INSTITUTO DE EDAFOLOGIA Y FISIOLOGIA VEGETAL

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STUDY OF THE PHYSICAL PROPERTIES OF SOILS THROUGH INTERPRETATION OF AERIAL PHOTOGRAPHS

I

by

J. M. Albareda

and

A. Guerra, E. F. Galiano, F. Monturiol, J. G. Vicente

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Juan Jp. Herrero Isern

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ABSTRACT

The purpose of the research work proposed is the study of the physical properties of the soils by means of the interpretation of aerial photographs. This study is to be carried out in two years and thus it is not possible to give definite conclusions at the end of the first year, although the results we have obtained are highly satisfactory. In our opinion and after the experience of the first year, the working problem of the study of the physical properties of the soils through aerial photographs, can be examined from two different aspects. The first of them could be called the "deductive" method and consists in acquiring knowledge of the physical properties of the soils by means of successive interpretations of aerial photographs; through photo-interpretation we study the physical Geography of an area, its hydrographic net, natural vegetation and man-introduced cultivations, the forms of erosion and the nature of the geological material, All these interpretations, together with the climate, allow to "deduce" the nature of the soils of that area, as all the pedological processes which the different geological materials have undergone can be know perfectly well, which also shows the intensity of physical and chemical desintegration of the materials that form the starting point of soil formation.

During this first year the work has, in the main, been carried out in the field and in the laboratory; we have studied the soils and vegetation of two large, representative, areas of Spain, having mapped them -the soils series and the vegetation- with the aid of photo-interpretation in one case but not so in other case, the aim being to compare the advantages offered by aerial-photography interpretation on the science of soil. In both cases representative profiles have been taken for the purpose of testing in the laboratory the accuracy of the interpretations made in the field. These determinations have been made through granulometric analysis using the den-

simeter without destroying the carbonates, and also by means of the international method, that is to say destroying the carbonates, determinations having been made of plasticity and plastic index, real and apparent density, permeability, decay coefficient, soluble-salts contents and X-ray analysis of the clay fraction.

Thus we see that it is possible to know the physical properties of soils by "deducing" them indirectly from photointerpretation as they depend from a series of variables and factors which are known directly on the aerial photograph. These physical properties have also been studied in the laboratory, and we have carried out a great number of determinations which are specified in the conditions of the contract.

During the second year of the contract we will try to deduce the physical properties of the soil "directly from the aerial photographs by means of establishing dicotomic keys. This work will be carried out by the combination of the different methods of photo-interpretation, convergence towards evidence, induction and deduction, extrapolation and interpolation and analogy, with the real criteria and which are the important and elaborate part of a systematic study. Among those criteria we can mention as the most important those of a morphological order, those of vegetation, the shades of grey, the texture and the action of man. This work leads to the confection of the so called "clés" or keys, which can be used later on by non-specialized people which would only require a previous preparation in a short time. In pedology a "clé" is formed by a type-photo of a homogeneous and well defined pedological area and the detailed and precise description of its specific characteristics such as the aspects of the photograph, the importance of the shades, distribution of the hydrographic net, the nature of the vegetation, of the cultivation and the lithology, the morphologic details, forms of erosion and other micro-criteria.

For all this we shall use the aerial photographs of a 1:10,000 and 1:30,000 scales and will carry out the profound study of the soil types already known and which by their nature represent a large surface of the

Spanish soils. We shall complete the study of these physical properties by comparing them with the vegetation and cultivation, relief and geological material, all the variables which put together give the "forms of relief" of the aerial photographs, with the intention that these properties can be interpreted, as we say above, by technicians not specialised in Pedology.

We will also produce a key by which it will be possible to learn how by means of direct photo-interpretation it is possible to recognize the adaptability of each of the "forms of relief" and soils, to the principal applications, such as ways of communication, agricultural profit, possibility for carriage, passage and transport, building of airports and other buildings.

INTRODUCTION

Under this chapter, serving as an introduction, we start the exposition of the results and knowledge acquired with a view to solving a specific problem as is the one posed in the work entitled "Study of the physical properties of soils by the use of aerial photography". In other words we analyze all those aspects whose better knowledge will facilitate that task of interpretation. We may fix the question further by grouping these different aspects into a single one, a synthesis of the whole and which in actual fact is what the observer "sees": a landscape appears before his eyes and that concept, which arose for the first time in the brilliant mind of the great Humboldt, was later called geographical landscape and more recently natural landscape and defined by Hernández Pacheco as the synthetic manifestation of the geographical conditions and circumstances concurring in a same territoy, is the one we shall endeavour to develop in this introduction, separately analyzing the Calatayud and Chinchón areas, in which all the studies and observations making up the present work were conducted.

Before describing the zone corresponding to Calatayud we should like to indicate that within the large group of elements constituting the natural landscape we can make a sub-division by categories according to the order of importance and in this way we include as primary factors the lithological nature of the geological materials, "roquedo" of other authors, the types of natural vegetation and their formations, and the climatic elements that make up the different climates. We regard relief, hydrography, and luminosity or cloudiness of the ambient, as complementary factors. Finally as an accessory factor we include human action. We now pass to analyze some of these factors but for the sake of a better exposition and methodical arrangement of this introduction we shall firstly deal with all the aspects concerning the Calatayud region and then those of the Chinchón one.

CALATAYUD

Geology: The Calatayud zone studied corresponds to sheet 409 of the topographical national map to scale 1:50,000 edited by the "Instituto Geográfico y Catastral". The base sheet of our works corresponds to a second edition published in 1954 and brought up to date by the "Servicio Geográfico del Ejército" ("Army's Geographical Service"). The territory covered by this sheet belongs in its entirety to the province of Zaragoza and is bounded by meridians 1º 50' and 2º 10' East longitude and parallels 41º 20' and 41º 30' North latitude.

From a geological point of view the stratigraphy of the formations and lithology of the various facies is of fundamental interest, two aspects intimately connected not only with the landscape but, above all, with the formation of soils and which are characteristics that can be observed with relative facility on an aereal photography.

If we cast a glance at a general geological map of Spain, for instance at the 1:1,500,000 map, we may readily recognize at the Peninsula NE three large tertiaries, namely those of the Ebro, Duero and Tajo, the first one separated from the other two by a mountaineous group running in a North-west -South-east direction and which is called the "Celtibérico" system. This mountaineous system is constituted by two main ranges of which the Northernmost receives the name of Cadena or Cordillera Ibérica and the Southernmost is called Cordillera Hespérica. The former, which is the one concerning us, starts at the Sierra de La Demanda and shortly after entering the Zaragoza province becomes in turn subdivided into two branches separated by the Calatayud graben of tectonic origin, a depression which extends to Teruel and along which the river Jiloca flows. Upon observing the Calatayud sheet we see that its North-east end is occupied by the eastern branch of the "Cadena Ibérica" whilst the western branch is found at the southwest angle. Between them we can see the Tertiary depression of Calatayud, already indicated.

The oldest soils in the Calatayud sheet correspond to the Cambrian system, its three stages, Georgian, Acadian and Postdam, being shown, although there is no place where the Cambrian series forms a single profile. The oldest formations are found at the Jalón valley whereas the middle and upper Cambrian appears at the Jiloca valley.

The stratigraphic series of the Jalón valley, that is to say of the "Cadena Ibérica Oriental" is composed of the following horizons:

6.- Quartzitic sandstone ans sandstones (Daroca quartzite)

5.- Greenish-grey biotiferous phyllites (Huermeda shales)

4.- Calcareous dolomites and marls (Ribota dolomite)

3.- Variegated series of sandstones, shales and dolomites (Jalón variegated shales)

2.- Green shales and graywackes (Embid layers)

1.- Quartzites and puddingstones (Banbola Quartzite)

Series 1 and 2 correspond to the older part of the lower Cambrian whereas the rest belong to other upper stages of the lower Cambrian.

On the other hand the series corresponding to the "Cadena Ibérica Occidental" is as follows:

7.- Quartzites and shales (Ateca layers)

6.- Grey and bluish clayey shales and sandstones (Jiloca layers)

5.- Greenish or blueish marls ans sandstones (Villafeliche layers)

4.- Grey marls and also limestones or dolomites (Murero Marls)

3.- Whitish quartzites (Daroca quartzite)

2.- Grey clayey shales with biotite (Huermeda shales)

1.- Dolomites with marls (Ribota dolomites)

Levels 1, 2 and 3 belong to the more modern stages of the lower Cambrian, levels 4 and 5 to the middle Cambrian, and levels 6 and 7 to the upper Cambrian. We see that levels 1, 2 and 3 of the western series coincide with levels 4, 5 and 6 of the eastern series and by superposing the two series we shall have, therefore, the complete stratigraphy and this implies a thickness of more than 4,000 metres. Finally, by comparing the different levels an idea may be gathered of the conditions ruling in the Cambrian sea and which apparently have been considerable steady.

On the Calatayud sheet we do not find materials belonging to the Silurian, which are however present at other points in the Iberian chains but never with the extension of the Cambrian. Neither do we find in the studied sheet any representation of either the Devonian or Carboniferous. On the other hand the Mesozoic era is represented by the Trias, in a strong unconformity over the upper Palaeozoic, it being found at the area studied at Northeast angle and constituting the so called "Mores graben" an area of very complex tectonic and whose description is irrelevant to this work. This Trias is of German facies and hence it shows the three classic conventional stages, Buntsandstein, Muschelkalk and Keuper. The lithology is the typical one for these three stages: Red Sandstone, limestone and variegated marls but with some small variants, the main ones being the presence of an upper Buntsandstein in Röt facies represented by gypsiferous red clays and the characteristic that the Muschelkalk appears at the bottom in very thick banks and at the top in thin banks, well stratified and very rich in Rhizocorals, these small differences serving to establish, in this so dislocated zone, a division within the Muschelkalk. Finally the whole of the Trias series shows on its ceiling the typical Carniolas.

The largest extension of the territory studied corresponds, doubtless, to the Tertiary but there is in no other geological formation so much confusion as to the different stages of this era, partly due to the fact that the existing unconformities have not been recognized or perhaps they were not given the importance they deserve; but it must in particular be ascribed to the difficulty of demarcating with a petrographical criterion the several stages since they are almost devoid of fossils.

At any rate in this Calatayud Tertiary it is possible to recognize two groups separated by a clear unconformity: that is to say we distinguish in principle a lower Tertiary and an upper Tertiary. The lower Tertiary is of small extension, it is constituted by a series of well bonded conglomerates with levels of intercalated marls. This conglomerate is almost exclusively formed by calcareous stones, although some of them may be sandstones and, very rarely, paleozoic rocks. The upper Tertiary has scarcely being subjected to tectonic phenomena and because of this it occupies an almost horizontal arrangement distributed along extensive areas which even nowadays preserve their old boundaries. This upper Tertiary presents at the edges of the basin a marginal facies of thick elements, passing towards the interior to a calcareous facies and, further inside the basin, it becomes converted into a powerful series of gypsums. All this will explain -assuming that the basin represents the bottom of a closed lake- an endorrheic basin in which the deposited materials underwent a classification according to size for which reason the thicker and heavier elements were thrown down in the margin and the finer and lighter, sands and marls, settled further inside. The dissolved substances still contained in the water were settling at the centre of the basin and due to both endorrheism and evaporation the concentration of dissolved salts was increasing at the same time. As soon as a calcium carbonate reached its saturation point it precipitated in the form of limestone, and then calcium sulphate would separate forming the beds of gypsum. At the center of the basin, for instance between Terrer and Calatayud, we find in addition to gypsum other chemical precipitates such as epsomite and glauberite.

As regards the age of the Tertiary deposits, the small representation found of the lower Tertiary must belong to an age ranging from the middle Oligocene to the Aquitaniense. On the other hand the upper Tertiary of the Calatayud graben belongs almost without a doubt to the Miocene, from the Sarmatiense to the Pontiense, as is proved by the remains of mammals (Mastodon Longirostris and Hipparión gracile) found near Daroca in a marly layer underneath the limestone of "Los Paramos", which has enabled us to fix the Pontiense age of that formation.

