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SOIL HORIZON DESIGNATION AND CLASSIFICATION

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SOIL HORIZON
DESIGNATION AND CLASSIFICATION

A coordinate system for defining soil
horizons and their use as the basic
elements in soil classification
for different purposes

E.A. FITZPATRICK
Department of Soil Science,
University of Aberdeen

International Soil Reference and Information Centre
(ISRIC)
Duivendaal 9, P.O. Box 353
6700 AJ Wageningen, The Netherlands

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PREFACE

This publication is the updated text of Dr. FitzPatrick's coordinate system for defining soil horizons and their use as the basic elements in soil classification. The author's ideas on the matter, though published in several articles and books, have not yet been taken up in any national or international soil classification system. His comprehensive definitions and innovative naming of key soil horizons, and their possible grouping, do however merit the attention of all those who are engaged in devising or perfecting new comprehensive systems for the classification of soils in a region or in the world at large. They may also be of use at the elaboration of an International Reference (or Referral) Base for soil classification, a current undertaking of Commission V of the International Society of Soil Science.

The format of this Technical Paper, as a "pocket edition", is the same as two earlier ones, viz. ISRIC's "Field Extract of Soil Taxonomy" (TP 4)* and the French originated "Project of Soil Classification" (TP 7). This facilitates the use of the three publications side-by-side at discussions on the merits of different approaches to classification at inspection of soils in the field.

Negotiations are underway with FAO to prepare a similar pocket edition of the forthcoming FAO World Soil Resources Report 60, which contains the Revised Legend of the FAO/Unesco Soil Map of the World.

Wageningen, March 1988
W.G. Sombroek,
Director ISRIC

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* an up-to-date version with all approved amendments of this US originated system is available nowadays, also in pocket-form, from Cornell University as "Keys to Soil Taxonomy" (SMSS Technical Monograph no. 6, December 1987).

INTRODUCTION

This is the complete compilation of ideas about soil horizon designation, whole soil designation and soil classification that have been published elsewhere (FitzPatrick, 1967, 1971, 1980, 1984, 1986). It starts by describing a system for defining soil segments (horizons) based on coordinates and is regarded as complete. This is followed by a brief description of all the segments (horizons) so far recognised and other data pertaining to the segments themselves. For most of the segments there is a fairly full description of the micromorphology that was prepared for a previous publication (FitzPatrick, 1984). There is then a full and detailed description of a few segments. Finally, there is a simple horizon key. In due course full descriptions will be produced of all the segments hopefully with the help of other pedologists. Offers of help will be welcomed.

The nomenclature and classification of soils fall into two parts. On the one hand there is the nomenclature and classification of horizons and on the other there is the nomenclature and classification of whole soils. McRae and Burnham (1976) state that 5 differing and, perhaps, irreconcilable aims exist as reasons for making a soil classification.

1. To communicate an impression of the nature of a soil profile or of the soil in an area in relation to others, i.e. to use as a language. In this case:

   (a) it must be widely accepted; a language that has wonderful elegance of grammar and syntax but is little spoken is not worth learning.

   (b) It must be easily taught; if it is to be used, the gist of the classification must be reasonably easy to hold in the memory and to be so it must be logical and not too complicated.

2. To simplify processing soil data. In this case:

   (a) more complication can be tolerated, as a specialist with a manual or even a computer can be used to assign soils to classes.

   (b) more precision of definition is required, or too much of the information content of the original observations is lost.

3. To reveal or study genetic relationships. In this case:

   (a) the selection of properties used as a criteria may be irrelevent to important uses of soil, e.g. plants are colour-blind.

   (b) It must be capable of modification as knowledge grows.

4. To use as a legend in a soil map and as mapping units. In this case:

   (a) there may be conflict between the criteria used, often on an ad hoc basis, by the field surveyor to differentiate soils and the criteria imposed by the classifier.

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I should like to thank my colleagues and students for making many useful suggestions, especially Drs N.M. Court, A.J. Koppi, A.B. McBratney and R. Webster.

(b) an instant decision is required to annotate the field slip.

(c) non-soil characteristics are often involved in the classification

5 For a specific purpose. In this case:

(a) the criteria used will emphasis those factors of specific interest to the classifier and may ignore other properties of the soil, e.g. a civil engineer may classify soils on their bearing capacity or permeability, but ignore the existence of different genetic horizons.

(b) numerous different classifications are likely to be needed.

1.0 ASPECTS OF SOIL CLASSIFICATION

When constructing systems of nomenclature and classification for soils it is necessary to consider the following aspects:

Horizon recognition
Horizon homology
Juxtarelationships of horizons
Intergrading of horizons
Horizon nomenclature

1.1. Horizon recognition

It is generally accepted that soil can be classified according to the type and number of horizons present. Therefore, the recognition of horizons is of paramount importance. However, there are innumerable difficulties and it would seem fair to say that so far horizon recognition has been more of an art based on experience rather than a science based on any set of defined principles.

Many attempts have been made to define horizon and it now appears that very lengthy definitions are required in order to attain precision as shown by the USDA (1975) and FitzPatrick (1971). These definitions suggest that the recognition of horizons is not as simple as was once thought and recourse to laboratory data is often required. A further serious problem is that it is not always possible to use the intrinsic properties of the horizon; it is often necessary to compare the properties with the horizon above or below. This indicates clearly that the most fundamental aspects of soil recognition and classification are still to be resolved.

1.2 Horizon homology

The usual approach to soil classification is to attempt to classify whole soils or full assemblages of horizons within any one soil. This approach appeared to be very sound when it was thought that soils resulted from the straightforward interaction of the present day factors, parent material, climate, organisms and topography acting through time, such interactions leading to soils with characteristic horizon sequences. This led implicitly to the belief that the concept of homology could be applied to soils and it could form the basis of a classification. Within the plant and animal kingdoms, major divisions are based on homologous relationships, but, it is difficult, if not impossible, to establish such relationships for all soils. In the animal kingdom, humans, horses, and birds are homologous because they all have a head, two forelimbs and two hind limbs. There may be a prima facia case for soils since many soils with similar horizon sequences do exist, but there are also many departures from this somewhat ideal model.

The difficulties with soil homology are represented in Fig. 1, which shows six different horizon sequences overlying the relatively unaltered material, represented by the open shading.

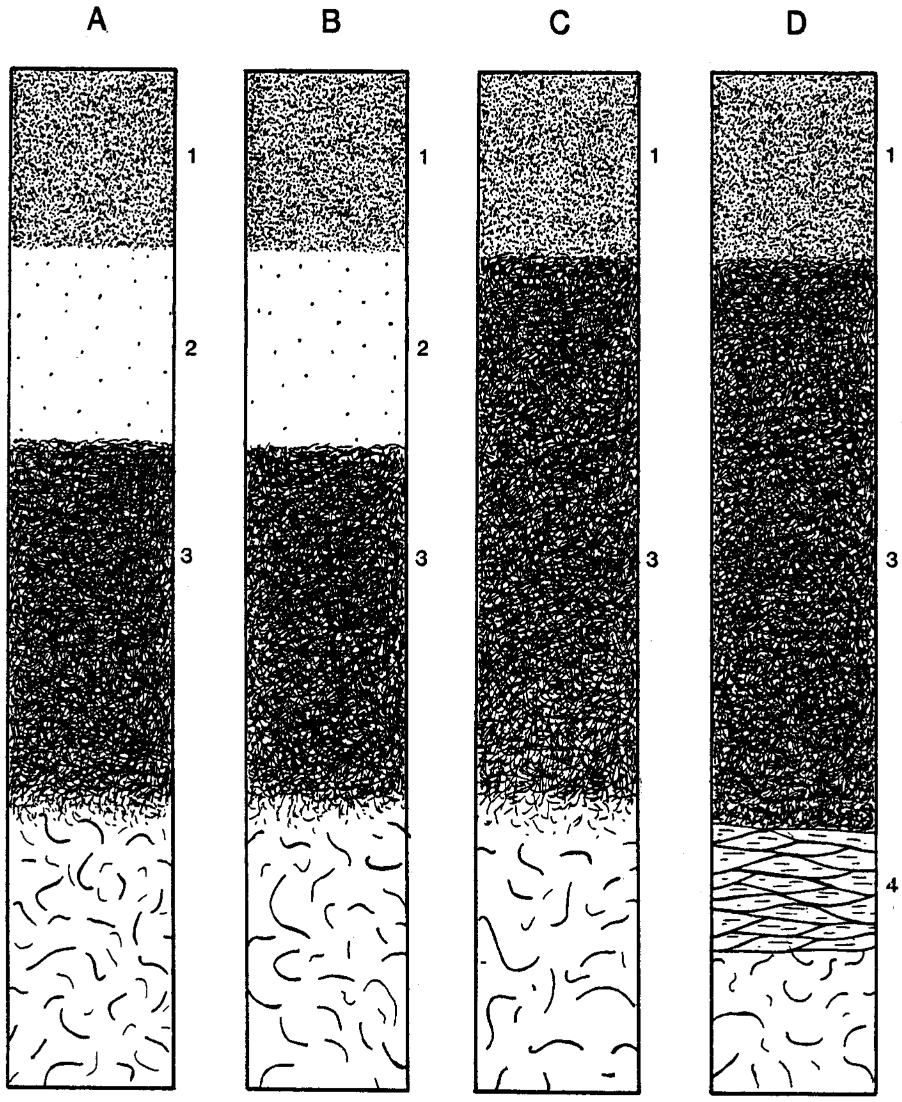
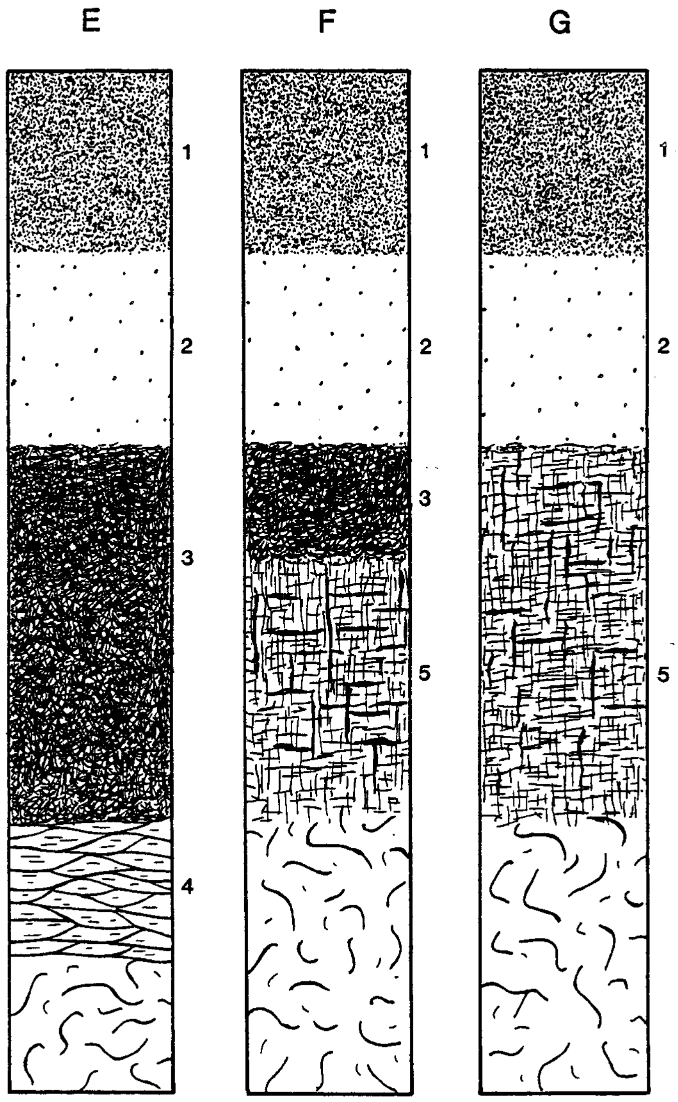


Fig. 1 Seven profiles showing six different sequences

Profiles A and B represent two soils that are homologous since both have the same three horizons and they are in the same position and vertical sequence. This situation is very common. Profile C is partly homologous with profiles A and B since horizons 1 and 3 are present but, it is not completely homologous since the vertical sequence is different because horizon 2 is absent and horizon 1 immediately overlies horizon 3. This situation is also very common. Profile D is partly homologous with profile C since horizons 1 and 3 are present in both and in the same vertical sequence but, profile D has the extra horizon 4 and is therefore not completely homologous with profile C. Profile E is partly homologous with profiles A and B but like profile D it has the extra horizon 4. The situation regarding soil homology is even more complex since horizons 1 and 3 can be replaced together or separately by other horizons so that the number and type of horizon sequences become extremely large.

The situation is further complicated since many factors, particularly climate change through time, and properties formed under one set of climatic conditions can be inherited into the new set of climatic conditions and often themselves determine the direction of soil development. For example, profile B may gradually lose its homology with profile A through time and may develop into yet another sequence. Thus, the homology between soils may only be temporary since each may be developing in different directions. The result is that the juxtarelationships of horizons are extremely diverse.



of horizons

Thus, although homology exists for many soils it is by no means universal and this seems to make it impossible to create a fixed number of classes based on homologous relationships. In fact it is true to say that nearly every horizon can occur in juxtaposition with nearly every other horizon.

However, it may be argued that since horizon 3 is present in all the soils so far mentioned, the concept of the diagnostic horizon (USDA, 1975) can be applied, but since all of the horizons in all of the profiles can be diagnostic horizons it means that some diagnostic horizons are more important than others. Another major problem with this concept is that often two or more important diagnostic horizons appear in the same soil, thus, making such a soil partly homologous with other soils that contain only one of the 2 diagnostic horizons. This situation is illustrated by profile F which has two important diagnostic horizons 3 and 5. Therefore, it is partly homologous with profiles A to E because of the presence of horizon 3 and partly homologous with profile G because of the presence of horizon 5. Thus, profile F has to be placed either in the class with horizon 3 or horizon 5 thus, producing a ranking even among the important diagnostic horizons. This is another example of the absence of homology in soil science. The diagnostic horizons and their approximate equivalents are given in Table 2 (page 83).

1.3 Juxtarelationships of horizons

A detailed study of soils containing a thin iron pan has shown that the pan has many relationships with other horizons and that a thin iron pan can be:

1. sandwiched between a reduced horizon above and an indurated layer below;
2. beneath, above or within horizons of humus and iron accumulation in Podzols;
3. within indurated layers;
4. above a horizon of clay accumulation;
5. within the relatively unaltered underlying material;
6. form multiple pans in any one of the above situations.

A similar type of varied relationship can be found for horizons with clay accumulations.

1.4 Intergrading of horizons

Figure 2 illustrates a relatively simple situation in which the lateral continuum in the middle horizon of a number of soils is from those containing more translocated iron and aluminium than the horizon above to those in which the contents of iron and aluminium are similar to the horizon above. Since it is virtually impossible to communicate information in terms of continuous variation unless lengthy descriptions are used, some attempt must be made to impose boundaries in the continuum both with regard to the areas with maximum expression of the dominant property or properties as well as with regard to the intergrading situations even though the boundaries are of necessity somewhat arbitrary. There would seem to be 3 methods of creating divisions in a continuum such as soil.

The first method is to set a boundary in the continuum, at point 2 in Fig. 2, thereby creating two segments. Each segment could then be defined in terms of the maximum expression of some specific property or properties as well as in terms of the lateral variations. This might be a practical solution if each

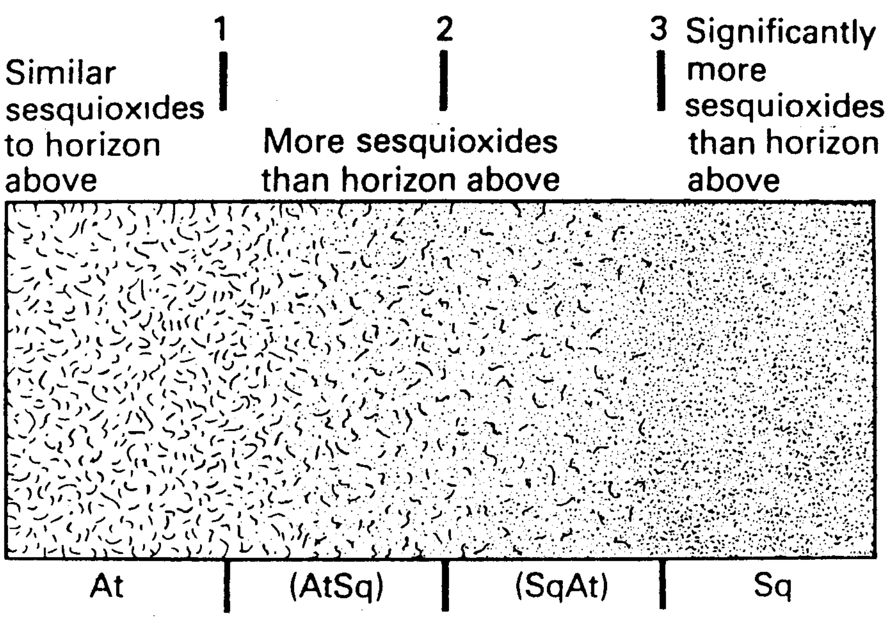


Fig. 2 Intergrading of soil horizons

segment formed a continuum with only one other segment, but, in reality segments have continuous variations vertically as well as horizontally. Furthermore, in another situation a specific segment might form a lateral continuum into other quite different segments. The result is that segment definition would have to be written in terms of all the possible continua which would be cumbersome and could even be meaningless as is the case with the definitions of the diagnostic horizons.

A second approach is to divide up the continuum somewhat arbitrarily and to ascribe a name and symbol to the range between each division. In this method the range between each arbitrary division is given equal status. This would tend to blur the concept of intergrades but, although in reality all soils are intergrades in time, it is still necessary to give prominence to the concept that some parts of the continuum are intergrades in space while others are not.

A third and more realistic approach is to create what would appear to be two reference or polar segments and two intergrade segments by placing boundaries at positions 1, 2 and 3. This method produces relatively few reference segments, but there are very many intergrades since any one segment may intergrade into two or more other segments. However, it must be stated that these boundaries have no fundamental meaning because any two adjacent points situated on either side of a boundary are more like each other than each is to distant points within its own segment.

These difficulties are summarised by Webster (1976) who states "Furthermore soil populations are generally evenly distributed in character space. There seem to be few gaps and even fewer clusters. This is the nature of variation in soil, and it is against this background that the work of soil taxonomists needs to be seen and its outcome understood".

1.5 Horizon nomenclature

The classical approach to horizon nomenclature used the letters, A, B and C to designate the upper, middle and lower positions and by the use of appropriate prefixes and suffixes to add specificity. Thus Ah is used for the upper organic mineral mixture in Podzols, E for the bleached horizon, and Bhs for the horizon of accumulation of iron and humus. Although this scheme appears simple and straightforward it has not been very successful, so that each major soil survey organisation has its own set of prefixes and suffixes. However, the greatest deficiencies in this scheme are found in tropical areas where the soils are very old and have been through many contrasting phases of soil formation, and where many of those in the mid and lower slope positions are stratified as a result of material being washed down over the surface. The difficulties have led workers such as Nye (1954), Watson (1964) and Webster (1965) to abandon the ABC system and to develop their own systems to suit their local needs. The problem also arises in the designation of alluvial and tundra soils. Pons and Zonneveld (1965) in discussing alluvial soils state "It would thus seem that there is no really pure C horizon in alluvial soils". French (1976) states "In profile, tundra soils show considerable variation and the application of the conventional horizon desgination has little meaning". In spite of these valid and highly justified rejections of the ABC nomenclature it is still used by a considerable number of soil scientists.

It seems that the time has come for the complete abandonment of the ABC concept and to replace it by a concept that does not indicate that the juxtarelationships of the horizon forms an invariable sequence as implied by ABC, since B always follows A and C always follows B in the alphabet; whereas in soil there is no such consistent relationship. Furthermore, the term "C horizon" is a complete misnomer since many C horizons are not horizons but unaltered material. It is probably more realistic to think of the soil as having 4 positions, surface, upper, middle and lower and briefly defined as follows:

Surface: discontinuous features on the surface of the ground, e.g. earthworm cast and mole hills

Upper positions: have one or more of the following:

1) Organic horizons
2) Organic-mineral mixtures at or near to the surface
3) Uppermost mineral horizons

Middle positions: have one or more of the following:

1) Beneath organic-mineral mixtures which are at or near to the surface
2) Accumulated sesquioxides, and/or clay, and/or humus by translocation
3) Accumulated sesquioxides and clay by weathering in situ
4) Beneath leached and bleached horizons
5) Some horizons that are periodically or permanently saturated with water
6) Beneath main rooting zone

Lower positions: have one or more of the following:

1) Relatively unaltered material
2) Weathered rock
3) Fossil horizons
4) Thick middle horizons
5) Some horizons that are periodically or permanently saturated with water

1.6 The unit of study: the pedo-unit

Features such as soils that change continuously in space and time pose a number of practical and theoretical problems with regard to their study, designation and classification.

Although the inspection of a profile is usually the first step towards categorising a soil, profiles in themselves are not units of complete study since they have only two dimensions - breadth and depth. Thus, profiles can be studied only by visual examination, whereas, it is the soil continuum that must be investigated.

The research carried out on soils aimed at their quantitative characterisation is extremely varied and is determined primarily by the requirements of individual workers. The assessment of a tangible property such as the total amount of iron is usually conducted in the laboratory on samples collected from the continuum. On the other hand, the measurement of moisture or temperature fluctuations are more satisfactorily carried out by inserting suitable probes into the soil and taking continuous or intermittent readings. The data obtained by these techniques yield information about the intrinsic properties of the continuum at any one point and by collecting data from a number of points inferences can be made about the rate and type of change from point to point. Thus, the unit of study or pedo-unit can be defined as follows: the pedo-unit is a selected column of soil containing sufficient material in each horizon for adequate laboratory and field characterisation.

Figure 3 illustrates the pedo-unit and some other units of study.

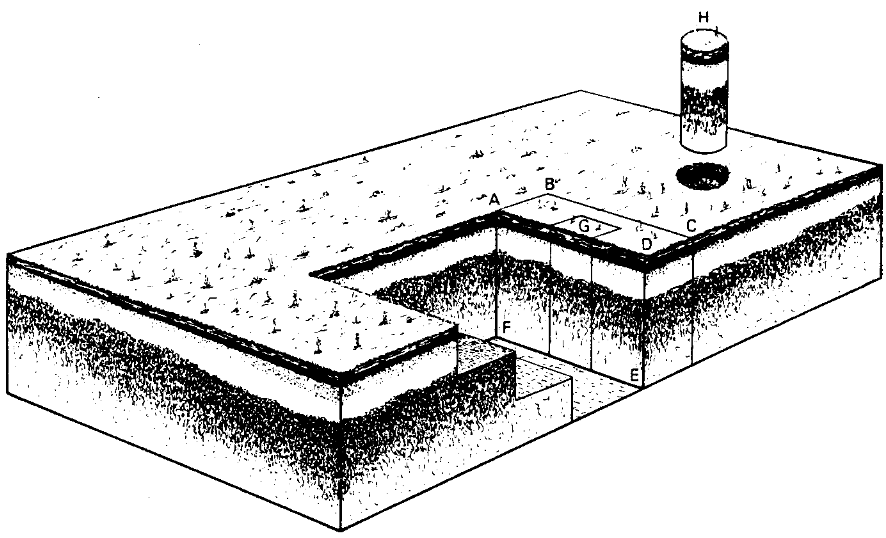


Fig 3 The pedo-unit

The pedo-unit occupies the volume of soil extending below ABCD and the soil profile is the exposed section ADEF. A monolith is shown extending below G and there is a core at H. The pedological characterisation of the soil is normally performed in the laboratory on bulk or undisturbed samples obtained from the pedo-unit. Duplicate or triplicate bulk samples are collected from each horizon in a vertical sequence which ideally forms a column. The size of the individual horizon sample should always be minimal because many small samples are statistically more valid than a few large ones. However, the precise amount is determined by the nature of the soil itself and by the requirements of the quantitative analytical techniques used to assess the various soil properties. The sample can be as small as a few grams but, if information is required about the proportion of stones, several kilograms may be needed. However, a smaller sample may have to suffice if the horizon is very thin. A rectangular column with surface dimensions of about 100 x 30 cm and extending down to include the relatively unaltered underlying material is the usual size of the pedo-unit, being large enough to give triplicate samples. This is not to be regarded as a fixed amount since the volume of soil examined will vary with the nature of the soil.

Thus, there can be no fundamental unit of study or of classification since the nature of the unit is decided on the one hand by the desires of the operator and on the other by the nature of the soil itself. Sometimes, the nature of the soil allows the operator to do exactly as he wishes but, on many occasions the nature of the soil imposes severe limitations.

1.7 Soil - a part of the landscape

Soil can be considered as the thin veneer that covers a considerable part of the earth's surface and like most veneers is very vulnerable. Thus, we find that the top part of the soil is constantly being disturbed and redistributed by running water. Generally, as water flows over the surface, varying amounts of soil are picked up in suspension and either deposited lower down the slope or carried away by rivers. This incessant removal of material leads to an extremely varied pattern of natural erosion and deposition. The result is that the majority of soil on slopes show some evidence of stratification, the amount varying from place to place, being greatest in the older landscapes such as those in many parts of the humid tropics where it can be considered as normal in most areas.

In many temperate areas the slopes are covered by solifluction deposits produced during previous arctic conditions. In some cases the formation of the strata is periodic so that the surface may remain static for a sufficiently long period for the formation of a soil which is buried by the next depositional episode. Thus, soil not only shows a vertical differentiation of horizons, but also one due to lateral surface movement. Therefore, they must be considered as forming part of the landscape with soil and landscape evolution proceeding together and becoming more and more obvious as the age of the landscape increases. In fact, the wearing down of mountains to produce plains is really the progressive formation, removal and redistribution of the soil veneer. Thus, any system of soil designation must take account of this conspicuous and very common feature.

2.0 A COORDINATE SYSTEM OF HORIZON DEFINITION

From the above it should be clear that the situation is very confused at present. Some workers use the ABC system together with or separate from diagnostic horizons, while others construct systems to suit local requirements particularly in tropical areas.

A new approach is needed, and I proposed and developed a system (FitzPatrick, 1971) that incorporates suggestions made earlier by the Russian scientists, Vilensky (1927) and Sokolovsky (1930) and by Crowther (1953).

Vilensky disagreed with the ABC system of horizon nomenclature and suggested that horizons should be designated by the letters, A, E and I, and qualified by a second small letter to give a more specific indication of their composition. Sokolovsky also criticised the use of the ABC designation of soil horizon and agreed with the proposals of Vilensky that a number of horizons be recognised and that the first letter of each horizon be used as a symbol for that horizon, for example, H - humus, E - eluvial horizon, I - illuvial horizon, Gl - glei horizon, G - gypsum horizon, S - horizon of accumulation of soluble salts, P - parent rock. Further, he suggested that the letters could be used in combination to indicate complex horizons and that they could be used to desginate the whole soil. For example, a Podzol might be designated as follows:

$$HE_{14}E_{14}EI_{40}I_{40}IP$$

where the letters indicate the different horizons and the subscripts number the thickness of the horizons in centimetres. These suggestions have been virtually ignored and were unknown to me at the time of the publication of my first paper on soil classification (FitzPatrick, 1967). It is very unfortunate that these ideas have largely remained dormant for over 40 years: their implementation might have allowed pedology to develop much faster.

Crowther (1953) considers that the basic concept in soil classification should be one of infinite coordinates in hyperspace. By selecting certain soil properties and using them as coordinates it is possible to produce diagrams such as ternary diagrams for particle size distribution and the feldspars. In such diagrams the arbitrary divisions create spaces or segments with defined values and are regarded as the units of classification.

Soils are generally regarded as forming a continuum in space and time therefore, arbitrary lines have to be drawn within the continuum. In order to achieve this, the various properties of soils are considered as coordinate axes that can be conveniently divided.

Generally, three or more coordinates in a geometric arrangement are involved, as shown in Fig. 4, which attempts to resolve some of the difficulties in classifying tropical soils.

It shows part of the range of variability among the strongly weathered soils thus, 4 coordinates are involved.

1 Colour
2 Clay content
3 Cation-exchange capacity
4 Weatherable minerals - all the segments have < 0.5% Total Basic Cations (TBC) - and therefore is not shown as a separate coordinate in the diagram.

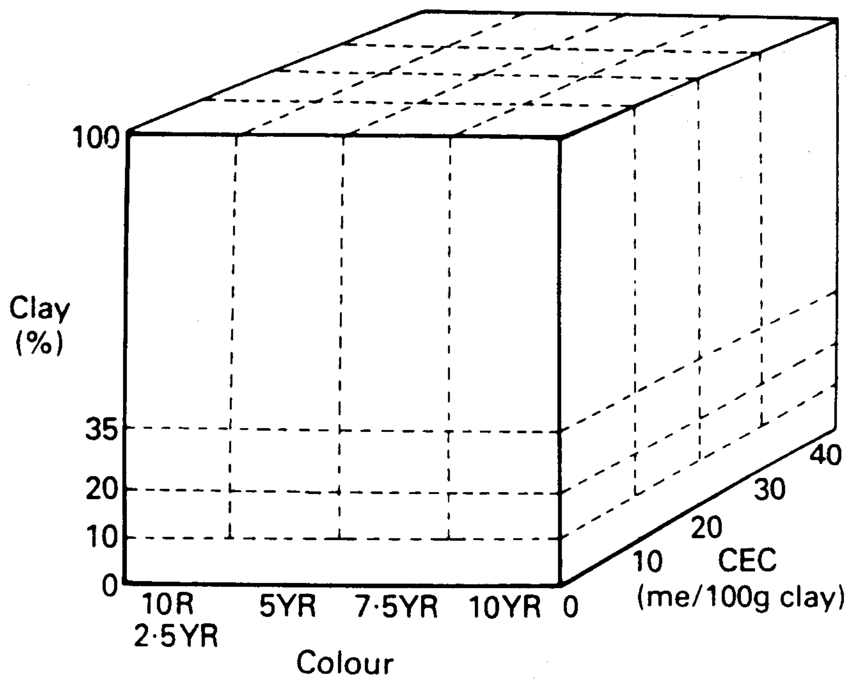


Fig. 4 Some soil segments in the humid tropics

This range of variability is large, and it seems to warrant the creation of 49 segments of both theoretical and practical significance. Objections might be raised to the above principles in that the difference between adjacent segments is usually only one of degree within one property. This seems to be inevitable but as the segments become more and more distant their differences become greater and greater.

Although it might not be difficult to accept the principles of coordinate classification, the problem is to decide exactly where to draw the arbitrary lines. This is clearly demonstrated by the fact that nearly all major soil survey organisations have their own ternary diagram for particle size distribution. This does not mean that each organisation considers that its own diagram is correct and the others are wrong. It means that the diagrams have been constructed to accommodate local requirements and are not designed to be universally acceptable. This is not ideal, but it does demonstrate clearly that soil classifiers are usually influenced very strongly by local conditions and that agreement has not been attained even at the simplest level. It is hoped that eventually agreement will be reached with regard to putting in the arbitrary divisions within coordinate diagrams.

Indeed, it is generally agreed that the whole of soil classification is concerned with drawing arbitrary divisions but, is easier to see the problem when set in a coordinate framework. By using a coordinate system, spaces are created, each with a given range of variability for the properties that have been chosen. Previously, these spaces have been called horizons, but it now seems inappropriate to use the term horizon, both for a somewhat finite feature that can be observed in the field as well as for a conceptual spatial entity delimited by coordinants. Whereas, a specific horizon in the field will have a fairly narrow range of variability, the conceptual space of which it forms a part will have a much wider range. In fact, it is normal to have two or more horizons that do not have the same range in the chosen properties but, are within the same conceptual spatial entity. Therefore, it seems that two terms are required: one for the conceptual space and the other for the observed feature in the field. The term horizon could be retained and used in the field while the term 'segment' might be used for the conceptual volume in space.

Thus, the basic theoretical unit becomes the segment and it may be defined as follows: 'A segment is a part of the conceptual model of soils having defined ranges of properties created on coordinate principles and embracing a number of individual horizons'. In this system it is suggested that the starting point is an attempt to create the various segments using coordinates. Butler (1980) is in agreement with these ideas and stresses the need to concentrate efforts at this level. At present two basic types of segments are recognised:

Reference or polar segments
Intergrade segements

2.1 Reference or polar segement: one that has a single unique dominating property or a unique combination of dominating properties and formed principally by a single set of processes.

2.2 Intergrade segment: one that contains properties that grade between two reference segments.

From the above it is possible to say that a segment is a class and a horizon is a member of the class and to recognise four types of horizon:

Reference horizons
Intergrade horizons
Compound horizons
Composite horizons

2.3 Reference horizon: one that has properties that fall within a reference segment.

2.4 Intergrade horizon: one that contains properties that fall within an intergrade segment.

2.5 Compound horizon: one that contains a combination of properties of two or more reference segments. These properties are usually contrasting and develop as a result of either contrasting seasonal processes or they have one set of properties superimposed upon an earlier set. This may be as a result of climatic change or progressive soil evolution.

2.6 Composite horizon: one that contains discrete volumes of two or more segments.

2.7 Designation of reference or polar segments and horizons

Each and every reference segment that is created is given a name and symbol. The name is based on some conspicious or unique property of the segment; this may be its colour or some substance present in significant proportions. The symbols are formed by using the first letter of the segment name plus one other which is usually part of the name.

All of the names of segments are coined words ending with 'on', the same as for the word horizon. When creating these new words every attempt was made to modify words that already form part of pedological terminology so that the new names appear to be somewhat familiar. For example, the name mullon is the well known term mull with an 'on' ending, and designated by the symbol Mu; fermenton - Fm and humifon - Hf are derived from fermentation and humification respectively. Each horizon within a segment is given the same symbol. All of the reference segments recognised up to the present are described in Chapter 7.

2.8 Designation of intergrade segments and horizons

The intergrades are not given names but are designated by the use of the reference segment symbols. Referring again to Fig. 2 the intergrades are designated by combining the appropriate symbols in round brackets according to the proportion of each set of properties, the dominant set being placed first. The intergrade (AtSq) displays properties of alton At and sesquon Sq but is more like alton. Each intergrade horizon within an intergrade segment is given the same symbol.

2.9 Designation of compound horizons

Compound horizons are designated in a similar manner to intergrades but the symbols are put in curley brackets thus: { InFg }.

2.10 Designation of composite horizons

For a composite horizon, the symbols for the discrete volumes of each horizon are placed in round brackets and separated by a stroke. One of the best examples is found in Chernozems which have crotovinas and are designated (Ch/2Cz-) here Ch is the symbol for a chernon and 2Cz- the symbol for calcareous loess.

2.11 Designation of a selected number of segments and their intergrades

An example of the designation of a number of reference segments and their intergrades is given in Fig. 5 which is the 'exploded' and fully annotated version of Fig. 4. In this diagram five reference segments are recognised krasnon - Ks, zhelton - Zh, rosson - Ro, flavon - Fv and arenon - Ae. The diagram should be read as follows: at the top Ks intergrades to Zh, Ro and Fv so that adjacent to Ks there are (KsZh), (KsRo) and (KsFv). All of the top segments intergrade to the arenon, so that Ks intergrades to Ae through (KsAe) and (AeKs): similarly (KsFv) intergrades to Ae through (KsFvAe) and (AeKsFv) with Ae being subordinate in the first place and dominant in the second.

