NEW ZEALAND
DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

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SOIL BUREAU BULLETIN 26(1)

SOILS OF NEW ZEALAND
PART 1

By the staff of Soil Bureau,
New Zealand Department of Scientific and Industrial Research
with contributions from members of
Plant Diseases Division, Department of Scientific and Industrial Research; Extension Division, Department of Agriculture; New Zealand Forest Service; Town and Country Planning Branch, Ministry of Works; and Lincoln College, University of Canterbury.

1968

A. R. SHEARER, GOVERNMENT PRINTER, WELLINGTON, NEW ZEALAND

Price: $5.50

Editor, Jean Luke
Information Service, D.S.I.R.
assisted by
Janice Heine, Soil Bureau

Bibliographic Reference:
N.Z. Soil Bureau 1968: Soils of New Zealand. Part 1.
N.Z. Soil Bur. Bull. 26(1).

Printed by Whitcombe and Tombs Limited, Christchurch
Under authority A.. R. Shearer, Government Printer, Wellington, New Zealand—1968

CHAPTER 2. CLASSIFICATION OF NEW ZEALAND SOILS

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2·1· INTRODUCTION

Soil work in New Zealand, and particularly the mapping and classification of soils, developed in an atmosphere of comparative isolation from the rest of the world. It contains many imperfections, as New Zealand pedologists are only too well aware, but it has served New Zealand well, has withstood critical examination by the chemist, the physicist, and the biologist, and above all has assisted the progress of land development through a difficult state by providing a new basis for the study of many agricultural and forestry problems. With the coming of closer liaison among pedologists throughout the world, New Zealand methods will undoubtedly change. Before these changes proceed too far, the present system and its philosophy need to be recorded so that such good features as exist may be preserved.

Two main approaches have been adopted. First, in order to meet immediate agronomic needs, soil types were recognised and mapped; they were grouped into series, and various attempts were made to group them into families following early practices in the United States (Taylor and Pohlen, 1962). Secondly, to facilitate soil and related investigations, broad soil groups were recognised and subdivided in an interpretative way according to soil-forming processes. Various arrangements of the classification have also been used for particular investigations, notably the soil suites which comprise soils from like parent materials arranged in order of profile development, thus allowing characteristics acquired during soil formation to be separated from those inherited from the parent material. The interpretative or genetic approach based on the recognition of broad soil groups is the subject of this analysis, the purpose of which is not to evolve a new classification but to examine logically the one that has already been evolved to meet New Zealand conditions and is at present in use.

Because of the early period of isolation, many New Zealand soil terms have tended to be used in a local sense and are not acceptable to workers overseas. Other terms, introduced tentatively as common names, are too long for technical use particularly for the expression of intergrades. Many of the common names are necessarily somewhat inexact and have a strong land-use bias. In the interests of precision, therefore, certain words have had to be coined in presenting this classification, but they have been kept to a minimum. They are not intended to replace the common names for other than purely technical purposes, since pedology, if it is to live and be part of the everyday thinking of land users in general, should have a popular terminology suited to local needs. The new terms should be regarded merely as technical translations of the popular or common names in order to permit the more precise nomenclature required for scientific use.

The classification is based mainly on studies in the New Zealand sector, which extends from the antarctic to the tropic zones, the climate throughout being for the most part oceanic and lacking the seasonal extremes associated with continental conditions.

2·2· SOIL FORMATION

The soil is a dynamic system activated by the sun's energy. As Nikiforoff stated (1959, p. 186), 'Without agronomic bias, the soil or its geochemical equivalent might be defined as an excited skin of the subaerial part of the earth's crust.'

At any one site the system is not a closed one. It is receiving material from outside sources and is losing material to the broader geological cycles of rock weathering and rock building; and its nature is determined by the relative effectiveness of each of the five prime soil-forming factors—climate, living organisms, parent material, topo-

SECTIONS 2, 6, and 8 of Chapter 2 are reproduced for this bulletin with only minor alteration from *N.Z. Soil Bur. Bull. 25*, Soil Survey Method, by N. H. Taylor and I. J. Pohlen, 1962.

graphy*, and time. It changes in response to any change in any of the soil-forming factors, the effects being reflected in greater or less degree in the form of the soil body. Despite efforts to deprecate time as a soil-forming factor, the soil system does change with time, and in some circumstances it changes rapidly. On the whole, however, it tends towards a nearly steady state in which overall changes are slow in relation to human events. This nearly steady state gives rise to soil bodies that are relatively stable in form over long periods.

Between the soil and the soil body there is a real and necessary distinction. The soil is a dynamic entity that embraces not only the lifeless constituents but also the living organisms within it including the roots of plants. The soil body, on the other hand, is the lifeless medium, formed of inorganic and organic materials, in which the living organisms operate. It is the body that retains the impression of the soil-forming factors, as reflected in most soils by the development of soil horizons which are the result of gradual changes with time.

Many soil bodies retain the more persistent characters developed in earlier periods of their history when the combination of soil-forming factors was different. By some the old soil body is regarded as merely the parent material of the present soil. By others the old soil is considered to persist modified by present-day conditions. If, however, the soil is regarded as a system embracing soil life and tending towards a nearly steady state, attention is focused on the soil as it functions here and now. Thus a soil that retains an obsolete impress that modifies the present system may be regarded as having a polycyclic soil body, but strictly it is not a polycyclic soil.

*In its pedological sense, topography is generally restricted to land form (see Joffe, 1949, pp. 129-31).

For purposes of analysis the soil system may be divided into three interdependent parts (Taylor, 1949, pp. 111-12)—the wasting, organic, and drift regimes.

WASTING REGIME

The wasting regime includes the processes of both physical and chemical weathering, together with the associated concentration of elements in various horizons and loss of elements in the drainage waters.

The most important aspect of physical weathering of the soil is *comminution*, the mechanical breaking of the mineral parts of the soil into finer and finer fractions. It is particularly active in regions where the soil is subject to a wide range of temperature fluctuations, especially where this is accompanied by freezing and thawing, and in arid and other regions where the soil lacks the insulating protection of vegetative cover.

The most important aspect of chemical weathering of the soil is *argillisation*. If processes conditioned by the organic regime be excluded, it consists of the decay of the mineral skeleton of the soil—the breaking down of complex minerals to simple more inert ones by a series of reactions (Polynov, 1937, pp. 15-22; Nikiforoff, 1959, p. 188) such as oxidation and hydration, which dissipate intrinsic energy. For a given argillisable mineral its rate is dependent on the background temperature and the supply of air and moisture, and hence proceeds faster in the soils of warm moist regions than in the soils of cold dry ones. The kinds of argillisation leading to the particular kinds of residual products and their primary aggregation are dependent on the nature of both soil skeleton and weathering environment; but, in general,

TABLE 2·2·1· Relative Mobility of Elements During Weathering of Rocks (Polynov, 1937, p. 162)

	Average Composition of Igneous Rocks*	Average Composition of the Mineral Residue of River Waters	Relative Mobility of Elements and Compounds
SiO_2	59·09	12·80	0·20
Al_2O_3	15·35	0·90	0·02
Fe_2O_3	7·29	0·40	0·04
Ca	3·60	14·70	3·00
Mg	2·11	4·90	1·30
Na	2·97	9·50	2·40
K	2·57	4·40	1·25
Cl′	0·05	6·75	100·00
SO_4''	0·15	11·60	57·00
CO_3''	..	36·50	..

*These figures are approximately the average composition of the lithosphere (Clarke, 1924, p. 34).

argillisation leads to loss of bases and silica to the drainage water (Table 2·2·1) and to concentration of the sesquioxides and simple compounds containing them.

With the movement of water through the soil, the processes of soil weathering are accompanied by the translocation of minerals from one horizon to another, and, especially in humid regions, by losses from the soil system by the removal of soluble elements in the drainage waters. These associated processes include leaching (loss by solution) and illimerisation* (translocation of colloids), both of which lead to eluvial or illuvial concentrations that may result in the formation of pans.

Although comminution is in many respects a rejuvenating process, the wasting regime as here defined is for the most part a collection of one-way processes, which, on a stable site, use up the intrinsic energy of the soil skeleton. Were these processes to operate alone, the wasting soil system would inevitably run down and become inert. Of such a condition no examples are known because of the concurrent processes of the organic and drift regimes.

ORGANIC REGIME

The organic regime—the impact of life on the soil—is the medium by which intrinsic energy is replaced in the soil system and keeps it operating. Being dependent on life, it stems from the processes of metabolism, which take place in large part outside the soil itself. Basically it depends on the processes of photosynthesis by plants and the subsequent enrichment of the soil with organic compounds. The energy released by the breakdown of these compounds helps to maintain the balance in the soil system, with a corresponding increase in the endothermic reactions (Polynov, 1937, pp. 17-22) as evidenced by the impetus given to reduction and a consequent conditioning of all the wasting processes.

The organic regime may be regarded as a struggle by soil life to maintain the fertility of the soil against the exhausting effects of the wasting porcesses. It is but part of the struggle of all living organisms to survive in their environment.

The outstanding effects of the organic regime may be analysed as follows:

1. Addition to the soil system of organic matter with its supplies of carbon, nitrogen, and mineral elements, its power to retain cations and anions, and its effects on aggregation and on soil moisture and soil air.
2. Cycling of mineral elements by organisms that return elements to surface horizons from lower depths.
3. Conditioning of leaching, illimerisation, and argillisation by modifying the chemical and energy balance.
4. Mixing within the soil.
5. Modifying comminution, by physical attack from organisms and by insulation from extremes of temperature.
6. Modifying processes of the drift regime—erosion and accumulation.

On decomposition the organic matter added to the surface in such forms as plant litter, animal droppings, and other residues, together with similar materials added inside the soil from the roots of plants and from the droppings and remains of other organisms that dwell wholly or partly in the soil, gives rise to melanisation—the incorporation of humus in the soil. The consequent darkening and associated aggregations in the topsoil are among the most conspicuous morphological effects of the organic regime. The greater part of this process is carried out by soil micro-organisms as they fulfil their role in the often described carbon and nitrogen cycles.