Finally more recent formations are also found, such as some "plasenciense" conglomerate in other words a pliocene formation, old diluvial terraces at different levels, erosion glacis and present river-deposits specially those of the Jalón.

Climate:

We now proceed to describe the climatic characteristics of the Calatayud area; climatic studies are always lengthy and complex due to the multiplicity of metereological phenomena to be analyzed and to the circumstances to be borne in mind for their explanation. That is to say we may define the climate as the result of the interaction of metereological factors influenced by geographical characteristics. In these lines we shall not endeavour to make a true metereological study but only to give a general idea of the climatic characteristics of the Aragonese region where the materials of the Calatayud sheet are located and which idea will enable us to appreciate its influence on the development and evolution of the soils.

Aragon occupies a special position in the Iberian Peninsula. "Welded" to the Castillian Meseta on one side and encircled by mountains on all other sides, it is however close to two large water masses of quite different climatic characteristics. On one side the Atlantic which behaves as a cold sea, where the polar-front cyclone and the Azores anticyclone originate. On the other side the Mediterranean, far more warmer, and where a nucleus of low pressures is formed centering on the Baleares or Gulf of Genoa according to the seasons. To these three elements, Azores anticyclon, North Atlantic cyclones and Baleares depression we must add the influence of the central spanish mesetas, solid masses of high lands which behave as a small continent.

All these circumstances led to the distinction, within the Aragon whole, of three different types of climates or climatic regions, two of which are more or less represented in the Calatayud area. One of them is the climatic zone of the Iberian Cordilleras, which is on the whole an area of continental climatologic regime, of extremely cold winters, copious snow and occasional rains during a not very severe summer. The average annual rainfall always exceed 500 mm and the winter averages are the lowest in the Peninsula.

The other area is the climatic area of the llanura Ibera (Ibera plain) or Ebro depression, a well defined climatic region, also of extreme continental type, with very cold and considerable dry winters but of extremely hot and also very dry summers, rainfall being generally below 400 mm.

In what follows we are setting out observations taken at the Calatayud metereological station for 20 uninterrupted years:

Height above sea level 534 metres, mean annual temperature 13.5º C; rainfall 453.7 mm; mean annual oscillation 11º and days of rain 75. Lang's Index $\frac{P}{T} = 33.5$. Martonne's Index $\frac{P}{T \times 10} = 19.3$. Dandin's Index $\frac{T\ 100}{P} = 3$. In these indexes P is the annual rainfall in mm and T the mean annual temperature. (Table I).

If we were to compare all these data with those of other metereological stations which although outside the Calatayud sheet may be regarded as relative close - we would deduce that the Calatayud climate is somewhat different to that of the two general climatic zones, Sierra Iberica and Ebro depression. This is a consequence of the geographical circumstances, as we may consider the area under study to be a small depression surrounded by mountains but these, being mere foothills, do not participate of the typical climate of the authentic Cordillera Iberica, neither is the Jalón depression similar to the large plain along which the Ebro flows. In general lines, in addition to the strong continental character we may note four very marked characteristics: in the first place the aridity, which although not reaching the values attained in the Ebro depression-in Zaragoza the Martonne's index is 12.5- is considerably accentuated. In the second place as a result of combinations of cold and stable air masses with cyclone winds we find large irregularities in the "regimen", intensity and distribution of precipitations, as may be seen from the figures set down in the above general table, rainfall is decidedly equinoctial with a minimum in the Autumn and another in the Spring; in the third place as a result of its continental character, thermal contrasts between Summer and Winter are very pronounced and, lastly, it is worth noting the intensity and frequency of the winds particularly the North West wind, called "cierzo" in Aragón.

PERIOD: 1950-1963

	Mean values of maximum daily temperatures	Mean values of minimum daily temperatures	Mean annual temperature	Thermal Oscillation monthly average	Mean values of minimum monthly temperatures	Absolute minimum temperatures	Days of rain	Total precipitation in mm.
January	9,4	1,1	5,2	8,3	-5,2	-11,0	6	27,4
February	11,6	1,4	6,5	10,2	-4,3	-10,0	5	18,2
March	15,0	4,1	9,5	10,9	-1,9	-6,0	7	38,2
April	18,3	6,0	12,1	12,3	1,0	-2,0	7	36,8
May	22,7	9,4	16,0	13,3	3,9	-2,0	7	54,1
June	26,3	11,2	18,7	15,1	7,9	5,0	8	59,2
July	30,8	15,3	23,0	15,5	10,7	8,0	4	28,5
August	29,8	15,0	22,4	14,8	10,1	8,0	4	22,0
September	26,4	12,7	19,5	13,7	8,2	5,0	6	55,7
October	19,7	8,1	13,9	11,6	2,0	0,0	7	40,7
November	13,7	4,1	8,9	9,6	-2,1	-4,0	7	34,0
December	10,2	2,2	6,2	8,0	-3,8	-13,0	7	38,9

SEASONAL DISTRIBUTION

	Days of rain	Total amount in mm.	Percentage of total rain
Winter	18	84,5	18,6
Spring	21	129,1	28,4
Summer	16	109,7	24,2
Autumn	20	130,4	28,8

Rain in July and August: 11%.

T a b l e I

Luminosity is very good, in line with the number of entirely clear days, without any cloudiness, and which may become 140 days in a year. Concluding these considerations we should like to emphasize another important aspect in the study of precipitations, namely the intensity with which they take place, usually calculated by dividing the rainfall by the days of rain; but this figure does not reflect the reality, for in this region the most intensive rains take the form of storms and although their duration is short it is sufficient to bring the ramblas into operation with the result that sometimes communication-ways are cut as happens to the Madrid-Zaragoza road at Ateca.

Hydrography:

The most important river crossing the Calatayud sheet is the Jalón, a river of great geographical importance since it forms a depression cutting across the whole of the Sierras Ibéricas and it constitutes the most important flow of water discharging into the Ebro at its right bank.

The right slope of the Ebro is fed by waters from the Sistema Ibérico, which is lower and less irrigated than the Pyrenean. The most important of these tributaries is on the right side, as we have said, the Jalón which entirely cuts, by means of narrow gorges excavated in very hard rocks, the two series of parallel sierras flanking the Calatayud trough, thus being able to reach the Ebro from its Castilian origin. The Jiloca which joins the Jalón at Calatayud is on the other hand a river of entirely Iberian course. In what follows we shall endeavour to set down, briefly the "regimen" of these rivers but remembering before the meaning of the terms which will be used. The elements of the fluvial "regimen" are the aboundance of flow, inter-annual irregularity and seasonal variations in the height of its waters.

The flow if absolute is expressed in cubic metres per second and the relative flow by liters per second per square kilometer. When many years of observations are available the value of the flow is termed "modulo" ("modulus"). This is approximately an average and it is the flow that flowing steadily throughout the period of observation would have totalized the total amount of water actually passing through the river of the gauging station during that lapse of time.

The inter-annual irregularity is expressd by a coefficient obtained dividing the maximum annual flow during the observed period by minimum flow during that same period.

Seasonal variations, the most important element of the "regimen", are expressed by a monthly coefficient obtained by successively diving the average flow in each month by the annual "modulus". (Table II).

In general and except for the Jalón and Jiloca, all the remaining water courses we found in this Calatayud area are of small flow, the most important among them being the Manubles, Ribeta and the Perejiles, the three being tributaries of the Jalón.

All these rivers are of high irregularity as pertains to a non-oceanic pluvial feed. Rain is more frequent towards the mountaineous region in the North West and its influence is noted in the Jalón itself in the curve of seasonal variations with a melting peak in March and snow retention in January. In addition to this feature of the Jalón we shall mention another displayed by the Jiloca: of its flow of 3.77 m^3 when passing Daroca half of it is due to the "Fuente de Cella", located in the neighbourhood of Teruel and which is one of the largest resurgences of the Peninsula. To end these considerations relative to the hydrography of the Calatayud sheet we shall point out that most of the Jalón and Jiloca tributaries are of a torrential regimen, namely "ramblas", caused by the continental character of the climate and rainfall. The volume of transport materials following intensive rain is such that powerful dejection cones are formed at the bottom of the valleys and which, in the case of the Jiloca, are burying its best meadow soils.

Relief:

The relief of the studied Calatayud area is in general rugged since this region participates of the foothills of the Iberian cordilleras, which

REGIMEN ELEMENTS

River and station	Upper basin in Km^2	Average flow m^3/seg.	Average flow 1/s. y Km^2	Seasonal variations Máx. 1io	Id. 2io	Min. 1io	Id. 2io	Inter-annual irregularity
Jalón (Jubera)	202,4	0,45	2,22	1,71 (Mr)		0,53 (Ag)		3,8
Jalón (Cetina)	1.820	4,90	2,69	1,95 (Jn)	1,70 (Ab)	0,22 (Ag)	0,55 (D)	10,03
Jalón (Calatayud)	6.828	20,79	3,04	1,27 (F)		0,51 (Ag)	1	4,47
Jiloca(Calamocha)		2,88		1,55 (D)	1,35 (F)	0,59 (Jl)	1,28 (Ja)	1,88
Jiloca(Daroca)	2.178	3,77	1,73	1,55 (D)		0,31 (Ag)		10,06

Table II

group follows at this end of the Zaragoza province a NW to SE line with a medium height ranging from 700 to 1100 metres. The foothills are located at the N.E. and S.W. ends of the Calatayud sheet confining a zone occupied by Tertiary and Quaternary materials, but this central space is not a uniform plain because of the strong erosive action of its rivers and streams which have excavated these materials dislocating the whole ensemble. Doubtless the most rugged are corresponds to the North East end where the maximum heights are also situated. We may say that there is here a single line divided into two stretches by the Jalón river; the Westernmost part corresponds to the Sierra de la Virgen, its more important heights being the peaks of San Cristobal, Pedro Fuentes, Morés, Los Pedrosos, Almeno and El Carrascal, the maximum altitude being at Mingoaranda with 1283 metres. The Eastern part belongs to the Sierra de Vicort with some peaks such as Noguerilla and La Concha, also more than 1,000 metres high.

CHINCHON

The land included in the Chinchón sheet, Number 606 of the "Mapa Topográfico Nacional", third edition, 1948, is situated between meridians 0º 10' and 0' 30' East longitude and parallels 40ºand 40º 10' North latitude and corresponds to the provinces of Madrid and Toledo; the river Tajo, flowing from East to West, being almost always the natural boundary between the two provinces.

Geology:

In the domain of the Chinchón sheet we find only grounds belonging to the Tertiary and Quaternary but there is no doubt that the largest extension corresponds to the Tertiary and, within it, to the Mioceno-lacustre, Miocene period, which is many aspects is similar to that of the Calatayud graben.

The upper stage of this Miocene is represented by Paramos limestone, a compact lacustrine limestone of conchoidal fracture and very fragile, it is of clear coloration and at some places in the Tajo basin, to which the

Chinchón area belongs, it reaches from 20 to 30 metres of thickness. In some places this limestone shows calcite rhombohedra due to subsequent crystallization and together with them in some crevices it is occasionally possible to see pyrolusite dendrites.

Under this limestone level there is one of typically detrital facies and whose lithology is somewhat complex. It is a continuous horizon although little uniform laterally. Fundamentally it is formed by marly and sandy sediments, but as other places of the basin are also argyllaceous hence the name: sabulose clay level, by which this horizon is designated. As above stated the heterogeneity of the strata is large, for we find sands, marls of several colorations, fine marly sands, limestone layers, highly-calcareous hardened white marls, gypsiferous sandstones with glauconite and, sporadically, fine levels of gypsum. But these gypsums are systematically crystalline and specular as if of second formation, in other words recrystallized.

