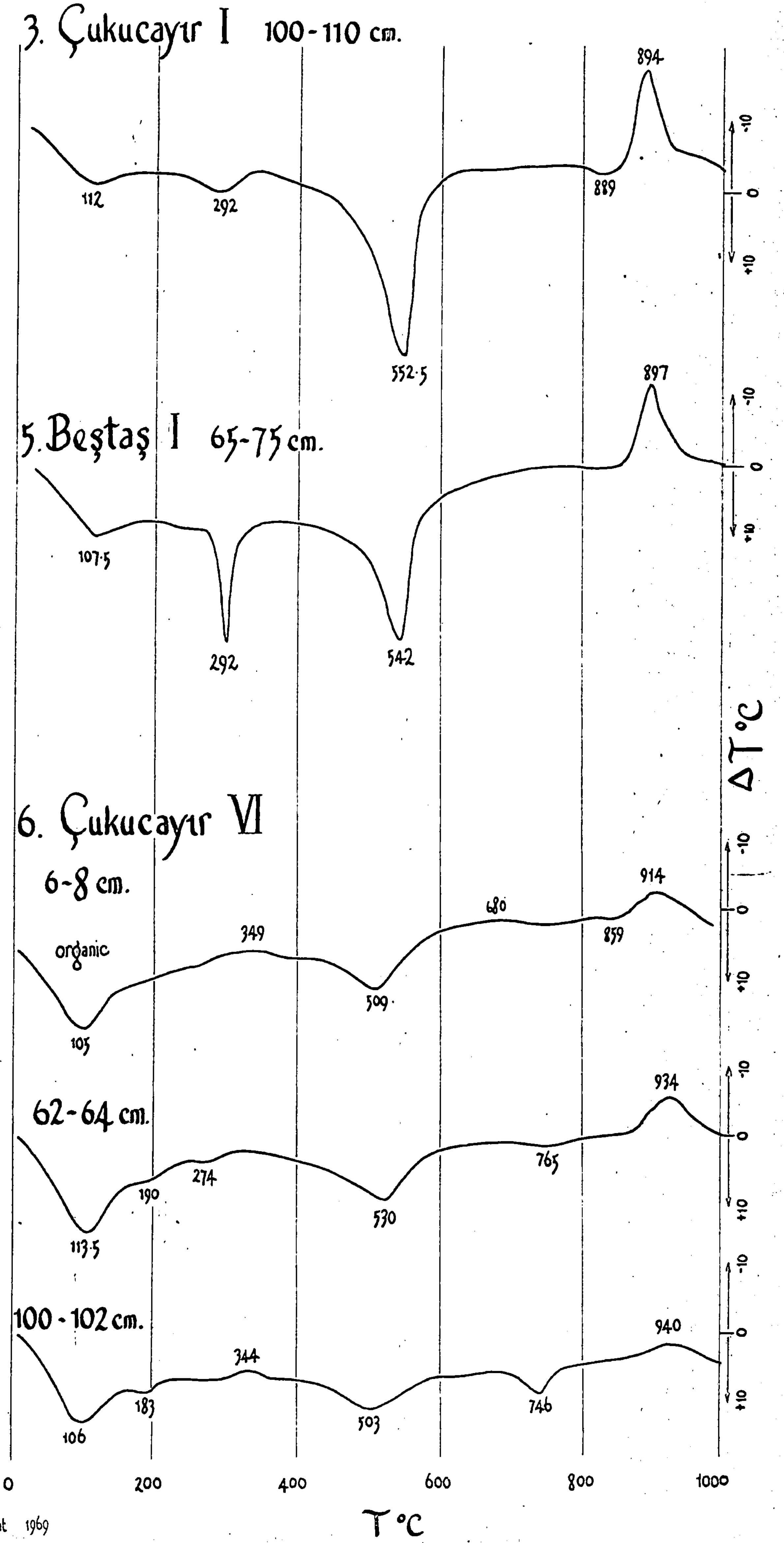
In each profile the predominant mineral is of the kaolin type, giving characteristic endothermic peaks between 520 and 552•5°C. and exothermic peaks in the range 912 to 918•6°C (figures 6.3 and 6.4). In addition to normal kaolinite, the presence of an unusual variant with a somewhat larger spacing is indicated by the X-ray diffraction data (figures 6.5 and 6.6). Profile 5 contains b-axis disordered kaolinite with a spacing of 7•15 Å; samples from profile 3 give a major peak at 7•35 Å with a suggestion of a secondary peak at 7•15 Å. In both profiles the 020 peak is normal at 4•46 Å, its asymmetry indicating b-axis disorder. The two 001 peaks are exhibited simultaneously in profile 2; the 7•15 Å peak is stronger in the upper horizons, the 7•35 Å peak is stronger lower in the profile. Again

6.3 Differential Thermal Curves

Çukucayır II



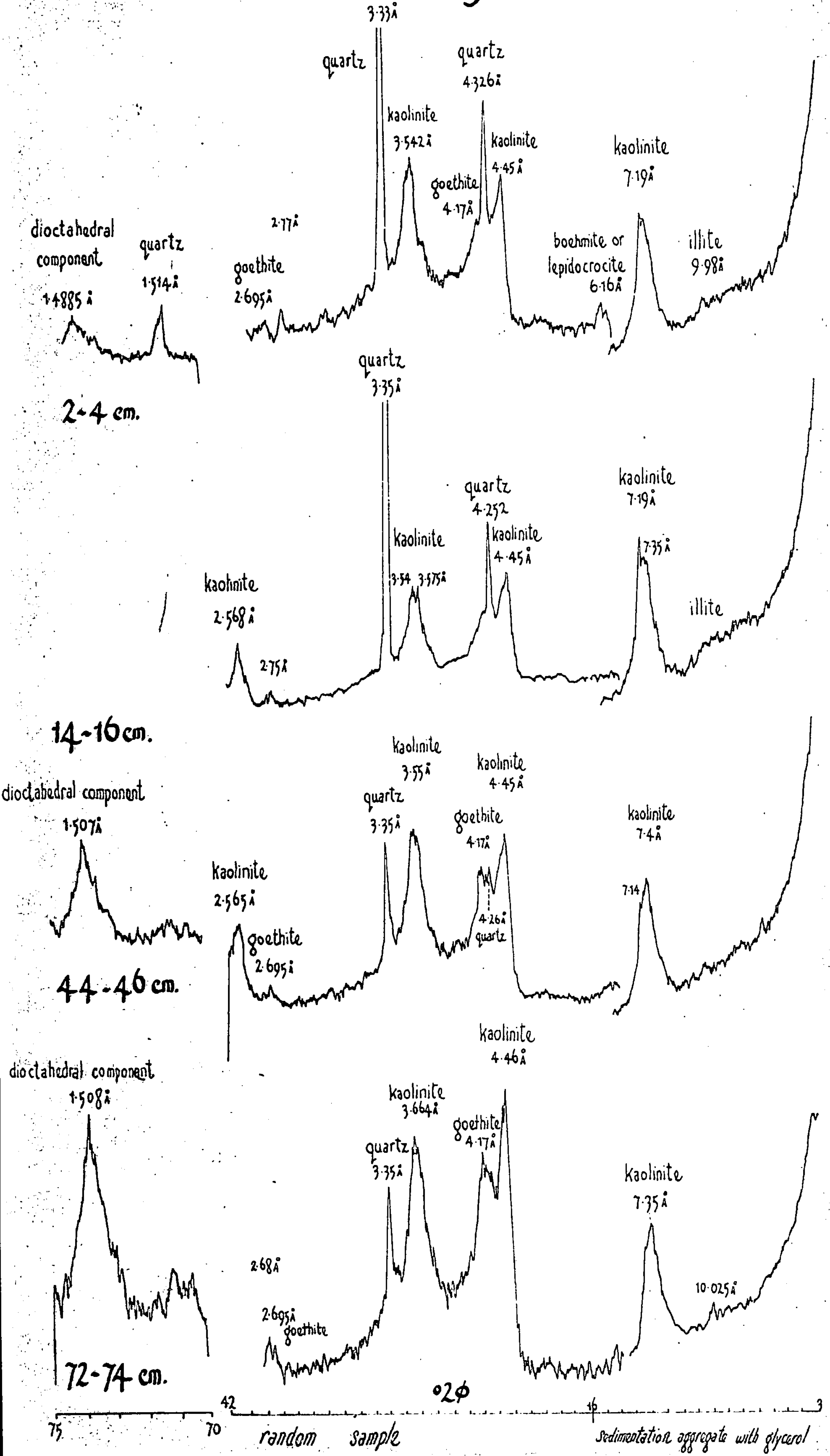
6.4 Differential Thermal Curves



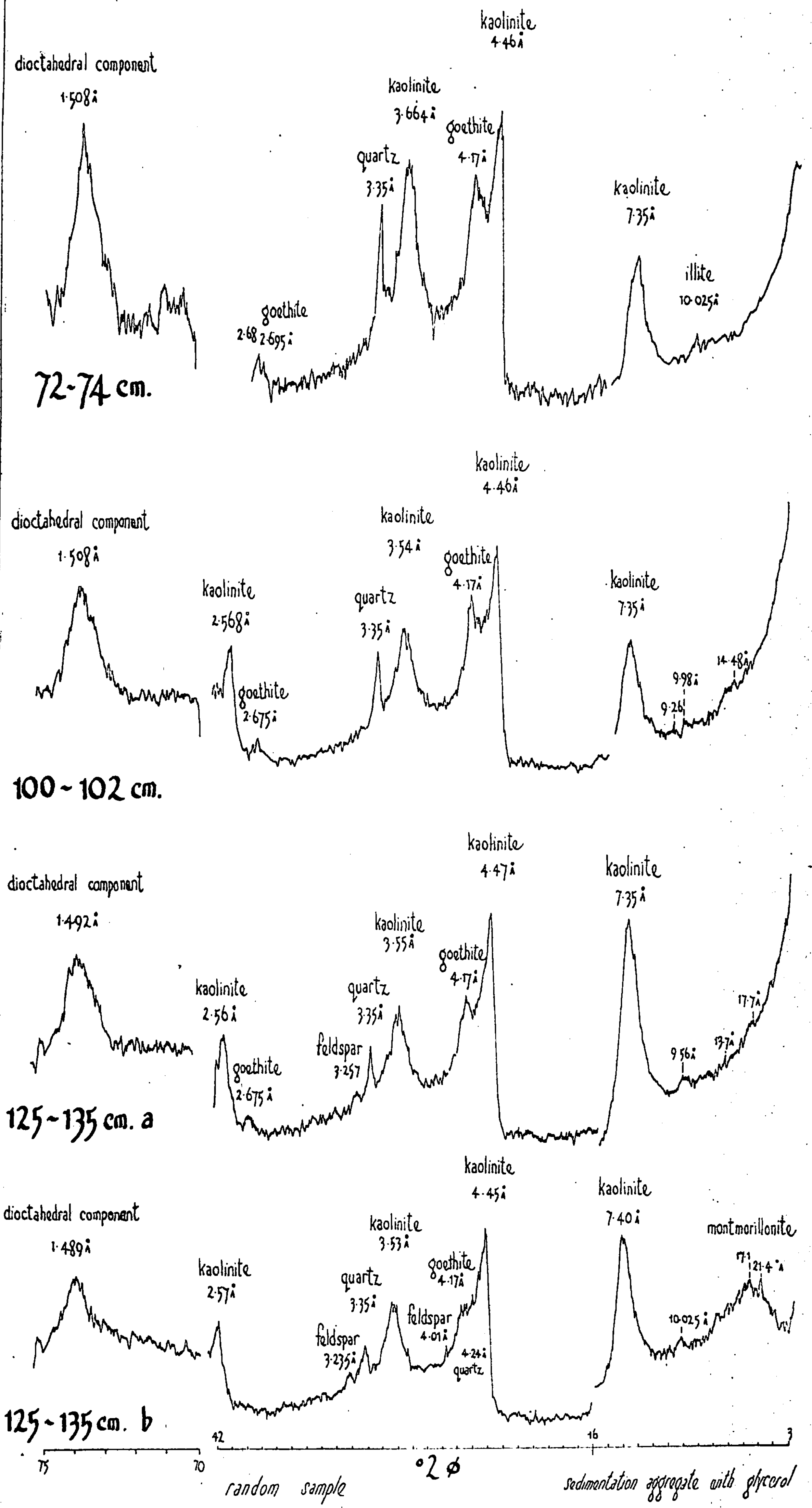
David Dent 1969

facing page 54

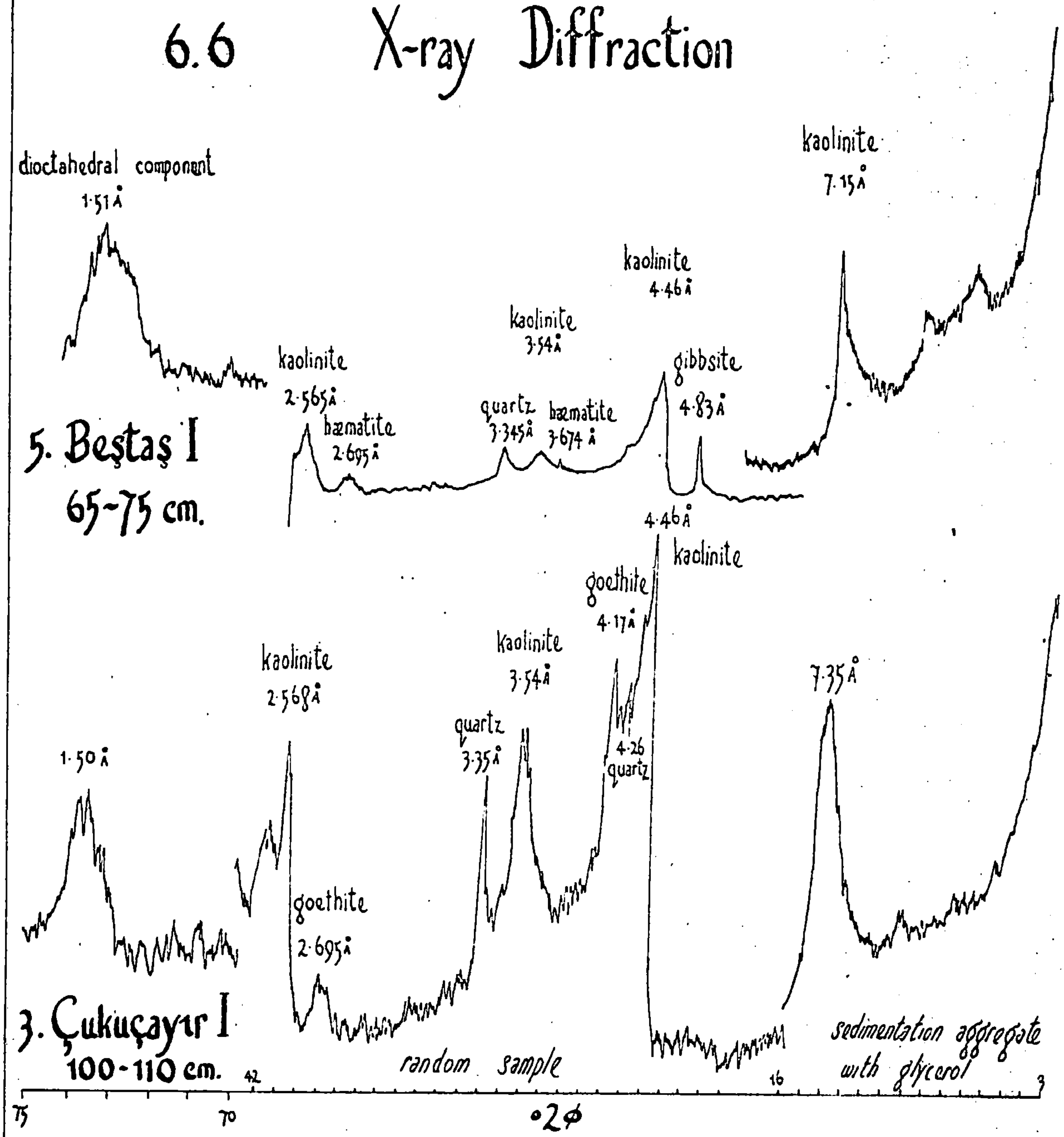
6.5 X-ray Diffraction
2. Çukuçayır II



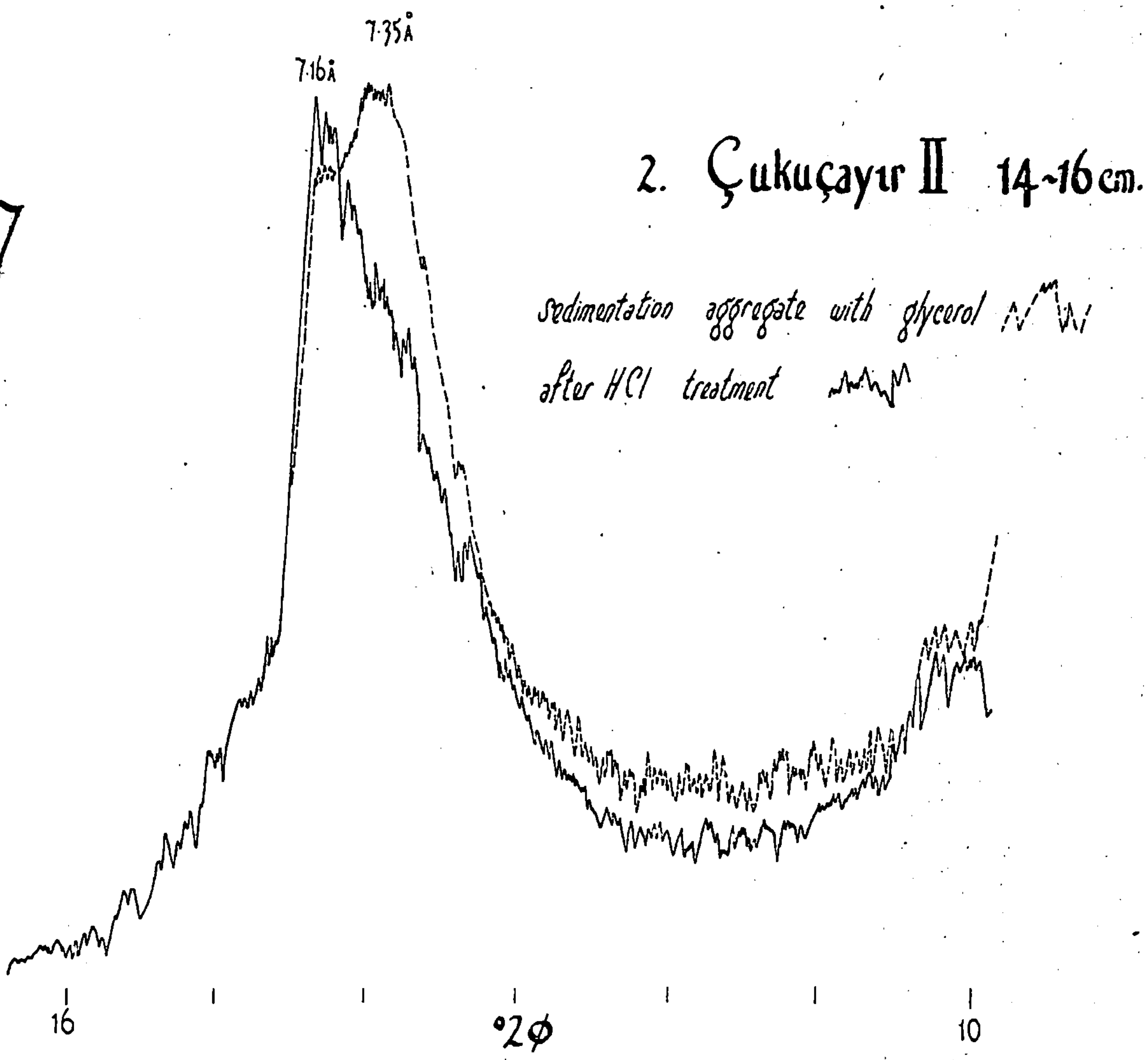
2. Çukuçayır II



6.6 X-ray Diffraction



6.7



there are asymmetrical 020 peaks at 4•46Å, and further peaks at 3•54Å, and at about 1•47Å - the 060 dioctahedral peak.