Mineral elements that would otherwise escape from the soil system may be caught up in the organic cycle and circulated from the soil to the organisms and back to the soil again and again. A simple example of this cycling process is that associated with a forest tree growing in a humid temperate region on a well drained stable site. Mineral elements set free by weathering, and in the process of being leached away to the drainage water, are intercepted by the roots and taken into the tree. Those that reach the twigs and leaves are returned regularly to the topsoil, others await the death of the tree for their return. This cyclic return of elements prevents in part the losses by leaching. It is most noticeable in the topsoil, since it is here that the greater part of the minerals is returned and it is here (in and on the humic fraction) that they tend to be held. In the lower horizons, however, the cycling process is less effective, and below the root zone leaching by the downward moving waters continues freely. Although in the example given the cyclic return is confined to one site, this is not always so. For example, animals grazing on vegetation on one site for the most part return droppings to a different site—a phenomenon known to grassland ecologists as the transference of fertility. Extreme examples of this kind are to be found where sea birds nest on the land and enrich the soil with their droppings.

*Fridland (1958). See also Gerasimov (1960).

The conditioning of argillisation arising from the altered energy balance is dependent on the kind of organic matter and upon aeration. This is well illustrated by the example of the tree given above. Where the tree demands high fertility and cycles plant-nutrient elements strongly, the base-charged organic matter is broken down quickly by organisms and is rapidly incorporated in the soil, giving rise to a mulloid organic profile. Although this process, by controlling such properties as acidity, undoubtedly does condition argillisation, its results are not conspicuous in the field because it does not reverse the overall trend of weathering in the wasting regime. Where the tree withstands low fertility and cycles plant nutrients weakly, the organic matter is broken down more slowly and tends to accumulate above the mineral soil as a moroid organic profile. Under these circumstances the conditioning of soil argillisation by the organic regime is patently evident: active organic radicles draining from the moroid horizons above attack mineral particles and by combining with polyvalent cations peptise the clay; thus, by the process known as podzolisation, secondary silica becomes concentrated in the upper horizons while compounds of the sesquioxides are transferred to lower horizons and may even be lost to the drainage water. Similar reversals of the overall trend of weathering are prominent in gleyed soils.

It is essential to recognise the difference between the grade of argillisation and the effects of conditioning by the organic regime. In many places the two are out of step because argillisation is a relatively slow process. Thus, in two well developed podzols occurring side by side in the mild temperate zone, the mineral skeleton of one may be weathered conformably with that of other stable soils of the zone while the mineral skeleton of the other is very weakly weathered, for example, if it is formed on pumice ejected from volcanoes a few centuries ago. Although the morphology of the two profiles appears so similar, the impress of podzolisation is etched much more deeply on the soil skeleton of one than on the other.

Mechanical mixing by burrowing organisms occurs within most soils. It is illustrated by the well known activities of earthworms, which are greatest in moist fertile soils and are favoured by conditions such as those under mulloid humus (with its high base return), where they tend to prevent the development of well defined horizons. The overturning of forest trees, especially in areas subject to cyclonic storms is a powerful factor in mixing soil horizons. It is wrong, however, to assume that all forest trees overturn as they die giving rise to a general mixing of forest soils within a period dependent on the life span of the tree; many forest trees die and rot away without overturning—a process that depends on the kind of forest, the degree of shelter, and the depth of rooting. In addition to these obvious examples, there are many other ways in which mixing is caused by the organic regime; termites on basalt soils near Auckland transport kaolin clays from adjacent mudstone soils, and even the common blackbird contributes its share when, to build a nest, it carries as much as three-quarters of a pound of soil material that ultimately is returned to another site.

Physical weathering of the soil (comminution) is also modified by the organic regime. It is reduced by the insulating effect of vegetation with its associated organic-rich topsoil that protects the soil from extremes of temperature, and it is increased by such means as root penetration and the swaying of trees.

From the above it is clear that the wasting and organic regimes are interdependent, each influencing every aspect of the other. The various kinds of wasting occasioned by different kinds of rock and of climate strongly influence the kinds of organisms and their products, and these in turn condition the wasting processes including weathering, illimerisation, and leaching.

The processes that have been described are those on stable sites. Despite the rejuvenating effects of the organic regime, wherever there are overall losses to the drainage water there is a steady decrease in the mineral reserves of the soil. Over a long time the soil skeleton becomes depleted of its argillisable minerals and of its bases other than those cycling in the organic regime. Soils reduced to this state occupy many areas on stable parts of the earth's crust, notably in the humid tropics. They support shallow-rooted vegetation that depends for its continuance on the efficacy of its own cyclic return of plant nutrients. If for some reason this cycle is broken, with substantial loss of plant nutrients, vegetative cover of a lower order takes over. An assemblage of soils in this condition may be regarded as a pedologic peneplain. Such areas are almost confined to the tropics and subtropics, where argillisation is more rapid than elsewhere and time for soil wasting is longer because it extends beyond the last glaciation. They are simulated in many places where leaching is strong in relation to the release of elements by argillisation, and where consequently soil formation is at a stage not generally favourable for the growth of higher plants although a large proportion of argillisable minerals, with their potential for rejuvenating the soil, may still remain.

Were the earth's surface stable it would be covered largely by these depleted areas (pedologic peneplains and their simulations), but since it is not stable, erosion of the land and accumulation of drift affect soils not only in the unstable areas but in adjacent areas as well. This mechanical modification of soil sites by erosion and accumulation belongs to the drift regime.

DRIFT REGIME

The drift regime embraces the mechanical disturbance of the soil system by inorganic agencies. It includes the mechanical processes of erosion (movements down slope by gravity, and removals by wind and water), accumulation (colluvial, alluvial, and air-deposited), and mixing (by such means as expansion and contraction).

Where these processes are so strong that they destroy or overwhelm the soil, they belong to the realm of geology rather than pedology; but where they simply modify the soil, as they do on a large part of the earth's land surface, they are to be regarded as soil-forming processes. This distinction is illustrated in the volcanic region of North Island, where the paroxysmal eruption from Tarawera and neighbouring vents in 1886 covered a wide area with lapilli and mud. Near the main vents, where the detritus was thick, it destroyed the vegetation, overwhelmed the soil, and initiated a new cycle of soil formation; at a considerable distance from the vents, where the detritus was thin, it barely affected the vegetation and merely modified the existing soil processes by the addition of unweathered material to the surface. Other examples of this distinction occur on mountain sides, on dune lands, and on the flood plains of rivers.

Although the mechanical processes of erosion produce many striking examples of soil destruction, they modify in a less spectacular way a great many soils. On the crests of downlands in North Auckland are soils with clay skins still persisting in the surface horizons, showing that as the surface has been steadily lowered by erosion the topsoil has moved down into what was formerly the subsoil. Other examples of this phenomenon have been described for the downland soils of Canterbury (Raeside, Cameron, and Miller, 1959, p. 15). Owing to movement downhill, the soils on many steep slopes show successive stages of modification ranging from clearly expressed horizons where the overall movement is very slow, through weakly expressed horizons where it is slow, to the complete absence of horizons where it is rapid. Even on gentle slopes movement with consequent sorting of the soil may occur, as is indicated by features such as stone lines. On graded slopes there is a marked correspondence between the shape of the slope and the balance of soil-forming, soil-removing and soil-accumulating processes. The steeper upper parts of the slope correspond to the places where downhill movement is greatest, and the more gentle lower slopes to those where the soil is accumulating.

Examples have been given of soils that are strongly modified by alluvial and air-deposited accumulations. All soils, however, are subject to some extent to additions of new materials by inorganic agencies. New Zealand soils, even outside the main areas of accumulation, receive small quantities of air-borne dust not only from river beds but also from the arid areas of Australia, together with additions of salt blown inland from the sea.

Flushing—a process whereby substances dissolved from one site are conveyed by percolating waters into the soils of other sites—is also referred to this regime. It commonly occurs on sloping land and is the medium whereby such compounds as soluble salts, calcium carbonate, or iron hydroxides are conveyed into the horizons of soils on concave sites.

Mixing within the soil by physical agencies is caused not only by downhill movement of the soil but also by frost action, and by wetting and drying, which lead to upward movement of part of the subsoil. In New Zealand, mixing due to frost heave, with consequent sorting, is common in alpine and open subalpine areas where the soil is not protected by a vegetative cover (Zotov, 1938, p. 241; Gradwell, 1957, 1960; McCraw, 1959). Large stone polygons and allied phenomena are well developed in many places, but most of them are clearly relics from the last glacial period. In the Ross Dependency there is evidence of mixing of the soil above the permafrost by freezing and thawing on sites where sufficient moisture is available. Most antarctic soils, however, do not have sufficient moisture available for mixing processes to operate (Claridge, 1965).

Soil mixing due to wetting and drying is most evident in soils with expanding clays. During dry seasons deep cracks are formed and are partly infilled by material from above which increases the mass of the subsoil; in wet seasons the augmented subsoil swells, and a part is forced upwards into overlying horizons. This churning process, much less marked in New Zealand than in some other countries, is indicated by slickensided peds in montmorillonitic soils of subhumid regions and domed columns in solonetzic soils of Central Otago.

The processes of the drift regime are, on the whole, rejuvenating ones. They tend to prevent the formation of soil horizons, to offset generally the processes of the wasting regime, and to provide a new source of nutrients to the organic cycle. They also lead to new soil formation on subsoils or parent materials by thinning or removing the old soil.

2·3· PRINCIPLES AND CRITERIA OF GENETIC CLASSIFICATION

Besides the normal way of describing profile and site, a soil may be described in an interpretative way by reference to the processes of the three regimes outlined in the previous section. This method is used in many sciences where objects are described in terms pertaining to their origin and implying the processes that have produced them. It has the advantage of conveying information about the intrinsic nature and properties of the object and thus is more than a means of identification. It has the disadvantage of depending upon reasoning from the available evidence and therefore is not always perfect nor always completely objective. Since the striving for perfection in nomenclature is a powerful stimulus to further enquiry, the names tend to change with advancing knowledge.