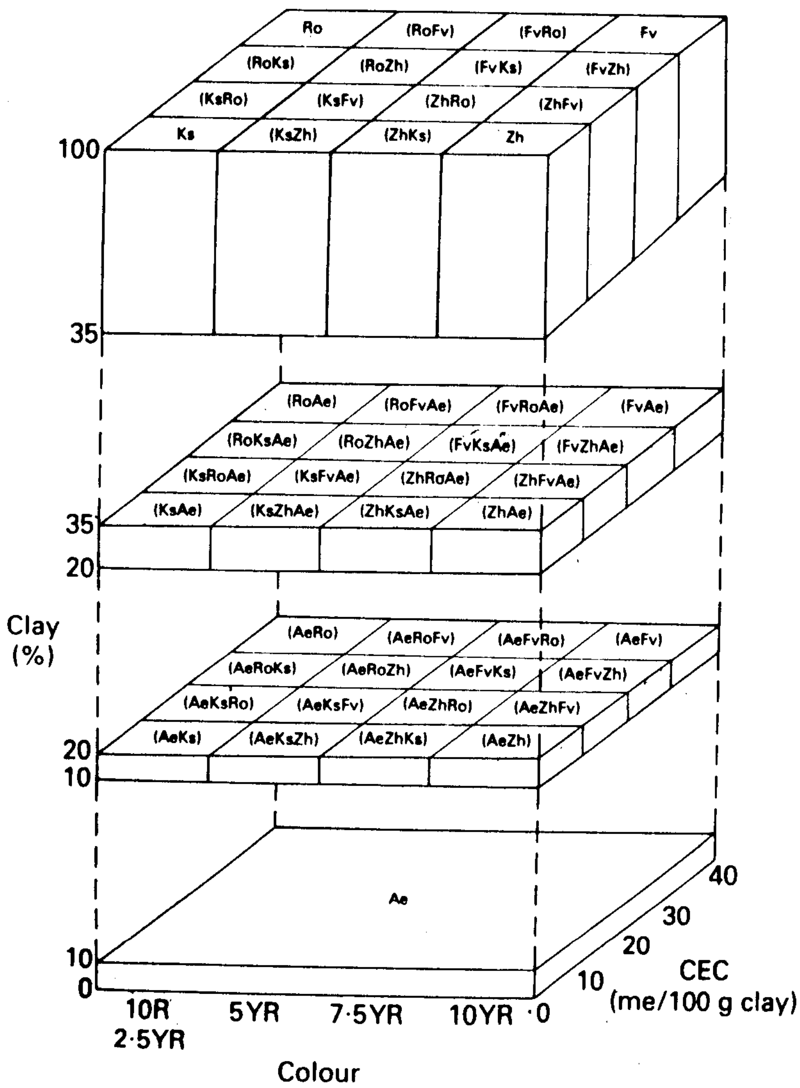


Fig. 5 Exploded and fully annotated version of Fig. 4 showing all of the references or polar segments and their intergrades

Some other relationships between segments are shown in Figs. 6, 7, 8 and 9. In Fig. 6 krasnon is shown as having a range of variability in four properties and as each property changes a new segment is created. Figs. 7 and 8 show the relationships between some strongly weathered segments. Fig. 9 shows the intergrating pathways among Scottish soil segments.

This system of notation is an attempt to recognise and preserve the reality of the soil continuum and to accommodate soils with polygenetic evolution. It must be emphasised that segment names and symbols are merely a means of communicating information in a concise form and are not a substitute for a full and comprehensive characterisation which involves a detailed description of the soil and supporting analytical data. In many cases, a specific horizon may be very thick and it may be necessary for it to be sub-divided for analytical purposes in which case the sub-horizons are designated with the aid of arabic numbers - a sesquon which has three subdivisions would be symbolised as follows: Sq1, Sq2, Sq3

Creating boundaries and attempting to introduce the concept of reference segments is not as easy as it might appear at first, because each segment has a wide variety of properties. Therefore, the first step is to delimit

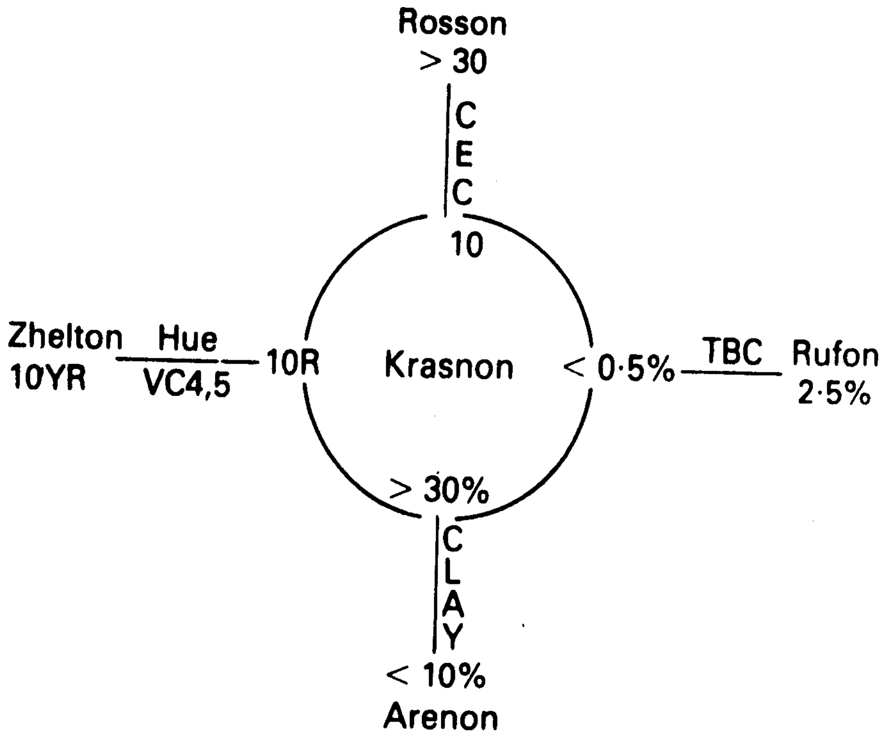


Fig. 6 The intergrading of krasnons into four other segments

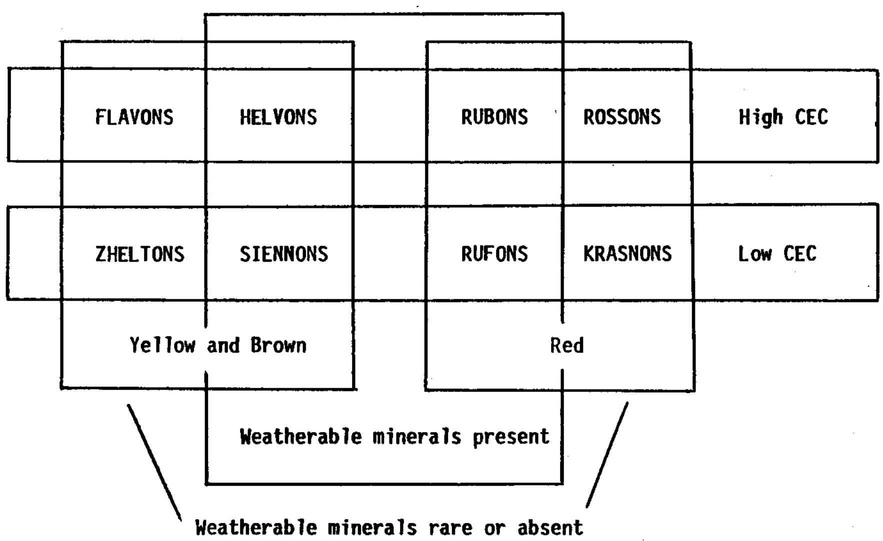


Fig. 7 Relationships between some strongly and very strongly weathered horizons

	KRASNONS	ROSSONS	ZHELTONS	FLAVONS	RUBONS	RUFONS	HELVONS	SIENNONS
Position	Middle	Middle	Middle	Middle	Middle	Middle	Middle	Middle
Colour	Red	Red	Brown, Yellow	Brown, Yellow	Red	Red	Brown, Yellow	Brown, Yellow
Texture			>30% clay			medium to fine		
OM%				>5				
pH	4.5-6.0	4.5-7.0	5.5-7.5	4.5-5.5	4.5-7.0	4.5-7.0	4.5-7.5	4.5-7.5
CEC meq Kg^{-1} (clay)	<100	>300	<100	>300	>300	<100	>300	<100
Clays				Kaolinite D 2:1 minerals R-A Iron oxides O-A Gibbsite R-D				
Weatherable minerals		<5				>5		

Fig. 8 Properties of some strongly and very strongly weathered horizons

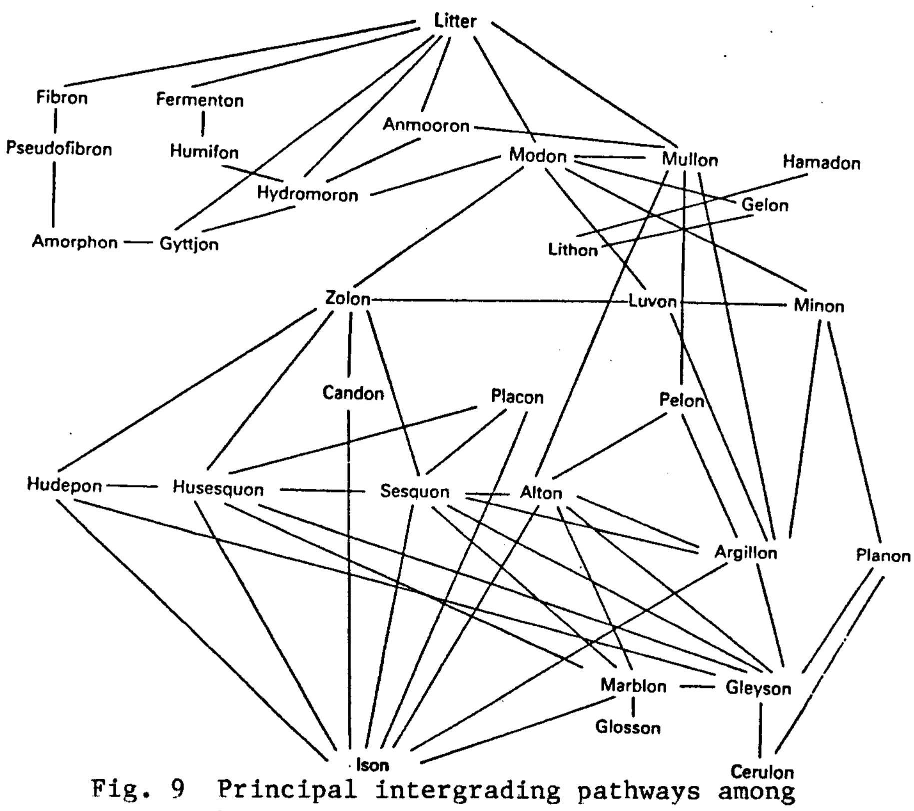


Fig. 9 Principal intergrading pathways among horizons in Scottish soils

the various reference segments based on their known intrinsic properties, although in a few cases a comparison with another segment may be necessary. The lack of intrinsic differentiating criteria for some segments is probably due to a lack of knowledge rather than to lack of criteria. It is hoped that further research will supply these criteria. At present, the limits are set on a purely subjective basis and, with present computing methods, involving the use of ordination techniques, it may be possible to set objective standards and create more exact limits in the future.

In the field and in the general description of soils the names and symbols of the segments are used to designate the horizons which form part of a segment.

3.0 CLASSIFICATION AND DESIGNATION OF PARENT MATERIALS

Parent materials may be classified on the basis of their mineralogical and chemical composition, degree of consolidation, texture and larger separates, which are themselves coordinates and given in Fig.10. Each unit of classification is given a symbol which can be combined to give a composite symbol for the various types of parent materials, examples of which are given below. This classification is designed primarily to accommodate the very wide range and abundant sediments that form the parent materials of most of the world's soils. The consolidated parent materials including rocks such as granite, gabbro, schist and slate can also be classified. It may appear superfluous to have this additional system for classifying these rocks but it has the advantage of giving a symbol for use when writing soil formulae.

All parent material can undergo chemical and/or physical weathering whether originally consolidated or not. Then they are variously regarded as part of the soil or as parent material and can be classified by adding one of the symbols given in Table 1.

TYPE	COMPOSITION	SYMBOL
Sulphate		S
slightly sulphate	1-5% $CaSO_4$	1S
moderately sulphate	5-20% "	2S
strongly sulphate	20-50% "	3S
dominantly sulphate	50% "	4S
Saline		H
slightly saline	1-5% soluble salts	1H
moderately saline	5-20% "	2H
strongly saline	20-50% "	3H
dominantly saline	>50% "	4H
Organic		P
slightly organic	1-5% organic matter	1P
moderately organic	5-20% "	2P
strongly organic	20-50% "	3P
dominantly organic	>50% "	4P

CONSOLIDATED

TYPE	COMPOSITION		SYMBOL
Ultrabasic	>90% ferromags		U
Basic	40-90% "	45-55% SiO_2	B
Intermediate	20-40% "	55-65% "	I
Acid	5-20% "	65-85% "	A
Extremely acid	<5% "	-	E
Carbonate			C
slightly carbonate	1-5% (Ca+Mg) CO_3		1C
moderately carbonate	5-20% "		2C
strongly carbonate	20-50% "		3C
dominantly carbonate	>50% "		4C

MINERAL SIZE	SYMBOL
Non-crystalline	N
Fine grained < 1 mm	F
Medium grained 1-5 mm	M
Coarse grained > 5mm	K

UNCONSOLIDATED

*PARTICLES < 2 mm

NAME	SYMBOL
Clay	c
Silty clay	zc
Silty clay loam	zcl
Silt	z
Silt loam	zl
Clay loam	cl

NAME	SYMBOL
Sandy clay	sc
Sandy clay loam	scl
Loam	l
Sandy loam	sl
Loamy sand	ls
Sand	s

PARTICLES > 2 mm

give modal size range and state frequency according to Appendix I

Fig. 10 Classification of parent materials

By combining symbols given in Fig. 10 and Table 1 any parent material can be given a compound symbol to indicate its mineralogy, particle size distribution, degree of stoniness and degree of weathering. The following examples illustrate how the system works.

AK: acid coarse grained crystalline rock such as granite

BK2w: chemically weathered coarse grained basic rock such as gabbro with core stones set in a disaggregated mass

AF3p: physically weathered fine grained acid rock such as slate, abundant angular rock fragments and poorly preserved rock structure

Es-S: extremely acid sand with stones

2Cz-: moderately calcareous silt

Ascl: acid sandy clay loam

Table 1 Classification of rock weathering

	DEGREE OF WEATHERING	ROCK	SEDIMENTS	SYMBOL
CHEMICALLY WEATHERED	Slightly chemically weathered	Alteration along fissures and cracks, little mineral alteration	The rock fragments are easily recognisable but show signs of mineral alteration. Some alteration of fine earth	1w
	Moderately chemically weathered	Core stones well developed and/or predominant disaggregation, clear evidence of mineral alteration	Disaggregation of most of the rock fragments. Clear evidnece of mineral alteration	2w
	Strongly chemically weathered	Original structure well preserved. Complete disaggregation, >20% of the minerals are weathered.		3w
	Very strongly chemically weathered	Original structure partly preserved, type of soil horizon Sapron		Sa
PHYSICALLY WEATHERED	Slightly physically weathered	Occasional fracture, rock structure well preserved	Occasional shattered rock fragments, adjacent particles can be fitted together	1p
	Moderately physically weathered	Frequent to abundant fractures, rock structure partially disrupted	Frequent shattered rock fragments, adjacent particles may fit together	2p
	Strongly physically weathered	Dominant angular rock fragments, rock structure poorly preserved	Many rock fragments shattered, adjacent particles may not fit together	3p
	Very strongly physically weathered	Type of soil horizon Lithon		Lh
			Nearly all original rock fragments shattered into two or more fragments	Lh

4.0 WHOLE SOIL DESIGNATION, NOMENCLATURE AND CLASSIFICATION

Soils are composed of horizons and as a whole form continua in space and time, which implies that any divisions or boundaries created within soils are similarly as arbitrary as the boundaries that separate segments. The divisions do not delimit discrete entities. THIS SITUATION DEFIES CLASSIFICATION. The best that is available for soil, is to give each soil a designation and to have one or two higher levels of grouping using subjective methods to suit individual users. This procedure recognises that it is impossible to create a fundamental system of soil classification and at the same time places great emphasis on the soil itself. The designation of the soil is achieved by using a formula which is produced by writing in order the horizons symbols as they occur in vertical sequence starting with the uppermost horizons and including the relatively unaltered underlying material which is shown by the last of set of symbols. The thickness of each horizon in centimetres is also indicated by means of a subscript number. Two examples are given below:

1	$Lt_2Fm_3Hf_2Mo_7Zo_5Sq_{40}As-$	Podzol
2	$Lt_1Mu_{20}At_{30}Bl-$	Altosol (Cambisol)

When the soil is of the type, that the relatively unaltered underlying material does not show in the pedo-unit, the parent material can be indicated by placing a point after the lowest horizon followed by the symbol for the underlying material e.g.

$Hy_{20}Gl_{25}Cu_{20+}.Icl$

The point after the cerulon, Cu, indicated that it continues below the depth of the exposed profile and may continue for several metres. The symbol Icl indicates that the unaltered underlying material is an intermediate clay loam.

The texture patterns in soils are known to be very varied. In a number of cases they are inherited from the stratification of the parent material while in others they are produced by pedogenic processes. Although the origin may be obvious in some case, there are numerous cases where it is not possible to be certain about the reason for the texture change between horizons. In order to be able to show the various patterns in the soil formula without invoking any process, it is suggested the > and < symbols should be placed between horizon symbols and used singly or in pairs as follows:

< the horizon above has slightly less clay or coarser texture than the horizon below

<< the horizon above has much less clay or much coarser texture than the horizon below

> the horizon above has slightly more clay or finer texture than the horizon below

>> the horizon above has much more clay or much finer texture than the horizon below

The use of these symbols is shown in the formula given below, and illustrates the situation in which the sesquon Sq has a finer texture than the ison In.

$Lt_2Fm_3Hf_2Mo_{10}Zo_{10}Sq_{25} > In_{20}.As-$

Each set of symbols in each formula characterises a group of soils, all of which have the same horizon sequence but there may be variations in the thickness of the horizons, particle size distribution and many other features. However, all the members of the group are sufficiently alike to be placed in the same category. Each distinctive member of each group is given a name, usually a local place name which is also given to the series (mapping unit) in which this group member is dominant. Most mapping units are defined as having a certain range of variability within each property. Sometimes the range may fall within the defined limits of the constituent segments but as often happens the range overlaps the arbitrary divisions separating the segments. Therefore, the mapping unit may span two pedo-unit classes in the same way that mapping units regularly span two arbitrary created particle size classes.

The groups are arranged in subclasses and classes, both of which, particularly the latter, are established on subjective basis to suit the operators requirements. The subclasses are established on the basis of two, three or four prominent horizons in the same pedo-unit. They are not given names but are desginated by writing the symbols of each horizon and placing them in square brackets. Four of the many subclasses of the Podzol class are:

[ZoSq] [ZoHd] [ZoHs] [ZoSqZoAr]

The classes are given names and are characterised by the presence of one prominent horizon in the pedo-unit or by a unique combination or relationship between constituent horizons. When a class is established on the basis of a single horizon it often derives its name from that horizon. The Argillosols are created because of a prominent and well developed argillon. On the other hand the Supragleysols are established because of the unique occurence of a markedly reduced horizon or horizons in the middle position of the soil, the upper and lower horizons normally being aerobic. Sometimes difficulties may be encountered in ascribing a group to a given class particularly if 2 prominent horizons are present. In such cases the group is placed in the class with which it seems to have the greatest affinities but realising that there is nothing fundamental about the grouping. The common classes and their equivalent in FAO-Unesco and USDA are given in Table 3.

This system allows the creation of various classes and hierarchies to suit various users as shown in Figs. 11 and 12. Fig. 11 shows a diagram of a Podzol profile and the information required about that soil by various disciplines. It is seen that seldom do two different disciplines require precisely the same information whether it be for fundamental or applied purposes.

Fig. 12 shows a number of formulae and how they would be grouped according to different disciplines. Perhaps, the most significant difference in grouping is for soils 5 and 6. For Pedology, Agriculture and Forestry soil 6

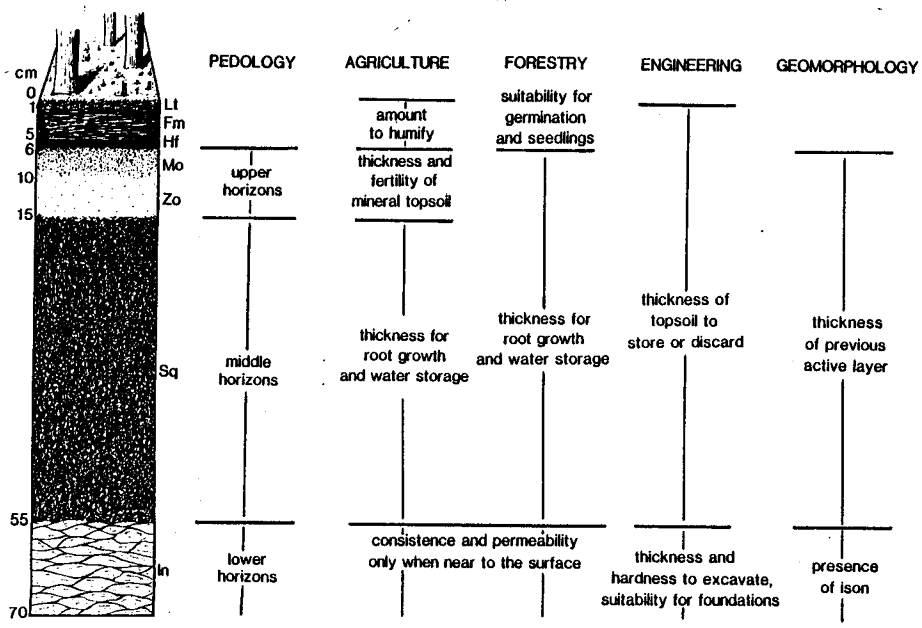


Fig. 11 Information required from a soil classification by different disciplines

SOIL FORMULAE / NUMBER OF CLASSES	PEDOLOGY	AGRICULTURE	FORESTRY	ENGINEERING	GEOMORPHOLOGY
	4	4	4	3	3
(1) Lt_1 Fm_2 Hf_1 Mo_4 Zo_5 Sq_{40} In_{50+} 01 02 03 Ah E Bs Cx	Similar upper, middle and lower horizons Zo Sq In (1)	Thin organic matter easy to humify, good thickness of top and subsoil, low fertility (1)	Thin organic matter, suitable for germination, good thickness of top and subsoil (1)	Normal thickness to the hard ison causing few excavation problems (1)	Normal thickness of previous active layer (1)
(2) $Lt_2Fm_{15}Hf_3$ Mo_3 Zo_4 Sq_{45} Ind_{55+}		Thick organic matter, difficult to humify, good thickness of top and subsoil, low fertility (2)	Thick organic matter, germination difficult, good thickness of top and subsoil (2)		
(3) Lt_2 Fm_{10} Hf_3 Mo_4 Zo_5 Sq_{10} Ind_{50+}		Thick organic matter, thin mineral soil, hard ison; not generally suitable for agriculture (3)	Thick organic matter, thin mineral soil, hard ison, tine ploughing required (3)	Thin organic matter plus top soil, very hard ison giving excavation problems (2)	Thin previous active layer over ison (2)
(4) Lt_1 Fm_2 Hf_1 Mo_4 Zo_5 Sq_{40} Asl_{50+}	Upper and middle horizons Zq Sq (2)	Thin organic matter easy to humify, good thickness of top and subsoil, low fertility (1)	Thin organic matter suitable for germination good thickness of top and subsoil (1)	Normal thickness of top soil, no ison but loose sand (3)	No ison present (3)
(5) Lt_1 Fm_2 Hf_1 Mo_{10} Sq_{40} In_{50+}	Middle and lower horizons Sq In (3)			Normal thickness to hard ison causing few excavation problems (1)	Normal thickness of previous active layer (1)
(6) Lt_1 Mu_{15} At_{30} In_{50+} Ah Bw Cx	Middle and lower horizons At In (4)	Very thin organic matter, very easy to humify, good thickness of top and subsoil, moderate fertility (4)	Ideal for germination and good thickness of top and subsoil, high fertility (4)		

Fig. 12 The classification of a number of soils by different disciplines

is in a separate class from all of the others because it is an Altosol (Cambisol) and the others are Podzols. For the purposes of Engineering and Geomorphology soil 6 is in the same class of soils 1, 2 and 5 because they all have normal thickness of previous active layers over isons which is more important in this case than the differences in their fertility.

From the above it is possible to give a set of principles upon which a classification might be based.

1) The soil horizon is the individual to be classified (the lowest common denominator).
2) There are no fixed vertical juxtarelationships between horizons in soil pedo-units i.e. non-homologous.
3) Horizons are more or less continuous in lateral geographical, character and temporal space.
4) There is no obvious single and fixed hierarchical or single level arrangement of horizon assemblages.
5) There are at least four different types of horizon, namely reference, intergrade, compound and composite, representing different combinations of two types of segment in chartacter space namely polar and continuum.

Perhaps, the word principle should be defined in the context of soil classification. A principle is a fundamental truth that applies to all the individuals of a specific feature, in the case of soil classification, a characteristic that is unique to soils. All soils have properties such as pH but these are not unique to soils and therefore are not fundamental truths. Horizons are the only fundamental feature that is common to all soils.

5.0 HORIZON KEY

Probably the ultimate in soil taxonomy and soil recognition is the production of a key that could be used in the field for the identification of soils. Two major attempts in this direction have been made, one by Northcote (1971) and the other Kubiëna (1953). Kubiëna produced four keys in all, three for soils and one for humus forms. Northcote's key is used extensively in Australia, but Kubiëna's keys have been little used.

The problem with most keys is that they cannot cope with the wide range of horizon assemblages. It would seem that for a key to succeed it must be constructed to operate at the horizon level as attempted by Kubiëna for humus forms, thus allowing each horizon to be identified separately. Furthermore, it is desirable to construct the key using coordinate principles in a similar manner to those used to draw the arbitrary lines and creating segments in the continuum.

A key is like a flora and produced to serve local needs. It would be ideal to have one for all soils, but this is probably beyond the capabilities of a single person, since a considerable amount of detailed local knowledge is required before a key can be constructed. An attempt is being made to produce a simple key but there are many difficulties. However, by using Tables 7 and 8, pages 93 and 98 respectively, it should be possible to reduce the number of possibilities for an unknown horizon to not more than 4 or 5 and then by consulting the definition of each of these to designate the unknown horizon.

The properties of the horizon to be used in the key are principally those that are recognised in the field but in same cases recourse will be made to laboratory data. The properties include texture, structure, consistence, water content and colour. Apart from colour the use of the properties follows very closely generally accepted principles. For colour, the V/C (Value/Chroma) rating introduced by Northcote (1971) will also be used.

6.0 CONCLUSIONS

This system posesses a high level of versatility, allowing classes to be created on the bases of any prominent horizon or upon any unique combination of horizons. Therefore, grouping can be produced to meet the demands and requirements of different disciplines as shown in Fig. 11. It also has advantages when trying to accommodate soils that have complex polygenesis or those that have been truncated by erosion. Furthermore, the horizon symbols can be used in the construction of maps and map legends(FitzPatrick, 1986). This makes it possible to put more information onto maps and to have a single set of symbols to cover most pedological work.

Thus, this is a completely integrated system for horizon names, horizon symbols, horizon juxtarelationships and soil map symbols. Therefore, it seems to meet all of the criteria required by McRae and Burnham (ibid).

The precision of this system is illustrated in Tables 4 and 5 where part of the range of variability in Orthic Podzols and Typic Fragiorthods are given. These tables show clearly that specific horizon symbols can give much fuller information about soils.

7.0 BRIEF DESCRIPTIONS OF ALL THE SEGMENTS

This part contains a brief description of each of the segments and their constituent horizons, so far recognised. The descriptions are followed by 7 tables.

Table 2 Diagnostic horizons and their approximate equivalent segments (page 83).

Table 3 FAO-Unesco class names and their approximate equivalents in FitzPatrick and Soil Taxonomy (pages 84 and 85).

Table 4 Part of the range of variability in Orthic Podzols (page 85).

Table 5 Part of the range of variability in Typic Fragiorthods (page 86).

Table 6 Soil segments and their equivalents in FAO-Unesco and Soil Taxonomy (pages 87 to 92).

Table 7 Segment grouping according to colour (pages 93 to 97).

Table 8 Segment grouping according to position (pages 98 and 99).

AGRON - Ao

General definition: middle, immediately beneath the plough layer, has more than 15% thick coatings of top-soil material as a result of cultivation

Synonyms: B1, Bt, agric horizon

Position: middle

Thickness: 10 to 100 cm

Colour: ranges from brown to reddish-brown to yellowish-brown with darker coloured coatings

Texture: medium to fine.

Stones: absent to occasional.

Structure: prismatic to angular blocky

Handling properties: plastic when wet, firm or hard when dry.

Bulk density: 1.3 - 1.5

Permeability: slow, except down cracks

Hydrology: varies from moist to dry with the season

pH: 5.5 - 7.0

CEC: 200 - 400 meq Kg^{-1}

BS: 60 - 100%

OM: 2 - 5%

C/N ratio: 8-15

$(Ca+Mg)\ CO_3$: variable

Weatherable minerals: variable

Clays: variable but mainly 2:1 types

Concretions: absent

Biological activity: weak

Micromorphology: see page

Genesis: during the dry season the subsoil cracks, when the top soil becomes wet it flows down the cracks. The formation of the coatings tends to be a fairly rapid process hence they do not have the same degree of particle orientation that is found, for example, in clay coatings.

Variability: in thickness, content of coatings and nature of the original material which may have been an argillon, pelon, rosson etc. Probably this segment should be regarded as a compound segment.

Associated horizons: below: various

Distribution: common in areas where agriculture has been practised for a long time.

Origin of term: L. Ager = field

ALKALON - Ak

General definition: upper, middle or lower horizons with high pH and high salinity
Synonyms: Az, Bz, Cz, Asa, Bsa, Csa
Position: upper, middle or lower, upper horizons are usually hard setting.
Thickness: 10-100 cm
Colour: yellowish-brown to brownish-grey
Texture: variable, similar clay content to the horizon above
Stones: absent to frequent
Structure: massive to very coarse prismatic to blocky
Handling properties: friable to firm to hard
Bulk density: 1.5 - 1.7
Permeability: moderate to low
Hydrology: usually dry, moist or wet during the rainy season
pH: > 8.5
CEC: 50-200 meq Kg^{-1}
BS: 100%
ESP: > 15%
OM: < 2%
C/N ratio: < 12
$(Ca+Mg)CO_3$: variable
Soluble salts: >30% CO_3^{--} + HCO_3^{-} in the saturation extract; EC > 4 mmhos
Weatherable minerals: variable
Clays: variable with a tendency to have much montmorillonite
Concretions: carbonate concretions may be present
Biological activity: weak to absent, may inherit features due to biological activity from a previous phase of soil formation
Micromorphology: similar to chloron
Genesis: accumulation of sodium and/or magnesium carbonate and bicarbonate
Variability: in the proportion of cations and anions
Associated horizons: below: a gleyson, cerulon, or relatively unaltered material
Distribution: in arid and semi-arid areas
Origin of term: A. Al-kali = calcined ashes

ALTON - At

General definition: middle or lower weakly weathered horizons with similar clay and sesquioxide contents to the horizons above
Synonyms: Bw, B1, B2, (B), cambic horizon
Position: middle or lower
Thickness: 15-50 cm
Colour: brown to yellowish-brown to brownish-red
Texture: loam to silt
Stones: absent to abundant
Structure: subangular blocky to vermiform to angular blocky
Handling properties: friable to firm to loose when clay is low
Bulk density: 1.1-1.6
Permeability: moderate to rapid
Hydrology: usually moist, rarely wet or dry
pH: 5.0 - 7.0
CEC: 100-200 meq Kg^{-1}
BS: 25-100%
OM: < 3%
C/N ratio: 8-12

(Ca+Mg)CO_3: absent to abundant from the parent material
Soluble Salts: absent
Weatherable minerals: 10-90
Clays: kaolinite, mica, vermiculite and allophane
Concretions: absent
Biological activity: weak to moderate
Micromorphology: see page 102
Genesis: weathering and in situ deposition of oxides of iron and aluminium with little addition from outside
Variability: in texture and colour
Associated horizons: above: a mullon or tannon; below: a fragon, ison, or relatively unaltered material
Distribution: humid temperate areas from base rich parent materials
Origin of term: L. Alter = other

ALUMINON - Al
General definition: weakly coloured high chroma, middle or lower, with a characterisic fine granular structure
Synonyms: (B), B1, B2, B3, Bw, Ale, cambic horizon
Position: middle or lower
Thickness: < 10 cm to > 50 cm
Colour: usually 7.5YR, 10YR, 5/6 or 6/6
Texture: sandy loam to silt loam
Stones: variable
Structure: very distinctive fine granular structure
Handling properties: very soft and friable
Bulk density: 1.2-1.7
Permeability: moderate to rapid
Hydrology: usually moist
pH: 4.5-5.0
CEC: 100-300 meq Kg^{-1}. Ex Al: 15-60 meq Kg^{-1}
BS: 5-20%
OM: < 3%
C/N ratio: 8-20
(Ca+Mg)CO_3: absent
Soluble salts: absent
Weatherable minerals: 0-100% of the sand fraction
Clays: kaolinite, aluminous vermiculite, vermiculite, smectite, hydrous mica and quartz
Concretions: intergrading situations to marblons have a few small black segregations and concretions
Biological activity: the fine granular structure suggests a high level of enchytraeid worm activity
Micromorphology: see page
Genesis: the granular structure is formed by either flocculation or enchytraeid worms
Variability: a small variability in texture and much larger variability in stone content
Associated horizons: above: a modon, zolon or sesquon; below: an ison, gleyson, (InAr) or relatively unaltered material
Distribution: in cool temperate areas
Origin of term: E. Aluminium

AMORPHON - Ap
General definition: dark brown or black well decomposed organic matter occurring under anaerobic conditions
Synonyms: H; amorphous peat, histic epipedon
Position: upper, middle or lower
Thickness: 5-30 cm
Colour: very dark brown to black
Texture: not applicable

Stones: absent
Structure: massive or laminated
Handling properties: moderately sticky, moderately plastic when wet, becomes hard when dry. VP 7-10
Bulk density: wet: <1.0; dry: <0.6
Permeability: very slow
Hydrology: permanently saturated with water
pH: usually 3.0-5.0 may be higher when the water comes from a base rich area
CEC: >1000 meq Kg^{-1}
BS: <30, greater when pH is high
OM: >60%; strongly decomposed
C/N ratio: 20-35
$(Ca+Mg)CO_3$: absent
Soluble salts: absent
Weatherable minerals: usually absent
Clays: not applicable
Concretions: absent
Biological activity: very low
Micromorphology: brown, isotropic, massive; contains < 30% easily recognisable plant residues; dead fungal mycelium and phytoliths may be present
Genesis: accumulation and slow decomposition of organic matter under anaerobic conditions
Variability: varies in thickness and extent of plant structure retention
Associated horizons: above: a fibron or pseudofibron; below: wet mineral material
Distribution: occurs in all humid areas particularly the cooler types
Origin of term: Gk. Amorphos = shapeless

ANDON - An

General definition: middle, friable to fluffy with granular to blocky structure, weakly weathered and isotropic
Synonyms: B2, Bw, (B), cambic horizon
Position: middle
Thickness: 10-50 cm
Colour: brown to yellowish-brown to reddish-brown
Texture: loam to silty loam to silt
Stones: usually rare to absent
Structure: granular to blocky to massive
Handling properties: friable or fluffy usually thixotropic, distinctive buttery feel when moist
Bulk density: <1.0
Permeability: freely permeable
Hydrology: usually moist, rarely wet or dry
pH: 5.0-7.0
CEC: 150-800 meq Kg^{-1} but varies widely with the technique used because of the high content of allophane
BS: 10-50%
OM: 3-8%
C/N ratio: 8-12
$(Ca+Mg)CO_3$: absent
Soluble salts: absent
Weatherable minerals: 50-90%
Clays: allophane and imogolite dominant with lesser amounts of iron oxide, halloysite and manganese dioxide
Concretions: generally absent
Biological activity: weak
Micromorphology: massive, alveolar or granular with pale yellowish-brown isotropic matrix. Differs from alton by having no anisotropism and a high content of isotropic sand and silt size grains of volcanic ash. Imogolite is often clearly seen with the SEM.