Electron microscope examination of the samples from the Bt(g) horizon of profile 2 revealed the normal platy kaolinite morphology, but no evidence of halloysite, which is generally tubular. However, the infra-red spectrum of these samples is reminiscent of halloysite. To distinguish between the 7•35Å kaolinite and the halloysite minerals, which have similar X-ray diffraction patterns, Wada's intercalation technique (43) was used. The potassium acetate complex of both kaolinite and halloysite gives a diffraction at 14Å. After washing with water this complex is destroyed in both cases, but if the washed samples are not dried below a relative humidity of 60 per cent halloysite will give a hydrated spacing of 10Å, whilst kaolinite reverts to 7•15Å. When samples from the lower horizons of profile 2 were intercalated with potassium acetate they gave a diffraction at 14Å, which disappeared on washing. The hydrated complex gave no coherent basal spacing.

A clay sample from profile 2, 14-16 cm., which gave distinct peaks at 7•14Å and 7•35Å, was boiled for ten minutes in 1N. hydrochloric acid and again examined with the diffractometer. The 7•35Å peak disappeared leaving a clearly-defined normal kaolinite peak at 7•14Å - figure 6.7. Ready solubility in dilute acid is an unusual characteristic for a kaolin mineral.

Profile 5, Beştaş I

In the Bt(g) horizon of profile 5 kaolinite is associated with gibbsite (an indicator of an advanced stage of humid tropical weathering), quartz, haematite, and small amounts of illite and chlorite or a mixed layer mineral - figure 6.6. Approximate quantitative results from measurement of peak areas on the D.T.A. trace, give proportions of 39 per cent kaolinite and 6 per cent gibbsite.

Profile 3, Çukuçayir I

The two varieties of kaolin are present in the Cg horizon of profile 3 (together comprising about 53 per cent of the clay fraction), with quartz, goethite (approximately 16 per cent) and small amounts of illite, montmorillonite, and vermiculite or chlorite - figure 6.6.

Profile 2, Çukuçayir II

Analyses of profile 2 - figures 6.3 and 6.5 - reveal important differences between successive horizons. In the A horizons (samples from 2-4 and 14-16 cm.) the largest 001 kaolinite peak is at 7•14Å, with a secondary peak at 7•35Å. Diffuse peaks on the D.T.A. traces, particularly the exothermic kaolinite-mullite peak at 912°C. to 918•6°C., indicate a poorly crystalline mineral. This may be attributed to a disruption of the crystal structure during the present cycle of soil formation. Quartz and small amounts of illite and goethite are present, and in the 2-4 cm. sample bohemite or lepidocrocite.

Lower in the profile the 7•35Å variety of kaolin becomes the dominant mineral, associated with normal 7•19Å kaolinite, quartz and goethite. The deepest samples contain 7•35Å kaolin, associated with quartz, goethite and increasing amounts of feldspars, illite, montmorillonite and mixed layer minerals which indicate a lesser degree of weathering.

Estimations of the kaolin minerals and goethite in profile 2 from their D.T.A. peak areas are given in table 6.2 below.

Table 6.2 Proportions of Kaolin Minerals and Goethite in the Clay Fraction (< 1·6μ) of Red Clay Profile 2

Sample	% Kaolin Minerals	% Goethite
2-4 cm	21	-
14-16	33	5
44-46	36	12
72-74	33	12
100-102	57	18
125-135a	43	12
125-135b	41	6

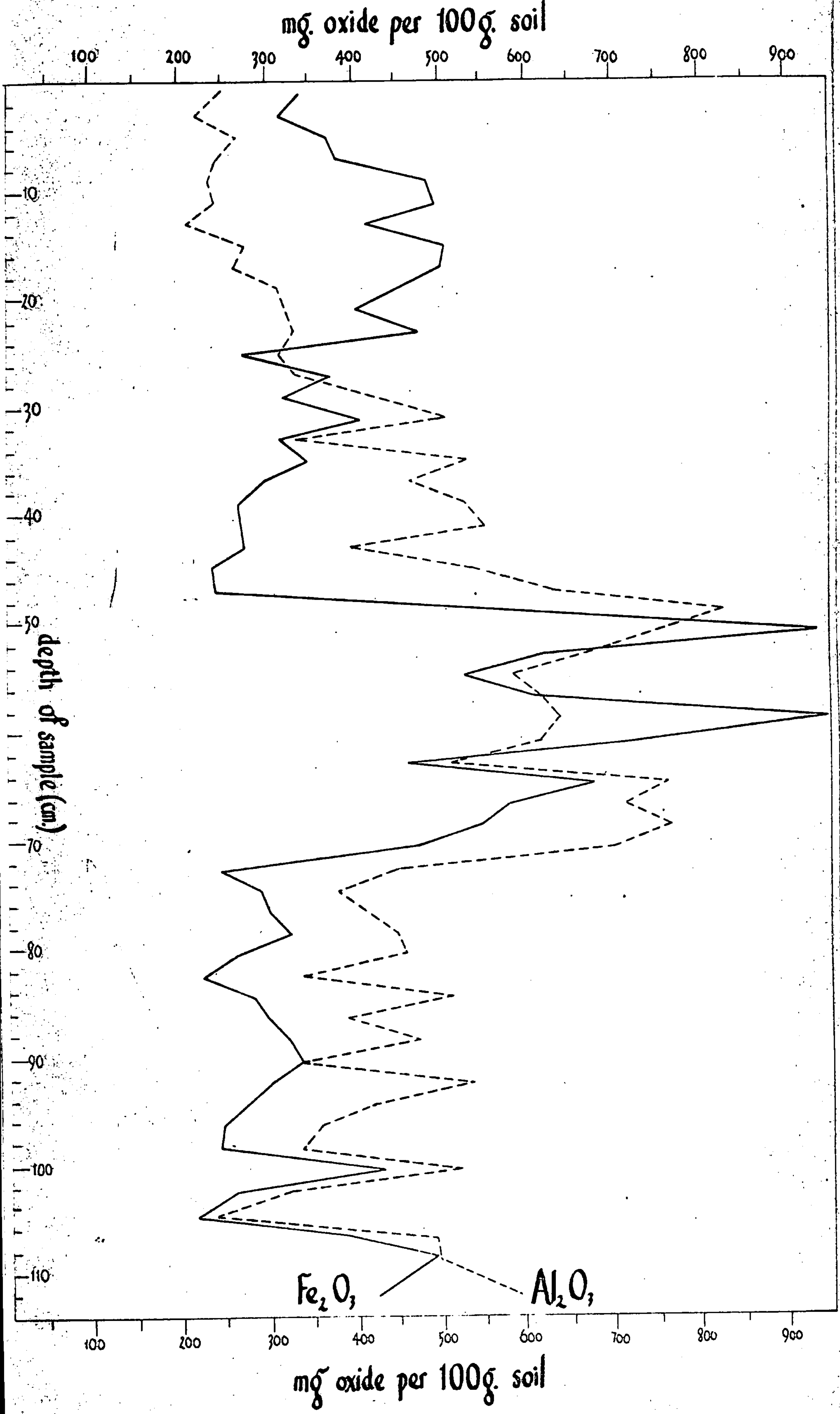
Amorphous Minerals

Although they comprise only a small fraction of most soils, particularly those which are highly-weathered, amorphous materials exert a large effect on soil properties because of their mobility within the profile and their great chemical activity which is derived from their enormous surface area. Amorphous inorganic materials in soils include silica, iron, aluminium and manganese oxides and hydroxides, and amorphous clay minerals known generally as "allophane" (44). There is no clear boundary between the crystalline and amorphous states: in this study Tamm's acid oxalate extractant has been used to make an arbitrary separation between the "amorphous" and "crystalline" fractions.

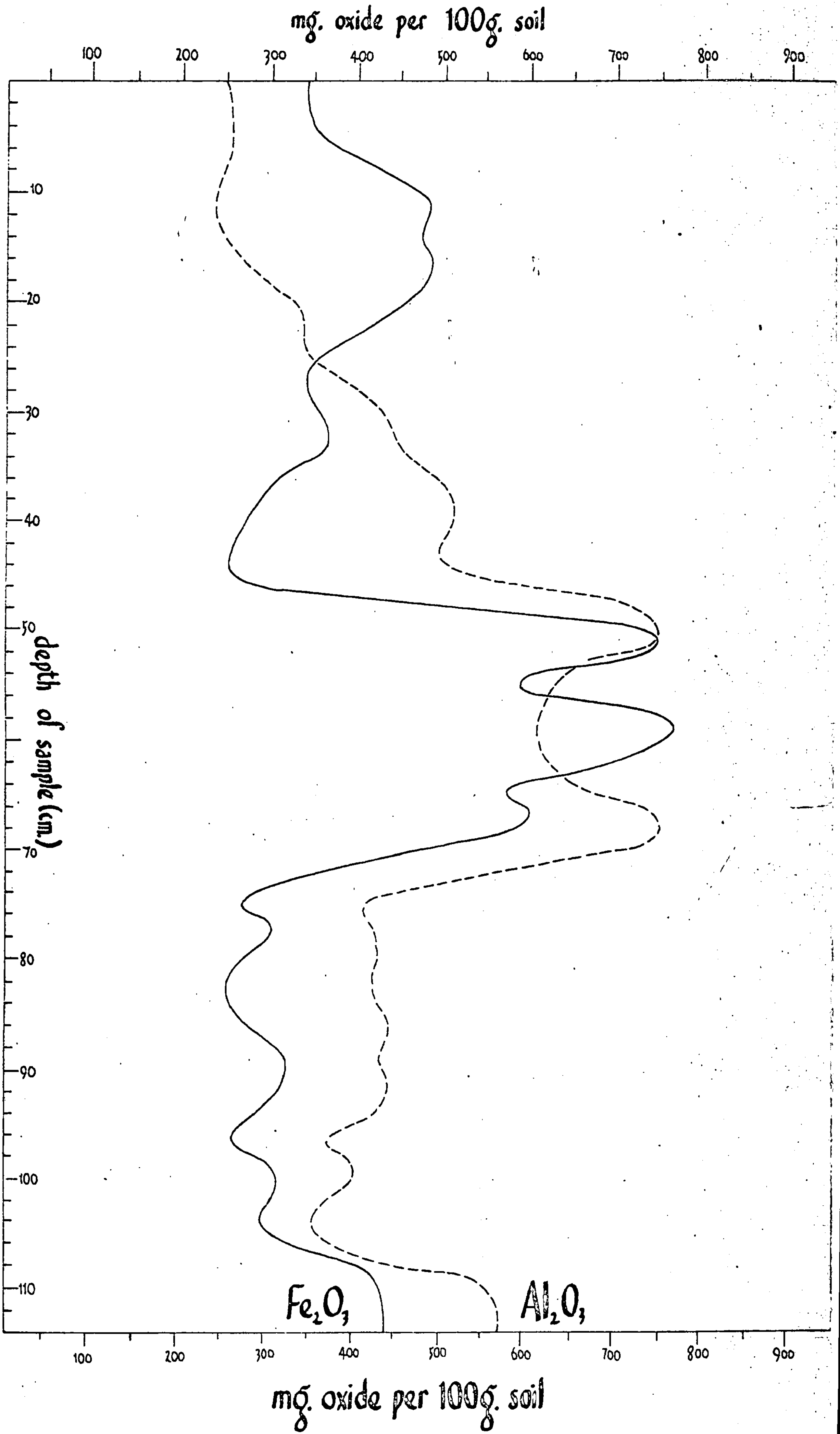
In general, the Red Clays show an accumulation of organically-bound, acid oxalate-extractable sesquioxides in the A_1 horizons. The lowest values are found in the albic (A_2) horizons, and there is a relative accumulation of sesquioxides in the argillic and gleyed horizons. Aluminium (estimated as Al_2O_3) is in excess of iron (estimated as Fe_2O_3) by from 10 to 100 per cent by weight.

A detailed analysis of profile 2 reveals a general similarity, but differences in detail, between the behaviour of extractable iron and aluminium - figures 6.8a and b. The salient features are the

6.8 Acid Oxalate Extractable Iron and Aluminium Çukuçayır II



6.8 Acid Oxalate Extractable Iron and Aluminium
Çukuçayır II



accumulation of sesquioxides between 46 and 72 cm. and the considerable variation between adjacent samples. Iron shows a minor, probably organically-bound, accumulation between 4 and 24 cm., and a dramatic increase between 46 and 50 cm. Aluminium rises more gradually from a minimum at the surface to the zone of maximum accumulation which coincides with the maximum iron accumulation. There is a third zone of sesquioxide accumulation below 106 cm. The concordance of maximum iron and aluminium accumulation suggests precipitation at a water table. (In freely-drained podsols iron is usually deposited higher in the profile than aluminium).

Soluble silica and manganese were not estimated quantitatively, but colloidal silica was precipitated from the extracts of all samples below 48 cm., increasing with depth to extremely large amounts below 100 cm. Extractable manganese, observed as a transient purple colour in the extract, was present in all deep, gleyed horizons.

Induration

The accumulation of sesquioxides in the B horizon does not lead to cementation in the natural soil: the high clay content of the soil presents an enormous surface area which can absorb the mobile iron like a "pigment", producing a powder of low cohesion. However, surface induration is observed on soils abandoned after cultivation. Following cultivation the sesquioxide-rich B horizon is exposed at the surface; mobilisation of iron at the surface is at a maximum in winter and spring when the soil is wet and biological activity is high; dehydration and high surface soil temperatures in summer lead to intense immobilisation of iron. This seasonal alternation of solution and immobilisation of iron may produce an indurated crust, which impedes recolonisation of the soil by forest and is only slowly disrupted once the forest is re-established - see profile 3.

The Organic Fraction

The highest organic contents were found in the surface horizons of forest soils, with 9·3 per cent carbon (Walkley and Black) in the shallow A_1 horizon of profile 1. The cultivated horizons examined contained up to 2·5 per cent carbon. Carbon contents decreased rapidly to 0·6-0·9 per cent in Bt horizons, and less than 0·2 per cent in B(g) and Cg horizons.

Carbon:nitrogen ratios of 10 to 14·2 were found in the A horizons of forest soils; in cultivated (Ap) horizons ratios were between 8·2 and 10·2. In every Red Clay profile analysed C:N ratios decreased with depth, generally to between 3 and 6 sometimes even to less than 1, and in some cases there was an absolute increase in nitrogen content in the B(g) and C horizons (e.g. profile 2). This accumulation of nitrogen is due, almost certainly, to the absorption of $(NH_4)^+$ by the clay minerals following the ammonification of organic matter under anaerobic conditions. All samples with very low C:N ratios freely emitted ammonia when warmed with concentrated sodium hydroxide solution.

Cation Exchange Capacity and Exchangeable Bases

Cation exchange capacity (C.E.C.) is a property of the colloidal fraction of the soil - the organic matter and clay minerals. Soil organic matter has a particularly high C.E.C., with values in excess of 200 milli-equivalents per 100g. Of the clay minerals, vermiculite and montmorillonite are the most reactive with C.E.C.s of 80 to 180m. equiv. per 100g., and kaolinite the least reactive with C.E.C.s of 3 to 15m. equiv. per 100 g.

Because of the problem of absorbed ammonium ions, the C.E.C. and the individual cations were estimated separately. C.E.C. was determined using Bower's method:- saturating the samples with Na^+ at pH 8·2, then leaching with neutral N. ammonium acetate solution followed by photometric determination of Na^+ in the leachate to give total C.E.C.

Ca^{++}, Mg^{++}, K^+ and Na^+ were also determined by a straightforward leaching of soil samples with neutral N. ammonium acetate, followed by spectrographic determination of the individual cations in the leachate; and H^+ was determined by leaching with N. barium acetate and electrometric titration of the leachate.

The trend of C.E.C. in the semi-natural profile is shown in figures 6.9a and b. The highest values are at the surface, due to the high organic content of the A_1 horizon, dropping steadily to a minimum in the albic (A_2) horizon between 14 and 26 cm. The gradual increase in C.E.C. to a second maximum at 48 cm. is an expression of the increase in clay content from about 30 per cent in the albic horizon to about 55 per cent in the argillic horizon. In this profile C.E.C. remains at a relatively high value although total clay content decreases with depth. The C.E.C. is maintained by a change in the type of clay mineral in the saprolite horizon, kaolinite being succeeded by the more active 7·35Å kaolin and small amounts of illite, montmorillonite and mixed layer minerals of high C.E.C.

