A STUDY OF THE GEOLOGIC HISTORY AND SOIL GENESIS IN, THISVI, GREECE

THESIS

PRESENTED IN PARTIAL FULFILLMENT OF THE
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Introduction

The objective of this study is to discover the nature, distribution and origin of the rocks and soils in the area of Thisvi Valley, Greece. Thisvi is a small village, with approximately 300 inhabitants, located 38° 15' 00" North Latitude, and 22° 15' 00" East Longitude, in the province of Boeotia, Greece. It is about 33 Km southwest of Thebes, the provincial capital, along the north shore of the Gulf of Corinth (see Fig. 1). Thisvi has a topographic advantage in terms of military, sea travel and trade. Reasons for this advantage include a source for fresh water, a zone of favourable arable land (the valley), and accessibility to the sea. Other areas are dissected and rugged, appropriate for defense but inhospitable for farming. Mt. Helikon, which would present insurmountable odds for military travel, lies to the north and west of Thisvi. The sea lies to the south of the Thisvi area, about three Km south of the village of Thisvi.

Geomorphology and Physiographic History

There are four physiographic units in the area: (1) the shoreline, (2) the rugged hills, (3) the gentle sloping valley sides, and (4) the central alluvial plain (See Fig. 2). The shoreline, which is deeply embayed and mostly made up of rocky cliffs, is sheltered by a peninsula which lies farther to the south and west, thus forming a protected harbor. There exist a few small isolated cobble beaches formed in the recesses between headlands (see Fig. 3). To gain

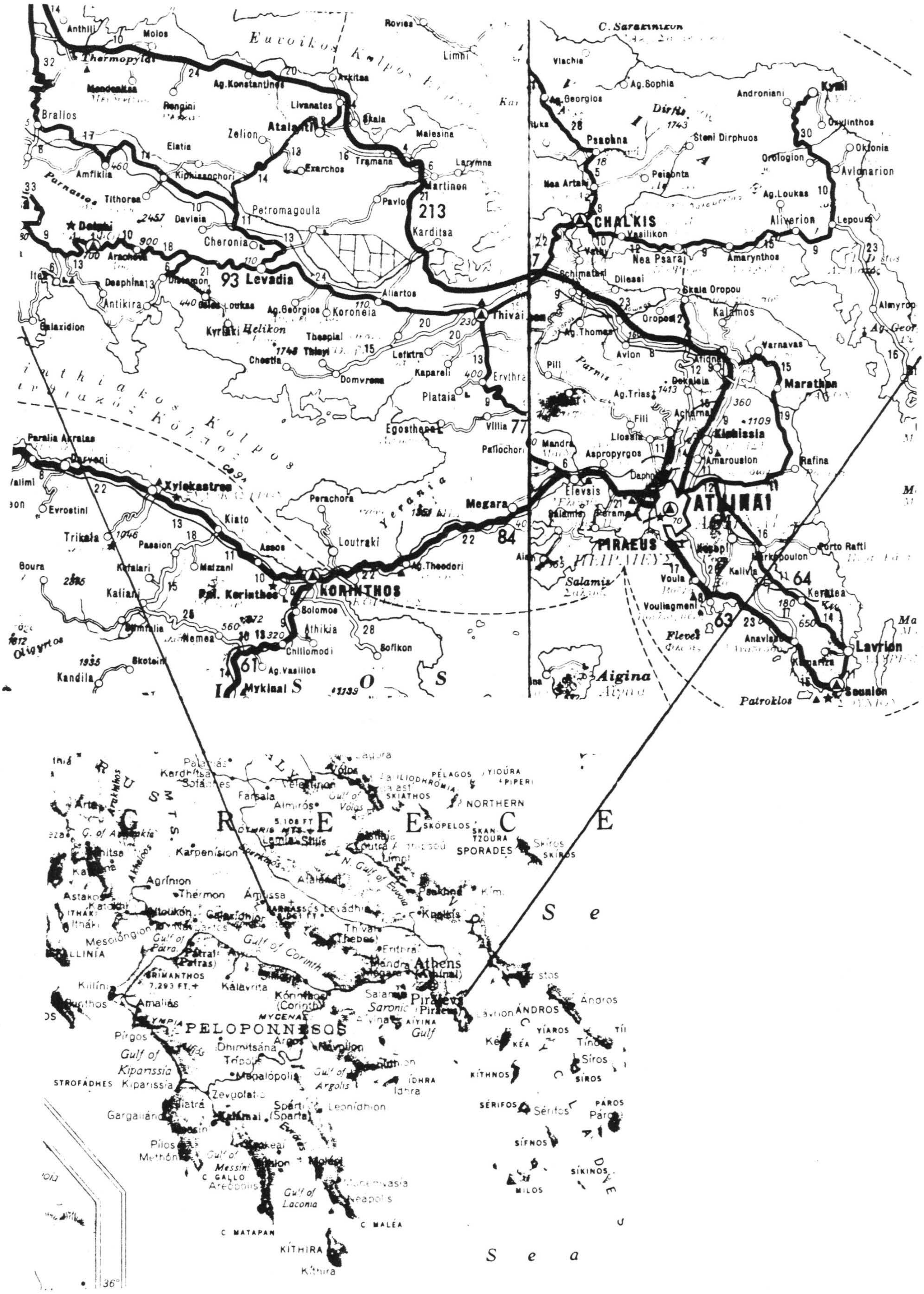
Thermopylai
Molos
Brallos
Ag.Konstantinos
Arkitsa
Livanates
Atalanti
Zelion
Elatia
Amfiklia
Tithorea
Kiphissochori
Petromagoula
Davleia
Delphi
Arachova
Cheronia
Levadia
Itea
Desphina
Distomon
Antikira
Galaxidion
Helikon
Koroneia
Aliartos
Martinon
Karditsa
Larymna
Malesina
Skala
Tragana
Pavlos
Exarchos
Thivai
Thespiai
Thisvi
Chostia
Domvrena
Lefktra
Kapareli
Plataia
Erythrai
Egosthena
Villia
Mandra
Pallochori
Evvoikos Kolpos
Limni
Rovies
C. Sarakiniko
Vlachia
Ag.Sophia
Ag.Georgios
Psachna
Dirfis
1743
Steni Dirphuos
Androniani
Kymi
Oxylinthos
Oktonia
Orologion
Avlonarion
Ag.Loukas
Aliverion
Lepoura
CHALKIS
Vasilikon
Nea Artaki
Vathy
Nea Psaraj
Amarynthos
Schimatari
Dilessi
Skala Oropou
Oropos
Kalamos
Almyropotamos
Ag.Thomas
Avlon
Varnavas
Marathon
Parnis
Dekeleia
Ag.Trias
Acharnai
Kiphissia
Amarousion
Fili
Liossia
Aspropyrgos
Elevsis
Daphni
Salamis
Perama
ATHINAI
PIRAEUS
Rafina
Porto Rafti
Markopoulon
Kalivia
Koropi
Keratea
Voula
Vouliagmeni
Anavissos
Lavrion
Sounion
Patroklos
Fleves
Aigina
Megara
Ag.Theodori
Gerania
Perachora
Loutraki
KORINTHOS
Pal. Korinthos
Bolomos
Athikia
Chiliomodi
Sofikon
Ag.Vasilios
Mykinai
Nemea
Skoteini
Kandila
Kaliani
Kefalari
Passion
Matzani
Assos
Kiato
Xylokastron
Derveni
Paralia Akratas
Evrostini
Trikala
Boura
Oligyrtos
Korinthiakos Kolpos
93
213
77
84
61
63
64
GREECE
NORTHERN SPORADES
PELOPONNESOS
Athens
Piraeus
Gulf of Corinth
Gulf of Evvoia
Saronic Gulf
Sea
ANDROS
KEA
KITHNOS
SERIFOS
SIFNOS
MILOS
PAROS
SIROS
TINOS
KITHIRA
C. MATAPAN
C. MALEA
Gulf of Laconia
Gulf of Argolis
Gulf of Messini
Gulf of Kiparissia
Gulf of Patra
36°