Genesis: weathering and in situ formation of ferric hydroxide, allophane and imogolite
Variability: andon intergrades to alton, sesquon, krasnon and zhelton
Associated horizons: above: a kuron; below: a fragon, duron or relatively unaltered material
Distribution: in most humid volcanic areas
Origin of term: J. An = soil and do = dark

ANMOORON - Am
General definition: dark to very dark mixture of organic and mineral material, massive, blocky or granular with faint to strong mottling especially along root passages
Synonyms: Ah, Al, umbric epipedon, anmoor
Position: upper
Thickness: 10-20
Colour: black to very grey to very dark brown with faint to strong mottling especially along root passages
Texture: loam, silt
Stones: rare to absent
Structure: massive to blocky, some show evidence of earthworm activity
Handling properties: firm to friable to plastic
Bulk density: 1.0-1.5
Permeability: freely permeable
Hydrology: wet for long periods of the year
pH: 4.5-7.5
CEC: 200-400 meq Kg^{-1}
BS: 30-100%
OM: 10-30%
C/N ratio: 12-20
$(Ca+Mg)CO_3$: 0-50 from parent material
Soluble salts: absent
Weatherable minerals: 0-50%
Clays: variable
Concretions: absent
Biological activity: moderate, decomposing and mixing the mineral and organic materials
Micromorphology: greyish-brown, isotropic, alveolar, granular or vermicular with much faecal material and plant fragments
Genesis: incorporating and decomposing of organic matter in a wet but not permanently saturated environment
Variability: in thickness, pH and organic matter content
Associated horizons: above: a humifon, litter; below: a gleyson or cerulon
Distribution: predominantly in cool humid areas
Origin of term: Kubiëna 1953

ARENON - Ae
General definition: upper, middle or lower with dominant quartzose coarse sand and high chroma colours
Synomyms: B2, Bw
Position: middle or lower
Thickness: 25-200 cm
Colour: yellowish-brown to yellowish-red to brown
Texture: loamy sand, sand, < 10% silt + clay
Stones: rare to absent
Structure: single grain to massive
Handling properties: loose to hard
Bulk density: 1.2-1.6

Permeability: rapid
Hydrology: usually dry maybe wet during the rainy season
pH: 4.0-7.0
CEC: <50 meq Kg^{-1}
BS: >80%
OM: <2%
C/N ratio: 8-15
$(Ca+Mg)CO_3$: absent
Soluble salts: low to absent
Weatherable minerals: <5%
Clays: kaolinite, gibbsite, hydrous mica
Concretions: absent to common
Biological activity: weak to absent
Micromorphology: see page
Genesis: preferential removal of fine material. Some may form directly from coarse textured materials
Variability: in colour, handling properties and frequency of concretions
Associated horizons: above: a tannon below: relatively unaltered material, weathered rocks or old soil horizon
Distribution: wet and dry tropics and semi arid areas
Origin of term: L. Arena = sand

ARGILLON - Ar

General definition: middle or lower containing more than 7% clay coatings, many argillons contain more clay than the horizon above
Synonyms: Bt, B2t, textural B, argillic horizon
Position: middle or lower
Thickness: 1 cm to >1 m
Colour: brown to reddish-brown to red
Texture: loam to clay
Stones: absent to frequent
Structure: blocky to massive to subcuboidal
Handling properties: friable to firm to hard
Bulk density: 1.5-1.8
Permeability: free to slow
Hydrology: usually moist, rarely wet or dry
pH: 5-7
CEC: 100-300 meq Kg^{-1}
BS: 10-80%
OM: <3% usually <1%
C/N ratio: 6-10
$(Ca+Mg)CO_3$: absent
Soluble salts: low to absent
Weatherable minerals: absent to dominant in the sand fraction
Clays: kaolinite, hydrous mica and vermiculite are dominant with subsidary montmorillonite
Concretions: absent
Biological activity: weak to absent
Micromorphology: see page
Genesis: translocation of clay to form clay coatings
Variability: in colour and texture
Associated horizons: above: a modon, mullon, luvon or alton; below: a fragon, ison, calcon or relatively unaltered material
Distribution: in moist continental areas
Origin of term: L. Argilla = clay

Soluble salts: low to absent
Weatherable minerals: variable
Clays: variable usually 2:1 minerals with palygorskite
Concretions: see $(Ca+Mg)CO_3$ above
Biological activity: absent to very rare
Micromorphology: the type of calcium carbonate accumulation varies from soil to soil. In soils such as Chernozems, the initial accumulation of calcium carbonate is in the form of pseudomycelium. These are very clearly seen in the field and in thin section where they occur as a large number of intertwining acicular crystals of calcite. Where there is a greater accumulation, rhombohedral calcite crystals tend to grow. These may occur singly or in clusters in pores or they may form concretions of various sizes. Where the soil contains rock fragments, calcite crystals will either form a pendant beneath the rock fragment or may form a complete coating. These rhombohedral crystals vary in size for reasons that are not fully understood, but might be due to such factors as concentration of calcium bicarbonate in solution and the speed of crystallisation. Within any one pendant the size of crystals varies from layer to layer suggesting that the speed of crystallisation varied from time to time, possibly from season to season or from year to year. Although the growing calcite crystals may derive their calcium carbonate from the soil solution it seems that there are cases where the calcite in pores grows at the expense of calcite in the surrounding soil. This results in the formation of large rhombohedral crystals within a pore surrounded by a decalcified zone within the soil. This seems to represent the well-known chemical situation in which large crystals will grow at the expense of smaller ones in the same immediate environment. As calcite crystals grow they progressively force away the previously existing soil: this can continue to the point that small islands of the original soil become completely surrounded by secondary calcite. In some cases calcite concretions become coated with manganese dioxide as in some Vertisols so that they look like small black pellets in the field. The manganese dioxide may even penetrate into the concretion along crystal faces to produce the very typical and distinctive dendritic forms. The presence of calcite seems in many cases to inhibit the formation of anisotropism in a clayey matrix so that thin sections containing much finely divided calcite do not show the development of domains or other anisotropic forms but there is the distinct anisotropism of the calcite itself. Where there are decalcified aureoles around pores containing calcite these decalcified areas often develop anisotropism of the matrix.
Genesis: accumulation of calcium carbonate and growth of calcite crystals
Variability: varies in the type of crystals and hardness
Associated horizons: above: a chernon, kastanon, buron, seron, argillon or verton; below: a gypson, halon or relatively unaltered material
Distribution: in all arid and semi-arid areas
Origin of term: L. Calx = lime

CANDON - Co

General definition: pale coloured, upper or middle, usually saturated with water. Candons contain similar or more clay than the horizon above
Synonyms: Eg, A_2g, albic horizons
Position: upper or middle
Thickness: 10 to > 50 cm
Colour: pale brown to olive, often with ochreous mottling, VC 2 and 4 hues of 2.5 Y, 5Y and 10 YR
Texture: loam, sandy loam, loamy sand; similar amount or more clay than the horizon above
Stones: absent to dominant
Structure: massive
Handling properties: firm or friable
Bulk density: 1.4-1.7
Permeability: variable, may be freely permeable and underlain by a slowly permeable horizon or may be slowly permeable
Hydrology: usually saturated due to impermeable or slowly permeable underlying horizon
pH: 3.5-5.5
CEC: 50-200 meq Kg^{-1}
BS: 10-40%
OM: < 10%
C/N ratio: 8-15
$(Ca+Mg)CO_3$: absent
Soluble salts: absent
Weatherable minerals: few to dominant
Clays: hydrous mica, vermiculite, montmorillonite and kaolinite
Concretions: small black concretions absent to occasional
Biological activity: very low to absent; occasional dead root (cf. Nekrons)
Micromorphology: massive or alveolar with pale olive grey or grey anisotropic clayey matrices surrounding abundant sand grains. Some pores have yellowish-brown iron impregnations while others may have pale coloured clay coatings. Minerals such as feldspars are weathering rapidly so that these horizons have similar or more clay than the horizons below.
Genesis: weathering near to surface under anaerobic conditions, may form an evolutionary phase after the development of an underlying impermeable horizon such as placon
Variability: mainly in texture
Associated horizons: above: a modon or nekron; below: a placon, pelon or ison
Distribution: common in cool humid temperate areas and in very humid tropics
Origin of term: L. Candela = candle

CERULON - Cu

General definition: olive, grey or blue, completely anaerobic
Synonyms: Br, Cr, cambic horizon
Position: middle or lower
Thickness: 20-200 cm
Colour: olive to grey to blue, hues of Y, GY, G N, BG or B
Texture: variable
Stones: absent to dominant, more weathered than stones in drier adjacent sites
Structure: massive, may be prismatic if dried

Handling properties: varies with texture, friable to plastic
Bulk density: 1.5-1.8
Permeability: variable but may be freely permeable in spite of being permanently saturated with water
Hydrology: permanently saturated with water which is not stagnant but constantly moving through the soil
pH: variable usually >5.0
CEC: varies with texture
BS: >40%
OM: <1%
C/N ratio: 8-15
$(Ca+Mg)CO_3$: variable from parent material
Soluble salts: low to absent
Weatherable minerals: variable - the intensity of the blue colouration increases with an increase in ferromagnesian minerals
Clays: mainly hydrous mica and smectite
Concretions: none
Biological activity: a few anaerobic bacteria that may reduce iron
Micromorphology: usually massive or very weakly alveolar with pale coloured anisotropic matrices containing numerous randomly oriented domains or there may be zones of domains and anisotropic aureoles around sand grains and pores. The degree of anisotropism increases with an increase in the clay content.
Genesis: weathering under complete anaerobism and reduction of iron to the ferrous state
Variability: mainly in texture
Associated horizons: above: a gleyson; below: relatively unaltered material
Distribution: in most humid climates particularly in the cooler areas
Origin of term: L. Caeruleus = blue

CHERNON - Ch

General definition: upper, very thick, very dark brown to black with very vigorous biological activity and well developed granular and/or vermicular structure
Synonyms: Ah, A1, mollic epipedon
Position: upper, extending into middle
Thickness: 50-150 cm
Colour: black to very dark grey to dark greyish-brown
Texture: silt loam to silt
Stones: usually absent
Structure: crumb to granular to subangular blocky to vermicular
Handling properties: firm to friable
Bulk density: 1.4-1.6
Permeability: freely permeable
Hydrology: usually dry to moist, wet during early spring
pH: 6.5-8.0
CEC: 150-400 meq kg^{-1}
BS: 50-100%
OM: 3-15% >20 kg per m^2
C/N ratio: 8-15
$(Ca+Mg)CO_3$: 0-60% from parent material, pseudomycelium and concretions in the lower part
Soluble salts: low to absent
Weatherable minerals: 30-70%
Clays: predominantly montmorillonite, vermiculite and mica
Concretions: see $(Ca+Mg)CO_3$ above

Biological activity: very vigorous earthworm and/or enchytraeid worm vermiforms, abundant pore space which decreases rapidly when cultivated
Micromorphology: vermicular, granular and subangular blocky, with dark brown isotropic matrix, the peds are mainly entire or fragments of faecal material. Abundant pore space including earthworm passages
Genesis: rapid breakdown and incorporation of organic matter in a cool dry environment; constant churning by soil fauna
Variability: in thickness, colour and organic matter content. Intergrades to mullons and kastanons
Associated horizons: above: a root mat in uncultivated soils; below: a calcon, gleyson, alton, argillon or halon
Other distinguishing features: the abundance of krotovinas particularly in Europe
Distribution: in the cool semi-arid areas of the world
Origin of term: R. cherni = black and zem = soil

CHLORON - Cl
General definition: upper or middle containing an accumulation of chloride ions
Synonyms: Az, Bz, Cz, salic horizon
Position: upper or middle
Thickness: 10-100 cm
Colour: yellowish-brown to brownish-grey to grey
Texture: variable
Stones: absent to frequent
Structure: blocky to prismatic to massive
Handling properties: firm or friable
Bulk density: 1.5-1.7
Permeability: moderate to low
Hydrology: usually dry, moist or wet during the rainy season
pH: 7.5-8.5
CEC: variable
BS: 100%
OM: <5%
C/N ratio: <12
$(Ca+Mg)CO_3$: 0-50% from the parent material
Soluble salts: >70% Cl^- in the saturation extract, EC > 4 mmhos
Weatherable minerals: variable
Clays: variable
Concretions: absent
Biological activity: very weak
Micromorphology: may be massive, alveolar or blocky with a range of secondary crystalline material including calcite, gypsum and halite. The crystals may occur within peds, between peds, singly or in clusters. Although significant amounts of halite may be present in chlorons its identification might be very difficult because its refractive index is very close if not identical to impregnating resins
Genesis: accumulation of soluble salts, especially chlorides in an arid or semi-arid environment
Variability: in the proportion of cations and anions
Associated horizons: an alkalon, halon or sulphon
Distribution: in arid and semi-arid areas
Origin of term: Gk. khloros = green

CRYON - Cy

General definition: permanently frozen subsoil usually with horizontally bifurcating ice veins enclosing soil lenses
Synonyms: permafrost, Cf
Position: middle or lower
Thickness: 100 cm
Colour: grey to olive grey
Texture: variable
Stones: variable
Structure: lenticular or subcuboidal or massive pore space filled with ice
Handling properties: hard to very hard
Bulk density: probably in the range 1.5 to 1.8
Permeability: impermeable
Hydrology: >50% ice
pH: not applicable
CEC: not applicable
BS: not applicable
OM: usually <1% maybe >30%
C/N ratio: >12
$(Ca+Mg)CO_3$: absent to dominant
Soluble salts: low to absent
Weatherable minerals: 5-100%
Clays: variable
Concretions: absent
Biological activity: none
Micromorphology: see page 111
Genesis: gradual freezing of a wet mass of soil
Variability: mainly in structure and content of ice
Associated horizons: above: a gelon, gleyson, (GlFm) alton or lithon; below: relatively unaltered material
Distribution: arctic and antartic
Origin of term: Gk. kurus = frost

CUMULON - Cm

General definition: upper or middle horizons that have a higher content of quartz gravel and concretions than the horizon below and formed by surface wash
Synonyms: Bc, Cc, gravel layer
Position: upper or middle
Thickness: 10-50 cm
Colour: red to reddish-brown to yellowish-brown to dark brown
Texture: loam
Stones: > 30% gravel and stones
Structure: crumb to granular to massive
Handling properties: loose to firm
Bulk density: normal for middle horizons
Permeability: moderate to rapid
Hydrology: usually moist or dry
pH: 4.5-6.0
CEC: 5-20 meq Kg^{-1}
BS: 10-80%
OM: < 3%
C/N ratio: 8-12
$(Ca+Mg)CO_3$: absent
Soluble salts: absent
Weatherable minerals: 0-10%
Clays: dominantly kaolinite
Concretions: absent to dominant
Biological activity: termite and earthworms usually frequent
Micromorphology: see page 117

Genesis: concentrations of quartz gravel and concretions by differential erosion, mass movement and termite activity
Variability: in the amount and type of coarse material
Associated horizons: above: a mullon or tannon; below: a krasnon, zhelton or chemically weathered rock
Distribution: mainly in tropical and subtropical areas
Origin of term: L. Cumulus = heap

DERMON - De

General definition: upper, dark brown to black, containing mainly montmorillonite clay and having a marked platy structure
Synomyms: Al, Ah, self-capping surface
Position: at the surface
Thickness: 2-15 cm
Colour: black to very dark grey to dark brown
Texture: clay loam to clay
Stones: usually absent
Structure: massive to coarse platy
Handling properties: hard when dry, plastic when wet
Bulk density: 1.4 to 1.8
Permeability: slowly permeable
Hydrology: usually moist or dry except during the rainy season
pH: 5.5 - 7.0
CEC: 400-700 meq kg^{-1}
BS: 60-100%
OM: <2%
C/N ratio: 8-12
$(Ca+Mg)CO_3$: 0-50% mainly from parent material, concretions sometimes present
Soluble salts: low to absent
Weatherable minerals: 20-40%
Clays: dominantly montmorillonite with lesser amounts of mica and kaolinite
Concretions: may contain numerous small concretions of calcium carbonate stained black with manganese dioxide
Biological activity: weak
Micromorphology: massive, alveolar or coarse platy surface horizons of some Vertisols. Yellowish-brown or greyish-brown isotropic or very faintly anisotropic clayey matrices. Rounded calcite concretions are often present sometimes stained black with manganese dioxide
Genesis: puddling of the surface, sometimes by raindrop impact
Variability: in thickness and degree of development, intergrades to granulon and verton
Associated horizons: below: verton
Distribution: predominantly in tropical semi-arid areas
Origin of term: Gk. derma = skin

DURON - Du

General definiton: middle or lower, strongly cemented by silica
Synonyms: Cmq, Csi, duripan
Position: middle or lower
Thickness: 10-50 cm
Colour: brown to reddish-brown
Texture: variable
Stones: variable
Stucture: massive
Handling properties: hard and cemented

Bulk density: 1.7 - 2.0
Permeability: very slowly permeable
Hydrology: usually moist or dry
pH: 7.5 - 8.5
CEC: not applicable
BS: not applicable
OM: <2%
C/N ratio: 8-12
$(Ca+Mg)CO_3$: absent
Soluble salts: low to absent
Weatherable minerals: variable
Clays: variable
Concretions: variable and inherited
Biological activity: very weak to absent
Micromorphology: in thin sections the silica normally occurs as opal which is clearly seen because it is isotropic and has a much lower refractive index than the impregnating resin. Thus, the areas of opal have a much higher negative relief and are clearly seen by their thin black outlines even though the opal itself is almost completely transparent. Some areas have a characteristic stippled appearance due to the way in which they have grown. The amount varies from thin coatings binding particles together to quite large segregations which may be over 1 cm in thickness. Since durons are in many cases silicified old soils, many other features not associated with the process of silification might be present. These features include clay coatings, secondary calcite, and there are cases in which faecal material of earthworms has become silicified. In addition, alluvium which may become silicified may itself contain soil erratics. These fragments include such features as clay coatings and granules of kaolinite from pallons. In a few isolated cases it appears that a duron will also contain a small amount of fairly well crystalline chalcedony.
Genesis: cementation through the deposition of opal
Variability: in colour, thickness and amount of opal
Associated horizons: above: a rosson or flavon; below: a pallon or relatively unaltered material
Distribution: in the semi-arid areas of old landscapes
Origin of term: L. durus = hard

FERMENTON - Fm
General definition: upper, partially decomposed organic matter that formed under aerobic conditions
Synonyms: 0
Position: upper
Thickness: 1-20 cm
Colour: very dark brown to black
Texture: not applicable
Stones: absent
Structure: laminated with easily recognisable plant fragments
Handling properties: fibrous
Bulk density: < 0.5
Permeability: very permeable
Hydrology: usually moist or dry
pH: 3.5-5.0
CEC: 800-1200 meq kg^{-1}
BS: 20-40%
OM: > 75%
C/N ratio: 25-30
$(Ca+Mg)CO_3$: absent
Soluble salts: absent

Weatherable minerals: <5%
Clays: not applicable
Concretions: none
Biological activity: very active microflora and microfauna, particularly fungi and mites
Micromorphology: numerous fragments of plant tissues including leaves, twigs, needles and bark; crudely laminated with abundant pore space. Frequent fungal mycelium decomposing the plant material and forming mycorrhizal sheaths around roots. Frequent faecal pellets in the pore space as well as in the plant fragments. Numerous sections of fresh plant roots. The most common fungus in the fermentons in cool temperate areas is Cencoccum graniforme which has distinctive thick dark brown mycelium as individual strands and root sheaths. This fungus is more resistant to decomposition than the root tissue and often remains as a hollow sheath after the root has been decomposed.
Genesis: accumulation and decomposition of organic matter under aerobic conditions
Variability: in thickness
Associated horizons: above: litter; below: a humifon, modon or zolon
Distribution: in many soils developed in humid areas particularly in cool climates
Origin of term: L. Fevere = to boil

FERRON - Fr
General definition: friable, yellowish or brownish, middle horizons containing significantly more sesquioxides than the upper horizon
Synomyms: Bs, B2, spodic horizon
Position: middle or lower
Thickness: 20-60 cm
Colour: brown to yellowish-brown, high chroma
Texture: loamy sand to loam
Stones: absent to dominant
Structure: single grain to fine granular
Handling properties: loose to firm
Bulk density: 1.0 to 1.5
Permeability: freely permeable
Hydrology: usually moist
pH: 4.5-5.5
CEC: 100-200 meq Kg^{-1}
BS: 10-20%
OM: <3%
C/N ratio: 12-20
$(Ca+Mg)CO_3$: absent
Soluble salts: absent
Weatherable minerals: 5-60%
Clays: allophane, hydrous mica, vermiculite
Concretions: absent
Biological activity: weak
Micromorphology: small granular, singly or in clusters, brownish-yellow coatings on sand grains and rock fragments
Genesis: accumulation of oxides and oxyhydroxides of iron and aluminium translocated from the horizon above and released by in situ weathering
Variability: in texture, structure and stone content
Associated horizons: above: a modon, zolon or sesquon; below: an ison, fragon or relatively unaltered material
Distribution: in cool humid continental areas
Origin of term: L. Ferrum = iron

FIBRON - Fi

General definition: upper or middle, fibrous, partially decomposed organic matter, permanently saturated with water
Synonyms: H, 01, histic epipedon
Position: upper or middle
Thickness: 50-300 cm
Colour: very dark brown to black
Texture: not applicable
Stones: not applicable
Structure: spongy to massive
Handling properties: fibrous when wet, hard when dry. VP 1-4
Bulk density: <1.0 when wet; <0.5 when dry
Permeability: very slow
Hydrology: permanently saturated except when drained
pH: 3.5-4.0, higher when base rich water is present
CEC: 800-1000 meq Kg^{-1}
BS: 10-30% higher when base rich water is present
OM: >75%
C/N ratio: 25-40
$(Ca+Mg)CO_3$: absent
Soluble salts: absent
Weatherable minerals: <5%
Clays: not applicable
Concretions: none
Biological activity: few anaerobic bacteria
Micromorphology: dark, massive and containing > 60% easily recognisable plant residues showing good sections through the various plant parts, strongly laminated and usually occurs near the top of a peat deposit
Genesis: accumulation and slow decomposition of organic matter under anaerobic conditions
Variability: in depth and degree of fibrousness
Associated horizons: above: litter; below: a pseudofibron or cerulon
Distribution: predominantly in cool humid and sub-arctic areas
Origin of term: L. Fibra = fibre

FLAMBON - Fb

General definition: middle or lower, mottled red and cream, strongly weathered with partly preserved rock structure, occurs mainly in the tropics
Synonyms: C, saprolite, mottled clay, cornbeef layer
Position: middle or lower
Thickness: 100-500 cm
Colour: mottled red to reddish-brown and cream
Texture: sandy clay loam to clay
Stones: absent to rare
Structure: massive, partially preserved rock structure sometimes hardens irreversibly on exposure to the atmosphere then Fbd
Handling properties: firm to plastic
Bulk density: 1.4-1.6
Permeability: slow
Hydrology: usually moist
pH: 5.0-7.0
CEC: < 150 meq Kg^{-1}
BS: 10 to 100%
OM: < 1%
C/N ratio: 6-10
$(Ca+Mg)CO_3$: absent
Soluble salts: absent
Weatherable minerals: <10%

Clays: predominantly kaolinite with lesser amounts of hydrous mica, goethite and gibbsite
Concretions: rare to occasional
Biological activity: weak
Micromorphology: generally massive with well-preserved rock structure and many weathered grains. Clay coatings are usually present and concretions range from rare to frequent. Often secondary crystalline kaolinite and sometimes gibbsite
Genesis: hydrolysis and clay mineral formation in a humid tropical climate
Variability: in frequency of coatings and amount of secondary materials
Associated horizons: above: a krasnon, rosson, pesson, veson or cumulon; below: less weathered rock
Distribution: in humid tropical countries
Origin of term: F. Flambe = flame

FLAVON - Fv
General definition: middle or lower, yellowish-brown moderate to strongly weathered occurs mainly in the tropics and subtropics
Synonyms: Bw, B2, cambic horizon
Position: middle or lower
Thickness: 50-200 cm
Colour: yellowish-brown to brown to yellowish-red to reddish-brown, 5YR-10YR
Texture: clay loam to clay, >30% silt plus clay
Stones: absent to rare
Structure: subangular blocky usually with smooth shiny ped surfaces
Handling properties: firm to friable
Bulk density: 1.4-1.6
Permeability: moderate
Hydrology: usually moist
pH: 4.5-5.5
CEC: >300 meq Kg^{-1} clay
BS: <20%
OM: <5%
C/N ratio: 8-12
$(Ca+Mg)CO_3$: absent
Soluble salts: absent
Weatherable minerals: <5%
Clays: predominantly kaolinite with lesser amounts of hydrous mica, vermiculite, goethite and gibbsite
Concretions: absent to occasional
Biological activity: variable, sometimes weak, sometimes with vigorous termite activity
Micromorphology: they range in structure from granular through subangular blocky to weakly developed wedge. This range is due to variation in the clay content of the horizons. Sometimes there are passages created by worms or termites with varying amounts of faecal material or termite granules in the passage. They have distinctive yellowish-brown matrices which in the granular soils are very weakly anisotropic to isotropic but become progressively more anisotropic as the structure changes to angular blocky and finally to wedge. With a high degree of anisotropism there are abundant randomly orientated domains, zones of domains and aureoles around sand grains and pores. The sand fraction is dominantly quartz and other resistant residual minerals.
Genesis: progressive hydrolysis through a long period of time

Variability: in structure and thickness
Associated horizons: above: a tannon or mullon; below: chemically weathered rock
Distribution: in humid tropical and sub-tropical areas
Origin of term: L. Flavus = yellow

FRAGON - Fg

General definition: middle or lower, weakly cemented with high bulk density; may have polygonal cracks
Synonyms: Cx, fragipan
Position: middle or lower with sharp to abrupt boundary
Thickness: 10-100 cm
Colour: yellowish-brown to olive, similar to the parent material
Texture: loam to loamy sand to sandy loam to sand
Stones: absent to abundant
Structure: massive to lenticular
Handling properties: firm to hard in the pedo-unit, explosive rupture when fragments are pressed between thumb and forefinger, weakly cemented
Bulk density: 1.7-2.0
Permeability: slow to very slow
Hydrology: usually moist but may be saturated for short periods of the year
pH: 5.5-7.0
CEC: 30-150 meq Kg^{-1}
BS: 30-100
OM: <2%
C/N ratio: 8-12
$(Ca+Mg)CO_3$: absent
Soluble salts: absent
Weatherable minerals: few to dominant
Clays: kaolinite with some mica and vermiculite
Concretions: none
Biological activity: very low to absent
Micromorphology: massive, prismatic, lenticular or weakly alveolar, dominantly angular silt and/or sand with indistinct isotropic matrices. Mineral grains are fresh or relatively fresh with little evidence of weathering. Clay coatings are rare to occasional in pores and form bridges between grains. The horizons are usually 15 to 50 cm thick
Genesis: accumulation of translocated aluminium and silica causing weak to moderate cementation
Variability: in thickness and degree of cementation
Associated horizons: above: a sesquon, husesquon, hudepon or argillon; below: relatively unaltered material
Distribution: in most cool and warm humid areas
Origin of term: L. Fragilis = fragile

GELON - Gn

General definition: upper organic mineral mixture with marked lenticular structure
Synonyms: A1, Ah, ochric and umbric epipedon
Position: upper
Thickness: 10-100 cm
Colour: brown to greyish-brown to yellowish-brown
Texture: loam, silt
Stones: variable, usually angular due to frost shattering
Structure: lenticular
Handling properties: loose to friable
Bulk density: 1.5-1.8

Permeability: freely permeable
Hydrology: moist during summer, wet during spring and autumn, frozen during winter
pH: 4.5-7.5
CEC: variable
BS: variable
OM: <10% mainly as recognisable plant fragments
C/N ratio: 12-25
$(Ca+Mg)CO_3$: variable
Soluble salts: absent
Weatherable minerals: variable
Clays: variable
Concretions: none
Biological activity: vigorous during summer otherwise weak to absent
Micromorphology: distinctive laminar or lenticular structure, the peds are usually non-porous with smooth upper surfaces that have a higher silt and clay content than the remainder of the ped. The lower boundaries of the peds are usually quite irregular, and the clay or clay/humus matrix within the peds is usually isotropic. There are usually rare roots and rare fragments of organic matter. There may be occasional to frequent ovoid faecal pellets which seem to be those of beetle larvae.
Genesis: the gelon is formed by freezing every winter and thawing every summer. The freezing causes the formation of ice veins and the differentiation of laminar and lenticular peds. When thawing takes place during the summer period, silt suspended in the soil water becomes deposited on the upper surfaces of the peds.
Variability: in thickness and degree of formation of other horizon properties thus forming many compound horizons, for example, {ZoGn} and {SqGn}
Associated horizons: above: litter; below: relatively unaltered material except in the case of compound horizons
Distribution: common in polar and high mountainous areas
Origin of term: L. Gelare = to freeze

GLEYSON - Gl
General definition: middle or lower strongly mottled and formed under wet conditions
Synonyms: Bg, Cg, cambic horizon having hydromorphic properties
Position: middle or lower
Thickness: 20-200 cm
Colour: grey to olive with yellow or brown mottling, > 5% prominent mottles
Texture: variable
Stones: variable
Structure: massive to prismatic
Handling properties: soft to firm to plastic
Bulk density: 1.5-1.7
Permeability: variable
Hydrology: saturated with water for long periods, thus causing reduction of the iron
pH: 4.5-7.0
CEC: 100-400 meq Kg^{-1}
BS: 20-100%
OM: <4%
C/N ratio: 8-15
$(Ca+Mg)CO_3$: 0-50% from parent material

Soluble salts: low to absent
Weatherable minerals: variable
Clays: mica, vermiculite, smectite
Concretions: none to frequent
Biological activity: very low
Micromorphology: olive, grey or blue colours, with conspicuous yellow or brown mottles; formed in the zone of fluctuating water-table. Usually massive or prismatic with rare to occasional spherical and subspherical pores and has pale grey anisotropic matrices with variable amounts of domains. When the sand content is high so that the matrix content is low the domains are rare to occasional and not easily distinguished. As the clay content increases so does the amount of matrix and degree of anisotropism so that there may be abundant domains, anisotropic zones and aureoles around the pores and sand grains. The mottles in the field are often seen as yellowish-brown and brown impregnations on the surfaces of pores and in some cases these pores also have thin clay coatings. When weatherable minerals are present they often show a higher degree of weathering than in the adjacent aerobic soils. Manganese dioxide segregations and/or concretions may be present
Genesis: alternate oxidation and reduction due to a fluctuating water-table
Variability: in degree of mottling, texture and content of concretions
Associated horizons: above: a modon, mullon or luton; below: a cerulon or relatively unaltered material
Distribution: absent from arid areas; present elsewhere
Origin of term: R. Glei - grey sticky loam

GLOSSON - Gs

General definition: middle or lower with well developed tongues that form a polygonal pattern in plan
Synonyms: Bg, Cg, Btg, argillic horizon
Position: middle or lower
Thickness: 30-150 cm
Colour: brown to red, mottled with pale vertical streaks or tongues
Texture: medium to fine, often silty, finer than the horizon above
Stones: absent to abundant
Structure: massive to prismatic
Handling properties: firm when wet, hard when dry
Bulk density: 1.5-1.7
Permeability: slowly permeable, faster down vertical streaks
Hydrology: usually moist or wet
pH: 5.5-7.5
CEC: 150-300 meq Kg^{-1}
BS: 40-100%
OM: < 2%
C/N ratio: 8-15
$(Ca+Mg)CO_3$: 0-20% from parent material
Soluble salts: absent
Weatherable minerals: few to abundant
Clays: kaolinite, mica, vermiculite, some smectite
Concretions: few to abundant small black
Biological activity: weak to absent
Micromorphology: yellow, brown and red with vertical pale coloured streaks. The coloured areas between the pale coloured streaks are usually massive to weakly alveolar with distinctly anisotropic clayey matrices.

There are usually frequent to abundant domains, zones of domains and aureoles around many pores and sand grains. Many pores have well-formed clay coatings or compound clay and manganese dioxide coatings. Also present are frequent to occasional manganese dioxide segregations that sometimes harden to form concretions. The pale coloured areas are surface residues of silt and sand from which much of the clayey matrix has been removed. In some cases clay coatings occur in these pale coloured areas, apparently at what used to be the junction between two prismatic peds.