The sciences of ecology and geomorphology, whose problems of nomenclature are similar to those of pedology, illustrate the value of genetic names. For example, a physiographer may describe a cliff-like feature in great morphological detail, but he does not convey the wealth of information given by the geomorphologist in his genetic term 'obsequent fault-line scarp'. This method of naming and classifying soils has long been used by Russian pedologists (Joffe, 1949, p. 178; Taylor, 1956, p. 13) and by others, notably Aubert and Duchaufour (1956, p. 597), and is the one that has been used in New Zealand.

Since, however, the soil embraces both the soil body and the living things within it, the soil as a system can be adequately expressed only when the soil body and its associated temperature and moisture regimes are considered as one. Many soil bodies do reflect the present environment quite clearly. However, some old soil bodies retain the impresses of former environments, which overshadow those of the present one. Others are too young to reflect the present environment in major definable characters such as are generally chosen for classification purposes. Consequently, either adequate weight needs to be given to characters of the soil body that do reflect existing soil temperature and moisture, or it must be given to these properties themselves or environmental factors that indicate them.

When soils are classified on this principle, correlations with the requirements of living organisms (soil fertility) begin to emerge almost as a corollary, being broad in the higher categories of the classification and progressively more detailed and complete in the lower ones.

The higher categories of the New Zealand classification are subdivided according to the following criteria:

- Category I—basal form of the soil body
- Category II—main energy status (as indicated approximately by the latitudinal and altitudinal zones and by soil moisture)
- Category III—(a) argillisation or (b) the counter processes of accumulation, removal, and mixing

The classes of Category I cut across latitudinal and altitudinal climatic zones, whereas those of Category II lie within them. Those of Category III are the principal classes, many of which are comparable with great soil groups of other classifications. Names of the classes are derived for the most part from the names of the basal forms, but a few are derived from processes of accumulation or removal. Those in Category I end in -iform, those in Category II in -ous, and those in Category III in -ic. Concise technical names for classes are coined at these levels only.

The lower categories are subdivided according to processes and properties of genetic significance that modify the principal classes as follows: kind and degree of illuviation, gleying, accumulation, etc., leading to or retarding the development of horizons (IV); state of enleaching (V); parent material (VI); texture and other properties, mainly of the topsoil (VII). Names of the classes in these lower categories are descriptive and are derived by modifying the name of the principal class by appropriate adjectives.

The classification of the main soils is necessarily considered independently of intergrades, the names of which may be derived at any level by compounding class names.

CATEGORY I
Basal Forms

The first category of the soil classification is built upon 11 distinctive basal forms of the soil body, which were recognised in the earlier stages of soil surveys. These basal forms really represent broad classes of form, each of which characterises certain sequences of soils. Consequently each basal form is defined in only the broadest of terms, differences in detail of morphology of individual soils being regarded as modifications of it. Nine of the basal forms, all dominantly mineral, are characterised by developed soil horizons; the remaining two, one dominantly organic, and the other mineral, lack clearly expressed soil horizons. The names of the soil classes are set out below:

CATEGORY I

	Technical Names	Common Names
Characterised by developed horizons	Sitiform	Brown-grey
	Palliform	Yellow-grey
	Fulviform	Yellow-brown
	Podiform	Podzols
	Spadiform	Red and brown
	Latiform	'Ironstone'
	Nigriform	Rendzina-like
	Soloniform	Solonetzic
	Madentiform	Gley
Characterised by lack of developed horizons	Organiform	Organic
	Skeliform	Skeletal (including recent)

Sitiform (brown-grey) soils are formed in semi-arid areas. Topsoils are brownish grey with platy structure, and subsoils are brown. There is little obvious development in the profile other than a thin topsoil and a marked clay illuvial horizon, which in most places is a stronger brown colour than the horizons above. Soluble salts are present in small amounts, and in many profiles there is deposition of a band of calcium carbonate below the clay illuvial horizon. Owing to the small area with a semi-arid climate these soils are not widely represented in New Zealand.

Palliform (yellow-grey) soils are formed characteristically in subhumid areas. They have well developed A_1 horizons, grey to very dark brownish grey in colour and with weak or coarse structure. A fragipan or genetically similar massive horizon occurs in most places at depths below 10–24 in. and is commonly yellowish in colour with a gammate or reticulate pattern of grey veins. The common name of 'yellow-grey earth' was derived from the general yellowish grey appearance of the soil exposed in road cuts and similar excavations.

Fulviform (yellow-brown) soils are characteristically in the humid areas. Typically they are well drained soils without spectacular differentiation of horizons although many have illuvial horizons commonly of clay. They have yellow to brown subsoils, which for the most part have block-like structures. This basal form is exceedingly common and, owing to the effect of modifying processes, gives rise to many sequences.

Podiform (podzol) soils are also characteristically in humid areas. They have prominent O, and ash-grey structureless silica-rich A_2, horizons, and commonly but not always have humus and iron illuvial horizons. Owing to the transient nature of the O horizon, after clearing of the forest the A_2 horizon is the main differentiating characteristic.

Spadiform (red and brown) soils have red or brown soil bodies, typically without spectacular differentiation of horizons and with innate blocky and granular structures that persist even when ordinary aggregates are crumbled to finer particles. They contain more sesquioxide colloids than do fulviform soils, hence the stability of their structures. They are commonly formed from basic igneous rocks or from sediments derived from these rocks.

Latiform ('ironstone') soils have a sheet-like form due to the arrangement of sesquioxides in distinct layers that are commonly concretionary. Their sand fractions are characterised by secondary minerals. Owing to their high content of sesquioxides they have the brown to red colours of the spadiform soils and for the most part are exceedingly friable.

Nigriform (rendzina-like) soils have deep dark non-peaty topsoils and little or no B horizon. Generally they have well developed structure. They are commonly derived from limestones or other rocks high in bases.

Soloniform (solonetzic) soils are poorly represented in New Zealand. They occur in semi-arid areas in low-lying or other places flushed with soluble salts. They have friable greyish topsoils and hard dark columnar structures with diffuse humus in the subsoils. Although their topsoils may be low in soluble salts, they have alkali subsoils with a high salt content. The lower parts of their subsoils in many places are lighter in colour and contain calcium carbonate.

Madentiform (gley) soils have predominantly gleyed horizons associated with high ground water*, while organiform (organic) soils have bodies dominantly composed of organic matter. Skeliform (skeletal) soils show little or no profile development and include a wide range of weakly developed mineral soils.

Sequences of form between basal classes of form are intergrades between the form classes and may be considered at this level. The well defined sequences of form within each of the broad basal classes are due to progressive differences in particular soil-forming factors and are considered at lower levels of the classification.

*Where high ground water is not present, soils that are dominantly gleyed but cannot be identified as gleyed modifications of other forms may be considered as pseudo-madentiform.

CATEGORY II

Main Energy Status (as indicated approximately by the latitudinal and altitudinal zones and by soil moisture)

Each of the broad basal forms is the expression within the soil body of very broad processes that have operated and are operating within the soil. Since broad basal forms cut across zones that receive different amounts of the sun's energy (Fig. 2·3·1) and have different temperature regimes (Fig. 2·3·2), they do not of themselves indicate adequately the soil as a dynamic system. With the notable exception of skeliform, however, they do reflect the kinds of soil processes governed in large measure by effective moisture. Consequently, with the exception of skeliform, the soil as a system may be expressed approximately by indicating both the basal form and the latitudinal or altitudinal zone in which it occurs.

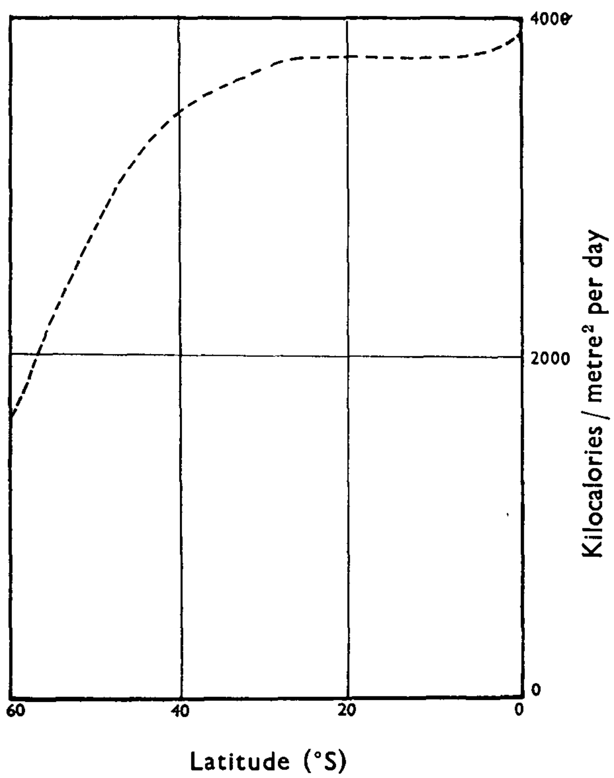

FIG. 2·3·1· Yearly mean of average daily values of the solar energy flux received on horizontal surface at sea level at different latitudes in the southern hemisphere (after Vincze, 1960).

In the second category of the classification the classes of Category I are subdivided accordingly. The latitudinal zones chosen correspond roughly with those commonly known as tropic, subtropic, temperate, subantarctic, and antarctic. The altitudinal ones are approximately the alpine, subalpine, and other recognised altitudinal belts, which somewhat resemble the latitudinal zones in effective mean temperatures but differ markedly from them in length of day and night and in seasonal and diurnal fluctuations of temperature. In New Zealand the lower boundary of the alpine soils corresponds approximately with the general upper limit of a continuous plant cover, and the lower boundary of the subalpine soils is generally somewhat lower than and roughly parallel to the upper limit of the continuous cover of woody vegetation (see Fig. 2·3·2). In practice, however, the boundaries of these zones are necessarily determined by reference to the dominant soils and not merely by latitude or altitude.

In common soil names the zone is indicated either directly by such names as 'subtropic (yellow-brown earths)' or indirectly by indicating the relative position of the zone in New Zealand, e.g. northern, central, southern. This arose from the early attempts to distinguish the warmer North Auckland yellow-brown earths and podzols from the cooler and generally less argillised soils further south. In the Soil Map of New Zealand (N.Z. Soil Bureau, 1948) an attempt was made to use weathering (argillisation) as a zonal indicator; in general it was satisfactory, but in detail it proved unsuitable where the actual state of weathering of particular soil bodies is unconformable with the overall weathering pattern of the zone.