Fig. 1

Fig. 2

Fig. 3

access to the sea, from the upland, one must descend a steep rocky valley (see Fig. 4). Evidence such as carved and polished rock surfaces suggest that a road has been cut into the rocks of one of the valleys (Vathee). Inland and north from the shoreline are foothills approximately 250 meters in elevation and 100 meters in height, relative to the plain. The hills are rounded, with many rugged limestone bedrock outcrops on which terra rosa soil is seen as local patches on the more prominant underlying bedrock (see Fig. 5). The Thisvi plain, just north of the foothills, is a relatively small, essentially level, alluvial plain or basin mainly producing wheat (see Fig. 6). Olives are found growing closer to the rocky slopes on a gently sloping transition zone between the plain and the hills (see Fig. 7).

Fig. 4

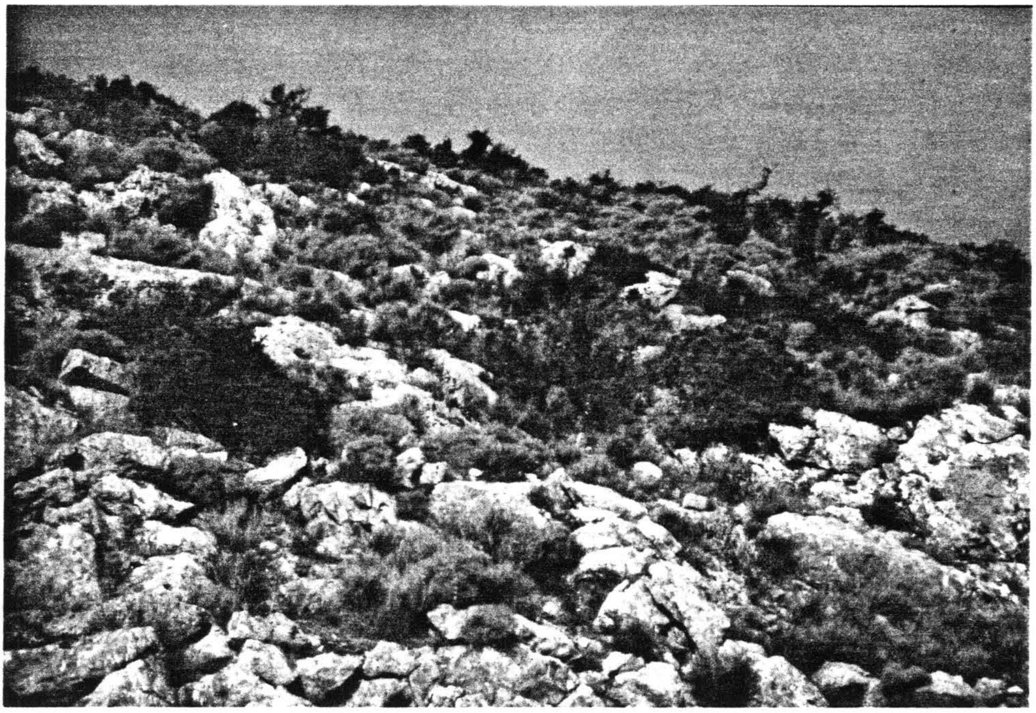

Fig. 5

Fig. 6

Fig. 7

Results of Survey

A survey was made to determine the differences between the soils on the slopes and the valley-fill soils. The properties measured were soil color, soil texture, type of vegetation, slope, and the percentage of coarse fragments found on the soil surface. There are three main units in the immediate area which can be mapped according to slope changes, soil color, soil texture, coarse fragment abundance, or vegetation types (see appendix for description of methods). All criteria will yield a map having essentially the same boundaries (see topo maps). The rocky hills with limestone bedrock outcrops have the steepest slopes, ranging from 4-10%. There are no loose coarse fragments on the surface, and the vegetation consists of scrub pines and various types of nonprofitable grasses, weeds and scrub oak. The second unit displays a sharp break in the slope from the previously discussed unit, with a range of 1-4%. This unit also displays a marked change in coarse fragments and vegetation. It has "common" to "many" coarse fragments on the surface and no limestone bedrock outcrops and the soil is cultivated, with olive trees being the predominant crop. The third unit is the nearly level alluvial valley. This area is less than 1% in slope, has "few" to "none" coarse fragments and wheat and some grapes are the common crops. Color and textural differences were also apparent among the three mappable units.