Genesis: the tongues may be relic ice wedges or formed by shrinking and cracking, then translocation of material down the cracks and removal of iron from the sides of the tongues

Variability: in degree of mottling and texture contrast with the horizon above

Associated horizons: above: a candon, minon, alton or argillon; below: relatively unaltered material

Distribution: in many cool to warm continental areas with seasonal climate

Origin of term: Gk. Glossa = tongue

GLUTON - Gt

General definition: dark coloured, cemented by iron and manganese oxides

Synonyms: Bms, Cms, laterite, iron stone

Position: upper or middle

Thickness: 10-100 cm

Colour: dark brown to reddish-brown

Texture: not applicable

Stones: occasional to frequent

Structure: massive

Handling properties: hard to very hard

Bulk density: 1.7-2.0

Permeability: very slow to non permeable

Hydrology: moist to dry

pH: not applicable

CEC: not applicable

BS: not applicable

OM: <1%

C/N ratio: not applicable

$(Ca+Mg)CO_3$: absent

Soluble salts: absent

Weatherable minerals: <10%

Clays: dominantly goethite and manganese dioxide with lesser amounts of kaolinite and hematite

Concretions: variable

Biological activity: none

Micromorphology: black or very dark brown with an opaque matrix, massive containing much quartz sand, gravel and small rock fragments. The quartz grains are often very irregular in shape

Genesis: cementation of sandy material by goethite and manganese dioxide brought in by lateral seepage

Variability: in thickness and particle size distribution

Associated horizons: variable

Distribution: in seasonal tropical areas

Origin of term: L. Gluten = glue

GRANULON - Gr

General definition: upper dark brown to black montmorillonite clay with marked granular structure; self-mulching surface

Synonyms: Ah, Al, self-mulching surface, ochric epipedon
Position: at the surface
Thickness: 2-15 cm
Colour: black to very dark grey to dark brown
Texture: clay loam to clay
Stones: usually absent
Structure: distinctive granular structure
Handling properties: loose when dry, plastic when wet
Bulk density: 1.2-1.6
Permeability: very freely permeable
Hydrology: usually dry except during the wet season, then wet
pH: 5.5-7.5
CEC: 400-700 meq Kg^{-1}
BS: 60-100%
OM: <2%
C/N ratio: 8-12
$(Ca+Mg)CO_3$: 0-50% mainly from parent material, sometimes concretions are present
Soluble salts: low to absent
Weatherable minerals: 20-50%
Clays: dominantly smectite or mica with lesser amounts of kaolinite
Concretions: often contains numerous small concretions of $CaCO_3$ stained black by manganese dioxide
Biological activity: weak
Micromorphology: extremely well-developed small granular structure and frequent to abundant pore space. The individual granules have a dark brown or yellowish-brown isotropic to weakly anisotropic clayey matrix. The mineralogy of the sand grains is variable but there is often some calcite which occurs as fine grains within the granules or as clusters of grains forming small spherical concretions which may be stained black by manganese dioxide
Genesis: repeated wetting and drying in a dry environment also in some humid climates
Variability: varies in thickness and development of the granular structure. Intergrades to verton, mullon, dermon and tannon
Associated horizons: below: a verton or mullon
Distribution: predominantly in semi-arid tropical areas
Origin of term: L. Granulum = granule

GYPSON - Gy

General definition: middle or lower with an accumulation of gypsum
Synonyms: By, Cy, gypsic horizon
Position: middle or lower
Thickness: 5 cm
Colour: pale brown to brown to greyish-brown
Texture: variable
Stones: variable
Structure: massive to blocky to prismatic
Handling properties: firm to friable to hard, when hard Cyd
Bulk density: 1.7-1.9
Permeability: slow
Hydrology: usually dry, moist in the wet season
pH: 7.0-9.0
CEC: variable
BS: 100%
OM: < 2%
C/N ratio: 8-12

Gypson, Gyttjon

(Ca+Mg)CO_3: <5%
Soluble salts: > 5% $CaSO_4$
Weatherable minerals: variable
Clays: variable
Concretions: frequent to abundant concretionary clusters of gypsum crystals
Biological activity: weak to absent
Micromorphology: usually massive or very coarse angular blocky with a range of colours but tend to be pale because of the presence of gypsum which may occur as individual crystals but more usually as clusters. In both cases the crystal form is very distinctive with the characteristic diamond cross-section. Where the material has rock fragments the gypsum may form pendants beneath the rock fragments. Calcite is also nearly always present so that anisotropic matrices never develop but the horizons are dominantly anisotropic because of the high frequency of small calcite crystals. The gypsum may also accumulate in fine grain sediments that have marked horizontal alignment of domains.
Genesis: gradual growth of gypsum crystals from ions in solution
Variability: in texture and thickness
Associated horizons: above: a calcon; below: relatively unaltered material
Distribution: in semi-arid areas
Origin of term: Gk. Gypsus = gypsum

GYTTJON - Gj
General definition: upper, middle, very plastic, organic and mineral mixture formed under anaerobic conditions
Synonyms: O, H, peat, histic epipedon
Position: upper, middle
Thickness: 20-200 cm
Colour: black to very dark brown, VCl
Texture: not applicable
Stones: absent
Structure: massive
Handling properties: plastic when wet, hard when dry
Bulk density: wet: 1.0; dry: 0.5
Permeability: very slow
Hydrology: permanently saturated except when drained
pH: 3.5-7.5
CEC: 500-1000 meq Kg^{-1}
BS: 10-30%, higher when developed in base rich water
OM: 30-60%
C/N ratio: 12-20
(Ca+Mg)CO_3: absent
Soluble salts: absent
Weatherable minerals: 0-20%
Clays: variable
Concretions: none
Biological activity: very weak but sufficient to cause considerable breakdown of the organic matter
Micromorphology: dark coloured, massive with < 30% easily recognisable plant remains, abundant diatoms and phytoliths and occasional to rare detrital grains. Some doplerite may be present
Genesis: accumulation of organic and mineral material under anaerobic conditions
Variability: in content of mineral material and degree of decomposition of the organic matter
Associated horizons: above: litter; below: a cerulon
Distribution: occurs in all humid areas, particularly the cooler types
Origin of term: S. Gyttja

HALON - Hl

General definition: upper or middle with an accumulation of a mixture of soluble salts
Synonyms: Ahz, Az, Bz, Cz, having salic horizon
Position: upper, middle or lower
Thickness: 10-100 cm
Colour: yellowish-brown to brownish-grey
Texture: variable
Stones: absent to frequent
Structure: massive to prismatic
Handling properties: firm to friable to hard
Bulk density: 1.5-1.7
Permeability: moderate
Hydrology: usually dry, moist or wet during the rainly season
pH: 7.5-8.5
CEC: variable
BS: 100%
OM: < 5%
C/N ratio: < 12
$(Ca+Mg)CO_3$: 0-50% from the parent material
Soluble salts: < 70% Cl plus 70% SO_4^{2-} in the saturation extract; EC < 4 mmhos
Weatherable minerals: 0-80%
Clays: variable with a tendency to have much montmorillonite
Concretions: absent
Biological activity: weak
Micromorphology: massive, alveolar or blocky with a range of secondary crystalline material including calcite, gypsum and halite. The crystals may occur within peds, between peds, singly or in clusters. Although significant amounts of halite may be present its identification might be very difficult because its refractive index is very close if not identical to that of the impregnating resin
Genesis: accumulation of soluble salts in an arid and semi-arid environment
Variability: in the proportion of cations and anions
Associated horizons: an alkalon, chloron or sulphon
Distribution: in the arid and semi-arid areas
Origin of term: Gk. Hals = salt

HAMADON - Ha

General definition: surface accumulation of large fragments of rock, laterite or silicrete
Synonyms: hamadon, yermic properties
Position: surface
Thickness: 5-15 cm
Colour: black to dark grey to brown
Texture: loam to sandy loam to sand may be present between the large fragments
Stones: > 30% of the surface covered by the large fragments
Structure: single grain between the large fragments
Handling properties: loose or friable
Permeability: very rapid
Hydrology: usually dry except after thunderstorms
$(Ca+Mg)CO_3$: 0-100%
Soluble salts: low to absent
Weatherable minerals: 5-100%
Clays: variable
Concretions: absent
Biological activity: weak, an occasional plant
Micromorphology: not known

Genesis: removal of fine material by deflation or surface wash; frost heaving or wetting and drying, moving the large fragments to the surface
Variability: in the abundance, size and shape of the stones and boulders and other materials
Associated horizons: below: a gelon, gluton, halon, seron, verton or sometimes an argillon
Distribution: in arid and tundra areas
Origin of term: Kubiëna 1953

HELVON - He
General definition: middle or lower, yellowish-brown moderate to strongly weathered, occurs in the tropics and subtropics
Synonyms: Bw, B2, cambic horizon
Position: middle or lower
Thickness: 25-100 cm
Colour: yellowish-brown to brown to yellowish-red to reddish-brown, 5YR-10YR
Texture: clay loam to clay, >30% silt plus clay
Stones: absent to rare
Structure: subangular blocky usually with smooth shiny ped surfaces
Handling properties: firm to friable
Bulk density: 1.4-1.6
Permeability: moderate
Hydrology: variable
pH: 4.5-7.0
CEC: >200 meq Kg^{-1} clay
BS: variable
OM: <5%
C/N ratio: 8-12
$(Ca+Mg)CO_3$: absent
Soluble salts: absent
Weatherable minerals: 5-25%
Clays: predominantly kaolinite with variable amounts of hydrous mica, vermiculite, goethite and gibbsite
Concretions: absent to occasional
Biological activity: variable, sometimes weak, sometimes with vigorous termite activity
Micromorphology: the structure ranges from granular through subangular blocky to weakly developed wedge. This range is due to the variability in the clay content of the segment. Sometimes, there are passages created by worms or termites with varying amounts of faecal material or termite granules. There is a distinctive yellowish-brown matrix which in the granular soils is very weakly anisotropic to isotropic but becomes progressively more anisotropic as the structure changes to angular blocky and finally weakly developed wedge. With a high degree of anisotropism there are abundant randomly orientated domains, zones of domains and aureoles around sand grains and pores. The sand fraction contains occasional to frequent weatherable minerals
Genesis: progressive hydrolysis through a long period of time
Variability: in structure and thickness
Associated horizons: above: a tannon; below: a pesson, petron or chemically weathered rock
Distribution: in tropical and subtropical areas

HUDEPON - Hd

General definition: middle, very dark horizons with accumulations of humus
Synonyms: B2, Bh, spodic horizon
Position: middle or lower
Thickness: 5-60 cm
Colour: black to very dark brown VC1
Texture: medium to coarse
Stones: absent to dominant
Structure: single grain to weak crumb to massive
Handling properties: loose to firm to hard to cemented
Bulk density: 1.5-1.7
Permeability: freely permeable
Hydrology: usually moist
pH: 4.5-5.5
CEC: 150-400 meq Kg^{-1}
BS: 10-20%
OM: 3-25%
C/N ratio: 18-22
$(Ca+Mg)CO_3$: absent
Soluble salts: absent
Weatherable minerals: rare to abundant, the amount decreases with an increase in temperature
Clays: mica, kaolinite, vermiculite
Concretions: none
Biological activity: low
Micromorphology: the grains are covered by cracked coatings which also form bridges between the grains. These coatings are isotropic and dark coloured ranging from reddish-brown to black
Genesis: accumulation of translocated humus
Variability: in thickness, structure and consistence
Associated horizons: above: a zolon or modon; below: a sesquon, argillon or relatively unaltered material
Distribution: common in cool humid areas, rare in humid tropical areas in quartzose sands
Origin of term: Hu = from humus; Dep = from deposit

HUMIFON - Hf

General definition: upper, amorphous, aerobic, strongly decomposed organic matter
Synonyms: 02
Position: upper
Thickness: 1-10 cm
Colour: black to very dark brown
Texture: not applicable
Stones: absent
Structure: amorphous to small granular
Handling properties: plastic when wet, hard when dry
Bulk density: <1.0
Permeability: free
Hydrology: usually moist, sometimes wet or saturated
pH: 3.5-4.5
CEC: 800-1000 meq Kg^{-1}
BS: 20-50%
OM: >75%
C/N ratio: 15-20
$(Ca+Mg)CO_3$: absent
Soluble salts: absent
Weatherable minerals: <10%
Clays: not applicable
Concretions: absent
Biological activity: very active micro-organisms
Micromorphology: generally very fine granular and fine vermiform with abundant pore space. The granules and

vermiforms are isotropic and vary in colour from yellowish-brown to black and are composed entirely of organic material. Also present are larger fragments of partially decomposed organic material and fungal hyphae. There may be occasional to frequent sclerotia.
Genesis: decomposition of organic matter by arthropods, bacteria and fungi
Variability: in thickness
Associated horizons: above: litter or a fermenton; below: an aluminon, modon or zolon
Distribution: in cool humid areas
Origin of term: E. = Humification

HUSESQUON - Hs
General definition: middle, friable to hard, weak crumb to blocky to massive, contains significantly more sesquioxides and humus than the horizon above or below
Synonyms: Bhs, Bhir, spodic horizon
Position: middle or lower
Thickness: <30 cm to >1 m
Colour: black, VCl
Texture: loamy sand to loam
Stones: absent to dominant
Structure: weak crumb to blocky to massive
Handling properties: friable to firm to hard, slightly thixotropic
Bulk density: about 1.2 to 1.7
Permeability: freely permeable
Hydrology: usually moist
pH: 4.5-5.5
CEC: 100-300 meq Kg^{-1}
BS: 10-30%
OM: <20%
C/N ratio: 8-22
$(Ca+Mg)CO_3$: absent
Soluble salts: absent
Weatherable minerals: absent to frequent similar to the material below
Clays: abundant sesquioxides, some hydrous mica, vermiculite SiO_2: R_2O_3 ratio of the clay less than horizon above by ≥ 0.5
Biological activity: few roots, low faunal and floral activity
Micromorphology: small granules that occur singly or in clusters which sometimes lead to the formation of a crude alveolar structure. Brown isotropic material forms the matrix of the granules and coats the coarse sand grains. There is usually a very high porosity and occasional to rare roots and fragments of roots undergoing decomposition
Genesis: accumulation of humus and sesquioxides translocated from the horizons above also some *in situ* weathering
Variability: varies mainly in texture, structure, handling properties and stone content
Associated horizons: above: a modon or zolon; below: a fragon, ison, marblon, glosson or relatively unaltered material
Distribution: common in cool and warm temperate areas
Origin of term: Hu- from humus and sesq- from sesquioxides

HYDROMORON - Hy

General definition: upper, black, plastic mixture of organic and mineral material, usually wet
Synonyms: 02
Position: upper
Thickness: 5-25 cm
Colour: black to very dark brown
Texture: not applicable
Stones: usually absent
Structure: massive when wet, dries with vertical cracks
Handling properties: plastic when wet, hard when dry
Bulk density: < 1.0 dry
Permeability: slow
Hydrology: usually wet, sometimes saturated
pH: 3.0-5.0
CEC: 500-1000 meq Kg^{-1}
BS: 20-40%
OM: > 50%
C/N ratio: 15-25
$(Ca+Mg)CO_3$: absent
Soluble salts: absent
Weatherable minerals: < 10%
Clays: variable
Concretions: none
Biological activity: moderate to slow
Micromorphology: dark coloured, massive with > 30% plant remains and frequent detrital grains. Some have faunal passages and faecal material.
Genesis: accumulation of organic matter under wet but not waterlogged conditions
Variability: thickness, mineral content
Associated horizons: above: litter; below: a gleyson, cerulon or minon
Distribution: in cool humid areas
Origin of term: Duchaufour - Hydromor

ISON - In

General definition: lower, varying from friable to hard with a characteristic lenticular or massive structure and cappings of silt on the upper surfaces of stones
Synonyms: Cx, fragipan, indurated layer
Position: lower
Thicknes: 10-200 cm
Colour: greyish-brown to olive
Texture: sand to loam
Stones: absent to dominant
Structure: medium and coarse lenticular to massive
Handling properties: firm to very hard
Bulk density: 1.7-2.0
Permeability: moderate to very slow
Hydrology: usually moist or dry
pH: 5-7
CEC: 20-50 meq Kg^{-1}
BS: 20-100%
OM: <1%
C/N ratio: 8-12
$(Ca+Mg)CO_3$: absent to dominant
Soluble salts: absent
Weatherable minerals: 0-100% of the < 2 mm fraction
Clays: kaolinite, mica and vermiculite
Concretions: absent
Biological activity: very weak
Micromorphology: see page
Genesis: derived from cryon by disappearance of the ice. Followed by slight cementation by aluminium hydroxide, silica or carbonates

Variability: parent material
Associated horizons: above: a sesquon, alton, candon, placon or gleyson; below: relatively unaltered material
Distribution: mainly in the temperate areas that had permafrost during the Pleistocene period
Origin of term: OE. Is = ice

JARON - Ja

General definition: middle or lower, grey or olive with yellow mottles of jarosite
Synonyms: Bg, Cg, sulphuric horizon
Position: middle or lower
Thickness: 10-50 cm
Colour: grey to bluish-grey to olive with yellow mottles
Texture: medium to fine
Stones: usually absent
Structure: massive to prismatic
Handling properties: firm to hard to plastic
Bulk density: 1.5-1.7
Permeability: slow to very slow
Hydrology: moist or wet
pH: 3-4.5
CEC: 200-400 meq Kg^{-1}
BS: 30-50%
OM: <3%
C/N ratio: < 15
$(Ca+Mg)CO_3$: absent
Soluble salts: may contain gypsum
Weatherable minerals: variable, some secondary gypsum
Clays: hydrous mica, montmorillonite, kaolinite
Concretions: absent
Biological activity: very low, old pneumataphores outlined with brown iron oxide
Micromorphology: mainly massive with a few spherical or subspherical pores. Greyish in colour due to its previous anaerobism and mottled with clusters of very small, bright yellow, jarosite crystals. With high clay content there are well-developed matrices which contain numerous domains either singly, in zones or forming aureoles around pores and mineral grains. The jarosite appears as a yellow, weakly translucent mass because of the large number of small crystals.
Genesis: drainage of a thion causing the oxidation of pyrite to form a straw coloured basic ferric sulphate - jarosite
Variability: in thickness, texture and amount of jarosite
Associated horizons: above: an anmooron or hydromoron; below: a thion or cerulon
Distribution: in drained estuaries and coastal marshes
Origin of term: Jarosite

KASTANON - Kt

General definition: upper, thick dark brown with much earthworm faecal material
Synonyms: Ah, Al, mull, mollic epipedon
Position: upper
Thickness: 35-50 cm
Colour: dark brown to very dark grey
Texture: loam to silt
Stones: usually absent
Structure: crumb to granular, sometimes prismatic in the lower part

Handling properties: firm to friable
Bulk density: 1.2-1.6
Permeability: moderately
Hydrology: usually moist except at the end of the dry season and in the wet season when dry and wet respectively
pH: 7.0-8.5
CEC: 100-400 meq Kg^{-1}
BS: 100%
OM: 2-5% 15-20 Kg OM per m^2
C/N ratio: 8-12
$(Ca+Mg)CO_3$: pseudomycelium and concentration in the lower part, variable from the parent material
Soluble salts: low to absent
Weatherable minerals: 20-60%
Clays: mainly hydrous mica and montmorillonite
Concretions: see $(Ca+Mg)CO_3$ above
Biological activity: very strong
Micromorphology: vermiform, granular and subangular blocky, the peds are entire or fragments of faecal material. Mainly abundant pore space and numerous channels formed by earthworms. Where enchytraeid worms are dominant the faecal material is mainly small granular. Kastanons that have been cultivated for a long period of time usually have much less pore space due to compaction
Genesis: rapid breakdown and incorporation of organic matter in a dry environment
Variability: in content of soluble salts
Associated horizons: above: litter; below: a calcon
Distribution: in cool semi-arid areas
Origin of term: R. Kastano = chestnut

KRASNON - Ks
General definition: red, strongly weathered with low CEC and low base saturation
Synonyms: Bsw, oxic horizon
Position: middle or lower
Thickness: 50 cm to >2 m
Colour: red, hues of R, 2.5YR and 5YR VC2, 4, 5
Texture: clay
Stones: generally absent
Structure: granular to blocky to massive
Bulk density: about 1.2 to 1.7
Handling properties: friable to firm
Permeability: freely permeable
Hydrology: usually dry, moist during the wet season seldom wet
pH: 4.5-6.0
CEC: <15 meq Kg^{-1}
BS: usually <20%
OM: <2% usually <1%
C/N ratio: 8-12
$(Ca+Mg)CO_3$: absent
Soluble salts: low to absent
Weatherable minerals: <5%
Clays: kaolinite, gibbsite and iron oxides
Concretions: <30% may be dominantly iron oxide or gibbsite
Biological activity: many large roots, few fine feeding roots, may have a very active termite and/or earthworm population
Micromorphology: granular, incomplete angular blocky, labyrinthine; usually poorly transparent and isotropic, domains not usually seen in sections of normal thickness

but often seen in sections about 15 µ m thick. Clay coatings range from absent to occasional, when more than 2% the horizon should be regarded as the compound horizon {KsAr}
Genesis: very advanced weathering under humid tropical conditions
Variability: varies in texture, structure and content of concretions
Associated horizons: above: a tannon or mullon; below: there is a gradual change to progressively less weathered material that is usually rocks
Distribution: common in humid tropical areas and in some drier tropical and substropical areas that were wetter in the past
Origin of term: R. Krasni = red

KURON - Ku
General definition: upper, very dark mixture of organic and mineral material, containing allophane
Synonyms: Ah, Al, umbric epipedon
Position: upper
Thickness: 10-25 cm
Colour: black to very dark brown
Texture: loam to sand
Stones: absent to rare
Structure: granular to crumb to subangular blocky
Handling properties: friable to smeary
Bulk density: 1.0-1.5
Permeability: freely permeable
Hydrology: usually moist
pH: 4.5-6.5
CEC: 200-500 meq Kg^{-1}
BS: 10-30%
OM: 5-20%
C/N ratio: 12-20
$(Ca+Mg)CO_3$: absent
Soluble salts: absent
Weatherable minerals: 5-80%
Clays: dominantly allophane, sometimes with lesser amounts of halloysite and kaolinite
Concretions: absent
Biological activity: active root growth, bacterial and worm activity
Micromorphology: granular with a tendency to be alveolar or massive with dark coloured isotropic matrix. Much faecal material and passages of soil fauna, many brown fragments of plant material
Genesis: decomposition and blending of organic and mineral material
Variability: in texture and content of organic matter
Associated horizons: above: litter; below: an andon, relatively unaltered material
Distribution: in humid volcanic areas
Origin of term: J. Kurobou = dark

LIMON - Lm
General definition: sub-aquatic accumulation of precipitated calcium carbonate or calcareous skeletons of aquatic animals
Synonyms: Ckg, lake marl
Position: upper, middle
Thickness: 3-100 cm
Colour: grey to white
Texture: silt

Stones: absent
Structure: massive
Handling properties: firm to plastic
Bulk density: 1.4-1.6
Permeability: slow
Hydrology: saturated with water but may be drained naturally or artificially
pH: 7.5-9.0
CEC: not applicable
BS: not applicable
OM: $<5\%$
C/N ratio: 15-40
$(Ca+Mg)CO_3$: $>30\%$
Soluble salts: low to absent
Weatherable minerals: variable
Clays: variable
Concretions: none
Biological activity: none
Micromorphology: unknown
Genesis: accumulation of precipitated calcium carbonate and calcareous skeletons of aquatic animals on the bottom of a lake
Variability: in the content of minerals
Associated horizons: above: an amorphon or gyttjon; below: a cerulon
Distribution: in cool humid areas, particularly in a glaciated landscape with many small ponds
Origin of term: L. Limus = slime

LITHON - Lh
General definition: upper, middle or lower, dominant angular rock fragments
Synonyms: stony layer
Position: upper, middle or lower
Thickness: 20 to >100 cm
Colour: brown to red
Texture: sand to loamy sand, $<30\%$ fine earth
Stones: dominant angular formed by physical weathering usually frost or expansion and contraction
Structure: single grain with abundant pore space
Handling properties: loose, rock fragments
Bulk density: >2
Permeability: very permeable
Hydrology: usually moist or dry
pH: variable
CEC: not applicable
BS: not applicable
OM: $<2\%$
C/N ratio: 8-15
$(Ca+Mg)CO_3$: variable
Soluble salts: absent
Weatherable minerals: variable
Clays: variable
Concretions: none
Biological activity: very low
Micromorphology: the fine earth usually has the micromorphology of alton, aluminon, sesquon or husesquon
Genesis: physical shattering of rock in situ or moved only a short distance
Variability: size of stones and degree of porosity
Associated horizons: above: a gelon; below: rock
Distribution: in polar and sub-polar areas
Origin of term: Gk. Lithos = stone

LUTON - Ln
General definition: upper, mixture of organic and mineral material, massive to blocky with faint mottling particularly along root passages
Synonyms: Ahg, A1, some ochric and umbric epipedons
Position: upper
Thickness: 10-60 cm
Colour: black to dark browm to brown with faint mottling particularly along root passages, mottling may be destroyed by cultivation; 10YR, 2.5Y, VC1, 2
Texture: medium to fine
Stones: absent to occasional
Structure: massive to anglular blocky to granular
Handling properties: firm to hard to plastic, hard setting
Bulk density: 1.5-1.7
Permeability: moderate to slow
Hydrology: usually moist or wet, saturated for short periods
pH: 5.0-8.0
CEC: 150-1000 meq Kg^{-1}
BS: 30-100%
ESP: <10%
OM: 1-10%
C/N ratio: 8-15
$(Ca+Mg)CO_3$: variable from parent material
Soluble salts: low to absent
Weatherable minerals: variable
Clays: variable
Concretions: absent
Biological activity: low when saturated with water, high when moist or dry
Micromorphology: massive, weakly alveolar or blocky with dark yellowish-brown to brown isotropic or faintly anisotropic clayey matrices. Rare to occasional passages which may be partially or completely filled with faecal material. Some pores have brown or yellowish-brown surfaces impregnated with iron-oxide. Occasional to frequent decomposing plant fragments and rare to occasional roots
Genesis: decomposition and incorporation of organic matter in a moist soil, degradation of structure due to poor cultivation
Variability: in degree of structure development and mottling
Associated horizons: below: an alton, pelon or verton
Distribution: in most humid areas
Origin of term: L. Lutum = mud

LUVON - Lv
General definition: upper, very pale coloured and bleached, containing less sesquioxides and clay than below
Synonyms: E, A2, albic horizon
Position: upper
Thickness: 3-80 cm
Colour: very pale, VC3
Texture: medium to coarse
Stones: absent to occasional
Structure: single grain to weak crumb to lenticular
Handling properties: loose to firm
Bulk density: 1.2-1.5
Permeability: free
Hydrology: usually moist or dry
pH: 3.5-5.5
CEC: 5-20 meq Kg^{-1}

BS: 10-20%
OM: 0.5-5%
C/N ratio: 10-20
$(Ca+Mg)CO_3$: absent
Soluble salts: absent
Weatherable minerals: absent to frequent
Clays: kaolinite, hydrous mica
Concretions: absent
Biological activity: low
Micromorphology: similar to zolon
Genesis: removal or destruction of clay
Variability: thickness, texture
Associated horizons: above: litter, modon or zolon; below: an argillon, planon or solon
Distribution: mainly in cool humid to sub-humid, seasonal climates
Origin of term: L. Luo = to wash

MARBLON - Mb

General definition: middle or lower, yellow to brown with marbled pattern and faint mottling
Synonyms: Bg, Cg, cambic horizon
Position: middle or lower
Thickness: 10-50 cm
Colour: yellow to brown with marbled pattern, ped surfaces often grey; MnO_2 staining may be present as discontinuous coatings and surface impregnations
Texture: variable
Stones: variable, often weathered with yellow oxidised iron giving a mottled appearance to the horizon
Structure: massive to prismatic to blocky
Handling properties: firm to hard
Bulk density: 1.3-1.7
Permeability: variable
Hydrology: usually moist or wet, frequently saturated
pH: 5.0-7.5
CEC: 150-300 meq Kg^{-1}
BS: 40-100%
OM: <3%
C/N ratio: 8-12
$(Ca+Mg)CO_3$: absent
Soluble salts: absent
Weatherable minerals: few to abundant
Clays: mica, vermiculite, smectite
Concretions: absent to occasional small black
Biological activity: low to very low
Micromorphology: marbled pattern of yellows, browns and greys. Usually massive to weakly alveolar with clayey matrices that have variable properties. In the brown and yellowish areas the matrix tends to be faintly anisotropic or may even be isotropic, whereas, in the grey areas there is a greater development of anisotropism, the amount determined by the clay content, so that as the clay percentage increases so does the amount of anisotropism. Many of these horizons show yellow and brown impregnations of pore surfaces and black segregations and concretions of manganese dioxide. Sometimes rare clay coatings are present.
Genesis: weak reducing conditions for a short period during each year
Variability: in texture and degree of marbling
Associated horizons: a wide range
Distribution: in most humid climates
Origin of term: Gk. Marmaros = sparkle

MINON - Mi

General definition: upper, pale coloured with mottling and sometimes black segregations and concretions
Synonyms: Eg, A2g, albic horizon
Position: upper
Thickness: 3-80 cm
Colour: pale to very pale VC2, 3 with yellow and brown mottling, black segregations and concretions absent to abundant
Texture: medium to coarse with significantly less clay than the horizon below
Stones: absent to occasional
Structure: single grain to massive to weak crumb
Handling properties: loose to firm, may be very hard when dry
Bulk density: 1.2-1.5
Permeability: free
Hydrology: usually wet or saturated due to slow permeability of the underlying horizon
pH: 3.5-5.5
CEC: 50-200 meq Kg^{-1}
BS: 10-20%
OM: 0.5-5%
C/N ratio: 8-20
$(Ca+Mg)CO_3$: absent
Soluble salts: absent
Weatherable minerals: absent to frequent
Clays: kaolinite, hydrous mica, montmorillonite
Concretions: absent to abundant
Biological activity: low
Micromorphology: massive or alveolar with pale olive grey or grey matrices often surrounding abundant sand grains. The matrices are often difficult to differentiate but are sometimes fairly anisotropic. Some pores may have yellowish-brown surface impregnations and black manganese dioxide concretions may be present. These are most numerous at the bottom of the horizon and from basic parent material. The lower parts of these horizons may appear as sandy residues around peds as they develop at the expense of the underlying horizons. These horizons overlie slowly permeable horizons.
Genesis: removal or destruction of clay in a partially anaerobic environment, formation of mottles and concretions
Variability: in texture and content of concretions
Associated horizons: above: a modon; below: a planon, glosson, gleyson or solon
Distribution: in humid and sub-humid seasonal climates
Origin of term: L. Minus = less

MODON - Mo

General definition: upper dark or very dark mixture of organic and bleached mineral material, massive or blocky
Synonyms: Ah, A1, some ochric and umbric epipedons
Position: upper
Thickness: 3-20 cm
Colour: dark to very dark VC1, 2
Texture: loam to loamy sand to sandy loam
Stones: absent to frequent
Structure: massive to poorly developed blocky
Handling properties: firm to friable to slightly plastic
Bulk density: 1-1.5

Permeability: very permeable
Hydrology: usually aerobic with good moisture retention
pH: 3.5-6.5
CEC: 100-400 meq Kg^{-1}
BS: 10-30%
OM: 3-20%
C/N ratio: 15-20
$(Ca+Mg)CO_3$: absent
Soluble salts: absent
Weatherable minerals: few to dominant
Clays: hydrous mica, kaolinite
Concretions: absent
Biological activity: moderately active microflora, earthworms few to absent
Micromorphology: alveolar or massive with dark coloured isotropic matrices, may be composite single grain and granular with very dark isotropic fine material forming the matrix of the granules and coating the sand grains
Genesis: weathering of the minerals and decomposition of incorporated organic matter at low pH values
Variability: mainly in texture and thickness
Associated horizons: above: a humifon, litter; below: a zolon, luvon, sesquon, husesquon or placon
Distribution: common in cool humid temperate areas
Origin of term: Kubiëna = moder

MULLON - Mu

General definition: upper, dark or very dark, intimate mixture of organic and mineral material, crumb or granular with vigorous earthworm activity
Synonyms: A1, Ah, some mollic and ochric epipedons
Position: upper
Thickness: 10- 50 cm
Colour: dark to very dark VC1, 2 or 5
Texture: medium to fine
Stones: absent to frequent
Structure: very well developed crumb to granular to vermicular
Handling properties: firm to friable to moderately plastic
Bulk density: 1-1.5
Permeability: very permeable
Hydrology: usually aerobic with good moisture retention
pH: 5.5-7.0 may be higher when carbonates are present
CEC: 200-800 meq Kg^{-1}
BS: 40-100%
OM: 3-10%
C/N ratio: 8-12
$(Ca+Mg)CO_3$: absent to abundant from parent material, when present Muc
Soluble salts: absent
Weatherable minerals: few to dominant
Clays: variable
Concretions: absent
Biological activity: very active microflora particularly bacteria, many earthworms
Micromorphology: vermiform, granular and subangular blocky. The peds are entire or fragments of faecal material, abundant pore space and numerous channels formed by earthworms. When enchytraeid worms are dominant the faecal material is small granular Mullons that have been cultivated for a long period of time, usually have less pore space due to compaction but there are still many channels and vermiforms of faecal material

Genesis: vigorous mixing of organic and mineral material by the soil fauna particularly earthworms
Variability: mainly in texture
Associated horizons: above: loose litter; below: many different horizons
Distribution: occurs in all humid areas
Origin of term: E. Mull

NEKRON - Nk

General definition: very dark, periodically saturated with water and contains an abundance of fine dead plant roots
Synonyms: Ah, A1, some ochric and umbric epipedons
Position: upper
Thickness: 5-20 cm
Colour: very dark when wet but becomes significantly lighter when dry, change of 2-4 units of value
Texture: loam to sandy loam to sand
Stones: absent to dominant
Structure: massive when wet, vertical cracks form upon drying
Handling properties: firm to friable to moderately plastic
Bulk density: 1.0-1.5
Permeability: variable
Hydrology: usually saturated with water but has dry spells when roots can penetrate and are later killed when saturation returns
pH: 3.0-5.0
CEC: 200-800 meq Kg^{-1}
BS: 10-40%
OM: 10-20%
C/N ratio: 15-20
$(Ca+Mg)CO_3$: absent
Soluble salts: absent
Weatherable minerals: few to abundant
Clays: hydrous mica, vermiculite and montmorillonite; there may be some kaolinite
Concretions: absent
Biological activity: spasmodic; vigorous when moist, little or none when wet
Micromorphology: massive with dark coloured isotropic clayey matrices. Usually frequent to abundant sand grains with some showing signs of weathering. The distinctive feature is the frequent to occasional dead plant roots undergoing decomposition
Genesis: weathering of the minerals and decomposition of dead roots under very wet conditions
Variability: mainly in texture
Associated horizons: above: a hydromoron or modon; below: a candon or placon
Distribution: common in cool humid temperate areas
Origin of term: Gk. Nekros = corpse

ORON - O

General definition: middle or lower deposits of manganese dioxide and iron oxides, varies from loose to very hard
Synonyms: Bs, Cs
Position: middle or lower
Thickness: 5-30 cm
Colour: black to very dark brown
Texture: medium to coarse
Stones: absent to frequent

Structure: single grain to massive to nodular
Handling properties: loose to firm to hard
Bulk density: 1.5-1.9
Permeability: free to impermeable when hard
Hydrology: usually wet or saturated
pH: 4.5-6.0
CEC: variable
BS: moderate
OM: < 4%
C/N ratio: 8-15
$(Ca+Mg)CO_3$: absent
Soluble salts: absent
Weatherable minerals: variable
Clays: amorphous or microcrystalline oxides of manganese and iron
Concretions: absent to abundant usually irregular in shape
Biological activity: very low
Micromorphology: alveolar to massive with dark brown or black isotropic matrix
Genesis: accumulation of hydrous oxides of iron and manganese due to lateral seepage
Variability: in consistence
Associated horizons: often occurs above an impermeable horizon or along a seepage line within the underlying material
Distribution: in most humid areas
Origin of term: E. Ore

PALLON - Pl

General definition: very pale subsoil composed dominantly of kaolinite and quartz
Synonyms: pallid zone, saprolite
Position: lower
Thickness: 100-300 cm
Colour: pinkish-grey with red mottles
Texture: clay loam to clay
Stones: absent to rare
Structure: massive to prismatic
Handling properties: plastic to hard
Bulk density: probably about 1.8
Permeability: slow
Hydrology: usually wet or saturated
pH: 4.5-5.5
CEC: 10-20 meq Kg^{-1}
BS: <50%
OM: <1%
C/N ratio: < 15
$Ca+Mg)CO_3$: absent
Soluble salts: up to 0.5%
Weatherable minerals: <5%
Clays: kaolinite, gibbsite, goethite, mica
Concretions: absent
Biological activity: very weak to absent
Micromorphology: see page 125
Genesis: progressive hydrolysis and clay mineral formation
Variability: in texture
Associated horizons: above: a krasnon, veson or spheron; below: chemically weathered rock
Distribution: in humid tropical areas
Origin of term: L. Pallere = pale

PELON - Pe

General definition: middle or lower, aerobic, fine textured, contains similar clay content to the horizon above
Synonyms: Bw, B2, cambic horizon
Position: middle or lower
Thickness: 20-100cm
Colour: brown, reddish-brown to red, uniformly coloured or slightly mottled
Texture: fine to very fine
Stones: usually absent
Structure: angular blocky to prismatic, sometimes with a few slickensides
Handling properties: firm to hard or plastic
Bulk density: 1.5-1.9
Permeability: very slowly permeable
Hydrology: usually moist, wet in the wet season
pH: 5.0-7.5
CEC: 200-400 meq Kg^{-1}
BS: 30-100%
OM: <2%
C/N ratio: 4-12
$(Ca+Mg)CO_3$: <30% from the parent material
Soluble salts: low to absent
Weatherable minerals: variable
Clays: predominantly kaolinte and hydrous mica
Concretions: absent
Biological activity: weak
Micromorphology: massive, prismatic to weak wedge structure with occasional to frequent spherical and subspherical pores. Faunal passages absent to occasional, with varying amounts of faecal material. These usually have well-developed clayey matrices with occasional to abundant clear domains and anisotropic zones and aureoles around pores and grains. A few clay coatings may be present.
Genesis: weak weathering and expansion and contraction in a clayey sediment
Variability: in colour and structure formation
Associated horizons: above: a tannon or mullon; below: relatively unaltered sediment
Distribution: in the lower slope and depression situations in many humid and sub-humid climates
Origin of term: Gk. Pelos = mud

PESSON - Ps

General definition: middle or lower, with abundant black concretions in red or reddish-brown matrix
Synonyms: Bcs, Ccs, ironstone
Position: middle or lower
Thickness: 20-200 cm
Colour: black
Texture: loamy sand to sandy loam
Stones: absent to rare
Structure: granular to alveolar to massive
Handling properties: loose to friable to firm to hard
Bulk density: 1.6-1.8
Permeability: moderate to rapid
Hydrology: usually moist
pH: 4.5-5.5
CEC: low
BS: low
OM: < 1%
C/N ratio: 6-12
$(Ca+Mg)CO_3$: absent

Soluble salts: absent
Weatherable minerals: < 5%
Clays: dominantly kaolinite
Concretions: abundant, black
Biological activity: weak
Micromorphology: very dense, massive material dominated by subspherical black iron oxide concentrations embedded in a reddish-brown matrix. The iron oxide concentrations may or may not be magnetic. In some cases the matrix may contain much gibbsite and shows little organisation, but in others there is concentric ringing of material around the concretions suggesting that the concretions formed first and were later surrounded and cemented by the red material
Genesis: *in situ* formation of concretions
Variability: in the size of the concretions and amount of matrix
Associated horizons: above: a modon or mullon; below: weathered rock
Distribution: predominantly in the wet and dry tropics
Origin of term: Gk. *Pessos* = oval stone

