E. M. BRIDGES

WORLD SOILS

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SECOND EDITION

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PREFACE TO THE SECOND EDITION

The second edition of this book, like the first, attempts to provide students of agriculture, biology, geography, environmental science and soil science with an introduction to the study of the soils of the world. It is specifically directed at students who are in their last years at school or are taking courses in colleges or universities at an introductory level. The policy of the author has been to convey information concisely and with the minimum of pedological jargon. The book aims to give the student a satisfactory basis of knowledge upon which further studies can be built if so desired. Although information has been obtained from many sources throughout the world, the presentation reflects the British approach and background of the author.

In preparing this edition for the press, the opportunity has been taken to incorporate a number of modifications into the text. The factors and processes of soil formation have been placed in separate chapters to stress the importance of the internal processes which are responsible for soil profile development. The chapter on soil classification has been brought up to date and now includes reference to both U.S. Soil Taxonomy and the Legend of the F.A.O./U.N.E.S.C.O. Soil Map of the World as well as the current British system of soil classification. Synonyms of soils have been introduced where practicable to familiarise readers with these international systems of soil classification. The chapter concerned with soil mapping now serves as a link between the soils described and their distribution, fertility, land use capability and other applications of soil science which are discussed in the last chapter. Whilst not departing radically from the first edition it is hoped that these changes will improve the usefulness of the book and bring it up to date.

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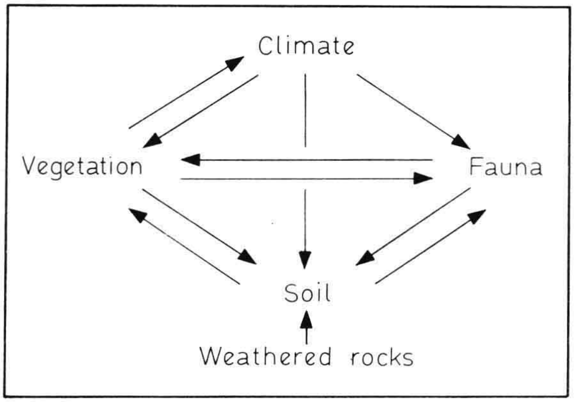
1 INTRODUCTION

Soil has a peculiar fascination, which impinges upon all of us at some time or other. Farmers or horticulturalists till it, engineers move it about in Juggernaut-like machines, small boys dig in it, and mothers abhor it as being dirty. Unfortunately, for many people soil is synonymous with dirt. They should know better, for the soil has a vital and important role to play in the life of the world and mankind. As Sir John Russell has written, 'a clod of earth seems at first sight to be the embodiment of the stillness of death'; however, he goes on to show that it is in fact a highly organised physical, chemical and biological complex on which all of us are dependent. As the support of vegetable life, the soil plays the most fundamental of roles in providing sustenance for all animals and man.



1.1 The arrows indicate the various interactions of the environment which affect the soil

The position of soil in the biotic complex can be illustrated in diagram (Fig. 1.1) where it can be seen that climate influences plants, animals and soil directly. Plants influence the soil, animals and the climate near the ground. Animals play a considerable role in soil development and often the type of soil influences the animals which are present in it; animals also influence the vegetation which is growing in the soil. Finally climate, through weathering, influences the rocks, which in time become part of the soil as it is first weathered and later acted upon by soil-forming processes.

The study of soils is the occupation of the *pedologist*, and his science of *pedology* emphasises the study of the soil as a natural phenomenon on the surface of the earth. The pedologist is interested in the appearance of the soil, its mode of formation, its physical, chemical and biological composition, and its classification and distribution.

Pedology makes use of a large number of branches of scientific knowledge, and as an integrative science resembles the role of geography. As will already be apparent from the previous paragraph, aspects of physics, chemistry and biology have an important contribution to make to the study of the soil, so have studies in agriculture, forestry, history, geography, mineralogy, archaeology and geology. From all of these are obtained information which can be synthesised to make a scientific discipline and natural philosophy separate from, and yet closely related to, many other branches of natural science.