In the technical names the latitudinal zone is conveniently indicated by the simple prefixes per- (tropic), ad- (subtropic), pro- (temperate), de- (subantarctic), and e- (antarctic), which are added to the form name. The altitudinal zones are distinguished by the additional prefix el- (for elevated)*. Thus the prefix ele- denotes the alpine zone and elde- the subalpine; where in the tropic islands the land is high enough to have a subtropic temperature regime the appropriate prefix is elad-, and so on. To simplify the names as much as possible, the prefix pro- may be omitted from the names of soils that are well represented in the temperate zone—that is, of all except the spadiform and latiform soils, which are better represented in the subtropics and from the names of which the prefix ad- may be omitted.

In this way the basal forms are subdivided to give the second category of the soil classification in which the soils are classified according to their basal form and energy status. Since skeliform gives no indication of the effective moisture in the soil system and since other forms may cover too wide a range of soil moisture for some purposes, it is necessary at this level of the classification, or at the level of Category III, to introduce,

*If necessary, latitudinal differences in these zones may be expressed as phases (cf. tropic and temperate subalpine).

as needed, phasic subcategories based on the soil moisture classes outlined in section 6 of this chapter. These may be named either directly from the moisture class (e.g. hygrous skelous soils) or indirectly by indicating an associated soil with a characteristic soil-moisture regime (e.g. co-fulvous skelous soils).

Names of classes in Category II are indicated by the suffix -ous as in the following examples:

CATEGORY I	CATEGORY II	
	Technical names	Common names
Fulviform soils	Perfulvous	Tropic yellow-brown
	Affulvous*	Subtropic or northern yellow-brown
	(Pro-) Fulvous	Temperate or southern yellow-brown
	El(pro-)fulvous	(Elevated yellow-brown, corresponding to temperate, in tropics and subtropics)
	Defulvous	Subantarctic yellow-brown
	Eldefulvous	Subalpine or high country yellow-brown
Skeliform soils	Moist { Perskelous	Tropic skeletal
	Moist { Adskelous	Subtropic skeletal
	Moist { (Pro-) Skelous	Temperate skeletal
	Moist { Deskelous	Subantarctic skeletal
	Moist { Eldeskelous	Subalpine skeletal

*In prefixing 'ad', the common rule of assimilation is applied.

For the New Zealand sector, the latitudinal and altitudinal zones, their approximate ranges of mean annual temperature, and the nature of their associated vegetation are shown provisionally in Fig. 2·3·2.

CATEGORY III

(a) Argillisation or (b) The Counter-processes of Accumulation, Removal, and Mixing

In the third category of the classification the classes of Category II that contain mineral soils with developed horizons are subdivided according to the state of weathering of the soil body as indicated by the kind and grade of argillisation of the soil skeleton. The other classes, organiform and skeliform, are subdivided according to processes that tend to oppose the formation of horizons and the progressive development of a weathered soil body.

This category establishes the principal genetic classes of the New Zealand classification, the names of which, with appropriate modifying adjectives, are retained in the later categories. The names of the classes are distinguished by the suffix -ic.

Argillisation

As indicated above, argillisation may be assessed in two ways—by reference to the nature of the clay produced (the *kind*) and by reference to the proportion of weatherable minerals converted to clay (the *grade*). The kinds of argillisation are designated by the dominant residual clays* produced. They fall into three broad groups—amorphous, crystalline layer silicates, and crystalline oxides—which, where dominant, can be recognised with some degree of accuracy in the field and used as criteria for purposes of classification. Names of classes with characteristic properties dominated by amorphous clays and crystalline oxide clays are distinguished from those with crystalline layer silicate clays by the prefixes amo- and oxi- respectively. To simplify the names, the prefix oxi- is omitted from the latiform soils as, in these, crystalline oxides are usually dominant. Contractions are also used for some other common soils. Thus the fulvous and spadous soils of Category II are divided as shown below. Other classes of fulviform and spadiform soils in Category II are subdivided similarly. For special investigations the clay chemist may, especially at this level, conveniently introduce phases† based on the clay classes listed in section 8 of this chapter. Such phases, when genetically arranged, represent stages in the kind of argillisation.

Technical names*		Common names	Dominant clays
(Pro-) Fulvous	Fulvic	Temperate yellow-brown earths	Layer silicates
	Alvic	Temperate yellow-brown loams	Amorphous
(Ad-) Spadous	Spadic	Subtropic brown granular clays	Layer silicates
	Amadic	Subtropic red and brown loams	Amorphous
	Oxadic		Crystalline oxides

*Alvic is a contraction from amofulvic, amadic from amospadic, and oxadic from oxispadic.

The grade of argillisation as here defined is assessed by the proportion of argillisable minerals (originally in the soil skeleton) that has been converted to clay or through clay to nodules or other reaggregations of larger particle size; it is thus the proportion of these secondary products to the argillisable minerals in the soil after allowance has been made for the proportions of each inherited from the parent rock. It is independent of the kinds of residual clay; for example, if in a

*The word clay is used in the general sense of a residual product of fine texture in large part colloidal.
†A phase is a subdivision of any class in the system of classification but is not itself a category of the system.

soil from volcanic ash all the argillisable minerals were converted to allophane, the soil would be regarded as fully argillised although allophane would not represent the final stage of weathering and with time would decompose to more stable clays. Three main grades are recognised in the field: weak, where only a small proportion of the original argillisable minerals has been decomposed; moderate, where much has been decomposed but much still remains; and strong, where few of the argillisable minerals remain. This scale (or a more detailed one when available) can be used to make phases where required for special purposes.

At this level in the classification, the above criteria are used to assess the relative grade of argillisation of the soils within the soil regions of each zone. Having regard to broad differences in parent rocks, standards are obtained by observing the grade of argillisation on sites where neither erosion nor accumulation is abnormally active and argillisation has reached a maximum conformable with the particular moisture region of the zone. If moisture is adequate these standards are: weak, in the subantarctic; moderate, in the temperate; and strong, in the subtropic and tropic zones. Each standard represents the maximum grade of argillisation that has developed within the particular region since the last zone-wide soil-destroying catastrophe; it is considered wholly in relation to the present position of the zones (whether latitudinal or altitudinal) and is the consequence of the fluctuating climate of the zone. Differences in the standards are strikingly illustrated by the great difference in overall clay content of soils in the humid temperate compared with humid subtropic and tropic regions.

Not all soils are conformably argillised—some are markedly less (subargillised) and some more (surargillised). Many subargillised soils arise from local disturbances later in time than the last zone-wide catastrophe; others occur in places where the rate of erosion or accumulation is sufficiently rapid to rejuvenate the soil continuously. Soil bodies of surargillised soils are more strongly weathered than those of conformably argillised soils because they antedate them. Strictly, 'surargillised' should be applied only where the soil body (the complete profile) is retained continuously from a former weathering cycle to the present day. If an erosion interval has intervened, the remains of the old soil body are more correctly regarded as merely the surargillised parent material of the present one. Since it is often impossible to tell to what extent erosion has occurred, and since the horizons even of incomplete old soil bodies can strongly affect the development of present day soils, a convention is adopted: a soil is said to be surargillised, at least in part, if a recognisable depth of the old soil body remains; if, however, the material of the old soil body has been transported from its original site, continuity is broken and the new soil formed upon this material is regarded as being derived from a new sedimentary deposit of pre-argillised materials. Subargillised soils naturally tend to have soil bodies similar in many respects to those of conformable soils of cooler zones where argillisation is weak, and surargillised soils to those of warmer zones where argillisation is strong.

In Category III of the classification the grade of argillisation where not conformable with that of the zonal region is indicated by adding the prefixes sub- and sur- to the class names as illustrated in the tabulation below; these prefixes precede zonal prefixes which in turn precede amo- or oxi- which denote kind of argillisation. The divisions into subargillised, conformably argillised, and surargillised are applied in the broadest possible manner in this category, but it is sometimes necessary to split the subargillised soils into the younger and the older subargillised soils in the tropic and subtropic zones because of the wide range of weathering they embrace.

In those parts of the tropics where time has not been zonally interrupted, many soils have passed beyond the stage of strong argillisation

CATEGORY II	CATEGORY III			
	Technical names	Common names	Argillisation	
			Dominant kind	Grade
	Fulvic soils	Temperate yellow-brown earths	Layer silicates	Moderate (conformable)
	Subfulvic soils	Temperate yellow-brown sands, etc.	Layer silicates	Weak
(Pro-) Fulvous soils	Surfulvic soils	Temperate preweathered yellow-brown earths	Layer silicates	Strong
	Alvic soils	Temperate yellow-brown loams	Amorphous	Moderate (conformable)
	Subalvic soils	Temperate yellow-brown pumice soils	Amorphous	Weak