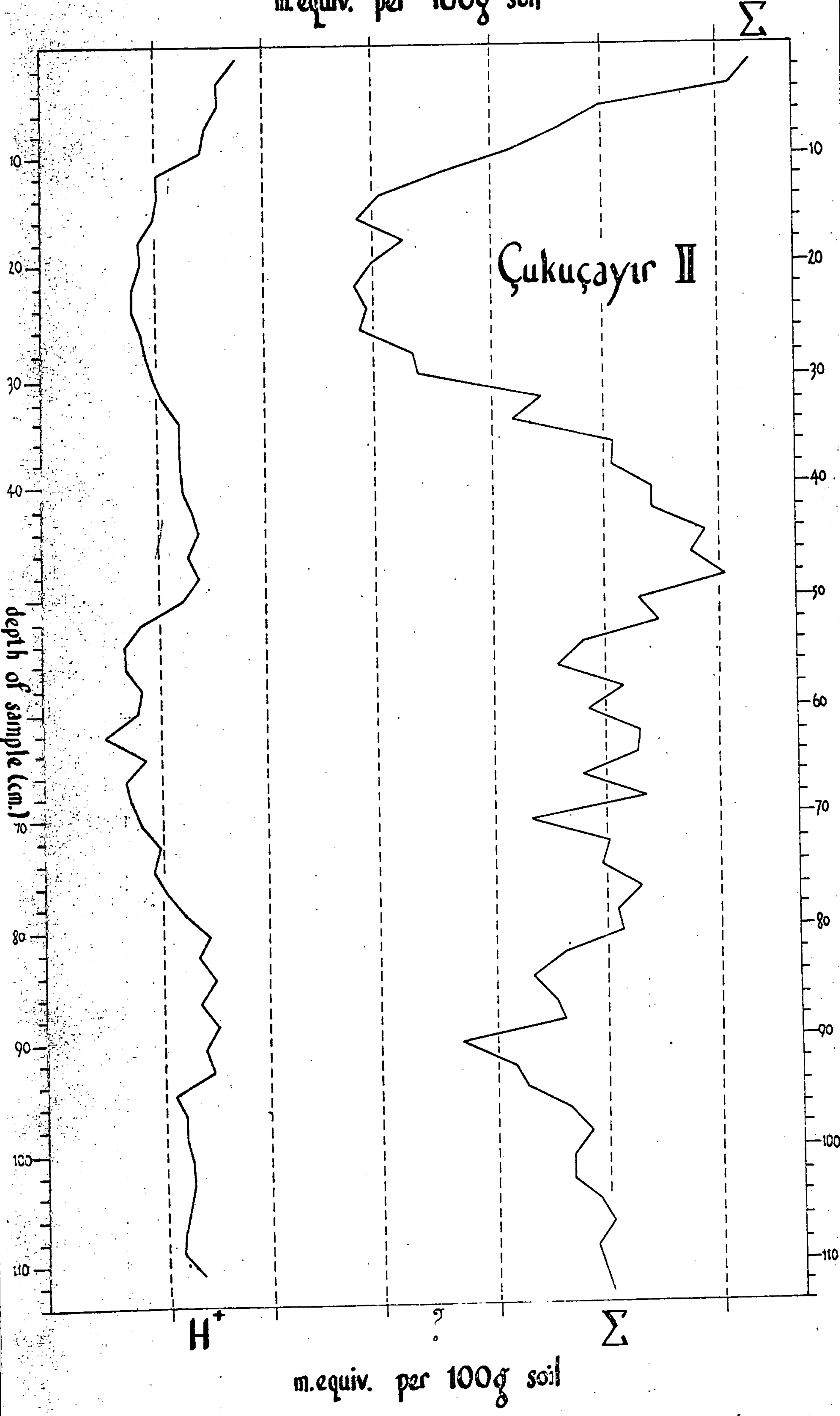
Table 6.3 summarises the determination of C.E.C. carried out on seven Red Clay profiles. Although the values for the various horizons overlap, the trend in each individual profile is for maximum values in the Bt and B(g), and when saprolite is not encountered, values in the C horizons are lower than in the B.

Table 6.3 Cation Exchange Capacity in the Red Clays

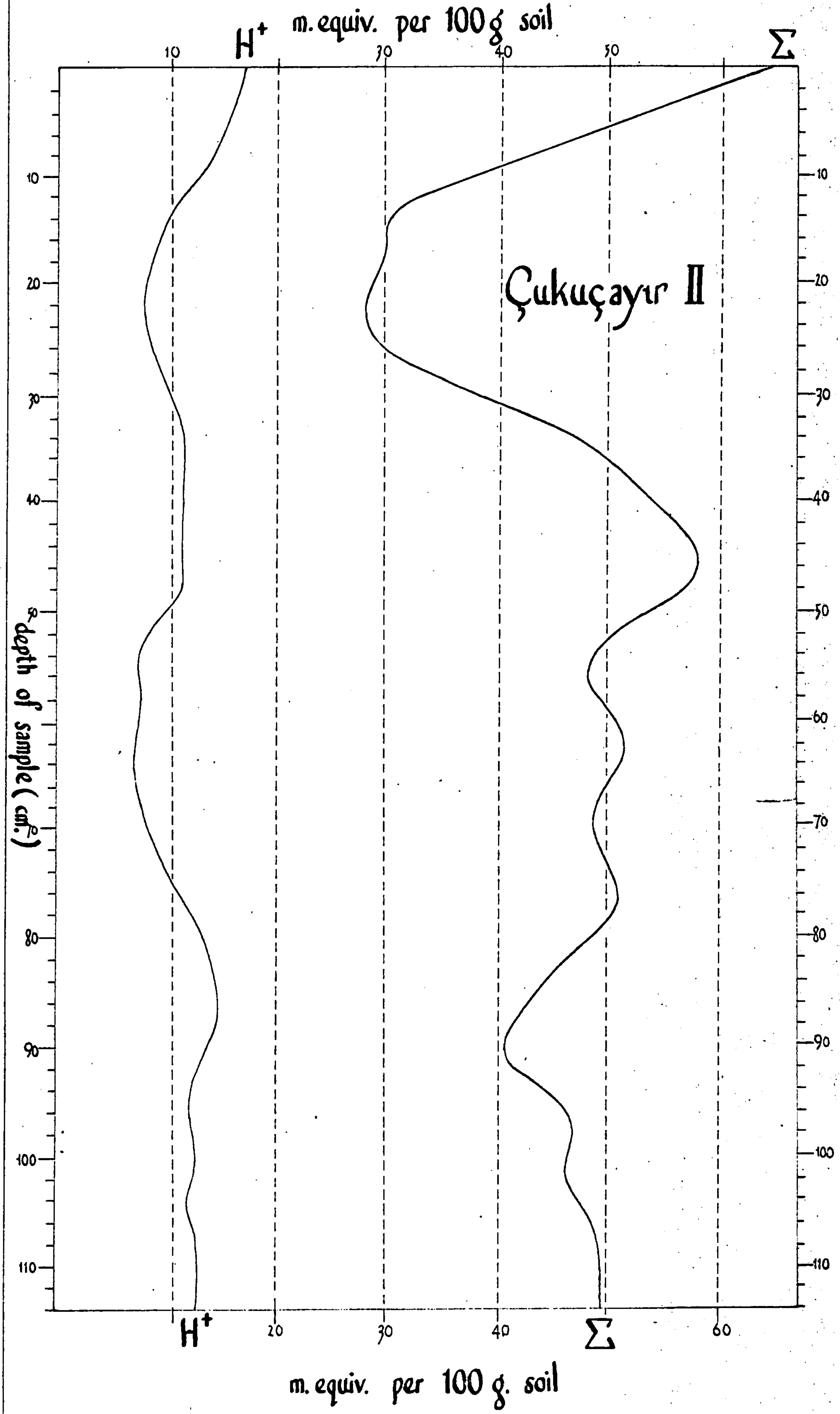
Horizon	Range of C.E.C. (m.equiv.per 100g. soil)
Ap	39-55
A_1	52-59
A_2	22-45
Bt	34-72
B(g)	34-63
Cg	29-63

6.9a Cation Exchange Capacity (Σ)
Exchangeable Hydrogen (H^+)

m.equiv. per 100g soil



6.9b Cation Exchange Capacity (Σ)
Exchangeable Hydrogen (H^+)



Exchangeable Bases

$(NH_4)^+$ was not determined directly, but in some gleyed horizons it may be the dominant cation, e.g. profile 5. Of the cations determined in the neutral N. ammonium acetate leachate, Ca^{++} is dominant, closely approached and occasionally exceeded by Mg^{++}, particularly in saprolite horizons where the influence of the ferro-magnesian parent material is strongest. The highest Ca:Mg ratios (3·5 to 4·4) are found in highly-weathered B(g) and Cg horizons.

Base Saturation

Because of the presence of large amounts of adsorbed $(NH_4)^+$ which is not usually encountered, at least in temperate soils, base saturation has been calculated as

a) $$\frac{(C.E.C. - H^+)}{C.E.C.} \times \frac{100}{1}$$

b) $$\frac{(Ca^{++} + Mg^{++} K^+ + Na^+)}{C.E.C.} \times \frac{100}{1}$$

Saturation of the exchange complex by Ca^{++}, Mg^{++}, K^+ and Na^+ is at a maximum in the thin forest A_1 horizons, drops sharply to a minimum in the A_2 horizons, and rises again in the B and C horizons - especially in saprolite horizons which contain some weatherable primary minerals. Base saturation in cultivated horizons is variable, depending on manurial treatment. Table 6.4 summarises determinations carried out on seven Red Clay profiles, and emphasises that the degree of base saturation depends very much on the method of calculation.

Table 6.4 Range of Base Saturation in the Red Clays

Horizon	$\frac{(C.E.C.-H^+)}{C.E.C.} \times 100$	$\frac{Ca + Mg + K + Na}{C.E.C.} \times 100$
Ap	77 - 87	32 - 42
A_1	64 - 83	37 - 79
A_2	63 - 78	14 - 36
Bt	65 - 92	20 - 41
B(g)	66 - 87	26 - 50
Cg	76 - 94	26 - 79

pH

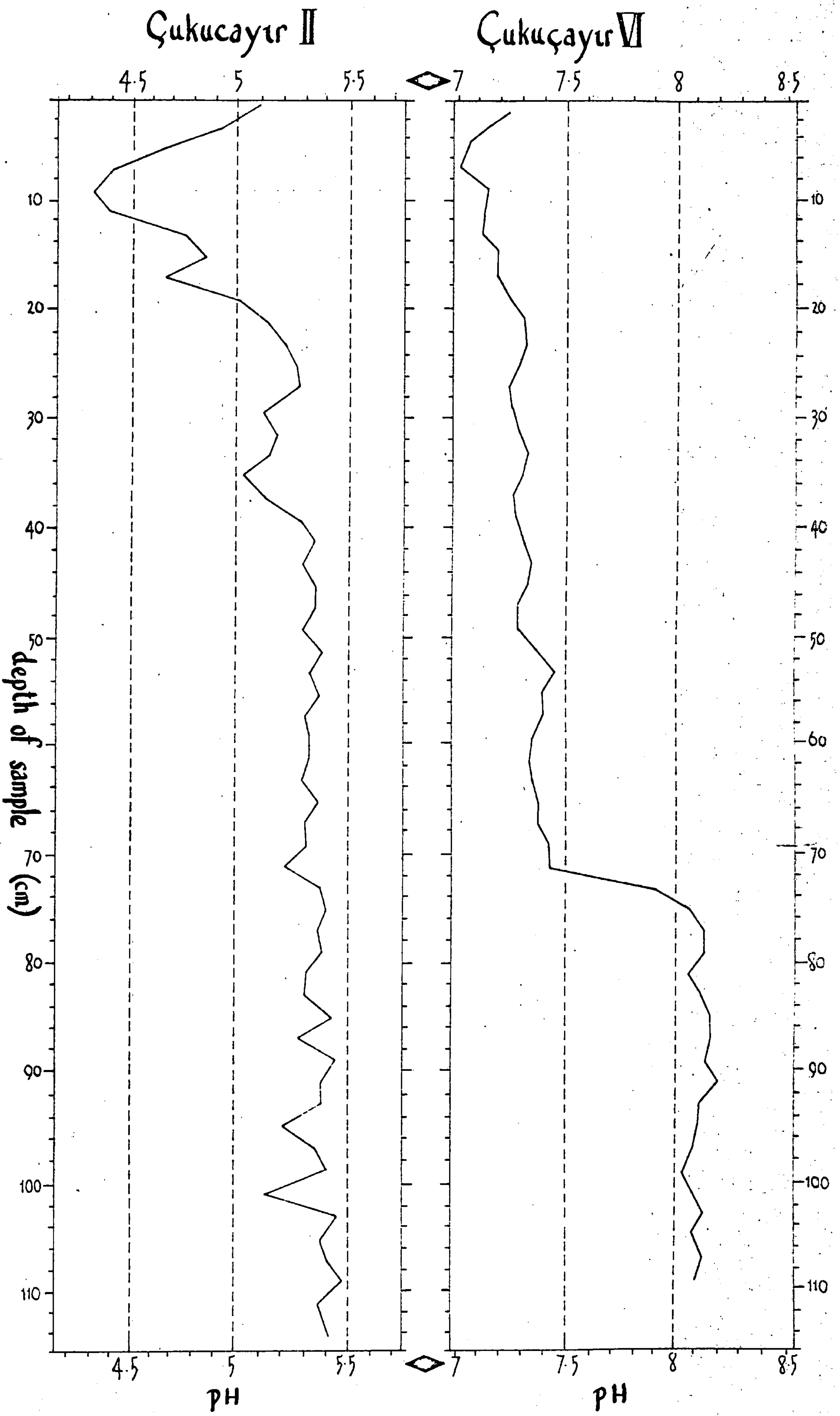
pH was determined in a 1:2•5 soil-water suspension. Figure 6.10 shows the trend of pH in a semi-natural profile. Values are high in the A_1 horizon, drop to a minimum in the A_2, and rise again in the B, thereafter remaining remarkably constant with depth. Comparable trends were found in the other Red Clay profiles, and there was remarkably little variation in pH in the group as a whole. However, significant micro-variations from point to point within any individual horizon are masked in relatively large bulk samples. In particular, where an albic horizon is invading an argillic horizon (profiles 1 and 2), the ped faces are distinctly more acid than the ped cores.

The pH of cultivated horizons in the Red Clays varied from 4•8 to 5•5; and pH in B and C horizons from 4•7 to 5•8.

Phosphorus

Total phosphorus was generally low (between 2•5 and 25 mgm. per 100g. soil except in profile 12), and phosphorus available as a plant nutrient was extremely low and confined to the humus fraction of forest and cultivated soils. A critical factor in phosphate nutrition in the Red Clays is almost certainly immobilisation of phosphorus by aluminium and iron. However, in the long-husbanded

6.10 pH in water



"plaggenboden", application of animal manure (especially fish) over a long period has raised total and available phosphorus to higher levels. In profile 12 the total phosphorus content is between 55 and 80 mgm. per 100g. soil to a depth of 70 cm.

Chapter 7

THE BROWN CALCAREOUS SOILS

The Brown Calcareous Soils occur on geomorphologically younger surfaces than the Red Clays. They are most often encountered on the shoulders on the ridges, on plane to convex slopes of 10^{o} to $22{\cdot}5^{o}$, and occasionally on ridge tops which have been stripped of red weathered material, leaving a residual capping of relatively little-weathered Pliocene molasse overlying the volcanic basement rocks. In the latter case slopes may be as little as 5^{o}. The Brown Calcareous Soils range in elevation between 60m. and 350m.

In contrast with the Red Clays they are youthful soils and not highly weathered. A secondary carbonate horizon may be present at depths up to 80 cm. below the surface, but although this horizon is often thick it is insufficiently enriched in carbonate to qualify as a Calcic horizon as defined in the 7th Approximation (40a).[1] The boundary between the two soil groups is sharp and often occurs over a few yards at a break in slope. South of Boztepe, acid Red Clay soils with well-developed albic horizons occur within 400m. of Brown Calcareous soils which have well-developed secondary carbonate horizons: this transition occurs within an altitudinal range of about 50m. At their lower extent the Brown Calcareous soils are abruptly cut off by the intersecting gorges which are cut into the volcanic basement rocks.

MORPHOLOGY

Profile 6 represents the nuclear concept of the Brown Calcareous Soils. The principal horizons present are as follows:-

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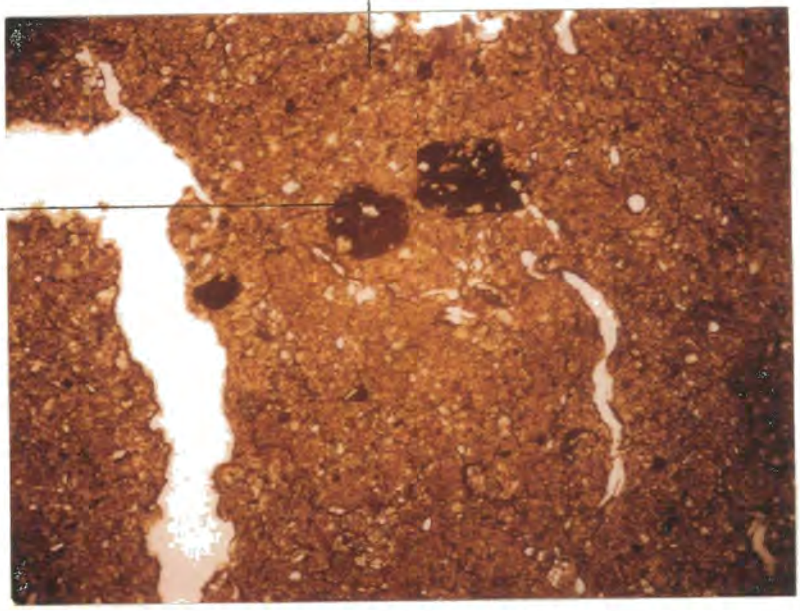
[1] As defined in the 7th Approximation a calcic horizon has 15 per cent $CaCO_3$ equivalent.