The only textural class found on the steep slopes, on which the soil is seen simply as patches on the limestone bedrock outcrops, was a silt loam. Of seventeen sites tested, the average clay content (based on the crude field techniques) was 21%. The values ranged from 14-36%. Only two sites had over 30% clay, indicating that the textural range for clay was quite narrow. The average value for the amount of sand was 10%, with a range from 5-18%, with only two values over 15%. As were the clay values, the sand percentages were suprisingly consistent. Eleven of the 17 sampled sites were a 5 YR 3/4 moist color. The remaining colors were very close in value, chroma and hue. These values and the fact that the textural differences were narrow indicate that all of these soils formed under the same soil-forming processes.

The soils found on the more gentle slope showed greater total amounts and greater amounts of variability in color and texture than the soils on the limestone bedrock outcrops. The average textural class was a loam, with 25% clay and 26% sand. This is slightly more clay and much more sand than the terra rosa soils found on the limestone bedrock hills. There was a 4% increase in clay and a 16% increase in sand percentages. The soils in this category contain "many" coarse fragments. Color variability also increased farther downslope. On the very gently sloping hills the colors were browner than those of the terra rosa soils as seen by the change from 5YR colors to 7.5YR colors. The overwhelming majority of the soils were 7.5YR 4/4 (eleven of the 19 sites tested). Four of the sites were just one color chip different, and the remainder of the soils in this category were within a few chips of each other.

The soils in the valley contain a much lower abundance of coarse fragments and a larger relative amount of fines. The variability in both texture and color was greater for the valley fill soils than in either of the soils found on the slopes. The amount of clay varied from a low of 20% to a high of 50%. The average, out of twenty sites sampled, was 33% clay and 11% sand. This is a substantial decrease in relative amounts of sand and an increase in the amounts of clay. Sand quantities ranged from a low of 0% to a high of 38%. As in the soil textures, the color variability was greatest in the valley soils. Eight of the twenty soils tested had moist colors of 10YR 4/4, while five sites were 7.5YR 3/4 and five were 7.5YR 4/4. The remaining two soil sites were only one chip away from one of the above colors.

Most of the bedrock in and around the Thisvi area are carbonates of various ages: Lower Triassic age marbles (metamorphosed during the early Alpine orogeny) and Upper Triassic, Lower Jurassic age limestones. The lower members are microcrystalline, mostly yellow-gray, red-gray, compact, well lithofied and of a nodulous appearance (Domvreni-Thisvi marbles). These marbles show no bedding, display no fossils, and sub-concoidal fractures are common. The sediments represent a neritic facies (Norton 1965). Also present are (Upper Triassic, Lower Jurassic age) light gray dolomites and limestones with patches of dark gray and light brown impurities. The rock is very fine-grained, well lithofied, and shows no apparent bedding. Small percentages of the bedrock in the area (larger near Vathee) consist of Upper Lias age (Upper Triassic argillaceous marly deposits, conglomerates, and others, with many limestone lenses or layers, and ophiolites being mostly serpentinized (Zaronikos 1971). In a few cases the ophiolites appear as a fracture filling of faults and/or joints.

Interpretation of Geomorphology

The general appearance of the area is a result of structural control. The valley appears to be a downdropped block, relative to the surrounding valley walls. It is widely believed that the tectonic deformation which began after a long epoch of marine deposition occured during the Alpine orogeny (Lower Tertiary period), the same time that the Swiss Alps were formed. Indeed, tectonic activity still exists in this area, as indicated by the frequent seismic activity. In Feb. 1981, the area was struck by a catastrophic earthquake which was followed by numerous smaller tremors, the epicenter of which was within several Km. of Thisvi. Emergency shelters are still seen throughout the village (see Fig. 8). Aug. 27, 1981 (the day after the Ohio Boeotia Expedition left the region), the area was struck by a smaller earthquake measuring 4.7 on the Richter Scale. Relatively recent fault scarps are seen on some of the surrounding hills (see Fig. 9), often having a strike subparallel to the valley. As a result of the tectonic activity, drainage of the valley has been modified, as evidenced by pockets of isolated subsurface drainage areas within the larger valley drainage system, and the limestone bedrock is somewhat porous and permeable, so springs are unpredictable in location. These features suggest near-karst conditions. The area does contain a number of wells and ancient cisterns, used for water supply.