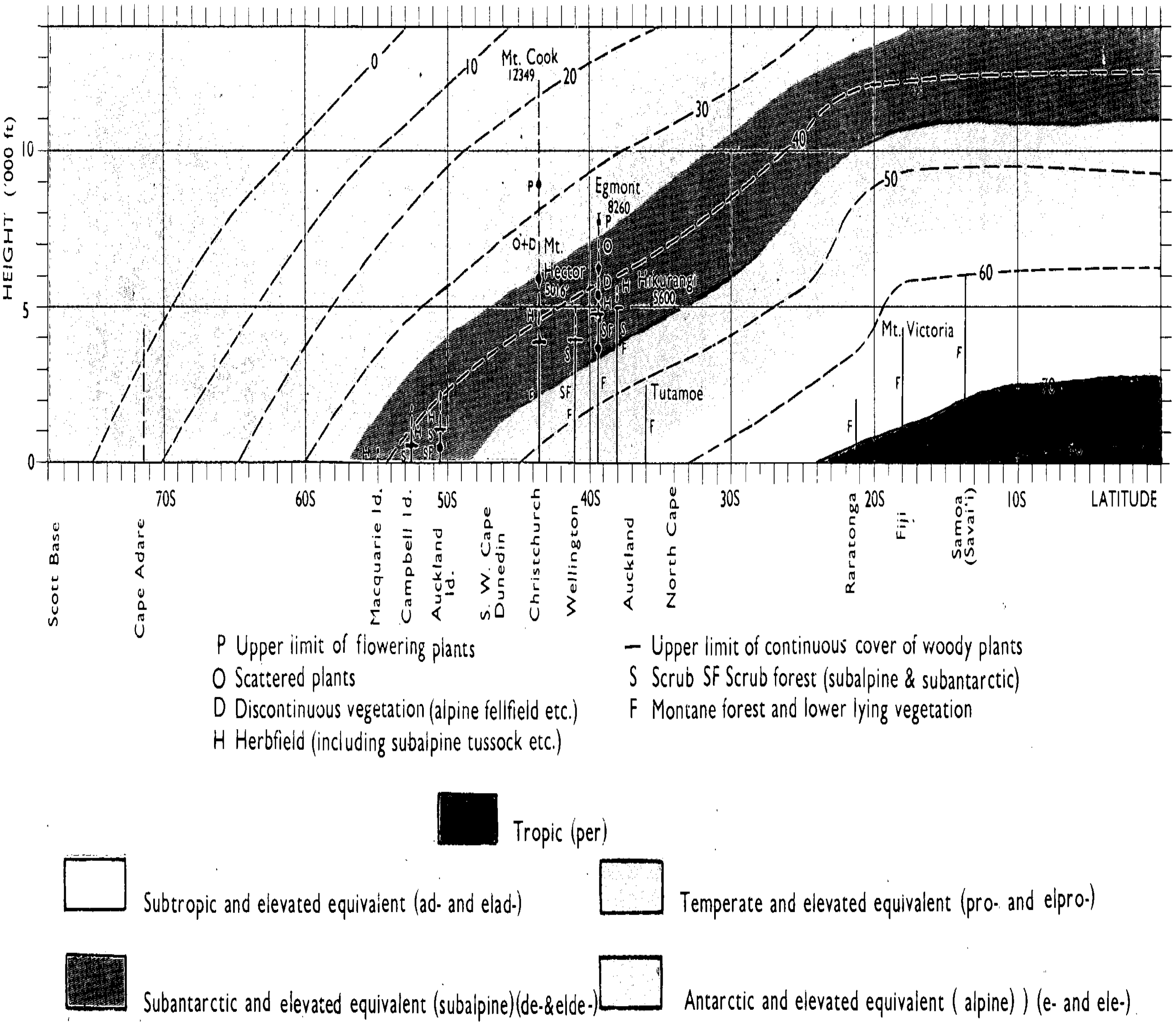

FIG. 2·3·2· Mean annual temperatures (°F), main temperature zones, and associated vegetation of the New Zealand sector about longitude 170° E.

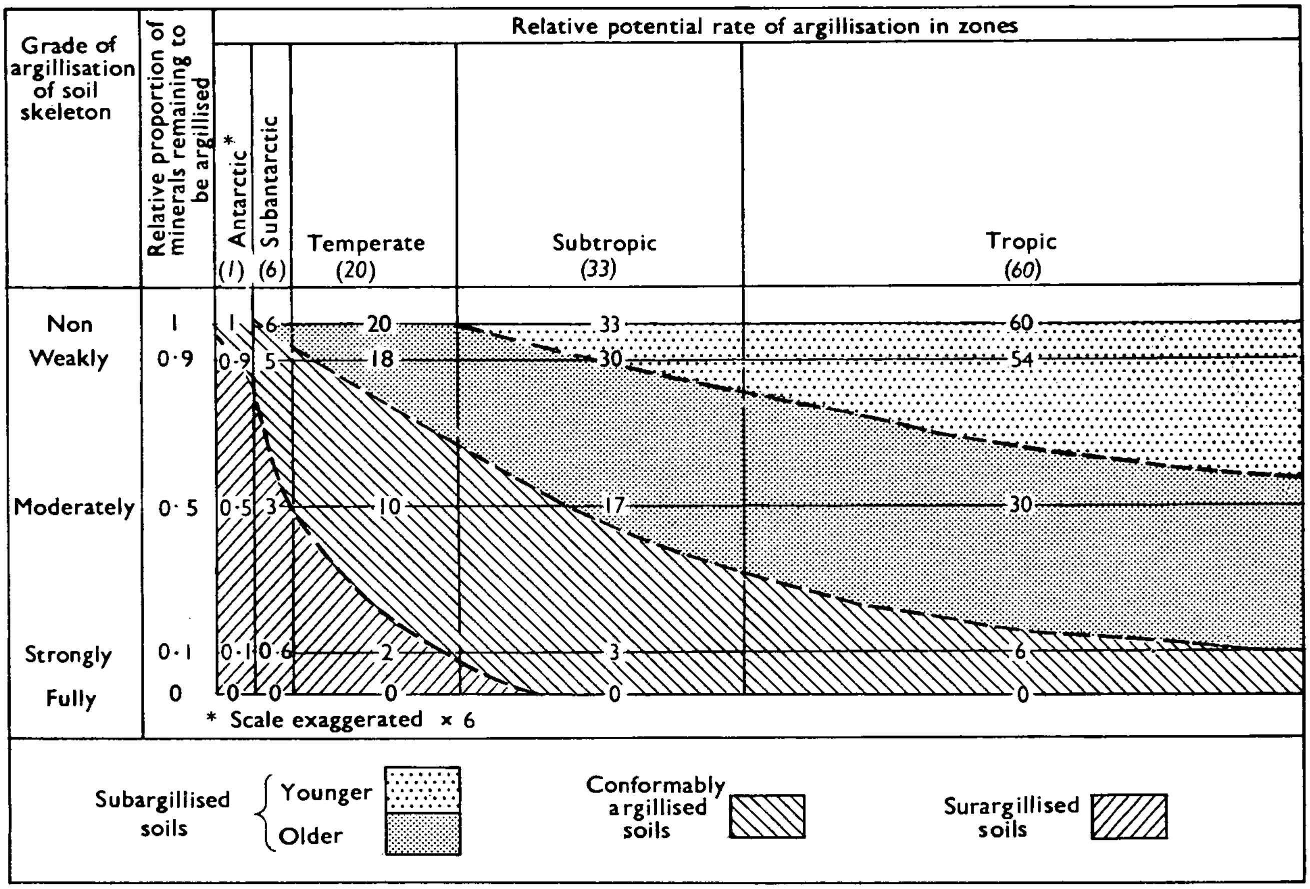

FIG. 2·3·3· Indices of relative rates of argillisation of conformably argillised, subargillised, and surargillised soils in the main energy zones.

and have reached a stage where the processes of chemical weathering are directed predominantly towards the destruction of colloids and the formation of aggregates with weak or no colloidal properties. Some have reached the critical stage where their dominant colloids become irreversibly aggregated when dehydrated. Such old soils may be regarded as supra-argillised since their mineral skeletons are passing beyond the phase of clay formation into a phase of reaggregation. In the New Zealand sector they occur in small areas only.

The value of adopting as a criterion the grade of argillisation in relation to the climatic zone is evident since it influences strongly the flow (from rock minerals in the soil skeleton) of new mineral elements available for the cycling processes of the organic regime, the relative rate depending on the kinds and physical condition of the rock minerals, on the moisture and temperature of the soil, and on other factors of the soil environment. An approximate idea of the relative potential rate of argillisation in the various zones can be obtained from the mean temperatures (Fig. 2·3·2) by applying van't Hoff's temperature rule for the rate of chemical reaction* and assuming other factors to be constant. In humid regions a crude index of the rate of argillisation for a stated set of conditions may be derived by multiplying the potential rate of argillisation of the soil by the proportion of minerals remaining to be argillised as indicated by the grade; indices derived in this way are presented in Fig. 2·3·3.

Although the indices are approximate, they bring into relief the extreme importance of the processes of argillisation in tropic and subtropic soils, and indicate why soil workers in the tropics have tended to think of their soils in terms of weathering, whereas workers in temperate regions think in terms of modifications stemming from the organic regime. It shows clearly the greater significance of tropic subargillised soils which are weakly weathered but strongly weathering, and

*For every 10°c rise in temperature, the velocity of a chemical reaction increases by a factor of 2 to 3 (Jenny, 1941, p. 143). The rule is empirical and is approximate only.

indicates why the most significant single soil boundary in these regions is that between the subargillised and conformably argillised soils (Fig. 2·3·3). It explains the persistent attempts to subdivide tropic soils genetically into monocyclic and polycyclic soils at the highest level of classification (von Klinge, 1956; Fink, 1956). It also directs attention to the differences in approach necessary in tropic and temperate regions when considering problems of degrading and regrading soils.

ACCUMULATION, REMOVAL, AND MIXING

The organiform and skeliform classes of Category II, which do not show developed horizons, require different treatment from the other soils and are subdivided according to the kinds of rejuvenating processes (such as accumulation and removal) that oppose the formation of developed horizons.

The organiform classes are subdivided according to the broad processes that govern the accumulation of the organic matter and determine in part its composition and the extent to which it is admixed with mineral material. Thus the organous soils are divided into lodic and platic soils as follows:

Category II	CATEGORY III		
	Technical names	Common names	Nature of Accumulation
(Pro-) Organous	Lodic soils	Blanket peats	Climatic (Ombrogenous)
	Platic soils	Concave basin peats	Local (Soligenous and Topogenous)

Lodic accumulations are climatic or ombrogenous. They are consequent on suitable conditions or rainfall and temperature, and cover particular climatic regions of the earth's surface. They are modified by, but do not result from, local conditions of topography. Platic accumulations on the other hand are local in distribution and occur where normal decomposition in the zone is slowed down owing to local conditions of topography, soil, and high ground water. For the most part, they occur in humid regions in basins where the ground water is close to the surface, but they are not confined to such regions. They include also the small patches that form near springs and seepages. In general they are higher in mineral matter than are the lodic accumulations. The soils of raised bogs which are in part ombrogenous and in part soligenous or topogenous, are regarded as intergrades e.g. lodi-platic soils.