Pedology can be studied as a pure science in which the identification of the processes producing the soil profile as well as the mapping and classification of soils form an important part. However, the results obtained in the pure science can be applied to practical problems in agriculture, horticulture, forestry, engineering, and in planning the future use of the land.

In cases of the proposed development of virgin lands or of lands previously used for extensive grazing, the pedologist can offer recommendations for the cultivation practices and the parcelling out of farm units within the developing area.

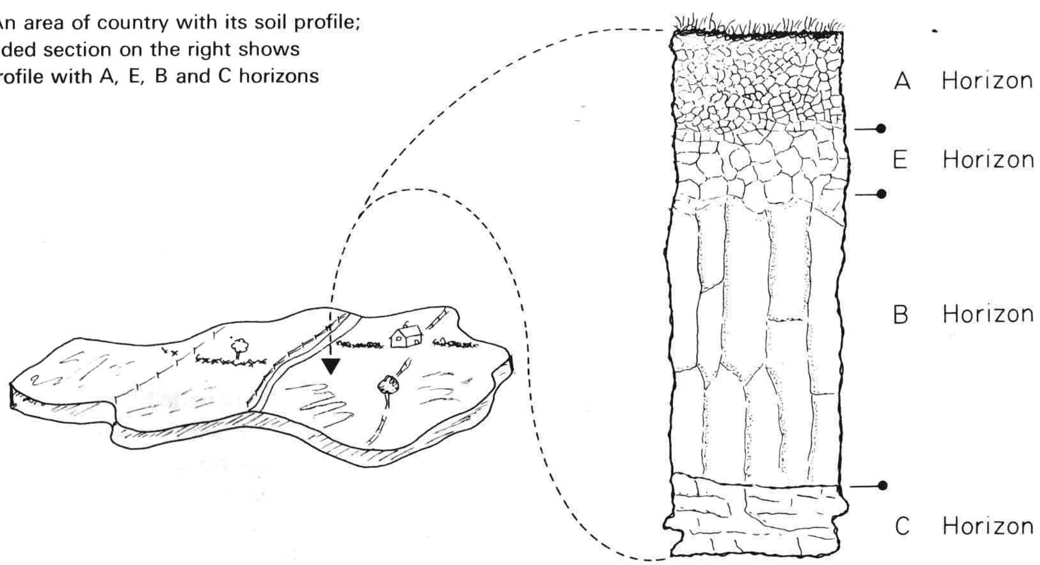
This type of work is particularly useful in irrigation schemes where the high cost of installation makes a knowledge of the soils essential before the civil engineering work is even planned. The classification of soils leads naturally to land capability, hence the pedologist's interest in the natural fertility of soils, and the ways in which this fertility can be put to the best use or even increased.

Definition of soil

Present-day soil science has emerged from two different schools of thought, one chemical, the other geological. The German scientist Liebig was probably the most renowned exponent of the chemical view of the soil, but even before Liebig, a Swedish scientist Berzelius described soil as 'the chemical laboratory of nature in whose bosom various chemical decomposition and synthesis reactions take place in a hidden manner'. Early pedologists with a geological background considered the soil to be comminuted rock with a certain amount of organic matter derived from the decomposition products of plants. As late as 1917, a German scientist, Ramann, described soil as 'rocks that have been reduced to small fragments and have been more or less changed chemically, together with the remains of plants or animals that live in it or on it'.

Current definitions of soil result mainly from the work of two men, in Russia, Dokuchaiev, and in America, Hilgard. Independently both noted that soils were related in a general way to climate, and that soils could be described in broad geographical zones, which at the scale of world maps could be correlated not only with climate but also with the associated belts of vegetation. Although this is only partly true, it did serve to direct attention to the environmental relationships of the soil cover of our planet. This environmental approach still holds true today but it has become clear that climate, although important, is only one of a number of factors in soil formation (p. 24). The variation of soils brought to light at larger scales of mapping in many different regions of the world shows that the soil pattern results from the interplay of climate with the other soil forming factors. In this sense, soils can be considered as being in a state of dynamic equilibrium or slow evolution.