At the contact zone between this detrital level and the upper level of the compact limestone the character of the sediments is less sabulose and here is where all geologists mention silica concretions either in zonal form, as opals and agates, or in a less organized form such as flint. Also at the higher limit of this horizon it is possible to find minerals that in other places of the basin become true deposits, among which we may mention sepiolite, magnetite and even manganiferous deposits.

Under the argyllaceous-sabulose detrital horizon we find another one of quite different characteristics. It begins by a layer of gypsiferous marls which soon give way to gypsums , appearing in large banks, and which are compact and of alabastrine appearance in some cases, indubitably they are of first formation.

Whereas there is unanimous opinion as regards the upper limestones since they are regarded as Pontienses by all geologists, in the case of the Geognosis of the lower horizon there was total disparity of opinions for a very long time. But taking into account several considerations, sedimentary, geotectonic and principally paleontologic, we may consider the Vindoboniense to end at the lower gypsiferous horizon since it exhibits the "Mastodon Angustidrins", all the other detrital and calcareous levels exhibiting the "Hipparion gracile" being therefore Pontienses.

The Quaternary is represented on the Chinchón sheet by pleistocene and holocene grounds. To the first of these correspond the various terrace levels some of which have boulders cemented with an arenaceous calcareous material these boulders being quartzites as a rule. Both the present alluviums, constituted by fine marly sands, and the terraces are in the majority due to materials received from the river Tajo which traverses the Chinchón sheet at its eastern part.

<u>Climate:</u>

Broadly speaking the Chinchón climate is that of the Central Spanish Meseta. This meseta being surrounded by mountains and being distant from the sea has a typically continental climate and hence with abrupt contrasts. Winter is cold with long periods of frost although snowfalls are neither very often nor very copious. Summer is fiery hot and this contributes to the dryness of the ambient due to the scarcity of rainfall; this lack of periodical rains during this part of the year is interrupted only by accidental storms. Autumn is the more regular season of the year, best atmosphere and of more uniform climatology. During its course the Summer heat is gradually descending and Winter makes its presence by degrees without any sudden changes. On the other hand the Spring varies a lot; very often it is absorbed by the long Winter and by the Summer which sometimes begins early. Total annual rainfall is not very large, for as a rule it never reaches 450 mm. a rainfall usually distributed in two maximum periods, one during the Winter and the other in the Spring. These two maxima are usually separated by a short drought in the Winter but the long drought coincides with the Summer, for the total rainfall during the months of July and August does not exceed 2%.

The figures given in the Table III correspond to observations taken at the Getafe metereological station, only a few kilometres from Chinchón, during the period 1950-1963.

The altitude of Getafe metereological station is 623 metres, mean annual temperature 14.4º, rainfall 404.2 mm., mean annual oscilation 11.3º and days of rain 76. Lang's index $\frac{P}{T} = 28$, Martonne's Index $\frac{P}{T.10} = 16.5$, Dandin's Index $\frac{T.100}{P} = 3.5$. (Table III)

Hydrography

Physiographically, in the Chinchón sheet the whole land appears subordinate to the valley of the river Tajo, a fluvial stream traversing it at its Southern area in a direction practically from East to West, giving rise to a local base level which entirely drains the hydrographic network of the territory. This river and its tributary, the Tajuña, located at the North East end of the sheet are the only two important streams to be appreciated in this area since the remaining of the hydrographic network is limited to deep ravines which transport water after a winter season.

The Tajo originates in the Cordillera Ibérica in the orographic knot constituted by the Sierra of Albarracin, and the Montes Universales, specifically the "Muela caliza de San Juan". From its birth to its confluence with the river Guadiana, it runs describing a very wide curve, over soils of widely different lithological nature and which in general are rugged and rocky, but from that confluence the river advances trough Miocene marly and calacareous soils following a South Easterly course to Villamanrique del Tajo, already in the Chinchón sheet, where it takes a Westerly direction, passing between the tablelands of Colmenar de Oreja and La Mesa de Ocaña; the fluvial stream deeply erodes the left bank where high vertical bluffs have been produced but upon reaching Aranjuez the river undergoes a large widening into which disembogues the important fluvial branch formed by the Tajuña, Henares, Jarama and Manzanares. This fan-shaped fluvial branch is due to the amphitheatre

PERIOD: 1950-1963

	Mean values of maximum daily temperatures	Mean values of minimum daily temperatures	Mean annual temperature	Thermal Oscil- lation monthly average	Mean values of minimum monthly tem peratures	Absolute minimum temperatures	Days of rain	Total pre cipitatio in mm.
January	9,2	1,1	5,1	8,1	-4,8	-8,0	7	41,1
February	11,7	1,8	6,7	9,9	-3,7	-10,6	6	36,9
March	15,3	4,2	9,7	11,1	-1,0	-4,0	9	39,4
April	18,4	6,0	12,2	12,4	0,8	-1,2	8	39,8
May	22,2	10,7	16,4	11,5	4,1	-1,1	8	43,3
June	27,7	14,0	20,8	13,7	7,9	5,0	5	22,4
July	32,3	17,5	24,9	14,8	12,1	9,0	2	6,4
August	29,7	16,7	23,2	13,0	12,0	8,0	3	2,0
September	27,0	13,8	20,4	13,2	8,4	3,6	5	33,9
October	19,9	9,0	14,4	10,9	2,7	-0,2	7	40,8
November	13,9	4,4	9,1	9,5	-1,3	-1,2	8	44,9
December	10,0	1,9	5,9	8,1	-3,8	-10,0	8	40,8

SEASONAL DISTRIBUTION

	Days or fain	Total amount in mm.	Percentage of total rain
Winter	21	131,3	32,5
Spring	25	122,5	30,3
Summer	10	30,8	7,6
Autumn	20	119,4	29,6

Rain in July and August: 2%

Table III

mountaineous edges of the basin in which edges all these fluvial streams originate. In this Chinchón area the Tajo forms, in general, a typical trough-shaped erosion valley, it is wide, somewhat asymetric, and of gentle gradient since this stretch of the course does not usually exceed 1 per 1000. Along this valley the meanders wind about time after time frequently giving rise to abandoned beds. The fluvial regimen of the Tajo is reflected in the following table, which shows the large variations in flow typical of all the Meseta rivers. (Table IV).

The other important river we observe on the Chinchón sheet and which, as already stated, is a tributary of the Tajo, is the Tajuña which originates in the high moorland North of Cifuentes in the Guadalajara province from which it advances through the valley, in the form of a trench, in a South-Westerly direction joining the Jarama at Ciempozuelos and together they flow out into the Tajo in the vecinity of Aranjuez after travelling 130 kilometres. On examining the monthly average-flows of this river, a season of high waters would be noticed, beginning in February and ending in April, a Summer minimum, very pronounced in August, and a secondary maximum during the Autumn. A great irregularity from year to year would also be noticeable. These data clearly show that the regimen of the river Tajuña is of the pluvial type particularly dependant on the Spring and Autumn rains.

Relief:

The Chinchón territory exhibits in part the relief and topography proper to the Castilian meseta, a country to a large extent of tabular structures and reliefs demolished by various erosive actions. In other words it shows the morphology characteristic to the so called paramos, high calcareous plateaux of an average altitude of about 750 metres and where the main urban nuclei are seated. There is great uniformity of the landscape, broken only by the course of the River Tajo the descent to which is sometimes gradual, the transition being really abrupt at other times, a declivity due to the erosive action of the Tajo, the difference in level between the paramo

Monthly averages in cubic metres for second of River Tajo flow when passing through the Azucaica ganging station

Years	January	February	March	April	May	June	July	August	September	October	November	December	Annual average
1920	73,9	92,3	169,5	136,4	68,4	56,4	38,0	20,0	19,0	34,6	22,6	63,5	65,7
1921	55,0	54,2	63,3	36,0	61,6	107,8	27,3	18,3	24,5	45,1	27,3	52,0	47,7
1922	42,7	108,7	70,7	143,0	57,3	38,7	24,0	16,6	22,6	38,2	71,9	38,9	56,1
1923	56,9	62,0	128,6	103,3	52,9	29,0	21,8	16,7	22,8	19,5	51,7	124,8	57,5
1924	87,9	156,5	225,5	274,6	79,4	29,7	20,5	18,0	19,4	18,7	26,2	60,2	84,8
1925	32,1	37,7	70,8	56,9	50,1	57,6	27,7	16,2	17,0	20,0	31,5	195,2	51,1
1926	68,3	250,2	92,7	127,3	118,2	36,3	24,5	16,5	23,4	55,0	195,0	165,9	97,4
1927	73,5	54,2	151,7	113,5	67,3	38,8	25,6	17,2	17,5	25,0	76,0	238,4	74,9
1928	140,6	81,9	209,3	250,0	198,7	80,1	37,5	28,6	46,3	58,6	46,3	39,8	101,5
1929	51,5	93,8	107,3	43,3	69,2	50,0	28,2	20,1	31,5	27,3	34,0	90,0	53,9
											Ten-year average.......		69,1

Average flows of the Tajuña in m3 for second at the Titulcia ganging station

1917	5,8	1924	5,3
1918	1,2	1925	2,8
1919	8,5	1926	4,3
1920	4,3	1927	3,5
1921	2,0	1928	8,6
1922	1,5	1929	1,3
1923	2,0	1930	3,5

T a b l e IV

and the present river-valley being about 230 metres. As we have said since this is not a mountaineous region there are no authentical accentuated reliefs but only some hills bearing witness to the erosive action of the streams that by excavating the soft materials originate these small accidents, almost always topped by hard "Pontienses" limestones. Hence the height of these hills is usually lower than the average altitude of the upper meseta and we may thus mention as more characteristic, among several other examples, the following peaks: Caridad (641 m.), Mata Asnos (735m.), La Pedrea (645 m.),Plata (725 m.) and El Palomar (740 m.), all of them below the height of 753 metres of the belfries at the Chinchón and Colmenar churches.

VEGETAL LANDSCAPE

The vegetal landscape of the Calatayud zone varies considerably within the relatively small limits which enclose its surface. The existence of a rugged topography and the presence of substrata of different chemical nature necessarily show themselves in the different regional types of vegetation, within the wide type of Mediterranean vegetation to which a great part of our country belongs.

Woods are not numerous nor they do occupy large extensions; they are concentrated in mountainous districts unsuitable for cultivation because of their topography or poverty of their soils. In this case, the two mountainous chains crossing the territory in a NW-SE direction are covered with arboreous vegetation in a seminatural state, helped by forestal conservation performed by the forestry services. The natural arboreous vegetation of these woods has disappeared to a great extent, having been progressively replaced by plantations of various pine species. However, in the North part of the eastern mountainous chain, at the foothills of Sierra de la Virgen and at the middle and high parts of Sierra de Vicort, it is possible to find testimonies of the constituents of natural forest such as oak trees, cork trees and holm-oaks, forming communities which will be detailed hereinafter.

In the Western cordillera, the poverty of soils and human influence have taken the arboreous vegetation to its complete destruction and the present woods are exclusively pine groves in the process of reforestation.

The Armantes district, North of the Calatayud town, is also extensively reforested with Pinus halepensis, although their growth is slow and the pine-trees have aged without acquiring their normal height, due to the dryness and poverty of the soils on which they grow.

The destruction of woods has caused the existence of numerous areas covered by bush in a more or less degradated condition and which are devoted to pastures or are simply waste land or abandoned cultivations. Depending on the degree of intensity of the pasturage, or on the time during which it remains abandoned, the bush may be more or less degraded, although it is always in an advanced stage of degradation. We may particularly mention those bushes growing on shales, calcareous marls or gypsiferous marls, the various communities being differentiated by the species that constitute them, in particular those growing on gypsiferous marls display a characteristic gypsicolous flora.

The herbaceous vegetation is found disseminated in a discontinuous form among degraded bushes, but without forming dense communities that might resemble prairies. It is only in saltish grounds located east of the town that small spots of herbaceous vegetation are found constituted, in the main, by plants which adapt themselves to saline grounds forming dense although discontinuous prairies, subjected to their edaphic requirements.