The skeliform classes are subdivided according to the rejuvenating processes of the drift regime. In many soil classifications based on the more stable parts of the earth's surface, these processes are not recognised as soil-forming; but, as indicated above, where they modify the soil system without actually destroying it they are necessarily an integral part of the soil-forming processes. Thus the skelous soils are divided into the luvic, volic, clinic, regic, and lithic soils as follows:

CATEGORY II	CATEGORY III	
	Technical names	Common names and processes
(Pro-) Skelous	Luvic soils	Recent soils rejuvenating by water-borne accumulation
	Volic soils	Recent soils rejuvenating by air-borne accumulation
	Clinic soils	Skeletal soils rejuvenating by movement down slope
	Regic soils	Regosols not rejuvenating — soils form quickly
	Lithic soils	Lithosols not rejuvenating — soils form slowly

Luvic soils are continually being rejuvenated by additions of alluvial material on the surface; with their intergrades to associated non-skeliform soils they are dominant on flood plains and fans. Volic soils include the soils around active volcanoes where thin layers of volcanic ash are added periodically to the soil surface, the soils adjacent to flood plains where loess is actively accumulating, and the soils adjacent to sand drifts which continually receive additions of wind-blown sand. Clinic soils show little or no profile differentiation, other than melanisation of the topsoil, because they are continually being rejuvenated by removal, accumulation, and mixing consequent on colluvial movement downslope. For specially detailed studies, they may be divided into phases according to the dominant process (regressive or accumulative clinic soils); and where necessary this principle may be used to subdivide other classes. The regic and lithic soils have little or no profile development because insufficient time has elapsed since the inception of soil formation rather than because of soil-rejuvenating processes. The regic soils are formed on drifts of fine texture. Where soil formation is rapid, as in warm humid regions, they are short-lived. The lithic soils occur on hard, massive rocks and coarse drifts (such as lava flows and moraines) which are so resistant to change that they persist for a long time without the formation of evident soil horizons.

In classifying the eleskelous and the eskelous soils, additional classes are needed, for example, the gelic and the frigic* soils which are commonly stirred by frost action. Gelic soils are found in alpine regions where the surface is bare of insulating vegetation. Under these conditions the surface soil is lifted by frost and, following the thaw, its finer fractions tend to be blown away leaving a stony surface layer or pavement. Frigic soils, which occur in antarctic regions where stirring by frost is prevented in many places by dryness, have subsurface permafrost.

In some small areas in the temperate regions of New Zealand the soils have little or no profile development owing to continuous mixing by organisms. They are classed as bioturbic soils. They are best illustrated in the nesting areas of burrowing sea birds where, besides being thoroughly stirred, they are enriched by droppings.

In the New Zealand sector (outside the antarctic and alpine regions) skeliform soils are for the most part very much less extensive than their intergrades to associated soils. In humid temperate regions, for example, soils on steep slopes are mostly intergrades to fulvic soils—and are not solely clinic soils; and similarly the luvic and volic soils are generally much less extensive than their associated intergrades since accumulation over wide areas is rarely so fast that it prevents the partial expression of basal forms other than skeliform.

Phasic Subdivisions Based on Soil Moisture

As described under Category II, phasic subcategories based on soil-moisture classes are applied at the level of Category III as needed, and are expressed directly or indirectly as outlined in section 6 of this chapter. For agronomic purposes this is also a convenient level of classification to introduce other phases that express more detailed climatic conditions so important when grouping soils for land use.

Naming of Intergrades between the Principal Classes

The names of intergrades at the level of Category III are derived by compounding class names. The stem of the subordinate name, with the connecting vowel i is linked by a hyphen to the full name of the class that the intergrade most closely resembles. Thus, in the progression from a clinic to a fulvic soil, a fulvi-clinic soil is one that shows some fulvic characters but has not the structural B horizon associated with fulvic soils, and a clinifulvic soil is one that shows the characters of a fulvic soil although they are modified by slope conditions. In a similar way a podi-fulvic soil is weakly podzolised and a fulvi-podic soil is moderately podzolised but retains some fulvic characters especially in the subsoil. For conciseness it is unnecessary to repeat zonal prefixes; thus a fulvialluvic soil is an intergrade between the northern rapidly accumulating recent soils from alluvium and the northern yellow-brown earths.

Where it is desired to indicate that the soil is an abnormal intergrade resulting from the burial of the whole or part of a former soil the connecting vowel o is used in place of i. Thus for a composite soil, the upper part of which is formed from fresh alluvium and the lower part from concave basin peat, the name luvo-platic is used to distinguish it from a luvi-platic soil which is a normal intergrade formed from a mixture of peat and alluvium. Similarly a fulvo-surfulvic soil is a composite one, the upper part being derived from soliflual or glacial material (conformably weathered) and the lower part from an older surweathered soil body.

Sequences of Principal Classes across the Divisions of Category II

To avoid confusion arising from the use of the technical names outside their precise definition, suitable adjectives are on occasion needed to refer collectively to the sequences of corresponding soils that cross the climatic zones, that is, to express soil body form at the level of Category III. Such adjectives may be formed by adding the suffix -oid to the stem of the class name, for example the perluvic, alluvic, (pro-)luvic and deluvic soils may be regarded collectively as luvoid soils, and other sequences as alvoid, spadoid, etc.

CATEGORY IV

Horizon Development

In Category IV the classes of Category III are divided according to the salient remaining morphological differences, which are interpreted in terms of the kind and degree of the processes that have produced them. Such processes fall into two groups—those that lead to, and those that tend to retard, the development of ordinary soil horizons.

The effects of the first group of processes include the kind and degree of illuvial development in the soil (such as arise from illimerisation, podzolisation, and in a few soils desalinisation) and the degree of gleying of soil horizons.

*Since the elegelic and efrigic soils are very limited in their geographic range the zonal prefixes may be omitted where the meaning is clear.

The degree of clay illuviation is subdivided as follows: weakly clay illuvial—search reveals patchy clay skins on peds and in some pores; moderately clay illuvial—distinct accumulation of clay in the subsoil, clay skins tend to be continuous but textural differentiation not marked; strongly clay illuvial—marked textural differentiation with eroded peds in upper horizons and continuous clay skins below.

Other kinds of illuvial horizons (for example in podzolised soils) are referred to as humus illuvial or iron illuvial, etc., or, as in the case of related formations, by referring directly to the formation itself (e.g. 'with concretions', 'with fragipan'). Fragipans may be incipient, or well developed, and may be subgammate, gammate, or netgammate.

The degree of gleying may be referred to individual horizons or to the soil as a whole; unless otherwise stated, it refers to the B horizon where it is most common. Gleying may be diffuse or spot: diffuse or complete gleying is the kind commonly occurring in the A_2 horizon of gley podzols; spot gleying (Kanno, 1957) found in the B horizons of many soils, is subdivided into weakly (less than 2%), moderately (2 - 20%), and strongly gleyed (more than 20%).

The effects of the second group of processes, which tend to retard the development of soil horizons, such as erosion and accumulation and those giving rise to mixing, are treated in a similar way, particularly for the skeliform soils and their intergrades as in 'slowly accumulating luvic soils'.

When making main divisions in Category IV the use of an unqualified morphological term implies moderate to strong expression of the characteristic. Thus clay illuvial, gleyed, and other terms, when used without qualification, are understood to connote 'moderately to strongly clay illuvial' in contrast to 'weakly clay illuvial' and so on.

CATEGORY V

State of Enleaching

Category V is based on the state of enleaching, which is the balance of the incoming and outgoing mineral ions in the active fraction of the soil body. Incoming elements arrive from the weathering soil skeleton, from the cyclic return of the organic regime, and from additions by way of the drift regime. Outgoing elements are leached away by downward and laterally moving water, some are lost by erosion, some are immobilised by reconstitution in the soil body, and some are withdrawn by organisms for varying periods.

Where the effects of the drift regime are small, the state of enleaching in a general way expresses the nearly steady state due to near equilibrium between the rate of weathering, the rate of leaching, and the efficiency of the organic cyclic return. It is not identical with, but is approximately indicated by, the degree of salinity and the percentage base saturation of the soil, which are the criteria used for classification. It may be applied to the soil as a whole or to individual horizons, but unless otherwise specified refers to the average for the solum. The classes of enleaching other than saline and their approximate correlation with percentage base saturation are: weakly (over 50), moderately (30-50), and strongly (less than 30) enleached. Where needed, the subclasses very weakly (70-100) and very strongly (0-15) are also separated.

CATEGORY VI

Parent Material

In Category VI the soil classes are divided in effect according to those combinations of soil properties due directly or indirectly to differences in parent materials and not already used in higher categories. In addition to its more obvious effects, parent material introduced at this level differentiates many intrinsic soil properties inherited directly or indirectly from the parent rock such as those of value in the study of trace element distribution. The names of the soil classes reflect these causal relationships as in the examples 'from strongly argillised greywacke' and 'from comminuted schist'.

CATEGORY VII

Surface or Subsoil Horizons

The final category of the classification is subdivided according to texture, the organic profile, and modifications (including those due to man) that affect portions of the soil profile but do not affect the whole soil strongly enough to be expressed in higher categories.

Commonly the texture of the topsoil is given but it may be supplemented as necessary by the texture of the subsoil, for example, 'sand on clay'.

The organic profile of many topsoils is subject to rapid modifications following changes in the vegetative cover, whether natural or man-induced. Consequently, as a differentiating character of the current soil system, it is introduced into the classification at this low level, its more stable effects having already been covered in the higher categories. It is classed as peaty, moroid, or mulloid, and is characterised in greater detail by adjectives expressing structure and consistence as is done for forest soils by Bornebusch and Heiberg (1936). In grassland soils, it is termed the sod. For example, three organic profiles developed under pasture at different levels of management (Taylor, 1955, p. 963) may be classed as moroid sod, strongly fibrous mulloid sod, and weakly fibrous mulloid sod.* In the absence of detailed information the differences in organic profiles have commonly been indicated in a broad way by reference to the vegetation that has produced them, as in the examples, 'scrub melanised' and 'tussock melanised'.