PETROCALCON - Pc
General definition: pale coloured, very hard and cemented by calcite
Synonyms: Bmk, Cmk, calcrete, caliche, petrocalcic horizon
Position: upper, middle or lower
Thickness: 50 to > 200 cm
Colour: pale coloured to brilliant white
Texture: not applicable
Stones: variable, usually occasional to absent
Structure: varies from chalky to massive to laminar
Handling properties: very hard
Bulk density: probably about 2
Permeability: generally impermeable
Hydrology: moist or dry
pH: > 7.0
CEC: not applicable
BS: not applicable
OM: < 1%
C/N ratio: not applicable
$(Ca+Mg)CO_3$: > 50%
Soluble salts: absent to rare
Weatherable minerals: dominant
Clays: not applicable
Biological activity: rare to absent
Micromorphology: ooids or subspherical concretions are probably the most common features and are produced by binding with algal fillaments. There are also cracks filled with large calcite crystals. Some petracalcons also have a laminar arrangement of small calcite crystals
Genesis: accumulation of calcium and magnesium carbonates
Variability: in thickness, content of stones and type of carbonate crystals
Associated horizons: above: a rosson or removed by erosion; below: a calcon that grades into relatively unaltered material
Distribution: in arid, semi-arid and mediterranean areas
Origin of term: Gk *Petros* = stone and calcon

PETROGYPSON - Py
General definition: pale coloured, very hard and cemented by gypsum
Synonyms: Bmy, Cmy, petrogypsic horizon
Position: upper, middle or lower
Thickness: 50 to >200 cm
Colour: pale coloured to white
Texture: not applicable
Stones: variable usually occasional to absent
Structure: massive
Handling properties: hard to very hard
Bulk density: probably about 2
Permeability: slow to very slow
Hydrology: moist or dry
pH: >7.0
CEC: not applicable
BS: not applicable
OM: <1%
C/N ratio: not applicable
$(Ca+Mg)CO_3$: rare to absent
Soluble salts: absent to common
Weatherable minerals: dominant gypsum
Clays: not applicable
Biological activity: rare to absent
Micromorphology: massive intergrowth of gypsum crystals with varying amounts of calcite
Genesis: accumulation of gypsum
Variability: in thickness, handling properties and percentage of gypsum
Associated horizons: above: a calcon; below: gradation to relatively unaltered material
Distribution: in arid, semi-arid and mediterranean areas
Origin of term: Gk. Petros = Stone and gypson

PETRON - Pt
General definition: thin accumulation of fragments of rock or laterite within the pedo-unit
Synonyms: stone line
Position: middle or lower
Thickness: <20 cm
Colour: variable, usually similar to adjacent material
Texture: variable matrices between the larger fragments
Stones: dominant angular or sub-angular
Structure: not applicable
Handling properties: loose to firm
Bulk density: probably >2
Permeability: very permeable
Hydrology: usually moist
pH: similar to adjacent horizons
CEC: similar to adjacent horizons
BS: similar to adjacent horizons
OM: <2%
C/N ratio: 8-10
$(Ca+Mg)CO_3$: usually absent
Soluble salts: absent
Weatherable minerals: variable
Clays: similar to the adjacent horizons
Concretions: variable
Biological activity: absent to rare
Micromorphology: similar to the adjacent horizons
Genesis: accumulation of rock fragments and/or laterite fragments at a specific depth in the soil; probably due to termite activity
Variability: in the nature of the large fragments

Associated horizons: above: a krasnon, zhelton or some other weathered horizon; below: weathered rock
Distribution: in most humid tropical areas
Origin of term: L. Petra = oval stone

PLACON – Pk

General definition: thin hard pan that is usually composed predominantly of iron with a little humus, may be dominantly manganese
Synonyms: Bms, Birm, thin iron pan, placic horizon
Position: middle or lower and may have a very irregular outline
Thickness: < 2 cm
Colour: very dark brown to black
Texture: not applicable
Stones: placons are usually continuous through stones when present in the soil
Structure: massive
Handling properties: hard to very hard
Bulk density: 1.5–1.8
Permeability: impermeable
Hydrology: above the placon is usually saturated with water but below is moist or dry
pH: not applicable
CEC: not applicable
BS: not applicable
OM: 1 to 20%
C/N ratio: 20–35
$(Ca+Mg)CO_3$: absent
Soluble salts: absent
Weatherable minerals: few to dominant
Clays: iron oxides
Biological activity: low, root mat often occurs at the surface
Micromorphology: see page 130
Genesis: this is not clear, it seems that various organic substances in the soil solution chelate iron as they percolate through the soil and at a critical concentration precipitation takes place
Variability: in composition which varies from predominantly iron to predominantly manganese
Associated horizons: above: a candon or modon; below: a sesquon, ison or argillon
Distribution: common in cool humid temperate areas, rare in humid tropics
Origin of term: Gk. Plax = plate

PLAGGON – Pg

General definition: upper and sometimes middle crude mixture of organic and mineral material added to the surface by man
Synonyms: Ah, Al, Ap, plaggen epipedon
Position: upper and sometimes middle
Thickness: 50–100 cm
Colour: very dark brown to brown to greyish-brown
Texture: medium
Stones: absent to occasional
Structure: crumb to granular to blocky
Handling properties: friable to firm
Bulk density: 1.3–1.5
Permeability: free
Hydrology: usually moist
pH: 5.5–7.0
CEC: 200–400 meq Kg^{-1}

BS: 60-100%
OM: 3-15%
C/N ratio: 8-15
$(Ca+Mg)CO_3$: absent
Soluble salts: absent
Weatherable minerals: variable
Clays: variable
Concretions: absent
Biological activity: very active micro and meso organisms
Micromorphology: similar to that of a mullon, but are mainly medium to coarse texture. There may be a certain amount of lamination due to the addition of material. In older types that are continuously cultivated, laminations have been destroyed and are then very similar to a mullon. The stucture ranges from crumb to granular to blocky to alveolar and there are occasional to frequent faunal passages containing varying amounts of earthworm faecal material. There is yellow or brown isotropic, fine material that ranges from coatings on the sand grains to forming a matrix. Occasional small fragments of plant material and charcoal
Genesis: addition of organic and mineral material to the surface by man to maintain fertility
Variability: in thickness and organic matter content
Associated horizons: below: various
Distribution: mainly in the densely populated parts of northern Europe
Origin of term: G. Plaggen = meadow

PLANON - Pn
General definition: middle or lower, relatively impermeable and contains a significant increase in clay
Synonyms: Bt, Bzt, argillic horizon
Position: middle or lower
Thickness: 30-160 cm
Colour: varies from brown to yellowish-brown to reddish-brown with faint to distinct mottling
Texture: medium to fine with a significant increase in clay
Stones: absent to frequent
Structure: varies from angular blocky to prismatic to massive
Handling properties: firm to hard to plastic
Bulk density: 1.5-1.8
Permeability: slow
Hydrology: usually moist, sometimes wet
pH: 5.5-7.0
CEC: 200-500 meq Kg^{-1}
BS: 20-100%
OM: < 2%
C/N ratio: 8-15
$(Ca+Mg)CO_3$: absent in the upper part
Soluble salts: low to absent
Weatherable minerals: few to abundant
Clays: variable
Concretions: small and black, rare to occasional
Biological activity: very low
Micromorphology: middle, yellow, brown or reddish with marbled or mottled pattern; prismatic to angular blocky, distinctly anisotropic clayey matrix with abundant domains, zones and aureoles. Clay coatings range from abundant and well formed to rare. The clay coatings vary from recent to old with grainy

anisotropic pattern and are being assimulated into the matrix. Occasional to frequent, black segregations that sometimes harden to form concretions
Genesis: weathering and clay mineral formation in a moist environment, and some clay translocation from the horizon above.
Variability: degree of mottling, content of concretions and amount of clay increase
Associated horizons: above: a minon or luvon; below: relatively unaltered material
Origin of term: L. Planus = level

PRIMON - Pr
General definition: upper, crude mixture of organic and mineral material; the initial stage in the formation of an upper horizon
Synonyms: A1, Ah, ochric epipedon
Position: upper
Thickness: 5-20 cm
Colour: varies from brown to greyish-brown to grey
Texture: variable
Stones: variable
Structure: varies with texture from single grain to angular blocky
Handling properties: variable
Bulk density: variable
Permeability: free
Hydrology: usually moist to wet
pH: variable
CEC: variable
BS: variable
OM: 1-5%
C/N ratio: 15-25
$(Ca+Mg)CO_3$: absent to abundant
Soluble salts: very low to absent
Weatherable minerals: absent to abundant
Clays: absent to abundant
Concretions: none
Biological activity: moderate to strong
Micromorphology: mixture of mineral material and partially decomposed organic matter, may have some faunal faecal material
Genesis: mixing of organic and mineral material in the initial stages in the formation of the horizon
Variability: thickness, degree of humification
Associated horizons: above: litter; below: relatively unaltered material
Distribution: small areas throughout the world
Origin of term: L. Primus = first

PSEUDOFIBRON - Pd
General definition: black, very dark brown partially decomposed organic matter, permanently saturated with water
Synonyms: H, O2, histic epipedons
Position: upper, middle and lower
Thickness: 10-200 cm
Colour: very dark brown to black
Texture: not applicable
Stones: absent
Structure: massive, appears fibrous but is easily broken down between the fingers
Handling properties: spongy to plastic VP 5-6
Bulk density: 0.075-0.195

Permeability: very slow
Hydrology: saturated except when drained
pH: 3-5.0
CEC: 800-1200 meq Kg^{-1}
BS: 10-30%
OM: >60%
C/N ratio: 25-40
$(Ca+Mg)CO_3$: absent
Soluble salts: absent
Weatherable minerals: <10%
Clays: none
Concretions: absent
Biological activity: very low
Micromorphology: dark coloured, massive with 30-60% easily recognisable plant remains but showing considerable alteration. Fungal hyphae and phytoliths are absent to occasional
Genesis: accumulation and decomposition of organic matter under anaerobic conditions
Variability: in thickness, mineral content and fibrousness
Associated horizons: above: litter or a fibron; below: an amorphon or cerulon
Distribution: predominantly in cool humid areas, rarely in other humid areas
Origin of term: Gk. Pseudo = false L. Fibra = fibre

ROSSON - Ro
General definition: middle and/or lower, red, strongly weathered with moderate to low cation exchange capacity
Synonyms: Bws, cambic horizon
Position: middle and lower
Thickness: 20-100 cm
Colour: red to reddish-browm, 5YR or redder
Texture: >30% clay
Stones: absent to rare
Structure: granular to blocky often incomplete
Handling properties: firm to friable to plastic
Bulk density: 1.4-1.7
Permeability: moderate to slow
Hydrology: usually moist, wet in the rainy season
pH: 4.5-7.0
CEC: >200 meq Kg^{-1} (clay)
BS: >30%
OM: <5%
C/N ratio: 8-12
$(Ca+Mg)CO_3$: usually absent, rare residual boulder
Soluble salts: absent
Weatherable minerals: <5%
Clays: variable amounts of kaolinite, montmorillonite and mica with lesser amounts of gibbsite, goethite and hematite
Concretions: rare to occasional
Biological activity: rare to occasional
Micromorphology: granular to subangular blocky to poorly developed wedge, due to the range in the clay content. Distinctive red clayey matrices which are very weakly anisotropic to isotropic when granular but becomes progressively more anisotropic as the structure changes to angular blocky and finally to wedge. With a high degree of anisotropism there are abundant small, randomly orientated domains, zones of domains and aureoles around sand grains and pores. The sand fraction is dominantly quartz and other resistant

residual minerals. Passages created by worms or termites with varying amounts of faecal material or termite granules vary from absent to occasional
Genesis: hydrolysis and clay mineral formation in a warm or hot humid climate
Variability: in clay mineralogy, texture
Associated horizons: above: a mullon or tannon; below: chemically weathered rock
Distribution: in many humid tropical and sub-tropical areas
Origin of term: I. Rossa = red

RUBON - Ru
General definition: middle and lower, red, moderately weathered with moderate to low cation exchange capacity
Synonyms: Bws, cambic horizon
Position: middle and lower
Thickness: 20-100 cm
Colour: red to reddish-brown, 5YR or redder
Texture: loam to clay
Stones: absent to occasional
Structure: granular to blocky, complete and incomplete
Handling properties: firm to friable to plastic
Bulk density: 1.4-1.7
Permeability: moderate to slow
Hydrology: usually moist, wet in the rainy season
pH: 4.5-7.0
CEC: >20 meq Kg^{-1} (clay)
BS: >30%
OM: <2%
C/N ratio: 8-12
$(Ca+Mg)CO_3$: absent
Soluble salts: absent
Weatherable minerals: 5-20%
Clays: variable amounts of kaolinite, montmorillonite and mica with lesser amounts of gibbsite, goethite and hematite
Concretions: rare to occasional
Biological activity: rare to occasional
Micromorphology: similar to rosson
Genesis: hydrolysis and clay mineral formation in a warm or hot humid climate
Variability: in texture, clay mineralogy and frequency of concretions
Associated horizons: above: a mullon or tannon; below: chemically weathered rock
Distribution: in many humid tropical and sub-tropical areas
Origin of term: I. Ruber = red

RUFON - Rf
General definition: middle and lower, moderately weathered with low to very low cation exchange capacity
Synonyms: Bws, cambic horizon
Position: middle or lower
Thickness: 20-100 cm
Colour: red to reddish-brown; 5YR or redder
Texture: loam to clay
Stones: absent to rare
Structure: granular to blocky, often incomplete
Handling properties: firm to friable to plastic
Bulk density: 1.4-1.7
Permeability: moderate to slow
Hydrology: usually moist, wet in the rainy season

pH: 4.5-7.0
CEC: >20 meq Kg^{-1} (clay)
BS: >30%
OM: <5%
C/N ratio: 8-12
$(Ca+Mg)CO_3$: absent
Soluble salts: absent
Weatherable minerals: 5-20%
Clays: variable amounts of kaolinite and mica with lesser amounts of gibbsite, goethite and hematite
Concretions: rare to occasional
Biological activity: often abundant termite passages and granules
Micromorphology: similar to rosson
Genesis: hydrolysis and clay mineral formation in a warm or hot climate
Variability: in texture, clay mineralogy and frequency of concretions
Associated horizons: above: a mullon or tannon; below: chemically weathered rock
Distribution: in many humid tropical and sub-tropical areas
Origin of term: L. Rufus = brownish-red

SAPRON- Sa
General definition: strongly weathered middle and lower with the original rock structure partially preserved
Synonyms: C, saprolite
Position: middle and lower
Thickness: usually >1 m
Colour: uniform brown to reddish brown to red
Texture: variable but usually contains much clay
Stones: rare to absent
Structure: massive with weakly preserved rock structure
Handling properties: firm to friable to plastic
Bulk density: 1.2-1.6
Permeability: variable, but usually very permeable
Hydrology: usually moist or wet; may be dry due to climate change
pH: 5.0-6.5
CEC: variable
BS: variable
OM: <1%
C/N ratio: 9-12
$(Ca+Mg)CO_3$: absent
Soluble salts: absent
Weatherable minerals: <10%
Clays: usually high amounts of kaolinite
Concretions: rare to occasional
Biological activity: rare to absent
Micromorphology: massive to weakly alveolar with partially preserved rock structure as seen by the orientation of the resistant minerals. Well-developed matrix with varying degrees of anisotropism with distinct to prominent domains and aureoles
Genesis: strong weathering
Variability: determined largely by the nature of the original rock
Associated horizons: above: a krasnon, rosson or similar horizon; below: progressively less weathered rock
Distribution: in the older landscapes with humid climates
Origin of term: Gk. Sapros = rotten

SERON - Sn

General definition: upper with very low content of organic matter, high base saturation and secondary calcite
Synonyms: A1, Ah, ochric epipedon
Position: upper
Thickness: 5-20 cm, often thin, due to erosion
Colour: yellowish-brown to reddish-brown to red
Texture: loam to silt usually contains less clay and more gravel than the horizon below
Stones: absent to frequent
Structure: weak platy to alveolar to massive with many circular or subcircular pores
Handling properties: firm to brittle
Bulk density: 1.0-1.5
Permeability: moderate to slow
Hydrology: usually dry except in the wet season then moist and rarely wet
pH: 7.0-8.0
CEC: 50-300 meq Kg^{-1}
BS: 100%
OM: <2%
C/N ratio: 8-12
$(Ca+Mg)CO_3$: 1-5%, may be higher from the parent material, then Sec
Soluble salts: <0.5%
Weatherable minerals: variable
Clays: variable
Concretions: usually absent
Biological activity: moderate root growth and some arthropods
Micromorphology: weakly laminar to alveolar to massive with many discrete pores; primary and secondary calcite, occasional to frequent, because these horizons occur under arid and semi-arid conditions; phytoliths, absent to occasional
Genesis: weak leaching, accumulation of some salts and carbonates, removal of fine material by wind and surface wash
Variability: in content of carbonates
Associated horizons: below: a calcon, halon or argillon
Distribution: in arid and semi-arid areas
Origin of term: R. Seri = grey

SESQUON - Sq

General definition: middle, friable to hard, weak crumb, blocky, massive; weakly weathered and contains a significant increase in sesquioxide
Synonyms: Bs, Bir, spodic horizon
Position: middle and lower
Thickness: <30 cm to >1 m
Colour: brown to dark brown, VC2, 4, 5
Texture: loamy sand to loam
Stones: absent to dominant
Structure: weak crumb to blocky to massive
Handling properties: friable to firm to hard
Bulk density: about 1.2-1.7
Permeability: freely permeable
Hydrology: usually moist or dry
pH: 4.5-5.5
CEC: 100-300 meq Kg^{-1} clay
BS: 10-50%
OM: 3-10%
C/N ratio: 12-20
$(Ca+Mg)CO_3$: absent

Soluble salts: absent
Weatherable minerals: absent to frequent similar to the material below
Clays: abundant sesquioxides, some hydrous mica, kaolinite, vermiculite
Biological activity: few roots, low faunal and floral activity, some attribute the small granular structure seen in the thin sections to fauna
Micromorphology: small granules that occur singly or in clusters which sometimes lead to the development of a crude alveolar structure. The granules have a yellowish-brown isotropic matrix
Genesis: accumulation of sesquioxides and humus translocated from the horizons above; also some in situ weathering
Variability: varies mainly in texture, structure, handling properties and stone content; also small variations in colour
Associated horizons: above: a modon or zolon; below: a fragon, ison, marblon, glosson or gradation to the relatively unaltered material
Distribution: common in cool and warm temperate areas
Origin of term: L. Sesqui = one and a half

SIDERON - Sd
General definition: black, very dark brown accumulation of siderite in amorphous peat
Synonyms: H, histic horizon
Position: middle and lower
Thickness: 20-30%
Colour: very dark brown to black, VC1, becomes dark rusty brown when dry
Texture: silt
Stones: absent
Structure: massive
Handling properties: plastic when wet, hard when dry
Bulk density: wet < 1.0; dry < 0.6
Permeability: very slow
Hydrology: saturated with water
pH: 4.5-6.5
CEC: 800-1200 meq Kg^{-1}
BS: 10-30%
OM: 50-90%
C/N ratio: 15-40
$(Ca+Mg)CO_3$: absent
Soluble salts: low to absent
Weatherable minerals: few to absent
Clays: absent
Concretions: occasional siderite concretion
Biological activity: very low to absent
Micromorphology: dark brown, massive with < 5% easily recognisable plant remains in an anisotropic matrix. Frequent acicular crystals of siderite and variable amounts of siderite concretions
Genesis: accumulation of siderite in amorphous peat
Variability: in the amount of siderite
Associated horizons: above: an amorphon; below: a cerulon
Distribution: occasional in cool humid areas
Origin of term: Siderite

SIENNON - Se

General definition: middle and lower, yellowish-brown, moderate to strongly weathered, occurs in the tropics and sub-tropics
Synonyms: Bws, B2, cambic horizon
Position: middle and/or lower
Thickness: 25-100 cm
Colour: yellowish-brown to brown to yellowish-red to reddish-brown, 5YR-10YR
Texture: clay loam to clay, >30% silt plus clay
Stones: absent to rare
Structure: sub-angular blocky; occasional to abundant smooth shiny ped surfaces
Handling properties: firm to friable
Bulk density: 1.4-1.6
Permeability: moderate
Hydrology: usually moist, rarely wet or dry
pH: 4.5-7.0
CEC: >200 meq Kg^{-1} clay
BS: <50%
OM: <5%
C/N ratio: 8-12
$(Ca+Mg)CO_3$: absent
Soluble salts: absent
Weatherable minerals: 5-25%
Clays: predominantly kaolinite with variable amounts of hydrous mica, vermiculite, goethite and gibbsite
Concretions: absent to occasional
Biological activity: ranges from weak to vigorous termite activity
Micromorphology: >5% weatherable minerals, otherwise similar to zhelton
Genesis: progressive hydrolysis through a long period of time
Variability: in structure and thickness
Associated horizons: above: a tannon; below: a pesson, petron or chemically weathered rock
Distribution: in tropical and sub-tropical areas
Origin of term: It. Sienna = brown soil of Siena in Tuscany

SOLON - Sl

General definition: middle, columnar or prismatic with pH > 8.5 and low salt content
Synonyms: Btn, natric horizon
Position: middle and/or lower
Thickness: 20-100 cm
Colour: grey to greyish-brown to brown with fine yellow mottles
Texture: loam to clay with a considerable clay increase
Stones: rare to absent
Structure: columnar to prismatic to blocky
Handling properties: firm to hard to plastic
Bulk density: 1.6-1.8
Permeability: very slow within peds, often moderate between the columns or prisms
Hydrology: usually moist or dry
pH: 8-9, usually a distinct vertical change to over 8.5 in the lowest part
CEC: 150-300 meq Kg^{-1}
BS: 100% > 15% exchangeable sodium or sodium plus magnesium exceeds calcium plus hydrogen
OM: < 3%
C/N ratio: 8-15

(Ca+Mg)CO_3: generally low but may be up to 35% in Turkey increasing with depth; similar to the Malle soils of Australia
Soluble salts: EC < 4 mmhos
Weatherable minerals: 5-50%
Clays: variable amounts of mica, kaolinite and montmorillonite
Concretions: small, black, absent to frequent
Biological activity: absent to weak
Micromorphology: thin sections usually only include a part of a prism or columnar unit. Within these units the structure is massive or weakly alveolar. Clay coatings range from rare to abundant and when present in large amounts seem to be undergoing much internal reorganisation. The matrices vary from weak to strongly anisotropic with the latter usually the more common. Mottles of iron oxide and manganese dioxide segregations and concretions are common in these horizons. The columnar or prismatic ped faces show evidence of removal of the fine material giving rise to sandy residues on their surfaces
Genesis: formation of clay in situ and a little translocated from above
Variability: in the degree of structure development
Associated horizons: above: a luvon; below: a calcon, gypson or relatively unaltered material
Distribution: in semi-arid areas
Origin of term: R. Solonetz = salt

SOMBRON - So
General definition: middle, dark brown to black accumulation of humus, forming coatings on pores and ped surfaces
Synonyms: Bh, B2, sombric horizon
Position: middle
Thickness: 20-50 cm
Colour: yellowish-brown to strong brown to dark brown
Texture: medium to fine
Stones: usually absent
Structure: blocky
Handling properties: friable to firm
Bulk density: 1.2-1.5
Permeability: usually freely permeable
Hydrology: usually moist, occasionally wet
pH: 4.0-5.5
CEC: low
BS: low
OM: 2-10%
C/N ratio: 6-12
(Ca+Mg)CO_3: absent
Soluble salts: absent
Weatherable minerals: absent to rare
Clays: dominantly kaolinite
Concretions: usually absent
Biological activity: weak
Micromorphology: generally blocky with a concentration of dark isotropic humic material on ped surfaces and pores
Genesis: accumulation of translocated humus in humid tropical upland situations
Variability: in thickness and colour
Associated horizons: sombrons seem to polygenetic horizons in which the humus is deposited in a previously well formed horizon which are often zheltons or flavons

Distribution: in humid tropical areas
Origin of term: F. Sombre = dark

SPHERON - Sp
General definition: middle or lower, massive, dominated by gibbsite concretions having an outer concentric shell
Synonyms: Bcm, Ccm, laterite, duricrust
Position: middle or lower
Thickness: 1-2 m
Colour: yellowish-brown matrix and outer coatings of the concretions, pale red inner parts of the concretions
Texture: not applicable
Stones: absent
Structure: massive
Handling properties: hard to very hard
Bulk density: probably about 2
Permeability: very slow
Hydrology: ranges from dry to wet with the season of the year
pH: not applicable
CEC: not applicable
BS: not applicable
OM: < 1%
C/N ratio: probably about 12
$(Ca+Mg)CO_3$: absent
Soluble salts: low to absent
Weatherable minerals: < 1%
Clays: gibbsite and kaolinite
Concretions: dominant gibbsite concretions that have an outer shell of clay size gibbsite and an inner core with partly preserved rock structure
Biological activity: very weak
Micromorphology: massive with dominant subspherical concretions. Each concretion has a central core of weathered rock or fragments of another concretion surrounded by a concentrically ringed coating of clay. Gibbsite is the dominant mineral in the fine material in both the core and the outer coating
Genesis: differentiation of concretions from a pallon accompanied by the transformation of kaolinite to gibbsite
Variability: in the size of the concretion, the thickness of the shell and the type of core
Associated horizons: above: an arenon; below: (SpPn)
Distribution: principally in western Australia
Origin of term: E. Sphere

SULPHON - Su
General definition: upper or middle with an accumulation of soluble salts particularly sulphates
Synonyms: Az, Bz, Cz, salic horizon
Position: upper or middle
Thickness: 10-100 cm
Colour: yellowish-brown to brownish-grey to grey
Texture: variable
Stones: absent to frequent
Structure: blocky to prismatic to massive
Handling properties: firm to friable
Bulk density: 1.5-1.7
Permeability: moderate to low
Hydrology: usually dry, moist or wet during the rainy season
pH: 7.5-8.5

CEC: variable
BS: 100%
OM: <5%
C/N ratio: 12
$(Ca+Mg)CO_3$: 0-50% from the parent material
Soluble salts: >70% SO_4^{2-} in the saturation extract, EC > 4 mmhos
Weatherable minerals: variable
Clays: variable with a tendency to have much montmorillonite
Concretions: absent
Biological activity: weak
Micromorphology: massive, alveolar or blocky with a range of secondary crystalline material including calcite, gypsum and halite. The crystals may occur within peds, between peds, singly or in clusters. Although significant amounts of halite may be present in these horizons its identification might be difficult because its refractive index is very close to that of the impregnating resin
Genesis: accumulation of soluble salts in an arid or semi-arid environment
Associated horizons: an alkalon, chloron or halon
Variability: in the proportion of cations and anions
Distribution: in the arid and semi-arid areas
Origin of term: L. Sulfur = sulphur

TANNON - Tn
General definition: upper intimate mixture of organic and mineral material, crumb or granular with low organic matter content
Synonyms: A1, Ah, some ochric horizons
Position: upper
Thickness: 5-25 cm
Colour: brown to yellowish-brown to reddish-brown to greyish-brown
Texture: variable
Stones: absent to frequent
Structure: crumb to angular to blocky
Handling properties: firm to friable to plastic
Bulk density: 1.2-1.5
Permeability: free
Hydrology: usually moist or dry
pH: 4.5-7.0
CEC: 50-200 meq Kg^{-1}
BS: 10-100%
OM: < 2%
C/N ratio: 8-12
$(Ca+Mg)CO_3$: variable from parent material
Soluble salts: absent
Weatherable minerals: occasional to dominant
Clays: variable
Concretions: absent
Biological activity: moderate to strong
Micromorphology: variable colour with medium to high chromas; crumb, granular or blocky structure with frequent to abundant pore space. The peds are often fragments of earthworm faecal material and have isotropic or faintly anisotropic clay or clay/humus matrices
Genesis: mixing of organic and mineral material by soil fauna
Variability: in colour and thickness
Associated horizons: above: litter; below: variable
Distribution: in humid and sub-humid areas
Origin of term: c. Tann = oak

THION - To

General definition: middle or lower, grey or bluish-grey, anaerobic with occasional to abundant pyrite

Synonyms: Br, Cr, sulphidic material

Position: middle or lower

Thickness: 50-100 cm

Colour: grey to olive to greyish-blue, with black pyrite grains as speckles or clusters

Texture: usually medium to fine

Stones: usually absent

Structure: massive to prismatic when dry

Handling properties: soft to firm to hard to plastic

Bulk density: 1.5-1.7

Permeability: slow

Hydrology: saturated with water

pH: 3-4.5 or 6-8; very acid when dry, about neutral when wet

CEC: 200-400 meq Kg^{-1}

BS: 30-50%

OM: 0-30%

C/N ratio: 20-35

$(Ca+Mg)CO_3$: absent

Soluble salts: low to moderate from sea water

Weatherable minerals: variable

Clays: hydrous mica, montmorillonite, kaolinite

Concretions: none

Biological activity: very low, may have pneumataphores

Micromorphology: pale grey or olive and massive with variable anisotropism of the clayey matrices and occasional to frequent opaque grains of pyrite

Genesis: reduction of iron and formation of pyrite in an anaerobic environment containing organic matter and sulphur

Variability: in colour and content of pyrite

Associated horizons: above: an amorphon or gyttjon; below: a cerulon

Distribution: throughout the world in estuaries and coastal marshes

Origin of term: Gk. Theion = sulphur

VERTON - Ve

General definition: middle, very dark coloured with a high content of expanding lattice clay and characteristic wedge structure

Synonyms: Al, vertic properties

Position: middle or lower

Thickness: 50-200 cm

Colour: black to very dark grey to reddish-brown

Texture: clay; >35% clay >20% strongly expanding lattice minerals

Stones: usually absent

Structure: usually a distinctive wedge structure, or blocky to massive with slickensides

Handling properties: hard when dry, firm when moist, plastic when wet

Bulk density: 1.6-2.0

Permeability: rapid when dry to very slow when wet

Hydrology: varies from saturated during the short wet season to dry during the dry season

pH: 5.5-7.0

CEC: 500-1000 meq Kg^{-1}

BS: 50-100%

OM: <2%

C/N ratio: 8-12

(Ca+Mg)CO_3: usually absent in upper part, may be present from the parent material then Vec
Soluble salts: low to absent
Weatherable minerals: 10-30%
Clays: dominantly montmorillonite with lesser amounts of mica and kaolinite
Concretions: sometimes occasional small black concretions of manganese dioxide or calcium carbonate concretions stained with manganese dioxide. Often white powdery concretions of calcium carbonate in the lower part
Biological activity: weak
Micromorphology: wedge, with brown to dark greyish-brown distinctly anisotropic clayey matrices containing abundant small domains and rare to occasional diagonal anisotropic lines. The matrices have abundant black speckles probably of manganese dioxide. Calcite concretions are sometimes present
Genesis: clay formation or transformation in a basic environment. Usually marked seasonal moisture variation causing expansion and contraction, churning and gilgai formation
Variability: in colour
Associated horizons: above: a crumon, dermon or luton; below: a calcon, gleyson, weathered rock or relatively unaltered material
Distribution: in many semi-arid areas
Origin of term: L. Vertere = to turn

VESON - Vs
General definition: upper, middle or lower vesicular accumulations of sesquioxides which harden on exposure
Synonyms: Bsm, Csm, vesicular laterite, plinthite
Position: upper, middle or lower
Thickness: 50-300 cm
Colour: mottled, red to brown to yellowish-brown
Texture: clay loam to clay
Stones: absent to rare
Structure: vesicular, labyrinthine; the labyrinthine structure has most probably been produced by the soil fauna, either they burrowed through a soft material which later hardened or certain parts of the material hardened and the soft parts were removed by the soil fauna
Handling properties: plastic to hard
Bulk density: 1.4-1.7
Permeability: very free
Hydrology: usually moist or dry
pH: not applicable
CEC: not applicable
BS: not applicable
OM: <2%
C/N ratio: not applicable
(Ca+Mg)CO_3: absent
Soluble salts: absent
Weatherable minerals: <5%
Clays: dominantly kaolinite, with lesser amounts of goethite, gibbsite and hematite
Concretions: rare to occasional
Biological activity: strong, see Genesis
Micromorphology: mottled red or dark brown and cream with massive or alveolar structure, often with partially preserved rock structure and may contain small, black concretions

Genesis: weathering in a moist to wet subsurface environment with subsequent faunal activity to produce the labyrinthine structure
Variability: in content of goethite and gibbsite and hardness
Associated horizons: above: a krasnon, zhelton or flavon; below: a flambon or weathered rock
Distribution: in most humid tropical areas
Origin of term: L. Vesica = cyst

ZHELTON - Zh
General definition: middle or lower, brown, strongly weathered with very low cation exchange capacity
Synonyms: Bsm, oxic horizon
Position: middle or lower
Thickness: 25-200 cm
Colour: yellowish-brown to brown to reddish-yellow to reddish-brown
Texture: clay > 30% clay; silt to clay ratio < 0.15 on crystalline rocks < 0.2 on sediments
Stones: usually absent
Structure: incomplete blocky and/or labyrinthine
Handling properties: firm to friable to plastic
Bulk density: 1.4-1.6
Permeability: moderate to slow
Hydrology: usually moist or damp, seldom dry
pH: 5.5-7.5
CEC: < 150 meq Kg^{-1}
BS: 10-50%
OM: < 5%
C/N ratio: 8-12
$(Ca+Mg)CO_3$: absent
Soluble salts: absent
Weatherable minerals: < 5%
Clays: dominantly kaolinite with variable amounts of goethite, gibbsite and sometimes small amounts of mica and chlorite
Concretions: absent to occasional, dark brown or black
Biological activity: occasional to abundant termite activity
Micromorphology: granular, but more usually incomplete angular blocky or labyrinthine, usually moderate translucence with moderately to strongly anisotropic matrix with domains, zones and aureoles. Clay coatings range from absent to occasional, when more than 2%, the horizons should be regarded as the compound horizons {ZhAr}
Genesis: hydrolysis and clay mineral form in a moist hot environment
Variability: in colour, thickness
Associated horizons: above: a tannon or mullon; below: a petron, chemically weathered rock or sediment
Distribution: in humid tropical areas
Origin of term: R. Zhelti = yellow

ZOLON - Zo
General definition: pale coloured, bleached upper horizons containing less clay and/or sesquioxides than the horizon below
Synonyms: E, A2, albic horizon
Position: usually upper, rarely middle or lower
Thickness: 1 cm to > 1 m
Colour: grey, pale brown, VC2
Texture: loam to sandy loam to loamy sand

Zolon

Stones: absent to frequent
Structure: single grain to very weak crumb to massive, to lenticular
Handling properties: loose to friable, in some rare cases very hard and cemented with opal then Zod
Bulk density: 1.2-1.5
Permeability: freely permeable
Hydrology: usually aerobic but may become anaerobic by the development of an impermeable middle horizon
pH: 3.5-5.0
CEC: 50-200 meq Kg^{-1}
BS: <20%
OM: 0.5-5%
C/N ratio: 16-20
$(Ca+Mg)CO_3$: absent
Soluble salts: absent
Weatherable minerals: absent to occasional
Clays: kaolinite and hydrous mica; smectite has been reported in some
Biological activity: very low
Micromorphology: usually single grains to alveolar with a tendency to be massive, the small amount of silt and clay may fill spaces between the larger grains but it is difficult to recognise a clayey matrix. Very pale coloured, usually with distinctive black speckling due to minerals like ilmenite and magnetite but more particularly to small fragments of charcoal. Most zolons have large fragments (1-5 mm) of charcoal from forest fires. With time these larger fragments become fragmented to cause much of the speckling. Some zolons have coatings of clay lining the bottoms of small pores. In many cold areas zolons freeze during the winter causing the formation of a distinctive laminar or lenticular structure in which the upper surfaces of peds have thin coatings or impregnations of fine material. Structures and fabrics of this type are very common in the soils of Canada, Alaska and the USSR
Genesis: strong weathering and the removal by leaching of iron and aluminium by percolating waters, some base cations, and silica are also removed
Variability: in thickness
Associated horizons: above: a modon or humifon; below: a sesquon, husesquon, hudepon and argillon
Distribution: common in humid temperate areas and in humid mid continental areas
Origin of term: R. Zola = ash