Horizon number in profile description

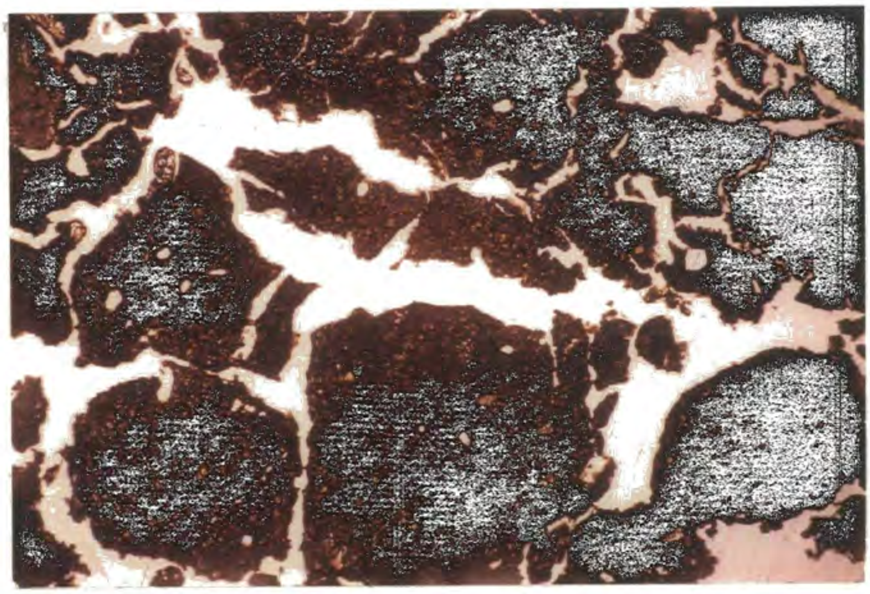
2	A dark yellowish brown cultivated (Ap) horizon of heavy texture, with common fine soft iron nodules; sticky when wet and shrinking to hard, blocky to prismatic peds on drying. (In summer the soil cracks to about 60 cm.). This horizon conforms to the definition of an ochric epipedon in the 7th Approximation (40a).
3,4	A cambic (B) horizon, yellowish brown in colour with common fine rusty mottles. The degree of weathering decreases gradually with depth and carbonate content increases.
5	A calcareous horizon (Cca) with pseudomycelia-like deposits of secondary carbonate on the ped faces and nodules of calcium carbonate within the peds.
6	Compact, light olive brown parent material (C); silt loam texture with occasional, rounded, weathered lava stones. It has a characteristic polyhedral structure, with fine manganese-iron cutans on the ped faces, and the entire mass is intersected by wafer-like iron pans (disrupted fragments of similar pans do in fact occur throughout the profile).

Various degrees of accelerated (soil) erosion are characteristic of these soils (see profiles 7 and 8). In extreme cases the Ap horizon is simply the cultivated limey parent material. On steep slopes abutting the gorges and on denuded ridge tops, the volcanic basement rock is encountered at shallow depth (profile 9).



24 **Ochric Horizon, profile 6 8-13 cm. x 8**

Dense fabric with iron concretions and hairline manganese deposition.
Puddled structure with random, irregular voids.



25 **Cambic Horizon, profile 6 45-50 cm. x 8**

Strong blocky structure.

photographs by L. Robertson and D.L. Dent

MICROMORPHOLOGY

Ochric Horizon (Ap)

Profile 6, 8-13•5 cm. - photograph 24

A dense fabric with few irregular un-oriented pores and a random distribution of occasional angular to sub-rounded fresh grit. Primary peds[1] 6-15 mm. across. (A puddled structure due to a loss of organic matter and the swelling properties of the clay fraction which shows slight wavy pressure orientation in polarised light).

The background colour in reflected light is 7•5YR to 10YR 5/4, with lighter colours - 10YR 6/4 - on ped faces. Throughout the matrix there is a blotchy iron staining which is made up by ovoid to spherical iron concentrations, about 50μ in diameter, merging diffusely with the matrix. There is also a honeycomb distribution of very fine manganese deposition, which is more clearly seen in the lower horizons.

Contrasting with the matrix are sharply-defined irregularly-rounded iron concretions, varying in size from 15μ to 1•5 mm., and varying in the intensity of iron deposition; they have probably been formed in situ. Sharply-defined irregular manganese concretions, up to 100μ in diameter, are also common; these too were probably formed in situ. There are occasional scattered fragments of laminated iron pan up to 1 mm. thick, and traces of secondary carbonate deposition on void walls.

There are numerous siliceous phytoliths in voids and in the soil matrix, rare earthworm burrows and faecal pellets and a little fresh root material.

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[1] The simplest natural unit of organisation within the soil body, separated from adjoining peds by natural voids.

Cambric Horizon (B)

Profile 6, 26-32 cm.

A more clearly-defined microstructure is exhibited than in the cultivated horizon; primary peds are 4-6 mm. across but some larger lumps of welded fabric are found. There is a random distribution of angular to sub-rounded grit up to 4mm. diameter, and weak clay orientation on ped faces and around grit particles, roots and earthworm burrows.

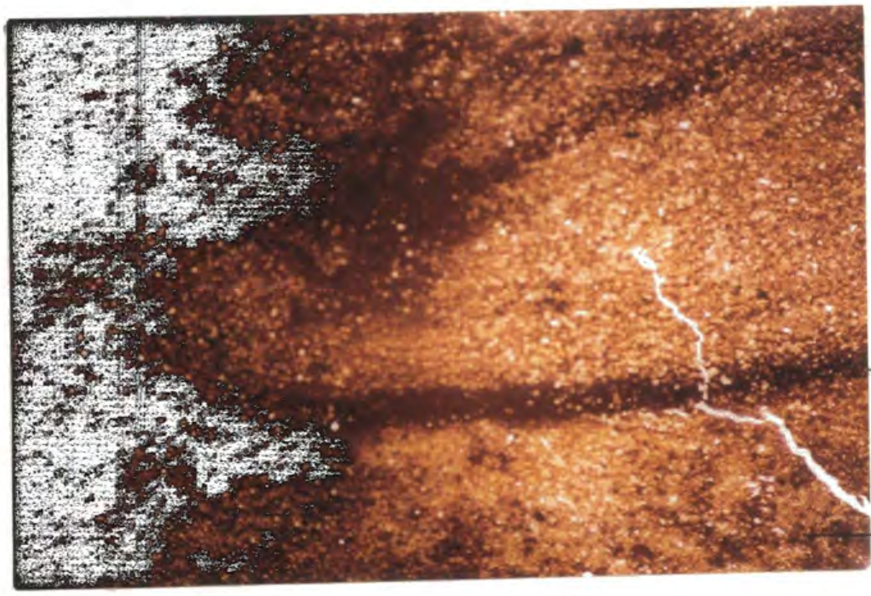
The background colour is 7•5YR 5/2, with evenly-distributed, diffuse, blotchy iron staining and a honeycomb pattern of very fine manganese deposition, apparently unrelated to any other feature.

Rounded iron concretions in situ are common; they measure 60µ to 6mm. in diameter and have peripheral manganese deposition. Occasional irregular manganese concretions up to 100µ in diameter are also present. There are fine manganese cutans on void walls, with $CaCO_3$ crystals occasionally superimposed. Phytoliths are numerous in the matrix and more particularly in voids. Earthworm burrows and pellets are rare, roots and rhizomes frequent.

Profile 6, 44 to 50 cm. - photograph 25

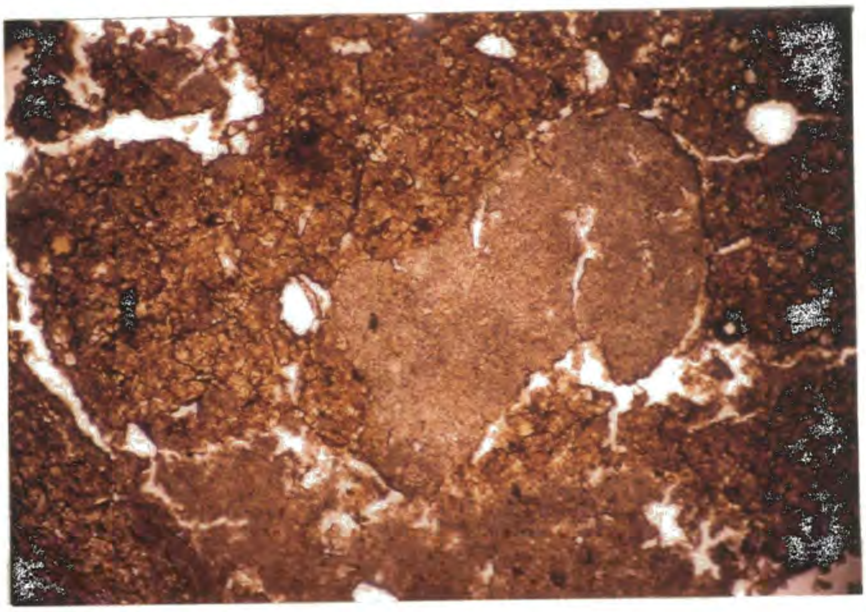
A strong microstructure is evident with blotchy peds 1mm. to 8mm. across, but there is a dense fabric within the peds, with weak pressure orientation of the clay fraction, particularly around grit particles. The fabric is dominated by closely-packed, sub-rounded, fine sand grains 10µ to 70µ in diameter, occasionally up to 100µ, but there are rare angular to sub-rounded grit particles up to 1•5mm. in diameter.

The background colour is 7•5YR 5/2, with diffuse, blotchy iron staining throughout and a honeycomb pattern of fine manganese deposition. Voids are lined by fine manganese cutans, often with very fine $CaCO_3$ deposits superimposed. Within the matrix are rounded iron concretions and irregular manganese concretions, up to 300µ in



26 Secondary Carbonate Horizon, profile 6

Dense, massive structure with banded iron deposition and blotchy manganese deposition



27 Secondary Carbonate Horizon, profile 6

Carbonate concretion in shatter zone, also showing hairline manganese deposition

photographs by L. Robertson and D.L. Dent diameter. Phytoliths are numerous in the matrix and particularly in the voids. There are rare earthworm burrows with faecal pellets.

Secondary Carbonate Horizon

Profile 6, 75-78 cm. - photographs 26 and 27

A dense, massive fabric dominated by sub-rounded fine sand/silt particles 10u to 30u in diameter. Voids occur chiefly in shatter zones, which run at about 30^{o} to the horizontal intersecting other features such as bands of iron deposition.

The background colour is 2•5Y 6/4, with iron and manganese staining superimposed. Iron has a banded to lenticular distribution, with lenses 30u across and 10u to 20u thick, bands •05mm. to 6•5mm. thick; at maximum devlopment colour is 5YR 6/8. Manganese concretions are black, sponge-like, and mostly less than 100u diameter, but are occasionally dendritic. There is also a honeycomb pattern of very fine manganese deposition, with cutans less than 5u thick dividing the whole fabric into polyhedral units about 150u across. Fine manganese cutans also line voids. Superimposed on the iron and manganese deposition within the matrix is a diffuse secondary carbonate deposition. Nodules of $CaCO_3$[1] are found within the voids, chiefly in shatter zones (photograph 27); they have grown inwards from the void walls, and phytoliths are found in their central cavities.

Phytoliths

Phytoliths are the siliceous skeletons of higher plants, chiefly grasses and sedges, and are widespread in grassland soils. The phytoliths in profile 6 are slender, rod-like bodies, generally 18•5u to 20u in length and about 1u to 1•5u in cross section. (In comparison, phytoliths observed in thin section in a Roumanian chernozem profile,

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[1] Secondary carbonate nodules up to 5 cm. in diameter were observed in this profile in the field.

supplied by J.C. Romans, ranged from 10μ to 50μ in length, and those illustrated by Tiurin (45) from Russian chernozems ranged from 5μ to 100μ in length). The phytoliths in profile 6 are not appreciably corroded. They were identified by their morphology, their birefringence and extinction lines in polarised light, and distinguished from soluble efflorescenses microchemically by their resistance to N. hydrochloric acid.

PHYSICAL AND CHEMICAL CHARACTERISTICS

Texture

In the mature Brown Calcareous Soil clay content decreases with depth. Maximum clay content ranges from 32-42 per cent in the ochric and cambric horizons to 6-20 per cent in the C horizons. In severely-eroded profiles the cultivated horizon may be no heavier than silt loam in texture. The dominant separate is the U.S.D.A. silt fraction (·05mm. to ·002mm.), especially in the C horizon where it may comprise 40 to 75 per cent of the soil mass. Coarse sand makes up only 0·1 to 3 per cent in the parent material, and in the upper horizons, where it comprises up to 7 per cent, it consists almost entirely of sesquioxide concretions.

Textures of C horizons and bulked samples from the upper 25 cm. of five Brown Calcareous Soils are shown in figure 6.2. C horizons are silt loams and loams, topsoils clay loams to silt loams.

Structure

Structure in the cultivated horizon varies with the humus content. With a low humus content (less than about 1 per cent C) under annual crops, it is near massive, but broken into coarse clods by cultivation. Under grass and hazels it is coarse prismatic to blocky, and in the best-managed bahçes a medium crumb structure may be found.

In the cambric horizon natural structures are closely fitting due to the swelling and shrinkage of the clay during wetting and drying. In the mature profile, structure is well-developed with prisms up to 20 cm. long axis, breaking to blocky, especially close to the surface where the soil dries out fairly rapidly in summer. Peds have clearly-defined pressure faces. Cracking of the soil in summer allows the darker surface soil to penetrate to a depth of 60 cm. or more between the peds, and this soil becomes welded onto the peds in the cambic horizon.

As clay content and fluctuations in soil moisture decrease with depth the structure becomes more massive or changes to the characteristic close-fitting pyramidal structure described in profiles 6 and 7, with individual triangular faces, 20 cm. to 40 cm. across, defined by manganese cutans. In the C horizon the soil has a characteristic fracture pattern, apparently unrelated to the pyramidal structure, with shatter zones running almost horizontally.

Consistence

In cultivated and cambic horizons consistence is generally hard to extremely hard when the soil is dry, firm when moist, sticky to very sticky and slightly plastic to plastic when wet. Consistence is ameliorated by a higher humus content.

In the secondary carbonate horizon dry consistence varies from very hard, to soft and fluffy in zones of heavy carbonate deposition. Moist consistence is firm, wet consistence slightly sticky and slightly plastic.

The C horizons are very compact, hard to very hard when dry, firm when moist, slightly sticky and slightly plastic when wet, but sticky if the clay content exceeds about 15 per cent.

Colour

Cultivated ochric horizons are dark yellowish brown; moist colours vary from 10YR 4/2 to 10YR 6/4. The cambic horizon, with less organic matter, may be redder with colours ranging from 10YR 4/3, 4/4 to 7·5YR 5/2. Both horizons have fine rust mottles.

The C horizons are light yellowish brown to pale olive; hues

Table 7.1

Analyses of Total Silica and Sesquioxides in the Clay Fraction of a Brown Calcareous Soil

Profile	Horizon (sample depth in cm.)	% by weight			Molecular proportion			Molecular ratios			
		SiO_2	Fe_2O_3	Al_2O_3	SiO_2	Fe_2O_3	Al_2O_3	$\frac{SiO_2}{R_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{Al_2O_3}$	$\frac{Al_2O_3}{Fe_2O_3}$
6. Çukuçayir VI	Ap 6-8	53•6	12•1	27•0	•893	•076	•255	2•69	11•70	3•50	3•36
	B 62-64	54•2	11•8	26•0	•903	•074	•255	2•74	12•20	3•54	3•45
	C 100-102	58•4	8•6	20•3	•970	•054	•199	3•83	17•96	4•87	3•69

2•5Y to 5Y, values 4 to 6, and chromas 3 to 4. Usually there is a laminar pattern of yellow-brown iron staining of variable intensity, occasionally as strong as 5YR 6/8. Manganese cutans on ped faces are a very dark reddish brown - 5YR 3/1 to 3/0 - or black.

Natural Drainage

There is a wide range of drainage classes in the Brown Calcareous Soils. Mature soils (profiles 6 and 10) are classed as imperfectly to moderately well drained. The compact parent material and the heavy texture of the surface horizons impede percolation in the wet season and a perched water table forms, the secondary carbonate horizon marking the lower limit of percolation from the surface. In summer the soil cracks to a considerable depth, allowing much summer precipitation to drain rapidly.

Profiles which have lost, or have never developed, heavy-textured surface horizons are classed as somewhat excessively drained - e.g. profile 8.

Mineralogy of the Sand Fraction

In the ochric and cambic horizons the small coarse sand fraction consists almost entirely of iron concretions: in the C horizons the coarse sand fraction is negligible. The fine sand (0•2mm. to 0•02mm.) separated from the C horizons of four Brown Calcareous soils was examined optically. Only one profile (Kisarna II) had a measurable heavy fraction - composed mainly of augite, with some brown hornblende, zircon and biotite. The light fractions proved difficult to identify but included quartz, calcite/dolomite and feldspars - mostly plagioclase.

Mineralogy of the Clay Fraction

Analyses of total silica and sesquioxides were carried out on clay samples ($< 1{\cdot}6\mu$) from the ochric, cambic and C horizons of profile 6 - table 7.1. The results show an increase in the silica:sesquioxide ratio down the profile, reflecting the greater degree of weathering in the upper horizons, which also show an increase in iron relative to both silica and alumina.

Differential thermal analysis and X-ray diffraction techniques were employed to identify the minerals present - figures 6.4 and 7.1.

C Horizon

The predominant clay mineral is montmorillonite. Quartz gives a sharp diffraction pattern, and there are small amounts of illite, kaolinite, feldspar, goethite, calcite and possibly lepidocrocite.

Cambic Horizon (B)

The cambic horizon shows a greater development of montmorillonite than does the C horizon. Also present are small amounts of illite, kaolinite, quartz, feldspar and goethite.

Ochric Horizon (Ap)

In the ochric horizon montmorillonite reaches its maximum development in this profile, and gives intense X-ray reflections at 17·7Å. Also present are illite, kaolinite, quartz, feldspar and goethite.

Rough quantitative estimations of montmorillonite and goethite, from their peak areas on the D.T.A. traces, are detailed in Table 7.2.