There exists a very well constructed stone wall that apparently extended from one side of the valley to the other side. The purpose for such a wall is unknown. Surface soils on both sides of the wall were sampled and tested. There was no observable difference between the soils of the two sides. It is possible that degradation of the wall through time has resulted in ineffectiveness of the original

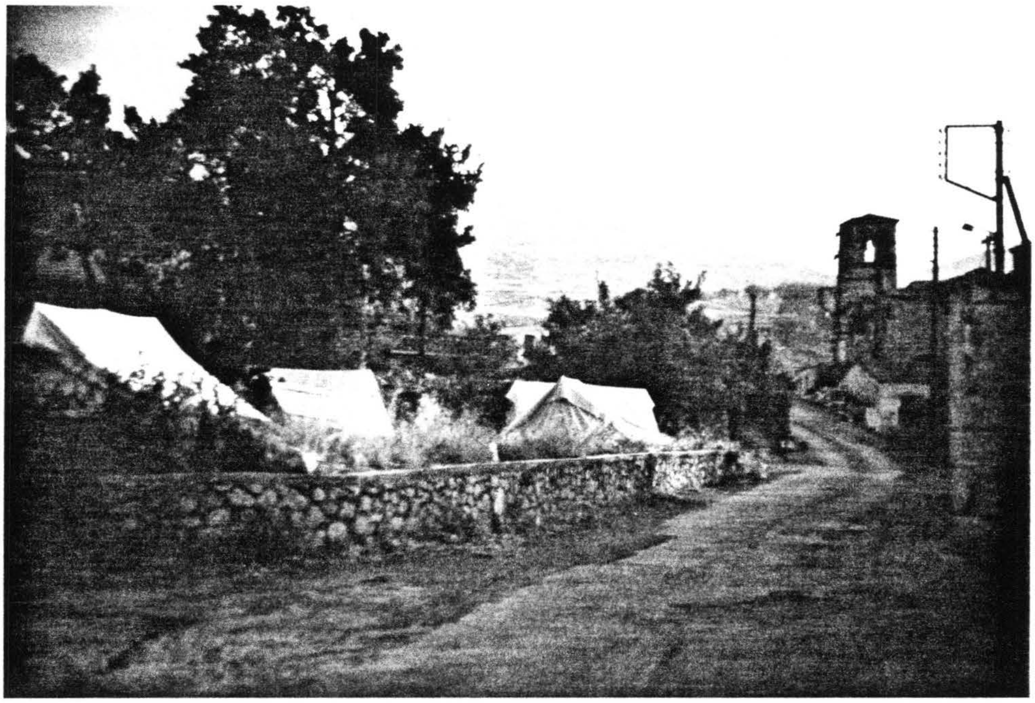

Fig. 8

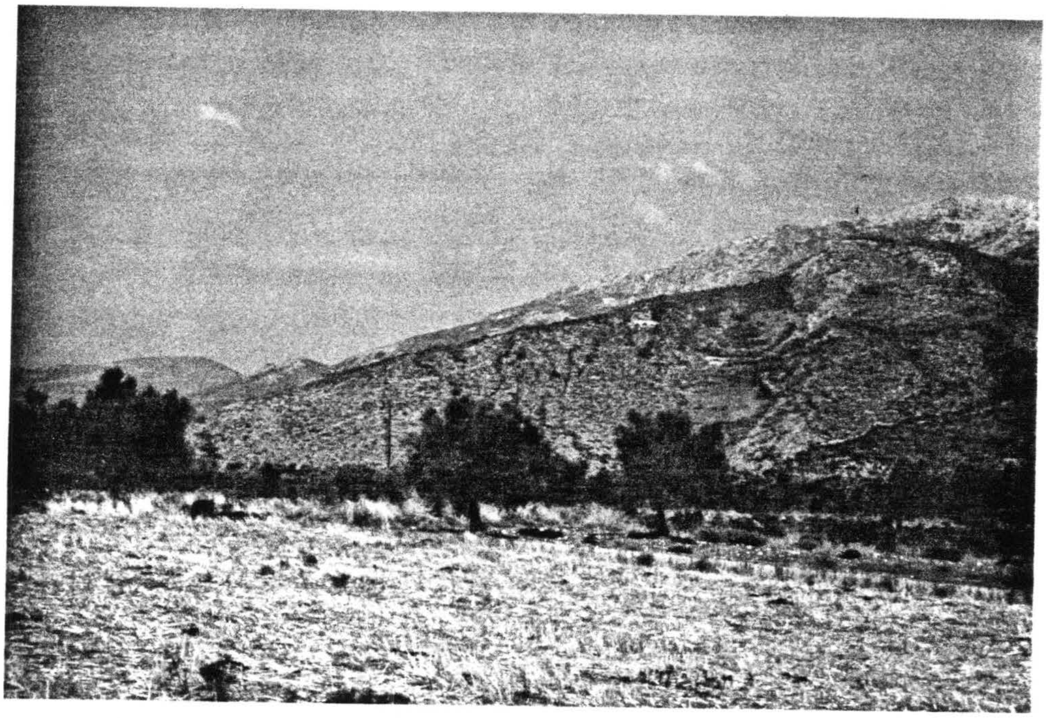

Fig. 9

purpose, and resulted in a return to natural erosional processes. It is possible that the purpose was as a retainer wall for sediment that erodes from the slopes and washes down the valley. The eroded surface soils are usually the most fertile, and very valuable to the farmer. Other workers have suggested that the wall (being so well constructed) was built to retain water for agricultural purposes. Because a pit could not be dug to determine differences between the subsurface soils on each side of the wall, no definite conclusions can be reached. Perhaps an exhaustive search into the literature would yield some answers.

Climate is a main factor controlling the post-glacial landscape. Temperature, moisture and vegetation are all directly affected. The usual generalized summary of the Mediterranean type of climate has periods of mild rainy winters alternating with periods of little or no rain during hot droughty summers; the vegetation is correspondingly restricted. Throughout the summer in the Eastern Mediterranean, a steady stream of air blows from the northern quarter on to the Egyptian and Libyan shores, because of the great heat of the African hinterland. These winds may take on a north-westerly direction during daytime in the lower layers of the atmosphere and may be regarded as very powerful sea breezes (Walker 1960). These winds were very pronounced in the Thisvi region. Following is a brief description of the climatic conditions during field work as quoted from Walker (1960):

> By July the Mediterranean is a parched and thirsty land; the brilliant greens of growing field crops have been replaced by the buff and yellow of stubble and bare earth; the sun glares back from naked rock anddried-up river bed; the blossom of the fruit trees has gone and the innumerable bulbous spring flowers have sunk back to rest; only the dark greens of pines and cypress stand out among the sombre greys of the olive groves and garrigue, and the oak and acacia struggle to breath through a coating of dust. The landscape, often obscured by a dusty haze, shimmers in the heat of a cloudless sky; the sun-bleached houses are closely shuttered and man and beast seek refuge in the shade till the midday heat is past; and even cities, banks, post offices and other public buildings close until the late afternoon when work resumes until 8 p.m. The village street or the city piazza, deserted a few hours before except for the indefatigable tyourist is now alive. . . .