The soil can be envisaged also as an open system through which the various hydrological, biological and geochemical cycles operate. The soil forms a specific type of open system known as a process–response system in which there is a close relationship between morphological structure and the inputs and outputs of mass and energy (Fig. 3.6). These inputs and outputs usually operate in a vertical direction at any one



1.2 An area of country with its soil profile; expanded section on the right shows soil profile with A, E, B and C horizons place on level surfaces but where slopes occur a horizontal component is introduced which finds expression in the different morphological properties of soil on slopes (pp. 26, 101).

The definition of soil propounded by Joffe has the advantage that it combines the physical, chemical and biological constituents, and throws the right amount of weight on the importance of morphology in the description of a soil.

'The soil is a natural body of animal, mineral and organic constituents differentiated into horizons of variable depth which differ from the material below in morphology, physical make-up, chemical properties and composition, and biological characteristics'. A more simple definition states that soil is 'the stuff in which plants grow'; however, this is not necessarily a full definition as everyone knows cress will grow on a damp piece of flannel without the aid of soil, and by the science of hydroponics many plants can be grown in water to which has been added the necessary mineral nutrients.

The succession of *horizons* which is exposed when a vertical cut is made through the soil to the parent material comprises the *soil profile* (Fig. 1.2). Since Dokuchaiev first labelled soil horizons A, B, C, a conventional notation has evolved which facilitates ease of discussion, comparison and classification. Horizons are designated according to their position in the soil profile and the processes which have brought them into being. The following notation has been adopted for *major soil horizons* in Britain and it accords with international usage.

Where present, superficial organic horizons are designated by the letters L, F, H and O; surface eluvial horizons by A and E; subsurface illuvial horizons by B; the parent material C, and unweathered rock is indicated by the letter R.

L. Fresh litter, original plant structure evident.

F. Partly decomposed and comminuted litter of previous years' growth.

H. Well decomposed material, plant structures no longer evident.

O. Peaty: plant remains accumulated under wet conditions.

A. Mineral soil horizon formed at or near the surface, characterised by incorporation of humified organic matter intimately associated with the mineral fraction. Incorporation of organic matter is presumed to result from biological activity or artificial mixing during tillage.

E. Subsurface mineral horizon underlying the A horizon that is lighter in colour and contains less organic matter, sesquioxides of iron and/or clay than the horizon beneath.

B. The B horizon is normally differentiated from adjacent horizons by colour and structure. It usually underlies an A or E horizon and is characterised by illuvial concentration of silicate clay, iron, aluminium or humus. Other forms of B horizon result from alteration of the parent material by removal of carbonates, formation, liberation or residual accumulation of silicate clays or oxides.

C. Unconsolidated or weakly consolidated mineral horizon which retains evidence of rock structure and lacks the properties diagnostic of the overlying A, E, and B horizons. The C horizon may possess accumulations of carbonates or more soluble salts; it may have dense, brittle properties and it may be modified by gleying.

R. Continuous hard or very hard bedrock.

The major soil horizons have many specific characteristics which are designated by the addition of lower case letters. These specific features are briefly described below and the processes which cause their formation are discussed in Chapter 4.

O horizons are peaty horizons accumulated under wet conditions.
They may be subdivided into:

Of	fibrous peat
Om	semi fibrous peat
On	amorphous peat

A horizons may be subdivided into:

Ah	uncultivated A horizon
Ap	cultivated A horizon
Ag	gleyed A horizon

E horizons may be subdivided into:

Ea	bleached horizon of podzol soils
Eb	lighter coloured horizon, depleted of clay and sesquioxides in brown soils
Eg	gleyed E horizon