Among unirrigated soils cultivations a prominent role is played by cereals, vine yards and olive groves. All the ondulated districts situated among mountainous areas are covered with these cultivations. Olive-trees in places specially protected to prevent the heavy frosts. Almond-tree cultivations are also found with some frequency in mountainous districts of poor soils.

The alluvials zones are occupied throughout their length by grounds devoted to orchard cultivation and fruit-trees.

The vegetal landscape of the Chinchón sheet shows a greater monotony, due in the main to the scarcity of forestal vegetation which is confined to small areas scattered about the district. Woods remain as relics in those places where the poverty of the soils will not allow a remunerative cultivation. It is a homogeneous type of highly degraded oak-holm wood, with "sotobosque" very poor in species and found over all types of soils.

In some waterways, ravines and wet places, facing northwards, small artificial oak-holm groves may be found, of which Quercus lusitanica also forms part as well as some species of Populus but these formations are rare, of very small dimensiones and not cartographica.

In the whole of the district there is only one wood, in a small spot near Belmonte de Tajo, with Pinus halepensis from an old reforestation.

The banks of the river Tajo, with its clay or gypsiferous marl slopes, are for the most part covered with a degraded bush plentiful in rosemary and which sometimes reaches considerable density and height. However, in places of excessive gradient or highly pastured, the bush has become degraded to the "tomillar" condition with few annual plants. This degradation is far larger in either poor or gypsiferous soils where gypsicolous plants thrive.

The top of the hills is practically flat and they are the seat of cultivation on both sides of the river Tajo. In the eastern part a district covered by "dehesas" is prominent; these "dehesas" are places in which part of the original oak-holm trees have been preserved and whose soil is cultivated for cereals of pasture. The rest of the district is devoted to the cultivation of olive-trees, almond-trees, vines or cereals.

The "vegas" of Tajo and Tajuña rivers are completely covered by orchards and fruit-tree cultivations, mostly irrigation cultivation.

SOIL PROFILES

COLMENAR SERIES

C-I PROFILE

Locality	Colmenar de Oreja
Position	Villamanrique to Colmenar Road -Km. 20.500
Altitude	720 m.
Topography	Gently undulated
Vegetation	Clear Quercus Ilex wood
Original material	"Pontienses" white greyish limestones
Drainage	Good
Profile development	ABC
Type of soil	Calcareous brown (Brown Mediterranean soil)

Depth (cms.)	Horizon	Color	Description
0 - 5	C-I-A	7.5 Y R 4/4	Limy-sandy, of regular organic matter, with granular structure, slight consistency, good permeability, limestone fragments at the surface and remains of leaves.
5 - 40	C-I-B	5 Y R 4/4	Limy, little organic matter, with polyhedral subangular structure, medium consistency, good permeability, coating and calcareous nodules.

Observations

Large biological activity

VILLACONEJOS SERIES

C-II PROFILE

Locality	Colmenar
Position	Colmenar to Villaconejos road - Km. 6
Altitude	660 m.
Topography	Undulated
Agriculture	Vines, olive-groves and cereals
Original material	Chalk marl
Drainage	Good
Profile development	A/B/C
Type of soil	Gypsum brown

Depth (cms.)	Horizon	Color	Description
0 - 20	C-II-A	10 Y R 6/1	Sandy with regular organic matter of little developed grumous structure, little consistency, good permeability
20 - 60	C-II-B	10 Y R 6/2	Sandy with little organic matter, almost without structure but grumous and little consistency
more 60	C-II-C	White	

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VILLAMANRIQUE SERIES

C-III PROFILE

Locality	Villamanrique
Position	Fuentidueña to Villamanrique Road -Km. 5
Altitude	560 m.
Topography	Gently undulated
Agriculture	Cereals
Original material	Sandy diluvial deposits
Drainage	Good
Profile development	A/C
Type of soil	Terrace brown

Depth (cms.)	Horizon	Color	Description
0 - 15	C-III-A	10 Y R 6/3	Sandy with regular organic matter, crumby structure, good permeability and slight consistency, having carbonates.
50	C-III-B	10 Y R 8/4	Sandy of polyhedral structure, medium consistency and good permeability, carbonates present.
100	C-III-C		Sandy, of polyhedral structure, medium consistency and good permeability, carbonates present.

Observations

Soil without visible evolution

TAJO SERIES

C-IV PROFILE

Locality	Villamanrique
Position	"De la Barca" road
Topography	Flat
Vegetation	Black poplars grove
Agriculture	Cereals, unirrigated land, vines
Original material	Alluviums
Drainage	Good
Profile development	A/C
Type of soil	Young alluvial

Depth (cms.)	Horizon	Color	Description
0 - 20	C-IV-A	10 Y R 5/3	Limy with considerable organic matter, well developed polyhedral granular structure, medium consistency and good permeability.
20	C-IV-C	10 Y R 6/3	Sandy without organic matter, or structure, no consistency and good permeability.

Observations

Young soil. Normally there is no A horizon.

TAJO SERIES

C-V PROFILE

Locality	Colmenar
Position	Km. 15.500 (Arroyo Valdepuerco)
Topography	Flat
Vegetation	Rushes
Original material	Chalk alluviums
Drainage	Medium
Profile development	$A_o/A_1/S_a/C$
Type of soil	Salty humic alluvial

Depth (cms.)	Horizon	Color	Description
0 -20	C-V-Ao	10 Y R 4/2	Limy with plenty of organic matter, granular structure, medium consistency and medium permeability.
20 - 75	C-V-A_1	2.5 Y R 3/2	Limy with copious organic matter, polyhedral structure, medium consistency and slight permeability.

Observations

Efflorescences appear at 25 cms.

COLLADO SERIES

C-VI PROFILE

Locality	Colmenar de Oreja
Position	Camino del Collado (Collado road)
Altitude	630 m.
Topography	Gently rugged
Vegetation	Rosemary, thyme
Agricoulture	Vine, olive groves
Original material	Limestone
Drainage	Good
Profile development	$A_0/A_1/C$
Type of soil	Xerorendzine

Depth (cms.)	Horizon	Color	Description
0 - 20	C-VI-A_0	10 Y R 6/2	Sandy-limy, regular organic matter, granular little developed structure, weak consistency and good permeability.
20 - 40	C-VI-A_1	10 Y R 6/2	Sandy-limy, little organic matter, little developed granular structure, weak consistency and good permeability.

Observations

Limestone fragments throughout the profile.

ARMANTES SERIES

Z-I PROFILE

Locality	Calatayud
Position	Camino del Maño Maño (Maño Maño Road)
Altitude	820 m.
Topography	25% Rugged
Vegetation	"Gemista, rosemary, thyme and pine woods
Original material	Marl, sandstone and limestone alternation
Drainage	Ext. good. Int. medium
Profile development	A/B/C
Type of soil	Brown calcareous soil on marl and sandstone

Depth (cms.)	Horizon	Color	Description
0 - 30	Z-I-A	10 Y R 6/2	Sandy-limy, with regular organic matter, of granular structure, medium consistency and good permeability.
30 - 60	Z-I-B	5 Y R 5/6	Limy-sandy, of little organic matter, sub-angular structure of small polyhedra, medium consistency and good permeability.
60 - 100	Z-I-C		Limy-clayey of polyhedral-laminated structure, with medium consistency and good permeability.

Observations

There are limestone rocks throughout the profile. White crystalline efflorescences. The Maño Maño and Armantes region is highly eroded. They are alternations of red marls, sandstones and limestones giving calcareous brown soils as this one and erosion rendzines and lithosoils forming a complex which cannot be separated.

VILLARROYA SERIES

Z-II PROFILE

Locality	Cervera
Position	Villaluenga to Cervera Road-Km. 4.5.
Altitude	786 m.
Topography	Highly undulated
Vegetation	"Gemista"
Agriculture	Cereals
Original material	Red marl
Drainage	Int. bad
Profile development	(A)/C
Type of soil	Non-developed young erosion soil

Depth (cms.)	Horizon	Color	Description
0 - 5	Z-II-A	7.5 Y R 6/4	Limy-sandy, little organic matter of highly developed granular structure, medium consistency and medium permeability.
5 - 100	Z-II-C	5 Y R 4/3	Limy of platty structure, strong consistency and little permeability.

Observations

Stones at surface. Horizon: D= Conglomerate.

CALATAYUD SERIES

Z-III PROFILE

Locality	Calatayud
Position	"Camino del Gurugu" (Gurugu Road)
Altitude	620 m.
Topography	Undulated
Vegetation	Thyme, helianthemus
Original material	Gypsums and chalk marls
Drainage	Good
Profile development	(A)/C
Type of soil	Gypsum rendzine eroded in lithosoils area

Depth (cms.)	Horizon	Color	Description
0 - 5	Z-III-A	10 Y R 7/1	Sandy-limy with little organic matter, non-developed structure weak consistency and good permeability.
more 5	Z-III-A	10 Y R 8/1	Sandy-limy, without organic matter, or structure, weak consistency and good permeability

Observations

This profile was taken South of Calatayud in an area eroded throughout, they are gypsum lithosoils. Limestone present in hillocks.

VICORT SERIES

Z-IV PROFILE

Locality	Calatayud
Position	Forest road branching off at Km. 244.500
Altitude	950 m.
Topography	very rugged
Vegetation	Heath, pine groves, formerly Quercus
Original material	Sandstone and quartzite
Drainage	Good
Profile development	A-B-C
Type of soil	Brown earth on quartzose sandstone

Depth (cms.)	Horizon	Color	Description
2-30	Z-IV-A	10 Y R 8/3	Sandy with little organic matter, micro-granular structure, little consistency and good permeability.
30	Z-IV-B	7.5 Y R 5/6	Limy, with little organic matter, highly developed grumous-polyhedral structure, of medium consistency and good permeability.

Observations

Somewhat degraded acid brown earth, forestal and gradient profile. Scarcely any humification. One A_{00} and one A_0 are undecomposed. The true humus horizon of brown earth is missing. In the profile IV region almost everything is litho-soil and quartzite ranker.

POZAS SERIES

Z-V PROFILE

Locality	Calatayud
Position	"Camino Maño Maño" (Maño Maño Road) Km.5.5
Altitude	880 m.
Topography	Very rugged
Vegetation	Pine grove reforestation
Original material	Limestones, marls and some chalk
Drainage	Good
Profile development	A/C
Type of soil	Rendzine of marly-calcareous-gypseous mull

Depth (cms.)	Horizon	Color	Description
0 - 30	Z-V-A	10 Y R 6/2	Limy, aboundant organic matter, well developed granular structure, medium consistency and good permeability.
30	Z-V-C	White	As above.

Observations

Sometimes there is a Ca horizon. Stones throughout the profile. Continuous-rock outcrops.

ATECA SERIES

Z-VI PROFILE

Locality	Viver de la Sierra
Position	At 1 Km. from Vivèr de la Sierra
Altitude	950 m.
Topography	Very rugged
Vegetation	Quercus, Cistus, Lavandula
Agriculture	In very small valleys, oli‑‑ gr‑‑es and rye
Original material	Slate
Drainage	Good but excessive at surface
Profile development	A/B/C
Type of soil	Brown earth on slate (beside sandstone quartzite)

Depth (cms.)	Horizon	Color	Description
0 - 5	Z-VI-A	10 Y R 6/2	Sandy-limy, with copious organic matter of grumous structure, weak consistency and good permeability.
5 - 25	Z-VI-B	10 Y R 7/3	Sandy-limy, little organic matter grumous structure, weak consistency and good permeability.
25	Z-VI-C		Slate

Observations

All the soil is very stony, particularly the B soil which has an 80% of slate fragments.