TABLE 2 DIAGNOSTIC HORIZONS AND THEIR APPROXIMATE EQUIVALENT SEGMENTS

Agric horizon:	Agron
Albic horizon:	Candon, luvon, minon and zolon
Anthropic epipedon:	Mullon
Argillic horizon:	Argillon, glosson and planon
Calcic horizon:	Calcon
Cambic horizon:	Alton, aluminon, andon, cerulon, flavon, gleyson, helvon, marblon, pelon, rosson, rubon, rufon and siennon
Duripan:	Duron
Fragipan:	Fragon and ison
Gypsic horizon:	Gypson
Histic epipedon:	Amorphon, fibron, gyttjon, hydromoron, pseudofibron and sideron
Mollic epipedon:	Buron, chernon, kastanon and mullon
Natric horizon:	Solon
Oxic horizon:	Krasnon and zhelton
Ochric epipedon:	Anmooron, dermon, gelon, granulon, kuron, luton, modon, mullon, nekron, seron and tannon
Petrocalcic horizon:	Petracalcon
Petrogypsic horizon:	Petragypson
Placic horizon:	Placon
Plaggen epipedon:	Plaggon
Salic horizon:	Alkalon, chloron, halon and sulphon
Sombric horizon:	Sombron
Spodic horizon:	Ferron, hudepon, husesquon and sesquon
Sulphuric horizon:	Jaron
Umbric epipedon:	Mullon intergrades

TABLE 3 FAO-Unesco class names and their aproximate equivalents in FitzPatrick and Soil Taxonomy

FAO-UNESCO	FITZPATRICK	SOIL TAXONOMY
Acrisols	Luvosols	Ultisols
Alisols	Luvosols	Ultisols
Andosols	Andosols	Andepts
Anthrosols	Plaggen soils	Plaggepts
Arenosols	Arenosols	Psamments
Calcisols	Serozems Burozems	Orthids
Cambisols	Altosols Flavosols Pelosols Rossosols Rubosols Rufosols	Ochrepts
Chernozems	Chernozems	Borolls
Ferralsols	Krasnozems Zheltozems	Orthox
Fluvisols	Fluvisols Thiosols	Fluvents
Gleysols	Subgleysols Cryosols	Aquents
Greyzems	Greyzems	Argiborolls
Histosols	Peat	Histosols
Kastanozems	Kastanozems	Ustolls
Leptosols	Lithosols Rankers Rendzinas	Lithic subgroups
Lixisols	Argillosols	Alfisols
Luvisols	Argillosols	Alfisols
Nitosols	Krasnozems and Zheltozems intergrades	Udults
Phaeozems	Brunizems	Udolls
Planosols	Planosols Solods	Aqualfs
Plinthisols	Vesosols Spherosols	Plinthic subgroups
Podzols	Podzols Placosols	Spodosols

Table 3 continued

FAO-UNESCO	FITZPATRICK	SOIL TAXONOMY
Podzoluvisols	Supragleysols	Glossudalfs
Regosols	Primosols	Entisols
Solonchaks	Solonchaks	Salorthids
Solonetz	Solonetz	Natrustalfs
Vertisols	Vertisols	Vertisols

TABLE 4

PART OF THE RANGE OF VARIABILITY IN ORTHIC PODZOLS

Spodic B horizon with $\frac{Fe}{C}$ <6; and either or both an E and Bhs

FAO-UNESCO	FITZPATRICK
E Bs C	Zo Sq Asl
E Bs Cx	Zo Sq Ind
E Bhs Bs C	Zo Hs Sq Asl
E Bhs Bs Cx	Zo Hs Sq Ind
E Bs Bhs C	Zo Sq Hs Asl
E Bs Bhs Cx	Zo Sq Hs Ind
E Bs Bms C	Zo Sq Pk Asl
E Bs Bms Cx	Zo Sq Pk Ind
E Bhs Bs Bms C	Zo Hs Sq Pk Asl
E Bhs Bs Bms Cx	Zo Hs Sq Pk Ind
E Bs Bhs Bms C	Zo Sq Hs Pk Asl
E Bs Bhs Bms C	Zo Sq Hs Pk Ind
E Bhs Cx	Zo Hs Ind
E Bhs C	Zo Hs Asl
E Bhs Bms C	Zo Hs Pk Asl
E Bhs Bms Cx	Zo Hs Pk Ind
Ah Bhs Bs C	Mo Hs Sq Asl
Ah Bhs Bs Cx	Mo Hs Sq Ind
Ah Bhs Bs Pk Asl	Mo Hs Sq Pk Asl
Ah Bhs Bs Pk Ind	Mo Hs Sq Pk Ind
Ah Bs Bhs C	Mo Sq Hs Asl
Ah Bs Bhs Cx	Mo Sq Hs Ind
Ah Bs Bhs C	Mo Sq Hs Pk Asl
Ah Bs Bhs Bms Cx	Mo Sq Hs Pk In

TABLE 5

PART OF THE RANGE OF VARIABILITY IN TYPIC FRAGIORTHODS

FAO-UNESCO	FITZPATRICK
Ah Bs Cx	Mo Sq Fg
Ah Bhs Cx	Mo Hs Fg
Ah Bs Bhs Cx	Mo Sq Hs Fg
Ah Bhs Bs Cx	Mo Hs Sq Fg
Ah Bs Cx	Mo Sq In
Ah Bhs Cx	Mo Hs In
Ah Bs Bhs Cx	Mo Sq Hs In
Ah Bhs Bs	Mo Hs Sq In
Ah Bs Bms Cx	Mo Sq Pk In
Ah Bs Bhs Bms Cx	Mo Sq Hs Pk In
Ah Bhs Bs Bms Cx	Mo Hs Sq Pk In
E Bs Cx	Zo Sq Fg
E Bhs Cx	Zo Hs Fg
E Bs Bhs Cx	Zo Sq Hs Fg
E Bhs Bs Cx	Zo Hs Sq Fg
E Bs Cx	Zo Sq In
E Bhs Cx	Zo Hs In
E Bs Bhs Cx	Zo Sq Hs In
E Bhs Bs Cx	Zo Hs Sq In
E Bs Bms Cx	Zo Sq Pk In
E Bs Bhs Bms Cx	Zo Sq Hs Pk In
E Bhs Bs Bms Cx	Zo Hs Sq Pk In
Ah Bs Eg Cx	Mo Sq Co Fg
Ah Bs Bhs Eg Cx	Mo Sq Hs Co Fg
Ah Bhs Bs Eg Cx	Mo Hs Sq Co Fg
E Bs Eg Cx	Zo Sq Co In
E Bs Bhs Eg Cx	Zo Sq Hs Co Fg
E Bhs Bs Co Cx	Zo Hs Sq Co Fg
Ah Bs Eg Cx	Mo Sq Co In
Ah Bs Bhs Eg Cx	Mo Sq Hs Co In
Ah Bhs Bs Eg Cx	Mo Hs Sq Co In
E Bs Eg Cx	Zo Sq Co In
E Bs Bhs Eg Cx	Zo Sq Hs Co In
E Bhs Bs Eg Cx	Zo Hs Sq Co In

There may be varying thickness of organic horizons and the Bs(Sq) and/or the Bhs(Hs) may be very or extremely firm; thus doubling at least the above possibilities.

TABLE 6

SOIL SEGMENTS AND THEIR EQUIVALENTS IN FAO-UNESCO AND USDA

FITZPATRICK		**FAO-UNESCO**		**USDA**	
Name	Symbol	Name	Symbol	Name	Symbol
Agron	Ao	-	Bt	Agric horizon	B1
Alkalon	Ak	Sodic phase	Az, Bz, Cz	-	Asa, Bsa, Csa
Alton	At	Cambic B horizon	Bw	Cambic horizon	B2
Aluminon	Ai	Cambic B Horizon	Bw	Cambic horizon	B2
Amorphon	Ap	Histic H horizon	H	Histic epipedon	O2
Andon	An	Andic soil material	Bw	Cambic horizon	B2
Anmooron	Am	Umbric A horizon	Ah	Umbric epipedon	A1
Arenon	Ae	-	Bw	-	B2
Argillon	Ar	Argillic B horizon	Bt	Argillic horizon	B2t
Buron	Bu	Mollic A horizon	Ah	Ochric epipedon	A1
Calcon	Ck	Calcic horizon	Bk, Ck	Calcic horizon	Bca, Cca
Candon	Co	Albic E horizon	Eg	Albic horizon	A2g
Cerulon	Cu	Hydromorphic properties	Br, Cr	Cambic horizon	B2g, Cg
Chernon	Ch	Mollic A horizon	Ah	Mollic epipedon	A1

FITZPATRICK		FAO-UNESCO		USDA	
Name	Symbol	Name	Symbol	Name	Symbol
Chloron	Ci	Salic properties	Az, Bz, Cz	Salic horizon	Asa, Bsa, Csa
Cryon	Cy	Permafrost	Cf	Permafrost	Cf
Cumulon	Cm	Petric phase	Bcs, Ccs	Cambic horizon	Bcn, Ccn
Dermon	De	-	Ah	-	A1
Duron	Du	Duripan	Cmq	Duripan	Csi
Fermenton	Fm	-	O	-	O1
Ferron	Fr	Spodic B horizon	Bs	Spodic horizon	Bir
Fibron	Fi	Histic H horizon	H	Histic epipedon	O1
Flambon	Fb	Plinthite (some)	C	Plinthite (some)	C
Flavon	Fv	Cambic B horizon	Bw	Cambic horizon	B2
Fragon	Fg	Fragipan	Cx	Fragipan	Cx
Gelon	Gn	Umbric or ochric A horizon	Ah	Umbric or ochric epipedon	A1
Gleyson	Gl	Hydromorphic properties	Bg, Cg	Cambic horizon	Bg
Glosson	Gs	Tonguing	Bg, Cg	Argillic horizon	B2t
Gluton	Gt	Ironstone	Bms, Cms	-	Cm
Granulon	Gr	Ochric A horizon	Ah	Ochric epipedon	A1
Gypson	Gy	Gypsic horizon	By, Cy	Gypsic horizon	Ccs
Gyttjon	Gy	Histic H horizon	H	Histic epipedon	O

FITZPATRICK		FAO -UNESCO		USDA	
Name	Symbol	Name	Symbol	Name	Symbol
Halon	Hl	Salic properties	Az, Bz, Cz	Salic horizon	Asa, Bsa, Csa
Hamadon	Ha	Yermic properties	A	-	-
Helvon	He	Cambic B horizon	Bw	Cambic horizon	B2
Hudepon	Hd	Spodic B horizon	Bh	Spodic horizon	Bh
Humifon	Hf	-	O2	-	O2
Husesquon	Hs	Spodic B horizon	Bhs	Spodic horizon	Bhir
Hydromoron	Hy	-	O	-	O2
Ison	In	Fragipan	Cx	Fragipan	Cx
Jaron	Ja	Sulphuric horizon	Bg	Sulphuric horizon	B2g, Cg
Kastanon	Kt	Mollic A horizon	Ah	Mollic epipedon	A1
Krasnon	Ks	Oxic B horizon	Bsw	Oxic horizon	B2
Kuron	Ku	Umbric A horizon	Ah	Umbric epipedon	A1
Limon	Lm	-	Ckg	-	Cca
Lithon	Lh	-	-	-	-
Litter	Lt	Litter	O	Litter	O1
Luton	Ln	Umbric A horizon	Ahg	Ochric and umbric epipedon	A1
Luvon	Lv	Albic E horizon	E	Albic horizon	A2

FITZPATRICK		FAO-UNESCO		USDA	
Name	Symbol	Name	Symbol	Name	Symbol
Marblon	Mb	Hydromorphic properties	Bg	Cambic horizon	B2g
Minon	Mi	Albic E horizon	Eg	Albic horizon	A2g
Modon	Mo	Ochric and umbric A horizon	Ah	Ochric and umbric epipedon	A1
Mullon	Mu	Mollic A horizon	Ah	Mollic and umbric epipedon	A1
Nekron	Nk	Ochric and umbric A horizon	Ah	Ochric and umbric epipedon	A1
Oron	Or	Petroferric phase	Bms, Cms	-	Birm
Pallon	Pl	-	C	-	C
Pelon	Pe	Cambic B horizon	Bw	Cambic horizon	B2
Pesson	Ps	Petric phase	Bcs	-	Bcn
Petracalcon	Pc	-	Cmk	Petracalcic horizon	Bca
Petragypson	Py	-	Cmy	Petragypsic horizon	Bcs
Petron	Pt	-	B	-	-
Placon	Pk	Thin iron pan	Bms	Placic horizon	Birm
Plaggon	Pg	Fimic A horizon	Ap	Plaggen epipedon	Ap
Planon	Pn	Argillic B horizon	Btg	Argillic horizon	B2t

FITZPATRICK		FAO-UNESCO		USDA	
Name	Symbol	Name	Symbol	Name	Symbol
Primon	Pr	Ochric A horizon	Ah	Ochric epipedon	A1
Pseudofibron	Pd	Histic H horizon	H	Histic epipedon	O2
Rosson	Ro	Cambic B horizon	Bws	Cambic horizon	B2
Rubon	Ru	Cambic B horizon	Bws	Cambic horizon	B2
Rufon	Rf	Cambic B horizon	Bws	Cambic horizon	B2
Sapron	Sa	-	C	-	C
Seron	Sn	Ochric A horizon	Ah	Ochric epipedon	A1
Sesquon	Sq	Spodic B horizon	Bs	Spodic horizon	Bir
Sideron	Sd	Histic H horizon	H	Histic epipedon	O2
Siennon	Si	Cambic B horizon	Bws	Cambic horizon	B2
Solon	Sl	Natric B horizon	Btn	Natric horizon	Bt
Sombron	So	-	Bh	Sombric horizon	Bt2
Spheron	Sp	-	Bcm	-	Bcn
Sulphon	Su	Salic properties	Az, Bz, Cz	Salic horizon	Asa, Bsa, Csa
Tannon	Tn	Ochric A horizon	Ah	Ochric epipedon	A1
Thion	To	Sulphidic material	Br, Cr	Sulphidic material	B2g, Cg
Verton	Ve	Vertic properties	Bu	Vertic properties	B2

FITZPATRICK		FAO-UNESCO		USDA	
Name	Symbol	Name	Symbol	Name	Symbol
Veson	Vs	Plinthite (some)		Plinthite (some)	C
		Ironstone (some)	Bsm		
Zhelton	Zh	Oxic B horizon	Bws	Oxic horizon	B2
Zolon	Zo	Albic E horizon	E	Albic horizon	A2

TABLE 7

SEGMENT GROUPING ACCORDING TO COLOUR

Black, Very dark brown, Very dark grey	Dark brown, Reddish-brown	Brown, Yellowish-Brown	Dark grey, Greyish-brown	Brownish-grey, Grey, Pale brown	Mottled	Bluish-grey, Olive brown, Olive	Red, Brownish-red, Yellowish-red
AGRON	AGRON	Agron	AGRON	Agron	-	-	-
-	-	-	ALKALON	-	ALKALON	ALKALON	-
-	-	ALTON	-	-	-	-	Alton
-	-	ALUMINON	-	-	-	-	-
AMORPHON*	-	-	-	-	-	-	-
-	ANDON	ANDON	-	-	-	-	-
ANMOORON	-	-	ANMOORON	-	-	-	-
-	-	ARENON	-	-	-	-	ARENON
-	ARGILLON	ARGILLON	-	-	-	-	Argillon
-	BURON	-	-	-	-	-	-
-	-	-	CALCON	CALCON	-	-	-
-	-	-	-	-	CANDON	-	-
-	-	-	-	-	-	CERULON	-
CHERNON	-	-	-	-	-	-	-
-	-	-	CHLORON	-	CHLORON	CHLORON	-

Black, Very dark brown, Very dark grey	Dark brown, Reddish-brown	Brown, Yellowish-Brown	Dark grey, Greyish-brown	Brownish-grey, Grey, Pale brown	Mottled	Bluish-grey, Olive brown, Olive	Red, Brownish-red, Yellowish-red
–	–	–	CRYON	–	–	CRYON	–
–	CUMULON	–	–	–	–	–	CUMULON
DERMON	–	–	–	–	–	–	–
–	DURON	DURON	–	–	–	–	–
FERMENTON*	–	–	–	–	–	–	–
–	–	FERRON	–	–	–	–	–
FIBRON*	–	–	–	–	–	–	–
–	–	–	–	–	FLAMBON	–	–
–	–	FLAVON	–	–	–	–	FLAVON
–	–	FRAGON	–	FRAGON	Fragon	Fragon	–
–	–	GELON	GELON	–	–	–	–
–	–	–	–	–	GLEYSON	–	–
–	–	–	–	–	GLOSSON	–	–
–	GLUTON	–	–	–	–	–	GLUTON
GRANULON	–	–	–	–	–	–	–
–	–	–	GYPSON	GYPSON	–	–	–
GYTTJON*	–	–	–	–	–	–	–
–	–	–	HALON	HALON	–	–	–

Black, Very dark brown, Very dark grey	Dark brown, Reddish-brown	Brown, Yellowish-brown	Dark grey, Greyish-brown	Brownish-grey, Grey, Pale brown	Mottled	Bluish-grey, Olive brown, Olive	Red, Brownish-red, Yellowish-red
-	-	HELVON	-	-	-	-	-
HAMADON	-	HAMADON	HAMADON	-	-	-	-
HUDEPON	-	-	-	-	-	-	-
HUMIFON*	-		-				
HUSESQUON	-	-	-	-	-	-	-
HYDROMORON*	-	-	-	-	-	-	-
-	-	-	-	ISON	Ison	Ison	Ison
-	-	-	-	-	JARON	-	-
KASTANON	KASTANON	-	-	-	-	-	-
-	-	-	-	-	-	-	KRASNON
KURON	-	-	-	-	-	-	-
-	-	-	-	LIMON	-	-	-
-	-	LITHON	-	-	-	-	-
-	-	LITTER	-	-	-	-	-
LUTON	LUTON	-	LUTON	-	LUTON	-	Luton
-	-	-	-	LUVON	-	-	-
-	-	-	-	-	MARBLON	-	-
-	-	-	-	MINON	MINON	-	-
MODON	-	-	Modon	-	-	-	-

Black, Very dark brown, Very dark grey	Dark brown, Reddish-brown	Brown, Yellowish-brown	Dark grey, Greyish-brown	Brownish-grey, Grey, Pale brown	Mottled	Bluish-grey, Olive brown, Olive	Red Brownish-red, Yellowish-red
MULLON	MULLON	Mullon	-	-	-	-	-
ORON	-	-	-	-	-	-	-
-	-	-	-	-	PALLON	-	-
-	PELON	PELON	-	-	-	-	PELON
-	PESSON	-	-	-	-	-	PESSON
-	-	-	PETRACALCON	PETRACALCON	-	-	-
-	-	-	PETRAGYPSON	PETRAGYPSON	-	-	-
PLACON	PLACON	-	-	-	-	-	-
PLAGGON	PLAGGON	PLAGGON	-	-	-	-	-
-	-	-	-	-	PLANON	-	-
-	-	-	PRIMON	-	-	-	-
PSEUDOFIBRON*	-	-	-	-	-	-	-
-	Rosson	-	-	-	-	-	ROSSON
-	Rubon	-	-	-	-	-	RUBON
-	Ruffon	-	-	-	-	-	RUFFON
-	SAPRON	SAPRON	-	-	SAPRON	-	SAPRON
-	SERON	SERON	-	-	-	-	Seron
-	SESQUON	SESQUON	-	-	-	-	-
SIDERON	-	-	-	-	-	-	-

Black, Very dark brown, Very dark grey	Dark brown, Reddish-brown	Brown, Yellowish-brown	Dark grey, Greyish-brown	Brownish-grey, Grey Pale brown	Mottled	Bluish-grey Olive brown, Olive	Red, Brownish-red, Yellowish-red
-	-	SIENNON	-	-	-	-	-
SOLON	SOLON	-	-	-	-	-	-
Spheron	SPHERON	SPHERON	-	-	-	-	-
-	-	-	SULPHON	-	SULPHON	SULPHON	-
-	TANNON	TANNON	-	-	-	-	-
-	-	-	THION	-	-	THION	-
VERTON	-	-	-	-	-	-	-
-	VESON	-	-	-	VESON	-	VESON
-	-	ZHELTON	-	-	-	-	-
-	-	-	-	ZOLON	-	-	-

* Predominantly organic horizons
Lower case indicates lower frequency

TABLE 8
SEGMENT GROUPING ACCORDING TO POSITION

UPPER	MIDDLE	LOWER	UPPER	MIDDLE	LOWER
ALKALON	ALKALON	ALKALON	-	KRASNON	Krasnon
-	ALTON	-	KURON	-	-
ALUMINON	ALUMINON	Aluminon	-	LIMON	-
AMORPHON	AMORPHON	AMORPHON	-	LITHON	-
-	ANDON	-	LITTER	-	-
ANMOORON	-	-	LUTON	-	-
-	ARENON	Arenon	LUVON	Luvon	-
-	ARGILLON	Argillon	-	MARBLON	MARBLON
BURON	Buron	-	MINON	Minon	-
Calcon	Calcon	CALCON	MODON	-	-
Candon	CANDON	-	MULLON	-	-
-	Cerulon	CERULON	NEKRON	Nekron	-
CHERNON	Chernon	-	-	ORON	-
CHLORON	CHLORON	CHLORON	-	Pallon	PALLON
-	Cryon	CRYON	-	PELON	PELON
Cumulon	CUMULON	-	-	Pesson	PESSON
DERMON	-	-	-	Petracalcon	PETRACALCON
	Duron	DURON	-	Petragypson	PETRAGYPSON

FERMENTON	-	-
-	FERRON	Ferron
FIBRON	FIBRON	FIBRON
-	Flambon	FLAMBON
-	FLAVON	Flavon
-	-	FRAGON
GELON	Gelon	-
-	GLEYSON	GLEYSON
-	GLOSSON	GLOSSON
-	GLUTON	-
Gypson	Gypson	GYPSON
GRANULON	-	-
GYTTJON	GYTTJON	GYTTJON
Halon	HALON	HALON
HAMADON	-	-
-	HELVON	Helvon
-	HUDEPON	-
HUMIFON	-	-
-	HUSESQUON	-
HYDROMORON	-	-
-	-	ISON
-	JARON	-
KASTANON	Kastanon	-

-	PLACON	PLACON
PLAGGON	Plaggon	-
-	PLANON	Planon
PRIMON	-	-
PSEUDOFIBRON	PSEUDOFIBRON	PSEUDOFIBRON
-	ROSSON	ROSSON
-	BURON	BURON
-	RUFON	-
-	Sapron	SAPRON
SERON	-	-
-	SESQUON	Sesquon
-	SIDERON	SIDERON
-	SIENNON	-
-	SOLON	Solon
-	SPHERON	-
SULPHON	SULPHON	SULPHON
TANNON	-	-
-	Thion	THION
VERTON	VERTON	Verton
Veson	Veson	VESON
-	ZHELTON	Zhelton
ZOLON	Zolon	-

8.0 DETAILED DESCRIPTIONS OF SOME SEGMENTS

This contains detailed descriptions of the following segments: agron, alton, aluminon, arenon, argillon, cryon, cumulon, ison and pallon

AGRON

General definition: dark coloured, immediately beneath the plough layer, and characterised by having more than 15% thick coatings of top soil material

Symbol: Ao

Synonyms: Bth, argic horizons, probably some plough pans

Position: immediately beneath the top soil in many medium and fine textured soils that have been cultivated for a long time

Boundary: sharp to abrupt upper boundary, clear to merging lower boundary

Thickness: usually less than 20 cm thick

Colour: the coatings on the surface are of similar colour to the top soil, the colour of the original soil is variable

Texture: medium to fine texture

Stones: occasional to absent

Structure and porosity: prismatic to large angular blocky with the structure faces coated with a dark humus-clay mixture that has been washed in from the horizon above. The individual peds usually have a low pore space of subspherical and/or irregular pores

Passages: vary from rare to frequent, prior to cultivation soils with agrons may have had few passages in what is now the agron, with cultivation and the development of a soil fauna, particularly earthworms, passages are created in the middle and lower horizons

Faecal material: varies from rare to frequent

Handling properties: firm to plastic

Bulk density: 1.3-1.5

Permeability: moderately to slowly permeable, most water movement takes place between peds

Hydrology: usually moist or dry

pH: 5.5-7.0

CEC: 200-400 meq Kg^{-1}

BS: 60-100%

OM: <2.5% small fragments of decomposing organic matter occur in the dark ped coatings. There may also be roots

C/N ratio: 8-15

$(Ca+Mg)CO_3$: variable

Soluble salts: none

Weatherable minerals: variable

Clays: kaolinite, hydrous mica, vermiculite and smectite occur in various proportions

Segregations and concretions: usually none and not significant but many occur in the original material particularly those showing some degree of anaerobism, in which case manganese dioxide nodules may often be found

Biological activity: weak

Micromorphology: the moderate to high clay content in soils containing agrons leads to the formation of a clearly visible matrix. The amount and degree of domain development is variable. When the original material is red the domains tend to be small and may be low in frequency. In such cases there are usually zones of domains and aureoles around rock fragments and detrital grains. Where the original material was of very fine texture and shows evidence of anaerobism the domains are usually quite large and the whole matrix is dominantly anisotropic with many anisotropic aureoles around grains and rock fragments. There should be more than 15% thick coatings of a humus-clay mixture. These coatings are similar or identical in composition to the overlying horizon but in many cases they may contain less sand because of the differential washing in of the finer material. Unlike well formed clay coatings these tend not to be very well laminated and show a very low degree of optical anisotropism. Many of these coatings contain small fragments of decomposing plant material, even when these are not clearly seen with transmitted light, they can be seen through their autofluoresence

Weathering phenomena: some of the detrital grains and rock fragments may show evidence of weathering

Genesis: these horizons form by the in-washing of top soil into cracks that develop in the subsoil during the dry periods of the year. During the dry season in medium and fine textured soils, the whole soil may dry out and crack from the surface down to within the middle horizon. During the following wet season the impact of raindrops at the surface may cause puddling of the material and the formation of a slurry or suspension of soil which flows down the cracks and into the underlying subsoil. Under natural conditions the vegetation would act as a buffer preventing the extreme dryness of the summer period and the strong impact of raindrops that cause puddling during the following wet season. Agrons usually form in a previously existing horizon. They may be altons, but often they are argillons or pelons. The material washed down from the surface not only outlines ped surfaces but will flow down old worm channels lining the surfaces and even completely filling the worm passages. In some cases, the passages become filled to a depth of many tens of centimetres

Variability: in thickness, content of coatings and nature of the original material which may have been an argillon, pelon, rosson etc. Probably these horizons should be regarded as compound horizons

Associated horizons: below: various

Distribution: common in areas where agriculture has been practised for a long time. They appear to be more common in the cool humid temperate parts of the world

Origin of term: L. Ager = field

ALTON

General definition: firm to friable, weakly weathered with variable clay mineralogy including allophane and microcrystalline ferric hydroxide forming an isotropic or weakly anisotropic matrix. Contains similar clay and sesquioxides to the horizon above

Symbol: At

Synonyms: Bw, B1, B2, (B), cambic horizons

Position: principal middle horizon in a number of soils, also in the lower position beneath other horizon such as an argillon or sesquon particularly in intergrading situations and polygenetic soils

Boundary: clear to diffuse, may have sharp lower boundary over ison, fragon or another hard horizon

Thickness: 20 cm to >1 m

Colour: brown to yellowish-brown to yellowish-red; hues of 2.5YR to 10YR, chromas 4 to 6, values 3 to 4. The redder colours are usually associated with reddish parent materials

Alton

Texture: usually of medium texture but some altons developed from calcareous or base rich parent materials are sands. Altons usually contain a similar amount of clay to the horizon above, but more than the horizon below, except in coarsely stratified material
Stones: absent to abundant - some are usually present. In areas influenced by Pleistocene periglacial activity the stones are often vertically orientated on flat sites and parallel to the slope on sloping sites
Structure and porosity: usually crumb to subangular blocky, but may be single grain. When the content of silt and clay is high, there is a tendency for the structure to be angular blocky, alveolar or prismatic in certain integrading situations
Handling properties: friable to firm, usually friable but may be firm particularly when dry
Bulk density: 1.1-1.6 - the lower value occurs when the content of allophane is high
Permeability: moderate to rapid
Hydrology: usually moist
pH: 5.0-7.0 for non-calcareous materials, increases to 7.5 when the material is calcareous. Such horizons are designated Atc
CEC: 100-200 meq Kg^{-1} but may be lower when the sand content is high
BS: 25-100%; non-calcareous altons with a base saturation greater than 65% are designated Ath
OM: < 3%
C/N ratio: 8-12
$(Ca+Mg)CO_3$: absent to abundant from the parent material
Soluble salts: absent
Weatherable minerals: rare to dominant from the parent material. These horizons are weakly weathered due to short time of formation
Clays: kaolinite, mica, vermiculite, chlorite and allophane are the principal minerals in the clay fraction. They occur in various proportions with mica or vermiculite usually dominant but allophane may be dominant when there are many easily weathered minerals. the silica: sesquioxide ratio of the clay is similar to the horizon above. The extractable iron is similar to the horizon above
Concretions: absent
Biological activity: weak to moderate
Micromorphology: alveolar, small granular or blocky. The alveolar and blocky structures are associated with the pH values just about or below neutrality. The small granular structure is associated with lower pH values and where there has been some accumulation of iron and aluminium and they are intergrading towards sesquons. When the clay content is moderate or high, these horizons have well-developed matrices which may be faintly to distinctly anisotropic but generally they are either faintly anisotropic or isotropic. Many of these horizons occur beneath horizons with a high faunal population which also burrows down into these horizons creating passages and leaving them filled to a greater or lesser extent with faecal material. Thus, in some cases there is a fairly high frequency of faunal vermiforms. When these horizons are intergrading to wetter horizons there may be spherical or subspherical segregations of manganese dioxide
Genesis: relatively weakly weathered and formed largely by hydrolysis and in situ deposition of sesquioxides and allophane, often tends to retain some of the characteristics of the original material which is

usually a sediment. When the material contains carbonates they may be partially or completely lost
Variability: in texture and colour but can easily be recognised by their relatively poorly weathered state
Associated horizons: an alton most frequently underlies a mullon but also occurs beneath a chernon and a tannon. An alton often grades into the parent material but commonly they are underlain by an ison, a fragon or a calcon
Intergrades: altons intergrade in a number of directions, among the more common intergrades and their distinguishing characterisitics are the following:

AtSq intergrades have a slight accumulation of sesquioxides and usually have a very small granular structure similar to sesquons
AtAr intergrades have a slight accumulation of clay and some clay coatings
AtPe intergrades have a finer texture and a tendency towards angular blocky or prismatic structure

Distribution: altons are particularly common in the humid temperate parts of the world particularly on base rich parent materials. Also in warm humid areas on recent sediments or steep slopes where fresh material is regularly exposed. They occur elsewhere on recent sediments or as an early stage in the weathering of rocks
Discussion: the limits set for the alton segment may appear to be narrower than is usually accepted. This has been done with the hope that greater recognition be given to the intergrading situations particularly the alton-sesquon and sesquon-alton intergrades. This might resolve the problem in Europe with regard to setting quantitative limits to: brown forest soils, braunerden, brown podzolic soils, concealed podzols and semipodzols
Origin of term: L. Alter = alter

References

Kubiëna 1953, Muir 1961, Ragg et al. 1978, Tavernier and Smith 1957, USDA 1975

ALUMINON
General definition: weakly coloured, high chroma, middle or lower, and firm to friable, has a characteristic fine granular structure with free and coalescing granules and high extractable aluminium
Symbol: Ai
Synonyms: (B), B1, B3, Ale, cambic horizon
Position: the position varies from middle to lower in different soils. In some soils it is the principal and dominant middle horizon and occurs beneath a thin modon. When it occurs in the lower position it may be beneath a sesquon or husequon and often overlies an ison or hard ison. Sometimes the lower part contains some ison characteristics and is then (Ai/In)
Thickness: varies from about 10 cm to about 50 cm. A thin aluminon usually occurs between a sesquon and an ison, while a thick aluminon forms the principal horizon in a soil and occurs beneath a thin modon.
Colour: uniform and usually 7.5YR, 10YR 5/6 or 6/6 but may inherit part of its colour from the parent material and may vary from brown to brownish-red.