The average number of days with rain, in Athens, is less than one per month in both July and August. The average daily maximum temperature in Athens for the month of July is 90°F (avg. min. is 72°). The period of year with the most frequent rain is Nov. through Feb., ranging from 6-7 days of rain per month. The average maximum and minimum daily temperature for Jan. in Athens are 54 and 42°F respectively, (Grosvenor 1966). McCoy reports a cyclic or rhythmic change is indicated for both temperature and moisture in the Mediterranean for the past 70,000 years (1980).

The amount and type of vegetation, from the post-glacial period to present, is also a subject of great dispute. Most workers believe that we are dealing with an area which was once forested, where the main check to growth is imposed by a summer drought of varying duration. A pollen diagram, from former Lake Xinian, 500 meters above sea level 39° 4' 0" N, 22° 5' 30" E, shows that at 21,390 ±430 BP reflects a steppe vegetation, trees were scarce, and the climate was cold and and dry. Then around 10,670 ± 90 years BP there was a increase in the percentage of tree pollen, evidently reflecting a warming and an increase in precipitation to favor oak forests. Gradually there was a decrease in deciduous trees and increase in conifers and finally a decline in forests all together, possibly because of hotter and drier climate (Brice 1978). However, Wright, in regard to climatic changes since Myceneaean times, states, "It may be a fair conclusion from the pollen studies in Greece that no vegetational changes may be attributed with any certainty to climatic changes" (Vita Finzi,1969). Many of the recent changes have undoubtedly been caused by man. Man affects vegetation, slope, and soil porosity by such processes as plowing, timber cutting, and animal grazing, and these can lead to changes in the topographic profile.

Sea level changes are a big factor in the geomorphic interpretation of the shoreline and the valleys that open to the sea. The Thisvi valley is topographically too high to be affected by sea level changes. The coastal changes are a function of numerous processes involving eustatic sea level changes, rock movement, sediment sinking and deposition. If sea level decreases, then increased erosion results in a topography of prominant cliffs and headlands that jut out into the sea (between which lie the bays and inlets). If sea level rises, then the low spots are filled in by sedimentation. A survey of the literature for eustatic sea level change reveals that within the same region, evidence can be found to conclude both eustatic constancy and oscillations of 25 ft. every 600 years (Fleming 1969). These varied results are often a result of the continued underthrusting of the European lithospheric plate by the African plate. Van Andel and Pope (1981) concluded that the sea level and the coastal geography during 9000 years BP was not much different than today (after ice melt and isostatic rebound). Fleming (1969) did a rather extensive study to determine once and for all what actually happened to the sea level in the past 2000 years. Of the 179 cities studied in the Western Mediterranean, definite conclusions were reached on 54: two cities were uplifted, 27 were fixed relative to sea level and 26 submerged. The submerged and uplifted sites are due to tectonic movement. Fleming concluded that there has been no net eustatic change of sea level in the last 2000 years to within an accuracy of ± 0.5 meters. The author believes that each sea level-change problem must be solved locally, with local evidence. There are too many variables to allow the application of a strict eustatic sea level fluctuation.

Interpretation of Soils

Soil is taken to mean a deposit which has been weathered and altered "in situ" to such a point that a vertical section taken through it will show some interior zonation, thus making possible a division into horizons, which are the result of the movement through the profile of certain constituents. Although not readily apparent, it is felt that vertical zonation exists within the valley soils. Many of the soils today, barring human disturbance, are the products of variable factors acting on them continuously since the beginning of the postglacial period at least, a stretch of perhaps 10,000 years. The factors include climate, topography, biotic, parent material and time. The soils of the area in question have been disturbed by ploughing, deforestation, and the ensuing denudation of considerable slopes. At least some of the factors--climate and vegetation in particular-- have varied considerably, as is known to us through pollen analysis, so that soil-forming processes have doubtless from time to time accelerated and slowed down in accordance with those changes (Cornwall 1958)

Some of the factors affecting soil color are the organic matter content, soil drainage, aeration and parent material. The organic matter imparts a gray, dark gray or dark brown color to soils, unless some other constituent modifies the color. If the soil is poorly drained, then usually there is a greater accumulation of organic matter, thus resulting in darker colors. In the lower horizons, with little organic matter, the soil will often be light gray in color, indicating chemical reducing conditions. Soil horizons that are dry part of the year and saturated part of the year tend to exhibit a mixture of both red and gray colors in a spotted pattern interspersed with the dominant color, commonly referred to as mottling.

Parent material is a significant soil-forming factor, and the limestones in the area are the parent material for the local soils. Soil forms in the residuum left from the dissolution of the carbonate during weathering. Thus, the kind of soil formed is related to the dominant kind of "impurities" in the limestone (Buol 1973).

The colors observed in the soils of this area are mainly due to humus and iron-compounds. The red tones found in the soils that lie as patches on the limestone slopes suggest some degree of peptization and dehydration of the iron, and so suggest warm, seasonally dry conditions. High temperatures alone do not produce redness. Irreversible dehydration (hematite Fe_2O_3) depends on seasonal drought as well as heat. These soils are viewed as the highly weathered remains of the limestone. Relief must not be so great as to permit rapid removal of particles detached from parent rocks, for should that be the case the soil color would be close to that of the (unweathered) parent rock. Humus contributes browner and, in the calcareous conditions, greyer shades. The light yellow-brown colors indicate poverty in organic matter. On the slopes the humus is not plentiful enough to mask the mineral colors. The pale color observed in the valley fill is common in calcareous soils and marly clays (Cornwall 1958).