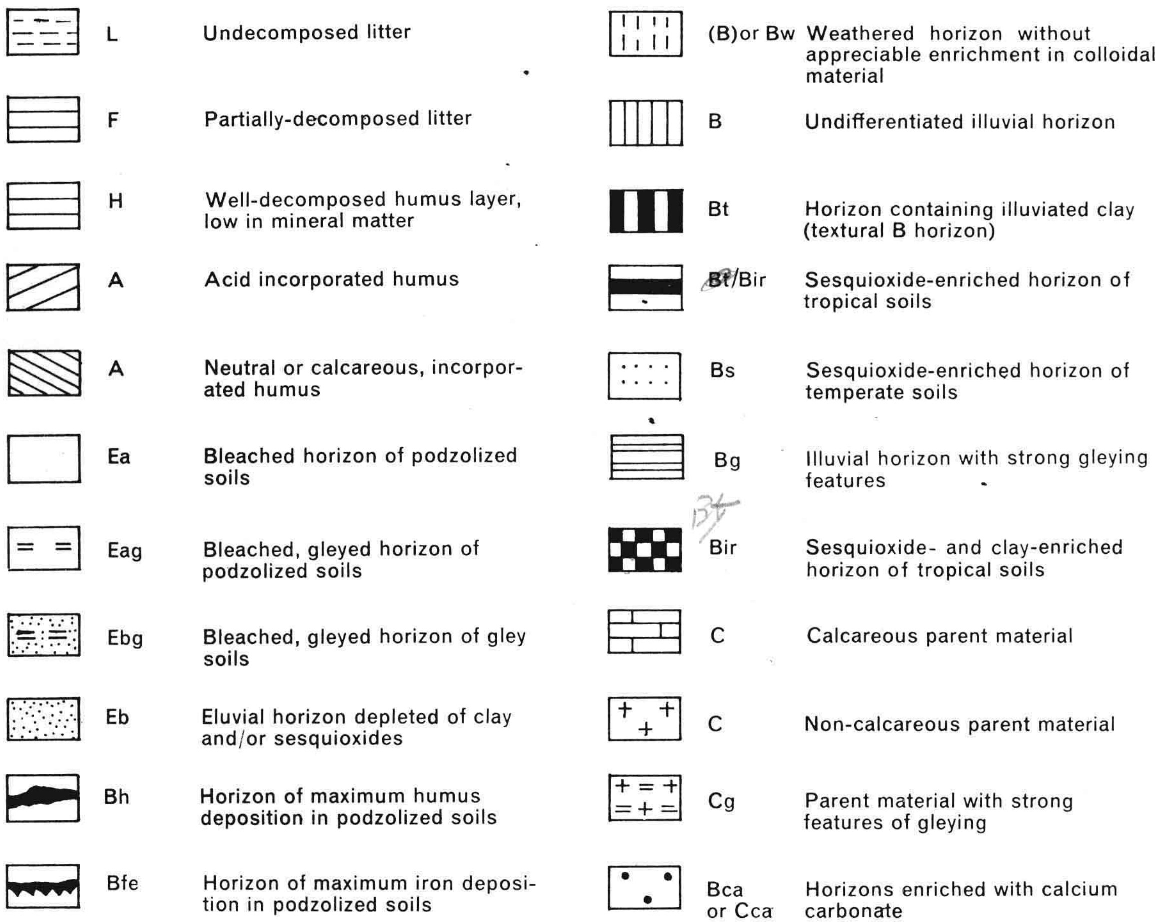
B horizons may be subdivided into:

Bfe	thin iron pan
Bs	ochreous-coloured, sesquioxide enriched B horizon of temperate soils
Bw or (B)	'weathered' B horizon without illuvial additions
Bt	clay-enriched B horizon
Bx	compact dense fragipan
Bh	organic matter enriched B horizon
Bg	gleyed B horizon
Bca	enriched with calcium carbonate
Bir or Box	enrichment with sesquioxides in tropical soils

C horizons may be subdivided into:

Ca	unconsolidated materials
Cca	enriched with calcium carbonate
Ccs	enriched with gypsum
Cg	gleyed C horizon
CG	strongly gleyed horizon which changes colour on exposure to air
Cx	compact, dense fragipan
Cm	cemented material