Aluminon

Texture: loams with the best development in silt loams, some of the best examples occur in the silty aeolian deposits of northern Europe but aluminons also form in till, solifluction deposits and weathered rocks.
Stones: absent to dominant as determined by the content in the parent material and any mixing with the underlying materials due to frost heaving and solifluction. On slopes the stones are often oriented with their long axes parallel to the slope and normal to the contour. On flat sites their orientation is more or less vertical.
Structure and porosity: very distinctive, fine granular structure that is visible in hand specimens but is better seen in thin sections. The best developed structure occurs in the silt loams
Handling properties: very soft and friable, crumbles easily in the hand and is very easy to dig especially when the content of stones is low
Bulk density: 1.2-1.7 this is low for soil horizons generally and is difficult to explain
Permeability: moderate to rapid, but may become wet at the base due to an underlying ison
Hydrology: usually moist
pH: 4.5-5.0 with a modal value of 4.8
CEC: 1000-3000 meq Kg^{-1} Ex. Al: 15-60 meq Kg^{-1}
BS: 5-20%
OM: <3%
C/N ratio: 8-20
$(Ca+Mg)CO_3$: absent
Soluble salts: absent
Weatherable minerals: 0-100% of the sand fraction. The precise content depends very largely upon the soil climate. In Scotland the content of amphiboles and pyroxenes needs to be fairly high or else they occur on moderate slopes that receive lateral drainage containing basic cations. To the south and into northern France the parent materials become progressively more acid eventually being dominated by quartz. Under the cooler northern conditions, where the soil organic matter is more acid, a higher content of base cations is required in the system. In Scotland, on flat sites with acid materials, aluminons will only occur beneath sesquons
Clays: ***Kaolinite and aluminous vermiculite, *vermiculite, smectite, hydrous mica and quartz
Concretions and segregations: absent to rare, black segregations
Biological activity: see Genesis below
Micromorphology: very distinctive, fine granular structure. The granules are 50-100 μm in diameter, subrounded and spherical with strongly translucent, brownish-yellow matrices enclosing the silt-size mineral grains. The granules may occur singly, in small clusters, but often as subangular blocky clusters with varying degrees of coalescence. Sometimes the granules are tightly packed forming alveolar or digitated pores. Some areas within a single thin section may have a lenticular structure indicative of previous freezing but these areas might not be horizontal due to disruption. Silt cappings may also occur on some of the rock fragments, such situations are composite horizons. When the texture is a sandy loam or loamy sand the large sand grains have a thin coating of fine material the same as that which forms the matrices of the granules. These granules differ from those of sesquons and husesquons which are smaller, darker and have a higher relief

Genesis: there would seem to be 2 possible mechanisms for the formation of the granular structure in these horizons. They may be formed by flucculation due to the presence of exchangeable aluminium or they may be formed by enchytraeid worms. The biological origin seems to be the most likely hypothesis since the granules are of the size that are produced by enchytraeids. In the lower part of many of these horizons the granules are seen to be filling a previously existing passage and also there may be a sharp junction between granulated and non-granulated areas, whereas, if flucculation was the mechanism the change would probably be more gradual. There is also a problem with regard to the origin of the passages since there are no earthworms in these soils at present. However, it is probable that these soils had a higher pH in the past immediately following the tundra phase when they might have been Altosols. Then the worms homogenised the upper part of the soil and made passages down to the top of the ison as is common in some soils at present. As the soils became progressively more acid the earthworms gradually died out but the enchytraeid worms have survived to produce the fine granular structure especially in those places previously worked by the earthworms. Thus the genesis of the soils containing aluminons seems to follow the following lines:

1) Simultaneously permafrost developed and solifluction took place in the mineral materials which may have been aeolian silt, glacial drift, alluvium or old weathered rocks

2) The material was reduced in thickness on the slopes

3) The permafrost melted slowly

4) There was wave after wave of vegetation and soil fauna

5) Climate stabilised with deciduous forest, earthworms and enchytraeid worms with the earthworms dominant

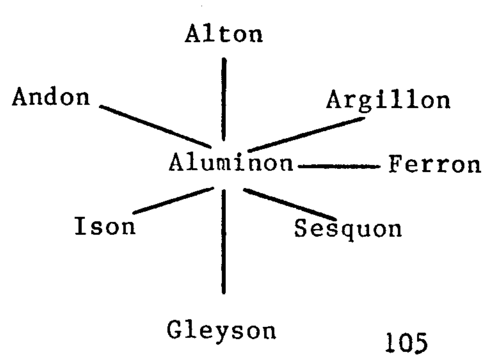
6) The soil becomes progressively more acid

7) The earthworms die out and the enchytraeid worms dominated

8) During stages 6 and 7 aluminium is released by weathering to form aluminons

9) These soils develop further to Podzols or Argillosols

Variability: these horizons seem to have a very narrow range of variability because they intergrade quickly into a number of other horizons as shown below:



Associated horizons: above: a modon, zolon or sesquon; below: an ison, gleyson, (InAr) or relatively unaltered material
Distribution: in cool temperate areas with aerobic conditions; with increasing leaching they gradually change into sesquons
Origin of term: E. Aluminium

Authors

P Aurosseau and E A FitzPatrick

ARENON
General definition: red, reddish-brown or yellowish-brown, middle, with coarse, sandy texture and composed mainly of quartz and other resistant minerals. Some arenons have a high concentration of sand size granules of kaolinite
Symbol: Ae
Synonyms: B2, Bw, Bv
Position: middle or lower
Thickness: 25-200 cm+
Colour: red to reddish-brown to yellowish-brown, hues of 10R, 2.5YR to 10YR
Texture: sand to loamy sand with less than 10% silt plus clay
Stones: rare to absent
Structure and porosity: single grain to massive
Handling properties: this varies from loose to hard and cemented
Bulk density: 1.2-1.6
Permeability: rapid
Hydrology: usually dry but may be wet during the wet season or in intergrading situations
pH: 4.0-7.0
CEC: < 50 meq Kg^{-1}
BS: < 80%
Organic matter: < 2%
C/N ratio: 8-15
$(Ca+Mg)CO_3$: absent
Soluble salts: low to absent
Weatherable minerals: < 5% of the sand fraction is dominated by quartz with small amounts of the resistant minerals such as zircon, sphene, ilmenite and magnetite
Clays: kaolinite is the dominant clay mineral but small amounts of other minerals may be present
Concretions and segregations: of variable frequency as erratics from a previous soil
Biological activity: weak to absent
Micromorphology: narrow bridges occur at the points of contact between the dominant angular, subrounded or rounded sand grains which are dominantly quartz with rare amounts of feldspars, micas and accessory minerals such as zircon and ilmenite. Most of the grains have very thin coatings of fine material or clay that may show some degree of anisotropism because the particles are parallel to the surface of the grains. There are often many grains of wustenquartz, namely quartz grains that have fractures filled with red clay and iron oxide. There is a high porosity and these horizons resemble accumulations of pure sand. In many arenons there may be small areas with clay coatings or there may be thin lamellae of clay coatings. Some horizons that appear to be typical arenons in the field are seen in thin

sections to have a high content of granules of kaolinite derived from eroded pallons. This is a common feature in Western Australia.
Genesis: there is still some uncertainty about the processes in arenon formation. In some situations it appears that they form through progressive hydrolysis of the primary minerals followed by the destruction or leaching out of the clay, particularly on slopes. In some other situations arenons appear to form from a previously strongly weathered soil through differential erosion during which the clay is washed out and a sandy residue is left. Both theories require a considerable amount of clay to be removed and might explain the occurrence of soils with a high content of clay at lower positions in the landscape. In Western Australia arenons form by the differential removal of sand from concretionary horizons and its deposition in a middle or low slope position. Some arenons have formed in aeolian deposits dominated by quartz sand. Leaching of shell sand may lead to the formation of arenosols which may be further differentiated into Podzols as occur in Western Australia
Variability: arenons vary mainly in their colour and in the ratio of coarse sand to fine sand. Also they show marked differences in handling properties, whereas, some are loose others appear to be cemented and very hard. Where these horizons are associated with highly weathered materials they often contain concretions
Associated horizons: the overlying horizon is usually a tannon. The underlying horizon may be a flambon, pallon or relatively unaltered material
Intergrades: into krasnons, rossons, zheltons, flavons, rubons, ruffons, helvons, siennons, glutons, etc.
Distribution: arenons are the principal horizon in Arenosols which occupy large areas in the wet and dry tropics and semi-arid tropics and sub-tropics
Discussion: arenosols sometimes occur in association with windblown sand with which they can be confused particularly if the wind blown material is itself derived from arenosols
Origin of term: L. Arena = sand

References

Anderson 1957, Mulcahy and Hingston 1961, Stace et al. 1968

ARGILLON
General definition: middle or lower, and contains more than 7% clay coatings. 10YR or redder and usually, but not always, contain more clay than the horizons above
Symbol: Ar
Synonyms: Bt, textural B, argillic horizon
Position: middle or lower, may be at the surface due to erosion. In many soils an argillon is the principal middle horizon and is then used as the basis to create the class of Argillosols. In some soils an argillon forms part of a second lower sequence
Boundary: the upper boundary varies from abrupt to merging; the lower boundary usually merges into the relatively unaltered underlying material or there may be a sharp change to an underlying horizon
Thickness: varies from < 1 cm to over 1 m. Those that are < 1 cm are usually very distinctive and have a

strong colour contrast with adjacent horizon, they also have >50% clay coatings. They are known to occur in loess derived soils in Alaska and also in sand dune derived soils in Sudan. Perhaps because of their thinness and high coating content they should be regarded as a special type of horizon and not grouped with the argillons generally
Colour: various shades of yellow, brown and red; colour pattern absent or faint. Hues of 10R, 2.5YR to 10YR, chromas 4 to 6, values 3 to 4. The redder colours are often associated with reddish parent material or intergrading or polygenetic situations
Texture: the texture range is very wide and it seems that clay coatings will form in material of any particle size distribution, even in clays, providing the mineralogy is correct. They usually, but not always, contain more clay than the horizon above
Stones: absent to frequent, usually absent or of very low frequency, they may be derived from the parent material but often they are incompletely weathered fragments of the underlying rock
Structure and porosity: many types of structure occur, these include, angular blocky, subangular blocky, irregular blocky, incomplete angular blocky, subcuboidal and prismatic. When peds are well formed they usually contain discrete pores. Many of the ped surfaces have clay coatings
Handling properties: this varies from friable, through firm to very hard and difficult to dig with a pick. In some cases this property varies with texture and moisture content, the coarser textures tend to be friable expecially when wet, the finer textures are often firm to hard especially when dry
Bulk density: this is greater than the overlying horizon and varies from about 1.5-1.8
Permeability: varies with texture, coarser textured argillons have high hydraulic conductivity and are freely permeable but, the finer textured ones have low values and are less permeable. As argillons develop and the clay coatings become thicker the hydraulic conductivity decreases and ultimately reaches almost zero
Hydrology: usually moist rarely wet or dry
pH: 5 to 7, usually higher than the horizon above but in some cases the values are slightly lower possibly due to exchangeable aluminium
CEC: 100 to 300 meq Kg^{-1}
BS: 10 to 80%
OM: < 3%, usually <1%
C/N ratio: 6 to 10, when the values are low exchangeable and fixed ammonium may be responsible
$(Ca+Mg)CO_3$: absent, but clay coatings can form on calcite coatings in polygenetic situations
Soluble salts: absent
Weatherable minerals: absent to dominant in the sand fraction
Clays: kaolinte, hydrous mica and vermiculite are the main clay minerals, in many cased with subsidiary montmorillonite. If the montmorillonite and vermiculite contents are high then argillons seem not to form
Concretions: absent
Biological activity: low, some roots but little mesofaunal activity which destroys these horizons
Micromorphology: the distinctive micromorphological feature and the principal distinguishing characteristic of argillons is the presence of prominent clay coatings

which must be greater than 7% of the total mineral material. In developing argillons the coatings have a characteristic laminar structure and occur on the surfaces of peds and lining pores, particularly the bottoms of pores, where the coatings are usually thickest. Between crossed polars the coatings normally have a black extinction band which sweeps through the coating as the microscope stage is rotated. Most clay coatings appear to be non-pleochroic but there are a small number with distinct pleochroism. When the coatings occur on the surface of large prisms some silt and fine sand is usually associated with them. It is difficult to be certain about the mineralogy of clay coatings from optical examination but a fairly general interpretation can sometimes be made on the basis of their interference colours. Kaolinite and chlorite give pale colours of the first order. Micas, vermiculite and montmorillonite give second order colours. However, using peels it is possible to make an X-ray examination of small areas of thin sections and thereby identify most features with greater certainty. In most cases the coatings are very transparent and are of higher value and chroma than the adjacent soil. In old coatings the laminar structure tends to disappear and the black extinction band is either absent or poorly developed. In such cases the coatings seem to be composed of a cluster of domains.

<u>Genesis</u>: most workers agree that argillons are formed by the translocation and deposition of clay onto surfaces. It is usually considered that clay is translocated downwards during the wet season and during the dry season the clay particles become fixed on surfaces. Repetiton of this process leads gradually to a build up of clay coatings and an increase in the amounts of clay in the horizon. It is generally considered that the translocated clay comes from the uppermost horizon viz., the organic-mineral mixture at or near the surface. Since the coatings have a higher value and chroma than the adjacent soil it would seem that organic matter is either very low or absent. Therefore, it is necessary to investigate the reason for the absence of organic matter in the coatings. There seem to be 3 possibilities:

1 preferential movement of clay
2 decomposition of the organic matter in the coating
3 source of clay other than the uppermost horizon

Since the maximum amount of clay coatings seldom occur immediately below the organic mineral mixture it is possible that the source of the clay is beneath the organic-mineral mixture. Clay coatings are not permanent phenomena. They undergo internal changes as well as fragmentation. Thus, in old argillons there are many fragments of coatings incorporated within the matrix. Also there seems to be some internal rearrangement of the orientation of the clay particles to form domains and it would seem that in some cases the domains eventually become part of the matrix. Experiments by Haldane and Brewer (1956) have demonstrated that clay coatings can be formed by percolating a column with a clay suspension

<u>Variability</u>: argillons vary much in their colour, texture and position in the soil pedo-unit. In many cases they occur just beneath a luvon and in such cases

it can be assumed that the clay has been translocated from the leached horizon into the argillon. In other cases the argillon occurs beneath a middle horizon with clay maximum and few coatings
Associated horizons: the overlying horizon includes a luvon, modon, tannon, alton and a placon. The underlying horizon includes an ison, fragon, calcon or they may grade into the underlying material
Intergrades and compound horizons: argillons intergrade into altons, planons, solons and other horizons. They also form compound horizons with a number of horizons including rossons, flavons, krasnons and zheltons
Distribution: argillons occur in moist continental areas that range from cool to hot. They are very common in continental Europe and North America
Discussion: a considerable amount of time and energy has been spent in attempting to define middle and lower horizons that have a higher clay content than the horizon above. In Soil Taxonomy (1975), the argillic horizon is defined as an illuvial horizon but need only have 1% clay coatings, provided it has a specific increase in clay. In that system it is felt that insufficient attention has been paid to establish that illuviation has taken place and that more emphasis should be placed on the content of clay coatings and less on clay increase which could result from differential erosion or clay destruction. Thus argillons are defined on their content of coatings irrespective of the clay percentage relationships with the adjacent horizons which can better be represented in soil formulae by > and < symbols
Origin of term: L. Argilla = clay

References

McKeague 1983, USDA 1975

CRYON
General definition: permanently frozen subsoil, usually with ice veins enclosing lenticular mineral soil peds but may have other forms of structure particularly massive and sub-cuboidal. Sometimes contains large ice masses and ice wedges
Symbols: Cy
Synonyms: Cf, permanently frozen subsoil or permafrost
Position: middle or lower
Boundary: abrupt upper boundary which may be smooth or undulating
Thickness: from less than 1 m to over 300 m
Colour: usually grey or olive grey, in some cases stained brown or dark brown by organic matter. Often the colour is inherited from the parent material and therefore may vary widely
Texture: variable, derived from the original material but strictly there is no texture because of the permanently frozen state
Stones: absent to dominant, almost invariably they are surrounded by a sheath of pure crystalline ice which is thickest beneath the stones
Structure and porosity: the structure varies with the particle size distribution. In coarse sandy material the structure is massive, in loams and silts the structure is distinctly lenticular with each lens of mineral soil surrounded by continuous bifurcating veins of ice. In clays the structure is subcuboidal with each

of the aggregates surrounded by ice. The porosity is low and usually is in the form of discrete spherical and subspherical pores within both the mineral and ice phases

Handling properties: very hard, due to its frozen state

Bulk density: no data are available, probably in the range 1.5 to 1.8

Permeability: impermeable, causing the soil above to be wet or saturated

Hydrology: > 50% ice

pH: not applicable - can only be determined after melting - then variable

CEC: not applicable - can only be determined after melting - then variable

BS: not applicable - can only be determined after melting - then variable

Organic matter: the amount of organic matter varies from less than 1% to over 10% and is determined by the previous history of the site as discussed below under genesis. It may be uniformly distributed or may occur as partially decomposed lumps

C/N ratio: > 12

$(Ca+Mg)CO_3$: absent to dominant

Soluble salts: variable, usually low to absent

Weatherable minerals: 0-100% of the sand fraction

Clays: variable, inherited from the original material, but hydrous mica and smectite are the two minerals most likely to form in this horizon

Concretions and segregations: absent

Biological activity: none

Micromorphology: in thin sections the various types of structure, mainly massive, lenticular and subcuboidal are clearly evident. The soil material has few pores with closely packed mineral grains while the ice shows well developed crystals, the size and orientation depending upon the type of structure. In lenticular material the ice crystals are orientated with the c-axis normal to the lense surface so that for most soils they are also more or less normal to the soil surface. In cryons with subcuboidal structure the ice crystals are again orientated normal to the ped surface which means that they can be either vertical or horizontal with respect to the whole soil. The ice crystals are usually fairly large and may be more than 2 mm in length, showing clearly that they have grown gradually along their c-axes. In some cases there is evidence for re-crystallisation of the smaller crystals. Where this occurs in the vertical ice surrounding the subcuboidal ped the orientation of the larger crystal is normal to that of the smaller crystals, thus indicating that the large crystals have grown in a new direction at the expense of the smaller crystals. Where there are large ice masses, as in ice wedges (see below) the ice crystals can be several centimeters in size and have clearly developed as a result of re-crystallisation.

Genesis: when discussing the details of cryon formation it is necessary to consider some of the properties of water and ice and also the mechanism of ice formation

Mechanism of ice formation: one of the most important properties of water is that when it cools it attains its maximum density at 4°C thereafter it expands slightly until it attains 0°C, whereupon it expands by about 9%. This sequence is of considerable importance in the formation of ice in soil. When soil is frozen artificially in the laboratory a number of distinct patterns develop as determined by particle size distribution, amount of water available, speed of freezing and to some extent the concentration of the various ions in the system. Generally, when freezing is slow and there is an ample supply of water a massive structure develops in sands, a lenticular structure in loams and silts and a subcuboidal structure in clays. In addition, a crude polygonal pattern of vertical ice segregations may develop, particularly in silty and loamy material. If stones are present, ice develops first and foremost around the stones because of their lower specific heat, and there is a migration of water to their cooler surfaces and a growth of ice crystals. Thus, the structure and pattern of ice found in cryons can be reproduced experimentally in the laboratory. Cryons also develop in consolidated rocks where the pattern of ice that develops seems to be related to the nature of the rock. In fine grained, low grade metamorphic rocks such as slates, the ice pattern forms subcuboidal or tabular rock fragments in a manner not dissimilar to the subcuboidal peds formed in fine textured soils. In the harder rocks such as granites and basalts the freezing process seems to have minimal effect apart from the development of ice between the pre-existing joint blocks but sometimes a coarse lenticular structure forms. When the soils starts to freeze from the surface downwards the process tends to be fairly rapid with the formation of needle ice on the freezing of the water in the pores. Below about 10-15 cm the process slows down considerably so that ice segregations develop. This develops because water is drawn by capillarity to the freezing front. As this happens the soil beneath the accumulation ice dries out fairly rapidly, shrinks and cracks develop, preventing any further movement of water. These cracks then form the sites for further ice crystal growth. In loams that do not shrink very much, the cracks are mainly horizontal with an occasional vertical crack that may form a polygonal pattern 50-100 cm in diameter. Ideally, the cracks should be parallel to the surface giving rise to laminar peds as occurs in some situations. However, since the material is variable the cracks are wavy giving rise to lenticular peds. Since clays shrink considerably upon drying they crack in both the horizontal and vertical directions to form subcuboidal peds surrounded by cracks in which ice then forms. Thus the density of the mineral material is increased by the three-fold processes of shrinkage, ice crystal growth and volumetric change of water into ice. Thus, freezing processes in soils not only give rise to a characteristic structure but produce very dense and compact peds. The compaction is taken a stage further since any fine crystals that form within the mineral material are attracted to the larger crystals in the ice lenses by creep or by vapour phase transfer. Although it might appear that cryons are static in that they are permanently frozen, it seems from examination of the crystallography as mentioned above, that progressive changes do take place. These changes involve the development of large ice crystals at the expense of the smaller ice crystals and possibly the addition of water from the overlying horizon during the summer period. This re-crystallisation and addition of material causes increased pressure on the peds and accounts for the extremely well developed structures and areas of pure well crystalline ice and also for the fact that in many cases the ice lenses may be very thick. The net result is well formed areas of pure crystalline ice surrounding highly compressed mineral peds virtually devoid of ice. Another feature of freezing is that any gases dissolved in the water are released - hence the presence of air bubbles in blocks of ice from the domestic refrigerator. This causes the formation of the discrete subspherical and vesicular pores both in the peds and ice and may also cause a little pressure, but probably not very much.

Formation of cryons: the formation of cryons can be approached from at least 2 different directions. Firstly, there is the situation in which cryons form in recently deposited material such as glacial drift, glacio-fluvial outwash and loess all of which may be deposited in a sufficiently cold environment for the subsoil to become permanently frozen. Secondly, cryons can form gradually in a previously existing soil as a result of progressive cooling of the climate. The formation of cryons in sediments deposited in a cold environment takes place within a single winter and gives rise to the various ice patterns described above. The formation of cryons in pre-existing soils is usually brought about by a change in climate and possibly in the following sequence. With the onset of the Pleistocene period the temperature of many countries of the middle latitudes became progressively cooler, so that the upper part of the soils froze during the winter and thawed during the summer. As the temperature dropped year by year the depth of freezing steadily increased and ultimately in some places the stage was reached when the amount of incoming solar radiation during the summer did not warm the soil sufficiently to melt the whole depth of frozen soils so that a sub-surface layer remained permanently frozen. Then the situation was one in which the top soil would freeze every winter and thaw every summer while the subsoil would remain permanently frozen. The upper freeze-thaw layer is commonly known as the active layer. Gradually, the permanently frozen layer or cryon would continue to increase in thickness until the mean annual temperature began to increase as the climate once again became warmer. Under these conditions cryons developed in pre-existing soils, the majority of which seem to have been deeply weathered tropical or sub-tropic soils, forming a number of compound horizons. There is evidence to show that many of the weathered soils in central Europe were frozen at some period during the Pleistocene. In many cases it is not possible to be certain about the original soil since it was largely destroyed by solifluction and frost heaving. The development of cryons in pre-existing soils took place at the beginning of each glaciation and probably at the end of each interstadial period so that cryons formed in many interglacial and interstadial soils.

Formation of ice wedges: another important property of ice is its high co-efficient of linear expansion, which is 51×10^{-6} cm/cm°C, so that when the temperature in the Arctic falls to about -40 to -60°C the cryon shrinks and often thin cracks result. These cracks display a polygonal pattern that may be about 20-40 m in diameter. After the cracks develop, hoar frost forms on the surfaces of these cracks, and becomes trapped as a thin lenticular lense during the succeeding summer when the temperature rises and the cryon expands again. This process is repeated many times, possibly not annually, but there may be a biennial or triennial cycle, so that the thin veins of ice become progressively thicker ultimately forming a wedge which may be more than a metre in thickness at the top and may extend 4 or more metres in depth into the cryon. The thin vein of ice in the active layer melts during the summer so that the mineral soil re-unites. Thus, the soil profile is one of mineral soil overlying ice. Ice wedges are ubiquitous on the flat and gently sloping sites throughout the Arctic, being largest in the older landscapes, such as Northern Alaska and Siberia. In some cases when the cracks develop, organic material such as leaves, lemming droppings, etc. fall into the cracks and thus become trapped and can be used a means of dating.

Variability: cryons vary enormously in their structural pattern, organic matter content and in the volume of ice which they contain. As stated above, the structural pattern is related to the particle size distribution of the material, the amount of water present and the speed of freezing. In some situations, where the climate may generally be regarded as cold there has been sufficient variations in the climate to cause the depth of the active layer to vary in thickness from time to time, so that the upper surface of the cryon varied in depth from the surface. This is particularly evident in Alaska where it seems that the northern part of that state was never glaciated, so that the climate varied from cold to very cold. Therefore, these soils can be regarded as the maximum expression of soils formed under tundra conditions. As the top soil freezes and thaws a churning action is initiated which causes the incorporation of surface organic matter into the active layer and for there to be a tendency for a maximum of organic matter to occur just above the surface of the cryon. In situations where the thickness of the active layer has varied, we find that what was at one time the bottom part of the active layer, now occurs within the upper part of the cryon, which as a consequence now contains a fairly high content of organic matter. This situation is extremely well displayed in Alaska and parts of the USSR but not found in recently de-glaciated areas, apparently because of the youthfulness of the soils. The upper part of these cryons that contain large amounts of organic matter show a soil, with a distinctly convolute pattern of the organic matter, indicating that this part of the soil was subjected to severe pressures, either subsequently or during, the gradual rise of the surface of the cryon. The thickness of the active layer is also related to aspect, elevation and the thickness of organic horizons at the surface. With an increase in thickness of the organic matter the depth of the active layer decreases and ultimately the situation is reached when the active layer is entirely within the organic matter and the cryon extends from the organic matter down into the mineral material. The variation in thickness of the active layer may take place over a relatively short distance where there are mud polygons or other surface features. On the other hand the change may be more gradual and take place over many metres as in gently undulating landscapes. At present the area of cryons is diminishing and as the ice melts new soils form in these old tundra soils. It is during the period of cooling down and at the maximum of the cold period that compound horizons form. These seem to have been present during the maximum cold phases of the Pleistocene throughout many parts of Europe,

Southern England, Central North America and elsewhere. Thus, cryons developed in the lower horizons of soils such as Podzols, Subgleysols and in the weathered rock of these areas. In fact, the evidence from other sources such as pollen analysis suggests that the subsoils throughout the areas listed above were frozen. At present in parts of the Arctic and sub-Arctic there are peat deposits which are completely frozen apart from the top 5-10 cm. These can be regarded as compound horizons in that the peat would have formed first and then would have become frozen afterwards, such horizons being designated {CyFi}.
Associated horizons: above is a gelon, gleyson or cerulon
Distribution: at present cryons are restricted to Alaska, Antartica, Canada, Scandanavia, North Siberia, extensions into Mongolia and Northern China. Outside these areas there are spasmodic occurrences, some of which are relic from cooler phases, others developing due to some unique characteristic of the environment. During the maximum of the Pleistocene glaciations the distribution was far more extensive, occurring throughout large parts of the now temperate areas of the world
Discussion: cryons are probably the most common type of soil horizon since they are the norm in the tundra area which occupies about one-fifth of the earth's surface. Thus, about one-fifth to one-sixth of the earth's soils have cryons within them. Probably, one of the most interesting aspects of cryons is their much wider extent during the Pleistocene and the relic features of them that we find in many soils in Europe and North America at present. For example, the occurrence of relic ice wedges filled with mineral material and the occurrence of isons, which seem to be the direct result of a cryon being present in an earlier period
Origin of term: G. Kuros = frost

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CUMULON
General definition: upper or middle, with a higher proportion of much coarser material than the horizon below. The coarse material is composed of quartz gravel, concretions, fragments of vesons and other nodular or cemented materials. These horizons are formed by the combination of mass movement and differential erosion during which the finer particles are removed to a lower part of the slope or to the drainage system
Symbol: Cm
Synonyms: Bc, Cc, gravel layer, concretion layer, ironstone gravel
Position: usually occurs as a middle horizon but may extend from the upper to the lower position depending upon thickness
Thickness: varies from 5 to 100 cm and in extreme cases may be over 200 cm thick
Colour: various shades of red and brown, usually with a very marked speckled appearance. This is due to the variations in colour of the coarse material which is usually different from the matrix and is most clearly

seen in thin sections. The most marked colour patterns are usually seen when a cumulon occurs over a pallon and the matrix has been derived from the pallon
Texture: the fine earth (< 2 mm) varies from sand to clay and contains 30% or more of coarser material than the horizon below
Stones: in a number of cases small stones (rock fragments) are present but usually their content is fairly low. There may also be fragments of flambons or coated flambons (see genesis) which on first appearance are like stones but when they are broken open they have the characterisitic mottled pattern and they may even have a vesicular structure
Structure and porosity: the structure depends very much upon the texture and the amount of faunal activity. When there is a high content of clay in the fine earth there may be an incomplete angular blocky structure with or without faunal passages. On the other hand coarse textured material often has a bridge structure with or without faecal pellets. In the field the bridge structure will appear as loose single grain
Handling properties: this varies from loose through friable to very hard and tenaceous
Bulk density: varies with texture but is normal for middle horizons
Permeability: rapid to slow depending upon the amount of clay in the matrix
Hydrology: usually moist or dry
pH: 4.5-7.0 but may be higher when intergrading to other horizons
CEC: <250 meq Kg^{-1}
BS: up to 100%
OM: <3%
C/N ratio: 8-12
$(Ca+Mg)CO_3$: absent, when present the horizon should be considered as an intergrade
Soluble salts: absent
Mineralogy: this varies widely depending upon the previous history of the soil as well as upon the nature of the parent material

Material >2 mm This usually contains a high percentage of quartz and sometimes there are a few rock fragments but on quartz-free rocks both may be missing. In most cases there are high concentrations of concretions or fragments of vesons, pessons, glutons or flambons which have come from exposure further up the slope. Although the general tendency is for the material to be the residue after weathering, very often fresh minerals are present, singly or within rock fragments. The composition of the concretions and cemented fragments of other horizons is very variable. The cementing material of these components is usually a combination of oxides of iron, aluminium and manganese which in some cases make up the entire composition of the concretions. In other cases, they form a coating around other material including fairly fresh minerals.
Material 2-.002 mm This is usually of similar composition to the gravel and is therefore high in quartz.
Material <.002 mm Since these horizons have been derived from highly weathered material the general tendency is for kaolinite to be the dominant mineral in this size range. In some cases hydrous

mica is an important second mineral. Variable amounts of goethite and gibbsite may also be present, while hematite and bohemite have been recorded in small amounts.

Biological activity: termite passages and granules are usually present in varying proportions
Micromorphology: usually alveolar but may be massive or a mixture of concretions, oxides of iron, aluminium or manganese, gravel and granular peds. The concretions may be entire or fragmented. The granules usually have an isotropic to faintly anisotropic matrix. Clay coatings vary from absent to frequent
Genesis: generally cumulons are regarded as forming at the surface through differential erosion during which there was a loss of fine material and a concentration of gravel and concretions. However, there is still a considerable amount of disagreement about the precise nature of the conditions and the exact period they were formed. Some workers consider that they formed under pluvial conditions while others hold the opposite view that differential erosion is most active under arid and semi-arid conditions with sparse vegetation and seasonal thunderstorms causing both surface washing and gullying. Another possibility that should not be overlooked is that progressive soil formation and gradual erosion under uniform climatic conditions might ultimately lead to an accumulation of gravel and concretions at or near to the surface of the ground. There is good evidence to show that some cumulons which occur beneath the surface did form at the surface and subsequently have been buried by termite and worm activity. It is sometimes difficult to differentiate between cumulons and pessons since it appears that in some cases the concretions and fragments in a cumulon may form the nucleus for the further development of a concretion. This is clearly seen in thin section of some cumulons where many of the individual concretions have a core surrounded by concentric rings which seem to be a contemporaneous process and which appears as though it will continue to form a hard massive material in which a great amount of material will be in the form of concentric rings. Thus, a cumulon may form by the erosion of a pesson and later begin to form again into a pesson when the concretions in the cumulon form the nucleus for the new depositon of iron
Variability: cumulons vary widely in the nature of the coarse material which can be dominated by quartz or concretions
Associated horizons: a cumulon usually occurs very near to the surface and most likely were a surface horizon originally but at present there may be up to about 20 cm of finer material at the very surface. This material is usually attributed to the activity of worms and termites. Thus, there may be a mullon or tannon above a cumulon. If leaching and clay destruction are dominant processes in the area there may be modon or luvon at the surface. In some cases a cumulon overlies a krasnon, zhelton and other weathered material. Beneath the cumulon there is often a flambon or pallon when erosion has been very active. In a few extreme cases they overlie unweathered hard rock.
Intergrade horizons: cumulons intergrade into other horizons for a number of reasons. They may intergrade because of insufficient erosion to remove all of the fine material or they may have been strongly affected by

certain specific processes since their formation. On slopes it is possible to have a gradual change from a cumulon in the upslope position to an arenon in the valley this giving (CmAe) and (AeCm) horizons. Cumulons intergrade to krasnons, zheltons, rossons, flavons, pallons and other weathered materials as a result of weak differential erosion of soils containing these horizons

Compound horizons: after the formation of a cumulon there may be translocation or reorganisation of clay leading to a slight increase in clay with the formation of clay coatings, such horizons are regarded as cumulon-argillon intergrades. Cumulon-luvon intergrades form by the progressive leaching of a cumulon to bring about further removal of clay imparting a distinctly bleached appearance to the sand grains

Distribution: cumulons are probably one of the most common horizons in many tropical and sub-tropical areas. Throughout West Africa and South West Australia they could probably be regarded as one of the major horizons. In many cases the thickness and continuity of the horizon is such that it can be considered as the main horizon and the one after which the soil should be named. In other cases where the cumulon overlies thick flambons or pallons it could still be used for naming the whole soil since it is the principal middle horizon

Origin of term: L. Cumulus = heap

ISON

General definition: lower, friable to extremely hard, with a characteristic lenticular or massive structure and cappings of silt on the upper surfaces of stones; generally regarded as a relic cryon

Symbols: In (friable and firm), Ind (hard)

Synonyms: Cx, fragipan, indurated layer

Position: lower, usually occur at 45 to 60 cm from the surface, may be shallower due to erosion or on north facing slopes, may be deeper on moderately steep south facing slopes

Boundary: sharp to abrupt upper boundary which may have a placon

Thickness: 10-100+ cm

Colour: often greyish-brown (10YR 5/2, 2.5Y 5/2) or olive (5Y 5/3); VC2, 4, 5; sometimes with weak mottling, especially on ped surfaces. The colour is sometimes inherited from the parent material and may vary from strong brown to reddish-brown to red

Texture: sand to loam with a high content of fine sand and coarse silt. The best developed isons have angular, faceted sand grains. The range for the <2 mm fraction is: sand 60-75%, silt 20-40%, clay 3-10%, higher when kaolinite only. The upper part often has less clay than the lower. Isons on slopes usually have distinctly less fine sand and silt than the horizon above. The material in which isons form is usually a till, solifluction deposit or weathered rock

Stones: absent to dominant - some are usually present, when present they are usually more frequent than in the horizon above. Almost invariably they have strongly adherent, firm capping on their upper surface mainly of fine sand and silt. Frequently, there are nests of coarser particles beneath the stones. The particle size range for the silt cappings is sand 15-55%, silt 25-75%, clay 10-25% On sloping situtations the stones are often orientated with their long axes parallel to the slope

and normal to the contour. On flat sites their orientation is more or less vertical in the upper part
Structure and porosity: medium to coarse lenticular or massive, in a number of cases a horizontal section shows a marked polygonal pattern of light coloured areas outlined by yellowish-brown iron staining. The polygonal cracks may be up to 2 cm wide and contain loose or friable material fallen from above. In the more humid areas the lighter coloured areas are formed by the reduction and removal of iron since these areas are the most permeable and form the main conducting system for soil water. In semi-arid areas the lighter coloured areas are due to the deposition of calcium carbonate - such horizon are desingated {InCk} . Many vesicular or irregular pores are usually present
Handling properties: this varies from friable through firm to very hard and difficult to dig with a pick. Friable and firm isons are designated In, hard isons are designated Ind and in hand specimens are fragile and easily broken producing an explosive rupture. This property does not vary with moisture content and therefore indicates physical compaction
Bulk density: this is greater than that of the overlying horizon and may have a maximum > 2
Permeability: moderate to very slow for very hard isons; appears impermeable in some places and may severely restrict root developments
pH: 5-7 but higher in Inc due to the presence of carbonates
CEC: 20-50 meq Kg^{-1}
BS: 20-100%
OM: <1%
C/N ratio: 8-12
$(Ca+Mg)CO_3$: absent to dominant
Soluble salts: absent
Weatherable minerals: 0-100% of the <2 mm fraction
Clays: kaolinite, mica and vermiculite are the main minerals; molecular ratios show high contents of aluminium
Concretions and segregations: absent
Biological activity: absent to very weak
Micromorphology: slightly porous, medium or coarse platy, lenticular to massive with many vesicular pores. Single sand grains sometimes occur in the pore space and beneath the stones. When stones are present silt cappings are common. There is only a small amount of fine material between the abundant angular and faceted sand grains; there may be a few small randomly distributed domains which can easily be confused with small flakes of mica but generally domains are absent. Silt coatings are occasional or common on ped surfaces but more usually occur on the bottom surfaces of pores or in the surfaces of the polygonal cracks and in some cases the pores are filled with silt coatings. Clay coatings are rare to common and in some cases the uppermost part of the ison has abundant clay coatings. When isons are overlain by gleysons some of the ped faces and pores may have yellowish-brown deposits of iron or black areas of manganese dioxide deposition
Genesis: most of these horizons were cryons (permafrost) during the Pleistocene period but with the amelioration of climate, the ice disappeared very gradually leaving behind the characteristic lenticular or massive structure. In soils that contain stones the disappearance of their sheath of ice caused the formation of large pore spaces above the stones which

became filled with fine material. The polygonal structure is also inherited from the cryon many of which have thin ice veins of ice forming a polygonal structure extending vertically. The high bulk density is also inherited from the cryon in which the mineral material was strongly compacted during the development of ice lenses and sheaths. Occasionally isons are formed as a result of contemporary deep freezing with ice vein formation. This produces the characteristic structure but annual thawing does not usually allow the development of such conspicuous silt cappings. This may account for the formation of some isons in the Lake States of the USA where throughout many soils there is lenticular structure which is apparently due to annual winter freezing. Evidence from the analysis of the clay fraction indicates that the preservation of the structure and a certain amount of cementation can result from the deposition of aluminium hydroxide, clay opal and possible other substances during the Holocene period. After the cryon thaws and an ison forms there may follow a number of evolutionary paths depending upon the chemical and mineralogical composition of the ison and the nature of the soil moisture regime as influenced by the climate. When these horizons form in areas where evapotranspiration greatly exceeds precipitation, calcium carbonate will accumulate to form the compound horizons {InCk} or {IncCk}. Such horizons occur in certain soils of the mid-western USA; the compound horizons {IncCk} also occurs in the drier parts of eastern England. If precipitation slightly exceeds evaportranspiration, the original ison - In - or calcareous ison - Inc - may remain unchanged for a long period. When these two horizons occur in a more humid area the calcareous ison is readily decalcified following decalcification of the horizons above and gradually the ison changes into an alton. On the other hand isons formed in acid or basic drift may accumulate aluminium hydroxide and/or opal translocated from above becoming progressively more cemented to form the compound horizons {InFg}. Since isons are usually of low permeability often there is a tendency for moisture to accumulate at their surfaces leading to reduction and the formation of a gleyson and the compound horizon {InGl} or {GlIn}. In place of the gleyson there may be a candon or cerulon depending upon the degree of waterlogging. It is conceivable that isons containing originally only a little calcium carbonate could become decalcified without losing their structure and changing into altons. In a number of places the ison comes very close to the surface, sometimes this can be attributed to erosion but in others it is related to the original irregularities in the upper surface of the cryon as caused by variation in the thickness of the organic matter in the previous Cryosol. When the ison comes close to the surface it seems that the evolution path of the soil during the Holocene period has been very strongly influenced and furthermore in many places the upper part of the ison has been modified. The main influence of an ison near to the surface is to create wet conditions due to its impermeability and the formation of a gleyson within the ison, to give the compound horizons {GlIn}. In some cases a placon forms within the ison so that the part above the placon is partially or completely anaerobic with the formation of a candon within the ison to give the compound horizon {CoIn}. This situation is very common in the middle elevation in N.E. Scotland and elsewhere

Variability: isons are derived from cryons that developed in unconsolidated deposits but it is essential for the material to be of the correct texture otherwise an extreme degree of compaction will not be achieved. In some situations where a cryon formed in weathered material one may find compound horizons such as {InAK2w} or {InBK2w}. Which are usually not very hard because of the predominance of one particle size

Associated horizons: the overlying horizon includes an alton, argillon, candon, gleyson, placon, sesquon and husesquon

Distribution: isons are particularly widespread in areas that were subjected to periglacial conditions during the Pleistocene and more especially where there are superficial deposits derived from coarse grained rocks. Thus, isons occur in central and southern Scandanavia, Belgium, British isles, the Netherlands, Canada, Alaska and the northern part of the USA. Isons are also very common in the acid and very acid material of north-west France

Discussion: these horizons appear to have received the greatest attention in Britain and the USA where they are often called fragipans. Generally, most workers in Britain are agreed that the structural features are the result of freezing, presumably under periglacial conditions. In the USA there seems to be a lack of agreement and no definite proposals have been put forward for their formation in that country. Because of the thickness of the ison in some places, and its occurrence in a number of soils, it is most likely to be an inherited feature rather than one developed under contemporary conditions. Observations by the author and discussion with a number of other investigators have indicated that in the USA there are probably at least 2 different horizons that have been called fragipans, hence the lack of agreement and confusion that exists. In the north-central and north-eastern USA and Newfoundland there are horizons which correlate exactly with the isons of Britain but elsewhere there are horizons that have some points of similarity but also differ in many respects. The 2 most important are the marked absence of silt cappings and softening upon wetting which are found in many of the fragipans of the USA as well as in New Zealand. Many of the isons in Britain and in the northern parts of the USA remain hard at all times and have prominent silt cappings. It should also be pointed out that although the bulk density in all cases is higher than the horizons above, this property should be interpreted with caution since the bulk density of till and some other sediments is similar to that of isons. Therefore, the change in bulk density could be due to a number of factors including settling, freezing or other methods of compaction. It seems necessary to recognise at least 3 separate horizons, ison, fragons and the compound horizon {InFg}. The first is due to freezing, followed by thawing. The second is due entirely to the presence of cementing material and the third a mixture of the 2 processes. The presence of polygonal cracks should also be interpreted with restraint since these occur in sediments of Holocene age and therefore in such cases they are most likely to be due to shrinkage and cracking

The developmental sequence of soils containing isons: Fig.13 attempts to illustrate the sequence of development from till through Cryosols to Podzols. Six stages are recognised as follows:

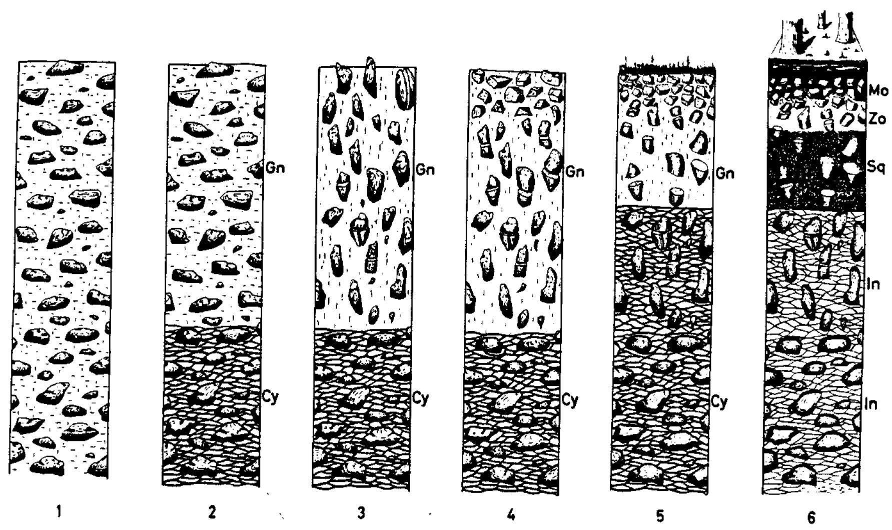

Fig. 13 Evolutionary sequence from till through Cryosols to Podzols.