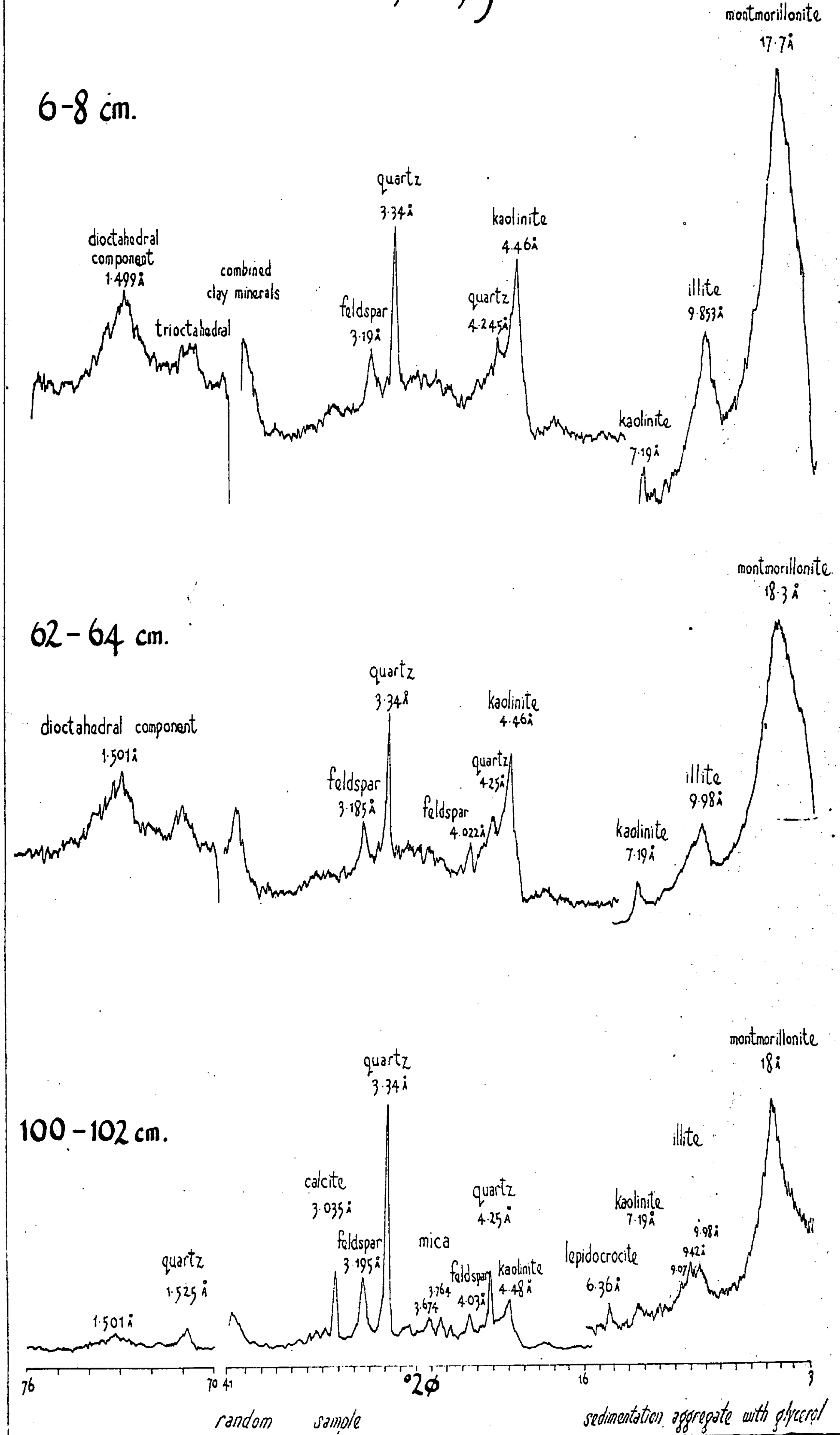
Table 7.2 Approximate Proportions of Montmorillonite Minerals and Goethite in the Clay Fraction ($< 1{\cdot}6\mu$) of a Brown Calcareous Soil - profile 6.

Horizon	Sample Depth	% Montmorillonite	% Goethite
Ap	6 - 8 cm.	70	3
B	62 - 64 cm.	81	4
C	100 - 102 cm.	48	4

Estimation of montmorillonite minerals from their D.T.A. peak areas is very approximate, and the X-ray diffractograms - figure 7.1 - suggest a steady increase in montmorillonite minerals from the C horizon to

7.1 X-ray Diffraction

6. Çukuçayır VI



the surface. The relative increase in total iron in the uppermost horizon (table 7.1) may be due to an increase in montmorillonite minerals (possibly nontronite), goethite remaining fairly constant. The presence of both dioctahedral and trioctahedral minerals is indicated by 060 reflections at 1•499 to 1•501Å (dioctahedral) and 1•52Å (trioctahedral).

Acid Oxalate Extractable Iron and Aluminium

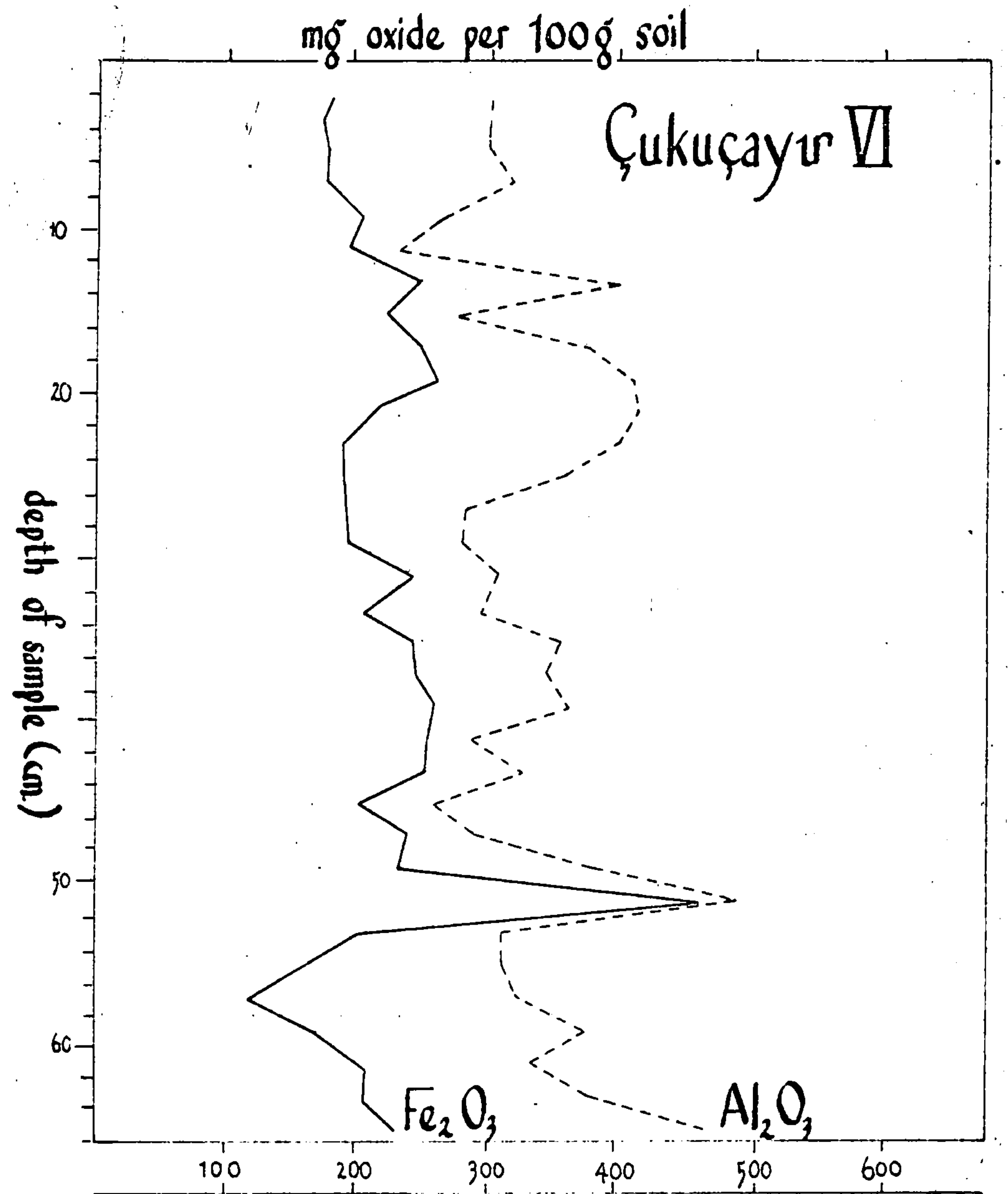
The presence of free carbonates in the parent material, and particularly the calcareous horizon, prevents the accurate determination of sesquioxides by acid extraction. Results from the ochric and cambic horizons of profile 6 - figure 7.2 - show a relatively subdued distribution of aluminium and iron compared with profile 2, the Red Clay - figure 6.8. However, there is a suggestion of translocation of sesquioxides from the upper 12 cm. (which may be correlated with the slight bleaching observed in the thin section from 8-13 cm.) and relative accumulation between 12 cm. and 24 cm., with the maximum aluminium accumulation lower in the profile than iron. The significance of the high results for aluminium and iron from the 50-52 cm. and 64-66 cm. samples is not known, but they may be connected with the higher pH of these samples - figure 6.10 - and may reflect the beginnings of sesquioxide deposition in the calcareous horizon, which represents the lower limit of active leaching in the profile. It is interesting that these lower iron and aluminium concentrations occur at about the same depth as the greatest iron and aluminium concentrations in the Red Clay profile 2.

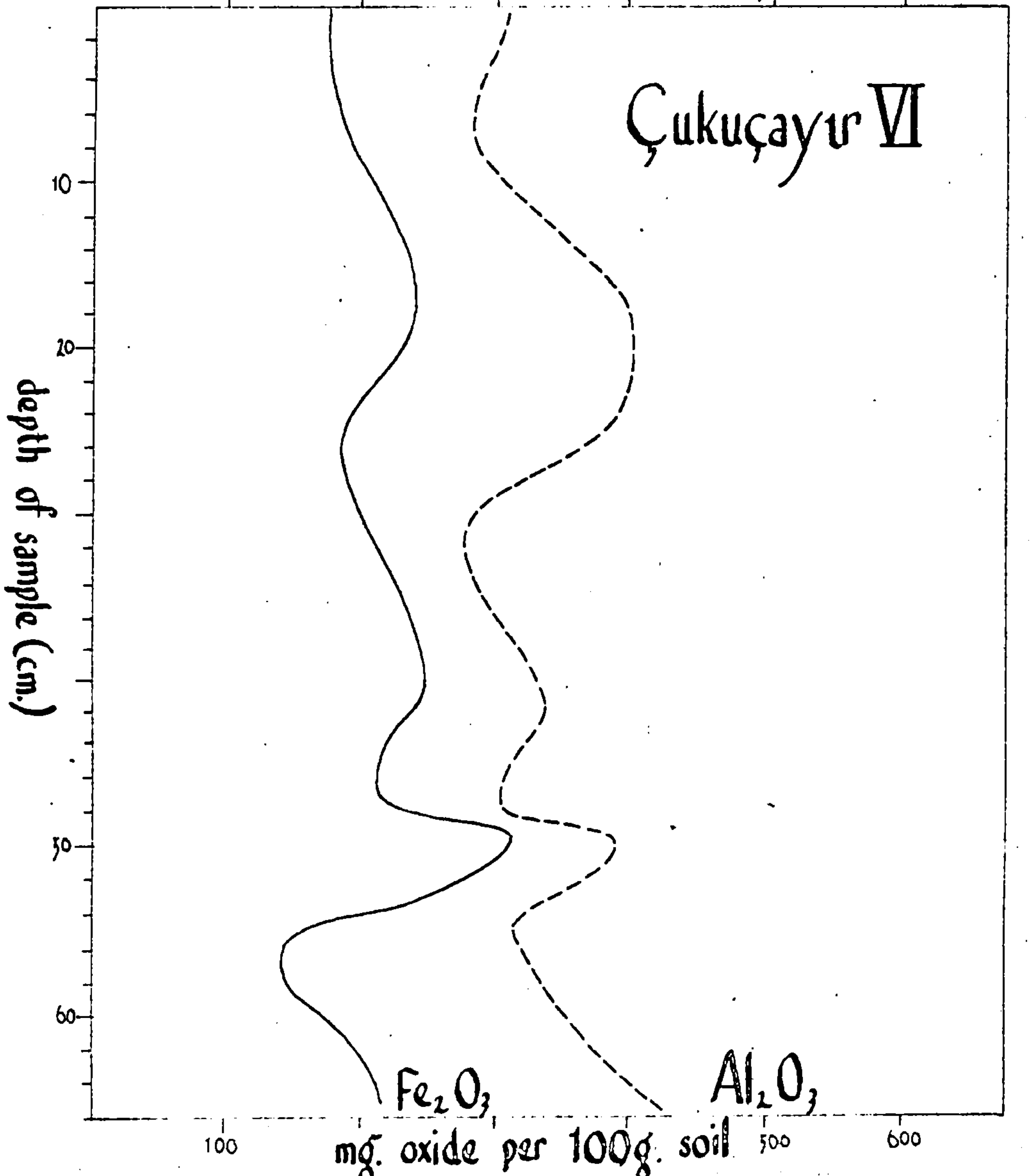
Manganese was not determined in the extract, but the development of a transient 'permanganate purple' showed a gradual increase in extractable manganese with depth.

The Organic Fraction

The organic content of the Brown Calcareous Soils is generally low. In cultivated horizons the carbon content varies between 0•5 and

7.2 Acid Oxalate Extractable Iron and Aluminium





1·85 per cent, and nitrogen between 0·06 and 0·29 per cent, C:N ratios ranging from 6 to 8. There is a sharp drop in humus content below the cultivated horizons, then a gradual decrease in the B and C horizons. The C:N ratio may also drop in the B horizon. This is attributed, as in the case of the Red Clays, to adsorbed $(NH_4)^+$ ions.

Cation Exchange Capacity and Exchangeable Cations

Soils containing free carbonates present particular difficulties in the determination of exchangeable cations. Total cation exchange capacity (C.E.C.) can be quite accurately determined by Bower's method, but estimates for individual cations are only approximations.

Figure 7.3 shows the trend of C.E.C. in the mature profile. The high figures of over 60 milli-equivalents per 100g. soil in the upper 18 cm. are boosted by the humus concentration of the old cultivated horizon. Thereafter C.E.C. drops gradually down the profile, reflecting decreasing clay and humus content.

In general, the C.E.C. of the A horizons of the Brown Calcareous soils is greater than that of the corresponding horizons of the Red Clays, although their clay content is significantly lower - compare tables 6.3 and 7.3. This is a result of the differences in clay mineralogy. In the Brown Calcareous Soils the principal clay minerals are montmorillonites, which have C.E.C.'s of 80 to 150m. equiv. per 100g., while in the Red Clays the principal clay minerals are kaolins, which generally have C.E.C.'s of 3 to 15m. equiv. per 100g.

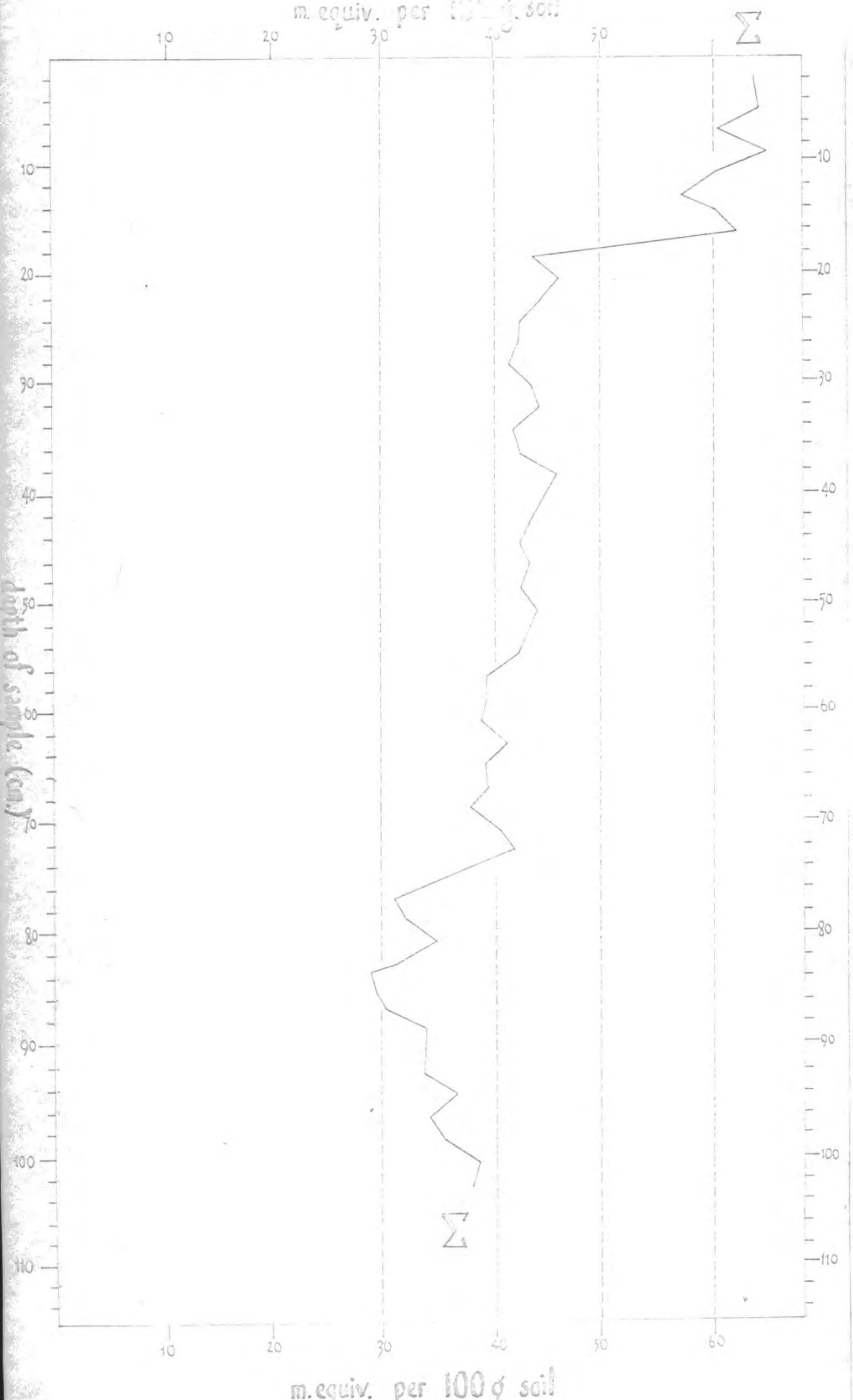
Table 7.3. Cation Exchange Capacities of Brown Calcareous Soils

Horizon	C.E.C.(m.equiv.per 100g.)
Ap	47 - 70
B	42 - 54
C	30 - 47

The exchange complex in Brown Calcareous Soils is saturated, or almost saturated, by bases - chiefly calcium and magnesium.