Where modifications due to man or other agents change both topsoil and subsoil sufficiently, they are classified systematically at appropriate higher levels of the classification or as intergrades. Where, however, modifications affect only the topsoil or affect partially conditions in other horizons they are best expressed at the low level of Category VII. Thus in fulvic soils of Southland that have been heavily limed and support high-producing pastures it is the topsoils that are enriched and markedly modified, whereas the subsoils have remained little altered even in their level of enleaching.

DERIVATION OF TERMS

Ad-: see Zonal prefixes
Alvic: contraction of amo+fulvic
Amadic: contraction of amo+spadic
Amo-: prefix indicating amorphous clays
Argillisation: from geology (secondary alteration to clays)
Bioturbic: Gk. *bios*=life, L. *turbare*=to disturb
Clinic: Gk. *klino*=slope
De-: see Zonal prefixes
Drift: from geology (superficial deposit made by current of water or air)

*The terms mulloid and moroid are used (in place of mull and mor) where they refer to the form of the whole organic profile as a unit. In mulloid profiles the bulk of the organic matter is incorporated with the mineral soil, and in moroid profiles it is for the most part unmixed and enough of it accumulates to produce F and H horizons, which lie above the mineral soil. The terms mull earth, moder, and raw humus are used for the particular kinds of organic matter within the various horizons of the organic profile. The terms mull and mor are avoided since in the present confused state of terminology they are used both for the kinds of organic profile and the kinds of organic matter.

E-: see Zonal prefixes
El-: contraction of elevated
Enleaching: en-(L. *in-* forming verbs from adjectives, etc. =to bring into this condition)+leaching
Fragipan: from 'Soil Survey Manual' (U.S. Soil Survey Staff, 1951, p. 243); L. *fragilis*=brittle
Frigic: L. *frigus*=cold
Fulviform: L. *fulvus*=yellow, yellowish brown, reddish yellow, etc.
Gammate: Gk. *gamma* (γ)
Gelic: L. *gelum*=frost
Hydrous: Gk. *hudor*=water
Hygrous: Gk. *hygros*=wet
-i-: L. (connecting vowel)
-ic: L. *icus* (forming adjectives)
-iform: **-i-**+**-form**; Fr. *-forme* from L. *formis*=having the form of (e.g. cruciform)
Latiform: from latosols; L. *later*=brick
Lithic: from lithosols; Gk. *lithos*=stone
Lodic: L. *lodix*=a blanket
Luvic: L. *luere*=to wash
Madentiform: L. *madens*=wet, marshy
Melanisation: Gk. *melas -anos*=black
Nigriform: L. *niger*=black, dark
-oid: Gk. *-oeides*=like. Used in sense of 'having the form of'
Organiform: from organic soils
-ous: L. *-osus*=abounding in (Chem.=with larger proportion of the element indicated by the stem than those ending in -ic, e.g. chlorous acid)
Oxadic: contraction of oxi+spadic
Oxi-: Prefix indicating crystalline oxide clays
Palliform: L. *pallor*=paleness
Permafrost: from 'Soil Survey Manual' (U.S. Soil Survey Staff, 1951, pp. 181, 184); =permanently frozen ground; ?contraction of permanent+frost
Platic: O.E. *plat*=flat
Podiform: from podzol
Per-: see Zonal prefixes
Pro-: see Zonal prefixes
Regic: from regosols
Sitiform: L. *sitis*=thirst, dryness
Skeliform: from skeletal soils
Soloniform: from solonetz
Spadiform: L. *spadus*=reddish brown
Sub-: L.=under, below
Supra-: L.=beyond
Sur-: L.=super=above
Volic: L. *volare*=to fly
Xerous: Gk. *xeros*=dry
Zonal prefixes:
- **Per-**: =completely, thorough
- **Ad-**: L.=up, to (with connotation of 'changing to')
- **Pro-**: L.=in front of, in favour of
- **De-**: L.=down (contrasted with ad-)
- **E-**: L.=ex=out of

2·4· GENETIC NAMES

Genetic names for soils emerge from the criteria applied to them under the various categories. To give each criterion its appropriate connotation, terms derived from Categories III to V and also those from VI to VII are reversed in order; that is those from Category V are given first and followed by those from IV and III and, where applicable, VII and VI. The complete names are generally long, but simpler names are derived by omitting characteristics that are weakly expressed and omitting terms that are subordinate or redundant. Usually, for example, the state of enleaching need not be given for podic or latic soils where it is almost always strong; 'fragipan' need not be included where it is indicated together with its form by the term gammate; and clay illuvial, gleyed, or other terms of Category IV that imply well expressed characters need not be qualified. If Table 2·4·1 be taken as an approximate analysis to Category VI of five common soil

TABLE 2·4·1· Genetic Analysis of Five Common Soils to Category VI

Soil Name	Category III	Category IV			Category V	Category VI
	Principal Class	Illuvial Horizons	Notes on Pans, Concretions, etc.	Gleying	Enleaching	Parent Material
Okaihau gravelly friable clay	Latic	..	Many concretions (Fe, Al)	..	Very strongly enleached	From strongly argillised basalt
Taupo sandy silt	Subalvic	..	..	..	Moderately enleached	From rhyolite pumice
Taita clay loam	Surfulvic	Moderately clay illuvial	..	..	Strongly enleached	From strongly argillised greywacke
Timaru silt loam	Pallic	Weakly clay illuvial	With gammate fragipan	Weakly gleyed	Moderately enleached	From moderately argillised loess
Conroy gravelly sandy loam	Sitic	Moderately clay illuvial	..	..	Very weakly enleached	From comminuted schist

types, the simple genetic names are:

- Okaihau gravelly friable clay: concretionary latic soil from strongly argillised basalt
- Taupo sandy silt: moderately enleached subalvic soil from rhyolite pumice
- Taita clay loam: strongly enleached clay illuvial surfulvic soil from strongly argillised greywacke
- Timaru silt loam: moderately enleached gammate pallic soil from moderately argillised loess
- Conroy gravelly sandy loam: weakly enleached, clay illuvial sitic soil from comminuted schist

For many purposes the names are further simplified by expressing them to Category V and phasing after the parent rock type, for example, the Taita soil is a 'strongly enleached moderately clay illuvial surfulvic soil after greywacke'.

Different kinds of podzols are readily distinguished at the level of Category IV. For example, among the various kauri podzols, the Wharekohe silt loam is a 'B-gleyed clay illuvial appodic soil', Te Kopuru sand is a 'humus iron illuvial appodic soil', and the ground-water podzol bordering Lake Ohia is a 'humus illuvial madenti-appodic soil'. The rimu podzols of the Rangitoto Range developed from Taupo pumice are 'humus iron illuvial subpodic soils'. Common gley podzols are 'A-gleyed iron illuvial podic soils'.

On the other hand, should it be necessary, names may be amplified and extended to Category VII. In a paddock near Kihikihi, for example, the modified Otorohanga silt loam (a yellow-brown loam from Mairoa ash) is in full a 'moderately enleached, very weakly clay illuvial, alvic silt loam with enriched weakly fibrous mulloid sod—from moderately argillised mixed rhyolitic and andesitic ash'.

2·5· THE CLASSIFICATION ZONALLY ARRANGED

In the early years of the Soil Survey the multiplicity of units and the many confusing ideas about their classification led to attempts to arrange the soils zonally in an endeavour to get some main threads of order. In effect this represented an attempt to classify the soils keeping certain factors constant. It was based on Marbut's definition of a 'normal site' (in Krusekopf, 1942), which, however, was modified to exclude not only steep land and hollows but also extremes of parent rock such as limestone and basalt, granitic composition being taken as the norm. The soils on such normal sites were called zonal since they occur in a clear zonal pattern. In this way, differences due to various miscellaneous factors were set aside, and differences due to climate and vegetation were allowed to emerge. Other soils were regarded as dominantly intrazonal or azonal, or as intergrades.

This arrangement has proved most valuable for demonstrating and helping to understand soil relationships and is still a useful method of presentation, but it is not a necessary part of the classification. It is no more than a special arrangement of the classes of Category III. The classification may be zonally arranged in two main ways—first, by arranging the soil classes in zonal, intrazonal, and azonal groups, and secondly, by arranging zonal soils and their associated intrazonal soils in groups according to the various zones. A zonal arrangement of the classification is illustrated in Table 2·5·1 in which the main soils of the New Zealand soil map in 'A Descriptive Atlas of New Zealand' (McLintock, 1959) are given with their common and technical names.

TABLE 2·5·1· Modified Legend of the New Zealand Soil Map (McLintock, 1959) with Common and Technical Names in a Zonal Arrangement