SEDILES SERIES

Z-VII PROFILE

Locality	Calatayud
Position	Dehesa de Inogés road
Altitude	640 m.
Topography	Flat
Vegetation	Lavender and chick pea
Original material	Crusts and sediments on polygenic alluviums
Drainage	Good
Profile development	A/C
Type of soil	Brown, of calcareous crust on alluvium terraced

Depth (cms.)	Horizon	Color	Description
0 - 5	Z-VIII-A	10 Y R 5/2	Sandy of regular organic matter, non-developed grumous structure, weak consistency and good permeability with large biological activity.
5 - 25	Z-VIII-B	10 Y R 5/3	Sandy-limy, of little organic matter undeveloped structure, very weak consistency and good permeability.

Observations

Stones at the surface. Have hardly been rolled.

STUDY OF DIFFERENT SOILS SERIES

CHINCHON SOILS

Colmenar Series

These soils have been formed on hard calcareous rocks which stratigraphically correspond to the higher level of the Miocene in this region. These are soils of A/B/C profile in which the A horizon has normally disappeared as a result of human action, so that on simply looking at them the B horizon, of colour 5 Y R 4/4, is always seen at the surface. The series belongs to the Great Group Mediterranean Redish Brown soils, they are highly developed soils but surface erosion and human action through workings have brought to their surface fragments of the calcareous rock. At places protected against erosion the soil is deeper and the colour becomes reddish, a detail noticed in aerial photography. The C-1 profile shows a humus horizon due to the fact that it was taken in a small Quercus Ilex wood. The transition from the B horizon to the rock is very abrupt for which reason the soil is highly influenced by the character of the rock.

The humus horizon, when it exists, is of the Mull calcareous type with an average content of 5 % and a pH of about neutral. The depth of this horizon is from 5 to 8 cms, of highly developed grain-type structure. The B horizon, of about 35 cms thickness, is generally highly calcareous on account of workings, has medium texture and passes without transition to the original material which is a very pure limestone.

Villaconejos Series

These soils whose morphology is described in profile C-II, are formed on sandy chalk marls, also of the Miocene age. As result of the nature of the original material and alkalinity of the profile, clay formation is prevented and there is no liberation of iron oxides, they are thus lithochromos soils. They belong to the Mediterranean Brown Soil Group of chalks and their physical and chemical properties and agricultural value are very much influenced by the contents in gypsum and calcium carbonate throughout the whole of the profile; because of this the structure is hardly developed and transition between horizons is very diffuse, it is difficult to distinguish them at first sight. The profile development is A/B/C but the humus horizon is also highly mineralized by the action of workings and cultivation and there are scarcely any morphological differences between horizons A and B.

Villamanrique Series

These soils are intimately connected with the Tagus river terraces which are preferently found at its right bank. These gravel deposits called "terraces" were formed during the Quaternary in the interglacial periods in which, due to the fast thawing of snow, large freshets of water were formed which dragged thick elements which were in turn deposited on the banks of the rivers when the water stream lost velocity, for which reason the origin of these sediments has a marked torrential character.

The soil consists of a fine material which became deposited on these gravels when the current lost considerable velocity for which reason the transition is very abrupt. These deposits are, as may be seen from profile C-III, of considerable thickness and have developed a A/B/C profile, the original material being the sediment itself and not the gravels which may be regarded as the D horizon.

Although the whole of the soil is highly calcareous, the B horizon is markedly developed, with a polyhedral structure developed "in situ" as a result of its paedogenesis. Liberation of iron oxides has not taken place because of soil alkalinity and for this reason the colours of the C and B horizons are the same; these two horizons have a very gradual transition, their only difference being a small change in their structure.

Tajo Series

These soils correspond to recent deposits of the rivers, principally that of the Tajo river, which originate soils of a great depth, with scarcely any development of edaphic horizons since they are very young soils; any variations found in the profile are due to changes in the sedimentation rate of fluvial waters. Agriculturelly these are very rich soils, and have been irrigation soils since the time of Roman domination.

They are soils of Ap/C profile in which the Ap horizon, an anthropic horizon caused by workings, is the only thing that may be seen at simple sight and it forms a top layer of about 35 cms.

The C-IV and C-V profiles have been taken in this series of soils which belong to the Great Group of alluvial soils. The C-V profile was taken at a zone where the vegetation suggested the existence of soluble salts; this profile does not belong to the alluviums of the Tajo river but to a small stream that runs between Miocene chalk marls, which explains the presence of soluble salts and the absence of cultivation.

Collado Series

These soils occupy a transition zone between the Colmenar and Villaconejos series, and form a sort of step between them. They are developed on marly limestones of medium consistency and belong to the Group of the rendzines of which profile C-IV is a good example. Normally a rendzine soil has an A/C profile in which the A horizon is rich in organic matter, because of this, in semiarid countries in which the rendzine is less rich in organic matter, the name xerorendzine is adopted as a result of the xerophytic character of the region.

They are soils of a small depth, 35 cms at most, agriculturally poor, with a Mull-type humus, organic matter contents ranging from 3 to 5 %, their structure is that of the A horizon, medium-developed granular, passing through smooth transition to the C horizon constituted by the marly limestone.

CALATAYUD SOILS

Armantes Series

The Armantes series corresponds to an extraordinarly abrupt zone due to intensive erosive processes on a geological material constituted by a tabular series of marls, sandstones and limestones. Since these materials are of such a different nature and physical properties it will be realized that the soil on them formed will have a variable morphology according to the proportion of the starting material. The description of the Z-I profile clearly reflects the nature and morphology of these soils which are in every instance of A/B/C profile; the top horizon, of medium content in humus due to the rapid mineralization of organic matter during the summer months, lies on the mineral B horizon, which is limy and of subangular polyhedral structure. In the case of the Z-I profile the original material is a calcareous marl for which reason it imparts to the soil a limy and somewhat impervious character. The average depth of these soils is about 60 cms but in more abrupt localities the lithosoil phase is found due to erosion.

The Armantes series belongs to the Bry calcareous brown soils group of the Mediterranean Area, in other words there is not calcium carbonate washing in the profile, the whole soil is calcareous and may be regarded as in a edaphologically stable estate, the variability of the morphological character of the soil being a consequence of the erosion.

Villarroya Series

The Z-II profile indicates that these are very superficial soils, of from about 5 to 15 cms thickness as they are formed on a considerably compact and impervious marl of laminated structure, on which the soil forming processes may display their effects. They are in every case young erosion soils, of A/C profile, poor in organic matter, highly calcareous and without any possibility of subsequent evolution. The soil may be regarded as a rendziniform soil of marls in its xerophytic variety and of lithochromo character.

Under the marl are found conglomerate layers alternating with it, and this imparts to the soil a stony character which improves it since it is thus rendered more permeable and loose.

Calatayud Series

These soils are formed on chalk marls and chalks in the neighbourhood of the Calatayud town. These soils are identical to those of the Villaconejos series of the Chinchón Región from which the only difference is the greater heaviness or clay contents in the original marl. For this reason no profile was taken since all their properties and morphological characters are common to both series. A different name has been given only because of local reasons as the Chinchón and Calatayud regions are very far away from one another.

Torres Series

These soils are also identical to the Cerro Pino series in the Chinchón región. The Z-III profile is a good example of them; they are almost lithosoils, formed on crusts of marly chalks, always highly eroded and thus the deepest soil is about 5 cms thickness, having an A/C profile very poor in organic matter, rich in gypsum and highly calcareous, for which reason it is classified as gypsum xerodendzine or gypsum desertic soil. In this series the lithosoil phase is predominate.

Vicort Series

In strong contrast with the Torres series soils the Vicort series is found on a zone of the Iberian Cordillera, which has a relative humid climate, and is of forestry type and extremely rugged. The Z-V profile belongs to the Great Group of Brown Forest soils, with an altitude near to 1000 m., rain fall of 800 mm, on an original material of siliceous nature and under woods of reforestation pines and Quercus lusitánica.

The acidity and good permeability of the rock promote soil development which is of A/B/C type with a very deep and stony B horizon since the soil is developed between gradient alluviums formed by fragments of rock of sandstone and quartzite. In this case the liberation of hydrated iron oxides has been intense, imparting an ochre colour to the B horizon. Due to the steep gradient of the soil the erosion was wery intensive before reforestation for which reason the soil in this soil is associated with areas of lithosoils in which the rock crops out. The evolution of this soil will be that of progressive acidification favoured by the nature of the humus, of Moder type, which derives from pine leaves which are very rich in lignines.

Pozas Series

This series also is identical with the Collado series of the Chinchón region since it is formed under a similar climate, same vegetation and on the same geological material. As already stated in the case of the Collado series, they are mull xerorendzines with the morphological and physical properties common to these soils so typical of Mediterranean countries.

Ateca Series

The Ateca series soils, superficial and stony, in a complex with lithosoils and more or less eroded areas, are found on slates of the Silurian and Cambrian in mountainous regions. The Z-VI profile is highly typical, it has a horizon abundant in humus as it was taken in a Quercus Ilex forest. The B horizon is very stony and, normally, in the case of cultivation soils, it is found at the surface since the organic horizon, and even part of the B.horizon, have vanished through erosion. The transition from the B to the C horizons is gradual and of imprecise limits since the B horizon is formed by physical disintegration of the slatey rock. This type of soil belongs to the Great Group of Mediterranean brown soils, well extended in Spain in regions of semiarid or subhumid climate and on siliceous rocks.

Sediles Series

This series of soils is morphologically closely related with the Villamanrique Series of the Chinchón series because although the soils are different both are formed on gravel or alluvium deposits of the Quaternary period. In the Calatayud region these soils are developed on enormous alluvium deposits coming from the Iberian Cordillera and which descend until they become mingled with the terraces of the Jalón river. They are very superficial soils of $A/C_a/C$ profile, stony even at the surface and with a calcareous horizon or hard-apn at 25 cms depth immediately above the gravel zone.

They are Brown soils of calcareous crust, with almost no organic horizon due to erosion and mineralization; are highly calcareous, of clear brown colour and without any structural development.

PHYSICAL PROPERTIES OF THE SOILS SERIES DEDUCED FROM THEIR MORPHOLOGY AND GENESIS

CHINCHON SOILS

Through the knowledge of the origin, morphology and vegetation of a soil it is possible to deduce a series of physical properties of interest for Agriculture and for technological purposes having various applications. These physical properties are connected with and have on the one hand, closely dependency upon the nature of the material which originated a soil and, on the other hand, upon the edaphological processes to which this material was subjected until originating the present soil. It is therefore possible to deduce these properties by examining the soil profile, and later make the necessary checks in the laboratory accumulating the necessary data so as to establish next year the dichotomus keys by means of photographic interpretation.

Colmenar Series

The formation of these soils has demanded a deep chemical desintegration of the calcareous rock for which reason soil characters are well developed. The structure is highly developed, it is polyhedral, which ensures medium permeability, soil aeration is good since oxidation phenomena predominate, the soil is well balanced as regards its texture since no fraction predominates; it has medium porosity and plasticity, it is neither saline nor alkaline and its humidity-retention capacity is somewhat low, not experiencing any change in volume when drying.

Due to the intrinsic conditions of the profile the soil is readily erodable since the material "may slide" over the original rock, but on account of its topographical conditions, almost flat, erosion is of very small intensity.

For all these reasons the soil is very good, almost ideal, for supporting buildings, aerodromes, communication ways, etc.

Villaconejos Series

The physical characteristics of these soils are inherited from the sandy-gypsiferous nature of the marl which constitutes the original material. The soils are deep, very little consolidated, without structure development, very permeable, with very low capacity for retaining water and non-plastic. Both penetrability and macroporosity are very good. These soils are readily erodable but the original material quickly replaces the losses caused by erosion. The gypsum contents impart to this soil very bad properties for the construction of either roads or buildings.