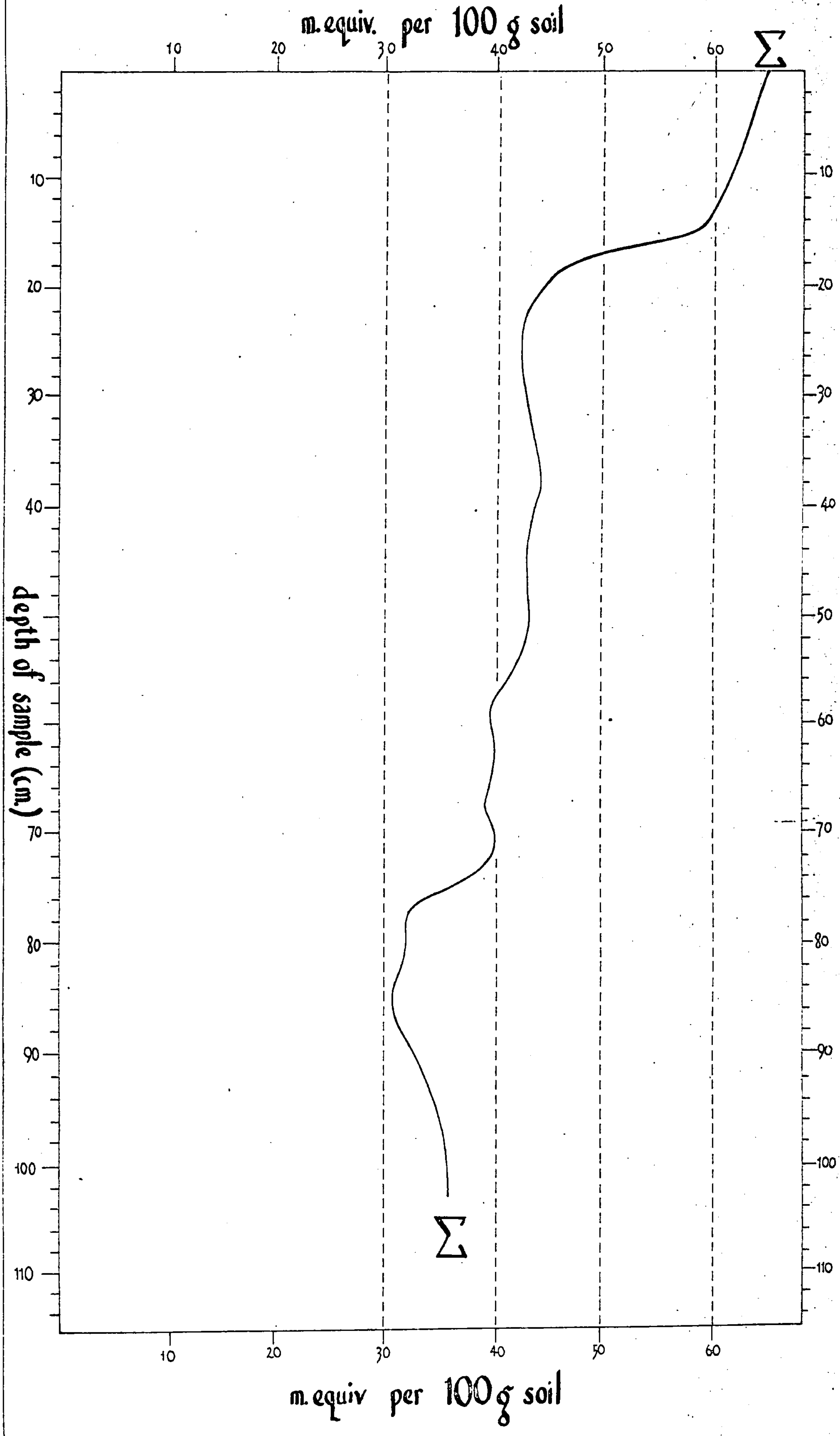
7.3 Cation Exchange Capacity (Σ)

Çukuçayır VI



7·3 Cation Exchange Capacity (Σ)

Çukuçayır VI



Carbonates

Free carbonates of calcium, and possibly also magnesium may be present throughout the profile, but they are concentrated in nodules and pseudomycelia in the secondary carbonate horizon which represents the effective depth to which soil water percolates. Determinations of free carbonate carried out on bulk samples from profile 6 show a $CaCO_3$ equivalent of 0•78 per cent in the parent material, 2 per cent in the secondary carbonate horizon, and 0•28 per cent in the cambic horizon. Profiles 6 and 10 show a slight summer accumulation in the surface horizons.

pH

The trend of pH in the mature profile is shown in figure 6.10. pH is remarkably uniform in the ochric and cambic horizons, increasing gradually with depth from 7 at 4-6 cm. to 7•4 at 68-70 cm. There is a slight increase at the surface, and a dramatic rise to between 8 and 8•2 in the secondary carbonate horizon. The pH of cultivated horizons of Brown Calcareous soils ranges from 5•9 in the most leached example to over 8 in badly eroded soils where the secondary carbonate horizon appears at the surface.

Phosphorus

The total phosphorus contents of the Brown Calcareous Soils are low. In the four profiles analysed they ranged from 6 to 23 mg. per 100g. in the parent material and up to 8 to 50mg. in cultivated horizons. In the Brown Calcareous soils phosphorus availability is limited by high pH.

Chapter 8

SOIL GENESIS AND CLASSIFICATION

In the Trabzon catena two groups of soils with sharply contrasting characteristics are developed on similar parent materials. The differing properties of the Red Clays and the Brown Calcareous Soils stem from their different ages, and from change in topography, climate and vegetation which have taken place during the history of the catena.

The Red Clays

The oldest soils of the catena are the Red Clays which are found on the remains of the Pliocene platform surface, and which exhibit a profound alteration of the parent material. It may be inferred from examination of thin sections from saprolite horizons, and observations on less-weathered material in similar stratigraphic positions, that the original parent material of the Red Clays was a molasse of rounded stones and boulders of basalt and andesite lava, tuff and agglomerate, set in a fine-grained matrix. Mineralogical analyses (pages 51 to 58) have shown that the end-product of the weathering process is a mixture of kaolin minerals, iron oxides and sometimes gibbsite, with quartz and a small residue of resistant heavy minerals. These are characteristic products of humid tropical weathering.

In the humid tropical weathering process, external (site) conditions are all-important to the direction of weathering. Good drainage leads to the removal of bases, silica and iron from the weathering crust, resulting in the eventual accumulation of gibbsite; poor drainage encourages the accumulation of soluble materials and the synthesis of a greater variety of clay minerals, particularly montmorillonites. The Red Clays of the Trabzon Catena occur on naturally water-shedding sites, but the Platform may have been less dissected, and therefore less well drained, during the earlier stages of pedogenesis; also the fine texture of the parent material does impede drainage, and the balance of weathering conditions has generally favoured the formation of kaolinite rather than gibbsite.

Various degrees of weathering are observed in profiles of the Red Clay group, culminating in the accumulation of iron oxides and gibbsite. (Fresh lava was observed only where the volcanic basement of the Platform was exposed, and it is probable that the volcanic materials had already undergone a certain amount of weathering before their deposition in the molasse). In the following proposed weathering sequence the stages are labelled according to their characteristic minerals.

Proposed Weathering Sequence in the Red Clays

1. Basalt and Andesite
2. Montmorillonite and mixed layer minerals
3. 7•35Å kaolin
4. Kaolinite
5. Gibbsite

The first stage in clay mineral formation is observed at the base of profile 2 where the original structure of the parent material is most clearly visible in the field - sample 125-135 cm.b. The dominant mineral is the 7•35Å variety of kaolin, but small amounts of montmorillonite, illite and mixed layer minerals are present, along with some feldspars from the parent rock - figure 6.5. Montmorill-onite formation requires an iron and base-rich medium which is provided by the ferro-magnesian parent rock. (Although the pH of the bulk sample is 5•5 it may well be 7 or more at the faces of weathering rock crystals). Goethite also appears at the earliest stages of weathering, as a result of the ageing of ferric hydroxide gels produced by the breakdown of olivine and feldspars.

In the Red Clays the montmorillonite stage is transient, the continuing leaching of bases, silica and iron carries the weathering process through to the more stable 7·35Å kaolin stage, which is represented by profile 3, 100-110 cm., and profile 2, 72-74 cm., and 100-102 cm. At this stage no primary minerals other than quartz remain, although the external faces and cleavage planes of the completely decomposed feldspar, olivine and augite crystals are outlined by sesquioxides of iron and manganese. The 7·35Å kaolin occurs as a pseudomorphy: it may be regarded as a highly-disordered variety of kaolinite, possibly with some interlayering of halloysite (page 56) and is probably an intermediate stage in the formation of kaolinite proper. Kaolinite is poorly represented in the saprolite horizons and may be confined to the translocated clay fillings of the pores. The kaolinite stage is represented by the upper horizons of profile 2.

Profile 5, 65-75 cm. contains about 6 per cent gibbsite (page 56) which is indicative of a more intensive de-silication of the medium than kaolinite. (The silica:alumina ratio in this sample is 2·02, the lowest encountered in the samples analysed). Gibbsite may form directly from olivine and feldspars or by breakdown of kaolinite. The latter course is suggested in this case by the diffuse X-ray diffraction pattern of the kaolinite - figure 6.6. Quartz is hardly weathered at all. Weaknesses in crystals may be penetrated and the crystals gradually broken down to smaller fragments which may finally dissolve, but it remains the outstanding residual mineral in the Red Clays.

The formation of the ubiquitous small "ironstone" nodules and the larger manganese iron concretions of profile 3 must have come at a relatively late stage in the weathering process, representing a local concentration of residual sesquioxides within the zone of a fluctuating soil water table (pages 46 and 47).

The kaolinisation of the parent material and the extensive formation of sesquioxide concretions in the Red Clays are suggestive of a more humid and probably warmer climate in the Trabzon area than that of the present day, when the younger Brown Calcareous soils are able to maintain their base status, and even secondary carbonate horizons, in a temporary equilibrium. The weathering process on the Red Clays may have begun in late Pliocene times, and similar red weathering crusts have been found in Georgia, buried under early Quaternary lavas (46), but the weathering of present profiles probably dates from warm, humid interglacial periods.

Erosion

The erosion of the old platform surface has removed the red weathering crust over extensive areas. Where it remains on the residual ridge tops, originally deep-seated concretion and saprolite layers may be found exposed at the surface, as in profile 3, and in some cases a deep layer of red weathered material has been deposited over the truncated profile, e.g. profiles 2 and 13. This suggests a relatively recent phase of catastrophic erosion, perhaps initiated by seismic disturbance or deforestation.

Lessivage

In profile 2 an argillic horizon developed, or at least continued to develop, after this catastrophe, since clay skins occur in both the redeposited material and the underlying saprolite (pages 44 to 46). The translocation of clay involves the dispersion of fine clay, its movement in percolating water, and its accumulation where it is filtered out of suspension on the walls on non-capillary voids by the absorption of water into the soil fabric. It is thought that the process is encouraged by a seasonal moisture deficit since the wetting of a dry soil tends to disperse the clay, the cracks formed by drying assist percolation of the clay suspension, and a dry soil has a large capacity for capillary absorption (40b, p.11-17). The layering of translocated clay has long been recognised as an indication of cyclical deposition (40a, p.39), and the most probable cycle is an annual one, with dispersion and transport of clay in the wet season, and stabilisation of the clay films on the void walls during the dry season. Bands of darker and sometimes coarser material mark individual "varves" (photograph 18) which may sometimes separate from one another during the drying of the soil sample prior to thin section preparation.

Counts were made of individual "varves" making up pore fillings in profiles 2 and 5. In the deepest thin section from profile 2 (94-99 cm.), all pores containing translocated clay were completely filled, e.g. a dendritic pore 250μ in diameter was filled by 32 to 34 concentric "varves". "Varve" counts from the 94-99 cm. section ranged up to 59, counts from the 50-54 cm. section ranged up to 75, and counts in the 40-46 cm. section also ranged up to 75. The longest continuous sequence was recorded in profile 5, 65-70 cm. - a count of 172 with a possible 25 further "varves" on the roof of this pore separated by a shrinkage gap.

If the "varves" do represent annual increments of translocated clay, then a period of a few hundred years would account for the formation of the argillic horizon in the Red Clays, even allowing for the possibility of a progressive filling of pore space from the base of the horizon upwards. The most likely period would be during the early stages of Greek colonisation, after 756 B.C. We may envisage a clearance of forest in the immediate hinterland of Trapezus, bringing about catastrophic erosion and redeposition of the Red Clays. Under a mediterranean climate similar to that of today, and a system of land use out of phase with the soil and climate, active lessivage may have taken place over a limited period, gradually decreasing as the agricultural system became adapted to environmental conditions. The translocated clay completely fills dendritic pores to a depth of a metre or more, and is strongly stained by iron oxides. In profile 2 it is a stronger red than the matrix, which suggests that ir was subject to reddening by heat and insolation[1] close to an unprotected surface, prior to lessivage.

This hypothesis is not consistent with the traditional view of very slow continuous development of argillic horizons under stable conditions over thousands of years expressed in the 7th Approximation (40b, p.12) and assumed by Romashkevitch in his micromorphological studies on Georgian krasnozems (32).

Lessivage is no longer active in the Red Clays. "Clay skins" described on ped faces in the field descriptions (profiles 2 and 5), upon thin section examination, appeared to be gleyed skins. Translocated clay identified in thin section is entirely in pores within the peds, and these clay-filled pores are frequently cut through by the present-day structural faces (pages 44 to 46). In the Brown Calcareous soils there is no evidence of lessivage. Probably the presence of free carbonates, and sometimes other soluble salts, prevents the initial dispersion of fine clay.

Gley-Leaching in the Red Clays

It is assumed that the most recent phase of soil development is indicated by the distribution of the most mobile constituents, which are the organic matter currently being cycled in the upper horizons, and the amorphous inorganic fraction. The semi-natural profiles (1 and 2) show an accumulation of organic matter, iron, adsorbed cations and acetic soluble phosphate in the O and A_1 horizons. The underlying albic horizons are depleted of sesquioxides - figure 6.8 - and there is evidence of a breakdown of kaolin minerals under the influence of the acid humus (page 57). In the B horizon there is an accumulation of mobile sesquioxides, probably at the soil water table - cf. D'Hoore (48). It would not be correct to describe this translocation of sesquioxides as podsolisation. Mobilisation probably takes

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[1] Dehydration of goethite to haematite (47).

28 Wafer Iron Pan, profile 6, 160 cm., x ½

photograph by A.D.Moir

place chiefly in winter under gley conditions and much leaching may be lateral because of the impermeability of the argillic horizon. Invasion of the argillic horizon by tongues of the albic horizon, penetrating particularly along structural faces, is a consistent feature of semi-natural Red Clay profiles.

In B(g) and C(g) horizons small soft manganese nodules indicate seasonal waterlogging.

The Brown Calcareous Soils

Red Clays will have covered most of the old Platform surface, but they have been eroded over extensive areas following the uplift and dissection of the Platform. The Lithosols and Brown Calcareous Soils which occur on young, actively-eroding surfaces, reflect essentially recent environmental influences. However, the wafer-like iron pans observed in the Brown Calcareous profiles 6 and 7 (photograph 28) were formed before the development of the present profiles. They may be inherited from the deposition of the sediment, or may have been formed by deposition at the water table as it was gradually lowered by erosion of the land surface. The groundwater was rich in manganese, which is more soluble than iron, and the characteristic pyramidal structure with manganese cutans may also date from the lowering of the water table. This would be accompanied by a shrinkage of the sediment with manganese oxides deposited on the newly-formed shrinkage planes. The microscopic honeycomb-like concentration of manganese oxides which occurs throughout the profile (pages 70 to 72) may be a bacterial deposition dating from a period of higher water table, with manganese precipitated in expanding peripheral zones around evenly distributed bacterial colonies, and the manganese "bubbles" merging to form the honeycomb structure which is now fossilised in the dry soil. This structure is most clearly seen in the C horizons and may have been partly dissolved in the A and B horizons.

As erosion has continued the solum has invaded the zone of sesquioxide deposition, disrupting the original structure and redistributing the sesquioxides. Because of the varying degrees of normal and accelerated erosion, individual Brown Calcareous profiles are at different stages of development, some approaching maturity, others rapidly colonising the parent material. They are all, however, products of a markedly seasonal climate with little net leaching. Soil-forming processes - biological activity, hydrolysis of aluminosilicate primary minerals and neosynthesis of clay minerals - are limited to the upper two metres of the profile, the secondary carbonate horizon marking the effective depth of moisture percolation from the surface in the mature profile.

The presence of phytoliths imprisoned in the central cavities of carbonate nodules throughout the secondary carbonate horizon of profile 6 indicates that this horizon has formed under a grassy or fairly open shrubby vegetation.

Clay Mineral Synthesis in the Brown Calcareous Soils

The principal clay minerals in the Brown Calcareous Soils are montmorillonites, which are characteristic of slow natural drainage. In a seasonal climate hydrolysis of aluminosilicate minerals takes place principally during the wet season, and montmorillonite synthesis is thought to occur principally during the drying-out of the soil in summer, when the soil solutions become saturated with Mg, Fe, Ca, Na and K ions which combine with O-Si-Al groups (49). These conditions are abundantly fulfilled in the upper horizons of the Brown Calcareous Soils. The small amounts of kaolinite observed may be inherited from the parent material.

In winter precipitation considerably exceeds transpiration (figure 3.9). The upper horizons become saturated with moisture, but percolation is slow through the compact parent material and especially in the montmorillonite rich ochric and cambic horizons. Hydrolysis of aluminosilicates and mobilisation of sesquioxides is encouraged by the high soil temperatures which, at a depth of one metre, fall only gradually from a maximum of 22°C in October to a minimum of 10° in March. The upper horizons begin to dry out in May, when transpiration and surface temperatures rise rapidly. As the soil solutions become concentrated, clay mineral synthesis is accelerated, mobilised sesquioxides are re-deposited in concretions and cutans, and finally, carbonates are deposited as pseudomycelia on ped faces in the upper horizons, and in pseudomycelia and nodules lower in the profile.

Montmorillonite clays swell considerably through the absorption of water, and shrink on drying, so that the soil cracks to a considerable depth at the height of summer. Most summer rainfall probably drains rapidly down the cracks, carrying loose material with it but without thoroughly moistening and leaching the surface horizons. The creamy cutans observed in the field in profile 6 on ped faces between 40 and 85 cm. may well have been a mixture of silt and carbonates washed down by summer rains, rather than fine clay skins resulting from lessivage. (No oriented translocated clay was observed in thin sections of this profile).

The fracture planes observed in the C horizons of profile 6 (page 72) may be caused by the heaving of the clay-rich solum during seasonal wetting and drying.