The symbols used to represent soil horizons throughout this book are given in Fig. 1.3. The presence of certain horizons and their order in the soil profile indicatees which soil forming process



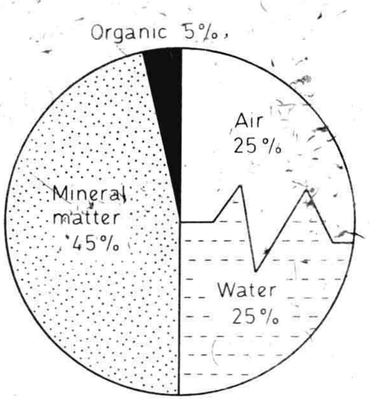
1.3 Symbols used to represent soil horizons thoughout this book. These symbols are not used by all soil scientists in their interpretation of soil profiles. Consequently, not all examples used in this book have them. Combinations of symbols indicate a horizon with features common to both are operating. A discussion of the factors which control these processes occurs in Chapter 3.

Soils are developed in material which has already been weathered from the solid rocks. This *weathered mantle* or *regolith* can be as deep as 50 m. in the humid tropics. In Britain and northern Europe the depth is variable, but on average is somewhere around 1 to 1.5 m. although in places it is non-existent. Before attempting an account of the soils of the world it is necessary to know something of the ways in which soils are classified. These are dealt with in Chapter 5. The soils of the world are described in broad latitudinal zones in Chapters 6 to 9 and the intrazonal and azonal soils in Chapter 10. Examples of soil profiles from published and unpublished sources are given as illustrations of different soil types. The original author's description has been retained where possible, but some rearrangement and simplification has often been necessary. This accounts for the variability of the different descriptions.

The different approaches to mapping soils are discussed in Chapter 11 together with the methods of soil description and sampling in common use. A discussion of world soil distributions, soil fertility, land use capability and other applied uses of soil data concludes the book.

2 COMPOSITION OF SOILS

There are four main constituents of soil: mineral matter, organic matter, air and water (Fig. 2.1). The mineral matter includes all those minerals weathered from the parent material as well as those formed in the soil by recombination from substances in the soil solution. The organic matter is derived mostly from decaying vegetable matter which is broken down and decomposed by the action of the many different forms of animal life which live in the soil. Normally both air and water occupy the spaces between the structures of the soil, but if a soil is saturated with water most of the air is driven out. In a soil which is freely drained some water is still present in the form of thin films around the mineral particles, leaving the spaces of the fissures and pores open for the penetration of the atmosphere.



2.1 Volume composition of a typical topsoil; amounts are approximate as the percentage of certain constituents, e.g. air and water, is constantly varying

Mineral matter

The mineral portion of soil is derived from the parent material by weathering and consists of a range of particle sizes from very small clay particles of less than 0.002 mm. diameter to sand-size particles of up to 2 mm. diameter. This part of the soil is known as the *fine earth* and it is upon this that the *texture* of the soil is determined. Larger particles or stones occur also, but except for their bulk are considered to be inert, contributing only by their physical presence. This can be useful in a fine-textured soil in that the stones break the continuity of the clay material. Taking the three different fractions of sand, silt and clay which occur in any soil, it is possible to relate them to the triangular diagram (Fig. 2.2a). The texture of a soil can easily be determined in the field by first moistening and then estimating the proportions of sand, silt and clay as it is worked between finger and thumb. (Sand 2 mm.–0.05 mm., silt 0.05–0.002 mm., clay < 0.002 mm.) Descriptions of the different classes of soil texture are given in Table 2.1.