Villamanrique Series

This is an extraordinarily calcareous soil as it calcium carbonate contents may reach near 50 %; this calcium carbonate specially accumulates in the silt fraction for which reason the interpretation of its granulometric analysis varies a lot, according to whether or not the carbonates are destroyed. This soil is very little plastic, considerably permeable, little consolidated, very little erodable, well structured and deep. Its physical properties derive from its sandy nature for although the calcium carbonate causes the silt content to be very high, it almost acts as an inert material being almost devoid of colloidal properties. Aeration is good and so are porosity and penetrability and this together with its topographical conditions renders the soil excellent for any technical applications.

Tajo Series

Profiles C-IV and C-V although belonging to the same series have very different physical properties. C-IV profile is the representative soil of this series, C-V profile was taken in a small valley in which the vegetation appeared to suggest the existence of some content in soluble salts. The physical properties deduced from profile C-IV indicate that this is a soil of medium permeability, silty-sandy, readily penetrable, little consolidated without drainage problems, well aerated and, on account of its depth, of large water-absorbing capacity. It is an irrigation soil of great agricultural value.

Profile C-V indicates this to be a soil of slow permeability, somewhat saline, plastic, of silty texture, medium consistency, little aerated and readily puddled. Because of its physical properties and gypsum contents its quqlities are very poor for building purposes.

Collado Series

They are soils of abrupt topography, of small depth and highly calcareous. Of sandy-silty texture, the calcium carbonate preferably accumulates in the silt and clay fractions. They are very loose soils, very little consolidated and plastic and of high permeability which is favoured by the presence of large quantities of limestone fragments in the soil mass. The physical properties of this series of soils, which belong to the Xerorendzine group, derivate from the frankly calcareous nature of the soil since it is a young soil, the lithological character is highly accentuated, and since the original calcareous rock is very porous and sandy grained, the soil has perfectly defined physical properties. A soil of good aeration which never becomes puddled even with intensive rainfall.

Cerro Pino Series

It will be dealt with conjointly with the Torres Series in the Calatayud region.

CALATAYUD SOILS

Armantes Series

It was stated in the edaphological study that since materials as different as marls, sandstones and limestone take part in the formation of these soils it is difficult to find a representative profile as this varies strongly with the topography. They are extraordinarily calcareous soils, of medium, either silty or silty-sandy texture; well developed structure giving rise to medium permeability favoured by the presence of copious fragments of limestone in the soil mass. Since this region is subjected to an continuous erosive process the external drainage is high and the internal drainage medium. Medium consistency and porosity, the latter diminishing with depth. These are soils entirely devoted to forestry and shooting reservations and totally unsuitable for agricultural or building activities of any kind.

Villarroya Series

A soil of physical characteristics rather peculiar and which are due only to the nature of the original material which is a marl of strong consistency and laminated structure. It is devoted to cereals and vines which are cultivated by plough-removing the marl which becomes continuously eroded by lack of care during the agricultural work. Texture is well balanced with a high calcium carbonate content; real density is high, macroporosity is low; very slightly saline, little plastic and little permeable soil. In those places where the marl is mixed with the conglomerate layers, permeability increases and the compactness of the sub-soil decreases.

Calatayud Series

This has the same morphological and physical characteristics as the Villaconejos series of the Chinchón region for which reason no profile samples were taken. All the considerations made in connection with that series apply to this case.

Torres Series

As in the case of the Cerro Pino Series of Chinchón, these are highly superficial soils of A/C profile and belonging to the gypsum Xerorendzine group. -All their physical characteristics are conditioned by their high gypsum contents. These are soils of low apparent density, non-plastic, very permeable, slightly saline, entirely incoherent, little consolidated and without any structure stability. They exhibit the worst possible physical conditions for the construction of roads and buildings of any sort.

Vicort Series

These are forestal, acidic, stony soils. On account of its topographical characteristics the soil is entirely devoted to forestry. The whole of the soil is stony and, thus, its physical properties are influenced by this circumstance. The soils are of high permeability, and very little consolidated silty, have small plasticity and are readily erodable if not sufficiently protected by reforestation.

Pozas Series

As with the Collado series these are mull Xerorendzines and have the same physical characteristics of that soil series. In this case the only noticeable difference is that the Calatayud region is completely reforested with pine grove whereas in Chinchón normally there is only bush.

Ateca Series

Highly eroded soils at places and alternating with lithosoils. On rocks of gentle slope or low woods the soil, in general of small depth, is silty arenaceous, of grumose structure and hence considerably permeable, little consistency, without plastical properties and good penetrability. Normally when the soil is a cultivation one and as a result of the work, the mass of the soil is mixed in small slate fragments.

Sediles Series

Sandy surface soils of almost flat topography with little developed structure, very little capacity for water retention and large permeability. They are little consolidated soils and of ready erosion; the subsoil is porous, permeable and consistent. It is a good soil for the construction or roads and buildings.

STUDY OF SOILS AND OF THEIR CARTOGRAPHY BY MEANS OF PHOTOGRAPHIC INTERPRETATION

In most treatises on photographic interpretation this activity is defined as the action of examining the photographic images of objects, identifying these objects and deducing their meaning; hence the interpretation is a very complex operation which based on a probable observation tends to elucidate the facts as they are. But when this interpretation is traslated to the field of Edaphology the complexity of the problem becomes greater since the direct image of the object cannot be examined but only a series of images of various objects more or less connected with the actual object. In the study of soils, aerial photography will never, or almost never, give us the image of the soil profile, that is aspect essential to know the morphology of the soil, its genesis and evolution, and hence to deduce the conclusions about its physical properties.

In order to arrive at the knowledge of these physical properties of the soils, through aerial photographies, two procedures are available namely, the direct procedure and the indirect one. The direct method, which we shall use in the second part of this work, to be carried out next year, consists in preparing and setting up a sort of interpretation keys -which French people call "clés"- where the physical properties of the soils are combined with different interpretation methods, and with the criteria of interpretation among which we may mention those of morphological order, vegetation, appearance of the different geological materials, erosion forms, distribution and appearance of the hydrography, grey tonalites observed in aerial photography and human action.

The indirect or deductive method consists in arriving at the physical properties of the soils through the knowledge of the different types of soils, since each type of soil series implicitly carries with it a particular range of physical properties. By following this method we have studied and characterized, in the field, different soil series through the analysis of characteristic profiles which have enabled us to assess their morphology and specific properties. Each of these soil series is distinguished in aerial photographies by a series of variable criteria -not always the same criterion- which enabled us to separate on the photographs the various units of soils by means of stereoscopic vision.

But the system used for mapping the various soil units in Chinchón and Calatayud has also been different. In Calatayud most of the territory of the sheet was mapped directly in the field by means of the free cartography system and by using topographic sheets to scale 1: 50,000, aerial photographs of the area to scale 1:30,000 and a pocket stereoscope for three dimensional vision. In zones of difficult penetration the cartography was made by interpolation, using also aerial photographs and placing the limits on the topographic map as closes as possible to the observed reality.

In the Chinchón sheet the cartography of the soil series previously studied was carried out in a completely different manner. The procedure consisted in tracing on "Kodatrace" paper the succesive aerial photographs that make up the Chinchón sheet mosaic in other words by making the relevant interpretations with the aid of the Zeiss mirror stereoscope and using binoculars of three magnification. These interpretation tracings -in which the various soils series were delimited- were carried out bearing in mind the criteria most relevant and more closely related with the morphology of the various soil series; among these criteria we may quote the nature of the original material, morphology and landscape, nature of natural vegetation, and the different use man makes of the soils. One these tracings were obtained, to an approximate scale of 1:30,000 -being of course the same scale as for the aerial photographs- they were translated to the Chinchón topographical sheet (1:50,000) by means of the Zeiss camera lucida: in this way the correct location of the several soil units was practically exact.

In both cases, following the drawing of the 1:50,000 topographical sheets the necessary rectifications and controls were made in the field, particularly with a view to checking the bounded units with the simple help of the stereoscope and following certain criteria, corresponding to the edaphologic reality and the results could be no better. What on the other hand soon becomes manifest on examining the final maps of the two areas selected is the superior cartographic detail of the Chinchón sheet, that is to say the one made by successive tracings; this confirms our first impression of aerial photography that is to say that in addition to the time-saving entailed by its use it gives a wealth of details and very great accuracy in all types of cartographic work.

In what follows we shall endeavour to set out for each soil series the whole of the criteria and aspects which enabled their identification through stereoscopic interpretation of the corresponding photographs.

In the sheet corresponding to Chinchón we have differentiated seven series of different soils. The Tajo series, corresponding to present alluviums of this river, can be stereoscopically differentiated by the plottings proper to and characteristic of irrigation cultivations, the completely flat topography and dark tones of the photographic copies. The Villamanrique series corresponds to soils formed on diluvial terraces of the river Tajo and it is characterized, on observing aerial photographies, by an also flat topography; occasionaly it is possible to notice a small and gentle ondulation, irregular plotting of the land, almost exclusively devoted to cereal cultivation and clear grey tones. On the other hand the slope between the "Vega" and terrace soils may be clearly appreciated as can also the limit between this Villamanrique series and the other boundary series. These two series, Tajo and Villamanrique, do not exhibit natural vegetation since these soils are entirely devoted to intensive cultivation. The Colmenar series shows very characteristic aspects: in the first place we have the nature of the geological material from which these soils originate. They are hard limestones, of horizontal stratification belonging to the "Pontiense" and occupy the upper stage within the Tertiary unit. They are the so called "paramos" limestones and their strong aspect and stratification are well defined in the side scarpments of these mesetas or paramos. On these scarpments the natural vegetation, with Quercus Ilex woods, may also be clearly appreciated, whilst in flat areas the small and considerably regular plottings denote ownership sharing and almost exclusive utilization on the basis of cereal and vine-grove cultivations. Topography is flat or very slightly ondulated and grey patches alternate although, on the whole, the aspect of these series is very characteristic. The most important population centers are seated on these soils and the straight and clear lay-out of the communication way denote the subsoil characteristics. Perhaps the series of least clear delimitation through aerial photography was the Collado series although it is characterized by the predominance of spontaneous vegetation, mostly Rosmarinus Officinalis bush which generally imparts to photography a somewhat dark hue. Topography is rugged due to the fact that erosion has cut ravines and, in general, because of the soft nature of the materials, water has left its trades during storming periods. In cultivation areas plotting is entirely irregular with limits which are not very straight.

On the other hand it was very easy to delimit the Villaconejos series since its soils are almost exclusively devoted to olive-tree cultivation and thair aspect in aerial photograph becomes patent on account of the more clear tones of the whole area, and in addition the topography is slightly ondulated. The Cerro Pino series constituted by gypsum Xerorendzines associated with lithosoils is perhaps the series which stands most clearly on stereoscopic examination, this is due to its highly specific lithology and to the characteristic erosion forms formed in gypsum and which generally present a branched aspect. The considerably characteristic intermediate and uniform grey tones are due to a typical Gypsophiletalia vegetation.

Finally we have been able to indicate and map out some areas of pronounced salinity with Salicornietea vegetation and which are characterized by the darker, almost black, areas readily noticeable in aerial photographs and which occupy topographically low areas; they are true depressions readily appreciable by stereoscopic vision and which are also more marked on account of their typical vegetation.

The criteria chosen for the Calatayud sheet -and whose connection with the soil series is more direct and close- are about the same as for the Chinchón sheet.