Common Names	No. on Legend	Technical Names	Related Steepland Complexes: Common Names	Related Steepland Complexes: No. on Legend	Related Steepland Complexes: Technical Names
ZONAL SOILS					
Brown-grey earths	1	Sitic soils	Steepland brown-grey earths	17	Co-sitic steepland soils (mainly siti-clinic, clini-sitic, co-sitic clinic soils)
Yellow-grey earths	2	Pallic soils	Steepland yellow-grey earths	18	Co-pallic steepland soils (palli-clinic soils, etc.)
—in association with calcareous soils	2r	—with nigric soils, etc.			
—related shallow and stony soils	2g	—co-pallic fulvic soils with stony subsoils			
High country yellow-brown earths	3	Eldefulvic soils	High country steepland yellow-brown earths	19	Co-eldefulvic steepland soils (fulvi-eldeclinic soils, etc.)
Subalpine gley soils and gley podzols	–	A-gleyed eldefulvic and eldepodic soils	Subalpine steepland gley soils and gley podzols	20	A-gleyed co-eldefulvic and co-eldepodic steepland soils (A-gleyed fulvi-eldeclinic soils, etc.)
Southern and central yellow-brown earths	4	Fulvic soils	Southern and central steepland yellow-brown earths	21	Co-fulvic steepland soils (fulvi-clinic soils, etc.)
Southern and central podzolised yellow-brown earths and podzols	5	Fulvi-podic and podic soils	Southern and central steepland podzolised yellow-brown earths and podzols	22	Co-podic steepland soils (fulvi-podi-clinic, podi-clinic soils, etc.)
Gley podzols	6	A-gleyed podic soils			
Northern yellow-brown earths	7	Affulvic soils	Northern steepland yellow-brown earths	23	Co-affulvic steepland soils (fulvi-acclinic soils, etc.)
—in association with calcareous soils	7r	—with annigric soils, etc.			
Northern podzolised yellow-brown earths and podzols	8	Fulvi-appodic and appodic soils			
—mainly sandy with well developed pans and associated with peaty soils	8s	—mainly sandy humus iron illuvial appodic soils with applatic soils			
INTRAZONAL and AZONAL SOILS					
Yellow-brown sands	9	Subfulvic, subaffulvic soils, etc.			
Yellow-brown pumice soils	10	Subalvic soils	Steepland yellow-brown pumice soils	24	Co-subalvic steepland soils (subalvi-clinic soils, etc.)
Yellow-brown loams	11	Alvic soils			
Brown granular loams and clays and red and brown loams	12	Spadous, prospadous, and latous soils	Steepland brown granular loams and clays and red and brown loams	25	Co-spadic and co-oxadic steepland soils (spadi-acclinic, co-oxadic amadi-acclinic soils, etc.)
Organic soils	13	Platic, lodi-platic, applatic soils, etc.			
Gley soils	14	Madentic and admadentic soils			
Recent soils from alluvium	15	Luvic, fulvi-luvic, alluvic soils, etc.			
—with swamps	15w	—with madenti-luvic soils			
Recent soils from volcanic ash	16	Volic soils from volcanic ash	Steepland recent soils from volcanic ash	26	Co-volic steepland soils from volcanic ash (voli-clinic soils from volcanic ash, etc.)
Steepland brown-grey earths, etc.	17 to 26	*See related steepland complexes on right*			
Alpine soils	27	Gelic soils and co-gelic steepland soils (geli-eleclinic soils, etc.)			

2·6· USE OF SOIL-MOISTURE CLASSES IN PHASIC SUBDIVISIONS

Where the soil classes do not adequately express the moisture regime of the soil system, it is necessary to introduce phasic subdivisions for this purpose. A convenient method of applying these subdivisions is in the form of phasic subcategories of the classification at the levels of Categories II or III, but, being phasic, they are used only as necessary.

The relation between climate and soil moisture is analysed by Thornthwaite (1948) in arriving at the water balance for drained soils. On the assumption that most soils have a water-storage capacity of 4 in., the water supply from monthly rainfalls is balanced against the potential evapotranspiration, which can be calculated approximately if latitude is known and temperature records are available. If allowance be made for differences in run-off (particularly on sloping land) and for accessions from the ground water, it is possible in this way to estimate the periods of water deficiency when the soil moisture is below wilting point, and the periods of water surplus when the moisture is above field capacity allowing water to drain through and leach the soil. Between these extremes there are periods when the moisture stored in the soil is being drawn upon or is being recharged. The moisture regimes for 113 stations in the New Zealand sector are analysed by Cox in section 7 of this chapter.

In an attempt to arrive at suitable soil-moisture classes for New Zealand, a soil rating based on pasture performance was proposed by Messrs S. H. Saxby and R. H. Scott (pers. comm.), and the calculated water balances were re-examined and classified using actual storage capacities in the soil for a depth of 18 in. in place of theoretical ones (McDonald, Chapter 9·3). In this way the following soil-moisture classes emerged:

DRY CLASSES

1. XEROUS
The soil is on the average below wilting point for all months of the year. Desert conditions prevail. Except perhaps in parts of the Antarctic, the class does not occur in the New Zealand sector.

2. SUBXEROUS
The soil is on the average below field capacity for each month and below wilting point for six months or more but not all the year. In pastures, ephemeral plants are favoured, for example, haresfoot trefoil, hairgrass, and brome. The class is characteristic of the soils of semi-arid regions, such as the brown-grey earths, which on the average are at wilting point for six or seven months of the year (between October and May) and have annual rainfall commonly of 15 in. or less.

MOIST CLASSES

3. SUBHYGROUS
The soil is on the average below field capacity for more than five months of the year and below wilting point for one to five months. There are resultant difficulties in maintaining white clover; on the drier subhygrous soils subterranean clover commonly predominates over white clover, and on the moister subhygrous soils white clover and ryegrass are retained with difficulty under good management but otherwise tend strongly to be replaced by low-producing annual clovers—suckling in South Island, and subterranean, clustered, and striated in North Island. The characteristically subhygrous soils are the yellow-grey earths with a pronounced dry season.

4. HYGROUS
The soil on the average does not reach wilting point for any month and is above field capacity for most or all of the year. Generally the drier hygrous soils are below field capacity for one to five months and the moister hygrous soils are above field capacity for all months. The moisture is adequate for good permanent pastures based on ryegrass and white clover. Characteristically hygrous soils are the yellow-brown earths, the podzols, and many soils affected by moderately high ground water. They are commonly associated with a humid climate, the lower limit of annual rainfall in the south being commonly about 30 in. and in the north about 40 in.

5. SUBHYDROUS
For approximately half the year, the soil on the average is moisture-deficient; for much of the remainder, it is above field capacity and over-wet (near saturation). Characteristically such soils occur in places with heavy annual rainfalls (80 in. or more) combined with a pronounced dry season. Such conditions are approached on the western side of Viti Levu in Fiji, and on other Pacific Islands.

6. HYDROUS
The soil on the average is above field capacity for all months of the year; in addition it is continuously above field capacity and over-wet for long periods. It is susceptible to pugging by stock at most times of the year. Characteristically hydrous soils include the yellow-brown earths and podzols of medium and heavy texture in superhumid regions and soils with ground water at or near the surface.

Under the same climatic conditions soils of coarse texture are in general one half class drier than those of medium texture. Thus Lismore stony loam and the associated well drained soils of finer texture are subhygrous, the Lismore belonging to the drier part of this class and the others to the moister part. Similarly, the sandy soils of the Manawatu coast have for the most part subhygrous moisture regimes, whereas the associated yellow-brown earths and gleyed yellow-grey earths of finer texture have moisture regimes that belong to the drier part of the hygrous class. In the superhumid West Coast district of South Island most soils of fine texture are hydrous or nearly so, whereas the coarser textured soils, because of their more rapid internal drainage, are hygrous.

In some arrangements of the soil classification, notably on the legends of some soil maps, the approximate moisture class for particular soils has been indicated indirectly by noting their association with a soil that has a characteristic moisture regime. Thus rendzina-like soils 'associated with yellow-brown earths' and those 'associated with yellow-grey earths' are indicated as falling into different moisture classes. The association of one soil with another, for this or for any other reason, can be conveniently expressed with an adjective formed by prefixing co- to the technical name of the soil class selected as appropriate for the purpose in hand, for example, co-fulvic nigric soils and co-pallic nigric soils.

In applying the soil-moisture classes it is important to appreciate that they express soil moisture only and are not a substitute for the more detailed characterisation of the soil body as required in the lower categories of the classification. For example, the Okarito soil of Westland is correctly classed as a hydrous podic soil at the level of Category III, but, however strong the implication, it is not definitely indicated as a gley podzol until it has been classed in Category IV.

2·7· EVALUATION OF CLIMATE AND ITS CORRELATION WITH SOIL GROUPS

by J. E. Cox

In this section the climate at stations in the New Zealand sector has been evaluated. The stations have been arranged in climatic classes that are closely related to the main soil groups and express the relation between precipitation and the water needed for evaporation and transpiration—a relation that determines to a large extent the kind of soil developed.

Thornthwaite's classification (1948) has been applied to New Zealand by Garnier (1951) who produced maps showing the distribution of the climatic types. Garnier gave tables of values for selected stations for the various Thornthwaite indices. He was satisfied with the way the classification differentiated the major moisture types of the country but proposed one modification to indicate seasonal contrasts in effective moisture in the drier parts of New Zealand. Concerning temperature divisions he thought the system unsatisfactory in not differentiating sufficiently between north and south, the only major contrasts being those between the mesothermal climates below an elevation of 2,500 ft and the microthermal and colder climates above.

Hurst (1951) compared Thornthwaite's classification (1948) and several others to rate their success in distinguishing between the climates prevailing in the yellow-grey earth (pallic) and yellow-brown earth (fulvic) zones in New Zealand. She concluded that Thornthwaite's classification gave the best differentiation between the soil groups on the basis of moisture status, and on several counts judged it the most useful. On the other hand a study of Hurst's data shows that Thornthwaite's moisture types do not correlate well with the soil groups because the moisture indices chosen to separate the moisture types do not correspond well with the moisture indices that differentiate the soil groups.

Since the work of Garnier and Hurst was published, the Meteorological Service has revised rainfall and temperature normals for all climate stations. The rainfall normals are for the 30-year periods 1921-1950 and differ substantially at many stations from the long-term averages used by Garnier and Hurst. Temperatures have been less affected by this revision; for many stations they are averages revised to 1950, but about one-third of the stations have short records mainly taken since 1950, and, for these, normals have been worked out by the Meteorological Service. Because the revised rainfall normals place stations on a fairer basis for comparison, Thornthwaite values for all stations have been recalculated using the revised data. From Hurst's work and the present study it appeared desirable to modify the boundaries of the moisture types defined by Thornthwaite, and this fact, coupled with the revision of meteorological data, has limited the use that could be made of Garnier's work, though his remains a most valuable reference.

ELEMENTS OF THORNTHWAITE'S CLASSIFICATION (1948)

Potential evapotranspiration is the amount of moisture lost by evaporation and transpiration from the soil when it is covered by vegetation and amply supplied with water. From study of rates of water use in irrigation projects and from catchment run-off records, Thornthwaite (1948) found that 'When adjustments are made for variation in day length, there is a close relation between mean monthly temperature and potential evapotranspiration. Study of all available data has resulted in a formula that permits the computation of potential evapotranspiration of a place if its latitude is known and if temperature records are available.'

Water need, calculated according to the formula, is balanced against the supply from rainfall. According to Hurst (1951), when rainfall is equal to water need, the soil is maintained at field capacity and no leaching takes place. When the supply is greater than the need there is a *surplus* for leaching the soil. When it is less the soil mois-