<u>A Recent Leaching Phase in the Brown Calcareous Soils</u>

There is an apparent anomaly in the co-existence of contemporary gley-leaching in the Red Clays (page 88) and the well-developed secondary carbonate horizon in most Brown Calcareous Soils. This might be explained in part by a higher rainfall on the ridge-top sites on which the Red Clays occur. Brown Calcareous Soils generally occur at lower elevations on more sheltered sites, and it may be significant that a Brown Calcareous Soil examined on a ridge-top at about 350 metres did not have a secondary carbonate horizon, its pH ranging from 5•9 in the Ap to 6•3 in the C horizon.

Evidence for a recent leaching phase in the Brown Calcareous Soils is limited to the translocation of sesquioxides in profile 2 shown in figure 7.3. This is inconclusive, but the reserve of bases in the Brown Calcareous soils is such that leaching would take a considerable time to manifest itself in the translocation of sesquioxides.

Cultivated Soils

Most of the soils of the Catena are cultivated, and many have been cultivated over a very long period. Under cultivation the Red Clays are essentially imperfectly-drained gleys. The Ap horizon incorporates part of the B horizon of the forest soil, its organic and nutrient status augmented to some extent by manuring and its tilth and aeration by cultivation, but it rests on a dense, impermeable subsoil. Cultivation of Red Clays with hand implements is very hard work and the soils are acid and intrinsically deficient in plant nutrients, particularly phosphate.

The Brown Calcareous Soils are naturally more fertile, but cultivation has generally brought about degradation of structure due to accelerated oxidation of humus, and often severe soil erosion - particularly under tobacco which is an exhausting crop and affords little protection to the soil for the greater part of the year.

Although cultivation has often brought about soil erosion, some long-cultivated soils have developed particularly thick, dark-coloured A horizons as a result of the incorporation of organic material and refuse of all kinds over a very long period, (profiles 11 and 12). These soils are analagous to deepened cultivated soils described by Glentworth (50) and the Plaggenboden described by Muckenhausen (51) in north-west Europe.

An outstanding characteristic of the ancient cultivated soils of the Trabzon Catena is their relatively high phosphorus content.

In profile 12, a cultivated Red Clay, the total phosphorus content is 60 mg. to 80 mg. per 100g. down to at least 70 cm., compared with values of less than 25 mg. in the A horizons of most Red Clays. The base of the old cultivated horizon is at 52 cm., but the highest phosphorus content is in the 60-70 cm. sample, and the P content of the saprolite horizon at 120-140 cm., is also rather high (3•1 mg. per 100g. compared with 3•5 mg. per 100g. in the saprolite horizons of profiles 2 and 3). Phosphorus is generally considered to be immobile in the soil, but Romans (52) has shown that a very slow translocation can take place. The rate of this translocation in the Red Clays is not known, but the degree of movement in profile 12 suggests a very ancient cultivated soil. The source of phosphorus may well have been fish, applied in moderate quantities over many hundreds of years (see page 30). It is interesting that this fish manuring corrected particularly the specific nutrient deficiencies of the Red Clays which have been revealed in the present study - phosphorus, lime, organic matter, and probably trace elements.

Classification

The principal characteristics of the Red Clays are inherited from a long period of humid tropical weathering. Essentially, they are relict "Ferrallitic Soils" - Aubert and Duchaufour, 1956 (53) - or "Kaolisols" - Sys. 1959 (54). The argillic and albic horizons are more recent and relatively minor modifications of the profile. Similar alterations of a ferrallitic weathering crust have been observed in Abkhazia by Romashkevich (32) and Gerasimov, who described such soils as "Subtropical Gleyey Pseudopodsols", (1966 (33).

The presence of inherited and recent characteristics makes it difficult to place the Red Clays in the strictly-defined categories of the 7th Approximation (40b) which has been applied by international survey teams elsewhere in Turkey. The natural place for the Red Clays is in the Order Ultisols,[1] and if the base saturation is calculated as $\frac{Ca + Mg + Na + K}{C.E.C.}$ x 100 (page 64) some Red Clays fulfill the requirements if the Ultisols (see definitions in Appendix V). In other Red Clays, base saturation is still greater than that allowed in the Ultisols, and these are classified as Paleudalfs in the Order Alfisols. A new sub-group - "Glossic Paleudalfs" - is suggested, to denote the invasion of the argillic horizon by the albic horizon. Profiles 1, 2 and 4 have been classified as Alfisols, but in the light of the evidence of the clay "varves" (page 87) reasonable doubt may be placed on the value of the argillic horizon in the Red Clays as a criterion of classification at the highest level.

The youthful characteristics of the Brown Calcareous Soils place them in the Orders Inceptisols in the 7th Approximation. Profiles with ochric and cambic horizons are classified as Vertic Eutrochrepts, because of their high base status and the swelling properties of their clay fraction (profiles 6, 9 and 10). Severely eroded profiles are classified as Entisols (profiles 7 and 8).

Soils with plaggen horizons 50 cm. or more thick are classified as Plaggepts.

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[1] Although the categories of the 7th Approximation are defined in terms of measurable soil characteristics, and not by genetic theory, there is a clustering of the artificially defined soil classes into groups which do have genetic significance.

Appendix I

CALCULATION OF POTENTIAL TRANSPIRATION

Many methods are available for estimating the natural balance between precipitation and water loss through evaporation and transpiration. Penman's method (55) has been chosen because it is the most soundly based on physical considerations and gives values which correspond closely with experimentally-obtained results in many parts of the world, cf. Wallen (56).

In the calculations detailed below, a modified form of Penman's original formula is used, as outlined in the 1967 Meteorological Office Bulletin on "Potential Transpiration" (57)

$$E = \frac{H.\ \Delta/\gamma + Ea}{\Delta/\gamma + 1}$$

E = potential transpiration

H represents the energy from solar radiation for evaporation

Ea is an aerodynamic term representing the evaporating capacity of the atmosphere

Δ and γ are numerical constants.

Mean values for temperature, vapour pressure, wind and sunshine are abstrated from the Turkish Meteorological Service Bulletin - "Ortalama ve Ekstrem Kiymetler Meteorologi Bülteni, 1962 (58) and mean possible sunshine values from solar radiation curves for the latitude prepared by Dr. R.W. Gloyne. Long-term sunshine data for Giresun is not available, but has been derived empirically from cloudiness records using the relationships between sunshine and cloudiness at Trabzon and Rize. Angot's formula -

extra terrestrial radiation = 1 - (·68 proportion cloud)

and Woodhead's empirical relationship (59) were discarded after trial because they gave sunshine values too high for the coastal areas of the Eastern Black Sea Region.

Full Penman Formulation Calculation

POTENTIAL TRANSPIRATION

from short grass

Station GIRESUN

Latitude 40° 55′ N

Altitude 34 m.

Period 1931 - 1960

	from line	MO3 Table		month	1	2	3	4	5	6	7	8	9	10	11	12
1			Mean Temperature °C		7·1	6·8	7·6	10·8	15·2	19·6	22·3	22·6	19·6	16·0	12·5	9·1
2			°F	T_a	44·8	44·2	45·7	51·5	59·2	67·3	72·1	72·7	67·3	60·8	54·5	48·4
3			Mean Vapour Pressure mm. Hg	e_d	5·5	5·4	5·9	7·6	10·7	13·7	16·0	16·0	13·9	11·0	8·5	6·2
4			Mean Wind Speed mi/day	$\bar{u}_2$	75·2	75·2	75·2	59·1	57·3	59·1	59·1	53·7	53·7	48·3	48·3	80·6
5			Mean Sunshine hr/day	n												
6			Mean Possible Sunshine	N												
7			LINE 5 / LINE 6	$\frac{n}{N}$	·267	·240	·240	·280	·361	·551	·456	·497	·456	·442	·362	·348
8		T.3	$0.75\ R_A$	$f\,R_A$	4·513	6·30	8·16	10·53	12·05	12·71	12·41	11·16	9·34	7·07	5·035	4·145
9	7	T.4	$0.18 + 0.55\frac{n}{N}$	$f_1\frac{n}{N}$	·338	·321	·321	·348	·404	·536	·469	·498	·469	·461	·405	·395
10			LINE 8 / LINE 9	R_I	1·526	2·051	2·618	3·663	4·858	6·810	5·820	5·560	4·375	3·260	2·100	1·668
11	2	T.5	$\sigma\,T_a^4$	S	12·30	12·23	12·39	12·97	13·77	14·65	15·19	15·25	14·65	13·95	13·27	12·65
12	7	T.4	$0.95(0.10+90\frac{n}{N})$	$f_2\frac{n}{N}$	·391	·369	·369	·402	·470	·628	·549	·582	·548	·537	·471	·459
13	3	T.6	$0.56 - .09\sqrt{e_d}$	$f\,e_d$	·30	·30	·29	·27	·24	·20	·18	·18	·20	·23	·26	·28
14			LINE 11 x LINE 12 x LINE 13	R_B	1·442	1·354	1·323	1·419	1·549	1·838	1·499	1·598	1·603	1·721	1·633	1·622
15			LINE 10 - LINE 14 $R_I - R_B$	H	·084	·697	1·295	2·244	3·309	4·972	4·321	3·962	2·772	1·539	·467	·046
16	2	T.8	$\Delta/0.27$	Δ/γ	1·067	1·044	1·100	1·333	1·704	2·185	2·526	2·570	2·185	1·793	1·467	1·204
17	2	T.9	Satn. vap. pressure T_a mm Hg	e_a	7·59	7·41	7·86	9·71	12·85	17·13	20·17	20·57	17·13	13·63	10·86	8·67
18			LINE 17 - LINE 3	$e_a - e_d$	2·09	2·01	1·96	2·11	2·15	3·33	4·17	4·57	3·23	2·63	2·36	2·47
19	4	T.10	$0.35\ (1 + u_2/100)$	$f\,u_2$	·614	·614	·614	·557	·538	·557	·557	·538	·538	·519	·519	·632
20			LINE 18 x LINE 19	E_a	1·281	1·232	1·202	1·173	1·157	1·851	2·318	2·460	1·739	1·366	1·226	1·559
21			LINE 15 x LINE 16	$\frac{\Delta}{\gamma}H$	·090	·727	1·425	3·000	5·650	10·800	10·91	10·17	6·06	2·76	·686	·055
22			LINE 20 + LINE 21	$\frac{\Delta}{\gamma}H + E_a$	1·371	1·959	2·627	4·173	6·807	12·651	13·228	12·630	7·799	4·126	1·912	1·614
23			LINE 16 + 1·00	$\frac{\Delta}{\gamma} + 1$	2·067	2·044	2·200	2·333	2·704	3·185	3·526	3·570	3·185	2·793	2·467	2·204
24			LINE 22 / LINE 23 mm/day	E_T	·663	·956	1·194	1·789	2·519	3·993	3·754	3·518	2·458	1·476	·774	·733
25			No. of days in the Month		31	28·25	31	30	31	30	31	31	30	31	30	31
26			LINE 24 x LINE 25 Potential Transpiration mm.		20·5	27·2	37·0	53·6	78·0	119·9	111·6	109·6	73·5	45·7	23·2	22·7

Adapted from K.W.M.t. O. Belfast 4/1958

Full Penman Formulation Calculation

POTENTIAL TRANSPIRATION

from short grass

Station TRABZON

Latitude 41° 00′

Altitude 37 m.

Period 1929-1960

	from line	M03 Table		month	1	2	3	4	5	6	7	8	9	10	11	12
1			Mean Temperature °C		7.2	6.9	7.7	11.2	15.6	19.9	22.7	23.2	20.1	16.6	12.9	9.3
2			°F	T_a	45	44.4	45.8	52.1	60	67.8	72.8	73.8	68.2	61.9	55.2	48.7
3			Mean Vapour Pressure mm. Hg	e_d	5.2	5.2	5.7	7.4	10.6	13.5	15.7	16.1	13.3	10.5	8.4	6.0
4			Mean Wind Speed mi/day	$\tilde{u}_2$	91	96	103	86	82	70	65	70	70	82	70	70
5			Mean Sunshine hr/day	n	3.1	3.6	3.7	4.3	5.8	7.7	7.7	7.3	5.1	5.7	3.7	3.4
6			Mean Possible Sunshine	N	9.5	10.7	11.9	13.3	14.5	15.1	14.8	13.8	12.5	11.15	9.92	9.25
7			LINE 5 / LINE 6	$\frac{n}{N}$	.326	.336	.311	.324	.400	.510	.520	.528	.408	.510	.373	.367
8		T.3	$0.75\,R_A$	$f\,R_A$	4.513	6.30	8.16	10.53	12.05	12.71	12.41	11.16	9.34	7.07	5.035	4.145
9	7	T.4	$0.18 + 0.55\,\frac{n}{N}$	$f_1\,\frac{n}{N}$	.380	.387	.370	.380	.431	.507	.514	.520	.436	.507	.412	.408
10			LINE 8 / LINE 9	R_I	1.715	2.44	3.01	4.01	5.20	6.45	6.38	5.80	4.07	3.58	2.08	1.691
11	2	T.5	$\sigma\,T_a^4$	S	12.32	12.26	12.40	13.03	13.85	14.70	15.27	15.38	14.75	14.05	13.35	12.68
12	7	T.4	$0.95\,(0.10 + .90\,\frac{n}{N})$	$f_2\,\frac{n}{N}$	.441	.456	.428	.440	.502	.593	.602	.608	.509	.593	.480	.475
13	3	T.6	$0.56 - .09\sqrt{e_d}$	$f\,e_d$	.30	.30	.30	.27	.24	.20	.18	.18	.20	.24	.26	.29
14			LINE 11 x LINE 12 x LINE 13	R_B	1.63	1.37	1.284	1.909	2.895	1.744	1.657	1.667	1.501	1.999	1.669	1.744
15			LINE 10 - LINE 14 $R_I - R_B$	H	0.085	1.07	1.175	2.10	2.305	4.704	4.729	4.133	3.569	1.583	0.408	-0.053
16	2	T.8	$\Delta/0.27$	Δ/γ	1.074	1.052	1.104	1.359	1.748	2.219	2.578	2.656	2.248	1.856	1.504	1.219
17	2	T.9	Satn. vap press T_a mm. Hg	e_a	7.65	7.47	7.89	9.94	13.24	17.43	20.64	21.35	17.67	14.16	11.14	8.76
18			LINE 17 - LINE 3	$e_a - e_d$	2.45	2.27	2.19	2.54	2.64	3.93	4.94	5.25	4.37	3.66	2.74	2.76
19	4	T.10	$0.35\,(1 + u_2/100)$	$f\,u_2$	.669	.686	.711	.651	.637	.595	.577	.595	.595	.637	.595	.595
20			LINE 18 x LINE 19	E_a	1.639	1.558	1.558	1.653	1.680	2.339	2.852	3.123	2.598	2.329	1.660	1.682
21			LINE 15 x LINE 16	$\frac{\Delta}{\gamma}H$	.091	1.074	1.298	2.850	4.033	10.43	12.38	10.97	8.030	2.938	0.629	-0.065
22			LINE 20 + LINE 21	$\frac{\Delta}{\gamma}H + E_a$	1.720	2.632	2.856	4.403	5.713	12.77	15.23	14.093	10.628	5.267	2.289	1.617
23			LINE 16 + 1.00	$\frac{\Delta}{\gamma} + 1$	2.074	2.052	2.104	2.359	2.748	3.219	3.578	3.656	3.248	2.856	2.504	2.219
24			LINE 22 / LINE 23 mm/day	E_T	0.833	1.283	1.353	1.879	2.039	3.968	4.259	3.856	3.273	1.846	0.913	0.723
25			No. of Days in the Month		31	28.25	31	30	31	30	31	31	30	31	30	31
26			LINE 24 x LINE 25 Potential Transpiration mm.		25.4	36.2	42.0	56.4	63.2	119.0	134.0	119.8	98.2	57.3	27.4	22.4

Adapted from K.W.M.t O. Belfast. 4/1968

Full Penman Formulation Calculation

POTENTIAL TRANSPIRATION

from short grass

Station RIZE

Latitude 41° 02′ N

Altitude 4 m.

Period 1931–1960

Line	from line	MO3 Table		month	1	2	3	4	5	6	7	8	9	10	11	12
1			°C		6.9	6.9	7.8	11.4	15.7	19.8	22.4	22.6	19.7	16.3	11.9	8.9
2			Mean Temperature °F	T_a	44.4	44.4	46.0	52.5	60.3	67.6	72.3	72.6	67.5	61.3	53.4	48.0
3			Mean Vapour Pressure	mm Hg e_d	5.4	5.4	6.0	7.7	10.9	13.8	16.4	17.0	14.3	11.2	8.5	6.1
4			Mean Wind Speed mi/day	$\bar{u}_2$	32.2	37.6	37.6	32.2	37.6	42.9	32.2	26.8	26.8	26.8	21.5	26.8
5			Mean Sunshine hr./day	n	3.0	3.4	3.3	4.3	5.4	6.7	6.2	6.7	4.6	5.1	3.4	3.1
6			Mean Possible Sunshine	N	9.5	10.7	11.9	13.3	14.5	15.1	14.8	13.8	12.5	11.15	9.9	9.25
7			LINE 5 / LINE 6	$\frac{n}{N}$	.318	.319	.278	.324	.373	.444	.419	.485	.368	.456	.343	.335
8		T.3	$0.75\,R_A$	$f\,R_A$	4.513	6.30	8.16	10.53	12.05	12.71	12.47	11.16	9.34	7.07	5.035	4.145
9	7	T.4	$0.18 + 0.55\frac{n}{N}$	$f_1\frac{n}{N}$	.373	.375	3.47	3.79	4.12	4.62	.444	.489	.408	.469	.392	.387
10			LINE 8 / LINE 9	R_I	1.682	2.360	2.832	3.990	4.965	5.970	5.506	5.451	3.818	3.240	1.974	1.595
11	2	T.5	σT_a^4	S	12.26	12.26	12.42	13.07	13.88	14.68	15.21	15.24	14.67	13.99	13.16	12.61
12	7	T.4	$0.95(0.10 + 0.90\frac{n}{N})$	$f_2\frac{n}{N}$	.434	.435	.400	.440	.479	.553	.539	.576	.508	.559	.496	.492
13	3	T.6	$0.56 - 0.09\sqrt{e_d}$	$f\,e_d$	.30	.30	.29	.27	.23	.20	.17	.17	.20	.23	.26	.29
14			LINE 11 x LINE 12 x LINE 13	R_B	1.596	1.599	1.443	1.608	1.558	1.640	1.390	1.494	1.492	1.796	1.698	1.801
15			LINE 10 − LINE 14 $R_I - R_B$	H	.086	.761	1.389	2.382	3.407	4.330	4.116	3.957	2.326	1.444	.876	−.206
16	2	T.8	$\Delta/0.27$	Δ/γ	1.052	1.052	1.111	1.378	1.767	2.207	2.541	2.563	2.200	1.822	1.419	1.819
17	2	T.9	Satn. vap. press. T_a mm. Hg	e_a	7.47	7.47	7.95	10.09	13.39	17.31	20.30	20.51	17.25	13.87	10.42	8.55
18			LINE 17 − LINE 3	$e_a - e_d$	2.07	2.07	1.95	2.39	2.49	3.51	3.90	3.51	2.95	2.67	1.92	2.45
19	4	T.10	$0.35\,(1 + u_2/100)$	$f\,u_2$	.463	.481	.481	.463	.481	.501	.463	.444	.444	.444	.425	.444
20			LINE 18 x LINE 19	E_a	.957	.995	.938	.904	1.191	1.757	1.809	1.559	1.308	1.184	.816	1.087
21			LINE 15 x LINE 16	$\frac{\Delta}{\gamma}H$	.090	.801	1.540	3.282	6.025	9.600	10.043	10.013	5.071	2.632	1.241	−.244
22			LINE 20 + LINE 21	$\frac{\Delta}{\gamma}H + E_a$	1.047	1.796	2.478	4.186	7.216	11.357	11.852	11.562	6.379	3.816	2.057	.843
23			LINE 16 + 1.00	$\frac{\Delta}{\gamma} + 1$	2.052	2.052	2.111	2.378	2.767	3.307	3.541	3.563	3.200	2.822	2.419	2.189
24			LINE 22 / LINE 23 mm./day	E_T	.511	.876	1.176	1.763	2.635	3.437	3.061	3.240	1.992	1.351	.851	.385
25			Number of days in the month		31	28.25	31	30	31	30	31	31	30	31	30	31
26			LINE 24 x LINE 25 Potential Transpiration	mm.	15.8	24.7	36.4	52.9	81.7	103.1	94.9	100.6	59.8	41.8	25.5	11.9

Adapted from N.W. Met. O. Belfast 4/1968

Appendix II

PRINCIPAL CROPS OF THE EASTERN BLACK SEA REGION

Agricultural statistics abstratced from the files of the Devlet İstatistik Enstitüsü, Ankara.