Table 2.1 Soil texture class descriptions

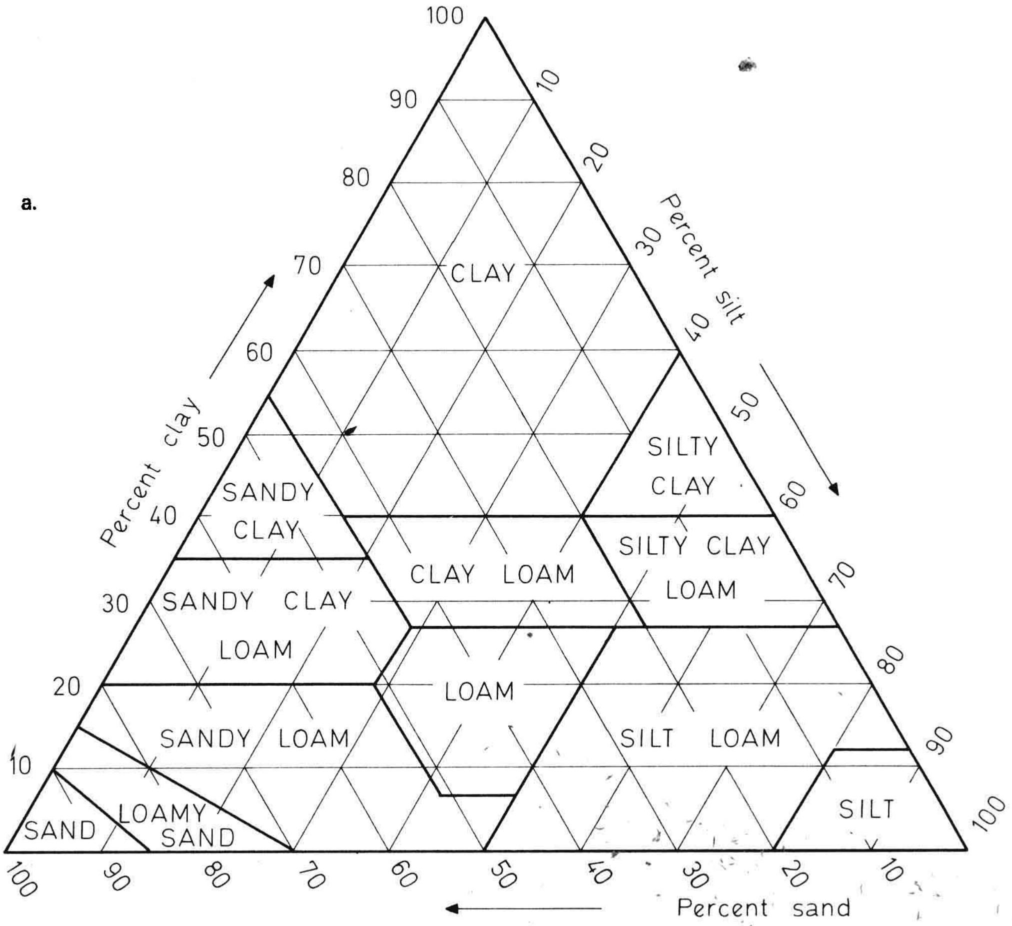
Sand. Soil consisting mostly of coarse and fine sand, and containing so little clay that it is loose when dry and not sticky at all when wet. When rubbed it leaves no film on the fingers.

Loamy sand. Consisting mostly of sand but with sufficient clay to give slight plasticity and cohesion when very moist. Leaves a slight film of fine materials on the fingers when rubbed.