Because of the noncalcareous terra rosa soils found on the slopes (which represent the highly weathered remains of the underlying limestone) it is assumed that a mature soil profile must have existed at one time. Sometime after its formation severe erosion occurred which resulted in the stripping away of the A1, A2 and most of the Bt horizon, until only the small patches of highly weathered soil remain between the more prominant limestone bedrock outcrops. It is apparent by the near-level valley that the slopes were severely eroded and the soil was deposited in this valley as an erosional product. In the immediate area there is evidence to suggest that

74 meters of sediment was deposited (a water well record of a well drilled near Dhombrena hit bedrock at 74 meters). The record shows that the overlying sediments consist mostly of various textures of light-brown to red soils; some gravels and serpentine are present.

It is widely believed that the mountains and surrounding hills were severely eroded, and that the lowlands were partially filled with sediment following the retreat of the great Pleistocene glaciers. In some areas the deposits are as much as 400 meters. A common interpretation for the geomorphic history of the Mediterranean area involves two cycles of erosion and aggradation. This older material is related to a period of low sea level during late Pleistocene time, resulting in "periglacial colluvium/alluvium". Some incision and erosion occured, followed by a second phase of deposition dated to late Roman and Medieval times (Bintliff 1976). He reports that similar results have been obtained by Paepe (1962), Ward-Perkins (1962), Davidson (1971) and Rapp (1973). These younger fills are now undergoing incision.

The reason for the second phase of aggradation is unclear at best, as is the precise time period during which it occurred. Most likely it is due to a climatic change, since deposition precludes direct human causation(Lamb 1966). Lamb mentions that during this time man was undergoing low and high population alternation (which evidently lessens the likelihood of him being the cause), and he mentions eustatic sea level change as a possible cause. Some workers (trying to date the second phase of deposition closer to Roman times) feel that the tremendous multiplication of goats and livestock were responsible for the deforestation and denudation that must have occurred (over grazing of the young shoots and buds by the ravenous domesticated animals). Others feel that extensive deforestation occurred because of the tremendous need for wood as both fuel for metallurgical and cooking needs and for construction purposes. During this past century, extensive deforestation and human activity has occurred in Greece; and no erosion and subsequent aggradation has occurred. Literary evidence for deforestation during classical times is sparse and unreliable.

Some of the factors affecting the processes of colluviation and alluviation include vegetation, climate, topography, parent material, sea level, tectonics and influence by man. It seems implausible that the complex interaction of these factors will yield such a simple two-phase scheme. The findings of Van Andel and Pope (1981), who worked in the southern Argolid in the Peloponnese, do not support this dicotomy. They feel that there have been six alluviation phases and four times of soil formation and stream intrenchment. Indeed, pertinent scientific evidence has not been generated to indicate the validity of such a proposition in the Thisvi area. It is clear that much additional work will be required before a complete understanding will be uncovered.

Calcareous Soils Discussion

One of the most interesting features of the soils in this area (from a soil genesis point of view) is the fact that the soils on the limestone bedrock are found to be noncalcareous, when checked with 10% HCl acid (even when the soil rests just centimeters above the limestone). The soils that are found as valley-fill are extremely reactive to the acid. This is also the case when the soil one meter below the surface at one valley site is tested. This phenomenon seems to be an enigma when the relief is considered. As a result of the runoff from the sloping areas, the depressional areas and valleys receive more surface water than surrounding upland soils. This, in effect, results in greater leaching of those soils formed at the base of the slope than those formed on upland areas and a minimum of leaching on the steep slopes for any given climate (Buol 1973).

One might conclude that with the increased percolation, the depth to carbonates in the soil increases down in the valleys.

One plausable explanation to be concidered involves subsurface water. The general movement of ground water is lateral and downward (resulting in the elluviation of materials such as clay and water soluable compounds) but may be locally upward during dry seasons. The rising waters evaporate at the surface and precipitate material from solution and colloidal suspension. Loss of water occurs from the soil mainly in the form of evaporation from the soil surface or via the plant (transpiration). These two forms of water loss from the soil are often considered collectively as evapotranspiration. If high evapotranspiration rates exist and if there is a underground source of water from which water can be drawn, the water will be pulled from the lower horizons towards the surface. Over time a substantial concentration of carbonates may occur. Sometimes the accumulation of these residues is great enough that it can be differentiated from the other material and named a separate horizon. This is termed the Ca horizon ($CaCO_3$ rich) or a caliche bed. The caliche bed was not seen in this area, and the calcareous material is seen throughout the vertical profile (thus shedding some doubt on this explanation). In most cases it is thought that the substances brought to the surfaces during dry seasons are washed downward and outward during wet winter seasons.

The free water moving over the soil surface (surface water) almost always carries some solid particles with it (and produces erosion and a change in the relief). When one considers that the surface water is flowing over limestone (which is usually considered to have greater than 50% carbonates by definition) then a source for the detrital and dissolved calcareous material becomes obvious.

Upon microscopic observation of some of the valley soils it was apparent that the $CaCO_3$ was derived from both a clastic and a dissolved and reprecipitated origin. If the calcareous material had all been drawn to the soil surface by evaporative processes, then it must have been dissolved in the water. If this is true, then when the water evaporates, the calcium carbonate residue should precipitate as a crust around the outer surfaces of the soil particles. Upon observation some carbonate material is indeed seen as a crust around the outer surface of the soil particles. But there is a larger percentage of calcite seen as descrete particles that are evenly distributed throughout the sample, of variable size (the vast majority are less than 0.1mm in size). These calcite fragments would indicate a clastic origin. Because the relief of the area varies through a wide range, there are places where vegetation is inadequate to protect the products of physical-chemical weathering. The sediments removed and later deposited range from a near-fresh rock fragment to particles of mature weathering and decompositon. The water which enters the slope soils is often fresh rain water, (with negligible amounts of carbonate material) which keeps the slope soils free of carbonates. As the water flows downslope over the limestone outcrops it becomes concentrated with carbonates. The valley-fill soils are then charged with the $CaCO_3$ rich water. Concentration of $CaCO_3$ results in the soil.