Table II.1

Sown Areas of Field Crops (in hectares) Average Areas 1961-'65

	GIRESUN excluding Alucra and Şebinkarahisar	TRABZON	RIZE and N.ARTVIN including Arhavi, Hopa Borçka and Artvin	EASTERN BLACK SEA REGION
Maize	28,725	49,083	22,931	110,739
Wheat	327	2,664	168	3,159
Barley	396	1,366	164	1,926
Rice	-	5	345	350
Rye	-	125	199	324
Potatoes	585	6,486	654	7,625
Beans	130	2,740	1,004	3,874
Onions	200	617	80	897
Soya	-	182	537	719
Tobacco	-	7,048	42	7,090

Table II.2.

Tree Crops, Average Numbers of Trees (in thousands) 1960-'64

	GIRESUN excluding Alucra and Şebinkarahisar	TRABZON	RIZE and N.ARTVIN including Arhavi, Hopa, Borçka and Artvin	EASTERN BLACK SEA REGION
Hazelnut	73,660	27,146	7,733	108,539
Tea	8	19	56	83
Apple	270	130	261	661
Pear	115	90	187	392
Cherry	53	37	45	135
Tangerine	23	44	187	254
Orange	5	31	35	71
Lemon	0·1	5	10	15
Vine	186	51	121	258
Fig	55	35	26	116
Olive	-	39	-	39

Data for Crop Distribution Maps

Table II.3

Figure 5.1, Maize in 1890 from Cuinet (25)

Caza	Hectares under Maize
Hoppa	34,860
Atina	53,400
Rizeh	89,190
Of	75,870
Surmènéh	64,180
Trébizonde Aktché-Abad	118,020
Vakfikebir	12,160
Guerele	31,310
Tripoli	66,130
Kérassunde	98,450

Data for Crop Distribution Maps

Table II.4

Vilayet	Caza	Figure 5.2 MAIZE 1961-'65 av. hectares	Figure 5.3 HAZELNUTS 1960-'64 av. thous. trees	Figure 5.4 TOBACCO 1960-'65 av. hectares	Figure 5.5 OLIVES and TEA 1961-'65 av. no. of trees	
ARTVIN	Artvin	300	1,300	-	-	-
	Borçka	2,334	233	-	-	1,733
	Hopa	1,466	213	-	-	3,577
	Arhavi	1,806	1,400	-	-	3,188
RIZE	Findikli	850	2,370	-	-	3,272
	Ardeşen	2,400	854	-	-	4,123
	Çamlihemsin	1,960	2	-	-	-
	Pazar	3,557	200	42	-	6,387
	Çayeli	804	400	-	-	7,547
	Rize	5,735	414	-	-	22,249
	Kalkandere	1,282	345	-	-	3,733
	Ikizdere	737	2	-	-	-
	Of	7,980	3,873	-	40	10,012
	Çaykara	6,539	172	-	-	-

Table II.4 contd.

Vilâyet	Caza	MAIZE hectares	HAZELNUTS thousand trees	TOBACCO hectares	OLIVES and TEA no. of trees	
TRABZON	Sürmene	7,370	4,200	-	123	5,312
	Arakli	4,100	5,230	-	400	997
	Arsin	1,760	2,162	-	104	403
	Yomra	1,530	1,720	-	109	345
	Trabzon	2,086	4,200	1,174	2,760	625
	Maçka	4,900	1,740	-	-	-
	Akçaabat	3,030	464	5,874	37,000	125
	Vakfikebir	7,208	3,160	-	8,200	779
	Tonya	2,580	225	-	-	-
	Eynesil	1,478	3,600	-	-	562
	Görele	2,960	7,000	-	-	1,411
GIRESUN	Tirebolu	6,477	10,000	-	-	1,470
	Esbiye	4,640	5,000	-	-	744
	Keşap	2,830	4,000	-	-	1,362
	Giresun	3,100	20,000	-	-	2,703
	Dereli	1,400	3,000	-	-	-
	Bulancak	5,940	21,000	-	-	380
GÜMÜŞANE		814	-	-	-	-

Appendix III

POPULATION IN THE TRABZON AREA, 1960

Source: Türkiye Istatistik Yilliği
Devlet Istatistik Enstitüsü
Yayin Puplication 490, 1963

Caza	Total Area in sq.km.	Land Below 500m. in sq. km. (approx.)	Population	Persons per km.^{2}	Persons per km.^{2} below 500m.
Of	511	134	54,893	107	407
Sürmene	473	73	43,648	92	598
Araklı	372	93	46,572	125	502
Arsin	169	89	27,757	164	312
Yomra	207	49	19,511	110	398
Trabzon Merkez	168	-	94,632	563	-
Trabzon, excluding city	163	-	41,593	255	-
Akçaabat	425	155	75,413	177	485

Appendix IV

SUMMARY OF ANALYTICAL METHODS

For the most part, analyses were carried out using the routine methods of analysis practised at the Macaulay Institute for Soils Research, Aberdeen.

Mechanical Analysis. The separates estimated were -

Coarse Sand	Fine Sand	Silt (U.S.D.A.)	Silt (International)	Clay
2000-200 μ	200-20 μ	50-2 μ	20-2 μ	>2 μ

Coarse and Fine Sand were deparated by seiving; other separates were estimated by a modification of the Bouyoucos hydrometer method.

BOUYOUCOS, G.J. (1927) The hydrometer as a new method for the mechanical analysis of soils Soil Science 23, p.343

Percentage Moisture. 5-10g. of sample was heated at 105°C. overnight, allowed to cool in a desiccator, and re-wighed. This "oven-dry" weight was used as a basis for the calculation of other analytical results.

Loss on Ignition. The "oven-dry" sample was ignited at 800-1000°C. for two hours, allowed to cool in a desiccator, and re-weighed. Although commonly used as a rough estimate of organic content, the loss on ignition includes some loss of chemically-bound water from clay minerals, and is therefore an ambiguous value in clay soils.

The Organic Fraction. Analyses were carried out on finely-ground samples. Carbon was determined by the Walkley and Black Method.

WALKLEY, A. and BLACK, I.A. (1934) An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chronic acid titration method. Soil Science, 37, p.29.

Nitrogen was determined by a semi-micro Kjeldahl method

MARKHAM, R. (1942) A steam distillation apparatus suitable for micro-Kjeldahl analysis. Biochem. J. 36, 70

Free Carbonate was determined gravimetrically using Schroeder's apparatus with 1N. HCl, and the results expressed as $CaCO_3$ equivalent.

pH was determined in 2:1 aqueous suspension using a glass electrode. Because of the variability of determinations on individual samples, especially Red Clay Soils with high cation exchange capacities, the mean of six determinations on each sample is quoted.

Exchangeable Cations

Exchangeable hydrogen was determined by electrometric titration of a neutral N. Barium acetate leachate.

PARKER, F.W. (1929) The determination of exchangeable hydrogen in soils. J. Amer. Soc. Agron. 21, 1030

Exchangeable calcium, magnesium, potassium and sodium were determined photometrically in a neutral N. ammonium acetate leachate.

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SCOTT, R.D. and URE, A.M. (1958). The determination of magnesium in solution by direct photometry. Analyst. 83, 501.

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Appendix V

DEFINITIONS OF SOIL CLASSIFICATION UNITS FROM THE 1967 AMENDMENT TO THE 7th APPROXIMATION (40b)

ENTISOLS: ORDER 1

Mineral soils that have no diagnostic horizon other than an ochric or an anthropic epipedon, an albic or an agric horizon.

Orthents. Entisols that

1. have textures of loamy very fine sand or finer in some horizon below the Ap horizon or 25 cm. (10 inches), whichever is deeper, but above a depth of 1m. (40 inches) or a lithic or paralithic contact, whichever is shallower;

2. have no fragments of diagnostic horizons that can be identified and that occur more or less without discernible order in the soil below any Ap horizon but within the series control section;

3. have an organic matter content that decreases regularly with depth and reaches levels of 0•35 per cent (0•2 per cent carbon) or less within a depth of 1•25m. (50 inches), or within a depth of 25 cm. (10 inches) below the upper boundary of any layer that remains frozen until two months after the summer solstice, whichever is shallower, or have mean annual soil temperatures of $0^{o}C$ ($32^{o}F$) or less;

4. are not permanently saturated with water and lack the characteristics associated with wetness defined for Aquents.

INCEPTISOLS: ORDER 3

Inceptisols are mineral soils that have no spodic, natric, or oxic horizon unless it is a buried horizon; that have no plinthite that forms a continuous phase within 30 cm. (12 inches) of the mineral surface; and either:

1. Are usually moist between 18 and 50 cm. (7 and 20 inches) or above a lithic or a paralithic contact shallower than 50 cm. (20 inches); that lacks a salic, or gypsic horizon within 1m. (40 inches) of the surface; and that have one or more of the following:

   a. A conductivity of the saturation extract at 25°C (77°F) of less than 2 mmho per cm. down to whichever of these depths is least: a lithic or a paralithic contact or within 1·25 m. (50 inches) of the surface if particle-size classes are sandy, 90 cm. (35 inches) if loamy, and 75 cm. (30 inches) if clayey; and, if without a fragipan, with increase in depth in the C horizon but above the depths for the different particle-size classes specified above, either there is no increase in saturation with Na plus K or there is exchange acidity in excess of Na plus K; and with one or more of:

      (1) A cambic or a calcic horizon or both;

      (2) A fragipan that has no clay skins as thick as 1mm;

      (3) A duripan with its upper boundary within 1 m. (40 inches) of the surface.

   b. Artificial drainage or saturation with water at some period of the year when not frozen and either:

      (1) A histic or umbric epipedon, and at depths of less than 50 cm. or immediately underlying the epipedon

a horizon with dominant moist colours on ped faces, or in the matrix if peds are absent, that meet one or both of the following:

(a) if there is mottling, chromas are 2 or less;

(b) if there is no mottling, chromas are 1 or less; or

(2) An ochric epipedon underlain at depths of less than 50 cm. by a cambic horizon with dominant moist colours that meet the requirements of (1) above;

c. Sodium saturation of more than 50 per cent in some part of the upper 50 cm. (20 inches) that decreases with depth below 50 cm. (20 inches) and the soil is saturated with water at some period within a depth of 1m. (40 inches); or

2. Have an umbric, histic, or plaggen epipedon; or a mollic epipedon with <u>one or more</u> of the following combinations of properties:

a. A bulk density of the fine earth fraction of less than 0·85 g. per cc. in the epipedon or the cambic horizon on both, and the exchange complex is dominated by amorphous materials;

b. An underlying cambic horizon with base saturation of less than 50 per cent (by NH_4OAc) throughout or decreasing to less than 50 per cent at a depth of 1·8m (72 inches) below the surface, whichever is shallower;

c. The mean summer and mean winter soil temperatures differ by less than 5°C (9°F) when measured at a depth of 50 cm. (20 inches) or at a lithic or a paralithic contact, whichever is shallower, <u>and one or both</u> of:

(1) 35 per cent or more clay with montmorillonitic mineralogy, and the epipedon rests on materials with less than 40 per cent $CaCO_3$ equivalent;

(2) Moist and dry values of the mollic epipedon are no darker than those of the underlying horizons.

Ochrepts. Inceptisols that

1. have an ochric epipedon; or have an umbric or mollic epipedon 25 cm. (10 inches) or less thick if (a) the mean annual soil temperature is 8°C (47°F) or more, or (b) the mean summer soil temperature at 50 cm. (20 inches) or at a lithic or a paralithic contact, whichever is shallower, is either 15°C (59°F) or more if cultivated or without an O horizon or 8°C (47°F) or more if with an O horizon;

2. have 5°C (9°F) or more difference between the mean summer and mean winter soil temperatures at 50 cm. (20 inches) or at a lithic or paralithic contact, whichever is shallower;

3. have an exchange complex that is dominated by crystalline aluminosilicate clay minerals and have less than 60 per cent vitric volcanic ash, cinders, or other vitric pyroclastic materials in the silt, sand, and gravel fractions;

4. have chromas too high or hues too red for Aquepts or are never saturated with water and are not artificially drained;

5. lack a plaggen epipedon.

Eutrochrepts. Ochrepts that

1. have one or both of:

   a. carbonates in the cambic horizon or in the C horizon but within the soil;

   b. base saturation that is 60 per cent or more (by NH_4OAc) in some subhorizon that is within 75 cm. (30 inches) of the soil surface;

2. are not dry for as much as 90 cumulative days in most years in any subhorizon of the soil between 18 and 50 cm. (7 and 20 inches) or above a lithic or paralithic contact shallower than 50 cm. (20 inches) and are not dry for as much as 60 consecutive days in more than 7 out of 10 years in all subhorizons between these depths;

3. have a mean annual soil temperature of $8^{o}C$ ($47^{o}F$) or more or have a mean summer soil temperature at 50 cm. (20 inches) or at a lithic or a paralithic contact, whichever is shallower, of either $15^{o}C$ ($59^{o}F$) or more if cultivated or without an O horizon or $8^{o}C$ ($47^{o}F$) or more if with an O horizon;

4. lack a fragipan or a duripan.

ALFISOLS: ORDER 7

Alfisols are mineral soils that have no spodic or oxic horizons overlying an argillic horizon; that have no plinthite that forms a continuous phase within 30 cm. (12 inches) of the soil surface; that have no mollic epipedon; that have no surface horizon and an upper subhorizon of an argillic or natric horizon that are separated by an albic horizon but that together meet all requirements for a mollic epipedon; and that have one of the following combinations of properties:

1. have no fragipan but have an argillic or natric horizon; are usually moist in some part of the soil between 18 cm. and 50 cm. (7 and 20 inches) unless the epipedon is both hard and massive when dry; and either have mean annual temperature less than $8^{\circ}C$ ($47^{\circ}F$), or have base saturation (by sum of cations) of 35 per cent or more at a depth of 1•25 m. (50 inches) below the top of the argillic horizon or at 1•8 m. (72 inches) below the soil surface, or immediately above a lithic or a paralithic contact, whichever is shallower;

2. have a fragipan in or below the argillic horizon or have oriented clay skins more than 1 mm. thick in some part of the fragipan; and either have mean annual temperature less than $8^{\circ}C$ ($47^{\circ}F$), or have base saturation (by sum of cations) of 35 per cent or more at a depth of 75 cm. (30 inches) below the upper boundary of the fragipan or immediately above a lithic or a paralithic contact, whichever is shallower.

Paleudalfs. Udalf's that have no natric or agric horizons or fragipan but have an argillic horizon with a clay distribution such that the content does not decrease from the maximum by as much as 20 per cent of the maximum within a depth of 1·5m (60 inches) from the surface and with one or more of the following:

1. hues are redder than 10YR and chromas are more than 4 in the matrix of at least the lower part of the argillic horizon; or
2. hues are 2·5YR or redder and moist values are less than 4 and dry values are less than 5 throughout the major part of the argillic horizon; or
3. many coarse mottles with hues redder than 7·5YR or chromas more than 5, or both.

ULTISOLS: ORDER 8

Ultisols are mineral soils that

1. have one of the following combinations of characteristics:

   a. have an argillic horizon but have no fragipan and have base saturation (by sum of cations) of less than 35 per cent at 1•25m. (50 inches) below the upper boundary of the argillic horizon, or 1•8m. (72 inches) below the soil surfaces, or above a lithic or paralithic contact, whichever is shallower; or

   b. have a fragipan that

      (1) meets all of the requirements of an argillic horizon or that has clay skins more than 1mm. thick in some part, and

      (2) has base saturation (by sum of cations) of less than 35 per cent at a depth of 75 cm. (30 inches) below the upper boundary of the fragipan;

2. have a mean annual temperature of $8^{o}C$ ($47^{o}F$) or higher, and if mean summer and mean winter soil temperatures at 50 cm. (20 inches) or at a lithic or a paralithic contact, whichever is shallower, differ by $5^{o}C$ ($9^{o}F$) or more, have mean summer soil temperatures of $15^{o}C$ ($59^{o}F$) or higher if without an O horizon, or of $8^{o}C$ ($47^{o}F$) or higher if with an O horizon;

3. have no spodic horizon, and no oxic horizon unless it underlies an argillic horizon;

4. have no plinthite that forms a continuous phase within 30 cm. (12 inches) of the surface.

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