On analyzing the several series we see that the Jalón series is quickly characterized in aerial photographs because the soils are dedicated to either norticultural cultivation or fruit-tree. Land plots are aboundant and minute

and the tones found are rather dark since being soils under irrigation the soil humidity, which imparts the shading, is rather dark. The Sediles series, soils developed on terraces and stony grounds, can also be readily delimited with the aid the stereoscope as they are found in well defined areas, with well marked edges and always in a grey uniform tone of medium intensity. The Calatayud series, developed on gypsiferous marls has highly marked differential characteristics, the main ones being the arrangement of the cultivations, always on a cereal basis, in small orchard plots taking advantage of the greater thickness of the soil and in the "gully" which the subsequent erosion of nearby areas was filling in. Typical of this series are the eroded zones in singular alternation with cultivated areas, also typical are the very clear grey tonalities present in the photographs. Intimately connected with this series is the Torres series formed by authentical gypsum lithosoils, hence the accentuated erosion-forms displayed by this material, which coupled with the almost white tone makes the characterization a ready matter. The more marked phot-interpretation characteristics of the Villarroya series are the almost flat topography, scanty and well integrated hydrography of the parallel type. The whole of the land is cultivated, cereal and vine groves predominating, olive trees growing on areas of soils of topography generally flat or slightly undulated; intensive plotting and grey hues predominate but with little homogeneity. In some places the typical erosion of the marl on which these soils are formed may be appreciated. The most characteristic detail of the Armantes series is the clear stratification of the several geological materials and the impressive erosion of these soils covered by a calcareous "tomillar" also visible with stereoscopic vision. The Pozas series soils formed on hard limestone are found in the high areas; it is possible to appreciate the hard calcareous reliefs and the intensive re-forestation carried out over these soils with Pinus halepensis.

The Ateca series can readily be distinguished by the aspect of its shales, with their characteristic stratification, its hydrography of dendritic type, of medium and slowly well-controlled density. The Quercus Ilex forest is well seen in low spots whereas vine groves are noticeable in the some-what calcareous zones of South-East end. Finally highly resembling the preceding series we have the Vicort series in which the greater alternancy of quartzites is well noticeable in aerial photographies. The soils are more acidic and wetter and hence of dark tones in the photographs, this is manifested by the position of the Quercus pirenaica at high places and which come out extremely well in stereoscopic vision.

ANALYTICAL METHODS AND DATA

The mechanical analysis of the soils has been effected by two different methods; the first one by following the technique of the Bureau of Reclamation Manual, Irrigated Land Use, utilizing the densimeter without destroying the carbonates and the second one by following the International Method of the "Sociedad Internacional de Ciencia del Suelo" using Robinson's pipette.

Permeability has been determined by Durand's method but with the important modification of operating on samples with undisturbed structure. The calculated value gives us the number of centimetres/hours of infiltration velocity and is calculated from two different mean values, the first one for the first five hours of measurement and the second as taken from hour 24 to hour 28.

Bulk density and particle density have been calculated in accordance with the standards laid down in U.S.D.A. Handbook nº 60, and so have the water contents at 1 and 15 atmorpheres and salinity. Plasticity was determined by Atterberg's technique.

The study of the clay samples is made using an X-Ray PW1010 Phillips generator with PW1050 wide range Goniometer and Electronic Circuit Panel with Recoder PW1051 was employed.

Working conditions were as follows: filtered copper radiation, 40 Kv, 20 mA; scan speed 1º per minute; divergence slit, 1º; scatter slit, 0,2; receiving slit, 1º; time constant, 4 seconds. The following diagrams were obtained; a) of the whole untreated clay. In the case of the existence of a larger amount of organic matter this was previously eliminated by treating it with 20 vols. hydrogen peroxide; b) of the clay after having been subjected to treatment to dissolve free sexquioxides; c) of the previous clay treated with glycerol; d) of the clay after heating to 500º C, during two hours.

Mechanical analysis of soils with Bouyoucos method

Sample		Coarse sand	Medium sand	Fine sand	Very fine sand	Total sand	Silt	Clay
C-I	A	2,42	4,80	6,72	15,26	29,3	33,80	36,90
"	B	1,02	3,98	5,94	11,66	22,6	26,80	50,60
C-II	A	2,02	7,16	8,62	It wasn't dispersed			
"	B	0,22	0,62	1,62	It wasn't dispersed			
C-III	A	0,18	0,28	0,38	24,36	25,0	50,40	24,60
"	B/C	0,00	0,00	0,54	24,86	25,4	48,00	26,60
"	C	0,00	0,00	0,62	26,38	27,00	48,40	24,60
C-IV	A	0,00	0,00	11,00	24,10	35,2	41,60	23,20
"	C	0,00	0,00	17,78	36,42	54,20	24,00	21,80
C-V	A_o	0,00	0,00	0,64	It wasn't dispersed			
C-V	A1	0,00	0,00	1,08	It wasn't dispersed			
C-VI	A_o	1,54	2,54	2,18	17,14	23,40	53,80	22,80
"	A_1	3,26	7,82	5,34	5,31	21,80	49,40	28,80
Z-I	A	3,36	3,34	3,70	12,73	23,20	35,50	41,30
"	B	0,68	1,02	2,12	6,72	10,60	39,40	50,00
"	C	0,00	0,00	0,20	0,00	0,20	57,60	42,20
Z-II	A	1,60	4,48	11,10	29,19	46,40	29,20	24,40
"	C	1,36	1,60	1,82	9,56	14,40	43,60	42,00
Z-III	A	1,77	4,70	4,84	24,07	35,40	It wasn't dispersed	
"	C	1,72	4,40	4,36	7,10	17,60	It wasn't dispersed	
Z-IV	A	26,22	18,95	10,65	4,76	60,60	20,60	18,80
"	B	9,82	12,22	5,75	7,80	35,60	27,40	37,00
Z-V	A	2,31	4,42	6,30	16,96	28,00	27,80	44,20
Z-VI	A	11,41	12,56	10,15	11,07	45,20	31,40	23,40
"	B	6,37	10,85	6,35	24,01	47,60	28,10	24,30
Z-VII	A_o	9,64	19,53	11,11	0,51	40,80	32,80	26,40
Z-VII	A_1	14,14	18,21	10,38	14,85	57,60	22,00	20,40

Mechanical analysis. International method

Sample		Coarse sand	Fine sand	Silt	Clay	CO_3Ca
C-I	A	11,21	35,26	18,4	30,35	0,6
"	B	8,11	32,18	15,35	42,6	2,2
C-II	A	8,96	14,21	It wasn't dispersed		25,5
"	B	0,37	17,74	12,30	7,25	47,0
C-III	A	0,72	37,46	4,90	10,45	46,3
"	B/C	0,34	35,50	5,20	10,55	47,0
"	C					46,3
C-IV	A	7,4	23,2	7,2	10,0	43,5
"	C	5,70	31,62	3,35	6,65	49,0
C-V	A_0	0,09	28,83	11,60	14,90	31,6
"	A_1	It wasn't dispersed				27,6
C-VI	A_0	0,58	13,28	8,52	16,45	55,7
"	A_1	0,15	4,23	5,42	15,80	67,1
Z-I	A_0	1,58	15,75	15,10	22,65	52,9
"	B	3,2	29,47	31,35	36,1	24,5
Z-II	A	7,14	58,94	15,85	13,8	24,1
"	C	0,97	22,88	23,95	22,10	30,4
Z-III	A	It wasn't dispersed				15,2
"	C	" " "				2,8
Z-IV	A	47,83	32,28	12,75	5,50	0
"	B	29,27	32,84	11,85	22,55	0
Z-V	A	10,58	38,76	21,22	28,57	26,1
Z-VI	A	32,87	27,45	22,97	11,42	0,3
"	B	33,08	28,39	25,65	11,15	0
Z-VII	A_0	34,79	35,68	10,45	14,05	13,6
"	A_1	19,47	45,87	14,60	18,70	35,3

Higroscopicity

Sample		Relative vapour tension $\frac{P}{P_o} = 0,96$	Relative vapour Tension $\frac{P}{P_o} = 0,99$
C-I	A	8,37	11,23
"	B	9,52	11,84
C-II	A	17,98	18,80
"	B	8,63	11,83
C-III	A	3,24	4,72
"	B/C	3,10	4,19
"	C	2,97	3,95
C-IV	A	6,03	6,30
"	C	2,70	3,01
C-V	A_o	9,84	11,46
"	A_1	11,82	13,28
C-VI	A_o	8,02	10,88
"	A_1	7,63	1 1,37
Z-I	A_o	6,97	8,12
"	B	5,48	8,33
"	C	5,03	6,30
Z-II	A	2,57	4,05
"	C	5,57	6,33
Z-III	A	13,84	16,23
"	C	16,87	18,45
Z-IV	A_1	1,27	1,52
"	B	5,14	6,06
Z-V	A	6,86	8,11
Z-VI	A	3,97	5,46
Z-VI	B	2,18	2,77
Z-VII	A_o	4,21	5,62
"	A	3,21	5,16

Permeability

Sample		1st Mean value	2nd Mean value	Limite
C-I	B	48,6	39,4	39,2
C-II	B	89,3	41,0	37,6
C-III	B	43,0	24,8	22,9
C-IV	C	117,9	51,2	49,6
C-V	A_1	4,6	3,8	3,7
C-VI	A_1	135,6	92,4	90,4
Z-I	C	1,12	1,09	1,04
Z-II	C	14,5	14,6	14,4
Z-III	A/C	24,0	16,8	16,8
Z-V	A	433,0	107,0	103,2
Z-VII	A	200,0	81,5	72,0

Soluble salts

Sample		Electrical conductivity Mhos 10^3	Sample		Electrical conductivity Mhos 10^3
C-I	A	0,50	Z-I	B	3,0
"	B	0,85	"	C	3,0
C-II	A	3,0	Z-II	A	0,45
"	B	3,0	"	C	1,40
C-III	A	0,85	Z-III	A	2,75
"	B/C	0,65	"	C	3,0
"	C	0,50	Z-IV	A_1	0,60
C-IV	A	0,85	"	B	0,16
"	C	1,85	Z-V	A	0,42
C-V	A_o	3,10	Z-VI	A	0,80
"	A_1	3,0	"	B	1,60
C-VI	A_o	0,45	Z-VII	A_1	0,92
"	A_1	0,37	"	A_o	0,55
Z-I	A_o	0,45			

Particle density

Sample			Sample		
C-I	A	2,25	Z-I	A	2,49
"	B	2,40	"	B	2,55
C-II	A	2,34	Z-II	A	2,65
"	B	2,50	"	C	2,64
C-III	A	2,49	Z-III	A	2,49
"	B/C	2,56	"	C	2,31
"	C	2,61	Z-IV	A_1	2,62
C-IV	A	2,50	"	B	2,56
"	C	2,61	Z-V	A	2,51
C-V	A_o	2,40	Z-VI	A	2,45
"	A_1	2,40	"	B	2,57
C-VI	A_o	2,36	Z-VII	A	2,56
"	A_1	2,46	"	A_o	2,48

Bulk density

Sample			Sample		
C-I	B	1,43	Z-I	C	1,74
C-II	B	1,22	Z-II	C	1,53
C-III	B	1,40	Z-III	A/C	0,84
C-IV	C	1,38	Z-V	A	1,36
C-V	A_1	1,23	Z-VII	A	1,52
C-VI	A_1	1,44			

Limits of Atterberg

Sample		Limit liquid	Limit plastic	Plasticity Index
C-I	A	45,2	25,8	19,4
"	B	42,1	18,3	23,8
C-II	A	Not plastic		
C-II	B	43,0	29,3	13,7
C-III	B	Not plastic		
"	B/C	24,8	22,1	2,7
"	C	Not plastic		
C-IV	A	" "		
"	C	" "		
C-V	A_o	56,6	37,3	19,3
"	A_1	54,5	29,5	25,0
C-VI	A_o	50,0	38,6	11,4
"	A_1	55,1	35,7	19,4

Soil water

Sample		1 atmosphere percentage	15 atmosphere percentage
C-I	A	6,11	15,87
"	B	5,67	16,01
C-II	A	11,54	26,46
"	B	8,20	17,44
"	B/C	3,67	10,14
"	C	2,87	5,26
C-IV	A	1,98	5,37
"	C	2,55	5,06
C-V	A_o	8,55	22,36
"	A_1	7,33	25,32
C-VI	A_o	8,59	17,96
"	A_1	7,60	20,76
Z-I	A_o	5,06	14,48
"	B	4,49	16,59
"	C	7,32	10,32
Z-II	A	3,38	6,87
"	C	5,53	10,35
Z-III	A	5,91	19,76
"	C	9,74	49,93
Z-IV	A	5,47	13,90
"	B	2,87	8,17
Z-V	A	5,05	13,63
Z-VI	A	5,84	9,90
"	B	3,92	8,88
Z-VII	A_o	4,54	13,34
"	A_1	5,88	9,99