Pot Shard Concentrations

The archaeologist, who is doing a surface survey, is very interested in knowing what processes caused the pot fragments to be located in areas of high concentration. If essentially no deposition or erosion occurred since classical times, then, when a high concentration of pot fragments is discovered on the present day surface, he can conclude that some sort of dwelling structure or foundation must lie at, and/or just below that spot. However it is possible and quite common that much denudation and/or accumulation has occurred and that the pot fragments where concentrated by some natural means.

The shards were dispersed over extensive areas of the flat valley and gentle slopes, with a average concentration of 1-2 shards per square meter and nucleated concentrations of 5-7 shards per square meter in some areas. A significant number of sites with high concentrations were located near physiographic boundaries. A feeble attempt was made to compare the angularity versus the roundness as related to the location, the assumption being that angular fragments must be "in situ", while the rounded fragments were mechanically ground down during transportation. It seemed to be the case that no discernable relationships existed in this area, possibly because short transportation distances did not allow fractionation. The shards were not sorted with respect to size, so one may rule out alluvial deposition in favor of a colluvial process involving the deposition of a loose heterogenous mass of soil and coarse fragments.

The fact that some of the sites of concentrations are located on the zone between the steep rocky slopes and the flat valley raises some questions. The key factor is to determine when the major periods of erosion occurred. If erosion occurred before the area was inhabited, then perhaps people lived on the transition zone because of a need to have access to both sets of resources. If erosion occurred after habitation, then a different reason must be considered One plausable method entails a homogeneous concentration of shards on the original habitation layer (see Fig. 10), which includes hills, slopes and valley, followed by a period of erosion where the upper area is stripped off the hills and deposited over the lower areas (resulting in the present day surface). The end product of this model would reveal, 1) no shards on the upper (stripped) areas, 2) a belt or zone of high shard concentration parallel to the contours of the hills, and 3) a lesser concentration throughout the lower valley areas. This model seems to fit the data fairly closely; however, not all of the sites of nucleated concentrations are found at physiographic boundaries, and there is not the expected belt of high shard concentration. Secondary processes must also be involved in this area.

It would be very beneficial to look for disconformities, with datable material (C^{14}, pot shards etc.), in each horizon. This would yield the maximum age for the surface and the minimum age for the underlying material. A person could then draw inferences and determine when erosion occurred and the nature of the ancient land surfaces.

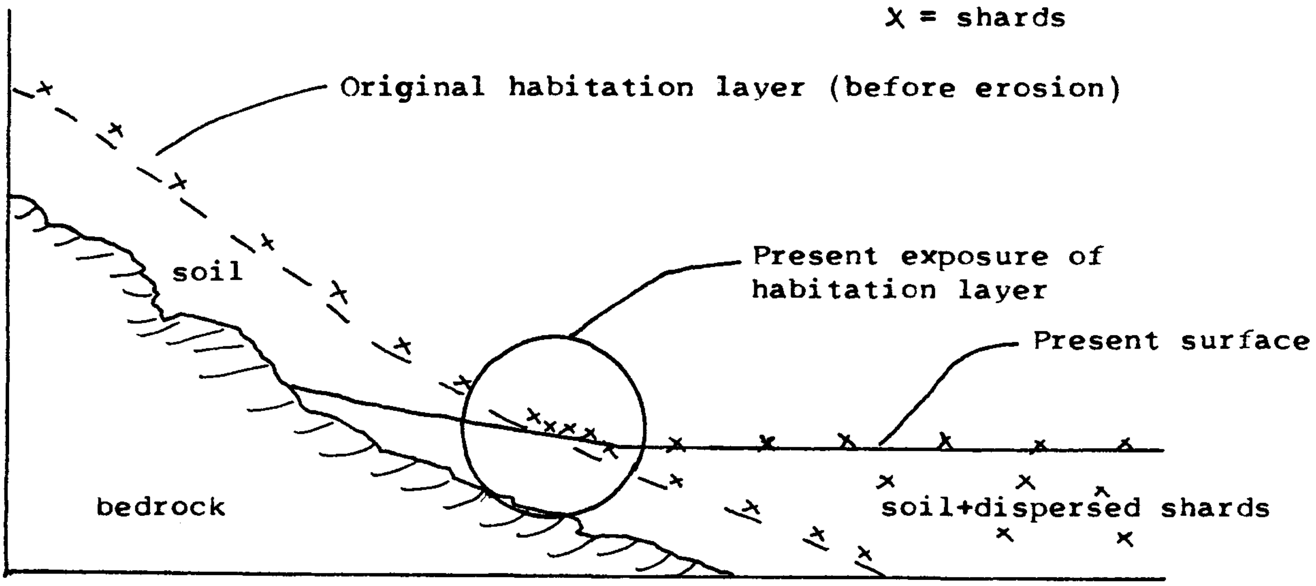

Fig. 10

One explanation for the great abundance (but not concentration) of shards might be from frost wedging processes. The annual cycle of freeze and thaw produces lateral stresses in the soil, ice and water mixture. On level ground rocks and cobbles may be lifted by frost heaving, and fine sediments fill in beneath them so that the layer becomes sorted, with the coarsest fragments at the surface (Bloom 1978). The average daily minimum temperature for the month of January, is 42°F in nearby Athens (Ruffner 1977). Ideally, for the greatest amount of frost wedging, the ground should average near 32°F, with temperature fluctuations above and below that point. Because the average climatic conditions of this area of Greece not near that of pariglacial conditions, the process of frost wedging of the pot fragments is not significant.