Stage 1 Initial deposit of glacial drift in which the stones and boulders are aligned horizontally.
Stage 2 A gelon -Gn and a cryon -Cy (permafrost) have formed in the glacial deposit. The gelon freezes every winter and thaws every summer. The cryon remains permanently frozen and has the characteristic structure of frozen lenses of soil surrounded by bifurcating veins of ice and a sheath of ice around each boulder.
Stage 3 The stones have become vertically orientated as a result of freeze-thaw cycles in the gelon. The stones remain aligned horizontally in the cryon.
Stage 4 Some of the stones in the gelon are now shattered by repeated freeze-thaw cycles. The stones remain aligned horizontally in the relatively inactive cryon.
Stage 5 The stones in the gelon have been heaved to the surface to form a concentration of angular frost shattered rock fragments. Further shattering has taken place, particularly at the surface. Also there has been an invasion of vegetation which acts as an insulator and reduces the depth of summer thawing so that the upper surface of the cryon moves nearer to the surface causing the lower part of the gelon to become the upper part of cryon which contains some vertically oriented and shattered stones.
Stage 6 The climate has changed to the present, leading to the formation of an ison in the previous cryon and a Podzol in the previous gelon. Thus, a number of features have been inherited by the Podzol from the previous soil forming phases, these include:

(i) An ison - In - with the typical sharp upper boundary, high bulk density, very hard consistence, lenticular structure and capping of fine material on the upper surfaces of the stones, the fine material filling the space created by the disappearance of the ice.
(ii) Two stone maxima - one at the surface and the second in the ison.
(iii) Frost shattered and vertically oriented stones throughout the profile and in the upper part of the ison.

(iv) The ison has vertically oriented and shattered stones in the upper part while in the lower part they are horizontally aligned. In some profiles a visible discontinuity separates the upper and lower parts of the ison.

This sequence has a Podzol as the present soil but there may be a number of other different soils, such as Altosols and Placosols, depending upon the mineralogy of the material, elevation and water regime. On slopes the evolutionary stages are very similar with 2 exceptions. Firstly the stones in the old gelon and the present Podzol are aligned parallel to the slope and normal to the contour and also have one maximum at the surface as for soil on flat sites. Secondly, the soil has a much higher content of silt than the underlying ison. This seems to be due to the final stages in the solifluction of the Pleistocene when only fine material was being moved down the slope. Thus, the soils on slopes show the same 2 discontinuities, but in addition, the upper one is marked by a change in particle size distribution.

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PALLON

General definition: pale coloured, strongly weathered and lower with red or brown mottles that range from small, indistinct and rare to occasional, large and prominent; forms by very strong subsurface weathering in hot, continuously moist climate

Symbol: Pl

Synonyms: pallid layer, saprolite

Position: lower with diffuse upper and lower boundaries, upwards they usually grade into strongly mottled flambons, spherons, argillons, durons, vesons or zheltons. With depth they grade very gradually through progressively less weathered rock into disaggregated rocks. They usually occur at a depth of 1-4 m but in many places they are at or near the surface due to erosion

Thickness: varies from 1-50 m. Within any one area the thickness may vary considerably and in extreme cases such as in south-western Australia the complete range of thickness can occur within the same landscape. The reason for this variation is not understood but it is now well established that the lower weathering front above the underlying rock is very irregular

Colour: The hues vary from 7.5YR to 2.5Y with high values of 6-8 and generally low chromas for the pale parts of the horizons. In some cases the colour of the matrix is uniformly pale but often there are yellowish-brown, pink or red mottles which range from faint, small and rare to very large, occasional and prominent being more than 1 m in size. The reason for this colour pattern is not understood but it could be linked to the original rock structure or to the internal drainage of the material. If there is less than 30% pale material it should be regarded as an intergrade - usually to a flambon. Because the mottles are very large, in some cases, it may be difficult in small pits

to decide on the basis of colour alone whether the horizon is a pallon, a flambon or an intergrade
Texture: this is very variable and is determined largely by the nature of the original material. When a pallon is derived from an acid, coarse crystalline rock such as granite in south-western Australia, they are clay loams and sometimes clays. When they are developed from sandstone they may be a sandy loam to sandy clay loam. Very fine clays develop from slates and shales in Sarawak. The silt:clay ratio is rather variable; the tendency is for it to be low, thereby reflecting the intense weathering that produced these horizons. In many cases however, there is a wide ratio due either to a high content in the original rock such as shale or to the presence of aggregates of secondary kaolinite.
Stones: core stones or rock pinnacles are usually present near the base of these horizons where they grade into the underlying less weathered materials. The best core stones occur on crystalline rocks such as granites and basalts. In some cases the core stones are weathered and appear as "ghosts" within the horizons
Structure and porosity: when this horizon is more than about 2 m from the surface it is massive but usually shows very well preserved rock structure, particularly at depth. This is sometimes not clearly visible in the field but can be seen clearly in thin sections. Nearer to the surface secondary processes affect this horizon and a variety of structures may develop. In fine textured material a prismatic or coarse angular blocky structure may form due to expansion and contraction. When termites are active the upper metre may have a number of their galleries filled or partially filled with granular material
Handling properties: these vary from friable to very plastic. With increasing clay content pallons become increasingly tenaceous and difficult to dig and a number harden upon drying
Bulk density: this is greater than that of the overlying horizon probably about 1.5-1.8
Permeability: this varies from moderate in sandy pallons to very slow as the content of clay increases. Therefore, many pallons can restrict vertical movement of water causing moisture to accumulate above their upper surfaces and to move laterally through the soil. In a number of cases ground water will move freely through the underlying partially weathered rock but only very slowly in the pallon above. The slow permeability leads to anaerobism which restricts root penetration
Hydrology: continuously moist or wet
pH: 4.0-5.5 sometimes higher in areas where the climate has become drier since the formation of the pallon, so that basic cations are accumulating in the system
CEC: usually < 150 meq Kg^{-1} clay but may be higher in pallons derived from sediments containing some 2:1 lattice clays. The CEC usually increases towards the base of the section where conditions seem suitable for the preservation of 2:1 clays or to their formaion as occurs on some granites
BS: < 30% in actively forming pallons but can be much higher in those that are now in a drier environment and accumulating bases
OM: < 1%
C/N ratio: not applicable
$(Ca+Mg)CO_3$: absent in actively forming pallons but can be present in large amounts in those that are now in a drier environment. When the content of carbonates is

above 0.1% they should be regarded as compound horizons (see below)
Soluble salts: absent in actively forming pallons but may be more than 0.5% in those that now occur in an arid or semi-arid environment as a result of climatic change. When the content of salts is higher than 0.1% they should be regarded as pallon-chloron compound horizons and designated {PlCi}
Mineralogy: the mineral suite is composed predominantly of the resistant residue, kaolinite and variable amounts of gibbsite

Material > 2 mm This is usually of low frequency and is mainly quartz gravel. Occasionally core stones may be present having a mineralogy similar to the rocks from which the pallons are derived.
Material <2 mm The predominant mineral is usually quartz and there can be up to 5% weatherable minerals in the sand fraction but the individual grains are usually highly corroded showing that they have been in a strongly weathering environment. The silt fraction is practically devoid of weatherable minerals.
Material < .002 mm The dominant mineral is kaolinite with variable amounts of gibbsite. Iron bearing minerals are virtually absent from the paler parts of the horizons but goethite is present in the browner and redder areas.

Concretions and segregations: absent to large areas of iron oxides
Biological activity: there may be considerable termite activity in the upper part but absent below
Micromorphology: massive with rare to occasional sinuous pores caused by shrinkage. The matrix is very pale and in most cases it is difficult to discern any features within it in plane polarised light. Between crossed polars the matrix is dominantly anisotropic and in some cases is seen to be composed of vermicular kaolinite occurring as single vermiforms or forming an intertwining mass. When present the vermiforms appear to be breaking down to form the matrix and it is possible to see all states from intact vermiforms to random formations formed of fragments of the vermiforms. On sedimentary rocks such as shales there is very little material present for the formation of secondary kaolinite so that vermiforms are rare to absent. Towards the base of sections where the pallon is intergrading to the underlying rock there are a number of partly decomposed minerals. For example, feldspars are sericitised while still maintaining much of their original form. Similarly muscovite appears to be very fresh but is being physically broken down to 5 randomly orientated particles. The sand fraction is dominated by quartz grains many of which appear as though they could easily fit together thus preserving the original rock structure. In the case of pallons derived from sedimentary and matamorphic rocks, zones of quartz grains indicate the original rock structure. In many cases there are numerous large, very pale coloured clay coatings but few of them appear to be forming at present. Most seem to be disintegrating and being gradually transformed into matrix. The presence of abundant large clay coatings is in many ways similar to those that occur in some flambons. Although many of the coatings seem to have a normal structure in plane

polarised light most give the appearance that they are composed of domains which have a number of different angles of orientation. This suggests that the coatings are disintegrating to form matrix as is clearly seen in many places. Thus the secondary features of coatings and vermiform kaolinite are being transformed gradually into a uniform matrix with randomly orientated domains

Genesis: at present pallons occur under a very wide range of climatic conditions that vary from the rainy tropics in Sarawak to the semi-arid in south-western Australia. Therefore, it is difficult to be precise about their method of formation. However, it would appear that the most likely condition for their development is under the wetter regime. Indeed, it seems that these horizons require a fairly narrow and specific range of conditions. These include high temperatures, fairly evenly distributed rainfall, flat or gently undulating landscape and a considerable period of time. Under these conditions the rock strata, to a depth of 50 m of more, remain saturated with water for the whole year because it is replaced as quickly as it is lost by percolation. As the water charged with CO_2 from the atmosphere as well as from the decomposing litter from the dense vegetation percolates through the soil it causes hydrolysis and takes away with it the displaced cations. Thus there is a thick layer of rock being vigorously weathered in an acid anaerobic environment. This leads to a thorough decomposition of the alumino-silicates and the formation of kaolinite and gibbsite. Because the environment is constantly anaerobic the iron released by hydrolysis is either lost in solution or remains in the ferrous state. However, the content of iron of some pallons over granite is the same as in the granite itself, therefore, there would appear to be very little loss in some cases. In some cases pallons seem to owe their pale colour to iron deficient rock such as those developed from the black shales in Sarawak that contain $<1\%$ iron. It is even more difficult to explain the presence of the large mottles within the horizon. Usually mottling is attributed to a fluctuating water table but the strong brown or red mottles suggest a large oxygen supply which is difficult to equate with the anaerobism suggested for the pale colours. It is possible that the oxidation of the iron is the result of more recent aerobism induced by landscape and drainage changes

Variability: as stated above these horizons vary in texture, thickness and content of salts. Whereas the variation in texture, mottling and thickness are related directly to the genesis, the amount of salt is related to the nature of the climate in which they occur today and to their position in the landscape

Associated horizons: above: a spheron, {PhAr} or cumulon; below: less weathered material

Intergrades: (PlSp) {PlAr} {ArPl} (PlVs)

Distribution: the greatest extent of these horizons occurs in Australia. Pallons are important horizons in central and western Sarawak where they usually occur at or near to the surface as a result of erosion. Elsewhere in SE Asia they seem to be present but of restricted distribution. Surprisingly, they do not appear to be common in other parts of the tropics and sub-tropics but small areas have been reported from South Africa, West Africa and Guyana in South America

Discussion: the rather peculiar distribution of these horizons and their unique properties are the 2 aspects that are commonly discussed and about which there is much speculation. It would seem that those in Australia developed under much wetter conditions than at present and are probably more akin to those prevailing in Sarawak at present

Origin of term: L. Palere = pale

References

Gilkes et al. 1973

PLACON

General definition: hard, less than 2 cm thick containing an accumulation of iron, organic matter and sometimes manganese. In thin section some or all of the original pore space contains deposited material which is usually red or reddish-yellow, but may be black or dark brown and is dominantly isotropic

Symbol: Pk

Synonyms: thin iron pan; placic horizon; hardpan; Bl; Bfe; Bhfe;

Position: usually middle, lower, or in solid rock but may be upper, for example, at the base of a plough layer. A single continuous placon may undulate with an amplitude of more than 50 cm. Sometimes several placons occur in a profile at variable distances from each other

Thickness, distinctness and outline: thickness varies from 0.5 mm to 2 cm (Crompton 1956; Crampton 1963; McKeague, Damman and Heringa 1968). In the field a single placon contains one to four layers, but the commonest type has 2 layers; the upper about 1-2 mm thick and the lower about 1 cm. the upper, thinner layer has a sharp upper boundary, is dark brown, dark red or black, dense and has a metallic lustre; the lower thicker layer is more porous, often contains thin dark areas and may not have a distinct lower boundary. A single layer placon may be of similar thickness to one with 4 layers and generally a root mat is present above most placons. Placons may branch repeatedly into roughly parallel horizons and sometimes they become contorted or even form pipes several cm in diameter that appear as irregular circles in the profile. Some have a small cupped outline with each cup 3-7 cm in diameter.

Colour: the colour tends to vary with the chemical composition and density; generally iron contributes to red hues and carbon and manganese to low values and chromas. In the more common placons the thin, dark upper layer hues of 10R to 10YR with values and chromas of VC1 and VC5. The thicker, lower layer normally has higher values and chromas, frequently VC4 and VC5. Middle and lower layers rich in manganese tend to be very dark (about N 2/0), and when iron is dominant the hue is often redder, about 5YR 2/1. According to McKeague et al (1968), crystalline goethite occurs very rarely in the upper layer of a placon and when present it imparts a strong brown colour (7.5YR 5/6). The upper iron-rich layers in iron-manganese placons may be relatively pale when the organic matter content is low.

Texture: in mature, well-formed placons the upper layer may be strongly cemented so that dispersion for particle size analysis is impossible. Generally the texture of placons is largely determined by the original material which is usually coarser than clay but in finer textures strong rusty mottles, with placon like coatings, may develop on structure faces and along old root channels (Crompton 1956).

Stones: in soils containing gravel and stones the smaller particles may become very firmly cemented together, especially in the upper layer of placons. Where larger stones are present placons may continue their course uninterrupted through them particularly in acid and very acid rocks.
Structure and porosity: the upper part is usually without pores and massive, while the lower part is more porous with a tendency towards single grain. The absence of pores being the result of the deposition of material within the pores of the original material. At the base of placons rich in manganese the black material tends to form coatings thereby reducing the porosity only a little. Stahr (1973) has shown that the porosity of some placons is very similar to that of the horizons immediately below and often greater than in the horizon above but this is not generally borne out by examinations of thin sections.
Handling properties: placons vary from very hard to friable. The hard placons are cemented and mature while those that are friable are regarded as incipient.
Bulk density: the bulk density of some placons is less than might be expected: values range from 1.4-1.6 g cm^{-3}, and are often lower than those of the horizon above (Stahr 1973).
Permeability: continuous and well-formed placons may restrict the vertical movement of water in the soil so that, while the horizons below are dry, the horizons above may be saturated. Stahr (1973) has found that the hydraulic conductivity (K, cm sec^{-1}) of some placons are often the same but sometimes less than that of the horizons above and below with values of K varying from 1 x 10^{-3} - 2 x 10^{-2} cm sec.
Hydrology: the upper surface is usually wet
pH: generally the value is similar to the subjacent horizons and a little higher than in the horizons above. Commonly it varies from pH 3.6-4.6. with values determined in 0.01M $CaCl_2$ saturated KCl or water being similar (Stahr 1973 and Koppi 1974). Iron-manganese placons have pH values in the range 4.2-4.8 (Brewer *et al*. 1973).
Exchange reactions: placons usually form in acid soils with low cation exchange capacity and base saturation but it is difficult to make such determination for cemented placons since the degree to which the material is broken down prior to analysis is somewhat arbitrary.
Organic matter: generally, the content seems to range from about 1-5% but a low value of 0.2% has been found in a manganese pan and up to 19% in an iron-organic pan. Usually the content of organic matter decreases downwards as does the iron content. It also decreases as the manganese content increases. The D.T.G. curve for the single pan containing 19% organic matter is almost indentical to that of a 6:1 ferric iron-fulvic acid complex prepared in the laboratory. All other pans give different curves and show no resemblance to iron-organic matter complexes. In the case of the single pan the organic matter extracted with NaOH had a very low ash content and contained COOH, phenolic and C=O functional groups. The COOH are the dominant functional groups and equal the amount occurring in the sesquon below. The phenolic groups are at their maximum in the placon. The C=O groups are in smaller amounts and all of the O extracted is in functional groups. Thus, in this particular soil the organic matter has a high capacity to complex metal ions and hydrous oxides.

However, the nature of the organic matter generally is not understood

C/N ratio: the amount of nitrogen in placons is very low and varies from about 0.03-0.1%. Stahr (1973) and Koppi (1974) have shown that the C/N ratio in common placons is usually greater than 20% and may be even greater than 30% in some less common types.

$(Ca+Mg)CO_3$: absent

Soluble salts: absent

Weatherable minerals: the content of weatherable minerals is very variable. In some areas placons occur in coarser textured acid superficial deposits such as glacial drift, alluvium and solifluction deposits, that may contain a high proportion of weatherable minerals, especially feldspars. In other areas placons form in deposits derived from quartzite or in some strongly weathered tropical soils with few weatherable minerals. They seldom occur in material having a high content of amphiboles or pyroxenes.

Iron: generally the amount of iron decreases from the top to the bottom of placons and is inversely correlated with the amount of manganese. The total amount of iron determined by fusion may range from as much as 26% Fe in the upper part (McKeague et al. 1968) to about 2% in the lower part (Damman 1965). The common 2 layered placons are mainly composed of iron and organic matter, with little, if any, apparent accumulation of other elements: in the upper part of these placons the Fe content may range from 5-20%. Some black single layered placons found on highly quartzose material poor in iron may be up to 2 cm thick, yet contain only traces of Mn and about 2% Fe. The iron in placons seems to be in a variety of forms. In iron-organic placons which seem to be the most common placons, between 20-85% of the iron is shown by McKeague et al. (1968) and Stahr (1973) to be extractable with oxalate and therefore is amorphous. However, the oxalate extractable iron is always less than that extractable by dithionite which is usually at least 50% of the total. On the other hand Damman (1965) found that only about 10% of the iron in the upper part of some placons is extractable by sodium dithionite and 0.02 M. E.D.T.A. McKeague et al. (ibid) have shown that the pyroposphate extractable iron is generally low for a number of placons, indicating that only a small proportion is complexed with organic matter in certain cases. This contrasts with the conclusion by McKeague et al. (1967) and Schnitzer (1969) that in a particular placon, where about 85% of the iron was extracted by oxalate, almost all the iron was present as an amorphous iron-organic matter complex. The D.T.G. curve of this particular, untreated, placon material was almost indentical to that of a 6:1 ferric iron - fulvic acid complex prepared in the laboratory, yet it was quite different from the curves for the purified organic matter from the placon and for a sample by hydrated ferric oxide. Further D.T.G. analyses of other placons made by McKeague et al (ibid) show little or no resemblance to iron-organic matter complexes. From the disparity between dithionite and oxalate extractable iron it seems that up to about half of the iron in some placons may have some degree of crystallinity, but forms of iron with a high degree of crystallinity are rare. McKeague et al. (ibid) found one placon to contain goethite and Crompton (1956) reported that the goethite was the main constituent in the upper dark portion of an apparently common placon which contained 30% Fe.

Chemical analysis does not reveal the precise distribution and concentration of iron in placons but this can be achieved with a microprobe. Such studies reveal that the common red or reddish-yellow isotropic material deposited within pores contain up to about 65% Fe. Furthermore, this material is present in similar concentrations in pores ranging in size from < 5 mm to those clearly visible under the normal petrological light microscope. Generally, as the hue of the isotropic pore material tends towards yellow, the amount of iron decreases.

Manganese: McKeague et al. (1968) state that placons containing manganese dioxide accumulations react violently with cold 3% hydrogen peroxide whereas, others react only mildly. The occurrence of manganese in placon has been reported from Canada by McKeague et al. (ibid) and Brewer et al. (1973) and from Germany by Stahr (1973). They have shown that, where iron and manganese are both abundant in the same pan, the areas of accumulation are usually separate with iron above and manganese below. The actual amount of manganese may amount to a 40 fold increase over the original soil content which is commonly less than 0.1%. The highest value so far recorded is 5% manganese (McKeague et al. ibid).

Aluminium: Dithionite and oxalate extractable aluminium usually show a small increase in placons relative to the horizons above and below (McKeague et al. 1967, 1968; Stahr 1973). This seems to indicate that there has been some depletion of aluminium from the upper horizons and an accumulation in placons. Electron probe studies show that very little aluminium accumulates with the iron; in fact the total aluminium content in placons is usually less than in the horizons above or below (Stahr 1973; Koppi 1974). This is an apparent and not a real decrease because of its dilution with other deposited material.

Other elements: as with aluminium there is an apparent decrease in the total content of some elements including silicon, calcium, mangnesium (Koppi 1974), potassium, titanium and zirconium (Stahr 1973).

Clay: the clay minerals are mainly those already present in the soil and because placons are of such widespread distribution the whole range of clay minerals are encountered. Also in the clay sized fraction there may be some amorphous and poorly crystalline material as well as some rare goethite.

Micromorphology: as noted above, the pore space contains material which is dominantly isotropic and may be black or dark brown but commonly is red (redder than 10R 4/8) or reddish-yellow. This material is especially abundant in the top half of placons and has many curved 3-limbed cracks which may be artefacts due to drying in the laboratory or formed through drying in the field. Sometimes the material is homogenous, but it may have a very granular appearance and when very dark brown or black it can usually be clearly identified by its characteristic cracks and isotropism; there are however some rare small areas of this substance which remain red between crossed polars. The very dark isotropic material seems to be similar to that observed in some placons by de Coninck and Laurelle (1964). The red isotropic material closely resembles "Material A" identified by Brewer et al. (1973) as amorphous iron and seems similar to that observed by McKeague et al. (ibid). With the scanning electron microscope this material has a scaly appearance with roughly hexagonal and diamond shaped scales side by side and seems to be very similar in a wide range of pore spaces, though the scaly morphology is more evident in the larger pores. Placons vary in colour from place to place in the thin section. Since the chemical composition appears to be uniform this colour variability can be attributed to differences in the size, shape and distribution of the pores or differential grinding. The lower part of the common placon often contains a paler reddish-yellow (7.5YR, VC4) substance which like the darker material is mostly isotropic (rarely showing interference colours and resembling clay coatings) and shows similar cracks to the material more common in the upper part of the placon. These 2 types of material often grade one into the other suggesting that thickness or density of the same substance varies. The reddish-yellow material is similar in appearance to "Material E" shown by Brewer et al. (1973) to contain less iron than the redder substances. Both types of material sometimes invade rock fragments in cracks or pore spaces. Some uncommon placons contain other substances. Brewer et al. (1973) have identified 3 additional chemically and optically distinct materials occurring in pore spaces - "Material B", "Material C" and "Material D". "Material B" was shown to be composed dominantly of manganese, which in thin sections appears dark brown to opaque with paler brown thinner edges and may be anisotropic. "Material C" has a dark core and is chemically and optically similar to "Material B" but with peripheral zones similar to "Material A". "Material D" seems to be very rare and is observed in the field as a thin strong brown (7.5YR 5/6) layer on the upper surface of the placon and identified as largely goethite. In thin section it has a drab brown "powdery" appearance and is isotropic. Incipient placons differ somewhat from those that are mature and well formed. In a Podzol the initial stages of placon formation are shown by isolated thin layers of placon-like material deposited over several cm. In thin section the pore space of these incipient placons is mostly filled with the paler reddish-yellow material "E", but where development is more advanced the material tends to become redder. Scanning electron microscope studies show that even the pale reddish-brown yellow material may be high in iron with up to about 40% Fe. Rarely in incipient placons, the pore material appears anisotropic with an undulose extinction not unlike a clay coating

Age: Stahr (1973) dated the organic matter in several placons by 14C measurements and recorded ages ranging from 1 780 ± 60 years to 5 950 ± 110 years. The common age seems to be about 2 000 years. Dimbleby (1952, 1962) believes that the development of heathland and some Placosols in Britain is the result of man's influence since the start of the Bronze age about 2 000 years B.C., since when the placons have become more strongly cemented. Some placons may be somewhat older since some soils buried beneath Stone Age barrows in NE Yorkshire contain placons. There are also many placons that occur in the upland humid tropics that are of unknown age. However, as Proudfoot (1958) has shown placons may form in the upper part of the soil within 100 years.

Variability: from the 11 pans examined by McKeague et al. (1967, 1968) it was concluded that there were at least 4 different types. Re-examination of these pans lead Brewer et al. (ibid) to decide that there are 6 different types depending upon the amount and arrangement of the 5 different types of material. It seems therefore, that in detail there is a very wide range of variability among placons. And it is possible that this variability represents local variation in the soil environment during their formation and could have important hydrological consequences for Tilsley (1977) has demonstrated that placons are very important in hydrological studies.

Genesis: at present there are no clear ideas about the formation of placons. Many theories have been suggested that might explain their occurrence in loose unconsolidated material but they fail to account for their presence in rock fragments. Certain conditions, however, do seem to be necessary, such as an acid surface litter, coarser than clay textured material and humid oceanic climates, both cool and warm, with moderately high to very high precipitation, usually at least 1 000 mm/year, though placons may be found under acid heathland with less than 1 000 mm/year. Muir (1934) put forward one of the earliest theories which was accepted by several other workers including Crompton (1956) and Damman (1965). The high precipitation and surface organic matter are thought to maintain anaerobic reducing conditions in the upper part of the mineral soil. In this zone iron is reduced to the mobile ferrous state and leached to lower levels where drier soil causes oxidation at an air-water interface. Since the thickness of the saturated upper zone is variable and determined by soil heterogeneity, waviness of the placons results. This theory requires a static system providing a constant air-water interface, which is unlikely in fairly uniform, coarse textured soils and requires the iron to be in the form of oxides or oxyhydroxides in placons. Stahr (1973) has shown that iron oxides are unstable under the redox conditions where some placons are found yet they may be thousands of years old. It is unlikely therefore, that the iron exists in a purely inorganic form. Furthermore, placons sometimes form where there seems to be no evidence of reducing conditions. For example, they occur commonly beneath black horizons of humus and iron accumulation - husesquons. Crompton (1952) beleives that placons may migrate downwards through the soil by a process of reduction and solution of iron on the upper surface of the placon followed by diffusion through the placon and reoxidation in the more aerated conditions beneath. However, oxidation-reduction theories neither account for the organic matter in placons, nor explain their occurrence through stone and boulders. Sorption theories have been applied to the formation of sesquons and husesquons by Bloomfield (1955), Russell (1961) and Crawford (1965). However, they cannot be applied successfully to placons because of the thinness of these horizons and their continuity through solid rock. Also the deposited material fills pore spaces and is not found only as coatings around minerals or lining pore spaces. Changes in soil pH have been used Russell (1961) and Loughnan (1969) in an attempt to explain iron precipitation in soils. This is also inadequate to account for the nature of thin placons and their tortuous path through stones and boulders. Furthermore, the difference in pH above and below placons is sometimes very small or zero. Interfaces within the soil cannot be found to determine the position of placons, although they sometimes form at interfaces. Very well developed placons commonly form at the junction where fine textured material overlies coarse material. Invariably the fine textured materials show strong reduction. Placons usually develop in a previously formed soil and do not seem to form at pre-existing horizon boundaries continuing through stones, show no regard for and may involute into and through many horizons including sesquons and isons. After they form, the previous horizonation above the pan is destroyed by the resulting wetness and reduction. Thus, sesquons can be changed into candons. Morison and Sothers (1914) and Atkinson and Wright (1957) have invoked microorganisms to explain the precipitation of iron in the soil. The organisms are thought to attack the ligands in the metal-organic complexes moving through the soil, resulting in the deposition of iron as sugggested by van Schuylenborgh (1965). FitzPatrick (1971) speculates about bacteria as possible agents for their formation, however, Paton (priv. comm.) examined a placon which is thought to be forming at present and found no evidence for iron bacteria but that does not rule out the possibility of their participation. Perhaps a better theory for their formation is similar to that for podzolisation proposed by Ponomareve (1964), Schnitzer (1969) and Petersen (1976). It is established that iron-organic complexes become more and more water insoluble as more metal ions are taken up, until at a particular metal-organic matter saturation precipitation of the complex occurs. In the podzolisation process, the organic matter complexes more and more metal as it moves down the pedo-unit, until the complex becomes so insoluble that precipitation occurs. The formation of placons is not the same as that of sesquons and husesquons, since placons differ from them in 2 important respects. Firstly, they are much thinner, and secondly, the accumulation of aluminium is very much less. In placon forming conditions, the particular iron-organic matter complex precipitates in the soil when the critical iron-organic matter ratio is reached at the time of maximum percolation. This precipitation may occur at any point in the soil or within a stone. It is possible the first precipitation forms a template upon which further precipitation occurs. In time the state of iron in the placon may undergo changes, for if the iron was precipitated in complex form then the pyrophosphate extractable iron should be higher than actually obtained. There may be one of two reasons for this. The iron may become less attached through degradation of the organic matter and in particular ligands, or the complex may consolidate into a form upon which the pyrophosphate has little effect. If the former is the case it becomes very difficult to explain the persistence of the iron oxides in unfavourable redox conditions. If the latter, the complex would be insoluble, and furthermore the presence of the organic matter would inhibit the formation of crystalline iron oxides (Schwertmann et al. (1968). If the iron is strongly bound in the complex it could also account for the conclusion (from the disparity between oxalate and dithionite extractions) that some placons contain up to 50% of some sort of crystalline material and also why goethite is rarely found. Where manganese is present there seems to be more than one process contributing to their genesis. Brewer et al. (1973) conclude that a sequential development may have taken place. Firstly, a

little iron-rich material may be emplaced ("Material E"), followed by manganese rich material, then iron-rich material ("Material A") a little higher in the profile and which may greatly reduce the pore space in the placon. The final deposition may be another iron-rich layer to form the surface of the placon ("Material D"). Brewer et al. (ibid) report that a fungus from the placon material has the capacity to oxidise divalent manganese at about the same pH as that of the placons, this suggests that the deposition of manganese may be due to biological oxidation. Furthermore, the microorganisms may have removed some complexed organic matter from the iron-rich zones. Brewer et al. (1973) conclude that biological activity in the relatively dry zone beneath the placon could explain the characteristics of the iron-manganese placons studied, provided the surface of the deeper water table were sufficiently stable. An alternative explanation may be feasible. Given that iron is emplaced first in the manner described earlier, this would then give rise to a restriction in water percolation and reducing conditions above the placon. The manganese reduced and mobilised in this zone would percolate or diffuse through the placon and be oxidised and deposited in the drier zone immediately beneath the iron-rich zone. This too would account for the particular morphology described and does not rely on microorganisms.
Associated horizons: above: a candon, zolon, husesquon or ison; below: a husesquon, sesquon, ison or relatively unaltered material
Distribution: placons are found in humid oceanic climates both cool and warm with a moderately high to very high precipitation. They occur at a variety of elevations in cool temperate climates but only a high elevation in warmer areas. They can be found in Alaska, Australia, Belgium, England, Germany, Ireland, Malayam Malaysia, Netherlands, Newfoundland, Scotland, South Africa, Tasmania, Wales and West Indies.
Discussion: because placons are very varied and can occur almost anywhere within the pedo-unit and without any fixed relationship to any other horizon, they have caused considerable classification problems.
Origin of term: Gk. Plax = plate

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A.J.Koppi and E A FitzPatrick

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