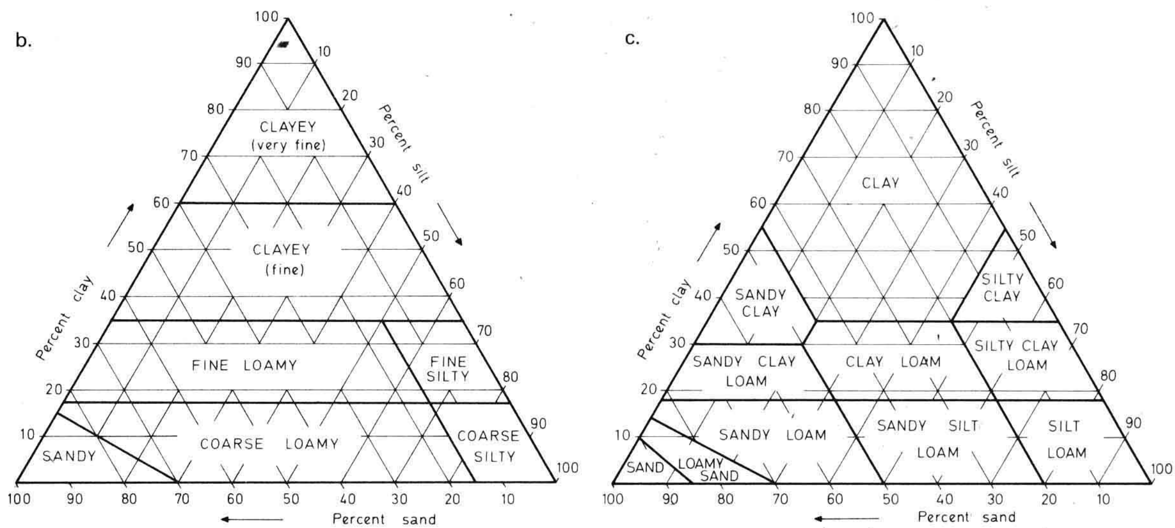
Sandy loam. Soil in which the sand fraction is still quite obvious, which moulds readily when sufficiently moist but in most cases does not stick appreciably to the fingers. Threads do not form easily.

Loam. Soil in which the fractions are so blended that it moulds readily when sufficiently moist, and sticks to the fingers to some extent. It can with difficulty be moulded into threads but will not bend into a small ring.

Silt loam. Soil that is moderately plastic without being very sticky and in which the smooth soapy feel of the silt is the main feature.



2.2 (a) Soil texture classes, U.S.D.A. The three sides represent base lines for sand, silt and clay with the apices opposite representing 100 per cent of each constituent. Percentages can be read off to give the textural name for any soil sample. (b) Broad soil texture groupings. (c) Soil texture classes, Soil Survey of England and Wales.



Sandy clay loam. Soils containing sufficient clay to be distinctly sticky when moist, but in which the sand fraction is still an obvious feature.

Clay loam. The soil is distinctly sticky when sufficiently moist, and the presence of sand fractions can only be detected with care.

Silty clay loam. This contains quite subordinate amounts of sand, but sufficient silt to confer something of a smooth soapy feel. It is less sticky than silty clay or clay loam.

Silt. Soil in which the smooth, soapy feel of silt is dominant.

Sandy clay. The soil is plastic and sticky when moistened sufficiently, but the sand fraction is still an obvious feature. Clay and sand are dominant, and the intermediate grades of silt and very fine sand are less apparent.

Clay. The soil is plastic and sticky when moistened sufficiently and gives a polished surface on rubbing. When moist the soil can be rolled into threads, and it is capable of being moulded into any shape and takes clear fingerprints.

Silty clay. Soil which is composed almost entirely of very fine material but in which the smooth soapy feel of the silt fraction modifies to some extent the stickiness of the clay.

These texture classes are used for the description of texture within a profile but there is a need for broader groupings of soil textures when describing the whole profile or groups of similar soils. These textural groupings are:

clayey	very fine
	fine
silty	fine
	coarse
loamy	fine
	coarse
sandy	

The relationship of the twelve texture classes to these seven textural groupings can be seen in the second triangular diagram (Fig. 2.2b). These broad textural groupings cut across several of the textural classes as they are based upon slightly different particle sizes. This has occurred because of the need for closer co-operation between engineers and soil scientists which has resulted in the pedological size grades being modified according to a scale having sand 2.00 mm. to 0.06 mm.; silt 0.06 mm. to $<$ 0.002 mm. and clay 0.002 mm.

2.3 Some of the less common (heavy) minerals present in the soil: (a), (b), zircon; (d), (e), (f), garnet; (g), tourmaline; (h), iron ore (magnetite)