Desiccation of the soil is very common in this area. During the dry summer months, mud cracks, open to variable depths, can be observed. The largest mud crack was over 36 inches in depth and over five inches in width (see Fig. 11). The cracks were big enough to cause hazardous conditions for the unobservant perambulator. The severe shrink-swell of the soils would not be a factor in transportation of the shards to the surface. As the soil shrinks, the coarse fragments are subjected to stresses, but they are not moved. If the soils are water saturated, then the effects of gravity will be strongest, so the shards will move down the vertical profile, if they move at all.

Fig. 11

It seems that the only plausible way the shards can be moved to the surface is by a combination of processes involving human intervention and erosion. This can be done by man plowing and redistributing the soil (which contains the shards), afterwhich erosional processes can refine and increase the apparent concentration of coarse fragments on the surface. During the seasonal rains the impact of raindrops hitting the soil surface will loosen and move soil particles, in a "splash and scatter" manner. Small soil particles are "washed off" the larger, more stable coarse fragments. The coarse fragments are essentially "chisled" out of the soil by this process. The same "washing off" effects (of the coarse fragments) can be produced by wind erosion, which reaches its greatest extent during the dry summer months (high rainfall during the winter period). The end result, of these two processes is the belief held by some farmers that they are actually growing rocks (hence the term "rock garden").

Sheet erosion is a plausible process to explain both the shard abundance and concentration. This process will entail the shards being brought near the soil surface (by some means such as plowing), and then during heavy rains thin layers of surface material are removed more or less evenly from an extensive area. With slow water velocities only soil size particles will be removed, resulting in a relative increase in the abundance of residual shards over the entire area. If the velocity of the surface water is faster, it can transport and concentrate the larger coarse fragments in various topographic lows. The explanation sounds reasonable until one considers that other coarse fragments, such as rocks, do not appear to be concentrated in the same area as the shards. A thorough investigation is in order to relate the age of shards to the locality and type of soil in which they are found. If there are high concentrations of fragments in specific areas from a particular time period, then it would seem reasonable to conclude that the concentration is due to man's presence, rather than a natural geologic process. Things such as building foundations in and around the concentration sites are also strong indicators that the sites are of significant archaeological interest.

APPENDIX

METHODOLOGY

A standard soil profile is usually devided into three general vertical horizons (which extend laterally in all directions). The "A" horizon, is considered to be a humus rich eluvial zone. The "B" horizon is a iluvial zone in which materials removed from the "A" horizon are deposited in the "B" horizon. The "C" horizon is considered to be chemically unaltered, but often weathered. The first several days of mapping were done by walking a transect accross the valley, and periodically sampling the soil. With time, the author found mapping of the area could be accomplished at a faster and equally accurrate rate by being selective with the sampling sites. Properties recorded include the percentage coarse fragments on the surface, type of vegetation, reaction to 10% HCl acid, color, and texture.

Soil texture is concerned with the size of mineral particles. It refers to the relative proportion of the various size-fractions, in a given soil. The system as defined by the United States Dept. of Agriculture was used (sand2mm-0.02mm, silt 0.02-0.002, clay below 0.002mm). The organic matter and fragments greater than 2mm in size do not enter into the analysis of the fine earth. Those amounts are usually rated separately. The amounts of coarse fragments (greater than sand size) were judged by a brief inspection of the relative percentages of the coarse fragments on the soil surface. If the amounts appear to be less than 2%, then the category is "few", if it was 2-20% then it is "common", and if the abundance was greater than 20% then the amount is described as "many". In this survey organic matter content was not rated.

Although the textural class connot be accurately determined without a particle size analysis, there are field tests which rely on the "feel" of the material, obtained by working a small moist sample between the fingers and hand. Sand grains "grate" against each other in the hand sample, and can easily be detected visually. Silt is finer-textured than sand and has a rather "silky" or "flour-like" feel. The individual grains will not be distinguishable without the aid of a hand lens. Clay will be sticky, cohesive and plastic when moist, and it will often leave a shiny surface when rubbed with the finger. It is rare to find sediments or soils composed entirely of sand, silt or clay, rather than combinations of the three. Soils will fall into one of 12 different textural classes (silt, silt loam, clay loam, etc.), based on the relative proportions of sand, silt and clay. This field method was used extensively for this survey, as it seemed to be a good criterion to separate the different types of soils. It is believed by the author that this field technique has an accuraccy of ± 4% of each constituent.

Color was another very valuable criterion used for differentiation between the various soil types. The variations in natural color are often extremely significant and may be a valuable aid to description. Color was described by reference to the Munsell system of soil color notation. This eliminates the subjective verbal color descriptions which mean different things to different people, and enables accurate communication of the exact color (between workers with normal color-vision). Reading of soil color is taken by comparing the moist sample with the color chips in the charts, and reading the notation of the chip nearest in color to the soil.

The Munsell system recognises three attributes of color: The hue (described as one of ten divisions of the visible spectrum), the value (described as the degree of lightness or darkness, where a figure one is black and 10 is white), and the chroma (the degree of departure of a given hue from a neutral gray of the same color, often referred to as the quality or pureness of color) (Shackley 1975). Each page in the charts contains a series of chips of different hues, with the value variations expressed on the vertical axis and the chroma variation along the horizontal. Ideally (in order to obtain uniform results) all colors should be measured using sun light, at the same time of day. The light source condition was easily adhered to, but the time of day when readings were made was varied. It was not felt that significant errors were introduced due to the time variations. A third condition is that all colors should be recorded by the same person (because color perception varies between individuals). The author recorded all of the colors. Because of color not being uniform within the soil specimen, the samples were rubbed in order to eliminate the variabilities.

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