STUDY OF THE CLAY FRACTIONS

Profile - Horizon		
C-I	A	The diagram obtained indicates that the extracted fraction is constituted by a crystalline material of very small size or, more likely, by a strongly altered crystalline material. Illite predominates, accompanied by a mineral of the kaolilite, fire-clay type. Likewise the existence of a mineral with mixed layers, probably montmorillonitic, is justified. Quartz in small amounts.
"	B	As above, but the presence of montmorillonitic mineral is more clear.
C-II	A	In view of the nature of the soil the clay fraction had to be extracted by energetic treatments. Despite this, we estimate the alteration of the existing material to be natural, not originating from the effected treatments. The basic material is illite accompanied by morillonite, possibly inter-stratified with illites. Gypsum, Quartz,
C-III	A	As in the previous profiles the existence of clay minerals with wide spacings is manifest, probably interstratified at random with illite. It must be noted that their amount seems to increase on digging deep into the profile. In this horizon illite predominates, accompanied by a mineral of the kaolinite type. Quartz.
"	B/C	As in the preceding paragraph.
	C	Same as the previous ones. As stated when studying the A horizon, the existence of minerals with a spacing over 10 Aº is obvious but everything seems to point to their being disorderly interstratified with illite. The existence montmorillonoides is highly probable.
C-IV	A	The mineral predominating is illite. It is accompanied by montmorillonite. In the test specimen heated to 500º C

Profile - Horizon		
C-IV	A	there is a small line at 7,05 Aº which appears to suggest the presence of chlorite, in a very small amount, and of a mineral of the kaolinite group.
"	C	Same as the preceding one.
C-V	A_o	Strongly altered material. Illite predominates. In very small amounts a mineral of the kaolinite group. Vermiculite and montmorillonite probably present.
"	A_1	Similar to the previous one. Montmorillonite, always in a small proportion, is more abundant.
C-VI	A_o	Much altered material. Illite predominates. Probably in mineral of the kaolinite group. Montmorillonite.
"	A_1	As in the previous paragraph, out there is no evidence of the existence of kaolinitic minerals. There are probably illite-montmorillonite inter-stratifications.
Z-I	A_o	The most abundant mineral, illite, is accompanied by kaolinite. Very little Quartz.
"	A_1	As in the previous paragraph.
Z-II	A	Well crystallized Illite and kaolinite. The diagram of the sample treated with glycerine shows a band that suggests the existence of a montmorillonitic mineral. Quartz.
"	C	Basically same as in the preceding paragraph. It must be stressed that the minerals appear to be less crystallized than in the A horizon. M.E. examination could confirm this assumption.

Profile	Horizon	
Z-III	A	The fraction extracted gives a very defective difraction diagrama. The presence of Illite and, naturally, gypsum and alkaline earth carbonates is obvious. The habit of the diagrams seems to suggest the existence of an interstratified, possibly inflatable, mineral.
Z-IV	A_1	Illite, Kaolinite, Quartz, Montmorillonite.
"	B	As above.
Z-V	A	Essentially Illite, accompanied by kaolinite and quartz.
Z-VI	A	Illite, Kaolinite and Quartz accompanied by chlorite or vermiculite.
"	B	As in the preceding paragraph, the presence of hydrous mica being possible.
Z-VII	A_g	Much altered material. Illite, Kaolinite and Quartz, possibly Vermiculite.
"	A_1	As in the preceding paragraph but accompanied by montmorillonite.

L I T E R A T U R E

ABRAMS, T.- "Essential of Aerial Surveying". Mac Graw Hill. New York 1944.

ALEIXANDRE FERRANDIS, V.- "Métodos físicos empleados en el estudio de las arcillas". I. Ión. 1950. 10: 644-650. 707-715.

ARCHIVES INTERNATIONALES DE PHOTOGRAMMETRIE.- Tome XIV. "Transaction of the symposium on photo interpretation". Delft. The Netherlands. September 1962.

BAVER, L.D.- "Soil Physics". Third edition. New York. John Wiley. 1956.

BOLETIN Mensual Climatológico.- Madrid. Servicio Meteorológico Nacional.

CASAS TORRES, J.M.- "La Naturaleza". Aragón. 2 Vol. Zaragoza 1960. Publicado por el Banco de Aragón.

CHOMBART DE LAUWE, P.- "Photographies aériennes".

CHOMBART DE LAUWE, P.- "Decouvert aérienne du monde". Horizons de France Paris. 1949.

DANTIN CERECEDA, J.- "Regiones naturales de España". Madrid. C.S.I.C. 1942.

DIAGNOSIS and improvement of saline and alkali soils. Pág. 112. Washington, U.S.D.A. Agric. Hand. nº 60. 1954.

DUCHAUFOUR, Ph.- "Précis de Pedologie". París.1960.

DUPUIS, M.- "Note complementaires sur l'utilisation des photographies aeriennes dans le domaine de l'étude des sols. Bulletin de l'Association française pour l'étude du sol. nº 2. Febrero 1962.

DURAND, J.H.- "Les sols irrigables". Imbert Alges. 1958.

EARDLEY.- "Aerial Photographs. Their use and interpretation".

FERNANDEZ-GALIANO, E.- (1954). "La fotografía aérea aplicada a la Cartografía botánica". Medicamenta, 22 (107).

FERNANDEZ-GALIANO, E. (1952).- "Observaciones ecológicas sobre las alineaciones silúricas de la provincia de Zaragoza". Anal. Inst. Bot. A.J. Cav. 11 (1).

FERRER REGALES, M.- "El campo de Cariñena". Depart. Geogr. Apl. Insti "Juan Sebastián Elcano". Serie Regional 4. núm. 16. Zaragoza. 1960.

GARCIA MANRIQUE, E.- "Las comarcas de Borja y Tarazona y el somontano del Moncayo". Inst. "Fernando el Católico" C.S.I.C. Zaragoza 1960.

GARCIA VICENTE, J.- "Estructura cristalina de los minerales de la arcilla". Madrid. Monografía de Ciencia Moderna. nº 30. 1951.

GOMEZ DE LLARENA, J.- "Excursión por el Mioceno de la cuenca del Tajo". Bol. R. Soc. Esp. Inst. t:13. pp. 229-237. Madrid.1913.

GONZALEZ QUIJANO, P.- "Mapa pluviométrico de España". C.S.I.C. Madrid. 1946.

HERNANDEZ PACHECO, E.- "Síntesis fisiográfica y geológica de España". Trab. Museo Nac. Cienc. Nat. Madrid. nº 38. 1932.

HERNANDEZ SAMPELAYO, P.- "Explicación del nuevo mapa geológico de España". Madrid. Inst. Geol. y Min. de España. 1935.

HURAULT, J.- "Manuel de Photogrammétrie". Institut Géographique National. París 1956. 2 vol.

KINDELAN, J.A.- "Notas sobre el límite inferior del Pontiense en Castilla la Nueva". Not. y Com. Inst. Geol. Min. de España. nº 31. pp. 101. Madrid.1953.

KINDELAN, A; CANTOS FIGUEROLA, J.- Escala 1:50.000. Explicación de la hoja nº 606 "Chinchón". Mapa geológico de España. Inst. Geol. Min. España. 1 t. 35 pp. 1 map.

KUBIENA, W.L.- "Claves sistemáticas de suelos". Madrid. C.S.I.C. 1952.

LADMIRANT, H.- "Photographies aériennes et géologie". Presses Universitaires de Bruxelles. 1962. 205 blz.

LAUTENSACH, H.- "Die Niederschlagshöhen auf der iberischen Halbinsel". Petermans Geographis. Mitt. 1951. 95:145-160.

MARTONNE, E.- "Areisme et indice d'aridité". C.R. Ac. Sc. París. 1924. 182: 1395-1398.

MARTONNE, E.- "Traité de Geographie Physique". Vol. I. Climat. París. 1925.

MASACHS ALAVEDRA, V.- "Los factores determinantes de la distribución en especial de los tipos de régimen de los ríos de la Peninsula Ibérica. Est. Geogr. nº 28. pág. 465-493. Madrid. 1947.

RICHARDS, L.A.-(Editor). "Diagnosis and improvement of saline and alkali soils". U.S.D.A. Handbook. nº 60. 1954.

RICHARDS, L.A.; BOWER, C.A.; FIREMAN, M.- "Test for salinity and sodium status of soil and of irrigation water". U.S.D.A. Circular nº 982. 1956.

RICHTER, G.- "Las cadenas ibéricas entre el valle del Jalón y la Sierra de la Demanda". Publ. Extr. Geol. España. 1956. 9: 61-142.

RIVAS GODAY, S.- "Los grados de vegetación de la Peninsula Ibérica"." An. Inst. Cavanilles. 1954. 13: 269-331.

RIVAS GODAY, S.; BELLOT, F. (1942). "Acerca de las regiones naturales de la provincia de Madrid". Rev. Univ. Madrid. 2 (5).

RIVAS GODAY, S.; BORJA, J. (1961).- "Estudio de la Vegetación y Flórula del Macizo de Gúdar y Jabalambre". Anal. Inst. Bot. A.J.Cav. nº 19.

SAENZ GARCIA, C.- "Estructura general de la Cuenca del Ebro". Est. Geogr. Mayo. 1942. 249-269.

SAN MIGUEL ARRIBAS, A.- "Estudio de la región volcánica del Bajo Ebro". Inst. "Lucas Mallada". C.S.I.C. Madrid, 1950.

SCHMITT, R.- "El clima de Castilla la Vieja y Aragón". Est. Geogr. Nov. 1945. 727-812.

SOIL Survey Manual. Washington. U.S.D.A. Agric. Hand. 18. 1951.

SOLE SABARIS, L.- "Geografía Fisica". Barcelona. Montaner y Simón. 1951.

SORRE, M.- "Geographie Universelle". VII. Mediterranee. Peninsulas Mediterranées. Espagne-Portugal. París 1934.

STILLE, H.- "La divisoria ibérica". Publ. Extr. Geol. España. 1948. Iv: 297-303.

TECHNIQUES récentes en microscopie electronique et corpusculaire. Toulouse. 4-8 avril 1955. París. Centre National de la Recherche Scientifique. 1956.

UNITED States Department of the Interior.- Bureau of Reclamation Manual V- Irrigated sand Use.

VICIOSO, B. (1890).- Plantas de Calatayud. Anal. Soc. Esp. Hist. Nat. 29.

A P P E N D I X

A).- Implications of the results for possible future work.

This work represent in the first place a contribution for the betterment in the agricultural and economic development of the two zones through the study of the soils and vegetation. In second place aids to coordinate the work of the soils scientist and botanists using the photointerpretation technical, for the first time in Spain. Finally, this work is the first step in a research towards establishing interpretatives keys by the combination of the physical properties of soils with the laws of the photo-interpretation which will be our aim in the second part, that we shall realize next year.

B).- Scientist personnel employed during the reporting period.

J.M. Albareda, A. Guerra, E.F. Galiano, F. Monturiol, J. García-Vicente.

C).- Manhours expended on the contract.

J.M. Albareda: one year's work at 130 hours per month.
A. Guerra: one year's work at 130 hours per month.
E.F. Galiano: one year's work at 130 hours per month.
F. Monturiol: one year's work at 130 hours per month.
J. García-Vicente: one year's work at 32 hours per month.
J. García: one year's work at 32 hours per month.
Mª del Carmen Laita: one year's work at 32 hours per month.

D).- Chemical expends in carrying out the contract

About $ 1000 in materials have been spent.

E).- Apparatus

No important property has been acquired during the reporting period at direct contract expense.

-FIN-